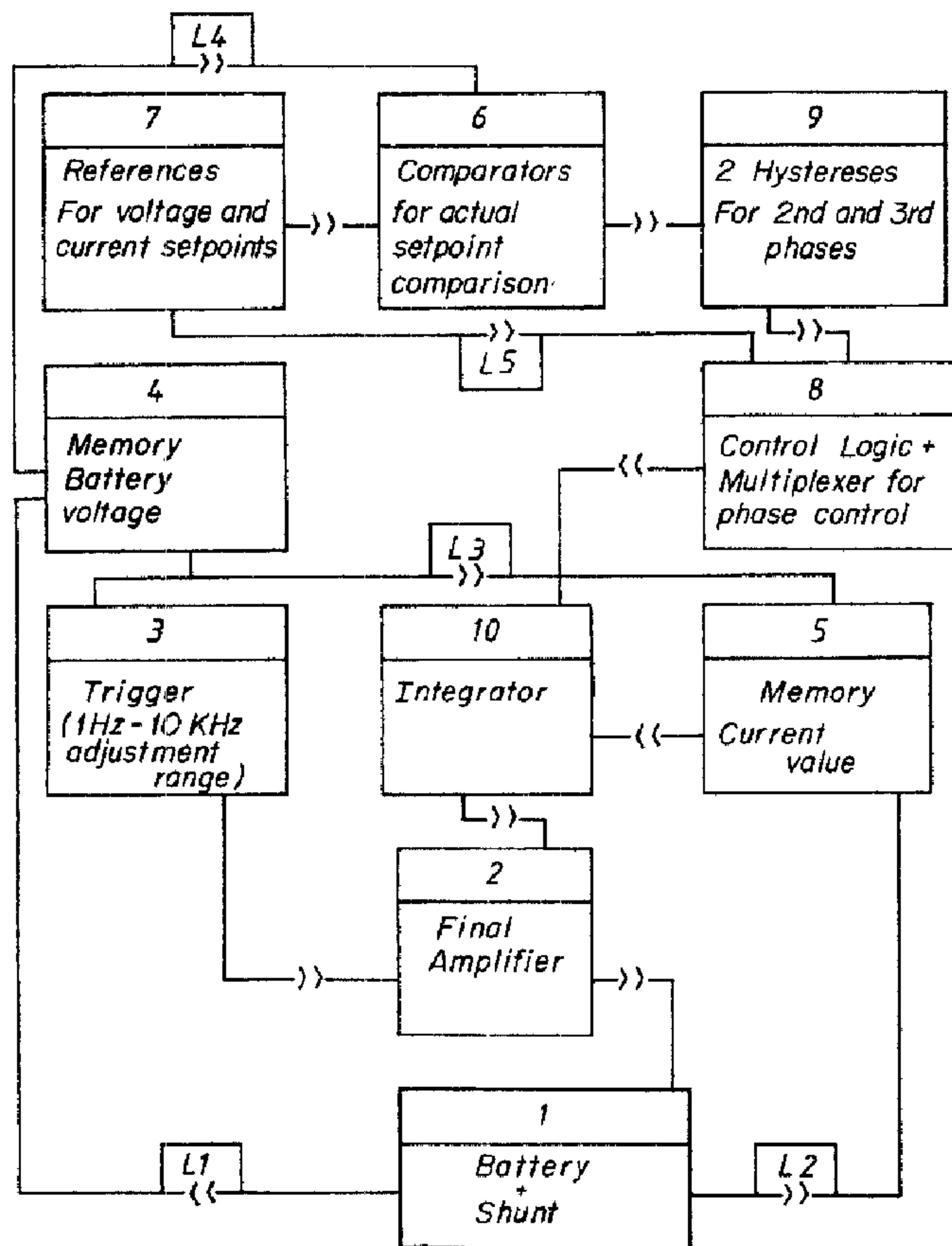




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(54) Titre : PROCEDE DE RECHARGE RAPIDE DE BATTERIES  
 (54) Title: METHOD FOR QUICK CHARGING OF RECHARGABLE BATTERIES



(57) Abrégé/Abstract:

A device for quick charging of batteries, whereby the charging current of the battery is directed in constant current impulses. Several charging current strengths of varying strengths are brought into effect, depending on the respective charging condition

(57) **Abrégé(suite)/Abstract(continued):**

of the battery, by clock impulses. Assigned to each charging current strength is a battery-specific zone in the electrochemical voltage gradient  $U=f(t)$ , whereby the individual zones are indicated by voltage set values. The voltage zone assigned to each charging current strength is so chosen that in passing through this zone, no heating or gassing occurs. Thereby, use is made of the fact that the battery at the beginning of the charging can accept a very high current. The charging condition of the battery is measured in each impulse pause, stored and compared with the voltage set value. Where there is a variance, the set-current value assigned to the zone is correspondingly adjusted.

**ABSTRACT**

A device for quick charging of batteries, whereby the charging current of the battery is directed in constant current impulses. Several charging current strengths of varying strengths are brought into effect, depending on the respective charging condition of the battery, by clock impulses. Assigned to each charging current strength is a battery-specific zone in the electrochemical voltage gradient  $U=f(t)$ , whereby the individual zones are indicated by voltage set values. The voltage zone assigned to each charging current strength is so chosen that in passing through this zone, no heating or gassing occurs. Thereby, use is made of the fact that the battery at the beginning of the charging can accept a very high current. The charging condition of the battery is measured in each impulse pause, stored and compared with the voltage set value. Where there is a variance, the set-current value assigned to the zone is correspondingly adjusted.

## Method For Quick Charging Of Rechargeable Batteries

The invention concerns a method for quick charging rechargeable batteries and a circuit arrangement for implementation of the method.

