Application of bipolar operational amplifiers for special measuring circuits in electro-energy

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***Abstract* —** This paper presents new possibilities for the involvement of special districts with bipolar operational amplifiers. The proposed circuits are designed primarily for applications in the field of measurement technology heavy current electrical engineering and electrical, for laboratory and process measurement. Although the circuits are designed primarily for basic operating frequency of 50/60 Hz, have a frequency bandwidth wide enough to handle even the signals from the drive. Circuits may be used for measuring and other devices in the processing of low frequency and DC signals and tracking slow processes. The diagrams are applicable to hybrid and monolithic operational amplifier, for special purposes, the precise form can also implement the discrete-based components. The article presents the basic starting points, principles, and equations for these circuits. Application possibilities of these connections are everywhere where it is needed to process and edit analog electrical signal in the higher voltage levels.

Keywords — analog signal, measuring equipment, operational amplifier, special electrical circuits.

I. Introduction

In the field of heavy current electrical engineering and electricity in some cases we need to measure relatively low voltage strip can be superimposed on high levels. Contradictory requirement in these cases, the requirement for linearity sensor, the minimum interaction circuit being measured and, if defined frequency response of the measuring amplifier. The primary signals are analog in most cases. They must be processed with the least distortion and transform to the required voltage, current or power level and then convert them into digital data.

Research work in the field of measurement technology, new materials and power electronics require new approaches in the design of analog sensors and analog signal processing. Department of Electrical Workers laboratory technical subjects Faculty of Education, University of Hradec Králové for many years engaged in the development of innovative involvement with bipolar operational amplifiers and their applications in sensing and power amplifiers for high-voltage measurements in the low-frequency technology, management and control circuits. Despite the dynamically expanding digital technologies are essential for signal processing analog circuits irreplaceable.

This paper presents test circuits implemented with bipolar operational amplifiers and utilizing the beneficial properties to achieve operational reliability and long-term stability. The measuring process signals amplifiers provide high voltage and gain core balance integral and derivative of the input voltage at a relatively large range of frequencies selectable with a single optional passive impedance. The advantage of those involved is that processed non-inverting phase voltage and frequency-dependent elements are placed outside the main signal path.

I. Measuring differential amplifier with high cumulative voltage

Measuring of AC and DC voltages (but even the currents) and scanning of their course on the sources and loads, which are not connected with the ground by one of their outputs, represents big problem paradoxically from the electric viewpoint. Contemporary measuring apparatuses fed from the distribution network (osciloscopes, milivolmeters, etc.) are usually equipped with non-symmetric inputs, connected with the apparatus device and across the protection conductor with the ground. The direct connection of measuring apparatus with ungrounded element leads to a fault and due to it to a damage or destruction of measuring apparatus. Even when using differential transformer we are limited to scanning only of one constant (variable, quantity). There is very often necessity to scan voltage and currents and their courses simultaneously on several positions (spots, locations) of the circuit. Differential amplifier with a high summation and high differential voltage makes it possible to scan voltage in heavy-current circuits on several spots simultaneously without mutual influence.

Measurement of AC and DC voltages in circuits that have the potential to zero (ground) high levels of cumulative voltage requires a special treatment of the measuring amplifier input. Today, monolithic operational amplifiers used have a maximum sum tractable voltage input signal, usually in the range 5 to 30 V in both polarities. If the amplifier is equipped with input divider (sometimes in combination with the gain switch), is essential that the ratio of the allowable range of input voltage of the differential operational amplifier to the maximum cumulative voltage all ranges remained the same or increased. Designed by measuring the differential amplifier which adds high voltage (Fig.1) is based on the concept of differential amplifiers in the classical connection (e.g. [1], [9]) and inverting operational amplifier with a resistor in a virtual zero [10], [11] .

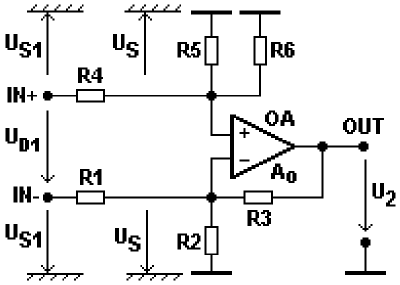

Fig. 1 Principle diagram of the measurement of the differential amplifier

Unlike the classic scheme are involved in that measurement of differential amplifier added resistors R2 and R5. To select the resistor is a condition that

$$R_1 = R_4,\ R_2 = R_5,\ R_3 = R_6 \tag{1}$$

And together is valid

$$R_2 = R_1 \cdot 10^{-4} \tag{2}$$

Transfer A_{in} of inverting input, while respecting the condition (2) and for sufficient voltage gain of the operational amplifiers (no-load: A_0] 10^6), will be

$$A_{\text{in}} = -\frac{R_3}{R_1} \tag{3}$$

Transfer of non-inverting input A_{n} from the perspective of theory quadripoles is the product of the non-inverting divider transmission input and transmission of A_{R} non-invertig input operational amplifier A_{na}.

$$A_{\text{R}} = \frac{R_5 \| R_6}{R_4 + R_5 \| R_6} \tag{4}$$

$$A_{\text{na}} = \frac{R_1 \| R_2 + R_3}{R_1 \| R_2} \tag{5}$$

Using (1) after substituting into (4) will

$$A_{\text{n}} = A_{\text{R}} \cdot A_{\text{na}} = \frac{R_2 \| R_3}{R_1 + R_2 \| R_3} \cdot \frac{R_1 \| R_2 + R_3}{R_1 \| R_2} \tag{6}$$

After edit (6) we get the final transfer

$$A_{\text{n}} = \frac{R_3}{R_1} \tag{7}$$

When sufficient voltage gain of the operational amplifier (load A_0] 10^6) and in compliance with (1) and (2) is then the differential amplification (A_{D}) independent of the value of resistors R_2 and R_5. And A_{D} is equal to

$$A_{\text{D}} = \frac{R_3}{R_1} \tag{8}$$

For maximum output voltage U_2 of the parameters of the operational amplifier, twill be the maximum possible voltage differential U_{D1} (in both polarities)

$$U_{\text{D1}} = \frac{U_2}{A_{\text{D}}} = U_2 \cdot \frac{R_1}{R_3} \tag{9}$$

The maximum permissible sum voltage U_{S1} (both polarities) on both inputs IN + and IN-can be determined from (10), where the U_{S} is the limit allowed in the sum voltage input of operational amplifier.

$$U_{\text{S1}} = U_{\text{S}} \cdot \frac{R_1 + R_2}{R_2} \tag{10}$$

We introduce a factor increasing the voltage summation F_{S1}

$$F_{\text{S1}} = \frac{U_{\text{S1}}}{U_{\text{S}}} \tag{11}$$

After substitution of (10)

$$F_{\text{S1}} = \frac{R_1 + R_2}{R_2} \tag{12}$$

Further increase of the differential and cumulative voltage can be realized using symmetric damping L-segment R_7, R_8 with partition resistor Rp, connected to the input of the measuring amplifier (Fig. 2).

