

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

Specification

10 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
15 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.

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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
25 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:

30

- Pulse frequency
- Pulse times
- Pause times

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

10 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
15 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
20 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
25 (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
30 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

5 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
10 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
15 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
20 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
25 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
30 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

5 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
10 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
15 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
20 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
25 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
30 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

5 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
10 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
15 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
20 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
25 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
30 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



5 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
10 $= 1$ 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
15 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) $\times$ 1,000 amperes = 5,000 watts. For
the span of one millisecond, the semi-conductor
20 elements 7 and 8, corresponding to the task set, then
carry four times the current. This power loss amounts
to $P_V = (2 \text{ volts} + 2 \text{ volts}) \times 4,000 \text{ amperes} = 16,000$
watts. The average high current switch power loss of a
cycle lasting 11 milliseconds is thus approximately
25 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
30 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

5 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
10 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
15 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
20 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.

25 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
30 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.

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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 realised at a favourable price.

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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. Preferably 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

5 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
10 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
15 Figs. 1 - 6. These show:

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

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

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

30

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

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

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

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

 In Fig.7 a traditional circuit arrangement,
20 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
25 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.

30 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

5 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
10 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
15 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
20 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.

25 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
30 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

5 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
10 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
15 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
20 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
25 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
30 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

5 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
 10 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
 15 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
 20 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
 25 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
 30 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

5 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
 10 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
 15 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
 20 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
 25 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
 30 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

5 primarily. The current is reduced with the current transformer reduction ratio $\bar{u}$.

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. 15 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.

20 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 25 consisting of an electronic switch with a forward voltage $U_F = 2$ volts, the switch power loss amounts to $P = 40$ amperes $\times$ 2 volts $\times$ (approximately) 10% current flow time ≈ 8 watts. In the same way, 8 watts are necessary for the reversed transformer current flow to 30 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

5 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
10 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
15 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
20 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.

25 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
30 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,

5 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
 10 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
 15 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
 20 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 .

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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
 30 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}

5 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
 10 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
 15 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
 20 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
 25 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
 30 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

5 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
10 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
15 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
20 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
25 (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
30 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

5 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
10 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
15 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
20 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.
25 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
30 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

5 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
10 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,
15 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
20 specification can be altered within wide ranges in
practical applications.

5 Terms used in the specification

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

List of reference numbers

20	1	Current transformer
	2	Bath direct current source
	3	Electrical conductors
	4	Bath resistor R_B
	5	High current circuit
25	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
30	11	Choke
	12	Auxiliary voltage source
	13	Charging capacitor with the capacity C_L
	14	Electronic switch

5	15	Voltage pulses
	16	Voltage diagram
	17	Protective resistor
	18	Current diagram
	19	Pulse current unit
10	20	Electroplating cell
	21	Goods to be treated
	22	Anode

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

Patent claims:



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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
15 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
20 bath current supplied from the direct current source
(2) is compensated or overcompensated.

25

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

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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



5 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
10 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).

15 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
20 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
25 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,
30 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



- 5 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
10 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.
- 15 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.
- 20 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
25 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
30 that the bath current supplied from the direct current
source (2) is compensated or overcompensated.



- 5 12. Circuit arrangement according to claim 11,
characterised by a capacitor C connected in parallel to
the direct current source (2).
- 10 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
15 than the secondary winding.
- 20 14. Method of generating short, cyclically repeating,
unipolar or bipolar pulse currents I_G , I_E for
electroplating, characterised by individual features or
all new features, or combinations of disclosed
features.
- 25 15. Circuit arrangement for electroplating, with which
short, cyclically repeating, unipolar or bipolar pulse
currents I_G , I_E can be generated, characterised by
individual features or all new features, or
combinations of disclosed features.

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

10 **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
15 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
20 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
25 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
30 current. This compensation can be a multiple of the
electroplating current, such that deplating pulses with
high amplitude are produced. The capacitor 10 guides

5 the compensating current through charging and
discharging.

