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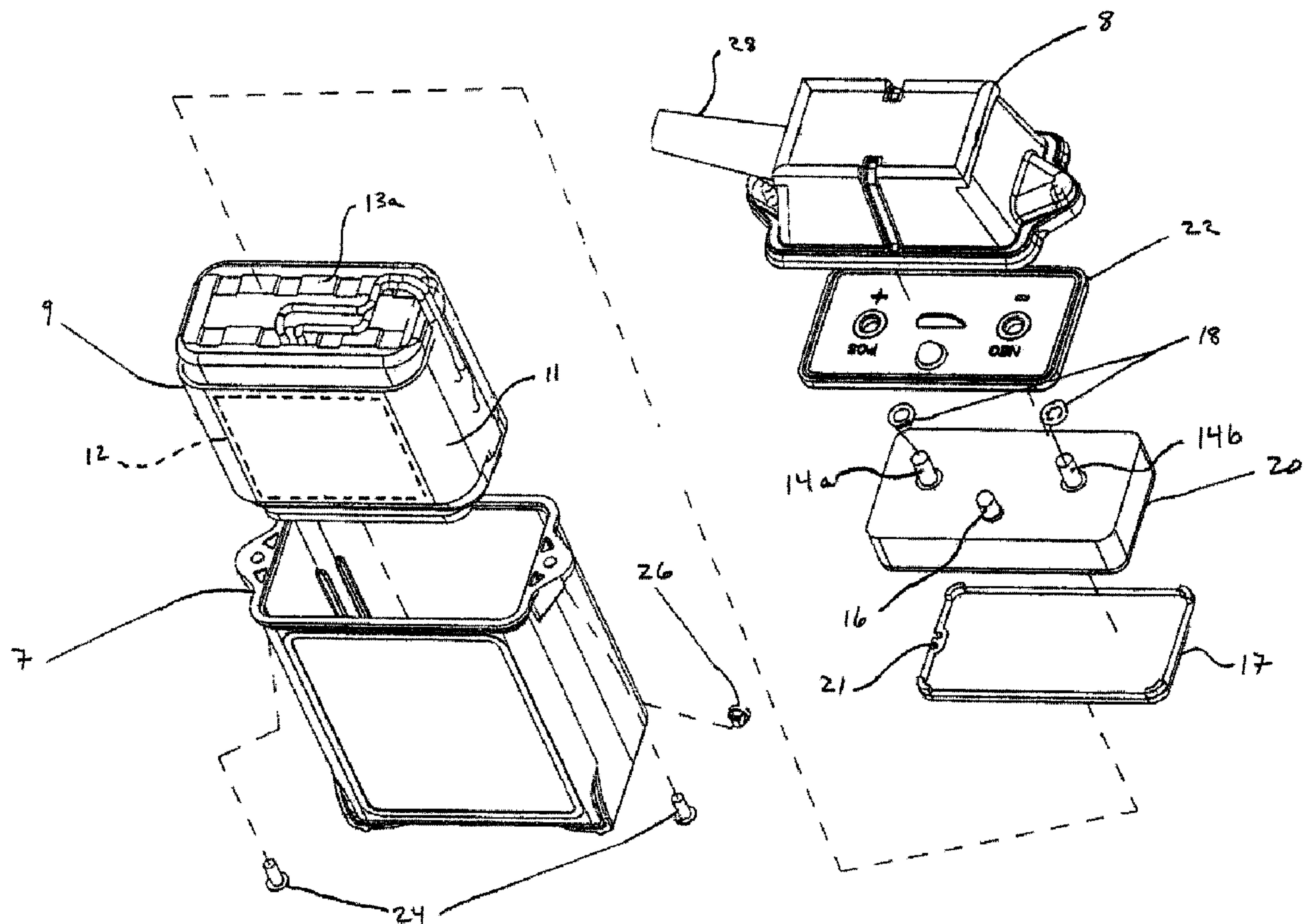
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(54) Titre : BLOC-PILES POUR LAMPE DE CASQUE DE MINEUR AVEC MODULE DE REGULATION DE CHARGE ET DE DECHARGE

(54) Title: BATTERY PACK FOR MINER'S CAP LAMP WITH CHARGING AND DISCHARGING CONTROL MODULE



(57) Abrégé/Abstract:

A battery pack features a shock-absorbing and sealed construction and an electronic control module that provides automatic recovery circuitry in the event of a short circuit in the load whereby the power is terminated and then restarted at a lower level so



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

that removal of the short circuit may be detected. Full power is restored to the load when the short circuit is removed. In addition, the electronic control module of the battery pack uses the battery pack load, such as a cap lamp, to provide an indication of a low battery charge level. The electronic control module also provides a soft-start feature where the power provided to the bulb is ramped up to avoid current in-rush to the bulb during startup.

ABSTRACT

A battery pack features a shock-absorbing and sealed construction and an electronic control module that provides automatic recovery circuitry in the event of a short circuit in the load whereby the power is terminated and then restarted at a lower level so that removal of the short circuit may be detected. Full power is restored to the load when the short circuit is removed. In addition, the electronic control module of the battery pack uses the battery pack load, such as a cap lamp, to provide an indication of a low battery charge level. The electronic control module also provides a soft-start feature where the power provided to the bulb is ramped up to avoid current in-rush to the bulb during startup.

**BATTERY PACK FOR MINER'S CAP LAMP WITH CHARGING AND DISCHARGING
CONTROL MODULE**

FIELD OF THE INVENTION

[0001] The invention relates generally to battery packs and, more particularly, to a battery pack that features a durable construction and operation directed by an electronic control module..

BACKGROUND OF THE INVENTION

[0002] Rechargeable battery packs find use in many industrial applications due to their portability, dependability and low maintenance cost. A common usage of rechargeable battery packs is to power lamps mounted on hard hats worn by miners. Such cap lamps provide illumination in underground mine shafts. Cap lamps are well known in the mining equipment industry and provide illumination while the miner's hands remain free to perform tasks.

[0003] The battery pack is typically secured to the user's waist and electrical wiring delivers power from the battery pack to the lamp on the helmet. Normally, at the end of each working shift, the helmet and battery pack are removed by the miner and the battery pack is placed in a recharging device so that it is ready for use during a future shift. An example of such a cap lamp and rechargeable battery pack arrangement is disclosed in U.S. Patent No. 4,481,458 to Lane.

[0004] Lithium-ion (Li-ion) batteries have a higher energy-to-weight ratio than any other commercially available rechargeable batteries. This makes them very desirable as a power source for portable devices, such as cap lamps. Most Li-ion battery packs, including those used to power mining cap lamps, must have a safety protection circuit to protect them from over-voltage, under-voltage and over-discharge conditions.

[0005] In addition, Li-ion battery packs often feature an electronic control module in series between the batteries and the cap lamp (or other load) to control operation of the battery pack. Such electronic control modules may include circuitry or a microprocessor that functions to provide an indication of a low battery, control battery charging and other functions. A need

1 exists, however, for a low battery indicator that is easier to detect and that provides extended
2 cap lamp operation so that a mine may be exited.

3 **[0006]** Electronic control modules may also cause a Li-ion battery pack to go into protection
4 mode in the event of a short circuit. Such short circuits may be caused by, for example, worn
5 parts in the cap lamp assembly or wires leading thereto. When the battery pack goes into
6 protection mode, the cap lamp (or other load) is automatically turned off. Prior art designs
7 require the user to manually turn the lamp off and then back on to reset the electronic control
8 module or other circuitry and allow current to resume flow to the cap lamp after the short circuit
9 condition is removed. An electronic control module that automatically turns the lamp (or other
10 load) back on when the short circuit condition is removed is desirable.

11 **[0007]** A mine provides a very harsh atmosphere for equipment, including battery packs. The
12 mine atmosphere contains an abundance of dirt, dust, coal particles and moisture. In addition,
13 there is always the potential of a build-up of explosive gases in a mine. As a result, it is
14 important to effectively seal a battery pack so that harmful elements can't reach the battery or
15 the related wiring and circuitry inside. Furthermore, battery packs used in mines may suffer
16 mechanical abuses during use as they are banged against machinery and rock, dropped and/or
17 jostled as they ride on the user's waist. As a result, a need exists for a battery pack that can
18 withstand shocks and vibrations.

19 **SUMMARY OF THE EMBODIMENTS**

20 **[0008]** In one aspect, there is provided a battery pack for powering a cap lamp comprising:
21 a. a battery pack housing;
22 b. a battery cell having a lithium-based chemistry positioned within the battery pack
23 housing and having a pair of terminals;
24 c. an electronic control module positioned within the battery pack housing;
25 d. a protection circuit electrically attached between the pair of terminals of the
26 battery cell and the electronic control module and positioned within the battery
27 pack housing;
28 e. a pair of battery pack posts in electrical communication with the electronic control
29 module and adapted to be electrically connected to the cap lamp;

1 f. the electronic control module controlling discharging of the battery cell when
2 powering the cap lamp and charging of the battery cell when the battery pack is
3 connected to a charger.

4 **[0009]** In another aspect, there is provided a cap lamp system comprising:

- 5 a. a battery pack housing;
6 b. a battery cell having a lithium-based chemistry positioned within the battery pack
7 housing and having a pair of terminals;
8 c. an electronic control module positioned within the battery pack housing;
9 d. a protection circuit electrically attached between the pair of terminals of the
10 battery cell and the electronic control module and positioned within the battery
11 pack housing;
12 e. a pair of battery pack posts in electrical communication with the electronic control
13 module;
14 f. a cap lamp attached to the pair of battery pack posts;
15 g. the electronic control module controlling discharging of the battery cell when
16 powering the cap lamp and charging of the battery cell when the battery pack is
17 connected to a charger.