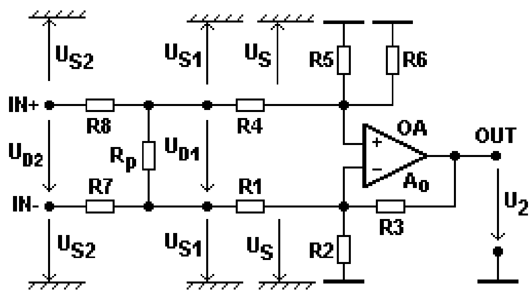

Fig. 2 Differential amplifier with partition L-part

Factor increasing of the differential voltage is defined by the ratio F_{D21}

$$F_{D21} = \frac{U_{D2}}{U_{D1}} \tag{13}$$

For the longitudinal damping resistors part applies $R_7 = R_8$ and their value can be selected according to the requirements of measurement. Generally valids $R_7 = F_{R1} \cdot R_1$, where F_{R1} ($F_{R1} > 0$), is the coefficient increases. For the partition resistor R_p when we apply (1) and (2) to derive

$$R_p = \frac{2 \cdot R_1 \cdot F_{R1}}{F_{D21} - 1 - F_{R1}} \tag{14}$$

New increase of cumulative voltage factor F_{S2} is analogous to (11), (12)

$$F_{S2} = \frac{U_{S2}}{U_S} \tag{15}$$

And after modification

$$F_{S2} = \frac{(1 + F_{R1}) \cdot R_1 + R_2}{R_2} \tag{16}$$

From (16) we can then derive the calculation of the coefficient increases F_{R1}

$$F_{R1} = \frac{R_2}{R_1} \cdot (F_{S2} - 1) - 1 \tag{17}$$

Ladder resistor R_p (14) we use if we want to increase the differential voltage factor F_{D21} rising faster than supply cumulative increase factor F_{S1}, which may be useful some measuring tasks. Another advantage of the proposed measuring amplifier is that the op amp input current is drained through a relatively small resistances of resistors R_2 and R_5, which not only improves the thermal stability, but according to [9] and the amplifier noise parameters. The connection will use operational amplifier with external compensation components for setting frequency compensation earnings authoritative approximately in the ratio R_3/R_2. The practical realization of the measuring amplifier must be based on the voltage level at the input section. This means that we must deal with the actual construction of such facilities at a high or very high voltage.

II. Practical Example of Application of Measuring Differential Amplifier with High Voltage Sum

Measuring the amplifier design, we used as an input unit for multi-channel display of laboratory measurements of currents and voltage waveforms for discharge lamps (sodium, sodium-xenon and metal halide lamps) (Fig.3) and the measurement of electric-powered drive.

The source of feeding voltage is standard distribution net TN-C-S 3 × 230/400 V - 50 Hz and so the highest voltages towards ground (total voltage), from which we can measure is 230 V. The highest voltage (differential) in given heavy-current circuits represent the ignition impulses for the discharged light sources. This voltage reaches maximal values 4 kV. We consider the working frequency standardly 50 Hz, only at the frequency converters for the electromotors feeding, it could be taken into account necessity of measuring at the frequency up to 5 kHz. If we assume even measuring at the feeding converters of light sources, than the scanning amplifier must transfer frequencies up to 250 kHz.

The scanning amplifier was used both for scanning of the size and course of the current by tetrapoint scanning resistors 100 mΩ. For the frequency area up to 400 Hz all the operating amplifiers work without phase angle error. The error of measuring caused by fading current does not exceed 0.5 %, while the permanent fading currents do not exceed value of 250μA.

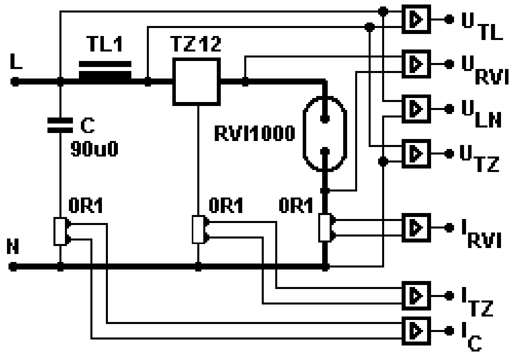

Fig. 3 Connecting the measuring amplifier in the circuit of high pressure discharge lamp (main circuit is strongly marked) TL1 - inductive ballast (coil), TZ12 - thyristor ignition

Fig. 4 Precise four-point measuring resistor HITANO TR35 0R1

Real engagement with the differential input unit, a measuring amplifier with high voltage is on the core balance Fig. 5

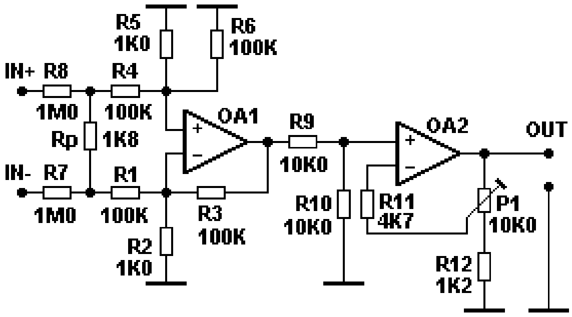

Fig. 5 Scheme of the input units

Without the damping element (like attenuator) R_7, R_8, R_p, has input unit maximum sum of the input voltage U_{S1} 1,5 kV DC or 1kV AC. High voltage differential U_{D1} remains at the original value of 15 V DC or 10 V AC. Damping element has input resistors $R_7 = R_8 = 1\ \text{M}\Omega$ ($F_{R1} = 10$). Ladder resistor should have according to (14) value of k R $R_P = 2.0387\ \text{k}\Omega$.