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

(Figure 2a)

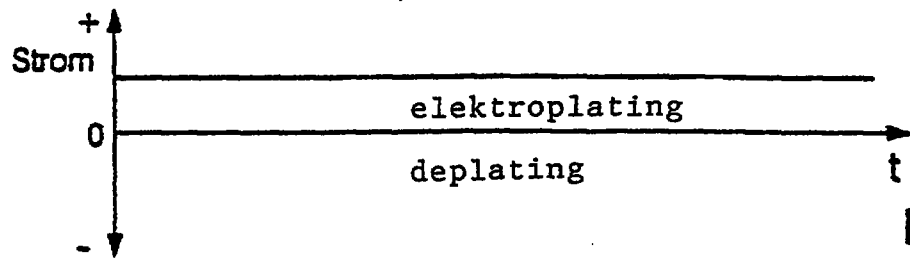


Fig. 1a

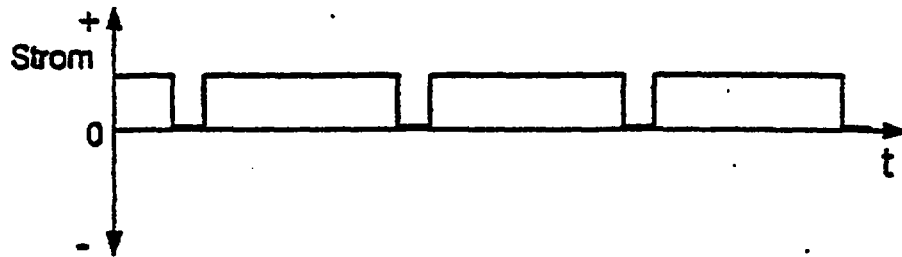