18 **[0010]** In another aspect, there is provided a battery pack for powering a cap lamp
19 comprising:

- 20 a. a housing having an open end and a closed end;
21 b. a separator positioned within the housing so that an electronic control module
22 compartment is defined on one side of the separator and a battery compartment
23 is defined on an opposite side of the separator;
24 c. a battery cell having a lithium-based chemistry positioned in the battery
25 compartment and having a pair of terminals;
26 d. an electronic control module positioned in the electronic control module
27 compartment;
28 e. a protection circuit positioned in the housing and electrically attached between
29 the pair of terminals of the battery cell and the electronic control module;
30 f. a pair of battery pack posts in electrical communication with the electronic control
31 module and adapted to be electrically connected to the cap lamp;

- 1 g. the electronic control module controlling discharging of the battery cell when
2 powering the cap lamp and charging of the battery cell when the battery pack is
3 connected to a charger;
4 h. a cover removably attached to and sealing against the open end of the housing
5 so that the pair of battery pack terminals are covered.

6 **[0011]** In another aspect, there is provided a cap lamp system comprising:

- 7 a. a battery pack housing;
8 b. a battery cell having a lithium-based chemistry positioned within the battery pack
9 housing and having a pair of terminals;
10 c. an electronic control module positioned within the battery pack housing and in
11 electrical communication with the battery cell terminals;
12 d. a pair of battery pack posts in electrical communication with the electronic control
13 module;
14 e. a cap lamp attached to the pair of battery pack posts;
15 f. the electronic control module including and using at least one transistor to control
16 a charging current during charging of the battery cell and to control a discharging
17 current when powering the cap lamp and the at least one transistor using pulse
18 width modulation to dim the cap lamp.

19 **[0012]** In another aspect, there is provided a battery pack for powering a cap lamp
20 comprising:

- 21 a. a housing;
22 b. a battery cell positioned within the housing;
23 c. a pair of terminals attached to the battery cell and adapted to provide power to a
24 cap lamp; and
25 d. an electronic control module positioned within the housing and attached to the
26 battery cell, the electronic control module controlling discharging of the battery
27 cell when powering the cap lamp and charging of the battery cell when the
28 battery pack is connected to a charger.

1 **BRIEF DESCRIPTION OF THE DRAWINGS**

2 **[0013]** Fig. 1 is an exploded top front perspective view of a battery pack including an
3 embodiment of the electronic control module of the present invention;

4 **[0014]** Fig. 2 is a perspective view of the battery cell bundle without a wrap or pads with an
5 electronic control module and protection circuit assembled thereto;

6 **[0015]** Fig. 3 is a bottom plan view of the battery cell bundle of Fig. 2;

7 **[0016]** Fig. 4 is a perspective view of the battery pack of Fig. 1 after being assembled;

8 **[0017]** Fig. 5 is a block diagram illustrating the primary components of the electronic control
9 module of the battery pack of Figs. 1-4;

10 **[0018]** Fig. 6 is an operation flow diagram of the microprocessor of the electronic control
11 module of Fig. 5.

12 **[0019]** Fig. 7 is a schematic of the charging section circuit of the electronic control module of
13 Fig. 5;

14 **[0020]** Fig. 8 is a schematic of the low battery warning/indication circuit of the electronic
15 control module of Fig. 5;

16 **[0021]** Fig. 9 is a schematic of the microprocessor and associated circuitry of the electronic
17 control module of Fig. 5;

18 **[0022]** Fig. 10 is a schematic of the battery sensing circuit of the electronic control module
19 of Fig. 5;

20 **[0023]** Fig. 11 is a schematic of the overload sensor circuit of the electronic control module
21 of Fig. 5;

22 **[0024]** Fig. 12 is a schematic of charge current sensor circuit of the electronic control
23 module of Fig. 5;

24 **[0025]** Fig. 13 is a schematic of the LED driver circuit of the electronic control module of Fig.
25 5.

1 DETAILED DESCRIPTION OF EMBODIMENTS

2 [0026] While the battery pack of the invention is described below in terms of use in
3 powering a cap lamp of the type used in the mining industry, it may find application in other
4 industries with other battery-powered devices. Indeed, the electronic control module of the
5 invention may be integrated into a battery-powered device itself or a load attached to the battery
6 pack, instead of a separate battery pack. In addition, while the battery pack described below
7 features Lithium-ion (Li-ion) battery cells, the battery pack of the invention may feature other
8 types of battery cells.

9 [0027] An embodiment of the battery pack of the present invention is illustrated in an
10 exploded view in Fig. 1. The battery pack includes a battery housing or jar 7, that is preferably
11 made of polycarbonate, with an open top end. A cover 8, also preferably made of
12 polycarbonate, removably covers the open top of the battery jar, as illustrated in Fig. 4.

13 [0028] As illustrated in Fig. 1, a battery cell bundle 9 is positioned within the battery jar 7.
14 The bundle features battery cells, indicated at 10 in Figs. 2 and 3, wrapped with a foam
15 vibration-reducing wrap 11. The foam wrap is preferably composed of neoprene and ethylene
16 propylene diene monomer (EPDM) and is preferably approximately 2" x 7.5" x 1/16" thick. In
17 addition, a pair of pads, one of which is indicated in phantom at 12 in Fig. 1, are positioned on
18 opposite sides of the bundle, between the cells and wrap. Each pad 12 is preferably
19 constructed from the same material as the wrap and is preferably approximately 1.25" x 2.5" x
20 1/16" thick.

21 [0029] Enlarged views of the battery cell bundle 9 of Fig. 1 with the wrap and pads (11 and
22 12 in Fig. 1) removed are provided in Figs. 2 and 3. While eight battery cells 10 are illustrated,
23 the battery pack could include an alternative number of cells. In addition, the cells preferably
24 are Li-ion battery cells. As an example only, the battery pack may have a maximum voltage of
25 4.2 Volts DC and a minimum voltage of 2.5 Volts (V) DC. The battery pack may discharge at up
26 to 2 amp, and may charge at up to 2.5 amp (A), also as an example only. The terminals of the
27 battery cells 10 engage contact plates 13a (Fig. 1) and 13b (Fig. 3) which, as will be explained
28 in greater detail below, are joined to a protection circuit, illustrated at 15 in Figs. 2 and 3.

1 **[0030]** As illustrated in Fig. 1, a separator plate 17 (preferably also made of polycarbonate)
2 is positioned over the battery cell bundle 9 so that a battery compartment is formed below and is
3 secured within the battery jar 7 by adhesive, preferably so that the edges seal against the
4 interior walls of the battery jar 7. As a result, an electronic control module compartment is
5 defined within the jar or housing 7 above the separator plate. An electronic control module
6 (ECM) 20, which contains circuitry and a microprocessor, as described in greater detail below,
7 is positioned on top of the separator plate 17, and communicates with the protection circuit 15 of
8 Figs. 2 and 3, and thus the battery cell bundle 9, via a pair of wires 19 (Fig. 2) that travel
9 through notches 21 (Fig. 1) of separator plate 17. The circuitry and microprocessor of the ECM
10 is preferably potted in a potting compound for protection. Potting compounds for circuitry and
11 the like are well known in the art.

12 **[0031]** The protection circuit 15 of Figs. 2 and 3 is in circuit with the wires leading from the
13 battery pack to the ECM and provides under-voltage cutoff, over-voltage cutoff and over-current
14 cutoff protection. The protection circuit may be a standard, off-the-shelf circuit, such as the
15 VC3053 from Venture Inc. As illustrated in Figs. 2 and 3, the protection circuit 15 preferably is
16 housed in a box-like structure composed of thermally conductive potting compound. This
17 protects the printed circuit board and components from stress and vibration.

18 **[0032]** As illustrated in Figs. 1 and 2, the ECM 20 includes positive and negative posts 14a
19 and 14b and a charging status light emitting diode (LED) 16. As illustrated in Fig. 1, a pair of O-
20 ring seals 18 are positioned over the positive and negative posts of the ECM 20 so that they are
21 sandwiched, and thus form a seal, between the top surface of the ECM 20 and the bottom
22 surface of the battery post holder 22.

23 **[0033]** The battery jar 7 and battery post holder 22 are preferably sonically welded together
24 to seal the battery cell bundle, ECM, and other internal components inside the battery jar where
25 they are protected from dirt and moisture. The cover 8 is reversible and secured to the battery
26 jar 7 with cover hold down screws 24 (Fig. 1) and a gasket, which may be molded into the cover
27 8, for easy service and removal as well as effective sealing. The back side of the battery jar
28 may be provided with a clip (not shown) so that the battery pack may be mounted on the belt of
29 a user and may also feature a plug 26 (Fig. 1) that seals a corresponding hole formed in the
30 battery jar 7 so as to serve as a pressure relief valve.

1 **[0034]** The cover 8 includes a cord strain relief 28 (Figs. 1 and 4), preferably constructed of
2 a rubber material, that receives insulated wires that attach to positive and negative posts 14a
3 and 14b to provide power to the cap lamp. An example of such a cap lamp is provided in U.S.
4 Patent No. 4,481,458 to Lane. The cover also features elongated, transparent windows 32a
5 and 32b (Fig. 4) which are illuminated by the LED 16 (Figs. 1 and 2).

6 **[0035]** The operational features of the ECM 20 preferably include the charging status LED
7 (16 in Figs. 1 and 2), short circuit protection, a low battery warning, a soft-start feature and a 2:1
8 charging/discharging ratio. In addition, the ECM preferably includes a charging voltage and
9 current converter so that the battery pack may be used with chargers originally designed for
10 lead-acid type batteries.