The highest admissible total voltage U_{S2} on the input of attenuator is in this case 16.5 kV DC or 11.5 kV AC, the highest differential voltage U_{D2} is then 15 kV AC or 10 kV DC. Total gain of the input amplifier is -60 dB and by it given the resulting transmission mV/V. In order to make possible to use the current components (with the tolerance 1%) for the construction of the amplifier and attenuator, the output of the differential amplifier was completed by a compensating amplifier with an adjustable gain (0.5 to 4.6) for the compensation of attenuator inaccuracy, which arises at application of direct route resistor, which value is selected from the standardisation array.

Option of the operating amplifiers depends on the measuring requirements. For the AC voltage up to 400 Hz any operating amplifier will be satisfying (series μA725, μA741, μA748, LM5532 and others). If measuring of DC voltages is not demanded, a condenser could separate the output of the scanning amplifier and operating amplifier need not have compensation of a DC drift. At measuring of DC voltages the drift must be compensated at each operating amplifier. Connection for the DC drift compensation operating amplifier is not introduced in charts, similarly as the circuits of frequency compensation. Typical connection is in [1], [9] or in the catalogue sheets of the producer. On the requirement of measuring on the frequencies up to 250 kHz, it is necessary to use some of the types of modern wide-band amplifiers (from the row OP 200, AD 600, etc.).

For precision measurements in DC circuits we have the original diagram (Fig. 1) added a balancing resistor R_{bal} (Fig. 6).

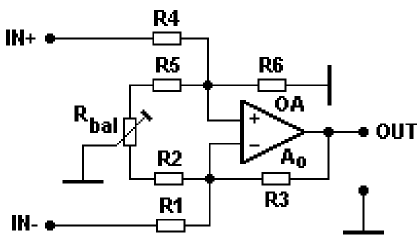

Fig. 6 Adjustment for setting input circuit

Assuming the correct settings symmetry op-amp balancing resistor allows accurate setting of symmetry R_{bal} input to operational amplifier circuit. Balance input circuit then provides further suppress the summation signal factor

$$F_N = \frac{R_1 + R_2}{R_2} \tag{18}$$

The value of the balancing resistor R_{bal} should be approximately

$$R_{bal} = 0{,}1 \cdot R_2 \tag{19}$$

Balancing is not primarily intended to compensate for inaccurate and unstable resistor network R_1 to R_6. For the design of the measuring amplifier must be stable resistors used with accuracy of 1%. Using resistors with higher precision (0.5% or 0.1%) is of course preferable. It is equally important long-term stability setting resistor R_{bal} and long-term stability of parameters and settings symmetry op-amp.

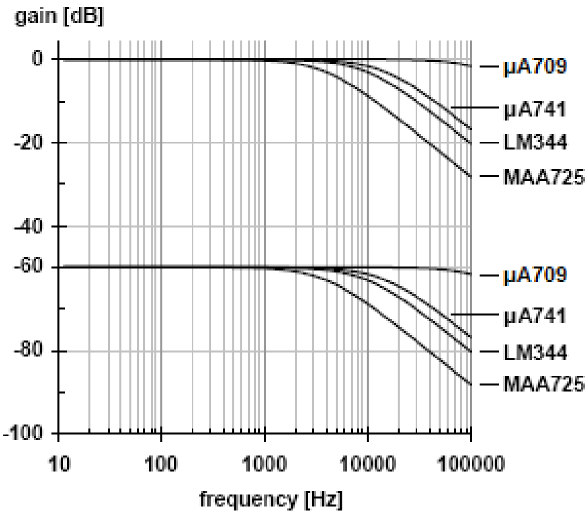

Fig. 7 Frequency response of the measuring amplifier according to Fig. 5

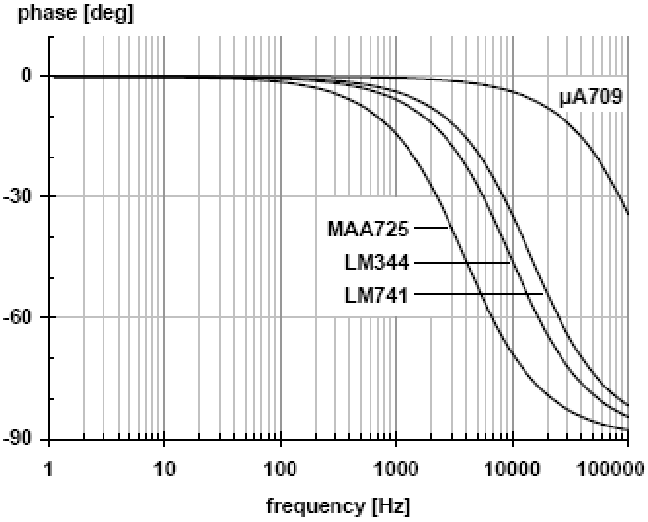

Fig. 8 Phase response of masurement amplifier at Fig. 5 for gain 0 dB (without attenuator R_7, R_8, R_p)

Frequency response of the differential amplifier by measuring Fig. 5 depends on the operational amplifiers and their potential external frequency compensation. The input buffer element (in this case, -60 dB) does not affect the transmitted frequency band (Fig. 7). If necessary, arrange for segments absorbing them as a sprocket segment.