Fig. 1b

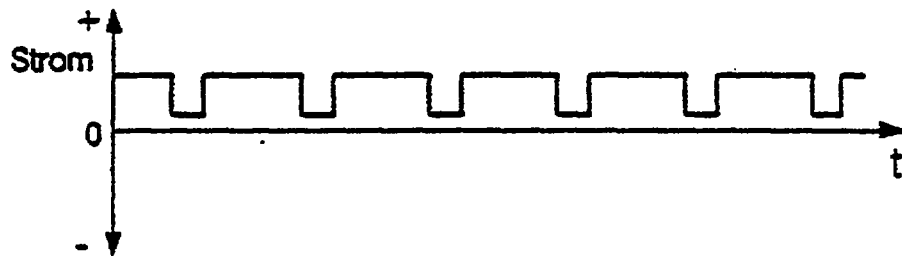


Fig. 1c

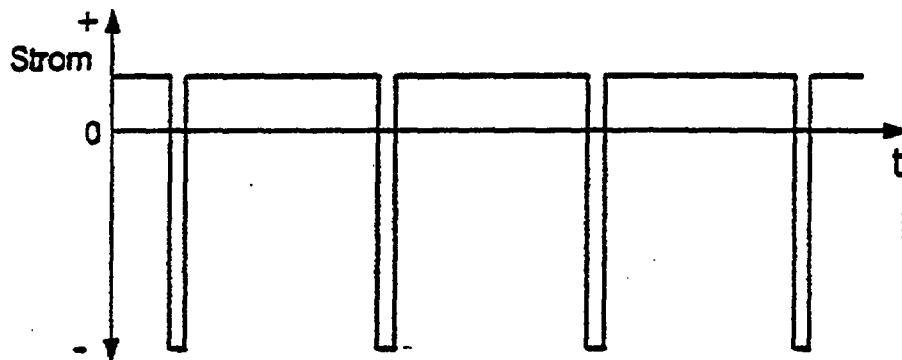


Fig. 1d

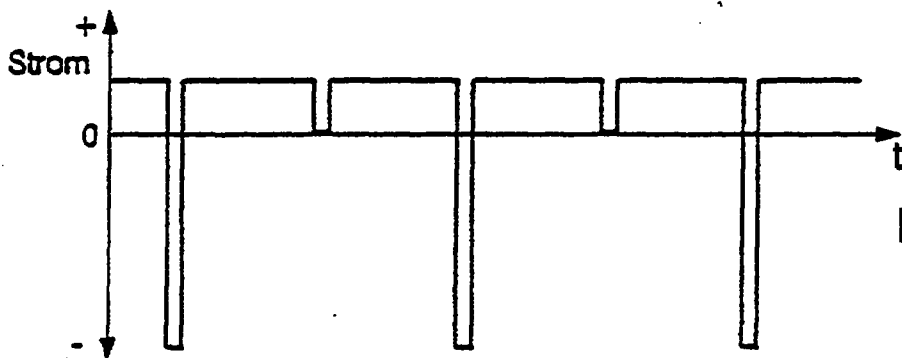


