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(12) (19) (CA) **Demande-Application**

(21) (A1) **2,241,055**
(86) 1996/09/27
(87) 1997/07/03

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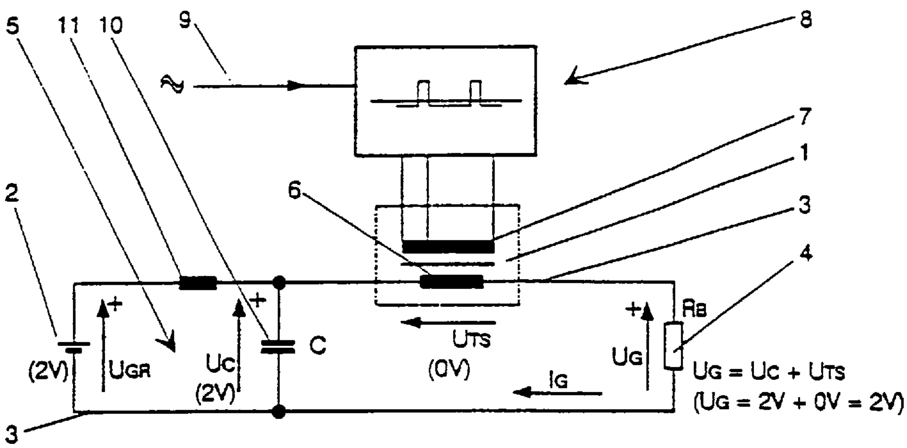
(71) ATOTECH DEUTSCHLAND GMBH, DE

(51) Int.Cl.^{6} C25D 5/18
(30) 1995/12/21 (195 47 948.3-45) DE

(54) **PROCEDE ET CIRCUIT POUR LA GENERATION D'IMPULSIONS DE COURANTS SERVANT AU DEPOT DE METAUX PAR ELECTROLYSE**

(54) **PROCESS AND CIRCUITRY FOR GENERATING CURRENT PULSES FOR ELECTROLYTIC METAL DEPOSITION**



(57) L'invention concerne un procédé qui permet de générer des courants pulsés I_G, I_E unipolaires ou bipolaires de courte durée qui se répètent cycliquement et servent à la galvanoplastie, ainsi qu'un circuit de galvanisation qui sert à générer de tels courants pulsés I_G, I_E. Ces procédés de galvanoplastie sont connus sous le nom de procédé de galvanoplastie par impulsions. Selon l'invention, l'enroulement secondaire (6) d'un transformateur de courant (1) est connecté en série au circuit à courant continu de

(57) A process is disclosed for generating short, cyclically repeated unipolar or bipolar electroplating pulse-shaped currents I_G, I_E, as well as an electroplating circuitry with which such pulse-shaped currents I_G, I_E can be generated. Such electroplating processes are known as pulse-plating processes. The secondary winding (6) of a current transformer (1) is connected in series to the electroplating direct current circuit (5) which consists of a bath direct current source (2) and a bath resistor (R_B) formed by an electroplating cell (4).

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galvanisation (5), qui lui est constitué d'une source de courant continu (2) pour bain et d'une résistance R_B pour bain, la résistance étant formée d'une cellule de galvanoplastie (4). L'enroulement primaire (7) du transformateur de courant a un nombre de spires plus grand que celui de l'enroulement secondaire. L'enroulement primaire est attaqué avec des impulsions de haute tension et de courant relativement faible. Le haut courant pulsé du côté secondaire compense temporairement par impulsions le courant continu de galvanoplastie. Cette compensation peut s'élever à un multiple du courant de galvanoplastie, produisant des impulsions de démétallisation de haute amplitude. Le condensateur (10) guide par charge et décharge le courant de compensation. Grâce à cette invention, il n'est plus nécessaire d'utiliser, pour la galvanoplastie par impulsions, les interrupteurs électroniques connus à maximum de courant dont le rendement est faible à cause des pertes élevées de conduction de courant.

The primary winding (7) of the transformer has a larger number of turns than the secondary winding. The primary winding is driven with high-voltage and relatively low-current pulses. The high pulsed current at the secondary side temporarily compensates in a pulsed manner the electroplating direct current. This compensation may be a multiple of the electroplating current, producing high amplitude demetallisation pulses. The capacitor (10) leads the compensation current by charge and discharge. Thanks to the invention, known electronic heavy current isolating switches which are uneconomical in operation because of high current conductivity losses may be dispensed with for the pulse plating.

Method and Circuit Arrangement for generating Current Pulses for Electrolytic Metal Deposition

Abstract

The invention relates to a method of generating short, cyclically repeating, unipolar or bipolar pulse currents I_G, I_E for electroplating, and to a circuit arrangement for electroplating with which pulse currents I_G, I_E can be generated. Electroplating methods of this type are referred to as pulse-plating methods.

According to the invention, the secondary winding 6 of a current transformer 1 is connected in series into the electroplating direct current circuit 5, consisting of a bath direct current source 2 and a bath resistor R_B which is formed by an electroplating cell 4. The primary winding 7 of the transformer has a larger number of turns than the secondary winding. The primary winding is controlled with pulses of high voltage and with relatively low current. The high pulse current on the secondary side temporarily compensates in pulses the electroplating direct current. This compensation can be a multiple of the electroplating current, such that deplating pulses with high amplitude are produced. The capacitor 10 guides

the compensating current through charging and discharging.

Through the invention, the necessity of using in pulse-plating the known electronic high current switches, which work uneconomically because of the great current conduction losses, is avoided.

(Figure 2a)

Method and Circuit Arrangement for generating Current Pulses for Electrolytic Metal Deposition

Specification

The invention relates to a method for generating short, cyclically repeating, current pulses with great current intensity and with great edge steepness. In addition, it relates to a circuit arrangement for electrolytic metal deposition, especially for carrying out this method. The method finds application in electrolytic metal deposition, preferably in the vertical or horizontal electroplating of printed circuit boards. This type of electroplating is referred to as pulse-plating.

It is known that the electrolytic deposition of metals can be influenced with the aid of pulse-like currents. This affects the chemical and physical properties of the layers deposited. It also affects, however, the even deposition of the layer thickness of the metals on the surface of the workpiece to be treated, the so-called dispersion. The following parameters of the pulsating electroplating current influence these qualities:

- Pulse frequency
- Pulse times
- Pause times

- Pulse amplitude
- Pulse rise time
- Pulse fall time
- Pulse polarity (electroplating, deplating).

In publication DE 27 39 427 A1, electroplating with a pulsating bath current is described. The unipolar pulses here have a width of 0.1 millisecond maximum. The pulse time, the pause time and the pulse amplitude are all variable. Semiconductor switches, here in the form of transistors, serve to generate these pulses. What is disadvantageous about this is that, through the use of switching transistors, the maximum applicable pulsating bath current is technically and economically limited. The upper limit lies at approximately 100 amperes.

The process described in the publication DE 40 05 346 A1 avoids this disadvantage. Here thyristors which can be switched off are used as quick switching elements (GTO: Gate turn-off thyristor) to generate the current pulses. Technically available GTOs are suitable for currents of up to 1,000 amperes and more.

In both cases, the technical outlay has to be reflected, i.e. to be doubled, if bipolar pulses are used. In publication GB-A 2 214 520, which is likewise concerned with pulse plating, a second bath current source is avoided in one form of embodiment by using mechanical, electro-mechanical or semi-conductor switches to reverse the polarity of the direct current voltage fed in. The necessary high current switches are disadvantageous however. Moreover this system is inflexible since the method must proceed in both polarities with the same current amplitude, for, with short high current pulses, the amplitude cannot be readjusted quickly enough in the bath current sources which are available in practice. Thus, in a further form of embodiment in this publication, two bath current sources are also used which can be adjusted independently of one another. These bath current sources are connected via a change-over switch with the work-piece located in the electrolytic cell and the electrode. Since in printed circuit board electroplating, for reasons of the precision required (constancy of the layer thickness), it is necessary to use individually adjustable bath direct current sources for the front side of the printed board and the rear side of same, there is a doubling of the outlay which is necessary for realising this method according to this form of embodiment, to four bath current sources altogether.