Known charging devices work according to the principle that either a constant voltage or a constant current is produced, and a corresponding charging current or the voltage is applied to the battery. With the so-called  
10 constant-voltage charge, a constant charging voltage is applied to the battery and the current that at first is very high progressively decreases throughout the duration of the charging time. To ensure that, at the end of the charging, no undue warming of the battery occurs, the charging current is correspondingly limited. This means a very long charging time, in order to fully charge the battery. With the so-called constant-current charge, a constant current with a correspondingly high charging voltage is applied to the battery. When the maximum voltage is reached at the  
20 battery, the charging current is shut off. This maximum voltage consists of the electrochemical voltage (EMK) and the shut-off value of a relay at the internal resistance of the battery, and results in the fact that the battery is not yet fully charged when shut off. If it is further charged despite this, the battery heats up and is thereby damaged. For these reasons, with known commercial charging devices, the charging current is limited to about 2 amperes, which necessitates charging times of between 12 and 24 hours.

However, there are also so-called quick-charging  
30 devices, which recharge batteries in essentially a shorter time, for example, in one hour. In these devices, use is

made of the fact that a fully discharged battery is able to initially accommodate a relatively high current. This applies especially to NiCd batteries, which have a slight internal resistance. If however the high charging current is not shut off at the right time, there is a danger that the battery so greatly overheats from overcharging, that gassing occurs, which can destroy the battery, or at least limit its service life.

Especially with quick-charging devices of this sort,  
10 there is the problem of finding the correct shut off point for the charging current or charging voltage, since if it is shut off too early, the desired charge capacity is not reached. The charging time, the temperature and the clamp voltage are used as shut-off criteria. The most exact are devices with a measurement of the clamp voltage, especially when the voltage is measured in the currentless condition of the battery. With known charging devices, this is accomplished by measuring the voltage during short pauses in the charging. It is further known to feed the battery with  
20 constant current impulses, whereby the clamp voltage is measured and controlled during pauses in the current impulses.

With a known device of this sort, called a DeltaV-device, use is made of the characteristic that the cell voltage is strongly dependent on the temperature of the battery, such that as the temperature increases, the cell voltage decreases. With this device it is therefore known that a considerable overcharge must be tolerated in order to maintain a short charging time and the desired temperatures  
30 increase, in order that the voltage drop of the DeltaV can be recorded. The disadvantage there is that this voltage

drop sets in earlier when the battery is charged with higher currents and with higher temperatures. In that case, the battery is not fully charged. Furthermore, the gassing that occurs from the heating greatly limits the service life of the battery.

With another known device of this sort, the steep voltage increase at the end of the charging is used as a criterion whereby the charging current is not shut off, but rather, it is continuously withdrawn. Thereby, a  
10 temperature increase toward the end of the charging process is effectively prevented. In this manner, batteries can be carefully charged, whereby a long service life and a high number of cycles can be guaranteed. Hereby the shortest charging time for a battery of 1-2 Ah is stated as 10 minutes. Also, charging can occur in a temperature region of -10 to +60° degrees Celsius.

With other known charging procedures, adjustment of the clamp voltage of the battery within a charging current impulse is used for controlling the charging process, and as  
20 a shut off point.

In the use of the procedure of this sort (EP-A1-0 034-003), the charging current of the battery is supplied in the form of current impulses, whereby in the impulse pauses, discharging of the battery is effected. The rectangular shaped current impulses thus produced show sections of smaller and larger intensity of current. With this known procedure, the adjustment of the clamp voltage of the battery during the charging step is measured for a predetermined time during a part of a charging impulse,  
30 whereby the charging process is interrupted when a parameter of the measured voltage exceeds a determined characteristic:

by way of example, the voltage adjustment exceeds a determined limit. Thus, the alteration of the operating voltage is measured during a period which begins with turning on a charging impulse. By way of example, immediately upon turning on a charging impulse and two seconds later, the battery voltage is measured and the voltage difference is formed. If a battery is fully charged, then the voltage difference is very large. If one puts the measured voltage difference values in a time  
10 diagram, then the climb of this resulting curve has a stationary point shortly before reaching complete charge, which presents itself as a criterion for terminating the charging process. This known procedure as a technique of measurement is not just costly, but it allows constant, exactly defined current impulses.

In DE-A1 811-371, a procedure for simultaneous charging and testing the condition of an NiCd battery has become known, with which the charging current of the battery likewise must be supplied in the form of constant, exactly  
20 defined current impulses, whereby the rectangular shaped current impulses show sections of smaller and larger current strengths. In the present case, in the current impulse pauses, measurement phases with discharge intervals of comparatively short duration are turned on, whereby at the beginning and in determined time intervals after the beginning of the sections of higher current strength, the battery voltage is measured and the difference of the measured voltage values is used for controlling the charging process. During the measurement phases, the internal  
30 resistance of the battery is measured under different charging and discharging conditions, whereby these internal

resistors are related to each other and also compared with internal resistors detected in successive measurement phases. From these relations, an abundance of information on different condition of the battery can be gathered, with whose help the charging process can be controlled and a declaration on the serviceability condition of the battery can be obtained. With this known procedure the absolute values of voltages are not referred to, but instead the voltage alterations at the battery, which are caused by the charging and loading processes.

From De-A1-3 806 865, a procedure for batteries with closed design has become known, with which, independent of the applied characteristic curve, the harmful gassing pressure is not allowed to be exceeded. This is thereby achieved, in that after reaching an upper voltage limit, which lies below the gassing voltage, the initially relatively high charging current sinks to a lower value, for example in the dimension of a conservation charge, until the sinking battery voltage has reached a lower limit, whereafter the complete, but slightly lowered charging current comes into effect. This pulsing charging procedure is set forth until the sinking charging current has reached a certain charging term. Thereafter follows a reloading with the lower value of the charging current for an allowed charging time. With this known procedure the frequency of the charging current impulse is determined from the respective charging condition of the battery, whereby correspondingly long charging times result.