11 **[0036]** A block diagram illustrating the primary components and circuitry of the ECM 20 of
12 Figs. 1 and 2 is provided in Fig. 5. As illustrated in Fig. 5, the ECM includes a microprocessor
13 34. The ECM also includes a charging section circuit 36, a low battery warning circuit 38, an
14 LED driver circuit 40, a battery sensing circuit 42, a charge current sensor circuit 44 and an
15 overload sensor circuit 46, all of which communicate with the microprocessor 34.

16 **[0037]** A flow chart illustrating the programming of the microprocessor 34 of Fig. 5 is
17 provided in Fig. 6. As indicated by block 47 of Fig. 6, when microprocessor 34 is initially
18 powered up, that is, connected to power, a number of default settings for the ECM occur. More
19 specifically, transistors Q4 and Q5 of the charging section circuit, illustrated in Fig. 7, are turned
20 off. As will be explained in greater detail below, transistors Q4 and Q5 of the charging section
21 circuit are responsible for controlling current flow to and from the battery pack during charging
22 and discharging.

23 **[0038]** In addition, the charging status LED 16 (Figs. 1, 2 and 13) is turned off as a default
24 setting of the ECM. The charging status LED 16 is controlled by the microprocessor via the
25 LED driver circuit 40 (Figs. 5 and 13) and illuminates windows 32a and 32b of the battery pack
26 (Fig. 4) with either a red or green color to indicate charging status. More specifically, a red LED
27 is an indication that the battery is connected to a charger and is accepting a charge current. A
28 green LED is an indication that the battery is connected to a charger, but it is no longer
29 accepting charge current because it is fully charged and ready for operation. The operation of
30 the LED driver circuit will be explained in greater detail below.

1 **[0039]** A "LAMP_WAS_ON" bit that is internal to the microprocessor is also set to "1" as the
2 default setting of the ECM. This bit is an indication of whether the fully charged battery pack
3 was used after being charged. This prevents the battery pack from being charged if it is
4 disconnected and reconnected to a charger without application of a load. Charging of the
5 battery pack may occur only if the bit is set to "1."

6 **[0040]** Next, as illustrated at 48 in Fig. 6, the LED_GREEN pin of the microprocessor is
7 checked for a high or low setting. The LED_GREEN pin is illustrated at 49 in Fig. 9 as is
8 microprocessor 34. The high setting of the LED_GREEN pin corresponds to the charging status
9 LED 16 being illuminated in green, and thus corresponds to the battery pack being in a fully
10 charged condition. If this is the case, the battery pack goes into monitoring mode, as illustrated
11 at block 50 in Fig. 6, where the battery capacity is monitored. If the battery voltage falls below a
12 threshold due to self-discharge, and the battery pack is connected to a charger, charging
13 restarts, as will be explained below.

14 **[0041]** When the LED_GREEN pin 49 (Fig. 9) of the microprocessor is set to high, this is
15 communicated to the LED driver circuit 40 (Figs. 5 and 13) via connection 43 of Fig. 13 so
16 that, as noted above, the charging status LED is illuminated in green. Power is received by this
17 portion of the LED driver circuit 40 by connection 45 (Fig. 13).

18 **[0042]** If the LED_GREEN pin of the microprocessor is low, the charging status LED is not
19 illuminated in green. If this is the case, as indicated at 51 in Fig. 6, the microprocessor checks
20 the battery pack for an over-discharged condition. More specifically, the battery sensing circuit
21 42 of Fig. 5 is illustrated in greater detail in Fig. 10 and features a voltage divider or
22 measurement portion, indicated in general at 53. The voltage measurement portion 53 of Fig.
23 10 communicates via connection 55 with line 56 of the charging section circuit of Fig. 6, and
24 thus the positive and negative terminals of the battery cell bundle, illustrated at 15a and 15b,
25 respectively, in Fig. 8, and determines the battery cell voltage. The battery cell voltage is
26 communicated by the battery sensing circuit of Fig. 10 to the microprocessor via the connection
27 57 (BAT) of Fig. 10 and corresponding input pin 59 (Fig. 9) of the microprocessor. If the battery
28 cell voltage is equal to or less than 2.5V, the battery pack is in an over-discharged condition
29 and, as indicated at 61 in Fig. 6, the charging status LED and transistors Q4, Q5 and Q8 (Fig. 6)
30 are shut off. As will be explained in greater detail below, pulse transistor Q8 is responsible for

1 controlling current during pulse width modulation operation of the battery pack. If the battery
2 cell voltage is greater than 2.5V, the next step of Fig. 6 is performed by the microprocessor.

3 **[0043]** As indicated at 63 in Fig. 6, the microprocessor next checks for a fault condition,
4 such as a short circuit or overload condition. As described previously, the ECM must handle a
5 short circuit or overload (the term "short circuit" being used to mean either situation herein),
6 such as caused by worn parts in the load or wires leading thereto, by causing the battery pack
7 to go into protection mode so that the load (a cap lamp in the present example) is turned off.
8 Prior art designs require the user to manually turn the cap lamp off and back on to reset the
9 associated circuit prior to allowing current flow back to the cap lamp after the short circuit
10 condition is removed. The ECM of the present invention features circuitry that automatically
11 turns the cap lamp (or other load) back on after the short circuit condition is removed. In other
12 words, the user does not have to manually turn the cap lamp off and back on to reset the battery
13 pack.

14 **[0044]** With reference to Fig. 5, the automatic recovery feature is provided by the
15 microprocessor 34, charging section circuit 36 and low battery warning circuit 38 of the ECM.
16 As noted previously, schematics illustrating the details of an embodiment of the charging section
17 and low battery warning circuits are provided in Figs. 7 and 8, respectively, while a schematic
18 illustrating the microprocessor 34 and associated circuit is provided in Fig. 9.

19 **[0045]** With reference to Fig. 7 and as noted previously, the positive and negative terminals
20 or posts of the battery pack are illustrated at 14a and 14b, respectively. During the discharge of
21 the battery (such as when it is powering a load/cap lamp) current from the load and post 14b
22 flows through ground point 52 (Fig. 7) to ground point 54 (Fig. 8), through resistor R25 and
23 negative terminal 15b of the battery cell bundle (9 in Fig. 1) into the battery cell bundle. Current
24 from the battery cell bundle flows through battery cell bundle positive terminal 15a, line 56 (Fig.
25 8) and line 58 (Fig. 7). As illustrated in Fig. 7, the current traveling through line 58 encounters
26 transistor Q5 and then transistor Q4 before traveling to the positive post of the battery pack 14a
27 and out to the cap lamp load.

28 **[0046]** In addition to the microprocessor pins already described, as illustrated in Fig. 9,
29 microprocessor 34 features a number of input and output pins which are connected to the
30 various circuits illustrated in Fig. 5. The input pins are illustrated on the left side of the

1 microprocessor 34 in Fig. 9 while the output pins are illustrated on the right side. The charging
 2 section circuit 36 of Fig. 7 communicates with the microprocessor voltage input pin Uinp 62 (Fig.
 3 9) via connection 64 (Fig. 7). In addition, with reference to Fig. 7, connections 66 and 68
 4 (CHARGE ON) and 72 (LOAD OFF) of charging section circuit 36 communicate with
 5 corresponding output pins 74 and 76 of the microprocessor 34. The low battery
 6 warning/indication circuit 38 of Fig. 8 features connections 78 (BATT ON) and 80 (DATA1) that
 7 communicate with corresponding pins 82 and 84, respectively, of the microprocessor 34 of Fig.
 8 9.

9 **[0047]** A coulomb counter, illustrated at 85 in Fig. 8, senses the discharge current flowing
 10 through resistor R25. The sensed current is outputted from the coulomb counter 85 through
 11 connection 86 (Is). The sensed current is monitored via overload sensor circuit 46 (Figs. 5 and
 12 11) as the circuit receives the sensed current through connections 86 (Fig. 8) and 88 (Fig. 11).
 13 As illustrated in Fig. 11, an operational amplifier 92 receives the sensed current from 88 and is
 14 programmed to check for the short circuit condition (indicated by a high current flow). When
 15 such a condition is detected, a signal indicating a short circuit condition is provided to the
 16 microprocessor via connection 94 (Fig. 11) and microprocessor input pin 96 (Fig. 9) so that the
 17 microprocessor input pin 96 (Overload Sens) is set to high. When conditions are normal (no
 18 short circuit), the Overload Sens input pin 96 of the microprocessor is set to low.

19 **[0048]** When a short circuit is sensed, as indicated at 63 and 97 in Fig. 6, the
 20 microprocessor turns off transistor Q5, and thus the load (cap lamp), via pin 76 (Fig. 9) and, with
 21 reference to Fig. 7, connection 72 and switch Q2 so that current may flow through line 99 and
 22 thus pulse transistor Q8. In addition, transistors Q4 and Q8 are turned off by the
 23 microprocessor via output pin 74 (Fig. 9) and, with reference to Fig. 7), connections 66 and 68
 24 and switches Q1 and Q10.

25 **[0049]** Next, as illustrated at 100 in Fig. 6, the voltage level at the terminals of the battery
 26 pack (Uinp) is measured using connection 64 of Fig. 7 and corresponding input pin 62 (Fig. 9) of
 27 the microprocessor to determine if the short condition still exists. If so, as indicated by block
 28 101 in Fig. 6, pulse width modulation using pulse transistor Q8 (Fig. 7) occurs until the load/cap
 29 lamp turns on. The pulsing of transistor Q8 allows small amounts of current to flow, all being
 30 sensed by the comparator circuit, indicated in general at 102 in Fig. 7. If the short circuit is still
 31 present, the comparator 102 will detect a rapid current rise when transistor Q8 is turned on.