In addition to this high technical outlay, especially for the respective second bath current source per printed circuit board side, the electronic high current switches cause great energy losses. On each electronic switch, when it is switched on, a voltage drop occurs on the inner non-linear resistor when the current flows. This is true for all kinds of semi-conductor elements in the same way, however with varying sizes of voltage drop. With increasing current, this drop in voltage, also called saturation voltage or forward voltage U_F, becomes greater. With the currents usually used in electroplating technology, e.g. at 1,000 amperes, the forward voltage U_F on diodes and transistors amounts to approximately one volt and on thyristors approximately two volts. The power loss P_V at each of these semi-conductor elements is calculated according to the formula $P_V = U_F \times I_G$, I_G being the electroplating current. Where $I_G = 1{,}000A$, the dissipated energy P_V reaches 1,000 watt to 2,000 watt. The heat produced additionally by the electronic switches has to be carried away by cooling. In the actual bath current source, a power loss occurs likewise of at least the same magnitude, which is unavoidable. These losses are not to be included in the further considerations. Only the power losses which have to be additionally applied to pulse generation are taken into consideration.

An electroplating system consists of a plurality of electroplating cells. They are fed with large bath currents. As an example, a horizontal system for depositing copper on printed circuit boards from acid electrolytes will be looked at. The application of the pulse technology improves the amount of the copper deposition in the fine holes of the printed boards quite substantially. What has proved particularly effective is changing the polarity of the pulses in cycles. With cathodic polarity of the article to be treated, for example current pulses with ten milliseconds pulse width are used. This pulse can be followed by an anodic pulse with a width of one millisecond. In pulse-like cathodic electroplating, preferably a current density is chosen which is greater than, or the same as, the current density which is used with this electrolyte during direct current electroplating. During the short anodic current pulses, a deplating process with a substantially higher current density takes place than during the cathodic pulse phase. Advantageous here is approximately the factor 4 of the anodic to the cathodic pulse phase.

The printed boards are electroplated on both sides, i.e. on their front and their rear sides with separate bath current supplies. As an example five electrolytic baths of a horizontal electroplating system are looked at. They have per side, for example, five bath current supply units each with 1,000 amperes of nominal current, i.e. 10 bath current supply appliances with 10,000 amperes in total. The bath voltage for electroplating with acid copper electrolytes is from 1 to 3 volts and is dependent on the density of the current. Because of the high currents, the energy balance for the circuit proposed in the publication DE

40 05 346 A1 is looked at as an example (Fig. 7). A positive pulse generated with this circuit arrangement as an electroplating pulse with a width of t = 10 milliseconds and a negative pulse as a deplating pulse with a considerably higher amplitude with a width of t = 1 milliseconds, underlie the following consideration. Inaccuracies caused by low edge steepnesses are here disregarded. Thus for the span of 10 milliseconds, the semi-conductor elements 6, 9, 5 in the circuit arrangement shown in Fig. 7 carry the full electroplating current. The power loss of these switching elements amounts, per bath current supply with the forward voltages U_F quoted above, to (2 volts + 1 volt + 2 volt) x 1,000 amperes = 5,000 watts. For the span of one millisecond, the semi-conductor elements 7 and 8, corresponding to the task set, then carry four times the current. This power loss amounts to P_V = (2 volts + 2 volts) x 4,000 amperes = 16,000 watts. The average high current switch power loss of a cycle lasting 11 milliseconds is thus approximately 6,000 watts. With ten bath current supplies this amounts to a power loss of 60 kW (kilowatts). To determine the degree of efficiency, this output must be compared with the output which is converted directly at the electrolytic bath for electroplating and for deplating. The bath voltages are, for this purpose, assumed to be for acid copper baths with 2 volts for electroplating and with 7 volts for deplating. Thus the average value of the overall bath output for pulse

electroplating amounts to approximately 4.5 kW (for 10 milliseconds, 2 volts x 1,000 amperes and for 1 millisecond, 7 volts x 4,000 amperes). With the losses calculated above amounting to 6 kW, only the efficiency of the high current switches, related to the overall bath output, is clearly below 50%.

An electroplating system equipped with electronic high current switches in this way works completely uneconomically. Moreover the technical outlay for the electronic switches and their cooling is very high. The result of this is that pulse current appliances of this kind are also large in volume which works against placing them in spatial proximity to the electrolytic cell. This spatial proximity is however necessary in order to achieve the required edge steepness of the bath current in the cell at the electrodes. Long electrical conductors work with their parasitic inductances against any quick rise in current.

In comparison to the electronic switches, electro-mechanical switches have a much lower voltage fall when they are in the switched state. Switches or protection devices are, however, completely unsuitable for the required high pulse frequency of 100 Hertz. For the described technical reasons, the known method of pulsed electroplating is restricted to special applications and by preference to low pulse currents as far as electroplating is concerned.

Thus the problem underlying the present invention is to find a method and a circuit arrangement with which it is possible to generate short, cyclically repeating, unipolar or bipolar high currents for electroplating without the disadvantages mentioned occurring, especially without said currents being generated with a considerable power loss. Moreover, the necessary electronic circuit for this method should also be realized at a favourable price.

The purpose is fulfilled by the invention given in patent claims 1 and 11.

The invention consists in the fact that there is coupled into an electroplating direct current circuit, called a high current circuit for short, comprising a bath direct current source, electrical conductors and an electrolytic cell with the electroplating article and anode in an inductive manner by means of a suitable component, for example a current transformer, a pulse current with such polarity that the bath direct current is compensated or over-compensated. The component is connected in series with the electrolytic electroplating cell. For example, to this end, the secondary winding of the current transformer with a low number of turns is connected to the bath direct current circuit in series in such a way that the bath direct current flows through it. In the primary winding, the current transformer has a high number of turns, such that the pulses feeding it in accordance with the turns ratio can have a low current with high voltage. The induced pulsed low secondary voltage drives the high compensation current. A capacitor, which is connected in parallel to the bath direct current source, serves to close the current circuit for the pulse compensation current.

The invention is explained in detail with the aid of Figs. 1 - 6. These show:

Figs. 1a - 1e unipolar and bipolar electroplating current paths, such as are usually used in practice;

Figs. 2a and 2b circuit arrangement for feeding the compensation current into the high current circuit; Fig. 2a is applicable during electroplating and Fig. 2b during deplating;

Fig. 3 a schematic representation of the current diagram for the bath current using the circuit arrangement shown in Fig. 2;

Fig. 4a voltage curves in the high current circuit, taking into account the rise and fall times;

Fig. 4b an electrical wiring diagram with potentials entered;

Fig. 5 a possible control circuit for the current transformer;

Fig. 6 an overall view of the circuit arrangement to be used for electroplating printed circuit boards;

In Fig. 7 a traditional circuit arrangement, described in DE 40 05 346 A1, is shown.

In the figures a bath current, indicated as positive, should apply for the electrolytic metallisation, i.e. the article being treated is of negative polarity in relation to the anode. A bath current indicated as negative should apply for the electrolytic deplating. In this case, the article to be treated is of positive polarity in relation to the anode.