Fig. 1e

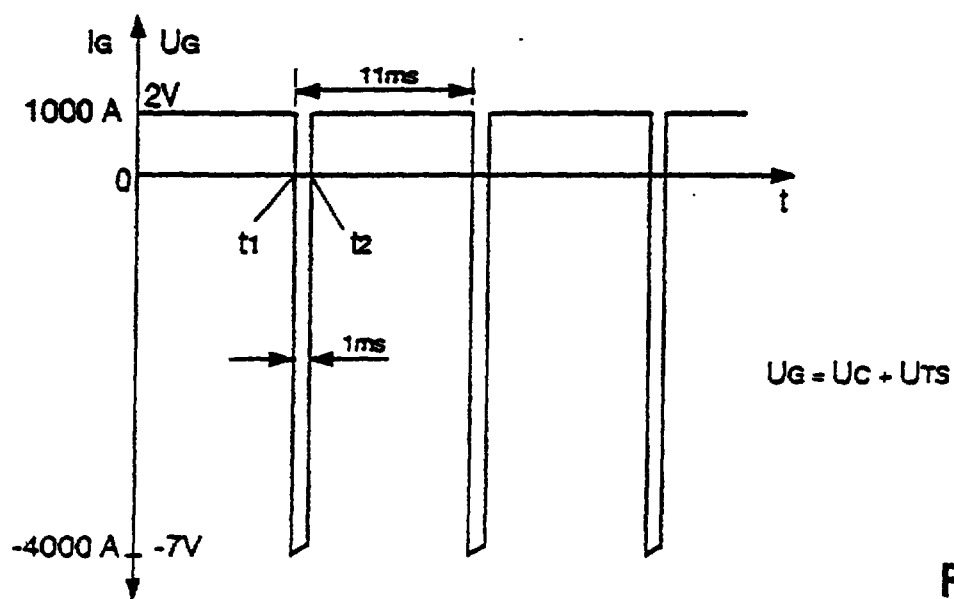
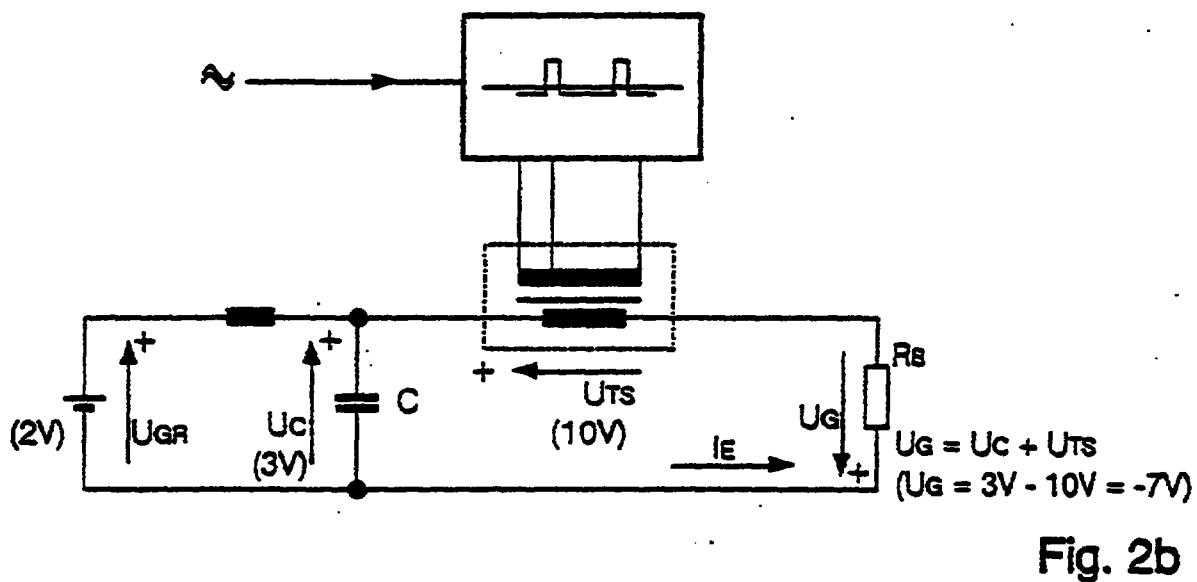
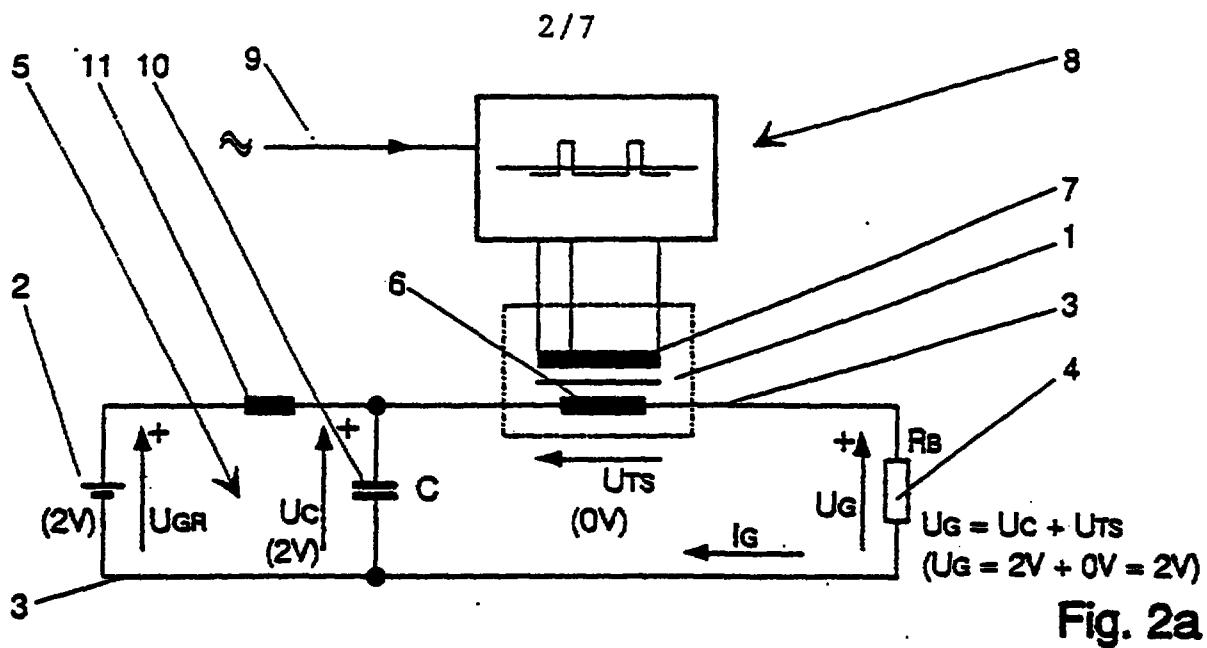