From German Patent G 90 10 972.4 (Polz), a charging device for batteries has become known, with which a measurement and control circuit is provided, which shows a

device for recording the instantaneous charging condition and a set value transmitter, which, by way of a computer to storage charts or algorithms, gives each collected measurement value which correspond to the charging condition, a set value for the charging current strength. The charging current controller is developed as an impulse controller with adjustable impulse and pause times, which controls the impulse current strength according to the allowed set values. Furthermore, gathered from the  
10 connections for measurement, the clamp voltage of the battery adjoining the charging device is allowed at least one upper and one lower limit, whereby a control logic of the control circuit accommodates the charging process after the reaching of the upper limit until the sinking of the clamp voltage to a lower value. Furthermore, it is known from this patent to provide immediate telltales for the instantaneous charging condition and for a fast polarity.

From FR 2 203 198 (Westinghouse) it is known to conduct a voltage measurement within the impulse pauses, in order to  
20 establish the respective charging condition. The respective charging condition is not directly determined from these voltage values, but instead indirectly through subtraction of these voltage values, which are obtained by means of the successive measurements at the end of each charging current impulse. The results of these measurements are directed to a computer, which arranges that the charging current is either left alone, shut off or adjusted.

EP-0 181 112 (Christie) has as an object a charging procedure with which constant charging current impulses are  
30 directed to the battery, whereby the clamp voltage is recorded at the end of the current impulse pauses. The

lowering of the electrochemical potential can be strengthened by means of a discharging process in the current impulse pauses. In this known procedure a computer is used in any case, especially for recording or figuring a time-dependent voltage deviation as a shut-off criterion.

It is further known from FR-A-2 274 156, in the charging conservation operation, to allow the battery voltage to rise and fall between an upper and lower limit. In similar manner, in the procedure described in EP-0 330 981, the battery voltage is held from reaching an upper voltage limit between this upper limit and lower limit.

EP 0 074 444 has as an object a rechargeable battery system, with which the charging and discharging process, depending on the specific gravity of acid (pH value), temperature and the like, is controlled by means of a microprocessor. Constant charging and discharging current impulses are used, whereby the impulse speed is adjustable corresponding to the desired charging current strength.

US 4,371,826 (Shelly) has as an object a charging connection, with which the charging current of the battery is supplied in the form of constant current impulses modulated by impulse width.

PCT/AT 89/00027 (Wiesspeiner) has as an object a procedure, devices and switching variants, with which a shutting off or reduction of the energy transport occurs for preventing an overload, whereby as a criterion for shutting off, the temporal gradient of the charging current and charging voltage is used and by means of a computational circuit, is recorded and analyzed.

US 4,710,694 (Sutphin) has as an object a battery charging system controlled by microprocessor, with which

three charging currents of differing height are provided which are successfully brought into effect. A microprocessor determines (when) the charging currents become effective in such a manner that first a very high charging current is turned on for at least a short period, for example, until a certain voltage value is reached, or the variance or the clamp voltage amounts to less than  $x/100$  Volt/h, wherein  $x$  should be a positive time; then the second charging current comes into effect and stays turned on until  
10 the voltage variance has reached a value that is less than  $x/100$  Volt/h. Finally the third charging current comes into effect at the end of the charging.

By means of WO-A-84/00614 (Stubbe), a procedure for observing the loaded capacity of accumulators has become known, with which, for the purpose of fast charging, several charging phases with pulsing charging currents of varying strength are provided. In a first charging phase a very high charging current is supplied, which acts as a multiple or the normal charging current. It is then switched from  
20 the first charging phase to the second charging phase, if either a certain switching voltage is built up or the temperature exceeds an adjustable value, and indeed, after whichever of these conditions first occurs. The second phase is then terminated, as soon as a selected time has elapsed or a certain shut off voltage is reached, or a certain temperature of the battery to be charged has been exceeded. For charging conservation, voltage conservation impulses are supplied at a greater time interval, within a third charging phase after ending a second phase.

30 It is an object of the invention to provide a new charging device, with which shorter charging times are

achieved and charging can occur in a broader temperature range, without harmful heating and subsequent tendency for gassing. Above all, the charging device is universally applicable for all commercial battery types and sizes, especially also for quick charging of motor vehicle batteries.

The present invention provides a charging device with which the charging current of the battery is supplied in the form of constant-value current impulses, whereby in the  
10 pauses of the current impulses, the clamp voltage of the battery is measured and, in reaching the previously determined maximum shut off voltage, the charging current is so diminished, such that no harmful heating of the battery occurs.

According to the device of the present invention, several charging currents of varying strengths are provided which are put into effect depending on the respective charging condition of the battery, and that the respective charging condition is registered by measuring the  
20 electrochemical voltages (EMK) at the electrodes of the battery.

This can be thereby achieved because each charging current intensity corresponds to a battery-specific region in the electrochemical voltage gradient of the battery, in such manner that in overreaching the upper regional limits, a shut off of the respective charging current and likewise a turning on of the connecting region ensues, while underreaching the lower regional limits restores power of the respective charging current (Hysteresis production). In  
30 contrast to the known charging devices, with which the battery is charged by outside currents and voltages, in the

device of the invention, the battery is offered varying voltages and currents among which it can select those which, when cycling through this region, cause no noteworthy heating and/or gassing.

Several charging currents of varying strength are provided, which are brought into effect depending on the respective charging condition of the battery, and with which each charging current strength is assigned a battery-specific zone in the electrochemical potential gradient of the battery, in such manner, that by exceeding the upper zone limit, a shutting off of the respective charging current and likewise a turning on of the adjoining zone ensues.

According to process of the invention, the charging current of the battery is held from reaching an upper zone limit in a transition phase between the current value of a first phase and that of a second phase, until the electrochemical potential (lowered because of the reduced charging current) of the battery is, after impulse pauses, again raised over this zone limit, whereby this charging current is then held in the second phase at the second current value, and when in this phase the upper zone limit (shut off voltage) is reached, the charging current in the reloading phase is slowly reduced by means of determining further zone limits in the electrochemical potential gradient.