The diagram in Fig. 1a applies to electroplating with direct current. In Fig. 1b the bath current is interrupted for a short time. It remains, however, unipolar i.e. the polarity of the current direction is not reversed. The pulse times lie by preference in the order of magnitude of 0.1 milliseconds up to seconds. The pause times are correspondingly shorter. Fig. 1c shows a unipolar pulse current with different amplitudes. Fig. 1d shows a bipolar current, i.e. a pulse current which is briefly reversed in polarity with a long electroplating time and with a short deplating time. The deplating amplitude here amounts to a multiple of the metallising amplitude. However, altogether, with an electroplating time of e.g. 10 milliseconds and with a deplating time of 1 millisecond, there is a clear excess of the amount of charge needed for electroplating as opposed to that needed for deplating. This pulse form is particularly suitable for electroplating on both sides printed circuit boards with fine holes. In Fig. 1e, a double pulse form is shown which can be achieved with the method according to the invention. Unipolar pulses here alternate with bipolar pulses.

The electroplating cell represents for the electroplating current an ohmic load as a good approximation. With a bath current supply according to Fig. 1b, bath current and bath voltage are therefore in phase. The low parasitic inductances of the electrical conductors to the electrolytic cell and back to the current source can be disregarded. Pulse currents contain on the other hand alternating currents. With increasing edge steepness of the pulses, the proportion of the high frequencies of the alternating currents becomes greater. Steep pulse edges have a short pulse rise and fall time. The line inductances represent inductive resistors for these alternating currents. They delay the pulse edges. However these effects are not considered below. They are independent of the type of pulse generation and therefore always the same if special measures are not taken. The simplest measures consist in using electrical lines with very low ohmic and inductive resistances. In the figures, in order to simplify the drawing, the electroplating current is always represented as, or assumed to be, in phase with the voltage.

Figs. 2a and 2b show the feeding in, according to the invention, of the compensating pulse current by means of the current transformer 1. The bath direct current source 2 is connected via electrical lines 3 with the electrolytic bath, which is here represented as the bath resistor R_B with the reference number 4. The secondary winding 6 of the current transformer 1 is connected into this high current circuit 5 in series with the electrolytic bath. The primary side 7 of the transformer is fed by the pulse electronic unit 8. The pulse electronic unit 8 is supplied with energy via the main supply 9. The current and voltage paths for the pulses according to Fig. 1d correspond in principle also to the pulse forms of the other diagrams in Fig. 1. They differ only in the momentary size of the compensating current. For this reason the voltages or currents belonging to Fig. 1d are indicated in the following figures and considered.

Fig. 2a shows the state of operation during the electroplating. As an example, potentials are indicated in brackets. The capacitor C is charged to the voltage $U_C \approx U_{GR}$. The voltage U_{TS} at the current transformer 1 amounts to 0 volts. Thus, apart from voltage drops at the line resistors and at the resistor of the secondary winding 6, the rectifier voltage U_{GR} is present at the bath resistor R_B and causes the electroplating current I_G. This temporary state corresponds to electroplating with direct current. In the high current circuit 5, no switches are needed according to the invention.

Fig. 2b shows the state of operation during deplating. The potentials can no longer be considered static. Therefore in Fig. 2b, the potentials for the end in time of the deplating pulse are shown in brackets. The starting point is provided by the potentials of Fig. 2a. The power pulse electronic unit 8 feeds the primary winding 7 of the current transformer 1 with a current which alters its amplitude in time. The current flow time corresponds to the time of the flow of the compensating current in the main current circuit 5. The primary voltage U_{TP} at the transformer is such that, corresponding to the number of turns in the transformer winding a transformer pulse voltage U_{TS} is achieved secondarily, which is in a position to drive the required compensating current I_K. Here, the capacitor C with the time constant $T = R_B \times C$, proceeding from the voltage $U_C \approx U_{GR}$, is further charged with the voltage U_{TS}. The charging current is the compensating current I_K and at the same time the deplating current I_E. With a large capacity of the capacitor C, the rise in voltage in the short time of the charge current flow can be kept low. Instead of the capacitor C, an accumulator can also be used in principle. The bath direct current source 2, consisting of a rectifier bridge circuit, switches itself off automatically for the period of the deplating, because through the charge, the voltage becomes $U_C > U_{GR}$. Without any additional switching elements being used, the direct current source 2, during the period of time in which the bath current I_{GR} is fed by the induced voltage U_{TS} into the current circuit, therefore feeds no current into the current circuit automatically. After the current compensation, the bath current is, however, supplied again from the direct current source. To avoid any short reverse flow in the switching-off moment with slow rectifier elements in the bath direct current source 2, a choke 11 can be inserted into the high current circuit 5. The energy for deplating is applied via the current transformer 1. The high, yet short in time, deplating current I_E in the secondary winding 6 is fed in primarily. The current is reduced with the current transformer reduction ratio ü.

If this transformer has a reduction ratio of e.g. 100:1, for a compensating current I_K of 4,000 amperes only approximately 4 ampere are to be fed in primarily. For the secondary voltage U_{TS} = 10 volt in this example approximately 1,000 volts are necessary primarily. The power pulse electronic unit is thus to be dimensioned for high voltage and for relatively low pulse currents. Semi-conductor elements which are favourable in price are available for this. Thus, no high current switch is necessary even for the high deplating current in the main current circuit 5.

The power loss incurred for pulse generation is very low in comparison with known methods. The calculation of the dominating losses already shows the difference: in the power pulse electronic unit for generating pulse currents on the primary side, amongst other things consisting of an electronic switch with a forward voltage U_F = 2 volts, the switch power loss amounts to P = 40 amperes x 2 volts x (approximately) 10% current flow time ≈ 8 volts. In the same way, 8 watts are necessary for the reversed transformer current flow to the saturation of the transformer. With ten bath current supplies there is thus a power loss of approximately 160 watts altogether. For the comparison of the total switch losses of the circuit according to the invention with the losses of the known circuits, the current transformer losses must be included with the circuit according to the invention. If a very good coupling of the transformer is used, for example with a strip-wound cut toroidal core and with highly permeable thin metal sheets, a transformer efficiency of $\eta = 90\%$ can be counted on. Thus these losses amount with a compensating current of 4,000 amperes and a voltage of 7 volts with approximately 10% current flow time to altogether approximately 560 watts. This produces for ten bath current supplies, according to the invention, a total power loss for generating the pulse electroplating current amounting to 160 watts for the switches and 5,600 watts for the current transformers. This sum includes approximately 6 kW for the dominating losses. In the example calculated above, according to the state of the art where 10 bath currents supplies were used, this amounted on the other hand to approximately 60 kW.

The technical outlay for carrying out the method according to the invention is likewise substantially lower than when traditional circuit arrangements are used. Only passive components are loaded with the high electroplating currents and with the even higher deplating currents. This substantially increases the reliability of the pulse current supply equipment. Electroplating systems equipped in this way therefore have a clearly higher availability. This is achieved, moreover, with substantially lower investment outlay. At the same time, the continuing energy consumption is lower. On account of the lower technical outlay, the volume of pulse devices of this kind is small, with the result that it makes it easier to realise them in proximity to the bath. The line inductances of the main current circuit are therefore also reduced to a minimum.

In Fig. 3 the path of the pulse current is represented diagrammatically at the bath resistor R_B (electroplating cell 20). On account of the ohmic resistor R_B, the bath current and bath voltage are here in phase. At the point in time t_1, the flow of the compensating current begins. The size and direction are determined by the instantaneous voltages U_C and U_{TS}. At the point of time t_2, the compensating current flow finishes. The following electroplating current I_G is determined by the rectifier voltage U_{GR}, in each case in connection with the bath resistor R_B.

