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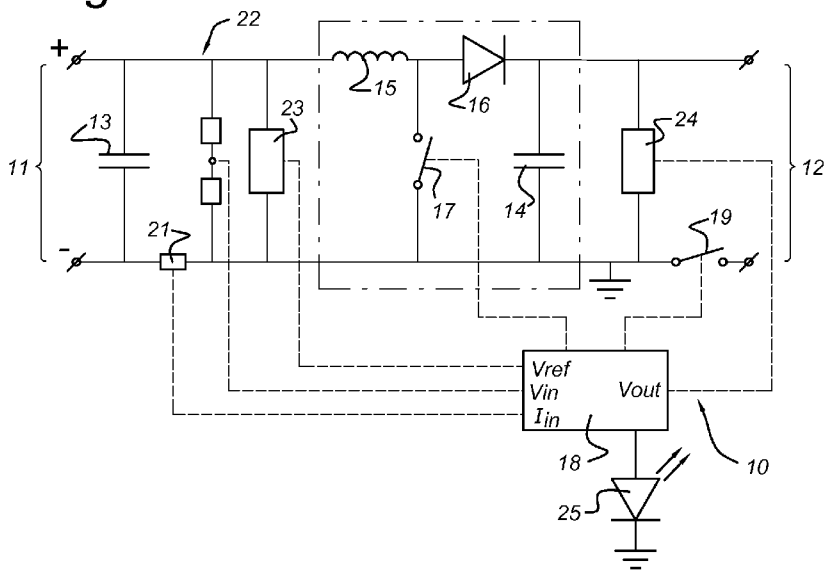
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Fig 5




(57) Abstract: Battery charging module to charge a battery in an apparatus (1) by means of a photovoltaic device (5). An electronic circuit (10) has a power supply connection (11) to connect the battery charging module to the photovoltaic device (5) and a load connection (12) to connect the battery charging module to the battery in the apparatus (1). The electronic circuit (10) is designed to supply a no-load voltage to the load connection (12) within a predefined charging voltage range, and is implemented as a switched power supply.

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Battery charger

**Field of the invention**

The present invention relates to a battery charging module to charge a battery in an apparatus by means of a photovoltaic device, comprising an electronic circuit with a power supply connection to connect the battery charging module to the photovoltaic device and a load connection to connect the battery charging module to the battery.

**Prior art**

It is known for an apparatus (for example a telephone) to be connected directly to a solar panel, whereby no control can be exerted over the voltage or supplied power. It is also known for the solar panel first to be connected to a battery, whereafter the battery is in fact used to charge the apparatus.

European patent application EP-A-0 859 454 discloses a circuit for increasing the voltage of a photovoltaic power supply source. The circuit measures the voltage on connections of the power supply source and adjusts the input voltage (not the output voltage) to an optimum voltage, but only during the operating condition wherein the battery is charged.

**Summary of the invention**

The object of the invention is to provide an improved battery charging module, which is suitable for effectively and efficiently charging a battery in an apparatus, such as a mobile device. The battery charging module must be compatible with the mobile nature of the apparatus, particularly if the apparatus is a handheld mobile device such as a mobile telephone, a PDA or other device of the same type.

According to the present invention, a battery charging module in accordance with the type defined in the preamble is provided, wherein the electronic circuit is designed to supply a no-load voltage to the load connection within a predefined charging voltage range and is implemented as a switched power supply. The term "no-load voltage" means that this voltage is present on the load connection when there is no load, i.e. when no power flows to the battery in the apparatus (for example because the charging circuit in the apparatus interrupts the connection to carry out a check on the

offered voltage). A 'switch mode system' of this type prevents the disadvantages of hitherto conventional electronic circuits, such as those in which a voltage regulator is used, which is associated with a loss of energy due to conversion into heat. Furthermore, it is possible for the charging module to start up as soon as the photovoltaic device supplies any voltage, and subsequently to charge the battery in the apparatus with the correct voltage.

In one embodiment, the electronic circuit is fed by the photovoltaic device during operation. Here, no single form of voltage supply, such as a battery or a super-capacitor, is necessary in the battery charging module itself. Similarly, the battery to be charged in the apparatus does not need to be activated, if that is at all possible.

In a further embodiment, the electronic circuit is designed to measure the open-circuit voltage on the power supply connection, and to supply power to the load connection when the measured open-circuit voltage is higher than a predefined threshold value. With this, it can first of all be determined whether the photovoltaic device can supply sufficient energy (sufficient light falls on it) before the battery in the apparatus is actually charged.

In one embodiment, the electronic circuit comprises a controlled switch and a control unit connected to the controlled switch, wherein the control unit controls the on/off ratio ('duty cycle') of the controlled switch. In addition, other parameters of the switched power supply, such as frequency, can be controlled so that the battery in the apparatus can be efficiently charged.

In a further embodiment, the control device is connected to measurement elements which measure the voltage and current supplied by the photovoltaic device, wherein the control device is designed to set a maximum power supply by the photovoltaic device (to the load connection), for example with an MPP (Maximum Power Point) algorithm known per se. In this way, power is supplied to the apparatus in an efficient manner to charge the battery (independently from the actual voltage during the charging process).

In one embodiment, the control unit adjusts the voltage on the load connection periodically during at least a predefined time period to a value within the predefined charging voltage range, for example 30 msec in every 2-second period. In this way, a charging circuit in the apparatus, which in some cases periodically measures and evaluates the supplied voltage, can, as it were, be fooled, so that the charging process is

not interrupted as soon as the voltage supplied by the photovoltaic device falls outside the predefined limits.