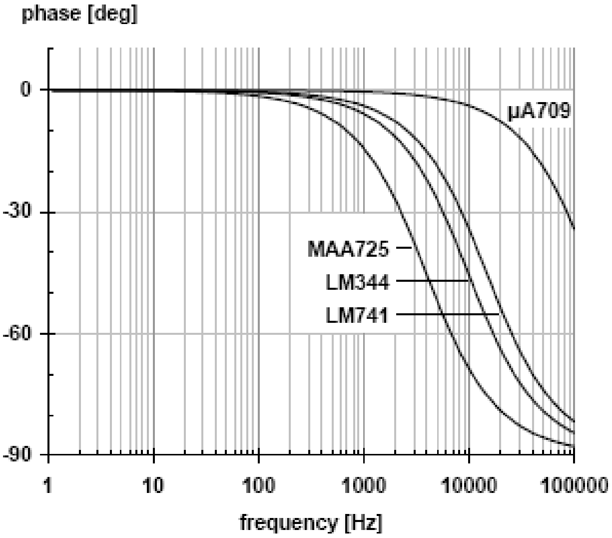

Fig. 9 Phase response of masurement amplifier at Fig. 5 for gain -60 dB (with attenuator R_7, R_8, R_p)

III. Non-inverting integrator amplifier with an impedance of in the virtual zero

Capture and processing of analog signals whose level is a function of frequency, usually requires the use of frequency-dependent circuits. They often use active four-poles that implement the integration or derivation of the processed signal. Steady and largely standardized operational amplifiers involved in the function of integration and derivation amplifiers are described in numerous publications. Fig. 7 shows a typical scheme of the circuit realizing the function

$$U_2 = \int U_1 dt$$

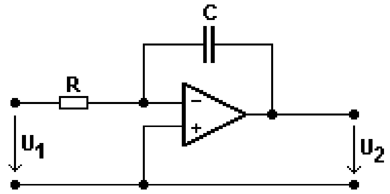

Fig.10 Scheme of typical integration amplifier [1]

Theoretical diagram of the integration amplifier (Fig. 10) must be completed for practical applications a resistor connected in parallel to capacitor C, to ensure the stability of the DC circuit.

Involvement of operational amplifiers with unbalanced differential input and a resistor in a virtual zero, as in [11] can be modified to the next version, which allows an easy way to obtain the integral in the large input voltage range of selectable frequencies using single selectable passive impedance. It retains the advantages of simple universal circumferential arrangement of other elements of the amplifier. In the original diagram (Fig. 11) instead of resistor R_0 locally series impedance circuit used in combination with *RC* or *RL* type.

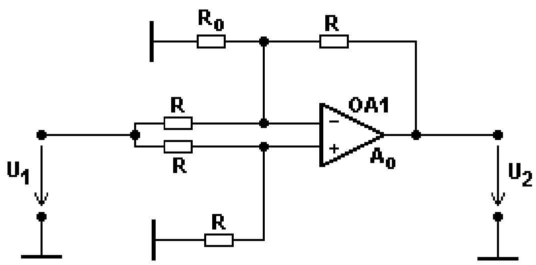

Fig. 11 Scheme of unbalanced differential amplifier [11]

The involvement of the amplifier (Fig. 12) is designed to integrate sinusoidal frequencies from several Hz and above depending on the type of operational amplifier can be operational frequencies up to tens of MHz. The circuit can be, for example in conjunction with a suitable current sensor type dI/dt. used for measuring alternating currents in a large current transmitters and frequency range, practically the entire current range radio frequency of 100 kHz to 100 MHz.

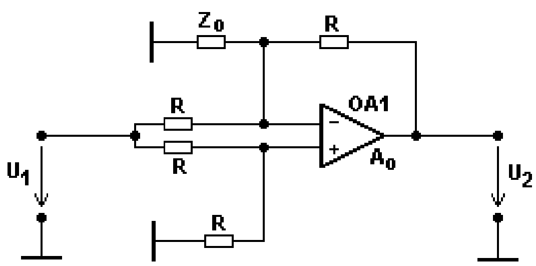

Fig. 12 Scheme of involvement of amplifier with impedance in virtual zero

In the [11] is for with one-input inverting operational amplifier with a resistor R_0 derived for inverting transfer equation that the condition $R_1 = R_2 = R$ leads to a new shape inverting transfer A_{in}.

$$A_{\text{in}} = -\frac{1}{\dfrac{2}{A_0} + 1 + \dfrac{R_0}{2 \cdot R_0 + R}} \tag{20}$$

The differential operational amplifier can be used for its non-inverting input, which is not included in the resistor R_0, derived in the same condition $R_1 = R_2 = R$, the transfer A_{n} non-inverting input of this, the pattern shape

$$A_{\text{n}} = \frac{1}{2} \cdot \frac{1}{\dfrac{1}{A_0} + \dfrac{R_0}{2 \cdot R_0 + R}} \tag{21}$$

When connected in parallel both inputs are then the sum of transmission A_{in} and A_{n}. Assuming that the voltage gain operational amplifier load A_0 is greater than 10^6 and the amplification circuit is chosen in the range of 10^{-3} to 10^3, can be members of the equations (20) and (21), includes the A_0 put equal to zero and adding the following simplified receive transmissions resulting A_{TOT} shaped transmission

$$A_{\text{TOT}} = \frac{R}{2 \cdot R_0} \tag{22}$$

From (22) shows that a single resistor R_0 is easy to change the overall transmission amplifiers, if we choose appropriately the same size of the other resistors in the circuit. Adhering to itself instead of resistor R_0 serial combination of R_0, L (while the coil resistance can easily be considered as part of the total resistance R_0), then (22) is modified in the shape:

$$A_{\text{TOT}} = \frac{R}{2R_0 \cdot \left(1 + \dfrac{\mathrm{j}\omega L}{R_0}\right)} \tag{23}$$

Lower limit frequency f_0 of the integration amplifier

$$f_0 = \frac{R_0}{2\pi \cdot L} \tag{24}$$

Since approximately ten times the lower limit frequency f_0 is a circuit according to Fig. 12 integrator with transfer

$$A_{\text{TOT}} = \frac{1}{\mathrm{j}\omega \dfrac{2L}{R}} \tag{25}$$

On the contrary, reduce the spread of the integrator for frequencies $f < f_0$ at a constant value given by (22), for the stability of participation desirable and necessary.

For the operational amplifier MAA725, MAA741 and the value of R_0 = 220 Ω and L = 15.7 H is the integration of the appropriate band from 10 Hz to 10 kHz (Fig. 13 to Fig. 17).