The time course of the voltages is represented more accurately in the diagrams of the figures 4a and 4b. The electroplating current I_G is practically in phase with the electroplating voltage U_G. I_G is therefore not indicated because it has the same path. At the point of time $t = 0$, the rectifier voltage U_{GR}, the capacitor voltage U_C and, moreover, also the electroplating voltage U_G are approximately the same. The voltage U_{TS}

amounts at this point in time to 0 volts. At the point in time t_1, the rise of the voltage pulse U_{TS1} begins at the secondary winding 6 of the current transformer 1. The voltage U_{TS1} is of such polarity that the electroplating voltage U_{G1} becomes negative, with the result that it is possible to deplate. U_G is formed from the sum of the instantaneous voltages U_C and U_{TS}. The voltage U_{TS} is poled at the capacitor C in the direction of the existing charge. The capacitor C therefore begins to charge itself again to the voltage U_{TS} with the time constant $T = R_B \times C$. At the point of time t_2, the drop in the voltage pulse U_{TS1} begins. Because of the final inductivity of the current transformer secondary circuit, the falling voltage pulse does not end at the zero line. Through voltage induction, a voltage U_{TS2} with reverse polarity occurs. This is now added to the capacitor voltage U_C. At the bath resistor R_B, a brief excessive rise in voltage U_{G2} occurs. The capacitor C begins to discharge itself with the time constants $T = R_B \times C$, it being at least partially or even completely discharged. At the time point t_3, the voltage U_{TS} therefore amounts to 0 volts. The bath direct current source U_{GR} takes over again the feeding of the bath resistor R_B, such that $U_G \approx U_{GR}$. The voltages U_{GR}, U_C and U_G are then approximately the same size again. The brief excessive rise of voltage at the bath resistor R_B is undesired for electroplating purposes. In practice this peak and the additional peaks, differently from what is shown here, are clearly rounded. A recovery diode, parallel to the secondary winding or parallel to an additional winding on the core of the current transformer, effects if necessary a further weakening of the increase in voltage at the bath resistor R_B. On the other hand, the low excessive voltage then is present longer. There will be no further discussion of these systems of wiring inductances, nor likewise of the construction of the current transformer which is to be constructed as a pulse transformer. Pulses are to be fed on the primary side into the transformer in such a way that magnetic saturation of the transformer iron is avoided. For desaturation, there is after each current pulse sufficient time available in the pulse pauses to feed in a current with reverse polarity. To this end, an additional winding can be attached to the transformer core. Fig. 5 shows an example of the primary side triggering of the current transformer 1. An auxiliary source 12 is supported by a charging capacitor 13 with the capacity C. An electronic switch 14, here an IGBT (Isolated Gate Bipolar Transistor) is triggered by voltage pulses 15. In the switched state of the electronic switch 14, a primary current flows into the partial winding I of the primary winding 7 of the current transformer, and to simplify the circuit a desaturation current in the partial winding II. When the switch is not connected, only a desaturation current flows in the partial winding II. To reduce the outlay, a possible additional electronic switch for this current is dispensed with. The number of turns in the partial windings I and II as well as the protective resistor 17, via which a current of low magnitude flows permanently, are so adapted to one another that no saturation of the transformer iron occurs. The current diagram 18 in Figure 5 shows diagrammatically the primary current I_{TP}.

Fig. 6 shows the application of the pulse current units 19 in an electroplating bath 20 with goods to be electroplated arranged vertically, for which bath two bath direct current sources 2 for the rear side and the front side of the flat article to be electroplated, for instance a printed circuit board, are used. Each side of the printed board 21 is separately supplied with electroplating current from one of these current sources 2. Opposite each side of the printed board an anode 22 is arranged. During the short deplating pulse, these anodes work as cathodes in relation to the article to be treated which is then poled anodically. Both pulse current units can work either in asynchronous or synchronous manner with one another. To electroplate the holes of printed boards, it is advantageous if the pulse sequences of the same frequency of both pulse current units are synchronised and if at the same time there is phase displacement of the pulses. The phase displacement must be such that, during the electroplating phase on the one printed board side, the deplating pulse occurs on the other side and the other way round. In this case, the dispersion of the metal, i.e. the electroplating of the holes, is improved. The pulse sequences of the same frequency can, however, where there is separate electrolytic treatment of the front and the rear side of the article to be treated, also run asynchronously towards one another.

The invention is suitable for all pulse electroplating methods. It can be used in electroplating systems, dipping systems and feed-through systems, working vertically or horizontally. In the feed-through systems, plate-shaped goods to be electroplated are held in a horizontal or vertical position during the treatment. The times and amplitudes mentioned in this specification can be altered within wide ranges in practical applications.

Terms used in the specification

U_G	Electroplating voltage
U_{GR}	Rectifier voltage
U_C	Capacitor voltage
U_{TP}	Primary transformer pulse voltage
U_{TS}	Secondary transformer pulse voltage
U_F	Forward voltage
I_G	Electroplating current
I_E	Deplating current
I_K	Compensating current
P_V	Power loss
ü	Current transformer reduction ratio

List of reference numbers

1	Current transformer
2	Bath direct current source
3	Electrical conductors
4	Bath resistor R_B
5	High current circuit
6	Secondary winding of the current transformer
7	Primary winding of the current transformer
8	Power pulse electronic unit
9	Mains supply
10	Capacitor with the capacity C
11	Choke
12	Auxiliary voltage source
13	Charging capacitor with the capacity C_L
14	Electronic switch

15 Voltage pulses
16 Voltage diagram
17 Protective resistor
18 Current diagram
19 Pulse current unit
20 Electroplating cell
21 Goods to be treated
22 Anode

Method and Circuit Arrangement for generating Current Pulses for Electrolytic Metal Deposition

Patent claims:

1. Method for generating short, cyclically repeating, unipolar or bipolar pulse currents I_G, I_E for electroplating, **characterised in that** there is coupled in an inductive manner into an electroplating direct current circuit (5), formed from a direct current source (2) and an electroplating cell (20) with a bath resistor R_B, by means of a component (1) connected in series with the electroplating cell (20), a compensating pulse current I_K of such polarity that the bath current supplied from the direct current source (2) is compensated or overcompensated.

2. Method according to claim 1, **characterised in that** a transformer is used as component (1).

3. Method according to one of the preceding claims, **characterised in that** the compensating current I_k is led to charge a component (10) acting as a capacitor C, preferably a condenser or accumulator.

4. Method according to one of the preceding claims, **characterised in that** the circuit element (10) acting as capacitor C is partially discharged during the

periods of time in which the bath current is not compensated or overcompensated.

5. Method according to one of the preceding claims, **characterised in that**, in order to generate unipolar current pulses, the amplitude of the compensating pulse current I_k is set to be at least as great as the amplitude of the bath current supplied from the direct current source (2).

6. Method according to one of the preceding claims 1 to 4, **characterised in that**, in order to generate bipolar current pulses, the amplitude of the compensating pulse current I_k is set to be greater than the level of the bath current supplied from the direct current source (2).

7. Method according to one of the preceding claims, **characterised in that** the amplitude of the pulse current for deplating I_E is set to be higher than the amplitude of the pulse current for metallisation I_G and that the pulse width of the current I_E is set to be shorter than the pulse width of the current I_G.

8. Method according to one of the preceding claims, **characterised in that** where there is separate electrolytic supply of the front and rear side of an article to be electroplated with pulse current, the

same-frequency pulse sequences of the two sides are adjusted to be synchronous.

9. Method according to claim 8, **characterised in that** a constant phase displacement between the pulse currents on the front and rear side of the article to be electroplated is set in such a way that deplating of said article does not occur on both sides at the same time.

10. Method according to one of the preceding claims, **characterised in that** a toroidal current transformer is used as the component (1) connected in series with the electroplating cell.

