

The present invention, according to claim 1, consists in a circuit arrangement for cleaning an electrode which is in contact with a substance and has a potential to be measured, by applying a direct or alternating voltage, characterized by a voltage source for applying the direct or alternating voltage to the electrode through two series-connected switches each having one contact element, with the first switch connected to the voltage source, and the second switch to the electrode, by a timer for synchronously moving the contact elements, whereby a connection between the voltage source and the electrode can be closed simultaneously or opened simultaneously by means of the first and second switches, and by an impedance transformer having a high input impedance and a low output impedance whose input is connected to the electrode, and whose output is coupled to the contact element of the second switch at least during the period in which the connection between the voltage source and the electrode is open simultaneously at the first and second switches.

The invention, according to claim 6, further consists in a circuit arrangement for cleaning two electrodes which are in contact with a substance and have potentials to be measured, by applying a direct or alternating voltage, characterized by a voltage source for applying the direct or alternating voltage, and by the following

per electrode: a switch for connecting the direct or alternating voltage to the electrode, an impedance transformer having a high input impedance and a low output impedance whose noninverting input is connectable through the switch to the voltage source, a series combination of a current-limiting resistor and a diode or two diodes connected in inverse parallel, with the output of the impedance transformer connected through the series combination to the electrode, and the junction of the current-limiting resistor and the diode/diodes connected to the inverting input of the impedance transformer, and an operational amplifier whose noninverting input is connected through a resistor to the electrode, and whose inverting input is connected through an additional resistor to the noninverting input of the impedance transformer and through a feedback resistor to the output of the operational amplifier, and further by the following: an additional resistor through which the inverting input of the operational amplifier associated with the first electrode is connected to the inverting input of the operational amplifier associated with the second electrode, and a timer for generating a signal which causes the switch to apply the output of the voltage source to one input of each of the impedance transformers.

In WO-A 88/07194, which was filed, but not published, prior to the present application and is therefore only relevant according to Article 54(3) EPC, an electrical cleaning process for the indicator electrodes of a titrator is described. With the measuring circuit disconnected, a low-frequency alternating voltage of 1 Hz to 10 Hz is applied through switches, e.g., relays, until the electrode is clean.

By this additional circuitry, however, the circuit formed by the electrode is loaded, particularly capacitively. This is undesirable mainly during magnetic flow measurements, in which the electrodes contacting the fluid generate a measurement signal (cf. a book published by the patent holder, "Durchfluss-Fibel", 1985, pages 15 et seq.). The electrodes represent a voltage source whose internal resistance depends particularly on the geometry of the inductive pickup and the conductivity of the fluid. The higher the internal resistance, the more sensitive the electrode will be to external circuit elements. In addition, switches may generate spurious voltages whose effects on the electrode signal are undesirable.

Accordingly, the problem underlying the invention is to free the electrode and/or its connecting/signal leads from spurious effects which originate from the circuitry for applying the voltage to the electrode.

According to the invention, this is achieved by coupling, at least during the time interval in which the voltage is not applied, approximately the potential of the electrode to those terminals of the switches which are not associated with, i.e., not connected to, the electrode. Thus, in the "off" state of the switches, i.e., in the state in which the connection to the cleaning voltage is open, potential differences between the terminal associated with the cleaning voltage and that associated with the electrode are made negligibly small. Consequently, unavoidable capacitive components of the switches can no longer load the electrode signal in an unpermissible manner. The means for coupling the potential of the

electrode(s) to the switches are advantageously implemented with active components, such as operational amplifiers. This has the advantage that any spurious voltages originating from the switching element can be largely compensated for by the output of the active component.

The circuit arrangement according to the invention can be used to advantage where electrodes are in contact with a fluid for measurement purposes and become contaminated. That is the case particularly during magnetic flow measurements, where the electrodes serve to generate a measurement signal, as is described, for example, in EP-A 219 725. There, the through-connection of the cleaning voltage can be incorporated into a measurement cycle as follows:

- Prior to the application of the cleaning voltage, a measurement signal from the electrodes is stored and/or output as a measured value;
- the cleaning voltage is applied to the electrodes for a given, selectable duration and at given, selectable intervals;
- after the cleaning voltage has been switched off, the start of the measuring operation is delayed by a pause in which the electrochemical conditions at the cleaned electrode can return to normal, and
- after this pause, the measuring operation is resumed.