In an alternative embodiment, the control unit measures the voltage on the load connection, and, as soon as the voltage attains a value above a threshold value, adjusts the voltage to a value within the predefined charging voltage range (in the absence of a load, for example 5.07 V). In this way, a charging circuit in the apparatus, which in some cases periodically disconnects the battery and measures and evaluates the no-load voltage, can, as it were, be fooled in an automatic manner.

In a further embodiment, the control unit is designed for synchronisation with a charging unit for the battery in the apparatus. This can be done, for example, by measuring when the supplied current is interrupted, which may be indicative of the measurement cycle of the charging unit.

In one embodiment of the present invention, the (no-load) charging voltage range lies between 4.9 and 5.1 V. This is a normal (no-load) charging voltage range for, for example, a large number of mobile telephones. As an example, the no-load voltage is adjusted to 5.07 V by the control unit.

In one embodiment, the electronic circuit is designed to supply a voltage on the load connection which is higher than the voltage on the power supply connection. The electronic circuit comprises, for example, a common negative conductor between the power supply connection and the load connection, a first capacitor which is connected across the power supply connection and a second capacitor which is connected across the load connection, a series circuit comprising a coil and a diode between the power supply connection and the load connection, and a controlled switch which is connected between, on the one hand, a node of the coil and the diode and, on the other hand, the common negative conductor.

In a further embodiment, the electronic circuit is designed to supply a voltage on the load connection which is lower than the voltage on the power supply connection. The electronic circuit comprises, for example, a common negative conductor between the power supply connection and the load connection, a first capacitor which is connected to the power supply connection and a second capacitor which is connected to the load connection, a series circuit comprising a controlled switch and a coil between the power supply connection and the load connection, and a diode which is connected between, on the one hand, a node of the controlled switch and the coil and, on the other

hand, the common negative conductor. This embodiment is to be combined with the preceding embodiment, so that a highly flexible battery charging module is provided which is usable in combination with a wide variety of apparatus and of photovoltaic devices.

In a further aspect, the present invention relates to a combination of a photovoltaic device and a battery charging module according to one of the preceding embodiments. In one specific embodiment, the photovoltaic device supplies a maximum voltage of less than the maximum voltage in the predefined charging voltage range. As a result, only one voltage-amplifying circuit is required, which keeps the costs limited.

In another further aspect, the present invention relates to a holder for a (mobile) apparatus, provided with a combination of a photovoltaic device and a battery charging module as described above. An integrated holder of this type is readily portable and easy to use.

**Brief description of the drawings**

The present invention will now be discussed in more detail on the basis of a number of example embodiments, with reference to the attached drawings, in which:

Fig. 1 shows a perspective view of a holder in which a battery charging module according to the present invention is used;

Fig. 2 shows a side view of the holder shown in Fig. 1;

Fig. 3 shows an embodiment of an electronic circuit which is used in the battery charging module;

Fig. 4 shows a further embodiment of an electronic circuit which is used in the battery charging module;

Fig. 5 shows a diagram of an alternative embodiment of the circuit shown in Fig. 4; and

Fig. 6 shows a flowchart of the functional operation of the control unit.

**Detailed description of example embodiments**

In the embodiments of the present invention, different variants are described which implement a battery charging module 10 which is suitable for effectively charging a battery of a (mobile) apparatus 1 with the aid of a photovoltaic device 5 (for

example a solar cell), even if the photovoltaic device 5 is not illuminated in an optimum manner. In one variant, the battery charging module 10 is combined with a holder for a photovoltaic device 5. The apparatus 1 can then, for example, be connected with a suitable cable and connectors. The battery charging module 10 can also be implemented in different ways, either separately or integrated with one or more other functional elements.

Fig. 1 shows a perspective view and Fig. 2 shows a side view in cross-section of a charger 4 according to one embodiment of the invention, which is provided with one or more photovoltaic elements 5 and a battery charging module 10. The charger or holder 4 is provided on one side with space to accommodate the (mobile) apparatus 1, in this example a mobile telephone. On one side of the holder 4, a connection part (connector) 8 is disposed which electrically connects the mobile apparatus 1 (or better, a charging terminal of the apparatus 1) to the battery charging module 10. In one embodiment, a rail element is provided on which a connector can slide so that contact can be made with various mobile devices with a connection in different positions. In a further embodiment, the connector is provided with a universal part on which a specific attachment part for a specific mobile device 1 is to be positioned.

In Fig. 1 and 2, it is shown that the battery charging module 10 is positioned on an underside of the holder 4. Other positions, such as closer to the photovoltaic elements 5, or a battery charging module 10 in a plurality of parts, can be regarded as alternative embodiments.

The photovoltaic device 5 may be of any known type of photovoltaic cell, such as polycrystalline silicon, monocrystalline silicon, amorphous silicon, for example a flexible solar cell, or a dye-based cell (dye cell or Grazel cell). The photovoltaic device 5 may comprise flexible photovoltaic elements. The use of flexible photovoltaic elements based on thin-film amorphous silicon (a-Si) or polysilicon photovoltaic cells revealed that flexibility which allows bending in all directions from the surface of the cells can result in damage to the cells. For this reason, a stiffening part can be disposed in the holder 4 to limit bending in a specific direction.