According to the invention, this can be obtained in that the zone assigned to each current value (current strength) the electrochemical potential gradient  $U=f(t)$  is determined by means of a lower and an upper voltage set value, whereby in the charging phases the lower voltage set

value preferably corresponds to the upper voltage set value of the previously cycling zone, in such manner, that after each over- and under-reaching of one of the zone limits of the electrochemical potential of the battery after a current impulse, the current value (the height) of the following current impulse is adapted to the respectively assigned zone (phase 1 or 2); that in reaching the uppermost zone limit, the succeeding current impulses are reduced (shut off) until the lower zone limit of the reloading phase is reached  
10 (phase 3); and that in the reloading phase (phase 3), after each over- and under-reaching of the zone limits (U3a, U3b) after a current impulse, the succeeding current impulse(s) are suppressed or released.

According to another characteristic of the invention, during the charging process, the decrease of the electrochemical voltage that normally occurs during each pause in the current impulses is strengthened in the current impulse pauses, by means of a targeted discharge process in a battery that is not fully charged. The discharging  
20 process in the current impulse pauses is strengthened by means of switching on an ohmic resistor, preferably of the value of 10 to 10,000 ohms. By means of this short term discharging within the current impulse pause, the actual electrochemical voltage is more quickly reached. Furthermore, by means of these measures a battery-specific crystal build up in the battery is prevented, which is known as the so-called "memory effect". As is well known, this effect reduces the capacity of a battery and its possible cell count.

30 More specifically, the present invention provides a method for quick charging a rechargeable battery, the method

comprising the steps of feeding a charging current to the battery in the form of constant value current impulses, wherein in reaching a maximum cutoff voltage the charging current is reduced, whereby no harmful heating of the battery occurs, and during pauses of the current impulses, measuring an individual charging condition of the battery by measuring a respective clamp voltage of the battery, wherein the charging current comprises a plurality of different strength charging currents which are brought into effect  
10 depending on the respective charging condition of the battery. The method also comprises the steps of assigning each of the plurality of different strength charging currents a specific zone in an electrochemical potential gradient of the battery, wherein an overreaching of an upper zone limit of one zone leads to a shut off of its respective charging current and a turning on of the charging current of an adjoining zone, in a transition phase, reducing the charging current fed to the battery from a first strength charging current of a first charging phase to a second  
20 strength charging current of a second charging phase when an electrochemical voltage of the battery reaches a first upper zone limit voltage of the first charging phase, and in the transition phase, increasing the charging current fed to the battery from the second strength charging current to the first strength charging current when the electrochemical voltage falls below the first upper zone limit voltage, whereby an average charging current fed to the battery in the transition phase is between the first strength charging current and the second strength charging current. When the  
30 electrochemical voltage of the battery climbs above a lower zone limit voltage of the second charging phase, the

charging current fed to the battery in the second phase is held on the second strength charging current, and if, in the second phase, a second charging phase upper zone limit voltage is reached, the charging current fed to the battery is reduced to a third strength charging current in a third phase, third phase lower and upper zone limit voltages are fixed, and the third strength charging current is switched on and off to further reduce an average charging current to the battery in the third phase.

10       The present invention also provides a switching arrangement for implementing the method as defined herein the switching arrangement comprising means for measuring, in each current impulse pause, the electrochemical voltage of the battery, means for storing the measured electrochemical voltage in a voltage real value reservoir, and comparator means for comparing the measured electrochemical voltage with voltage set values assigned to individual zones. The switching arrangements also comprises an RS-flip-flop combination, joined with exits of the comparator means, for  
20 assigning the respective voltage real value to the individual zones, and logic control means for joining the individual zones with assigned current set values whereby at an exit of the logic control means a current set value corresponding to the voltage real value appears.

It has been shown that, with the device according to the invention, the charging period can be reduced to five to seven minutes. Furthermore, it can be used with temperatures between  $-20^{\circ}$  and  $+80^{\circ}$  degrees Celsius.

30 Since charging, measuring and correcting occurs in a fraction of a second, charging is very careful, despite the initially very high efficiency, because the charging current

is completely received by the battery and not converted into heat.

In order to enable a controlled charging, the number of zones can be increased as desired and the high current zone can be moved to second rather than first place, or omitted altogether. It is consequently especially suited to charging a battery over a photo-voltaic.

Naturally, the device according to the invention can be used for charging battery packs. For this use, the  
10 corresponding parameters need only be altered or adapted.

#### DESCRIPTION OF THE DRAWINGS

FIGS. 1, and 1a-1c, are theoretical voltage and current gradients of a commercial, rechargeable NiCd battery.

FIG. 2 is a modular mimic display of a circuit arrangement for implementing the device according to the invention.

FIG. 3 is the actual voltage and current path at 50° C. operating temperature at the beginning of the charging.

20 FIG. 4 is the actual voltage and current path at 0° C. operating temperature at the beginning of the charging.

FIG. 1 shows the typical charging flow in a commercial Ni/Cd battery. The electrochemical voltage path (EMK) of the battery is indicated by  $U=f(t)$  and the clock-pulsed charging current is indicated with  $I=f(u)$ . As can be seen, three different high, constant charging currents  $I_1$ ,  $I_2$  and  $I_3$  are provided. The choice of the height of the charging current depends on the battery to be charged. Thereby, use is made of the fact that a completely discharged battery can  
30 accommodate a very high current at the beginning of the charging. This current can maximally lie in the dimension

of the short circuit current. With the chosen example, the currents amount to  $I_1=10A$ ,  $I_2=6A$ , and  $I_3=4A$ . To each of these currents is assigned a battery specific zone (phases 1 to 3) in the electrochemical voltage path  $U=f(t)$ , whereby each zone is indicated by a lower and upper voltage. The zone of phase 1 starts practically at 0 with a completely discharged battery and ends with the set value-voltage  $U_1$ . To this joins phase 2, with the lower set value-voltage  $U_{2a}$ , which scarcely differs from  $U_1$ . As will be more closely  
10 illustrated below, the passage from phase 1 to phase 2 is not for the most part accomplished steadily, but rather in steps, so that a passage phase 1 is formed, in which current  $I_1$  as well as current  $I_2$  alternately come into effect. This behavior is more closely illustrated by FIG. 2.