In the invention, an impedance transformer with a high input impedance and a low output impedance is provided whose output is connected to that of the terminals of the switch coupled

to the electrode which is not connected to the electrode. The input of the impedance transformer may either be connected directly to the electrode or the connecting lead of the electrode or be operated approximately at the electrode potential by means of separate coupling elements (e.g., operational-amplifier circuits).

According to the second variant of the invention, parallel to the application of the electrode potential, the direct-voltage source or alternating-voltage source for generating the cleaning voltage is connected to the input of the impedance transformer. In that case, switches are provided between the output of the voltage source and the input of the impedance transformer which are activated intermittently by a timer.

In one embodiment of the first variant of the invention, a terminal of the switch which is not connected to the electrode or its lead is associated both with the output of the voltage source and with the output of the impedance transformer. This may be implemented, on the one hand, with a changeover switch which switches the output of the cleaning-voltage source intermittently between a terminal connection to the electronics and the output of the impedance transformer. On the other hand, the output of the impedance transformer may permanently contact a terminal of the switch which is not connected to the electrode, with the cleaning voltage being switched intermittently to the output of the impedance transformer.

In a preferred embodiment of the second variant, the voltage source for generating the cleaning voltage and the impedance transformer are integrated to form a unit. This

may be implemented, for example, with an operational amplifier provided with a feedback-resistor network wherein at least one resistance value influencing the gain can be varied intermittently. In such a case, the operational amplifier is operated as a unity-gain impedance transformer during the time phase in which no cleaning takes place; during the cleaning phase, the gain is increased by influencing said resistance in accordance with the necessary cleaning voltage.

The circuit arrangements according to the invention are especially suited for use in magnetic flowmeters or in measured-medium-monitoring devices in which electrodes which are in contact with the medium are used to generate the measurement signal.

Further advantages and embodiments of the invention are defined in the subclaims and will become apparent from the following description of embodiments taken in conjunction with the accompanying drawings, in which:

Figure 1

shows a circuit arrangement according to the first variant of the invention;

Figure 2

shows a development of the circuit arrangement of Fig. 1, and

Figure 3

shows a circuit arrangement according to the second variant of the invention.

Like circuit elements are designated by like reference characters.

Figs. 1 to 3 each show a circuit arrangement for two electrodes, which represents a typical case of the magnetic flow measurement.

In Fig. 1, the two electrodes 1 are connected to a switch 2 and a switch 3 which each have two contact elements 2a, 2b, 3a, 3b designed as break contacts. A switch 7 with two contact elements 7a, 7b is provided between a voltage source U, which generates the voltage for cleaning the electrodes, and the switch 2; the switches 2, 7 are thus connected in series. The two contact elements 2a, 2b, 3a, 3b, 7a, 7b of each switch 2, 3, 7 are each associated with one of the two electrodes 1. Their directions of movement are indicated in Fig. 1 by arrows. Their movements are controlled synchronously by a timer T. Those terminals of the two contact elements 3a, 3b of the switch 3 which are not connected to the electrodes 1 are connected to one input of a first impedance transformer 4a and one input of a second impedance transformer 4b, respectively. The impedance transformers have a high input impedance and a low output impedance and may be implemented as feedback operational amplifiers. Each of the two aforementioned terminals is also connected to one input of a differential amplifier 5 for conditioning the electrode potentials. Each of the two impedance transformers 4a, 4b preferably has a current-limiting resistor R at its output. The resistors R connect the outputs of the impedance transformers 4a, 4b to those terminals of the contact elements 2a, 2b and 7a, 7b of the switches 2 and 7, respectively, which are not connected to the electrodes 1 and the voltage source U, respectively.

The operation of the circuit of Fig. 1 will now be briefly explained. In the positions shown, the switches 2, 7 interrupt the connection from the voltage source U to the electrodes, while the switch 3 establishes a connection between the electrodes 1 and the differential amplifier 5. Thus, the electrodes are not in the cleaning mode, but in the measurement mode. The switch 3 serves to keep the cleaning voltage U away from the differential amplifier 5 so as to prevent overloading of the latter.

If the two electrodes 1 are to be electrically cleaned, the timer T will control the switches 2, 7 in such a way that their contact elements 2a, 2b, 7a, 7b close to apply the voltage U to the electrodes 1. At the same time, the contact elements 3a, 3b of the switch 3 are open.