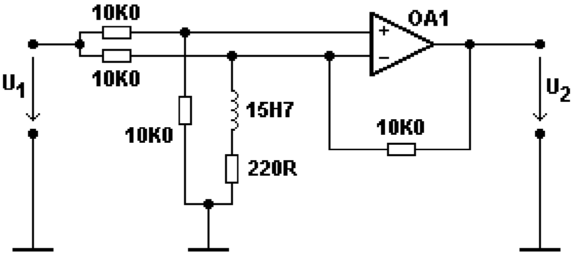

Fig. 13 Scheme non-inverting integration amplifier with impedance in the virtual zero

DC offset in output of non-ideal operational amplifier (μA725) by about 5 mV arises only for a maximum transfer order of 100 for low frequencies $f < f_0$ outside the area of integration and can eliminate the external offset compensation circuit, for example in [1]. It does not matter if the intended use of additional small circuit phase shifts obtained integral stress and emphasis is placed on the correct amplitude, can be used to separate the interfering DC component obtained capacitor voltage.

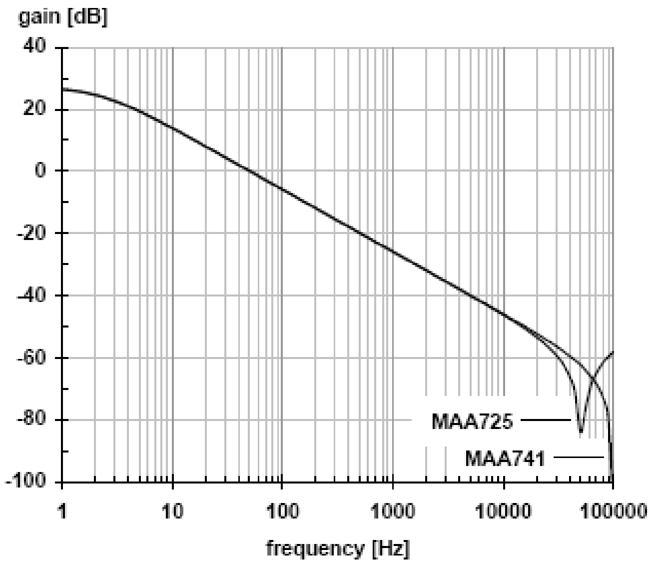

Fig. 14 Frequency response of integration amplifier at Fig. 13

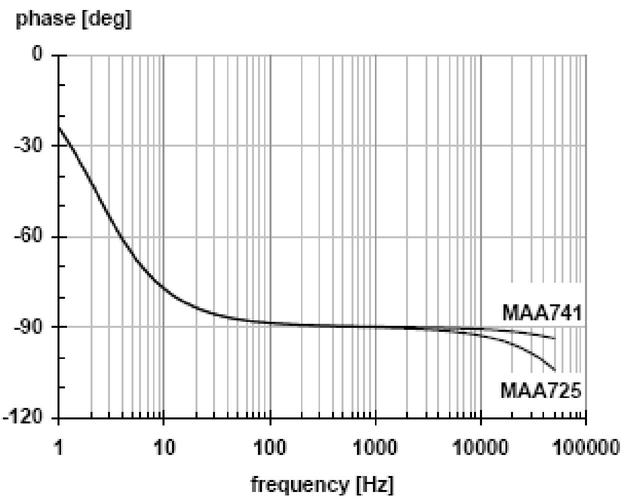

Fig. 15 Phase response of integration amplifier at Fig. 13

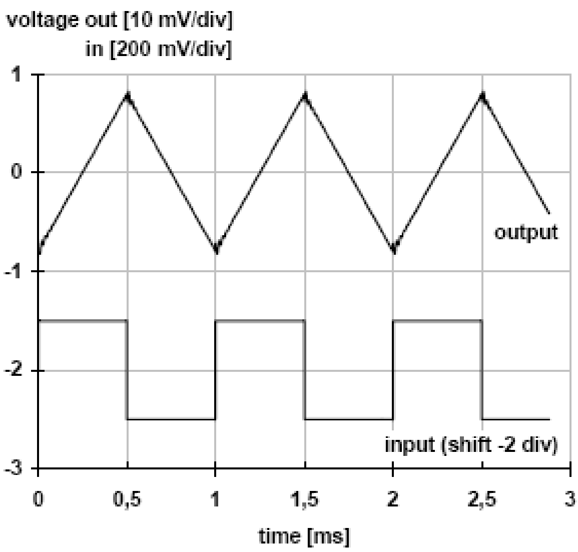

Fig. 16 Response on the input signal square of amplifier at Fig. 13

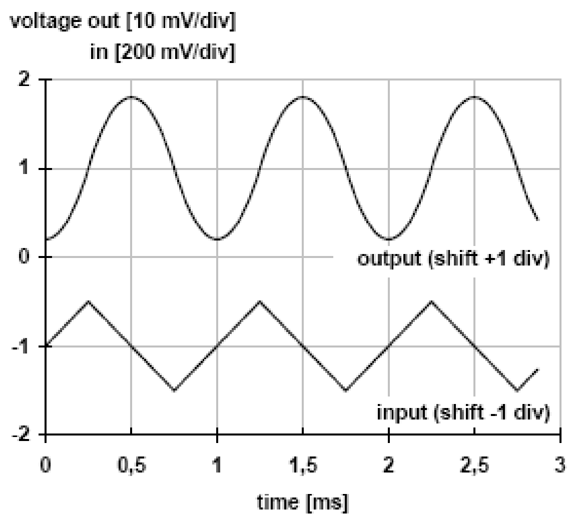

Fig. 17 Response on the input signal triangle of integration amplifier

V. NON-INVERTING DERIVATIVE AMPLIFIER WITH AN IMPEDANCE OF IN THE VIRTUAL ZERO

At fig. 13 it typical circuit diagram for realizing the function:

$$U_2 = \frac{dU_1}{dt}$$

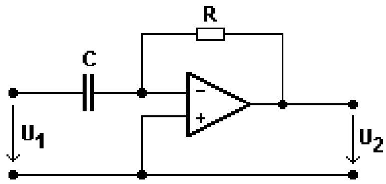

Fig. 18 Scheme of typical derivative amplifier [1]

Involvement of operational amplifiers with unbalanced differential input [11] and a resistor in a virtual zero, as in [10] can be modified into the next version, which allows an easy way to obtain the derivative in a large input voltage range of selectable frequencies using single selectable passive impedance. Involvement retains advantages of simple peripheral universal amplifier arrangement of other elements, but instead of resistor R_0 is the involvement of locally applied impedance type C (capacitor). Similar scheme was published in [8] as a non-inverting differentiator, especially for slowly varying DC voltage. For some types of operational amplifiers, but it was prone to oscillation. Therefore, there is the involvement of elected such treatment, which specifically limits the upper frequency limit differentiator, eliminating the above-mentioned instability.