A photovoltaic device 5 supplies a DC voltage with which, in the embodiments of the present invention, a battery of a (mobile) apparatus 1 can be charged directly, without the interposition of an additional battery or super-capacitor. This cuts down the manufacturing costs of the battery charging module 10, results in a lower volume and

weight, and increases the service life. The photovoltaic device 5 converts the (sun)light into an electrical current, and the supplied power is dependent on the current and the voltage. As soon as a current is drawn from the photovoltaic device 5, the supplied voltage will change, according to a specific V-A-curve which is dependent on the type and size of the photovoltaic device 5. If no current is drawn, the voltage which is supplied by the photovoltaic device 5 will be the maximum, for example 6 V with strong solarisation. If a maximum current is drawn from the photovoltaic device 5, the supply voltage will drop, even to 0 V. At these extreme points in the V-A-curve, no power is therefore supplied. A photovoltaic device 5 must then be operated as close as possible to a maximum power point in the V-A-curve in order to be able to operate with high efficiency.

The (mobile) apparatuses 1 with which the present battery charging module 10 interworks are provided with a charging circuit which, during the charging of the battery of the apparatus 1, ensures that the battery cannot be incorrectly charged. This charging circuit checks, for example, periodically whether the voltage supplied by a battery charger lies within a specific range.

The voltage which the photovoltaic device 5 supplies will have to be adapted to the requirements imposed by the (mobile) apparatus 1 in order to enable it to be charged. Without further adaptations, it is almost impossible to have the photovoltaic device 5 supply a specific voltage, and simultaneously a current which actually charges the battery of the apparatus 1. As soon as current is drawn from the photovoltaic device 5, the voltage thereof will drop, after which the charging circuit of the apparatus 1 can itself interrupt the charging process. Hereafter, the voltage again increases due to the loss of the current, and this process can be repeated without the battery in the apparatus 1 actually being charged.

In one embodiment of the present invention, the battery charging module 10 is provided with an electronic circuit with a power supply connection 11 to connect the battery charging module 10 to the photovoltaic device 5 and a load connection 12 to connect the battery charging module 10 to (the battery of) the apparatus 1. The electronic circuit is designed to supply a voltage to the load connection 12 within a predefined charging voltage range (as dictated by the charging circuit of the apparatus 1), and is implemented as a switched power supply. The switched power supply is an alternative to hitherto used voltage regulators which become hot during use, as a result

of which power is lost. In some cases, this power loss is between 20 and 40% of the power supplied by the photovoltaic device 5. With the switched power supply, it is possible to adjust the charging voltage on the load connection 12 to the required range, for example between 4.9 and 5.1 V, independently from the voltage supplied by the photovoltaic device 5 on the power supply connection 11. Fig. 3 and 4 show embodiments of electronic circuits with which the switched power supply can be implemented.

In one embodiment, the electronic circuit comprises a controlled switch 17 (as part of the switched power supply) and a control unit 18 connected to the controlled switch 17 (wherein the control unit 18 can measure the voltage on the power supply connection 11) which adjusts the on/off ratio ('duty cycle') of the controlled switch 17. In further alternative embodiments, the control unit 18 can furthermore be designed to control other operational parameters of the switched power supply, such as the frequency of opening and closing of the controlled switch 17.

In general, the apparatus 1 is provided with a circuit to charge the battery, which periodically checks whether the offered voltage lies within a specific operating range, for example between 4.9 and 5.1 V. At the time when this circuit carries out the measurement, the charging current to the battery is interrupted so that an open-circuit voltage can be measured. The charging current is then switched through to the battery (no power is therefore supplied to the battery in the apparatus 1 during the periodic measurement).

In one embodiment, the control unit 18 measures the voltage on the load connection 12 periodically during at least a predefined time period and adjusts it to a value in the predefined charging voltage range. In one specific embodiment, the control unit adjusts, for example, so that, for at least 30 msec during a period of 2 seconds, the voltage on the load connection 12 lies between 4.9 and 5.1 V. The charging circuit in the apparatus 1 is thus, as it were, fooled, as a result of which the charging process can carry on. Outside the predefined time period, the control unit can control the voltage on the load connection 12 in such a way that the photovoltaic device 5 can be operated at its most efficient operating point in the V-A-curve.

In a further embodiment, the control unit 18 is designed for synchronisation with a charging unit (charging circuit) for the battery in the apparatus 1. In some apparatuses 1, the charging circuit interrupts (internally), for example periodically, the

connection to the charger and then measures the voltage supplied by the charger. Only at these times must the voltage on the load connection 12 lie within defined limits. The control unit 18 can, for example, detect this by monitoring the current supplied to the load connection 12.

As an alternative, the control unit 18 can monitor the output voltage, wherein the battery charging module 10 supplies electrical power to the battery in the apparatus 1. At the time when the charging unit for the battery in the apparatus 1 performs a measurement (of the open voltage, for which purpose the connection to the battery is also interrupted), the load from the charging process is lost, as a result of which the output voltage of the battery charging module 10 quickly rises. In this alternative, no current measurement circuit is required in the battery charging module 10, given that the output voltage is continuously adjusted in a closed loop. This offers a saving in terms of hardware, but also in terms of energy consumption. In all of the embodiments described, the battery charging module 10 can respond appropriately to the behaviour of the charging circuit associated with the battery in the apparatus 1.

Fig. 3 shows an electrical diagram of an embodiment of the electronic circuit of the battery charging module 10, for a specific application wherein the nominal voltage supplied by the photovoltaic device 5 is higher than the required voltage on the load connection 12. The electronic circuit is designed here to supply a voltage on the load connection 12 which is lower than the voltage on the power supply connection 11. In this technical field, such a design of a switched power supply is also referred to as a step-down circuit or buck converter. The circuit shown in Fig. 3 specifically shows a common negative conductor between the power supply connection 11 and the load connection 12, a first capacitor 13 which is connected to the power supply connection 11 and a second capacitor 14 which is connected to the load connection 12. Furthermore, a series circuit of a controlled switch 17 and a coil (or inductor) 15 is provided between the power supply connection 11 and the load connection 12. Finally, a diode 16 is provided which is connected between, on the one hand, a node of the controlled switch 17 and the coil 15 and, on the other hand, the common negative conductor.