1 The microprocessor will be so signaled by the comparator through the overload sensor circuit as
2 connection 104 (Fig. 7) of the comparator communicates with connection 88 of the overload
3 sensor circuit (Fig. 11). When the short circuit is still present, the microprocessor will continue
4 to pulse transistor Q8 while sensing the current.

5 **[0050]** When the short circuit is removed, the microprocessor turns transistor Q5 on so that
6 full current is restored to the cap lamp. As a result, the circuitry provides a self-resetting
7 mechanism so that when the battery is shut down due to a short circuit, the load/cap lamp is
8 automatically re-powered when the short circuit or is removed. No additional action is required
9 by the user.

10 **[0051]** While the ECM of the present invention offers an automatic recovery feature for short
11 circuits, a battery pack or load may optionally also feature a push-button or switch that resets
12 the system and re-powers the load after the battery is shut down due to a short circuit when the
13 short circuit is removed.

14 **[0052]** The charging section circuit 36 of Figs. 5 and 7 of the ECM also preferably provides
15 the battery pack with a "soft-start" feature to avoid a massive inrush of current into the cap lamp
16 bulb at start up, and thus increase bulb life. When the cap lamp is shut off, the microprocessor
17 shuts off transistors Q4 and Q5 so that when the cap lamp is switched on or connected to the
18 battery pack terminals, current must flow through branch 99 of Fig. 7. The ramp-up of electrical
19 current (soft-start) is accomplished by pulse width modulation via transistor Q8 as controlled by
20 the microprocessor 34. More specifically, transistor Q8 is controlled in this manner as current
21 flows to the cap lamp until full current is achieved and communicated to the microprocessor.
22 Once full current is achieved, transistors Q4 and Q5 are turned on by the microprocessor and
23 transistor Q8 is turned off. Full current then flows to the cap lamp as described above.

24 **[0053]** Returning to Fig. 6, if no short circuit condition exists, the microprocessor checks for
25 the presence of a charging current, as indicated at 106. More specifically, a charge current
26 circuit sensor circuit 44 (Figs. 5 and 12) receives the current sensed in the circuit of Figs. 7 and
27 8 via connections 86 (Fig. 8) and 108 (Fig. 12). If a charge current is sensed, with the
28 assistance of operational amplifier 110 of Fig. 12, input pin 112 (ICharge) of the microprocessor
29 (Fig. 9) is notified via connection 114 (Fig. 12) so that ICharge > 0 for purposes of 106 in Fig. 6.
30 The flow chart then branches to the charge mode, as illustrated by Fig. 6.

1 **[0054]** For recharging, the battery pack is placed in a charging rack having a connector that
2 engages a corresponding charging connection on the cap lamp. Such charging racks are well-
3 known in the art. During recharging, the charging current enters the battery pack through the
4 positive post 14a (Fig. 7) of the battery pack and travels the reverse of the battery pack
5 discharge route described above so that the charging current passes through transistor Q4 and
6 then transistor Q5. The charging current exits the battery pack through negative post 14b. The
7 charge ratio for the battery pack preferably is 2:1. Therefore, for every twelve hours of use, it
8 will take six hours to recharge the battery pack.

9 **[0055]** As illustrated at 116 in Fig. 6, the LAMP_WAS_ON internal bit of the microprocessor
10 34 is again checked to ensure that it is set to 1, so that charging is permitted. If the
11 LAMP_WAS_ON bit is set to 0, the ECM is set to default for discharge mode whereby the
12 charging status LED is illuminated in green, Q4 is turned off and Q5 is turned on, as indicated at
13 118 and 120 in Fig. 6. In addition, as indicated at 120, the coulomb counter count is set to 16
14 amp hours (Ah) as an indication of full charge for the battery pack via output pin 84 (Fig. 9) of
15 the microprocessor and connection 80 of Fig. 8. Flow then branches back to step 51, as
16 illustrated in Fig. 6, so that the top portion of the flow chart, including the short circuit check
17 section, is performed.

18 **[0056]** If LAMP_WAS_ON = 1, the battery pack has been discharged an unknown amount
19 and must go into active charge mode and the next step, 122 of Fig. 6, is performed. At 122, the
20 battery cell voltage is checked by the microprocessor (via measurement portion 53 of the circuit
21 of Fig. 10, connection 57 of Fig. 10 and microprocessor input pin 59 of Fig. 9). If the battery cell
22 voltage is less than or equal to 4.2V, the flowchart branches to current mode, as illustrated in
23 Fig. 6. In current mode, as indicated at 124, a timer (125 in Fig. 9) is started and the charging
24 status LED (16 in Figs. 1, 2 and 13) is illuminated in red. With regard to the latter, the
25 microprocessor sends a signal to the LED driver circuit 40 (Figs. 5 and 13) via microprocessor
26 output pin 126 (Fig. 9) and connection 128 of Fig. 13. Power is received by this portion of the
27 LED driver circuit by connection 130. In addition, during current mode, pulse width modulation
28 via resistor Q8 is activated.

29 **[0057]** As indicated at 132 in Fig. 6, the charging current I_{bat} (or I_{charge}) is monitored by
30 the microprocessor. This occurs via the charge current sensor circuit 44 of Figs. 5 and 12 and
31 input pin 112 of the microprocessor (Fig 9). The microprocessor adjusts the charging current by

1 increasing or decreasing the pulse width modulation duty cycle of transistor Q8 (Fig. 7), as
 2 indicated by 134a and 134b in Fig. 6. As a result, a 2.5A mean charge current is achieved while
 3 the battery charging state is at a constant current. Flow then branches back to step 51, as
 4 illustrated in Fig. 6, so that the top portion of the flow chart, including the short circuit check
 5 section, is performed. The current mode of charging occurs until the battery cell voltage is
 6 greater than 4.2V, at which time voltage mode is initiated.

7 **[0058]** As illustrated at 136 in Fig. 6, the pulse width modulation of transistor Q8 continues
 8 and the charging status LED is illuminated in red during the voltage mode of charging. As
 9 indicated at 138, the timer 125 (Fig. 9), which was turned on at 124 of Fig. 6, is checked to
 10 determine if it is greater than the timeout value (Tmax). If so, as illustrated in Fig. 6, the
 11 charging status LED is illuminated in green, charging is stopped and the discharge mode is
 12 initialized as indicated at 118 and 120 in Fig. 6. The timer is used for safety purposes and
 13 voltage mode rarely terminates due to the timer exceeding the timeout value.

14 **[0059]** If the timeout value has not been exceeded at 138 in Fig. 6, the charging current is
 15 checked at 142 by the microprocessor to determine if it is greater than the value $I_{max}10\%$.
 16 $I_{max}10\%$ is equal to 10% of the maximum constant current (I_{max}) in the current mode. This is
 17 the typical termination mechanism for charging. If the charging current is not greater than
 18 $I_{max}10\%$, the charging status LED is illuminated in green, charging is stopped and the
 19 discharge mode is initialized as indicated at 118 and 120 in Fig. 6.

20 **[0060]** Returning to 106 in Fig. 6, if no charging current is present, the microprocessor, and
 21 thus the ECM, enters the discharge mode, as indicated at 144. As indicated by 146 in Fig. 6,
 22 capacitors Q4 and Q5 (Fig. 7) are turned on and the charging status LED is illuminated in green.
 23 Next, as indicated at 148, the coulomb counter (85 in Fig. 8) count is checked by the
 24 microprocessor as an indication of the charge level of the battery pack. If the count is greater
 25 than or equal to 2 Ah, normal discharge mode continues and processing loops back to step 51
 26 as illustrated in Fig. 6. As a result, a short circuit and general monitoring mode is performed
 27 continuously, whether the battery pack is in charge or discharge mode.

28 **[0061]** If the coulomb counter count is less than 2 Ah, the battery pack goes into low power
 29 mode where a low battery charge warning is provided. More specifically, as indicated at 152 in
 30 Fig. 6, the microprocessor turns transistors Q4 and Q5 (Fig. 7) off and operates Q8 in pulse

1 width modulation mode so that the discharge of the battery pack occurs at low power. This
2 causes the cap lamp load to dim. The dimmed light provides extended time for a miner to
3 depart from the mine and obtain a fully charged battery pack. In addition, as indicated at 154
4 and 156 in Fig. 6, every two minutes the microprocessor turns on transistors Q4 and Q5 for one
5 second so that the cap lamp flashes with full power, which acts as a warning of a low battery
6 charge condition. As indicated at 158, operation of Q8 in pulse width modulation mode resumes
7 after the flash so that the cap lamp is again dim.

8 **[0062]** The microprocessor 34 of Figs. 5 and 9 requires a constant voltage to run. This is
9 provided by the voltage regulator 162 of the circuit of Fig. 10. More specifically, as noted
10 previously, the circuit of Fig. 10 receives voltage from the battery cell bundle (VDD) via
11 connection 55. This is converted by the voltage regulator 162 to voltage (VCC) that is provided
12 to the microprocessor, and other components of the ECM such as the coulomb counter 85 of
13 Fig. 8 and the operational amplifiers 92 and 110 of Figs. 11 and 12, respectively, via connection
14 164 (Fig. 10).

15 **[0063]** As noted previously, the battery pack is provided with a protection circuit illustrated at
16 15 in Figs. 2 and 3 that provides under-voltage cutoff, over-voltage cutoff and over-current cutoff
17 protection. The protection circuit therefore acts as a backup to the ECM circuitry and
18 microprocessor programming discussed with respect to Fig. 6. As examples only, an over-
19 voltage condition may occur if the protection circuit detects a voltage of 4.35V or greater, while
20 an under-voltage condition may occur if the protection circuit detects a voltage of 2.5V or less.
21 An over-current condition may exist if the current exceeds 4.5A. If any of these conditions exist,
22 the protection circuit is tripped like a circuit breaker. As a result, the protection circuit must be
23 reset before the battery pack may be used again.