Scheme the amplifier (Fig. 19) is designed for sinusoidal frequency derivative from a few Hz amount and type of operating amplifier may be functional up to frequencies of tens of kHz. It is involved in [10], [11]. It expanded further in the second impedance inverting input of operational amplifier.

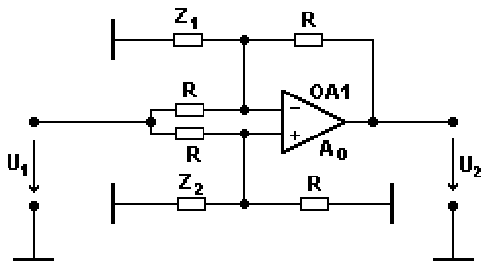

Fig. 19 Scheme of derivative amplifier with impedance in the virtual zero

Involvement in Fig. 19 can be used in a simpler case without impedance Z_2. You can then transfer to calculate the total involvement of the A_{TOT} operational amplifier used (22)

$$A_{\mathrm{TOT}} = \frac{R}{2 \cdot R_0} \tag{22}$$

After substitution we obtain $R_0 = Z_1$

$$A_{\mathrm{TOT}} = \frac{R}{2Z_1} \tag{23}$$

We choose the impedance Z_1 reactance capacitor C_1, and then we get

$$A_{\mathrm{TOT}} = \mathrm{j}\omega \frac{R}{2} C_1 \tag{24}$$

Thus executed differentiator only works well with an ideal operational amplifier (Fig. 20).

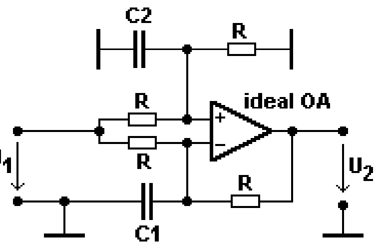

Fig. 20 Scheme derivative amplifier with of the ideal operational amplifier

With a true operational amplifier, which has effectively limited the upper frequency band limit frequency derivative, but it is usually prone to instability in the form of transient or permanent parasitic oscillations. To derive the overall transfer A_{TOT} full involvement applies to the first operational amplifier transfer A_{in} conducted from the input terminals of the inverting input connection [11].

$$A_{\mathrm{in}} = -\frac{1}{\frac{1}{A_0} + \frac{1}{A_0}\cdot\frac{R_1}{R_2} + \frac{R_1}{R_2} + \frac{1}{A_0}\cdot\frac{R_1}{R_0}} \tag{25}$$

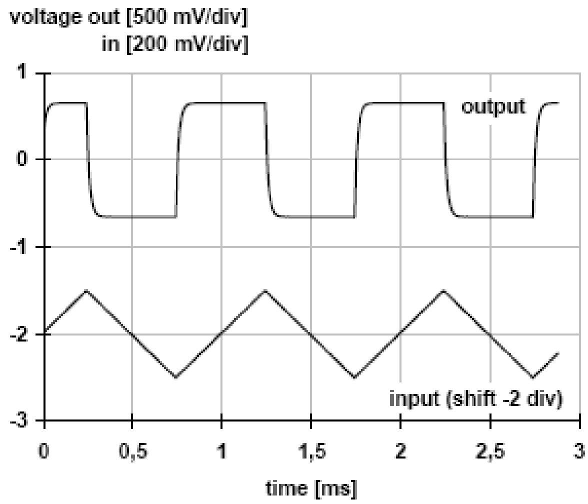

Fig. 21 Theoretical response on the input signal triangle (ideal operation amplifier)

When equal $R_1 = R_2 = R$ and gain operational amplifier load $A_0 = 10^6$ and order more leads (25) the outcome:

$$A_{\mathrm{in}} = -1 \tag{26}$$

To transfer from the input terminal connection to the non-inverting input of operation amlifier transfer are loaded A_{d} shaped divider:

$$A_{\mathrm{d}} = \frac{Z_2 \| R}{(Z_2 \| R) + R} \tag{27}$$

The symbol $\|$ is parallel combination impedance, and transmission of non-inverting A_{0z+} input operational amplifier at the output in the form

$$A_{0z+} = \frac{1}{\frac{1}{A_0} + \frac{Z_1 \| R}{(Z_1 \| R) + R}} \tag{28}$$

Here again we neglect $1/A_0$ member. Total non-inverting transmission A_{ni} is then obtained as the product of (27) and (28), which leads after adjustment for the final shape

$$A_{\mathrm{ni}} = \frac{Z_2(2Z_1 + R)}{Z_1(2Z_2 + R)} \tag{29}$$

If both inputs of operational amplifier connected across the circuit elements on a common input terminal, the added (26) and (29) in the resulting transfer of A_{TOT}

$$A_{\mathrm{TOT}} = \frac{Z_2(2Z_1 + R)}{Z_1(2Z_2 + R)} - 1 \tag{30}$$

Which can be adjusted to obtain the

$$A_{\mathrm{TOT}} = \frac{R\left(1 - \frac{Z_1}{Z_2}\right)}{2Z_1 + R\frac{Z_1}{Z_2}} \tag{31}$$

If you put in this equation $Z_2 \to \infty$ (impedance not use), it goes (31) to form $A_{\mathrm{TOT}} = R/2Z_1$, which is identical with (23). To the extent that is in place Z_1 and Z_2 capacity reactance (C_1] $100\cdot C_2$) when

$$Z_1 = \frac{1}{\mathrm{j}\omega C_1} \tag{32}$$

$$Z_2 = \frac{1}{\mathrm{j}\omega C_2} \tag{33}$$

Then after substituting (32) and (33) into (31) and get after adjusting for the A_{TOT} transmission amplifier derivative

$$A_{\mathrm{TOT}} = \frac{\mathrm{j}\omega \frac{R}{2}\left(C_1 - C_2\right)}{1 + \mathrm{j}\omega \frac{R}{2} C_2} \tag{34}$$