In the normal measurement mode, which is shown in Fig. 1, the impedance transformers 4a, 4b ensure that nearly no potential differences exist between the electrode-side terminals of the switch 2 and the terminals of this switch which are remote from the electrodes 1. As a result, nearly no voltage changes take place via the terminals of the switch 2, so that parasitic capacitances in the switch cannot affect signals obtained from the electrodes 1.

The circuit arrangement of Fig. 2 differs from that of Fig. 1 essentially in that the two contact elements 2a, 2b in the switch 2 between the outputs of the impedance transformers 4a, 4b and the electrodes 1 are designed as

break-make contacts, with the static, i.e., fixed, terminals connected to the switch 7. In the switch position shown, the arrangement is in the measurement mode, i.e., no cleaning voltage is applied to the electrodes 1. Parasitic capacitances in the switch 2 are essentially neutralized by the potential application through the two impedance transformers 4a, 4b, as explained in connection Fig. 1.

The circuit arrangement of Fig. 3 differs from that of Fig. 1 essentially in that switch functions are realized differently and that first and second amplifiers 6a, 6b are provided. Two electrodes 1 are each connected via a resistor R1 to the noninverting input of a respective operational amplifier 6a, 6b. The output of each of the two operational amplifiers 6a, 6b is fed back to the inverting input via a resistor R2. The inverting input of the first operational amplifier 6a is connected via a resistor R4 to the inverting input of the second operational amplifier 6b. The inverting inputs of the two operational amplifiers 6a, 6b are also connected via respective resistors R3 to the noninverting inputs of a first impedance transformer 4a and a second impedance transformer 4b, respectively. The output of a voltage source U is coupled to the noninverting inputs of the two impedance transformers 4a, 4b through a switch 7. The switch 7 is controlled by a timer T. The outputs of the first impedance transformer 4a and the second impedance transformer 4b are connected to a first diode pair 8a and a second diode pair 8b, respectively. Each of the diode pairs 8a, 8b is formed by two individual diodes. These two diodes are connected in inverse parallel, i.e., the anode of a first diode is connected to the cathode of a second diode, while the anode of the second diode

is connected to the cathode of the first diode. The output of each of the impedance transformers 4a, 4b is thus connected via a current-limiting resistor R to an anode and a cathode of one of the diode pairs 8a, 8b. Those terminals of the diodes of the first diode pair 8a which are not connected to the output of the first impedance transformer 4a are connected to one of the two electrodes 1. The same applies analogously to the other of the two electrodes 1. Shields 9 surrounding the electrode leads may be connected directly to the outputs of the impedance transformers 4a, 4b.

The operation of the circuit of Fig. 3 is as follows. In the position shown, the switch 7 is in the open condition. This means that the output of the voltage source U is not connected to the inputs of the two impedance transformers 4a, 4b, but these inputs are, at least approximately, at the respective potentials of the two electrodes 1. This is due to the fact that electrode potential is applied through the resistors R1 to the noninverting inputs of the first and second operational amplifiers 6a, 6b. The outputs of the two operational amplifiers 6a, 6b are fed via respective resistors R2 back to the inverting inputs.

Consequently, the voltage differences between the noninverting inputs and the inverting inputs of the respective operational amplifiers 6a, 6b are approximately zero, so that the inverting inputs of the operational amplifiers 6a, 6b are approximately at electrode potential. The latter is applied through the resistors R3 to one input of each of the impedance transformers 4a, 4b. The

latter transfer their input signals to their outputs approximately with unity gain. Those terminals of the diode pairs 8a, 8b which are connected to these outputs are thus at the same potential as the diode-pair terminals connected directly to the electrodes 1. Dynamic voltage drops between the terminals of the diode pairs 8a, 8b, to which parasitic capacitances might respond, are no longer developed. Any spurious voltages due to thermal drift etc. in the diodes are compensated for by the outputs of the impedance transformers. The measurement signal derived from the electrodes via the resistors (R1) is thus largely decoupled from spurious effects of the diode pairs 8a, 8b.

To electrically clean the electrodes (1), the timer T generates a signal which causes the switch 7 to connect the output of the voltage source U to one input of each of the impedance transformers 4a, 4b. The impedance transformers transfer the applied voltage from the voltage source U with unity gain. This means that one diode of each of the two diode pairs 8a, 8b, upon reaching its threshold voltage, is switched into the conducting state. The cleaning voltage from the voltage source U is thus applied to the electrodes 1. If the voltage source U generates a bipolar alternating voltage, the two diodes in each of the diode pairs 8a, 8b are switched alternately into the conducting state. Thus, because of the inverse-parallel connection of the diodes of the diode pairs 8a, 8b, the electrodes can also be subjected to a cleaning voltage in the form of an alternating voltage.