As will be seen in the chosen example, the zone of phase 2 ends when reaching the maximum voltage value of  $U_{2b}$ , where the current  $I_1$  of phase 2 is shut off and the current  $I_3$  of the compensation charge comes into effect. This zone is indicated by the lower set value-voltage  $U_{3a}$  and the  
20 upper set value-voltage  $U_{3b}$ . The compensation charge practically starts only when the measured voltage of the battery, after shutting off current  $I_2$ , as lowered to the set value-voltage  $U_{3a}$  of phase 3; that is, the battery was not fully penetrated with the charge. In so far as the charging current  $I_3$  extends, in order to achieve the set value-voltage  $U_{3b}$ , the charging current  $I_3$  is shut off and turned on again, when the voltage of the battery again sinks to the set value-voltage  $U_{3a}$ . The hatched region in phase 3 in the voltage path  $U=f(t)$  means that the current  $I_3$  is  
30 turned on and off corresponding to the hysteresis formed by the voltages  $U_{3a}$  and  $U_{3b}$ . As FIGS. 1a to 1c show, the

voltage of the battery oscillates between the values  $U_{3a}$  and  $U_{3b}$ , whereby the switching periods in the course of the charging time continuously increase. The hatched region in the current path  $I=f(U)$  shows that the current  $I_3$  of the compensation charge diminishes with increasing charging time, as a consequence to the later illustrated impulse duration control of the charging impulse of the clock-impulsed charging current  $I_3$ .

10 In so far as the charging current  $I_3$  is not sufficient to attain the set value-voltage  $U_{3b}$ , the voltage of a battery not fully penetrated with charge can sink so far that the set value-voltage  $U_{2a}$  is reached, which results in the charging current  $I_2$  of the phase 2 again coming into effect and the battery is now charged with the higher current  $I_2$ . As soon as the set value voltage  $U_{2b}$  is again reached, it is switched over, as before, to the compensation charge. This can be repeated many times. In this manner a transition region can also result within phase 2.

20 The transition phase 1 results when, in the course of charging the electrochemical voltage after reaching the zone of phase 1, which is indicated by set value voltage  $U_1$ , incomplete charge penetration of the battery falls below the set value voltage  $U_1$ , which results in charging current  $I_1$  again becoming effective and the charging current being shut off. The higher charging current  $I_1$  raises the battery voltage within the duration of the impulse again over the set value voltage  $U_1$ , which again effects a shut off of the charging current  $I_1$  and start up of charging current 2 ( $I_2$ ). If it is discovered in the following impulse pause that the  
30 voltage  $U_1$  has fallen, the process repeats itself. This

continues as long as the battery voltage within the impulse pauses no longer falls below the set value voltage  $U_1$ .

Within the transition phase the charging current impulses consist of two current strengths so that, after averaging, the charging current steadily decreases, as the transition phase in FIG. 1 shows.

When, for example, a partially-discharged battery should be recharged, phase 1 is omitted and the charging is begun in phase 2. If by accident a completely-charged  
10 battery is set into a device that works according to the invention, then phases 1 and 2 are bypassed in a fraction of a second, and the battery passes immediately to stopping phase 3.

With the assistance of light diodes or other optical displays the capacity condition of the battery can be thereby relatively easily monitored, since the zone-recognizing voltage set values  $U_1$ ,  $U_{2a}$ ,  $U_{3a}$ ,  $U_{3b}$  and  $U_{2b}$  are displayed.

FIG. 2 shows a modular mimic display of a circuit  
20 arrangement for implementing the charging gradient presented in FIG. 1. Also indicated is a battery which is to be charged. The respective charging current demanded by the battery is fed to it in clock impulses by means of an output amplifier 2, which is controlled by a trigger 3, so that constant current impulses are delivered. The clock frequency is dialed high, so that the battery can be very carefully charged. The clock frequency can lie between 1 Hz and 10 kHz and is preferably adjustable. Also adjustable is the break-make ratio of the clock frequency, for example  
30 between 5:1 and 100:1, that is, the impulse duration is 5 to 100 times as long as the impulse pause. As mentioned at the

beginning hereinabove, in each current impulse pause, the electrochemical voltage (EMK) of the battery, which represents the charging condition, is measured and conducted by a conductor L1 to a voltage reservoir 4 as a voltage actual value. It is stored there until the next measured value arrives out of the following impulse pause. The reservoir 4 is therefore consecutively corrected in the last position.

10 In a similar manner, the respective current real value is directed over a conductor L2 to a current real value reservoir 5 and stored there until the next current real value of the next current supplying phase arrives. To record the current real value, a shunt is used on which is calipered a voltage proportioned to the current, the voltage being directed as a voltage value to the current real value reservoir 5. Since the voltage real value reservoir 4 and the current real value reservoir 5 run synchronized with the output amplifier 2, both of the reservoirs 4 and 5 are alternately directed over the conductor L3 by the trigger 3,  
20 that is the one in the impulse pause and the other in phase directing thereto. The voltage real value comparator 6, in the voltage real value reservoir 4, is directed through a conductor L4 to the set value-real value comparison. The voltage and current set values necessary for the device are included in the small box 7.

The present current and voltage set values in the form of voltages are preferably produced in a simple manner with the aid of voltage distributors provided with constant voltages.

