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A.C. MICROPROCESSOR QUASI-BALANCED BRIDGES

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Abstract: Principles of building R, C, L-meters with wide functional capabilities and using Whetstone as base are described. Such meters can find a wide application in measuring instruments and in complex information control system
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1 INTRODUCTION

The given paper is devoted to an actual problem referring to the theory development of the quasi-balanced meters construction for the passive electric values parameters. The problem hasn't lost its significance, because the constant appearance method new application areas in the impedance method use which in their turn require the meters technical characteristics improvement (R, C, L). The latter makes the scientist try to improve the principles of the impedance meters formation (IM) and to create IM with the different functional capabilities.

The IM characteristics improvement is achieved due to the use of the progressive element base in them, that is why the IM construction in the paper is shown on the basis of the modern element base of the electronic engineering.

The analysis of the known techniques for the IM characteristics improvement has shown that IM basis is made up by the measuring circuits (MC) and naturally the scientists paid main attention to the improvement of these IM parts. This fact has led to the creation of the theory of the MC separate balancing, quasi-balanced and semi-balanced MC, methods of the signal formation for the NC parameters modulation balancing control, the methods of the co-ordinate balancing and also the ways of the MC properties structural improvement. Such a trend seems to be the most interesting (1) for the author that is why much place of the paper is given to the investigation of the structural methods use problems in Whetstone bridge (WB) for the highly–effective IM construction.

The research of the WB functional possibilities broadening in the quasi-balanced regime has led to the idea of the structural techniques application in WB. From all the structural methods [1] we have chosen the methods providing for the WB output characteristics linearization relative to the immitance of the comparison branch and methods providing for the lineriazation relative to the branch immitances with the research object (RO).

2 GROUNDS FOR BUILDING A.C. QUASI-BALANCED BRIDGES

2.1 The research of the Whetstone Bridge and linearized MCs properties

The conversion functions of WB and linearized MCs can be presented in the following way:

$$\dot A_b = \frac{\dot a \dot B_{x,y} - \dot b}{\left(1 + \dot a \dot B_{x,y}\right)\left(1 + \dot b\right)} \dot A_e, \qquad \dot A_b = \frac{\dot a \dot B_{x,y} - \dot b}{\left(1 + \dot a \dot B_{x,y}\right)} \dot A_e, \qquad \dot A_b = \frac{\dot a \dot B_{x,y} - \dot b}{\left(1 + \dot b\right)} \dot A_e,$$

where $B_{x,y}$ = x + j y — is the measured complex value which components x and y; a — immitance of the shoulder adjacent to the shoulder containing RO; b — product of the comparison branch immitances; A_b — output voltage of MCs; Ae — MC feeding voltage.

It is not difficult to imagine that for WB and linearized MCs capabilities manifestation in the quasi-balanced regime one should simply analyse the following functions.

$$\dot W_1 = \frac{\dot a \dot B_{x,y} - \dot b}{\left(1 + \dot a \dot B_{x,y}\right)}; \qquad \dot W_2 = \frac{\dot a \dot B_{x,y} - \dot b}{\left(1 + \dot b\right)}; \qquad \dot W_3 = \frac{\dot a \dot B_{x,y} - \dot b}{\left(1 + \dot a \dot B_{x,y}\right)\left(1 + \dot b\right)}; \qquad \dot W_4 = \dot a \dot B_{x,y} - \dot b.$$

They are realized by the bridges during the different conditions, i.e. while application of the following value pairs to the PSD: output voltage of MCs and the generator voltage; output voltage of MCs and the shoulder voltage of the comparison branch; the output voltage of MC and the shoulder voltage of the branch with the RO.

With the help of WB the functions — W_1, W_2, W_3 are realized with the help of the linearized MCs the function of W_1, W_4 and the functions of W_2, W_4 can be realized.

The investigation of the functions W_1—W_4 proves that both WB and linearized MCs in the quasi-balance module regime (mod W_1=1) don't provide for the module $B_{x,y}$ setting. In this regime, WB and MCs linearized relative to the comparison branch immitances provide for the settling of only the constituents during the function W_1 realization. MCs possess broader capabilities in the phase regime of quasi-balance when the equation: -arg $W_i=0+90^o$ is fulfilled. We shall prove it below.