24 **[0064]** The protection circuit is reset using the capacitor bank circuit indicated in general at
25 172 in Fig. 8. Transistor QB6 (Fig. 8) permits energy to flow into the capacitor bank circuit 172,
26 but does not permit it to escape until so directed by the microprocessor. As a result, energy is
27 stored in the capacitor bank circuit 172. When the protection circuit (15 of Figs. 2 and 3) is
28 tripped, input pin 59 (Fig. 9) of the microprocessor goes to zero and the microprocessor signals
29 the capacitor bank circuit 172 to release the stored energy via connection 78 (Fig. 8) and
30 microprocessor output pin 82 (Fig. 9). This release of energy causes the battery protection
31 circuit to reset.

1 **[0065]** The voltages, currents and times of Fig. 6 are presented as examples only and are in no
2 way to limit the scope of the invention.

3 **[0066]** The scope of the claims appended hereto should not be limited by the preferred
4 embodiments set forth in the present description, but should be given the broadest interpretation
5 consistent with the description as a whole.

6

WHAT IS CLAIMED IS:

1. A battery pack for powering a cap lamp comprising:
 - a. a battery pack housing;
 - b. a battery cell having a lithium-based chemistry positioned within said battery pack housing and having a pair of terminals;
 - c. an electronic control module positioned within said battery pack housing;
 - d. a protection circuit electrically attached between the pair of terminals of said battery cell and the electronic control module and positioned within the battery pack housing;
 - e. a pair of battery pack posts in electrical communication with the electronic control module and adapted to be electrically connected to the cap lamp;
 - f. said electronic control module controlling discharging of the battery cell when powering the cap lamp and charging of the battery cell when the battery pack is connected to a charger.
2. The battery pack of claim 1 further comprising a cap lamp directly connected to the housing.
3. The battery pack of claim 1 further comprising a cord attached to the pair of terminals and adapted to provide power to the cap lamp.
4. The battery pack of claim 1 wherein the battery cell is a Lithium-ion cell.
5. The battery pack of claim 1 wherein the electronic control module includes circuitry that, upon connection of the battery pack to the charger, detects whether the battery pack was used after being fully charged and disconnected from the charger, commences charging if so and entirely refrains from providing a charging current to the battery cell if not.
6. The battery pack of claim 1 wherein the electronic control module includes circuitry that checks the voltage of the battery cell.

7. The battery pack of claim 1 wherein the electronic control module includes circuitry that monitors the charging current during charging of the battery pack.
8. The battery pack of claim 7 wherein the electronic control module includes circuitry that adjusts the charging current during charging of the battery pack.
9. The battery pack of claim 7 wherein the electronic control module includes circuitry that terminates charging of the battery pack if the charging current drops below a predetermined level.
10. The battery pack of claim 1 wherein the electronic control module includes a timer that the electronic control module references to determine if a timeout value has been reached, said electronic control module terminating charging of the battery pack if the timeout value has been reached by the timer.
11. The battery pack of claim 1 wherein the electronic control module includes circuitry that provides a charge ratio whereby the battery cell charges more quickly when the battery pack is connected to a charger than the battery cell discharges when it is powering the cap lamp.
12. The battery pack of claim 1 wherein the electronic control module includes a microprocessor.
13. The battery pack of claim 1 wherein the electronic control module is in series circuit between the pair of terminals and the battery cell.
14. A cap lamp system comprising:
 - a. a battery pack housing;
 - b. a battery cell having a lithium-based chemistry positioned within said battery pack housing and having a pair of terminals;
 - c. an electronic control module positioned within said battery pack housing;
 - d. a protection circuit electrically attached between the pair of terminals of said battery cell and the electronic control module and positioned within the battery pack housing;

- e. a pair of battery pack posts in electrical communication with the electronic control module;
- f. a cap lamp attached to the pair of battery pack posts;
- g. said electronic control module controlling discharging of the battery cell when powering the cap lamp and charging of the battery cell when the battery pack is connected to a charger.

15. The cap lamp system of claim 14 wherein said cap lamp is directly connected to the housing.

16. The cap lamp system of claim 14 further comprising a cord attached to the pair of terminals and the cap lamp to provide power from the battery cell to the cap lamp.

17. The cap lamp system of claim 14 wherein the battery cell is a Lithium-ion cell.

18. The cap lamp system of claim 14 wherein the electronic control module includes circuitry that, upon connection of the battery pack to the charger, detects whether the battery pack was used after being fully charged and disconnected from the charger, commences charging if so and entirely refrains from providing a charging current to the battery cell if not.

19. The cap lamp system of claim 14 wherein the electronic control module includes circuitry that checks the voltage of the battery cell.

20. The cap lamp system of claim 14 wherein the electronic control module includes circuitry that monitors the charging current during charging of the battery pack.

21. The cap lamp system of claim 20 wherein the electronic control module includes circuitry that adjusts the charging current during charging of the battery pack.

22. The cap lamp system of claim 20 wherein the electronic control module includes circuitry that terminates charging of the battery pack if the charging current drops below a predetermined level.

23. The cap lamp system of claim 14 wherein the electronic control module includes a timer that the electronic control module references to determine if a timeout value has been reached, said electronic control module terminating charging of the battery pack if the timeout value has been reached by the timer.
24. The cap lamp system of claim 14 wherein the electronic control module includes circuitry that provides a charge ratio whereby the battery cell charges more quickly when the battery pack is connected to a charger than the battery cell discharges when it is powering the cap lamp.
25. The cap lamp system of claim 14 wherein the electronic control module includes a microprocessor.
26. The cap lamp system of claim 14 wherein the electronic control module is in series circuit between the pair of terminals and the battery cell.
27. A battery pack for powering a cap lamp comprising:
- a. a housing having an open end and a closed end;
 - b. a separator positioned within said housing so that an electronic control module compartment is defined on one side of the separator and a battery compartment is defined on an opposite side of the separator;
 - c. a battery cell having a lithium-based chemistry positioned in the battery compartment and having a pair of terminals;
 - d. an electronic control module positioned in the electronic control module compartment;
 - e. a protection circuit positioned in the housing and electrically attached between the pair of terminals of said battery cell and the electronic control module;
 - f. a pair of battery pack posts in electrical communication with the electronic control module and adapted to be electrically connected to the cap lamp;
 - g. said electronic control module controlling discharging of the battery cell when powering the cap lamp and charging of the battery cell when the battery pack is connected to a charger;

- h. a cover removably attached to and sealing against the open end of the housing so that the pair of battery pack terminals are covered.

28. The battery pack of claim 27 wherein the electronic control module compartment is positioned between the separator and the open end of the housing, and the battery compartment is defined between the separator and the closed end of the housing.

29. The battery pack of claim 27 wherein the cover includes a strain relief adapted to receive a power cord of a cap lamp.

30. The battery pack of claim 27 wherein the cover is removably attached to the housing by screws.

31. The battery pack of claim 1 wherein the electronic control module controls both a charging current during charging of the battery cell and a discharging current during discharging of the battery cell.

32. The battery pack of claim 31 wherein the electronic control module includes and uses at least one transistor to control the charging and discharging currents.

33. The battery pack of claim 32 wherein the at least one transistor uses pulse width modulation to control the charging and discharging currents.

34. The battery pack of claim 32 wherein the at least one transistor includes a first transistor to control the charging current and a second transistor to control the discharging current.

35. The battery pack of claim 34 wherein the first transistor uses pulse width modulation to control the charging current and the second transistor uses pulse width modulation to control the discharging current.

36. The battery pack of claim 35 further comprising a microprocessor that controls the first and second transistors.

37. The battery pack of claim 1 wherein the electronic control module controls a discharging current during discharging of the battery cell.
38. The battery pack of claim 37 wherein the electronic control module includes and uses a transistor to control the discharging current.
39. The battery pack of claim 38 wherein the transistor uses pulse width modulation to control the discharging current.
40. The cap lamp system of claim 14 wherein the electronic control module includes and uses a transistor to control a discharging current when powering the cap lamp.
41. The cap lamp system of claim 40 wherein the transistor uses pulse width modulation to control the discharging current.
42. The cap lamp system of claim 41 wherein the transistor uses pulse width modulation of the discharging current to indicate a low battery charge by dimming the cap lamp.
43. The cap lamp system of claim 41 wherein the transistor uses pulse width modulation to ramp up the discharging current when the cap lamp is first powered on.
44. The cap lamp system of claim 14 wherein the electronic control module includes and uses at least one transistor to control a charging current during charging of the battery cell and to control a discharging current when powering the cap lamp.
45. The cap lamp system of claim 44 wherein the at least one transistor uses pulse width modulation to control the charging and discharging currents.
46. The cap lamp system of claim 45 wherein the at least one transistor uses pulse width modulation to keep the charging current constant.