30 The voltage set values are directed to the comparator 6, whereby the count of the comparator corresponds to the

count of the voltage to be recorded. The voltage real value is offered to all of the comparators. The exits of the individual comparators are directed to a RS-flip-flop combination 9, which selects the individual zones (phases 1 to 3), in such manner that both the hysteresis 2 and 3 are formed.

Corresponding to the example presented in FIG. 1, the hysteresis 2 is formed by the two set value voltages U2a and U2b and the other hysteresis 3 is formed by the voltage set values U3a and U3b in such a manner that, with the voltage build-up of the electrochemical voltage of the battery from U2a or U3a to U2b or U3b, the corresponding charging current I2 or I3 remains turned on, while on the other hand, with the lowering of the battery voltage from U2b or U3b to U2a or U3a, the current I2 or I3 corresponding to this zone (phase 2 or phase 3) remains shut off.

The current set values corresponding to the individual phases are transmitted through a conductor L5 to a control logic 8. The flip-flops of the RS-combination 9 preferably give digital signals to the control logic 8 in order to inform it in which phase one already finds oneself. The control logic 8 contains a multiplexer for phase control in order to establish a corresponding coupling between the phases 2 and 3 with the coordinating charging currents I2 and I3. At the exit of the control logic 8 there appears consequently the current set value demanded by the battery, which set value is directed to an integrator 10. The integrator 10 compares and corrects the current set value prepared by the control logic with the current real value stored in the current real value reservoir 5.

By way of the, preferably multistage, output amplifier, the integrator 10 controls the maximum allowable charging current demanded by the battery. Since the output amplifier 2 is preferably clock-pulsed by way of a pre-amplification stage, exact current impulses are produced, which in the transition phase consist of two current strengths, for example, in the transition phase 1, of the currents I1 and I2, whereby the impulse duration remains constant.

The adaptability of such a charging device to different battery types is possible in a simple fashion by merely inserting a potentiometer or the like. It could therefore be rightly identified as an "electrode specific charging device".

FIG. 3 and FIG. 4 show actual recorded current-voltage diagrams, whereby the current and voltage curves  $U=f(t)$  and  $I=f(u)$  were recorded with a battery temperature of 50° C. or 0° C. respectively. The height of the charging currents I1 to I3 and the height of the voltage set values U1, U2a U2b, and U3a and U3b are similarly chosen as in FIG. 1. As can be seen, the curve gradient in FIG. 3 practically corresponds to that in FIG. 1, with the exception of the charging time, which in FIG. 3 lies between 5 and 7 minutes.

Depending on the value of the temperature, the battery takes up little current, as FIG. 4 shows, so that phase 1, after a short transition phase U1, immediately goes into phase 2 with the charging current I2. Since after reaching the maximum voltage set value U2b, the charging current I3 of the compensation charge is not sufficient, and in order to hold the voltage U3a, the charging current I2 is again switched on. In this manner the transition phase U2 results. Surprisingly and unexpectedly it has turned out

that when inserting an alkaline primary cell into a device that operates according to the present invention, this also proves to be rechargeable without danger. Closer research into this phenomenon has shown that, for example, an alkalimanganese primary cell considered nonrechargeable, was charged and discharged 50 times in a row and after the fiftieth time still had 75% of its claimed capacity. Certainly a quick recharging was not possible; the charging time took between 2 and 3 hours. Research has shown that  
10 this characteristic of rechargeability indicates quicksilver-quicksilver-oxide and silver-silveroxide primary cells and others. Understandably, a battery-specific adjustment of the charging device was necessary.

The somewhat higher circuit-technical use of the device according to the invention vis-a-vis the known quick charging devices can, by means of a meaningful integration of electronic components, be limited to an integrated switching circuit. This is however always suitable where it is a question of an extremely short charging time, careful  
20 handling of the battery, an elevated number of cycles, and prevention and possible adjustment of memory behavior.

Protection against incorrectly inserting a battery in the charging device, can be thereby realized since in the supply line to the voltage and current supply of the device, a switching transistor is attached, which can only be controlled with correct polarity of the battery. As is known, a fully discharged battery still has an electrochemical resting voltage of about 0.6 volts, which after corresponding strengthening, is sufficient to direct  
30 the switching transistor in the input circuit. Since a very faulty battery, for example as a result of a short circuit

between the electrodes of the battery, has no more resting voltage, and such a battery would be recognized by the aforementioned reverse battery protection and could be identified. In that case the charging process is not begun at all.

Finally, an additional device can be provided, for example, a sensor, in order to observe the temperature of the battery, which naturally is only meaningful when a battery is charged at a higher temperature, for example,  
10 over 60° C.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method for quick charging a rechargeable battery, the method comprising the steps of:

feeding a charging current to the battery in the form of constant value current impulses, wherein in reaching a maximum cutoff voltage said charging current is reduced whereby no harmful heating of the battery occurs;

during pauses of the current impulses, measuring an individual charging condition of the battery by measuring a respective clamp voltage of the battery, wherein said charging current comprises a plurality of different strength charging currents which are brought into effect depending on the respective charging condition of the battery;

assigning each of said plurality of different strength charging currents a specific zone in an electrochemical potential gradient of the battery, wherein an overreaching of an upper zone limit of one zone leads to a shut off of its respective charging current and a turning on of the charging current of an adjoining zone;

in a transition phase, reducing said charging current fed to the battery from a first strength charging current of

a first charging phase to a second strength charging current of a second charging phase when an electrochemical voltage of the battery reaches a first upper zone limit voltage of said first charging phase;

in said transition phase, increasing said charging current fed to the battery from said second strength charging current to said first strength charging current when the electrochemical voltage falls below said first upper zone limit voltage, whereby an average charging current fed to the battery in said transition phase is between said first strength charging current and said second strength charging current;

when said electrochemical voltage of the battery climbs above a lower zone limit voltage of said second charging phase, holding said charging current fed to the battery in said second phase on said second strength charging current; and

if, in said second phase, a second charging phase upper zone limit voltage is reached, reducing said charging current fed to the battery to a third strength charging current in a third phase, fixing third phase lower and upper zone limit voltages, and by switching on and off said third strength charging current an average charging current to the battery in said third phase is further reduced.