According to the function W_1 the quasi-balance state IM W_1=0 obtained by the regulation of one the components a or b is defined by the condition:

$$\frac{x\,\mathrm{Re}\,\dot{a}-y\,\mathrm{Im}\,\dot{a}-\mathrm{Re}\,\dot{b}}{x\,\mathrm{Im}\,\dot{a}+y\,\mathrm{Re}\,\dot{a}-\mathrm{Im}\,\dot{b}}=\frac{x\,\mathrm{Re}\,\dot{a}+y\,\mathrm{Im}\,\dot{a}+1}{x\,\mathrm{Im}\,\dot{a}+y\,\mathrm{Re}\,\dot{a}}$$

which after the conversion takes the form of:

$$-x\left(\mathrm{Im}\,\dot{a}\,\mathrm{Re}\,\dot{b}+\mathrm{Im}\,\dot{a}-\mathrm{Re}\,\dot{a}\,\mathrm{Im}\,\dot{b}\right)-y\left(\mathrm{Re}\,\dot{a}\,\mathrm{Re}\,\dot{b}+\mathrm{Re}\,\dot{a}-\mathrm{Im}\,\dot{a}\,\mathrm{Im}\,\dot{b}\right)+\mathrm{Im}\,\dot{b}=0.$$

The MC output values are set by the expression: $\dot{A}_{bi}=\dot{A}_{eoi}\,\mathrm{Re}\,\dot{W}_1$,

where $\mathrm{Re}\,\dot{W}_1=\dfrac{x\,\mathrm{Re}\,\dot{a}-y\,\mathrm{Im}\,\dot{a}+\mathrm{Re}\,\dot{b}}{x\,\mathrm{Re}\,\dot{a}-y\,\mathrm{Im}\,\dot{a}+1}$; $\dot{A}_{eoi}$ - is voltage applied to the base input of the PSD. In WB $\dot{A}_{eoi}=\dot{A}_e$. but in the linearized MC

$$\dot{A}_{eoi}=\frac{\dot{A}_e}{\left(1+\dot{a}\dot{B}_{x,y}\right)\left(1+\dot{b}\right)},$$

Similarly, at the moment of the quasi-balance state Re W_1=0 setting up in MCs, the condition takes place:

$$\frac{x\,\mathrm{Re}\,\dot{a}-y\,\mathrm{Im}\,\dot{a}-\mathrm{Re}\,\dot{b}}{x\,\mathrm{Im}\,\dot{a}+y\,\mathrm{Re}\,\dot{a}-\mathrm{Im}\,\dot{b}}=\frac{x\,\mathrm{Im}\,\dot{a}+y\,\mathrm{Re}\,\dot{a}}{x\,\mathrm{Re}\,\dot{a}-y\,\mathrm{Im}\,\dot{a}+1}$$

or its equivalent condition

$$\left(x^2+y^2\right)\left\{\left(\mathrm{Re}\,\dot{a}\right)^2+\left(\mathrm{Im}\,\dot{a}\right)^2\right\}+x\left(\mathrm{Re}\,\dot{a}-\mathrm{Re}\,\dot{a}\,\mathrm{Re}\,\dot{b}+\mathrm{Im}\,\dot{a}\,\mathrm{Im}\,\dot{b}\right)-y\left(\mathrm{Re}\,\dot{a}\,\mathrm{Im}\,\dot{b}+\mathrm{Im}\,\dot{a}-\mathrm{Im}\,\dot{a}\,\mathrm{Re}\,\dot{b}\right)+\mathrm{Re}\,\dot{b}=0, \quad (1)$$

and the MCs output values are found out by the expression:

$$\dot{A}_{bi}=\dot{A}_{eoi}\,\mathrm{Im}\,\dot{W}_i \quad (2)$$

where

$$\mathrm{Im}\,\dot{W}_1=\frac{x\,\mathrm{Im}\,\dot{a}+y\,\mathrm{Re}\,\dot{a}-\mathrm{Im}\,\dot{b}}{x\,\mathrm{Re}\,\dot{a}-y\,\mathrm{Im}\,\dot{a}+1}.$$

Having analysed the obtained expressions we can easily conclude that only in case of quasi-balance state $\mathrm{Re}W_1$=0 setting in MCs from the quasi-balance condition (1) it is possible to calculate module $B_{x,y}$ provided the equation: $\mathrm{Im}\,\dot{a}=\mathrm{Im}\,\dot{b}=0$, $\mathrm{Re}\,\dot{b}=1$ $\mathrm{Re}\,\dot{a}=\dfrac{1}{\sqrt{x^2+y^2}}$. is carried out.