47. The cap lamp system of claim 45 wherein the at least one transistor uses pulse width modulation to check for a fault condition during discharge of the battery whereby the electronic control module detects a short circuit condition indicated by a high discharge current flow.
48. A cap lamp system comprising:
- a. a battery pack housing;
 - b. a battery cell having a lithium-based chemistry positioned within said battery pack housing and having a pair of terminals;
 - c. an electronic control module positioned within said battery pack housing and in electrical communication with the battery cell terminals;
 - d. a pair of battery pack posts in electrical communication with the electronic control module;
 - e. a cap lamp attached to the pair of battery pack posts;
 - f. said electronic control module including and using at least one transistor to control a charging current during charging of the battery cell and to control a discharging current when powering the cap lamp and said at least one transistor using pulse width modulation to dim the cap lamp.
49. The cap lamp system of claim 48 wherein the electronic control module uses dimming of the cap lamp to reflect a charge status of the battery cell.
50. The cap lamp system of claim 48 wherein the electronic control module includes a capacitor bank that stores energy from the battery cell that is released under the direction of the electronic control module so as to reset the battery pack.
51. The cap lamp system of claim 50 wherein the energy that is stored in the capacitor bank and that is released under the direction of the electronic control module resets the battery protection circuit to reset the battery pack.
52. The cap lamp system of claim 14 wherein the electronic control module includes a capacitor bank that stores energy from the battery cell that is released under the direction of the electronic control module so as to reset the cap lamp system.

53. The cap lamp system of claim 52 wherein the energy that is stored in the capacitor bank and that is released under the direction of the electronic control module resets the battery protection circuit to reset the cap lamp system.
54. A battery pack for powering a cap lamp comprising:
- a. a housing;
 - b. a battery cell positioned within said housing;
 - c. a pair of terminals attached to the battery cell and adapted to provide power to a cap lamp; and
 - d. an electronic control module positioned within said housing and attached to said battery cell, said electronic control module controlling discharging of the battery cell when powering the cap lamp and charging of the battery cell when the battery pack is connected to a charger.
55. The battery pack of claim 54 further comprising a cap lamp directly connected to the housing.
56. The battery pack of claim 54 further comprising a cord attached to the pair of terminals and adapted to provide power to the cap lamp.
57. The battery pack of claim 54 wherein the battery cell is a Lithium-ion cell.
58. The battery pack of claim 54 wherein the electronic control module includes circuitry that, upon connection of the battery pack to the charger, detects whether the battery pack was used after being fully charged and disconnected from the charger, commences charging if so and entirely refrains from providing a charging current to the battery cell if not.
59. The battery pack of claim 54 wherein the electronic control module includes circuitry that checks the voltage of the battery cell.
60. The battery pack of claim 54 wherein the electronic control module includes circuitry that monitors the charging current during charging of the battery pack.

61. The battery pack of claim 60 wherein the electronic control module includes circuitry that adjusts the charging current during charging of the battery pack.
62. The battery pack of claim 60 wherein the electronic control module includes circuitry that terminates charging of the battery pack if the charging current drops below a predetermined level.
63. The battery pack of claim 54 wherein the electronic control module includes a timer that the electronic control module references to determine if a timeout value has been reached, said electronic control module terminating charging of the battery pack if the timeout value has been reached by the timer.
64. The battery pack of claim 54 wherein the electronic control module includes circuitry that provides a charge ratio whereby the battery cell charges more quickly when the battery pack is connected to a charger than the battery cell discharges when it is powering the cap lamp.
65. The battery pack of claim 54 wherein the electronic control module includes a microprocessor.
66. The battery pack of claim 54 wherein the electronic control module is in series circuit between the pair of terminals and the battery cell.
67. The battery pack of claim 54 further comprising: a cap lamp attached to the pair of terminals so as to receive power from the battery cell.
68. The battery pack of claim 54 wherein said housing has an open end and a closed end and further comprising:
- a. a separator positioned within said housing so that an electronic control module compartment is defined on one side of the separator and a battery compartment is defined on an opposite side of the separator with the battery cell positioned in the battery compartment and the electronic control module positioned in the electronic control module compartment; and

- b. a cover removably attached to and sealing against the open end of the housing so that the pair of battery pack terminals are covered.

69. The battery pack of claim 68 wherein the electronic control module compartment is positioned between the separator and the open end of the housing, and the battery compartment is defined between the separator and the closed end of the housing.

70. The battery pack of claim 68 wherein the cover includes a strain relief adapted to receive a power cord of a cap lamp.

71. The battery pack of claim 68 wherein the cover is removably attached to the housing by screws.

72. The battery pack of claim 54 wherein the electronic control module controls both a charging current during charging of the battery cell and a discharging current during discharging of the battery cell.

73. The battery pack of claim 72 wherein the electronic control module includes and uses at least one transistor to control the charging and discharging currents.

74. The battery pack of claim 73 wherein the at least one transistor uses pulse width modulation to control the charging and discharging currents.

75. The battery pack of claim 73 wherein the at least one transistor includes a first transistor to control the charging current and a second transistor to control the discharging current.

76. The battery pack of claim 75 wherein the first transistor uses pulse width modulation to control the charging current and the second transistor uses pulse width modulation to control the discharging current.

77. The battery pack of claim 76 further comprising a microprocessor that controls the first and second transistors.

78. The battery pack of claim 54 wherein the electronic control module controls a discharging current during discharging of the battery cell.
79. The battery pack of claim 78 wherein the electronic control module includes and uses a transistor to control the discharging current.
80. The battery pack of claim 79 wherein the transistor uses pulse width modulation to control the discharging current.
81. The battery pack of claim 67 wherein the electronic control module includes and uses a transistor to control a discharging current when powering the cap lamp.
82. The battery pack of claim 81 wherein the transistor uses pulse width modulation to control the discharging current.
83. The battery pack of claim 82 wherein the transistor uses pulse width modulation of the discharging current to indicate a low battery charge by dimming the cap lamp.
84. The battery pack of claim 83 wherein the transistor uses pulse width modulation to ramp up the discharging current when the cap lamp is first powered on.
85. A battery pack for powering a cap lamp comprising:
- a. a housing;
 - b. a battery cell positioned within said housing;
 - c. a pair of terminals attached to the battery cell and adapted to provide power to a cap lamp;
 - d. charging circuitry positioned within said housing and attached to said battery cell, said charging circuitry providing a charging current to the battery cell when the battery pack is connected to a charger; and
 - e. a microprocessor positioned within said housing and operatively connected to the charging circuitry.

86. The battery pack of claim 85 wherein the microprocessor maintains a constant charging current.
87. The battery pack of claim 86 wherein the charging circuitry includes a transistor that is in communication with the microprocessor to maintain the constant charging current.
88. The battery pack of claim 87 wherein the microprocessor uses pulse width modulation of the transistor to maintain the constant charging current.
89. The battery pack of claim 85 wherein the microprocessor is adapted to configure the battery pack to provide low power to the cap lamp, so as to dim the cap lamp, and to configure the system to provide full power to the cap lamp.
90. A cap lamp system comprising:
- a. a housing;
 - b. a battery cell positioned within said housing;
 - c. a pair of terminals attached to the battery cell;
 - d. a cap lamp attached to the pair of terminals so as to receive power from the battery cell;
 - e. charging circuitry positioned within said housing and attached to said battery cell, said charging circuitry providing a charging current to the battery cell when the charging circuitry is connected to a charger; and
 - f. a microprocessor positioned within said housing and operatively connected to the charging circuitry.
91. The cap lamp system of claim 90 wherein the microprocessor maintains a constant charging current.
92. The cap lamp system of claim 91 wherein the charging circuitry includes a transistor that is in communication with the microprocessor to maintain the constant charging current.
93. The cap lamp system of claim 92 wherein the microprocessor uses pulse width modulation of the transistor to maintain the constant charging current.

94. The cap lamp system of claim 90 wherein the microprocessor is adapted to configure the cap lamp system to provide low power to the cap lamp, so as to dim the cap lamp, and to configure the cap lamp system to provide full power to the cap lamp.

95. A cap lamp system comprising:

- a. a battery pack housing;
- b. a battery cell having a lithium-based chemistry positioned in the battery pack housing;
- c. a load attached to the battery cell, said load including a cap lamp;
- d. a cap lamp housing, said load positioned within the cap lamp housing;
- e. an electronic control module integrated into the load and electrically attached to the cap lamp;
- f. a protection circuit electrically attached between said battery cell and the electronic control module and positioned in the battery pack housing; and
- g. said electronic control module controlling discharging of the battery cell when powering the cap lamp and charging of the battery cell when the battery pack is connected to a charger.

96. The cap lamp system of claim 95 wherein said cap lamp housing is directly connected to the battery pack housing.

97. The cap lamp system of claim 95 further comprising a cord attached to the battery cell and the load to provide power from the battery cell to the load.

98. The cap lamp system of claim 95 wherein the battery cell is a Lithium-ion cell.

99. The cap lamp system of claim 95 wherein the electronic control module includes a transistor that is used to control discharging of the battery cell.

100. A cap lamp system comprising:

- a. a battery pack housing;

- b. a battery cell having a lithium-based chemistry positioned within said battery pack housing and having a pair of terminals;
- c. an electronic control module;
- d. a protection circuit electrically attached between the pair of terminals of said battery cell and the electronic control module and positioned within the battery pack housing;
- e. a cap lamp attached to electronic control module; and
- f. said electronic control module controlling discharging of the battery cell when powering the cap lamp and charging of the battery cell when the battery pack is connected to a charger.

101. The cap lamp system of claim 100 wherein said cap lamp is directly connected to the battery pack housing.

102. The cap lamp system of claim 100 further comprising a cord attached to the battery cell and the cap lamp to provide power from the battery cell to the cap lamp.

103. The cap lamp system of claim 100 wherein the battery cell is a Lithium-ion cell.

104. The cap lamp system of claim 100 wherein the electronic control module includes a transistor that is used to control discharging of the battery cell.

105. The cap lamp system of claim 100 wherein the electronic control module is incorporated into the cap lamp.

106. The cap lamp system of claim 100 wherein the electronic control module is positioned within the battery pack housing.