Fig. 4 shows an electrical diagram of an embodiment of the electronic circuit of the battery charging module 10, for a specific application wherein the nominal voltage supplied by the photovoltaic device 5 is lower than the required voltage on the load

connection 12. The electronic circuit is designed here to supply a voltage on the load connection 12 which is higher than the voltage on the power supply connection 11. In this technical field, such a design of a switched power supply is also referred to as a step-up circuit or boost converter. The embodiment of the electronic circuit shown in Fig. 4 specifically comprises a common negative conductor between the power supply connection 11 and the load connection 12, and a first capacitor 13 which is connected across the power supply connection 11 and a second capacitor 14 which is connected across the load connection 12. In addition, a series circuit comprising a coil (inductor) 15 and a diode 16 is provided between the power supply connection 11 and the load connection 12. A controlled switch 17 is connected between, on the one hand, a node formed by the coil 15 and the diode 16 and, on the other hand, the common negative conductor.

Through the selection of a suitable photovoltaic device 5 and the step-up circuit described with reference to Fig. 4, a combination of a battery charging module 10 and a photovoltaic device 5 can be produced with a minimum of components which meets all basic conditions allowing it to be used to charge the battery in the apparatus 1. A photovoltaic device 5 which supplies a maximum voltage of less than the maximum voltage in the predefined charging range can then suffice.

A further variant of the battery charging module 10 with a step-up circuit as described with reference to Fig. 4 is shown in the diagram in Fig. 5. The power supply connection 11 and the load connection 12 are again shown herein, and further elements which correspond to the circuit shown in Fig. 4 are indicated with the same reference numbers (in particular the first capacitor 13 and the step-up circuit formed by the second capacitor 14, the coil 15, the diode 16 and the controlled switch 17).

In the embodiment shown in Fig. 5, the control unit 18 is a (micro-)processor, controlled by a software program. The control unit 18 receives measurement information and controls the controlled switch 17. The measurement information originates from a number of measurement elements 21-24. A current measurement element 21 (for example a shunt resistor directly in the negative conductor of the power supply connection 11 with, for example, a downstream amplifier) measures the input current $I_{in}$ which the photovoltaic device 5 instantaneously supplies during operation. An input voltage measurement element 22 (for example a voltage divider comprising two resistors) measures the input voltage $V_{in}$ over the power supply connection 11. In

addition, a fixed reference voltage $V_{ref}$ can be derived with a suitable circuit 23 from the voltage drop over the photovoltaic device 5 and can be fed to the control unit 18 (for example with the use of a Zener diode). Finally, the output voltage $V_o$ over the load connection 12 can be measured with a suitable output voltage measurement circuit 24 and can be fed to the control unit 18. Furthermore, a second controlled switch 19 (for example a MOSFET) is incorporated into the circuit shown in Fig. 5, with which the load connection 12 can, as it were, be switched on and off by means of control from the control unit 18. This may be necessary, because, without further measures in a standard step-up converter circuit as also used here, the input voltage is always available as a minimum on the load connection 12. Finally, the circuit shown in Fig. 5 comprises an indicator 25 in the form of an LED directly controlled by the control unit 18.

In this embodiment also, the control unit 18 is supplied directly by the photovoltaic device 5 connected to the power supply connection 11. In Fig. 6, a circuit diagram is indicated which illustrates the functional operation of the control unit 18. Firstly, the control unit 18 checks in step 30 whether the input voltage $V_{in}$ (in the no-load condition of the photovoltaic device 5) lies above a specific threshold value $V_{th,in}$. Only if this (relatively high) threshold value has been exceeded will the battery charging module 10 switch over to a functional mode, indicated with step 32. In step 30, it is therefore tested whether sufficient light is available so that sufficient power is also deliverable with considerable certainty from the photovoltaic device 5 in order to charge the battery in the apparatus 1. If this were not the case, an attempt would be made to charge the battery with insufficient power. This uses up energy from the battery because the apparatus 1 is activated and on balance consumes more energy than can be supplied by the battery charging module 10. To prevent this, step 31 is carried out in this case, wherein the output is interrupted (with the second controlled switch 19), so that no current and power is supplied to the load connection 12. The circuit diagram then returns to check step 30.

In step 32, the load connection 12 is activated (if this had not already been activated) and an algorithm is run to control the step-up circuit 14-17 in order to maintain the power supplied by the photovoltaic device 5 at the optimum power point. To do this, use is made of the measured voltage $V_{in}$ and current $I_{in}$ on the power supply connection 11. These MPP adjustments are known per se to the person skilled in the

art. The load connection 12 is connected by the charging circuit in the apparatus 1 more or less directly to the battery to be charged, as a result of which the voltage on the load connection 12 is more or less equal to the battery voltage (for example 3.7 V). The MPP adjustment then still ensures the most efficient possible energy transfer.

In one embodiment, the coil 15 is selected in such a way that it cannot become saturated in the operating range of voltage and currents (power) which are deliverable by the photovoltaic device 5. This eliminates the need for a current measurement around the coil 15, as is used in conventional step-up converters.

In a following step 33, a check is carried out to ascertain whether the power deliverable by the battery charging module 10 (originating from the photovoltaic device 5) still remains sufficiently high. If this is not the case, the procedure returns to step 31 and the load connection 12 is interrupted. The MPP adjustment stops, and the battery charging module 10 is again in its starting position in step 30.