Fig. 4a

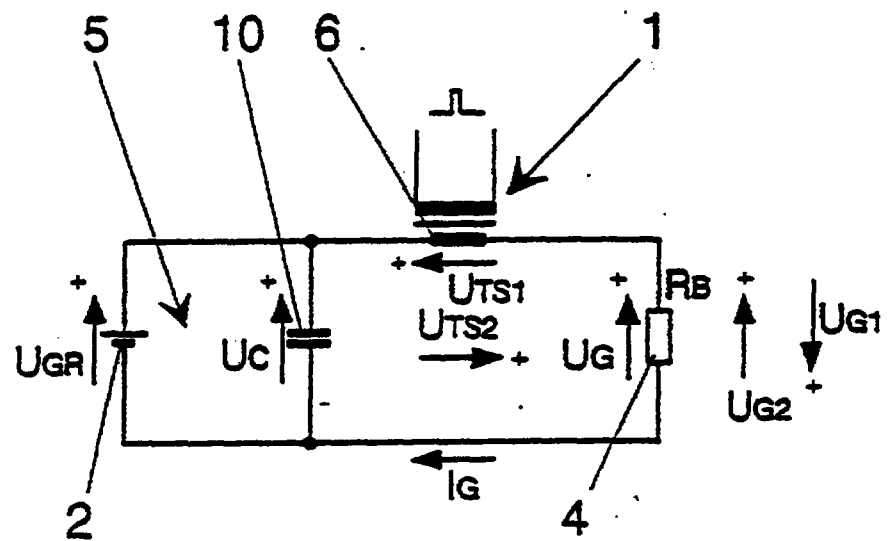


Fig. 4b

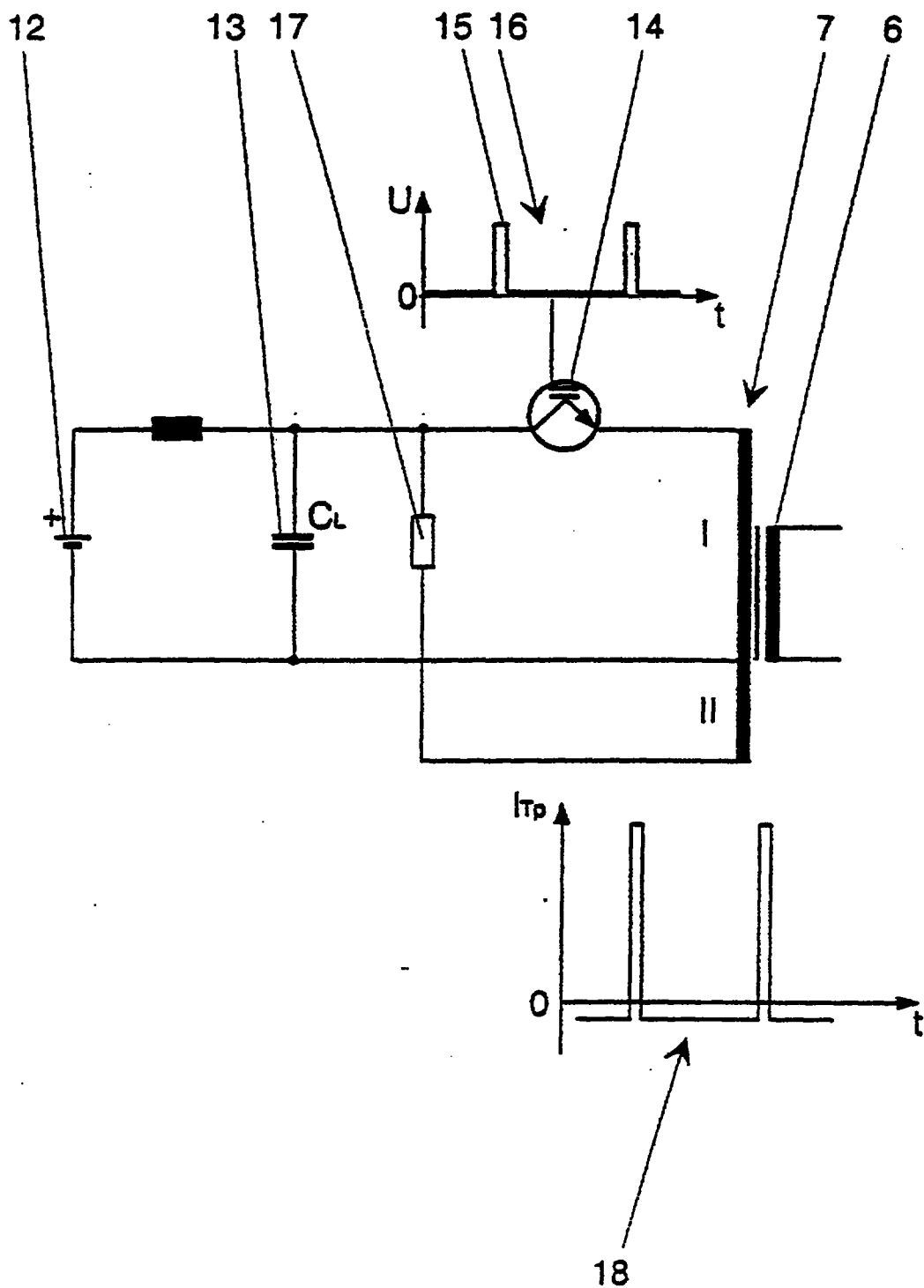