Transfer A_{TOT} has the value 1 at the frequency f_0

$$f_0 = \frac{1}{\pi R C_1} \tag{35}$$

and to the frequency f_{h}

$$f_{\mathrm{h}} = \frac{1}{\pi R C_2} \tag{36}$$

A circuit derives, but it is advisable not to elect the highest derived frequencies higher than $0{,}1 \cdot f_{\mathrm{h}}$, to avoid creating too large a negative phase error from the derived phase +90° tension. It is also desirable to choose the value of f_{h} (36) at least 10 times lower than the marginal operating frequency operational amplifier that occurred phase conditions suitable for the creation of own oscillations. In connection with the real circuit operational amplifier (Fig. 22) also reduced the differential input resistance operational amplifier parallel resistor R_{d} connected between the inputs of operational amplifier. This is achieved even higher resistance against oscillations involving mutual negative feedback inputs [8], [10].

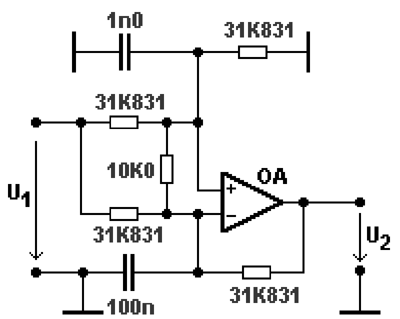

Fig. 22 Scheme derivative amplifier with of the real operational amplifier (for frequency 50/60 Hz)

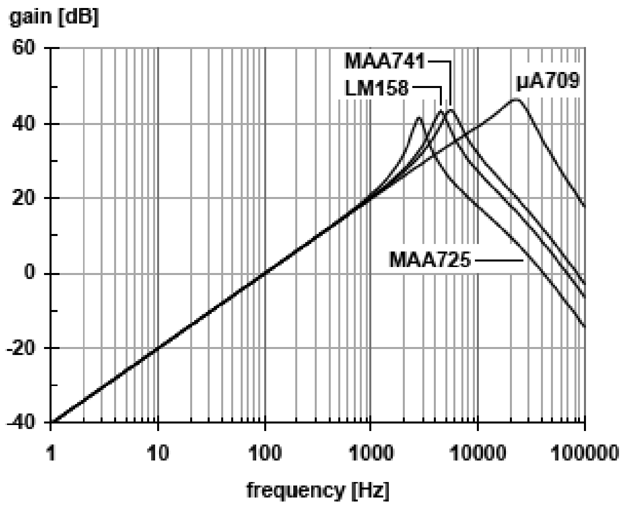

Fig. 23 Frequency response of derivative amplifier at Fig. 22

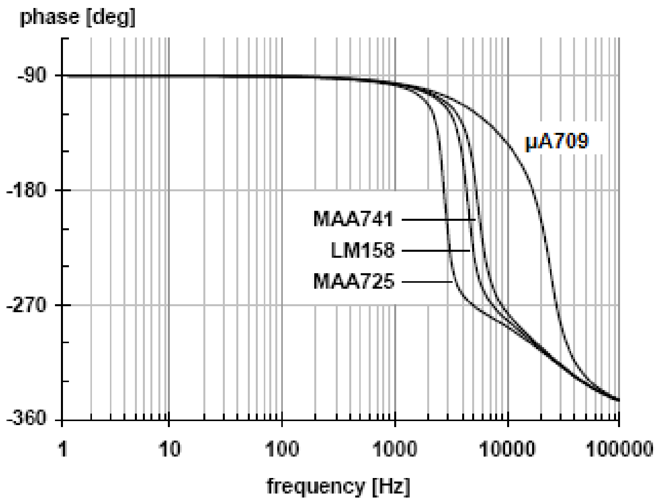

Fig. 24 Phase response of derivative amplifier at Fig. 22

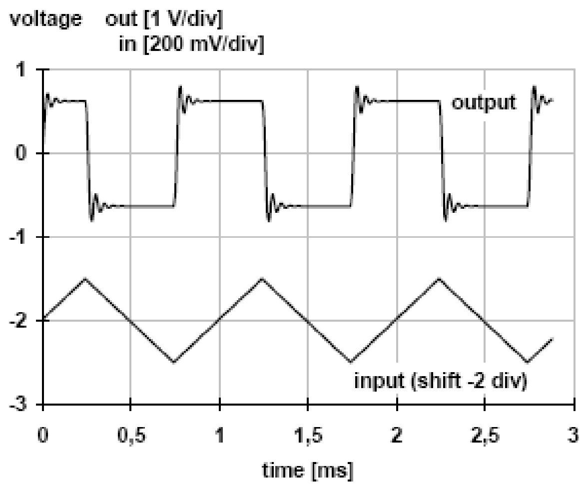

Fig. 25 Response on the input signal triangle (µA709)

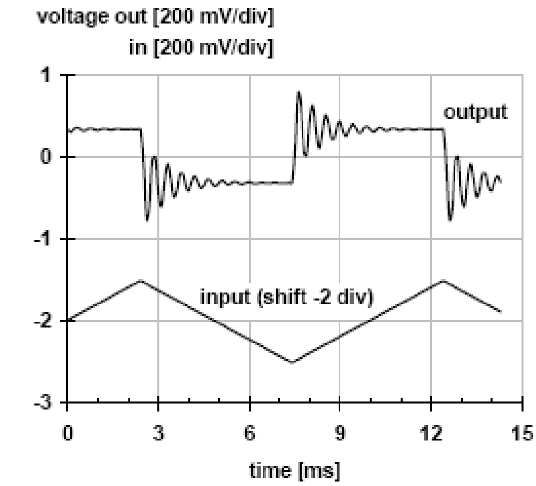

Fig. 26 Response on the input signal triangle (MAA725)