If the result of the test relating to the deliverable power is positive, the procedure moves on to step 34, wherein the output voltage $V_o$ is checked against a predefined threshold value $V_{th,o}$. As an example, a threshold value of 5.07 V is used, but this may be chosen differently depending on the type of apparatus 1 (and the battery and charging circuit used). The output voltage measurement circuit 24 (see Fig. 5) may be implemented in hardware (using, for example, the reference voltage $V_{ref}$ and active elements such as Zener diodes and transistors), or internal components in the control unit 18 (such as a comparator circuit) can be used.

As soon as the voltage on the load connection 12 is higher than the threshold value $V_{th,o}$, this is an indication that the charging circuit of the battery in the apparatus 1 is checking whether an adequate power supply is connected for the charging process (see above). In this way, it is possible to determine quickly and accurately when this measurement cycle occurs, and the control unit 18 can synchronise with it. This is, for example, effected with step 35, in which the control unit 18 carries out an adjustment so that the output voltage lies within the predefined range, for example between 4.9 and 5.1 V. The MPP adjustment is thus stopped, and no energy is supplied to the load connection 12. In step 35, a check is carried out continuously (or periodically) in one embodiment to ascertain whether the output voltage is still too high (indicating that the battery in the apparatus 1 is not being charged, but that the charging circuit in the

apparatus is carrying out a check) and the output voltage is adjusted in the same manner.

As an alternative, the adjustment in step 35 is carried out during a predefined time period (for example 50 ms), which is sufficient to withstand the test by the charging circuit in the apparatus 1.

If it appears in step 34 that the output voltage $V_o$ lies below the threshold value $V_{th,o}$, the procedure returns to step 32, and the MPP adjustment is continued.

The indicator 25 is controlled directly by the control unit 18, for example to indicate that the charging process is active (i.e. the loop of steps 32-35 in Fig. 6). The control unit 18 can also be programmed in order to indicate, for example, with a flashing frequency, how high the charging current is.

In one embodiment, the photovoltaic device 5 comprises a series circuit of separate solar cells. If, for example, use is made of 10 solar cells in series, which each supply a nominal 0.5 V, a voltage of 5 V is achieved. The voltage in the no-load condition will then still be higher, as a result of which a step-down circuit as described with reference to Fig. 3 must be used in each case.

More advantageously, a series circuit is used which comprises no more than three, for example two, solar cells, which can each supply a voltage of 0.5 V. With the step-up circuit described above, the voltage supplied to the load connection 12 can be increased to the required 5 V, while the photovoltaic device 5 with three or two cells is less sensitive to effects such as partial shielding of the solar cells, and is less expensive to produce. If, for example, a series circuit of 10 cells is used and some cells thereof are exposed to solar radiation and some are not, less power is then supplied on balance in comparison with a series circuit of two solar cells.

In the battery charging module 10 according to a further embodiment, both a step-up circuit (Fig. 4 or 5) and a step-down circuit (Fig. 3) are present, as a result of which it is possible to increase or reduce the voltage on the power supply connection 11 (supplied by the photovoltaic device 5) to the load connection 12. In one embodiment, the battery charging module 10 comprises a printed circuit board with only one layer, so that the production costs can remain as low as possible. A two-layer printed circuit board can also be implemented without increasing the costs.

In the embodiment described above, the controlled switch 17 can be implemented as a semiconductor circuit, such as a (MOS)FET, Power Transistor,

IGBT, etc. known per se to the person skilled in the art. As an alternative, the diode 16 can also be designed as a controlled switch in the form of a semiconductor.

The combination of a photovoltaic device 5 and a battery charging module 10 according to one of the described embodiments may be included in an embodiment of the holder 4 for a (mobile) apparatus 1, as described above with reference to Fig. 1 and 2.

A solar charger of this type will be less expensive than solar chargers which are currently available on the market, given that no separate battery or super-capacitor is required to store the energy, given that the already existing battery of the apparatus 1 can be charged directly. Losses in the charging/discharging of a buffer battery or super-capacitor will also be entirely absent in the present embodiments. Less energy will also be lost due to the absence of cables, or the presence of very short connection parts such as. If the user remains somewhere, the holder 4 can simply be rotated, for example, to charge a telephone 1. The holder 4 changes each telephone 1 into an eco-friendly solar energy telephone 1 and can be sold for both existing and new mobile telephones 1.

The holder 4 can be produced from various materials and can have any form and size, such as, for example, a wallet, bill fold, or transparent plastic to protect the telephone 1. The position of the connector 8 can be adapted depending on the model and type of the telephone 1.

The holder 4 can be produced from, for example, silicone rubber or a similar rubber-like material which is thermally insulating. As a result, the heating up of the mobile apparatus 1 when the solar cell 5 is exposed to sunlight can remain limited. Moreover, the attachment of the mobile apparatus 1 on or in the holder 4 can be simply implemented in such a manner.

The connection parts are incorporated into the connector 8 in order to bring the mobile apparatus 1 into electrical contact with the photovoltaic device 5.

It should be clear that the above description has been incorporated in order to illustrate the operation of preferred embodiments of the invention, and not to limit the scope of the invention. On the basis of the above description, many variations which fall within the spirit and the scope of the present invention will be evident to a person skilled in the art.

## CLAIMS

1. Battery charging module to charge a battery in an apparatus (1) by means of a photovoltaic device (5), comprising an electronic circuit (10) with a power supply connection (11) to connect the battery charging module to the photovoltaic device (5) and a load connection (12) to connect the battery charging module to the battery in the apparatus (1),
wherein the electronic circuit (10) is designed to supply a no-load voltage to the load connection (12) within a predefined charging voltage range, and is implemented as a switched power supply.