Fig. 5

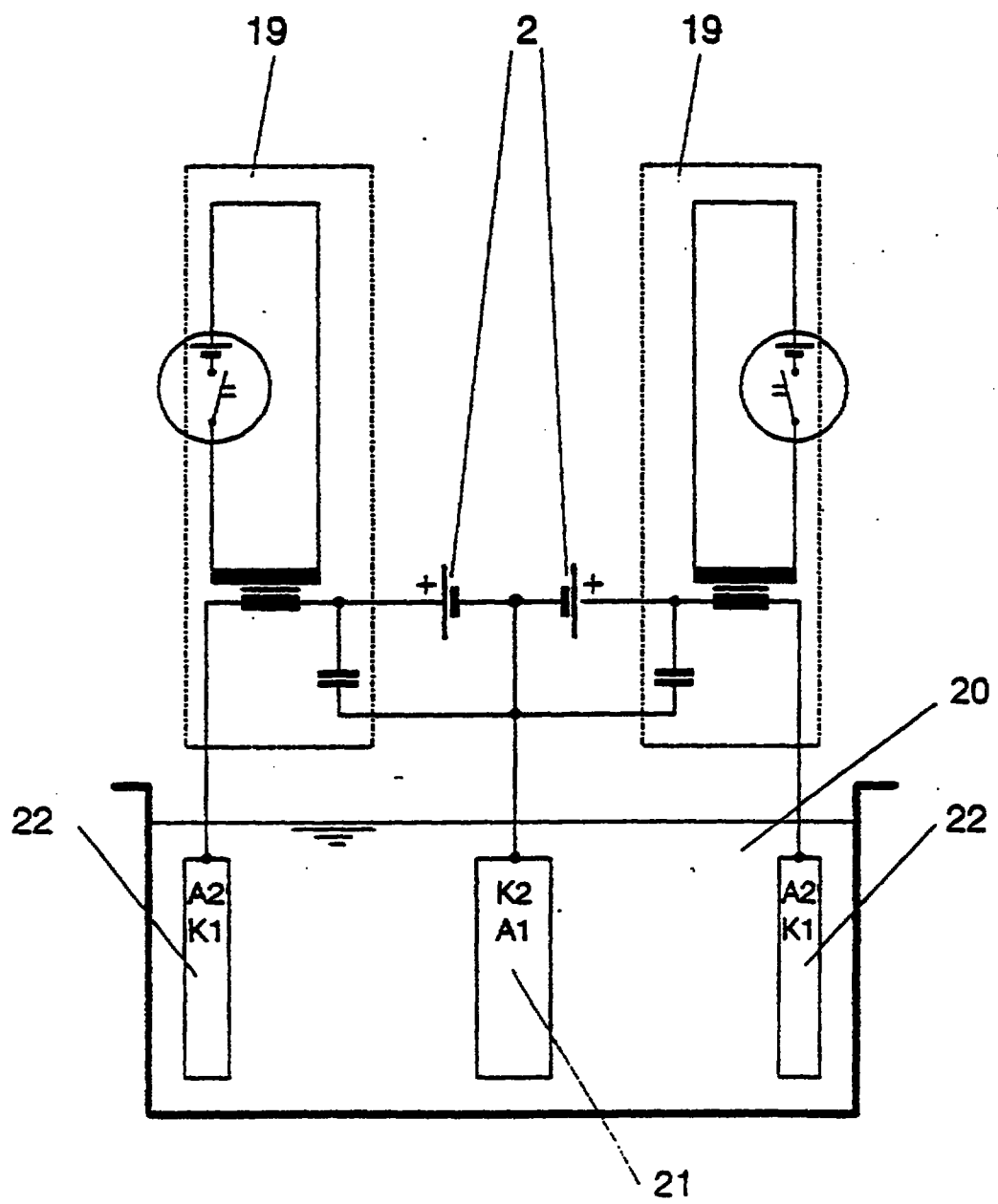


Fig. 6

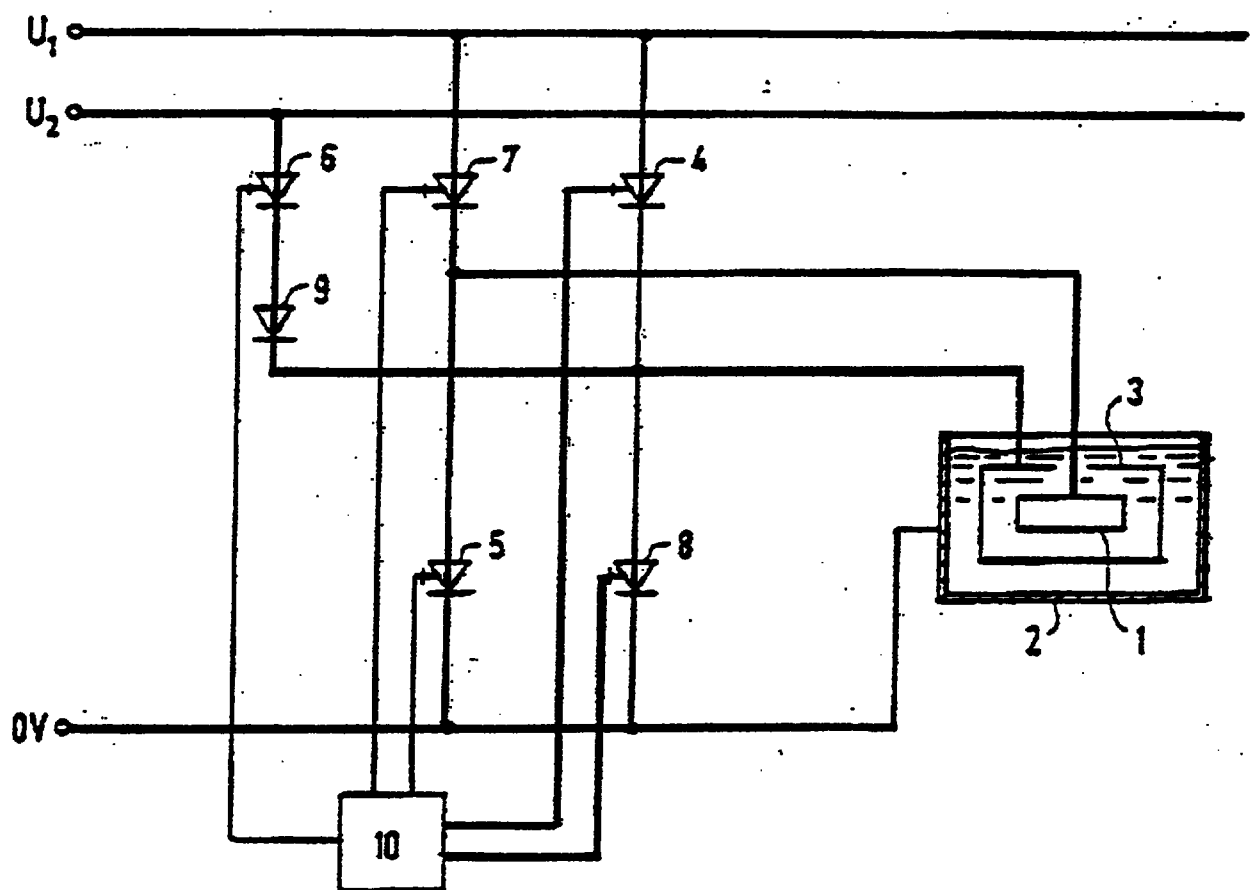
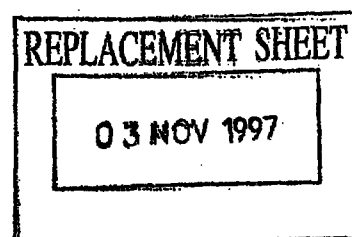


Fig. 7

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;