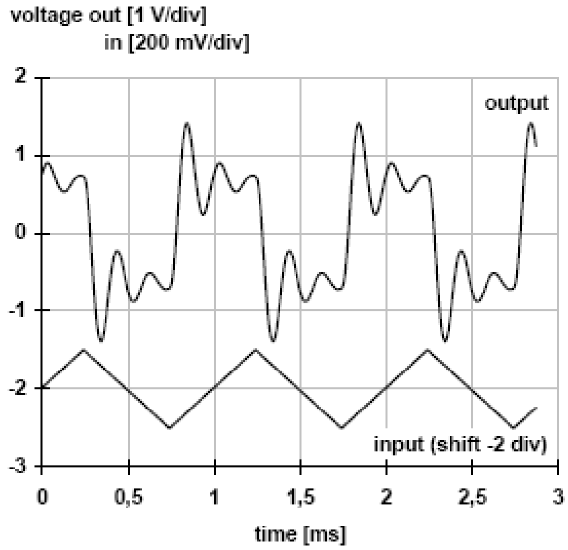

Fig. 27 Response on the input signal triangle (MAA741)

Frequency curves for the shunt amplifier according to Fig. 22 show the influence of the operating amplifier. For all the types of frequency response is linear up to a frequency of 1 kHz (Fig. 23). With the reserve meets the requirements for an operating frequency of 50 Hz power grids (or 60 Hz).

In the digital storage oscilloscope image (Fig. 25) is a derivative amplifier response on the input signal triangle. Operation amplifier special μA709 (product for military), $f = 1$ kHz, $U_{1\mathrm{peak}} = 100$ mV. Response on the input signal triangle for operation amplifier MAA725, $f = 100$ Hz, $U_{1\mathrm{peak}} = 100$ mV (Fig. 26) and MAA741, $f = 1$ kHz, $U_{1\mathrm{peak}} = 100$ mV (Fig. 27).

VI. Conclusion

Proposed involvement of operational amplifiers has been developed especially for the measurement technology and signal processing for current and voltage sensors in the electricity and industrial drives. Primarily, therefore, expected operating frequency of 50/60 Hz with the functionality of up to 5 kHz used in life-drives.

Differential measuring amplifier with high voltage core balance was developed primarily as a symmetrical input device for applications in measurement technology, DC and low frequency signals, which will be connected for additional modules (such as integration or derivation amplifier). For low frequency applications it is necessary to use an operational amplifier with a guaranteed minimum bandwidth 20 Hz to 20 kHz in the whole range of expected profits.

For the temperature dependence of the integration amplifier offset voltage are the conclusions drawn in [1]. There are, however, set the value of transmission to the DC input voltage up to 100, and an integrator used exclusively for processing AC signal, which can be from the DC component, if a defect in other downstream signal processing circuit, separate. The advantage of the circuit is that the processed does not invert phase voltage and enables saving inverter voltage. A significant advantage is fact that the internal resistance of the coil used may count resistor R_0 and used as the involvement of an "ideal" inductance L. Temperature dependence of the offset voltage of the derivation-it involved the same amplifier as the classical differential amplifier. For DC input signal transfer is determined by the involvement of only the transmission signal summation for a particular type of amplifier and is usually several orders of magnitude below the processed signals.

Derivative amplifier is the same quality as integration amplifier. The advantage of the circuit is that the processed does not invert phase voltage inverter allows you to save a further operational amplifier. A significant advantage is the fact that large leakage resistance of capacitors do not affect the transmission characteristics and involvement of the relatively low values of the surrounding resistors can be used in connection space is considered ideal [6].

All involvement can also use circuits constructed from discrete components. These circuits are usually designed as a customer for a specific use and usually are made of selected components with minimum tolerances [7], [8]. These circuits can be reasonably expected to significantly lower variance parameters, and thus significantly reduce the negative possible effects.

References

[1] CASIER, H. et al. *Analog circuit design.* Springer, 2008. ISBN 978-1-4020-8262-7.

[2] XU-HUA Y., SHENG-YONG CH., WANLIANG W. *Nonlinear Integrator Backstepping for Traffic Flow Speed Control of Automated Freeway System.* In WSEAS TRANSACTIONS on CIRCUITS and SYSTEMS, volume 10, issue 1, 2011, E-ISSN: 2224-266X.

[3] ERDEI, Z. et al. *Symbolic Equation for Linear Analog Electrical Circuits using Matlab.* In WSEAS TRANSACTIONS on CIRCUITS and SYSTEMS, volume 9, issue 7, 2010, E-ISSN 2224-266X.

[4] SEDIVY, J., HUBALOVSKY, S. *Mathematical foundations and principles in practice of computer aided design simulation.* In International journal of mathematics and computers in simulation, vol.6, 1/2012, ISSN 1998-0159.

[5] BIOLKOVA, V. et al. *State-Space Averaging (SSA) Revisited: On the Accuracy of SSA-Based Line-To-Output Frequency Responses of Switched DC-DC Converters.* In WSEAS TRANSACTIONS on CIRCUITS and SYSTEMS, volume 9, issue 2, 2010, E-ISSN: 2224-266X.
[6] DONDON, M. et al. *A practical modeling for the design of a sigma delta class D power switching amplifier and its pedagogical application.* In Proceedings of the 15th WSEAS International Conference on Circuits 2011, Published by WSEAS Press. ISBN 978-1-61804-017-6.
[7] LONG, K. *Intercept of Frequency Agility Signal using Coding Nyquist Folding Receiver.* In WSEAS TRANSACTIONS on SIGNAL PROCESSING, volume 9, issue 2, 2010, E ISSN 2224-3488.
[8] LOKVENC J. A non-inverting derivator. TESLA electronics 5, 1972, issue 1, pp.26-27.
[9] PUNCOCHAR, J. *The Operational Amplifiers in Electronics.* Prague. BEN. 1999. ISBN 80-86056-37-6.
[10] LOKVENC, J., DRTINA, R., SEDIVY, P. *Unusual involvement of operational amplifiers for measuring purposes, low frequency and DC applications.* In 16th WSEAS International Conference on CIRCUITS. Kos, Greece, 2012. Published by WSEAS Press. ISBN 978-1-61804-108-1.
[11] LOKVENC, J., DRTINA, R., SEDIVY, P. *Unusual involvement of operational amplifiers for measurement purposes: non-inverting amplifier integral and derivative.* In 16th WSEAS International Conference on CIRCUITS. Kos, Greece, 2012. Published by WSEAS Press. ISBN 978-1-61804-108-1.

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