2. Battery charging module according to Claim 1, wherein the electronic circuit (10) is supplied with power during operation by the photovoltaic device (5).

3. Battery charging module according to Claim 1 or 2, wherein the electronic circuit (10) is designed to measure the open-circuit voltage on the power supply connection (11), and to supply power to the load connection when the measured open-circuit voltage is higher than a predefined threshold value.

4. Battery charging module according to one of Claims 1-3, wherein the electronic circuit (10) comprises a controlled switch (17) and a control unit (18) connected to the controlled switch (17), wherein the control unit (18) adjusts the on/off ratio of the controlled switch (17).

5. Battery charging module according to Claim 4, wherein the control device (18) is connected to measurement elements (21, 22) which measure the voltage supplied by the photovoltaic device (5), and wherein the control device (18) is designed to set a maximum power supply by the photovoltaic device (5).

6. Battery charging module according to Claim 4 or 5, wherein the control unit (18) measures the voltage on the load connection (12) periodically during at least a predefined time period and adjusts it to a value within the predefined charging voltage range.

7. Battery charging module according to Claim 4 or 5, wherein the control unit (18) measures the voltage on the load connection (12) and, as soon as the voltage attains a value above a threshold value, adjusts the voltage to a value within the predefined charging voltage range.

8. Battery charging module according to one of Claims 4-7, wherein the control unit (18) is designed for synchronisation with a charging unit for the battery in the apparatus (1).

9. Battery charging module according to one of Claims 1-8, wherein the charging voltage range lies between 4.9 and 5.1 V.

10. Battery charging module according to one of Claims 1-9, wherein the electronic circuit (10) is designed to supply a voltage on the load connection (12) which is higher than the voltage on the power supply connection (11).

11. Battery charging module according to Claim 10, wherein the electronic circuit (10) comprises:
a common negative conductor between the power supply connection (11) and the load connection (12),
a first capacitor (13) which is connected across the power supply connection (11) and a second capacitor (14) which is connected across the load connection (12),
a series circuit comprising a coil (15) and a diode (16) between the power supply connection (11) and the load connection (12),
and a controlled switch (17) which is connected between, on the one hand, a node of the coil (15) and the diode (16) and, on the other hand, the common negative conductor.

12. Battery charging module according to one of Claims 1-9, wherein the electronic circuit (10) is designed to supply a voltage on the load connection (12) which is lower than the voltage on the power supply connection (11).

13. Battery charging module according to Claim 12, wherein the electronic circuit (10) comprises:
a common negative conductor between the power supply connection (11) and the load connection (12),
a first capacitor (13) which is connected to the power supply connection (11) and a second capacitor (14) which is connected to the load connection (12),
a series circuit comprising a controlled switch (17) and a coil (15) between the power supply connection (11) and the load connection (12),
and a diode (16) which is connected between, on the one hand, a node of the controlled switch (17) and the coil (15) and, on the other hand, the common negative conductor.

14. Combination of a photovoltaic device (5) and a battery charging module according to one of Claims 1-13.

15. Combination according to Claim 14, wherein the photovoltaic device (5) supplies a maximum voltage of less than the maximum voltage within the predefined charge voltage range.

16. Holder for an apparatus (1), provided with a combination of a photovoltaic device (5) and a battery charging module according to Claim 14 or 15.