2. The method of claim 1, further comprising the step of strengthening a lowering of the electrochemical voltage in a not yet fully charged battery which normally occurs in the charging process during each current impulse pause by a targeted discharging process in the current impulse pause.
3. The method of claim 2, wherein the discharging process is strengthened by switching on an ohmic resistor in the range of 10 ohms to 10,000 ohms.
4. The method of claim 1, 2 or 3, wherein said constant value current impulses comprise an impulse-to-pause ratio of between 5:1 and 100:1.
5. The method of any one of claims 1 to 4, wherein said first strength charging current is set at a value of a short circuit current of the battery.
6. The method of any one of claims 1 to 5, wherein the battery is a motor vehicle battery.
7. A switching arrangement for implementing the method as defined in any one of claims 1 to 6, the switching arrangement comprising:

means for measuring, in each current impulse pause, the electrochemical voltage of the battery;

means for storing the measured electrochemical voltage in a voltage real value reservoir;

comparator means for comparing the measured electrochemical voltage with voltage set values assigned to individual zones;

An RS-flip-flop combination, joined with exits of said comparator means, for assigning the respective voltage real value to the individual zones; and

logic control means for joining the individual zones with assigned current set values whereby at an exit of said logic control means a current set value corresponding to the voltage real value appears.

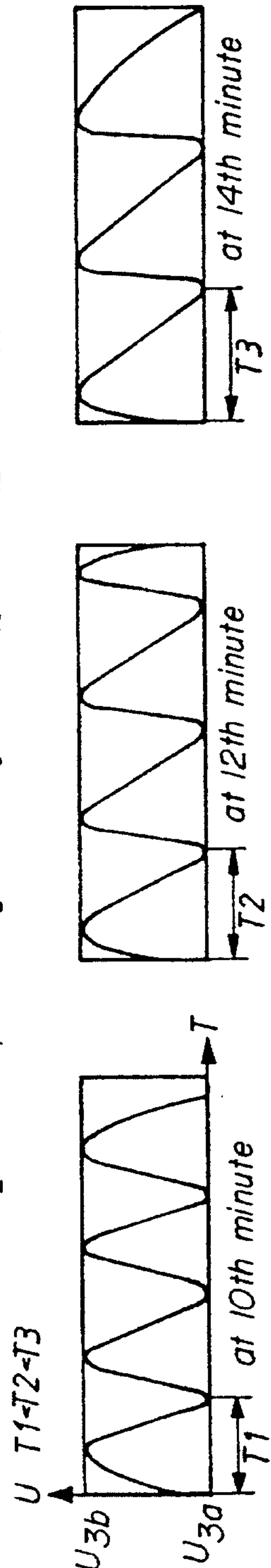
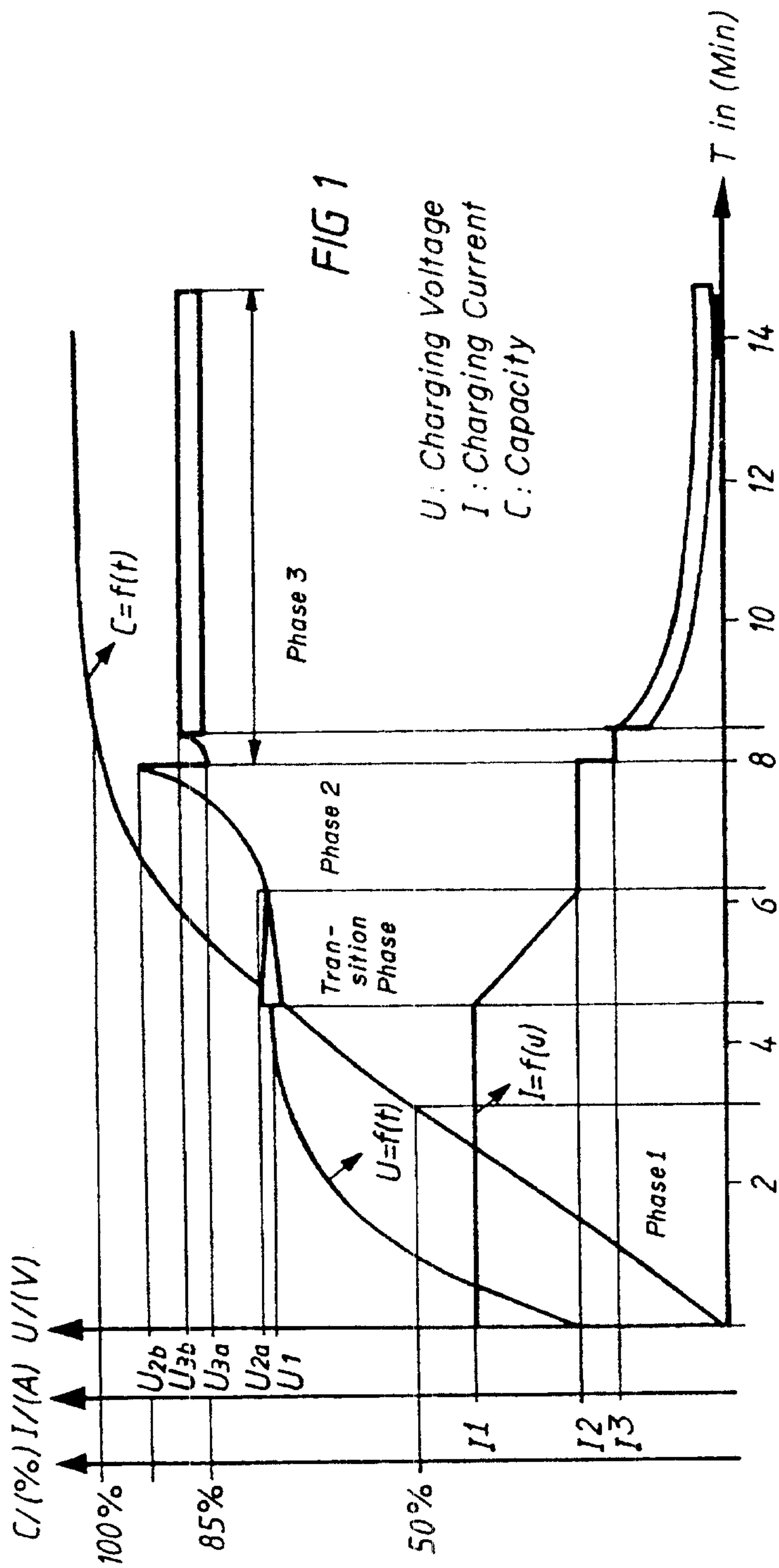
8. The switching arrangement of claim 7, further comprising integrator means for directing the current set value delivered from said logic control means to an output amplifier that feeds the battery, wherein said integrator means compares a current real value with the respective current set value and resets it within an impulse duration.