It is impossible to determine even one of the $B_{x,y}$ parameters during quasi-balance state by the MCs output values.

During the W_2 function realization MCs provide for the indentical calculation of the $B_{x,y}$ parameters in case of the quasi-balance state $\mathrm{Re}W_2$=0. There may be the following cases:

-at $\mathrm{Im}\,\dot{a}=\mathrm{Im}\,\dot{b}=0$ $x=-\dfrac{\mathrm{Re}\,\dot{b}}{\ldots}$, and MC's output values are found from the expression:

$$\dot{A}_{bi}=\dot{A}_{eoi}\,y\,\frac{\mathrm{Re}\,\dot{a}}{\ldots}.$$

-at $\operatorname{Re}\dot{a} = \operatorname{Im}\dot{b} = 0 - \quad y = \frac{\operatorname{Re}\dot{b}}{\operatorname{Im}\dot{a}}$, and MCs output values $\dot{A}_{bi} = \dot{A}_{eoi}\, x \frac{\operatorname{Im}\dot{a}}{1+\operatorname{Re}\dot{b}}$.

The regulated values may be either the value component a, or the value Reb. If the value is regulated, the value component will be a and the MCs output values are equal or $\dot{A}_{bi} = j\dot{A}_{eoi}\frac{y}{x}\frac{\operatorname{Re}\dot{a}}{1+\operatorname{Re}\dot{b}}$, or $\dot{A}_{bi} = j\dot{A}_{eoi}\frac{x}{y}\frac{\operatorname{Re}\dot{b}}{1+\operatorname{Re}\dot{b}}$, i.e. in this case it is possible to calculate the component and the relations of the complex value components at A_{eoi}=const or the influence reduction of the value $A_{\dot{y}oi}$ (in one MCs $\dot{A}_{eoi} = \dot{A}_e \Big/ \left(1+\dot{a}\dot{B}_{x,y}\right)$ and $\dot{A}_{eoi} = \dot{A}_e$ in the others).

The W_3 function is realized only in WB. His not difficult to prove that in case of $\operatorname{Re}W_3=0$ quasi-balance state in WB is fulfilled, so we can calculate the module if Ima, Imb are equal to 0 and Reb is equal to 1. The Quasi-balance State has then the form of: $\operatorname{Re}\dot{a}\sqrt{x^2+y^2} = 1$.

The W_4 function is realized in MCs which expressions for the output signal have the form of $\dot{A}_{bi} = \left(\dot{a}\dot{B}_{x,y} - \dot{b}\right)\dot{A}_{eoi}$. The representatives of such MCs are MCs with the BC with correspondent: $\dot{A}_{eoi} = \dot{A}_e \Big/ \left(1+\dot{a}\dot{B}_{x,y}\right)$ and $\dot{A}_{eoi} = \dot{A}_e \Big/ \left(1+\dot{b}\right)$. . The W_4 function is represented in the form of:

$$\frac{\dot{A}_b}{\dot{A}_{eoi}} = x\operatorname{Re}\dot{a} - y\operatorname{Im}\dot{a} + \operatorname{Re}\dot{b} + j\left(y\operatorname{Re}\dot{a} + x\operatorname{Im}\dot{a} + \operatorname{Im}\dot{b}\right),$$

and we can determine that two quasi-balance state conditions are possible in MCs: $\operatorname{Re}\dot{A}_{eoi}\dot{A}_b = 0$ and $\operatorname{Im}\dot{A}_{eoi}\dot{A}_b = 0$. These conditions allow to obtain the passive values proportional to the conversed value components but not to their relation. In case of the regulated value component is b, the output active values are proportional to the second component, and if it is a — the output active values are proportional to the $B_{x,y}$ value components relation.

MCs with linearized functions of conversion relatively to the branch immitances with the RO using as base voltage the shoulder voltage drop of the comparison branch and application of MCs disbalance voltage to the PSD input at the regulated value b provide for the measurement by the component passive value and the $B_{x,y}$ components relation by the output active value when $x\operatorname{Im}\dot{a} >> 1,\ y\operatorname{Re}\dot{a} >> 1,\ y\operatorname{Im}\dot{a} >> 1$. . In this case if the regulated value is a, MCs provide for the measurement by the component passive value the accurate measurement of the $B_{x,y}$ components relation by the output active value.