11. Circuit arrangement for electroplating with which cyclically repeating, unipolar or bipolar pulse currents I_G, I_E can be generated, especially for carrying out the method according to claims 1 to 10, **characterised by** an electroplating direct current circuit (5) formed from a direct current source (2) and an electroplating cell (20), into which there may be coupled in an inductive manner, by means of a component (1) connected in series with the electroplating cell (20), a compensating pulse current I_K of such polarity that the bath current supplied from the direct current source (2) is compensated or overcompensated.

12. Circuit arrangement according to claim 11, **characterised by** a capacitor C connected in parallel to the direct current source (2).

13. Circuit arrangement according to one of claims 11 or 12, **characterised by** a current transformer as component (1) with a primary winding (7) and a secondary winding (6), the secondary winding being connected in series with the direct current source (2) and the primary winding having a larger number of turns than the secondary winding.

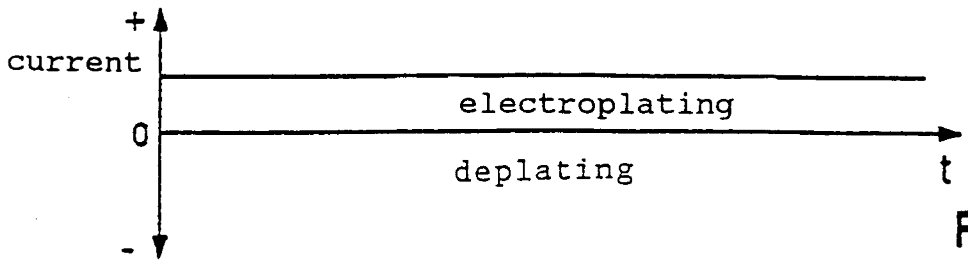


Fig. 1a

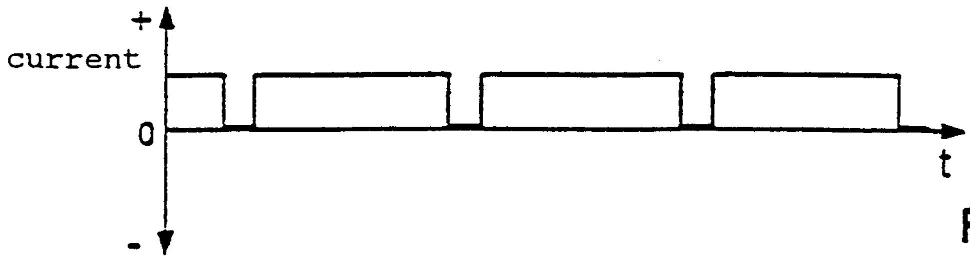


Fig. 1b

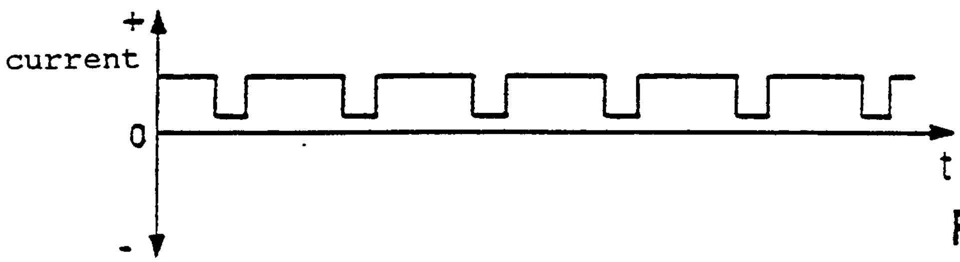


Fig. 1c

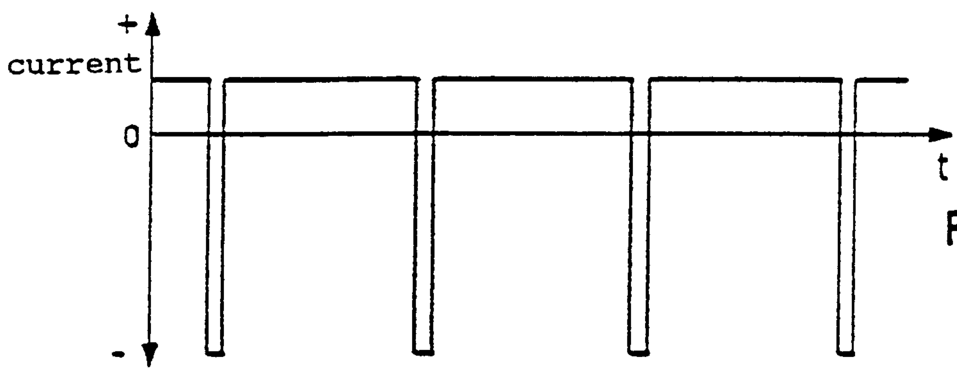


Fig. 1d

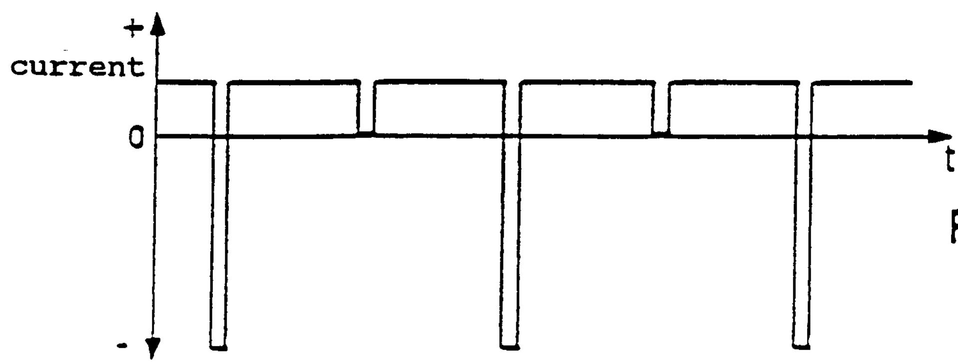


Fig. 1e

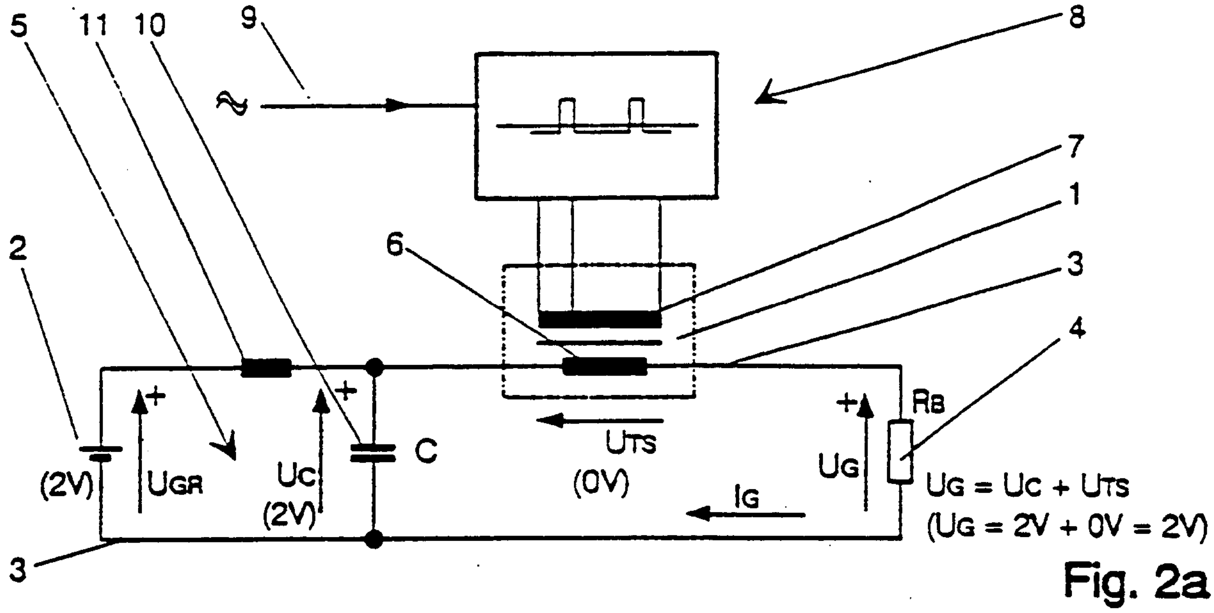


Fig. 2a

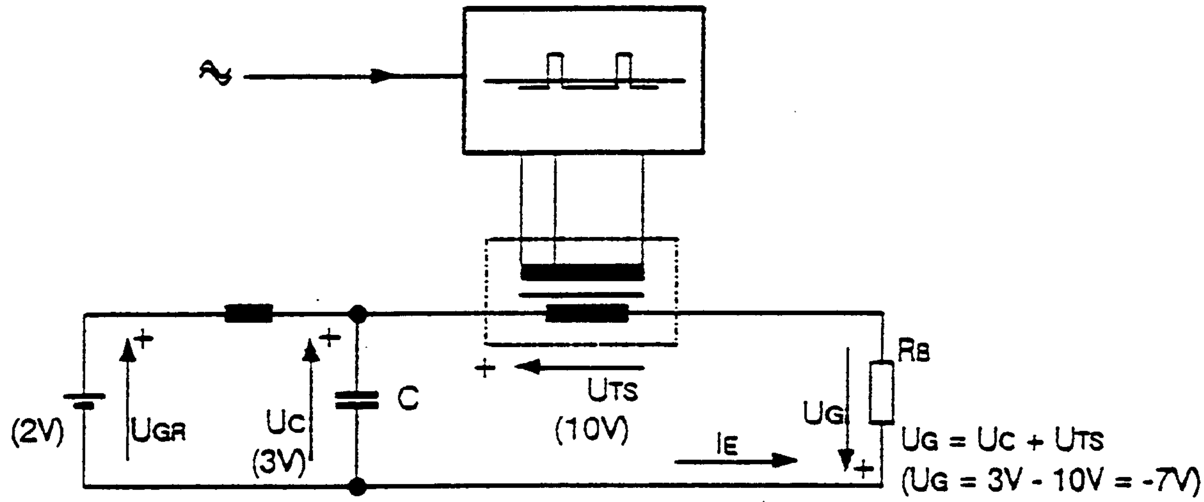


Fig. 2b

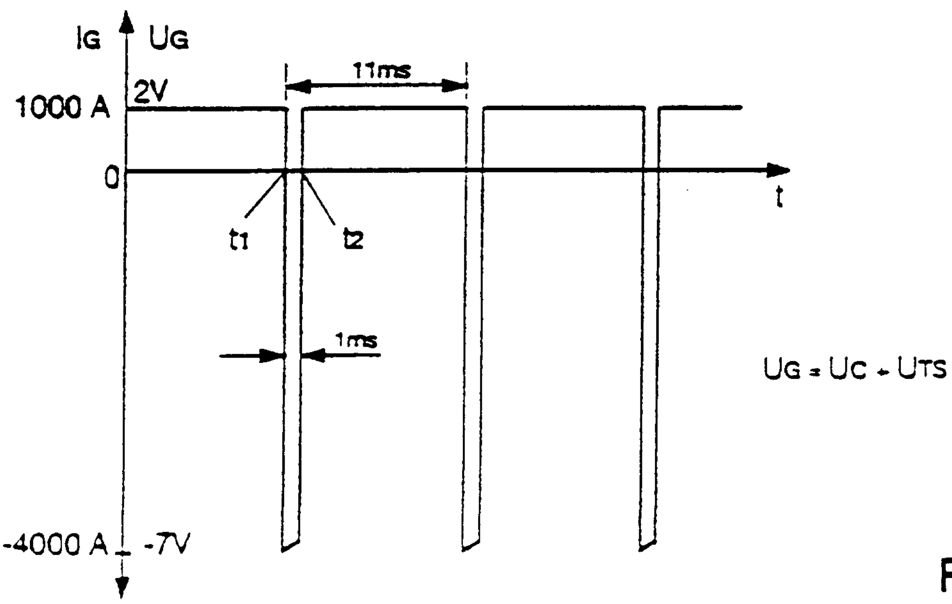


