

Cell Overcharge Protection Circuit

The invention relates to a cell overcharge protection circuit, preferably for rechargeable alkaline manganese dioxide-zinc cells.

Several types of rechargeable cells are sensitive
5 against overcharge during the charging process. Rechargeable alkaline cells e.g. can be charged up to about 1.7 V or they can tolerate a charging voltage up to about 1.9 V when this overvoltage is applied within a predetermined time period. The charging of several cells in a series chain is a common
10 and preferable method, however, if the cells in the chain are not uniform, the one that has the smallest capacity will reach first the fully charged state. If the charging process goes on, this cell will be overcharged i.e. the terminal voltage increases beyond the above mentioned upper voltage
15 limit value resulting in oxygen gas development which can be detrimental for the cell.

In U.S. Patent 3,148,322 issued to J. M. Booe et al. in 1964 the problems of overcharging has been solved by providing a shunt element arranged in parallel to each cell
20 charged in series. This element is substantially nonconductive when the terminal voltage produced across the cell shunted thereby is below its predetermined maximum value and becomes highly conductive when the terminal voltage produced across the cell incrementally exceeds that value. The patent
25 suggests using semiconductor diodes for shunt elements, preferably zener diodes or stacks of diodes of different types, wherein the sum of the gating voltages of the stacked diodes should give the permitted maximum terminal voltage of the cell.

30 U.S. patent 4,719,401 issued to Altmejd in 1988 deals in detail with the problems of designing such shunt elements. When diodes are used to shunt the cells to provide over-

charge protection, Altmejd has recognized the existence of a necessary trade-off between charging current and the size of the diode. For any reasonable charging current the size of diode would have to be large enough to dissipate the entire
5 amount of current so that when a cell becomes fully charged, the associated diode can conduct the remainder of the current around the fully charged cell. This would necessitate physically large components for any reasonable charging rate. The use of more intelligent units to sense the charge
10 on a cell and cause to switch around the cell according to a predetermined algorithm was found too sophisticated and expensive. Altmejd has suggested using specific zener diodes as shunt elements, which fuse permanently in a short circuit state when a predetermined amount of current is passed
15 therethrough in forward biasing direction. Such zener diodes can be used especially in high temperature batteries, such as sodium sulfur type.

Rechargeable alkaline batteries have become popular in the recent years, since such batteries have in many respects
20 better properties compared to several other types, e.g. they have no memory effect and can retain their charges through a longer period of time. Alkaline batteries are, however, sensitive against overcharging, and they cannot be used without some kind of overcharge protection. Owing to differing
25 voltage parameters, rechargeable alkaline batteries require charger devices differing from those designed primarily for nickel cadmium or other types of batteries. Currently available chargers for alkaline batteries have built in voltage limitation means that prevent the charging voltage
30 from exceeding 1.7-1.75V, and batteries are charged individually or in parallel.

Owing to the fact that such batteries are used in series connection or in series sets, their charging in series connection is a well-based requirement.

35 If such cells are charged in series, the overcharging of a member cell in the series chain cannot be prevented by the

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limitation of the voltage across the end terminals of the chain, since when the cell with the lowest capacity reaches the fully charged state and the charging process of the remaining cells goes on, this particular cell will be over-
5 charged.

Zener diodes cannot be used preferably as overcharge protection means together with alkaline cells, since the types that have a breakdown voltage in the range of 1.7-1.75V, have a substantial leakage current at the open cir-
10 cuit voltage of 1.45-1.5 V causing thereby a discharge when the charging process has been completed.

To provide respective series chains of forward biased diodes with a resulting voltage of 1.7-1.75 V as suggested by the cited Booe et. al. patent to form a shunt path for
15 each cell is not a practical solution, since at least three diodes are required and such diodes will have a non negligible leakage current.

The object of the invention is to provide an overcharge protection circuit that can be used for rechargeable alka-
20 line batteries when charged in series, which is simple and does not influence cell performance when the charging process has been completed.

According to the invention an overcharge protection circuit has been provided for rechargeable cells charged in
25 series and having predetermined maximum permitted charging voltage and an open circuit voltage, which comprises:

- diode means coupled across each of the cells to provide a shunt path if the voltage across the associated cell exceeds the maximum charging voltage;
- 30 -a charger circuit coupled to terminals of the series chain and applying a charging current of predetermined direction, characterized in that the diode means is a light emitting diode with a forward voltage substantially equal to the maximum permitted voltage, and the charger circuit
35 comprises current and/or voltage limiting means limiting the current through the series chain of the cells at most to a



value that corresponds substantially to the current that flows through the light emitting diode when the maximum permitted voltage is applied thereto, the light emitting diode is substantially non-conductive when a voltage corresponding to the open circuit voltage is applied in forward direction, whereby the light emitting diode constitutes no remarkable load for the associated cell when being stored or discharged, and fully shunts the cell after it has reached the fully charged state and provides simultaneously a visual indication that the associated cell has been charged.

At a preferable embodiment respective reverse diodes are coupled to each of the cell to prevent cell reversal during excessive load.

It is preferable if the limiting circuit comprises a series resistor and a voltage stabilizer. In a first embodiment the voltage stabilizer is a zener diode. In an alternative embodiment the voltage stabilizer comprises a set of diodes connected in series and a forward bias voltage is applied to the set.

The advantages of the invention will be more apparent if the cells to be protected are alkaline cells.

In a preferable embodiment the charger circuit comprises a mains transformer with a secondary winding coupled to respective sets of series cells each having respective ones of the limiting circuit, the sets are activated in opposing half waves of the voltage on the secondary winding.

The protection circuit can be arranged in a multiple cell package.