As shown in Fig. 3, the impedance transformers 4a, 4b can additionally be used to drive the shields 9 to the electrode potential so as to compensate for shielding capacitances and shielding noise if necessary.



Claims

1. A circuit arrangement for cleaning an electrode (1) which is in contact with a substance and has a potential to be measured, by applying a direct or alternating voltage, characterized by
 - a voltage source (U) for applying the direct or alternating voltage to the electrode through two series-connected switches (2, 7) each having one contact element (2a, 7a; 2b, 7b),
 - with the first switch (7) connected to the voltage source, and the second switch (2) to the electrode,
 - a timer (T) for synchronously moving the contact elements (2a, 7a; 2b, 7b), whereby a connection between the voltage source and the electrode can be closed simultaneously or opened simultaneously by means of the first and second switches, and
 - an impedance transformer (4a, 4b) having a high input impedance and a low output impedance whose input is connected to the electrode, and whose output is coupled to the contact element (2a; 2b) of the second switch (2) at least during the period in which the connection between the voltage source and the electrode is open simultaneously at the first and second switches.
2. A circuit arrangement as claimed in claim 1 wherein for flow-measurement purposes, the electrode (1) contacts



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a fluid, and wherein the direct or alternating voltage (U) is applied to the electrode (1) with a predetermined period.

3. A circuit arrangement as claimed in claim 2, wherein prior to the connection of the direct or alternating voltage (U) to the electrode (1), the potential of the electrode (1) is stored and/or output as a measurement signal, and wherein after a time delay following the end of the disconnection, the measuring operation is resumed.

4. A circuit arrangement as claimed in any one of claims 1 to 3 wherein a current-limiting resistor (R) is provided at the output of the impedance transformer (4a, 4b).

5. A circuit arrangement as claimed in any one of claims 1 to 4 wherein the switches (2, 7) are implemented with a relay, and wherein the output of the impedance transformer (4a, 4b) is also connected to the coil of the relay while the direct or alternating voltage (U) is not connected to the electrode (1).

6. A circuit arrangement for cleaning two electrodes (1) which are in contact with a substance and have potentials to be measured, by applying a direct or alternating voltage,

characterized

- by a voltage source (U) for applying the direct or alternating voltage, and
- by the following per electrode:
 - a switch (7) for connecting the direct or alternating



- voltage to the electrode,
- an impedance transformer (4a, 4b) having a high input impedance and a low output impedance whose noninverting input is connectable through the switch to the voltage source,
 - a series combination of a current-limiting resistor (R) and a diode or two diodes (8a, 8b) connected in inverse parallel, with the output of the impedance transformer connected through the series combination to the electrode, and the junction of the current-limiting resistor and the diode/diodes connected to the inverting input of the impedance transformer, and
 - an operational amplifier (6a, 6b) whose noninverting input is connected through a resistor (R1) to the electrode, and whose inverting input is connected through an additional resistor (R3) to the noninverting input of the impedance transformer and through a feedback resistor (R2) to the output of the operational amplifier,
 - and further by the following:
 - an additional resistor (R4) through which the inverting input of the operational amplifier (6a) associated with the first electrode is connected to the inverting input of the operational amplifier (6b) associated with the second electrode, and
 - a timer (T) for generating a signal which causes the switch (7) to apply the output of the voltage source (U) to one input of each of the impedance transformers (4a, 4b).

7. A circuit arrangement as claimed in claim 6 wherein the impedance transformer and the source of direct or



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alternating voltage (U) are physically combined into an amplifier unit whose gain is switchable between unity or greater than unity.

8. A circuit arrangement as claimed in any one of claims 1 to 7 wherein the output of the impedance transformer (4a, 4b) is also connected to a shield of the signal line of the electrodes (1).

9. Use of a circuit arrangement as claimed in any one of claims 1 to 8 in a magnetic flowmeter having measuring electrodes contacting the fluid, or in a measured-substance-monitoring device having electrodes for measuring the conductivity of a substance, the direct or alternating voltage (U) being connected to said electrodes intermittently.