Fig. 3

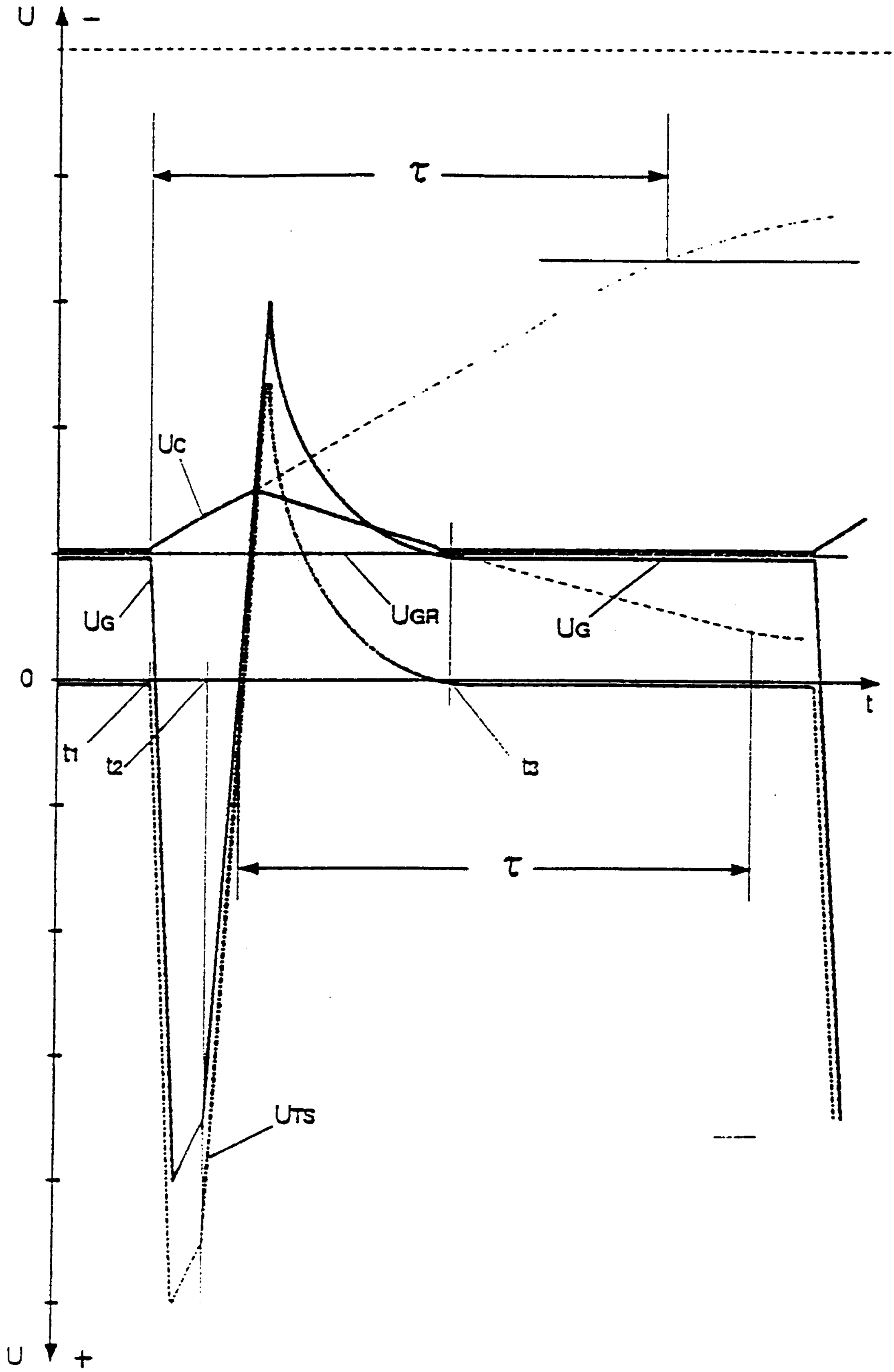


Fig. 4a

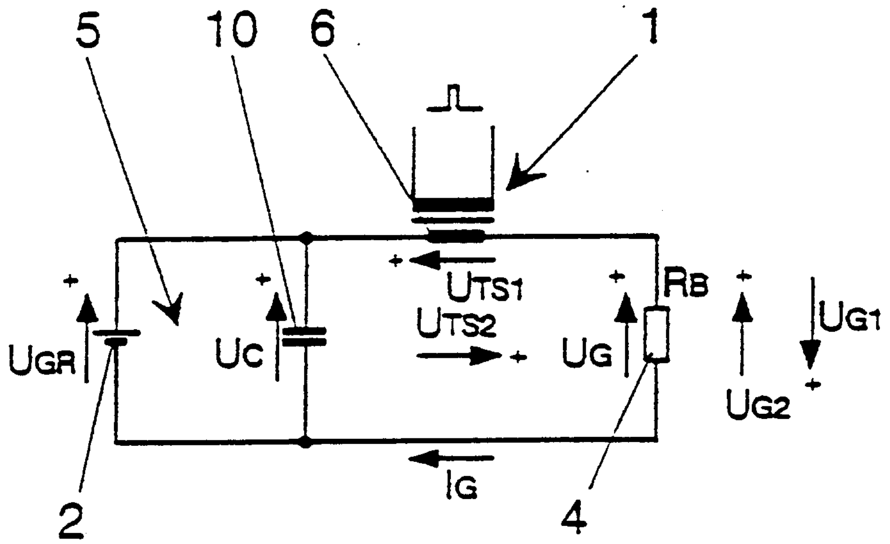


Fig. 4b

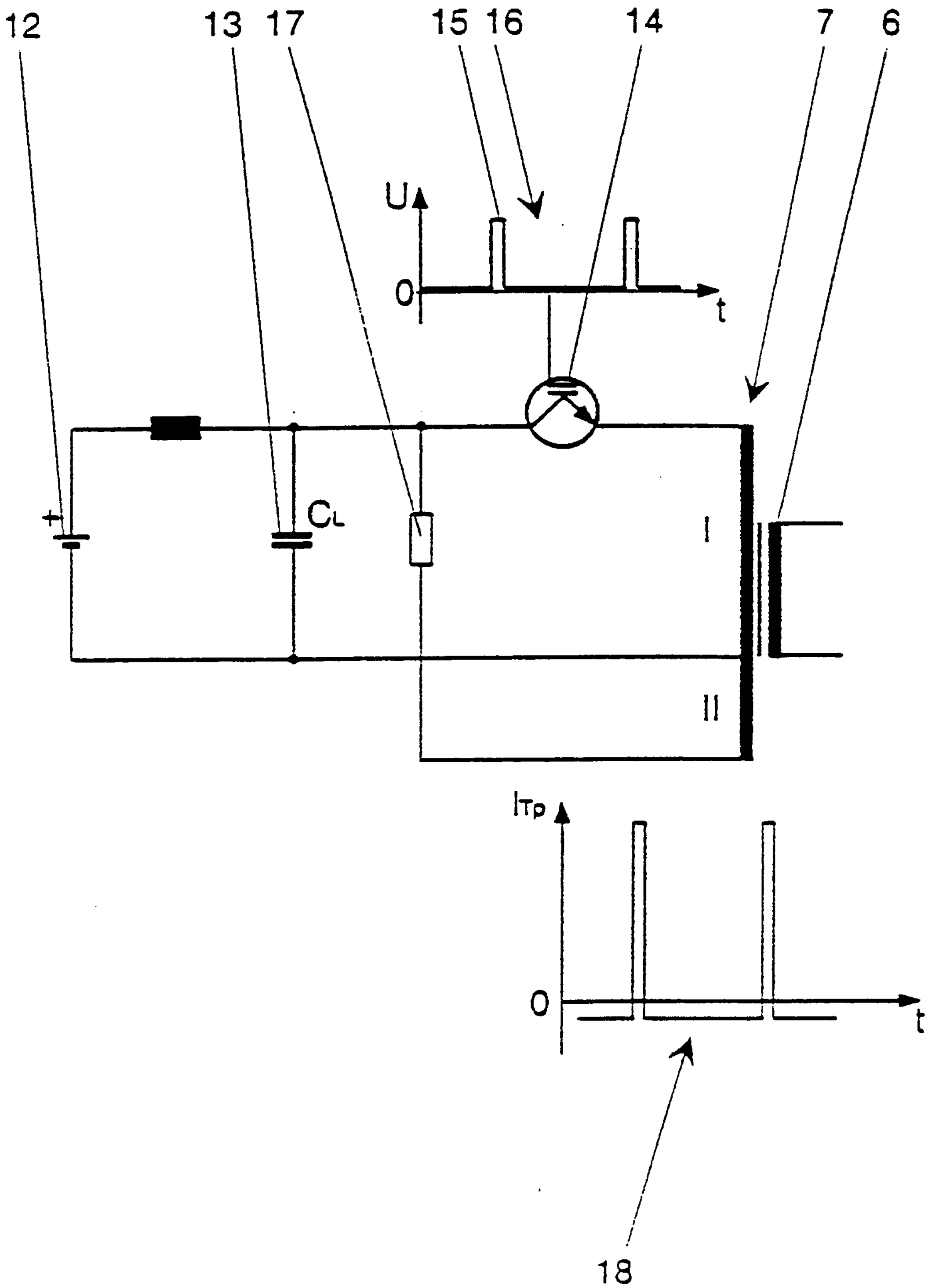


Fig. 5

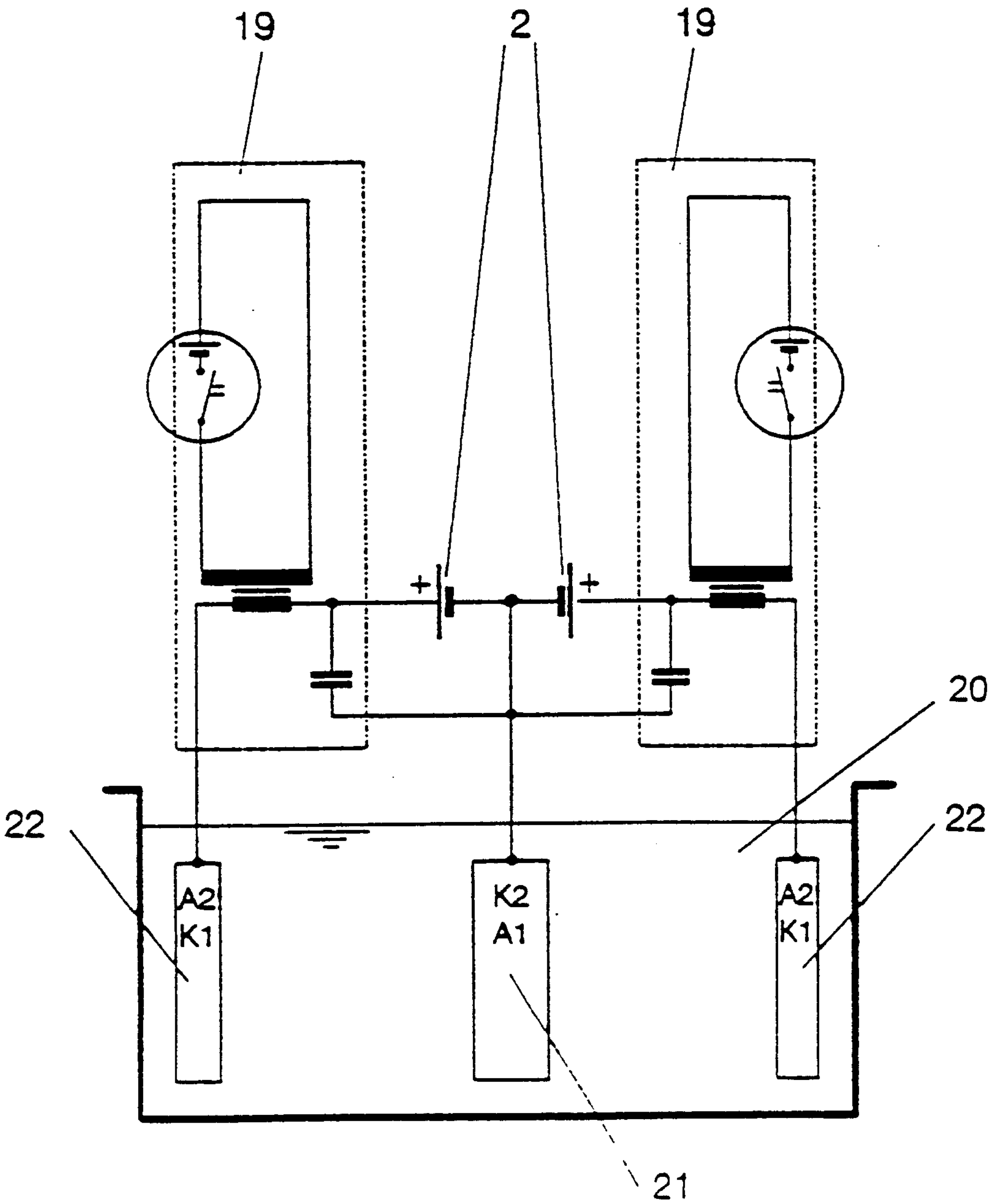


Fig. 6

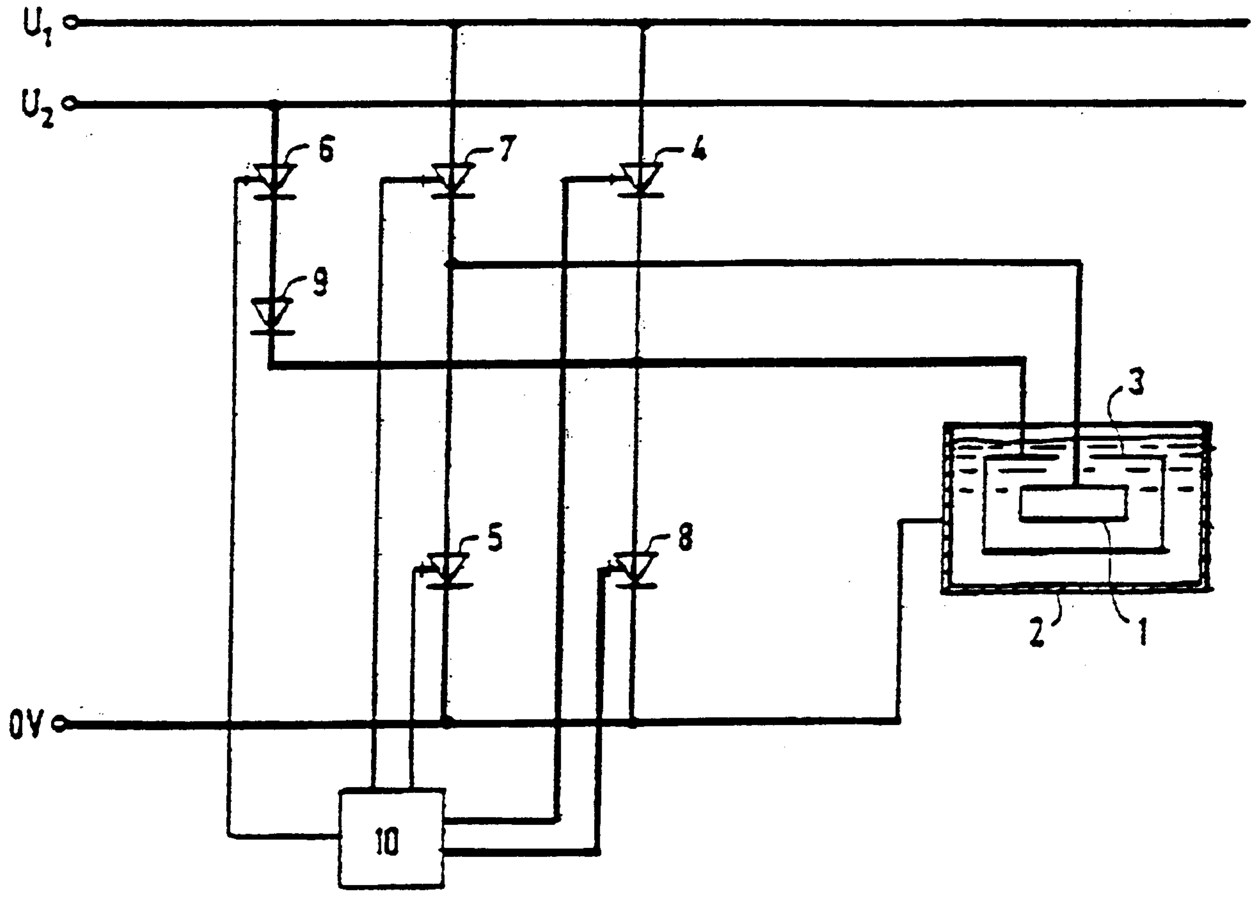
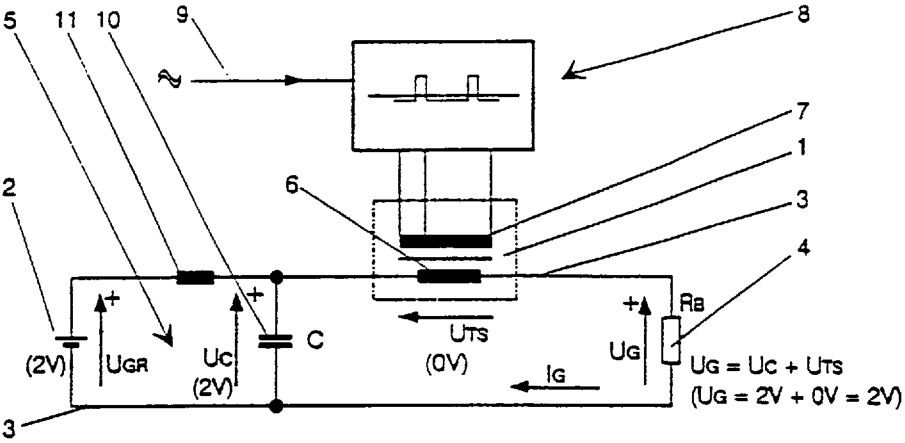


Fig. 7



5
11
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+
+
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C
UTS
(0V)
(2V)
UGR
UC
(2V)
UG
IG
UG = UC + UTS
(UG = 2V + 0V = 2V)
3