In case MCs with the linear functions of conversion relatively to the comparison branch immitances use the voltage drop on one of the branch shoulders with RO and the disbalance voltage application to PSD input with the regulated value b as the base voltage they provide for the impedance component measurement by the passive value. If the regulated value is a, MCs provide for the calculation by the passive value of the component $B_{x,y}$ and by the active output value (at y << x or vice versa).

The functional capabilities of the linearized MCs are considerably wider than those of WB. For example, it WB provides for the measurement of only one parameter $B_{x,y}$, the lineriarized MCs can measure two parameters. The wides functional of MCs are exhibited during the W_4 function realization.

2.2 Building of R, C, L meters on the MC basis influencing on the feeding diagonal voltage

In these MCs there are no voltages suitable for use as a base. That is why it is proposed to build MCs influencing on the feeding diagonal voltage in the quasi-balance regime with the similar character of the comparison branch immitances. We shall describe such MCs below.

a) MCs with the conversion functions, linearized relatively to the comparison branch immitances.

The important property of the given MCs is the opportunity to obtain an active value proportional to the measured component $B_{x,y}$ while calculating the regulated element in the comparison branch.

The important advantage of the IM built by the total graph (Fig. 1a) is the simplicity of the technical realization. As Fig. 1a shows, using and active D-current value Ae= and the regulated value Reb together with the passive value and the active value of the A-current Ag ~ proportional to the measured component, MCs provide for the obtaining of an active value of the D-current Ag = also proportional to the measured value. PSD, analog-digital converter (ADC) and microprocessor system (MS) used in IM are designated as F, C, L on the graph. The additional signals used during the data processing aimed at the calculation of all parameters of the RO impedance can get on the inputs of d MCs. All the information data must be present on the output P, the other output is used for sending signals of the balance control to MCs.

b) MCs with the conversion functions linearized relatively to the branch immitances with RO. The advantage of these MCs is the opportunity to use the generator voltage as a base one and the possibility of the calculation of the $B_{x,y}$ components relation by the output active value. The total IM graph built on these MCs basis is shown on Fig. 1.b. As it can be see on this graph such 1M has no active value Ag depending on the measured component. But there is an active value $\dot{A}_1 = \frac{\dot{A}_{e=}}{\dot{a}\,\dot{B}_{x,y}}$ which meaning is rather useful in some cases, for inst. at x<<y A_1~y and at Ima=0 DC voltage $\dot{A}_1 = \frac{\dot{A}_{e=}}{x \operatorname{Re} \dot{a}} \sim x.$

2.3 Building of R, C, L meters on the MC basis influencing on the feeding diagonal voltage

Such MCs possess more functional capabilities in comparison with all the others, as the comparison branch shoulders can be complex.

MCs allow measuring the parameters of the inductive objects without using inductive measures. The important advantage of MCs is the possibility to measure the second parameter using one logometric conversion.

a) MCs with the misbalance voltage application into the comparison branch.

Fig.3 shows the total IM graph built on the MC basis with the misbalance voltage application into the comparison branch. Using of one logometric conversion provides for he obtaining of an active value proportional to the second components. Thus, such MCs allow to build IM for the simultaneous conversion of two parameters of the $B_{x,y}$ complex value.

Having active comparison branch resistance's we can form an active value Ag= of DC proportional to the balanced component. For this can be done it is necessary to connect an additional source of DC active value Aý= in to a "node".

b) MCs with the misbalance voltage application into the RO branch.

And these MCs provide for the obtaining of an A_{b1} active value proportional to the $B_{x,y}$ second component using one logometric conversion. Here the regulated value must be b value component.

Fig. 4 show the total graph of such IM. As it can be seen on the graph it is possible to obtain an active value of DC $\dot{A}_1 = \frac{\dot{A}_{e=}}{x \operatorname{Re} \dot{a}}$ proportional to the measured value at Ima=0. An additional active value Ae= must be included into the node "m". Having the regulated value a these MCs without any logometric conversion provide also for the conversion of the component two parameters and these components relation. This is an important advantage of the investigated MCs in comparison with the MCs linearized relatively to the comparison branch immitances.

The graphs given on Fig. 1 help to build the structures of the necessary IMs in the phase quasi-balance regime. Having analysed MCs with one BC we have concluded that: the structural methods of the characteristics improvement provide for the new properties and possibilities of MCs in the quasi-balance regime; the new properties and possibilities depend on the method used in MCs and on the MC branch caught by the BC circuit; using the MC peculiarities being improved by the structural methods, one can build IM with the various functional capabilities.