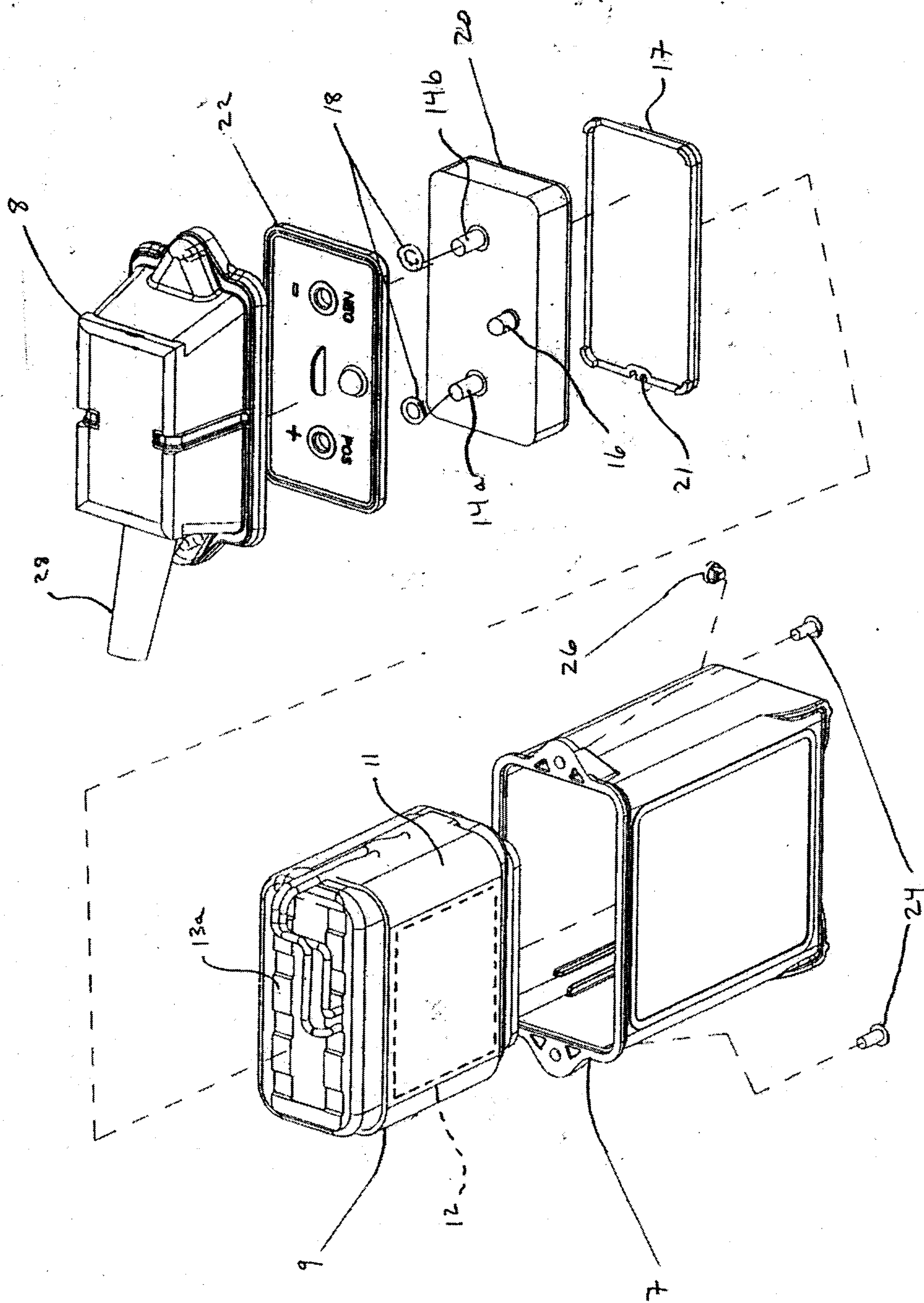


Figure 1

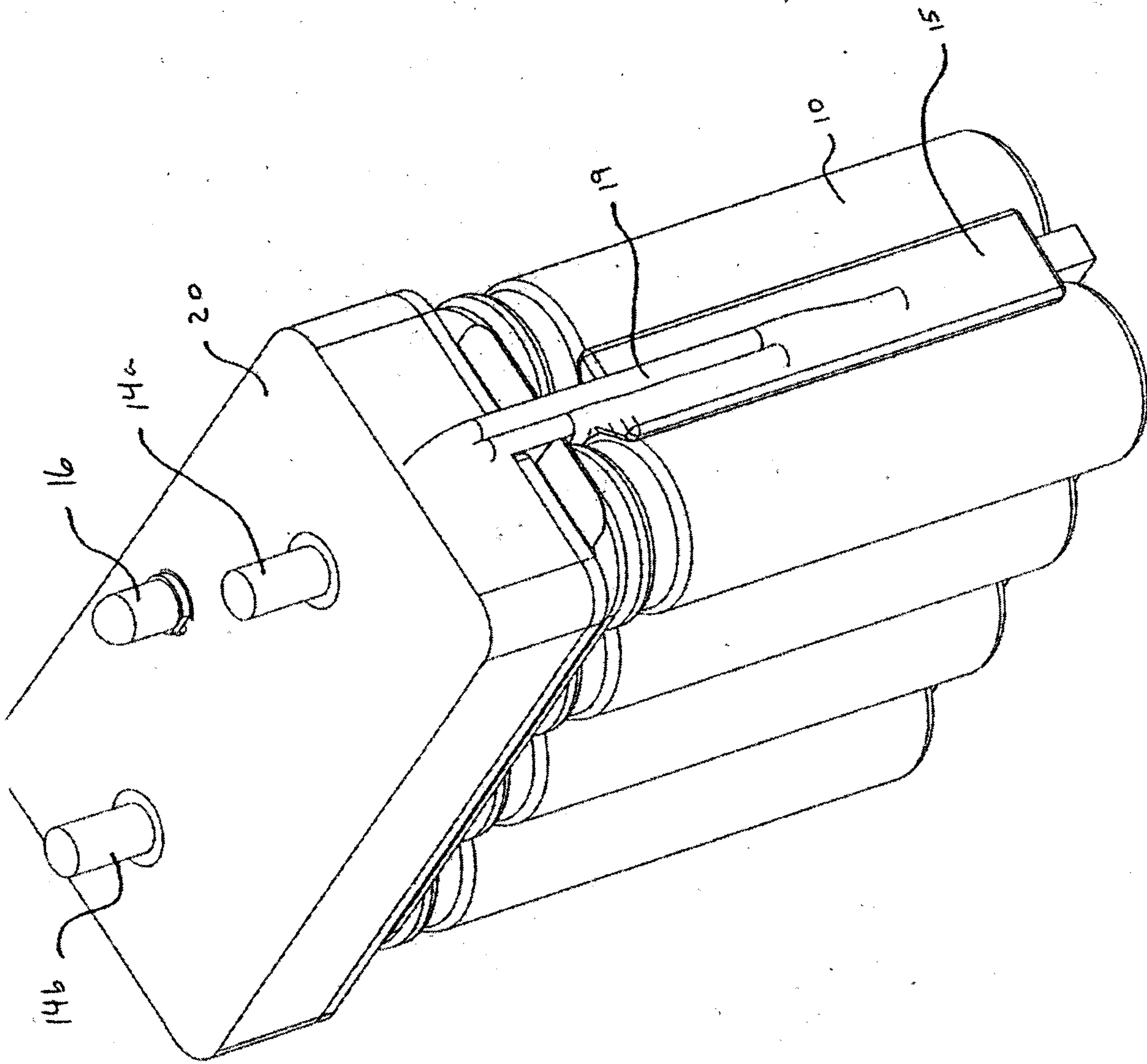


Figure 2