The invention will now be described in connection with preferable embodiments thereof, in which reference will be made to the accompanying drawings. In the drawing:

FIG. 1 is the circuit diagram of a first embodiment;

FIG. 2 shows the current-voltage graph of a LED; and

FIG. 3 shows a further embodiment built in a simple

charger circuit

FIG. 1 shows ten cells 1 to 10 constituted by rechargeable alkaline manganese dioxide-zinc cells of AA size, all connected in series to form a chain. The cell protection circuit consists of respective reverse diodes RD and light emitting diodes LED connected to terminals of the associated cell. The light emitting diodes LED are red and can be realized e.g. by the commercially available type Liton LTL 10203. Such a diode starts lighting when the cell voltage is higher than about 1.55 V. At 1.7 V it lights with full intensity and a current of about 70 mA flows therethrough. The voltage versus current curve of such a light emitting diode is illustrated in Figure 2. When the voltage drops to 1.5 V, the leakage current is about 1 mA, and if the voltage is lower than 1.45 V, the current drops to the micro ampere range and constitutes practically no load to the associated battery.

The series chain is charged through a current limiting resistor R and a diode D which prevents operation if connected to a direct current source of opposite polarity. A zener diode Z stabilizes the voltage over the series chain to about 17-18 V. If during the charging process any of the cells 1 to 10 gets fully charged, the terminal voltage increases and reaches the value of 1.7 V. Together with the increase of the voltage, the associated light emitting diode starts lighting, and its current follows the curve of FIG. 2. The charging current limited to about 70-75 mA by means of the resistor R and the zener diode Z will flow through the light emitting diode LED instead of the associated cell, whereby the terminal voltage of this cell will be limited to about 1.7V. The light of the diode indicates that the associated cell has been fully charged. As the charging process goes on, the other cells in the chain will be fully charged and the associated light emitting diodes LED will all be lighting, thus visually indicating that the charging process has been completed.

FIG. 3 shows a simple charger circuit capable of charg-

ing four alkaline cells which uses the overcharge protection circuit according to the invention. The charger circuit comprises four identical sub-units with respective batteries B1 to B4 arranged in two pairs. The batteries in each pair
5 are connected in series, and the pairs are coupled through respective current limiting resistors R1 resp. R2 with opposing polarity to secondary winding of a mains transformer T1. In each sub-unit respective voltage limiting circuits are arranged, each comprising three series diodes connected
10 via a fourth diode to the terminals of the associated battery. Light emitting diodes D17 to D20 that provide overcharge protection are connected directly across the terminals of the associated batteries. The four diodes in each sub-unit constitute part of a half-wave rectifier and of a
15 voltage limiter circuit. The four diodes are identical, preferably of the type 1N40001. When a forward voltage of about .80 V is applied to such a diode, the current will be about 120 mA, while at a voltage of about .85 V the associated current is about 400 mA. The voltage across the
20 series triplets of diodes will be close to 2.4 V during the peak period of the proper half wave of the mains voltage that causes forward bias to the diodes, and the diodes act as a simple voltage stabilizer. The fourth diode that connects the triplets to the batteries prevents the flow of
25 current if the mains voltage takes the opposite polarity. The forward voltage of this rectifier diode is deducted from the 2.4 V measurable across the triplet of diodes, thus the associated battery will receive a voltage of about 1.6-1.7V. As the charging process goes on, the voltage across the bat-
30 tery increases, and by the time the battery gets fully charged, the current will flow through the light emitting diode in the shunt path and this diode will be lighting. Due to the steep voltage-current curve of the LEDs, the battery will be prevented from being overcharged.

35 Each pair operates in every other half-wave of the mains voltage, so that each wave is utilized.



Claims

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1. Overcharge protection circuit for rechargeable cells charged in series and having predetermined maximum permitted charging voltage and an open circuit voltage, comprising:

-diode means coupled across each of said cells to

5 provide a shunt path if the voltage across the associated cell exceeds said maximum charging voltage;

-a charger circuit coupled to terminals of the series chain and applying a charging current of predetermined direction, characterized in that said diode means is a light
10 emitting diode with a forward voltage substantially equal to said maximum permitted voltage and said charger circuit comprises current and/or voltage limiting means limiting the current through the series chain of said cells at most to a value that corresponds substantially to the current that
15 flows through said light emitting diode when said maximum permitted voltage being applied thereto, said light emitting diode being substantially non-conductive when a voltage corresponding to said open circuit voltage is applied in forward direction, whereby said light emitting diode
20 constitutes no remarkable load for the associated cell when being stored or discharged, and fully shunts said cell after the cell has reached the fully charged state and providing simultaneously a visual indication that the associated cell has been charged.

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2. The overcharge protection circuit as claimed in claim 1, wherein respective reverse diodes are coupled to each of said cell to prevent cell reversal.

30 3. The overcharge protection circuit as claimed in claim 1, wherein said limiting circuit comprises a series resistor and a voltage stabilizer.



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4. The overcharge protection circuit as claimed in claim 1, wherein said voltage stabilizer is a zener diode.

5 3, wherein said voltage stabilizer comprises a set of diodes connected in series and a forward bias voltage is applied to the set.

10 6. The overcharge protection circuit as claimed in claim 1, wherein said cells are alkaline cells.

7. The overcharge protection circuit as claimed in claim 3, wherein said charger circuit comprises a mains transformer with a secondary winding coupled to respective sets of series cells each having respective ones of said limiting circuit, said sets being activated in opposing half waves of the voltage on said secondary winding.

20 8. The overcharge protection circuit as claimed in claim 1, characterized by being arranged in a multiple cell package.



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