Fig. 3 shows IM variant converting C_x capacity and conductivity G_x. The scheme is built on the MC basis, which branch with the regulated element R_3 is surrounded by the positive BC. The base voltage is the voltage drop on the object. On the output of the repeater P_2 the voltage U_2 is proportional to the measured impedance component. By applying signals from the MC components on MC input (L) we obtain the calculation of all RO parameters and the measurement accuracy increase.

For example, Fig.4 shows the bridge variant providing for the simultaneous measurement of capacity C_x and conductivity G_x of the RO by the substitution parallel scheme. By applying DC voltage on the accumulator input we provide for the DC analogue value obtaining U_2= Ue= R_0 G_x, proportional to the measured conductivity.

3 CHARACTERISTICS OF BRIDGES IMPLEMENTING CIRCUITS

We recommend using analogue and digital integral microcircuits with the computing capabilities in the proposed IMs which would provide for the calculation of more than one RO passive parameter and even slight measurement accuracy increase. Although the MC use is necessary to calculate all RO passive parameters, to broaden the IM functional capabilities and parameter measurement accuracy increase.

4 CONCLUSION

The new bridge structures providing for the module conversion in the quasi-balance regime and the impedance components' relation in broad limits are found out. The reading of the converted parameters is possible both by passive and active values.

The variants of the IM building with the microprocessor control systems on the basis of the developed MC structures with the improved functional capabilities are proposed.

The proposed A.C. bridges are relatively easy to implement and, at the same time, are characterised by wide functional capabilities, high measurement accuracy and calculation of passive electric parameters in the objects under investigation. They can be easily inserted both into the separate instruments and the complex systems.

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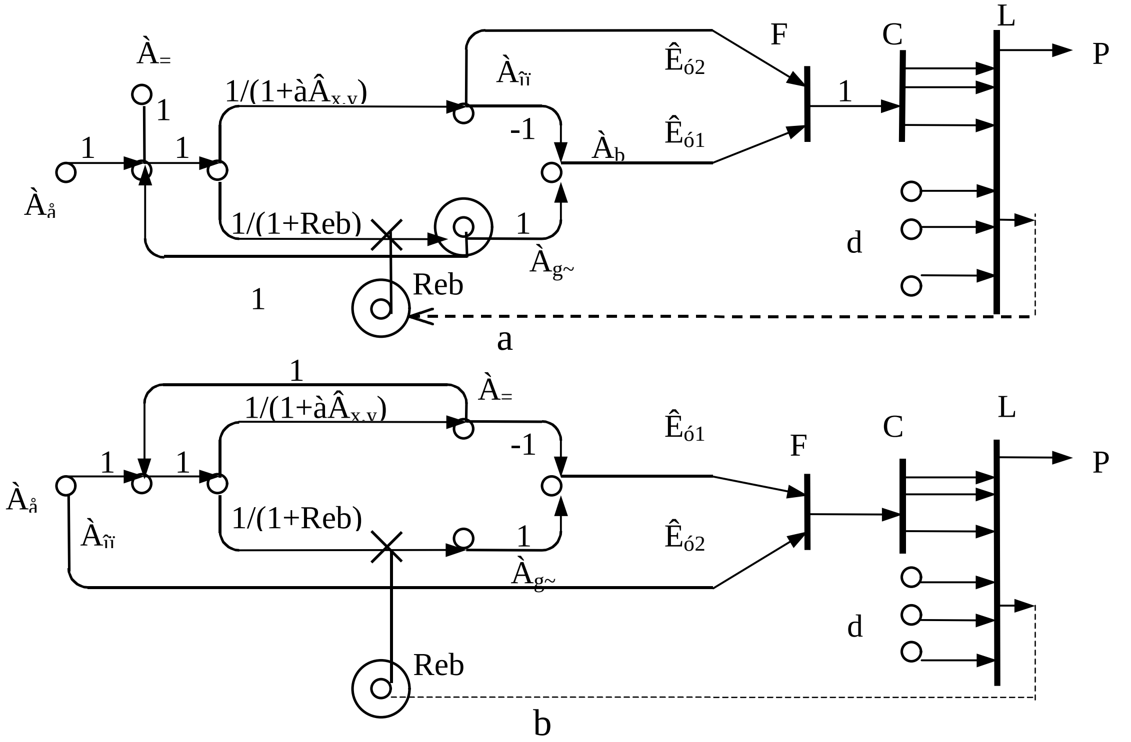

Figure 1. The graphs of the quasi-balance AC bridges.