Fig 1

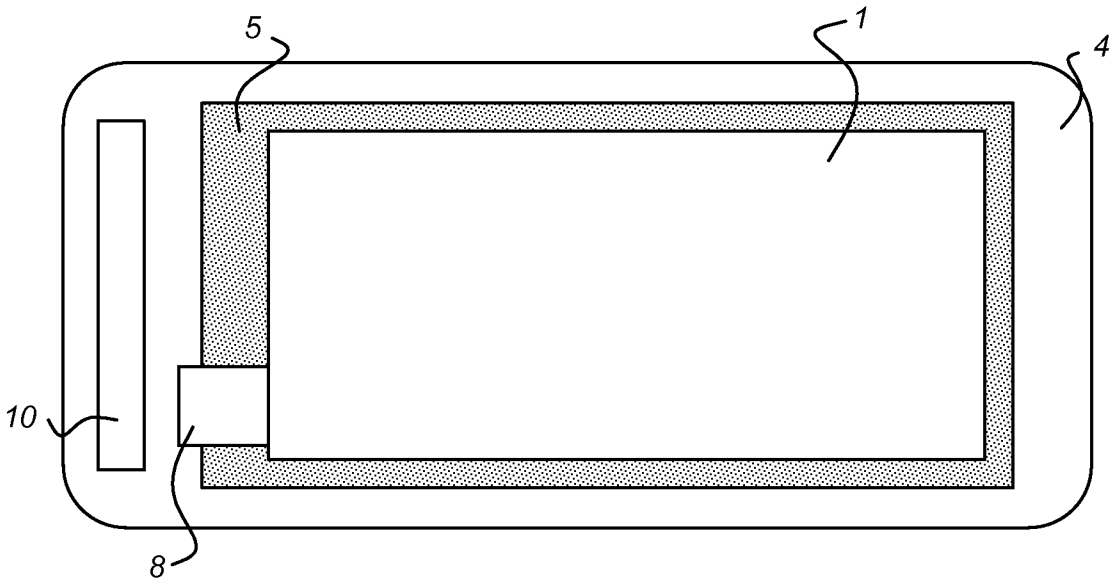



Fig 2

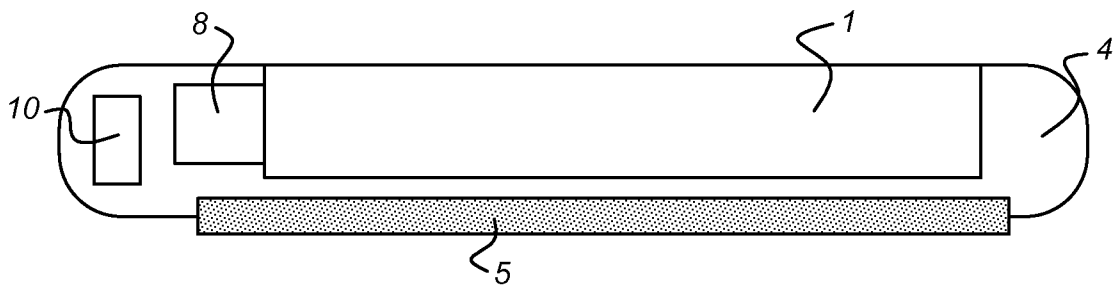


Fig 3

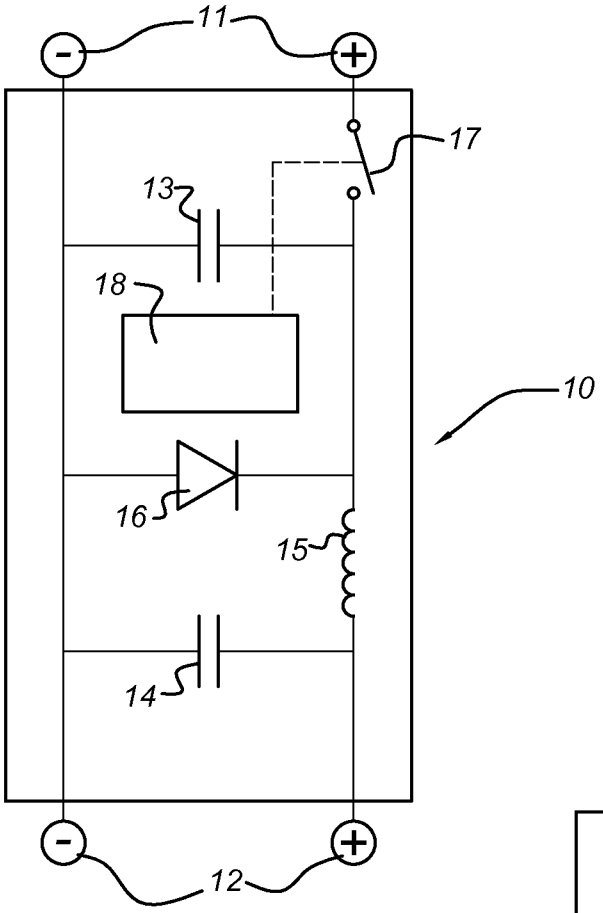



Fig 4

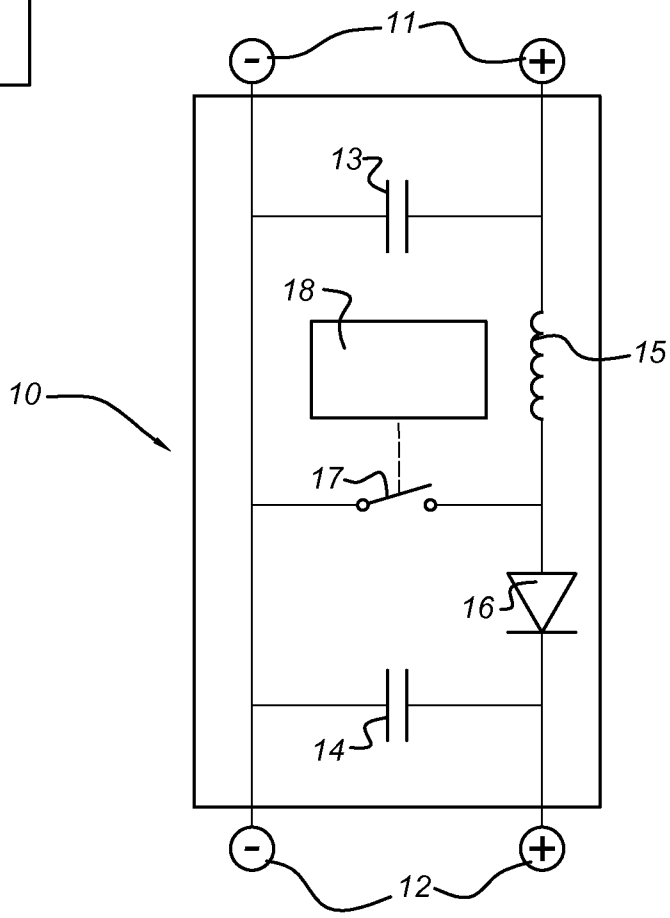


Fig 5

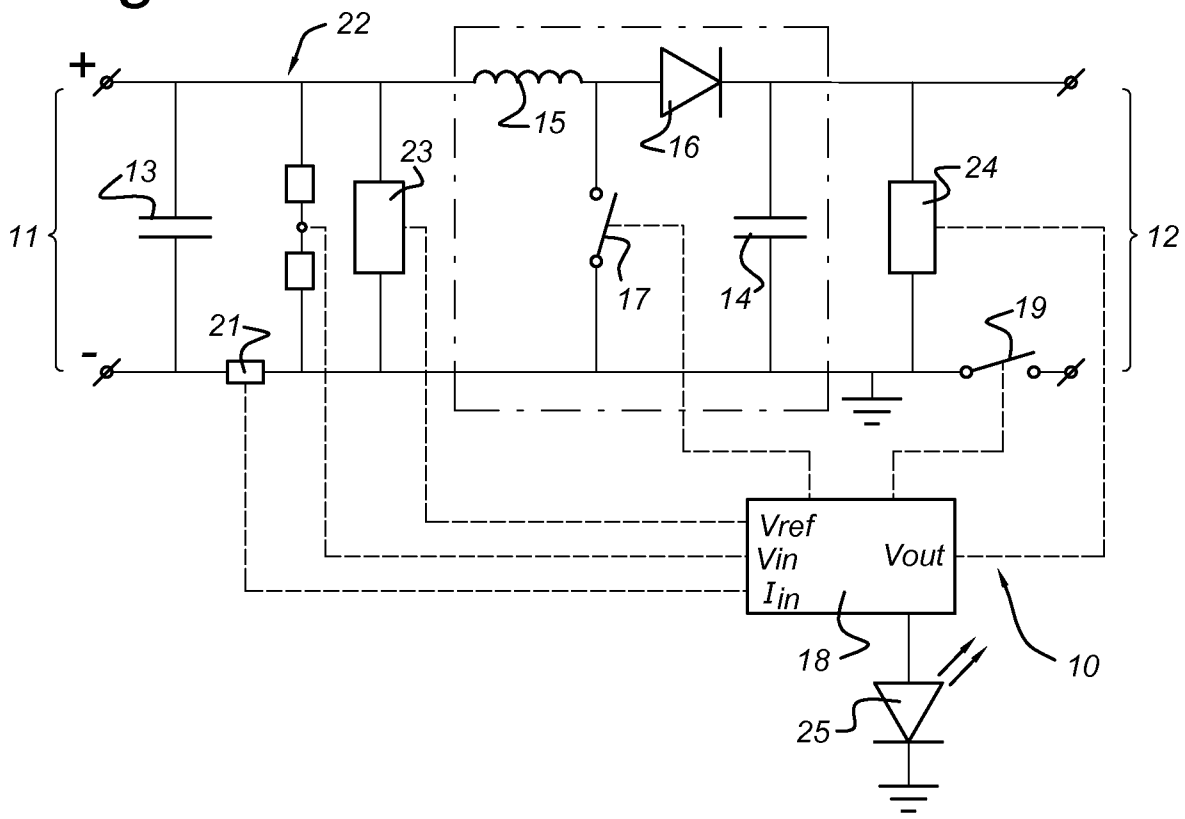
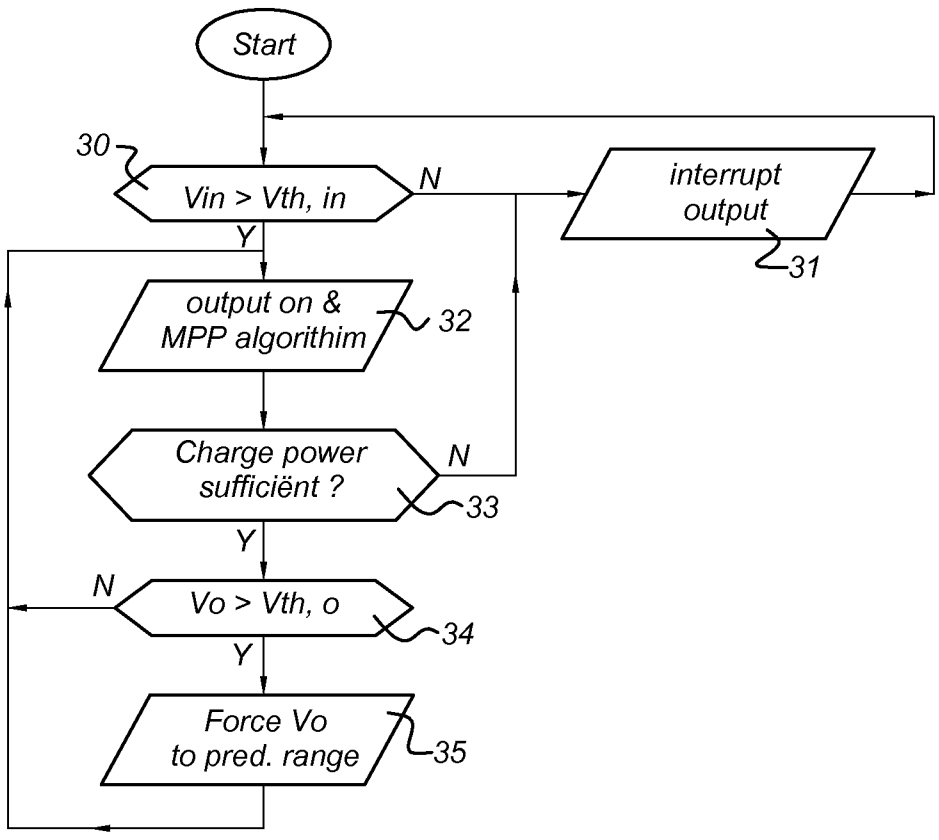

22
+
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23
13
24
11
12
17
14
19
21
-
Vref
Vin
Iin
Vout
18
10
25

Fig 6


Start
30
Vin > Vth, in
N
interrupt output
31
Y
output on & MPP algorithim
32
Charge power sufficiënt ?
N
33
Y
N
Vo > Vth, o
34
Y
Force Vo to pred. range
35