9. The switching arrangement of claim 7 or 8, further comprising shunt means for measuring the current real value of a clock-impulsed charging current within an impulse

duration, and means for storing the current real value in a current real value reservoir for the duration of the impulse.

10. The switching arrangement of claim 9, further comprising a trigger, wherein said output amplifier delivers the charging currents of different strengths and comprises a multistage amplifier, and wherein said output amplifier is clock-impulsed, together with said voltage real value reservoir and a current set value reservoir, by said trigger.

11. The switching arrangement of any one of claims 7 to 10, further comprising voltage distributors fed by constant voltage sources, and wherein said voltage and current set values are calipered by said voltage distributors.



**FIG 1c**

**FIG 1b**

**FIG 1a**

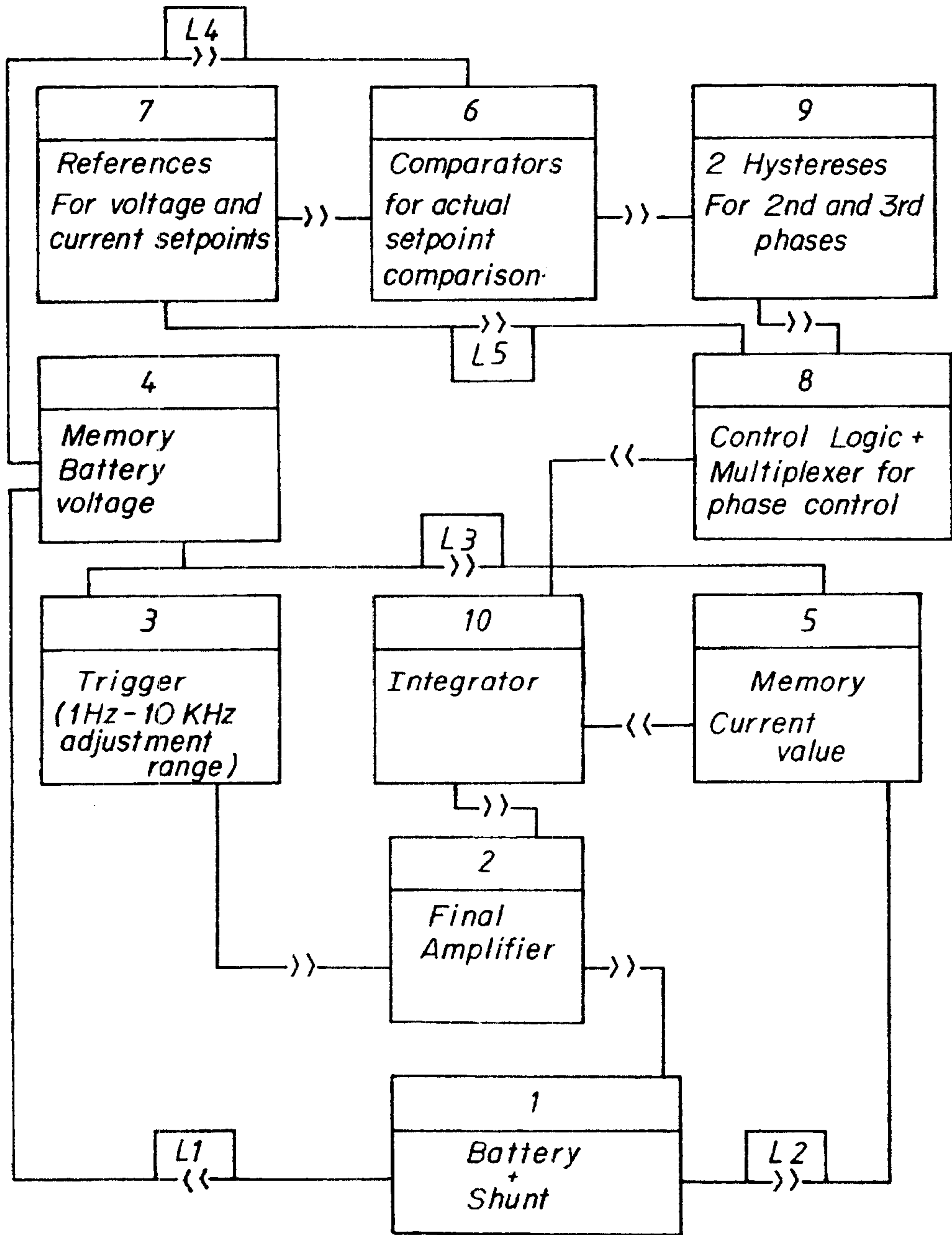


FIG 2