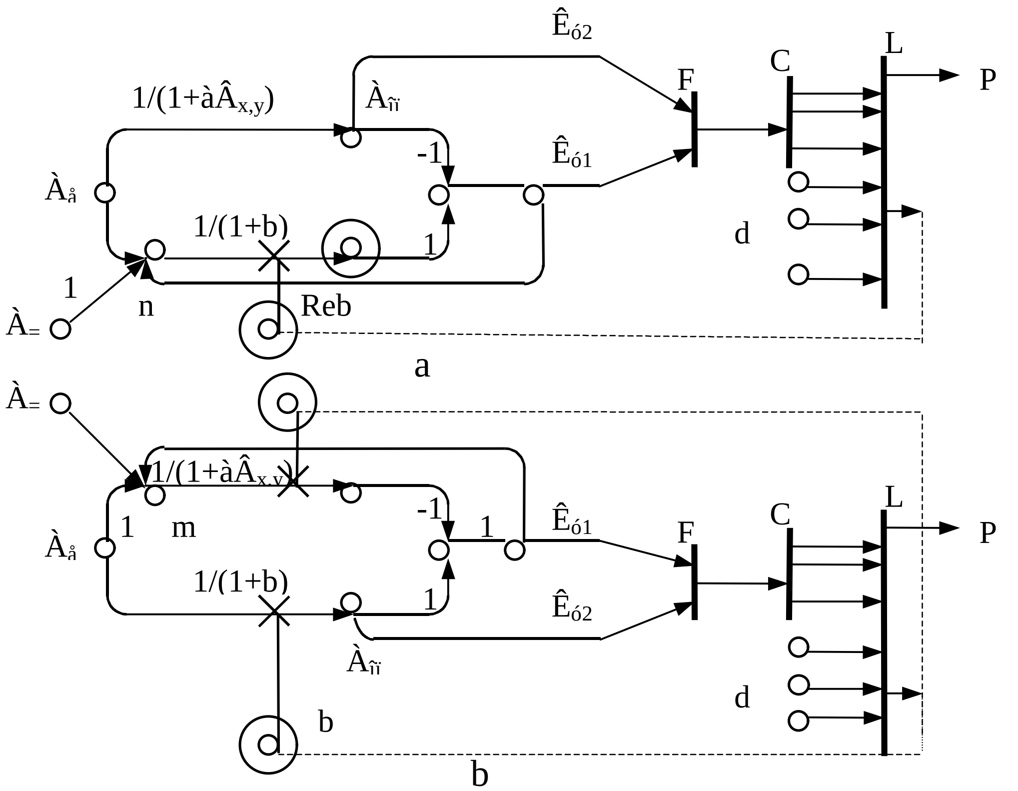

Figure 2. The graphs of the quasi-balance AC bridges.

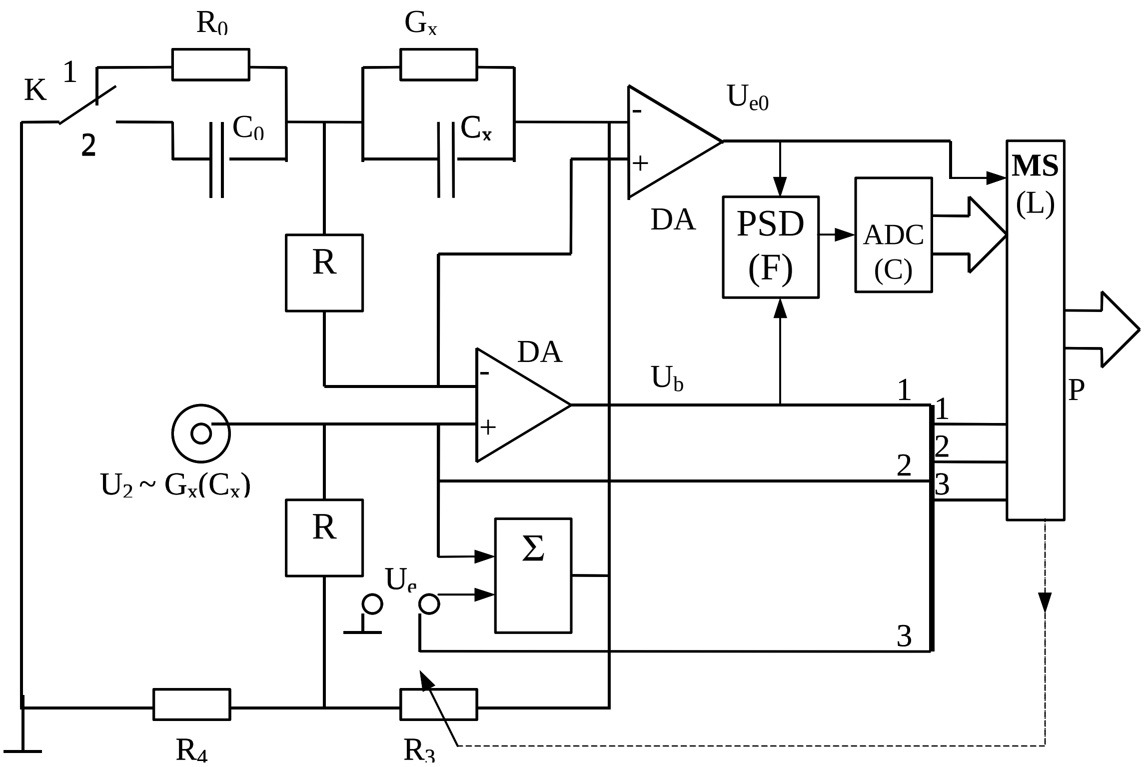

Figure 3. DC bridges variant.

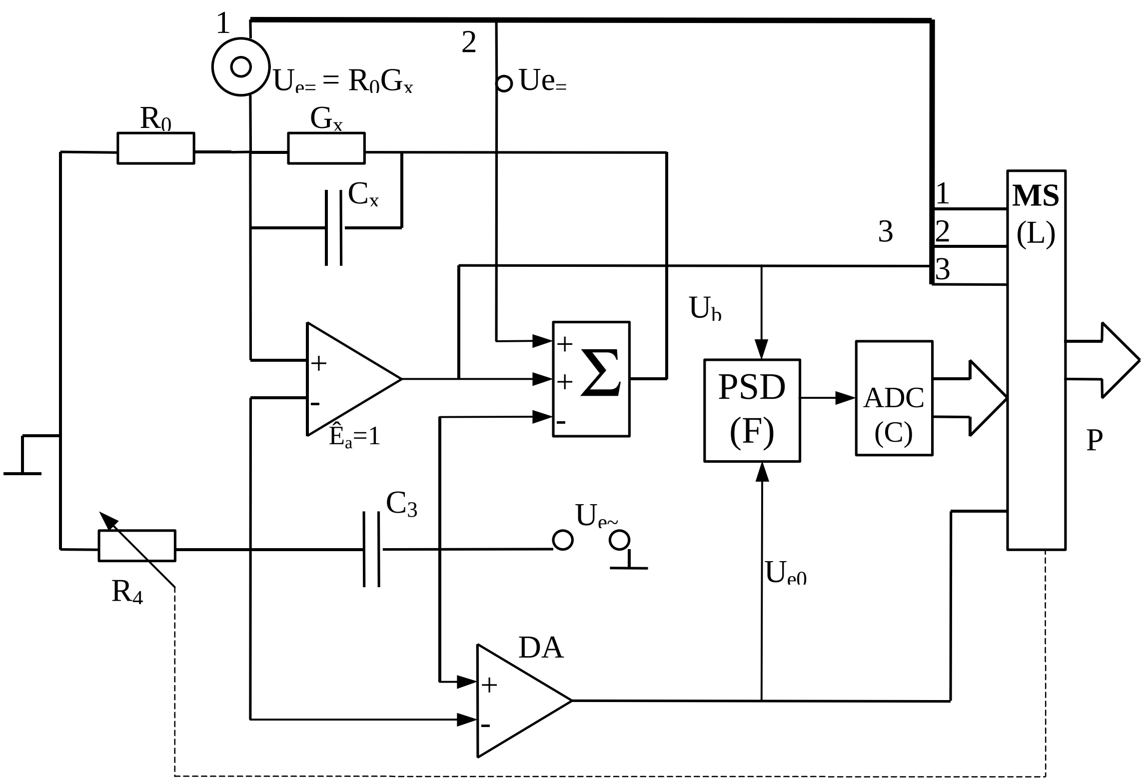

Figure 4. DC bridges variant.