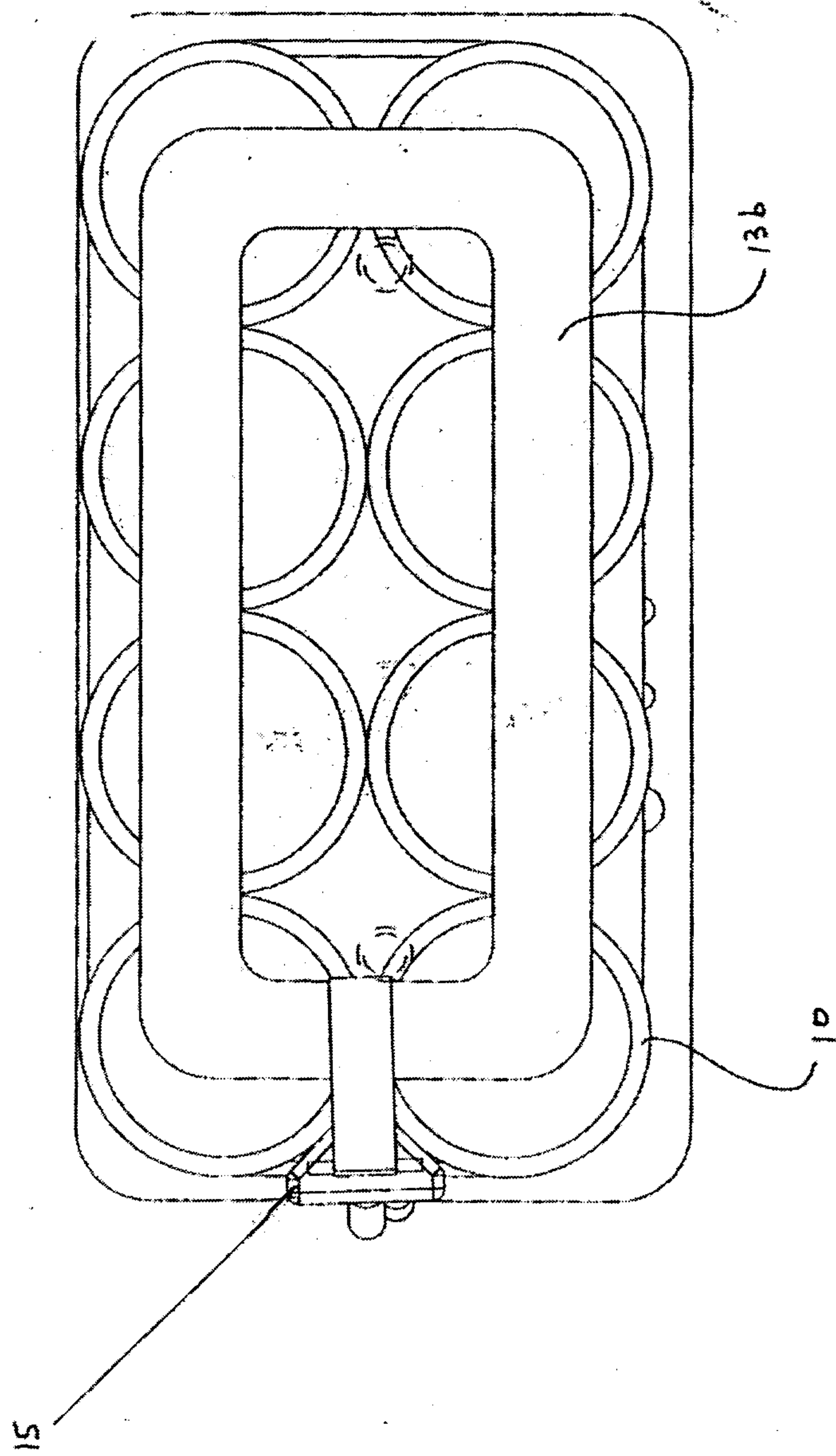


Figure 3

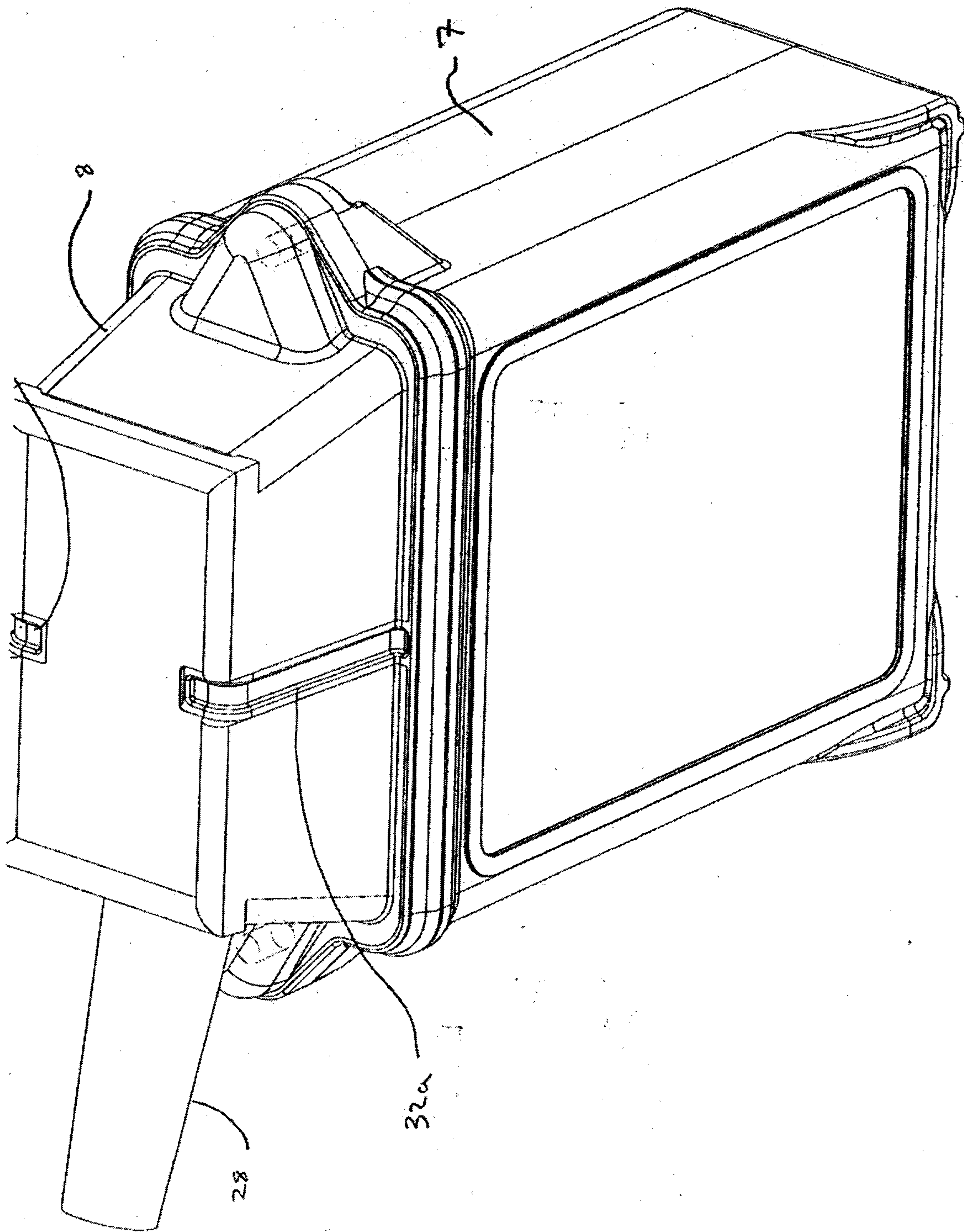


Figure 4

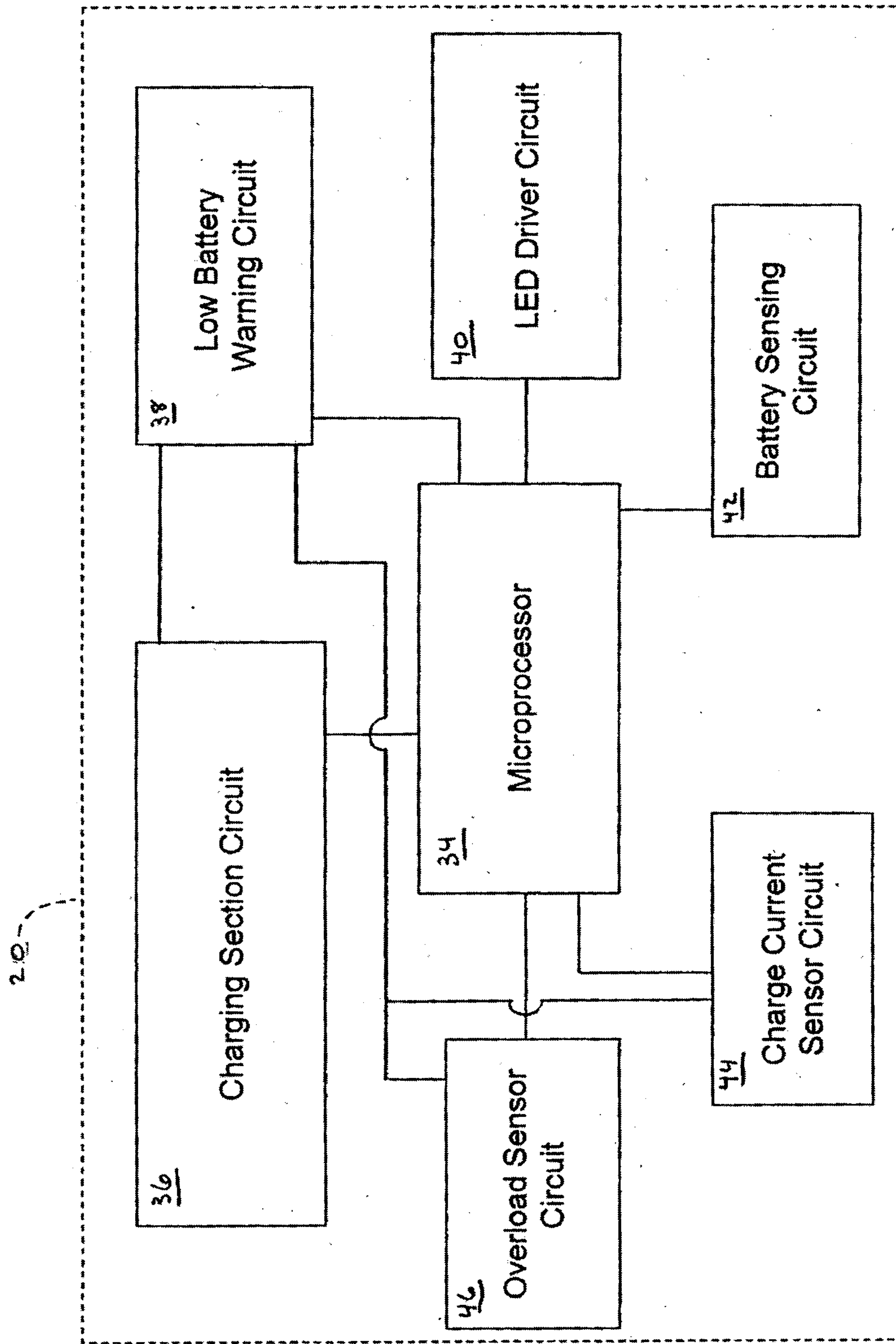
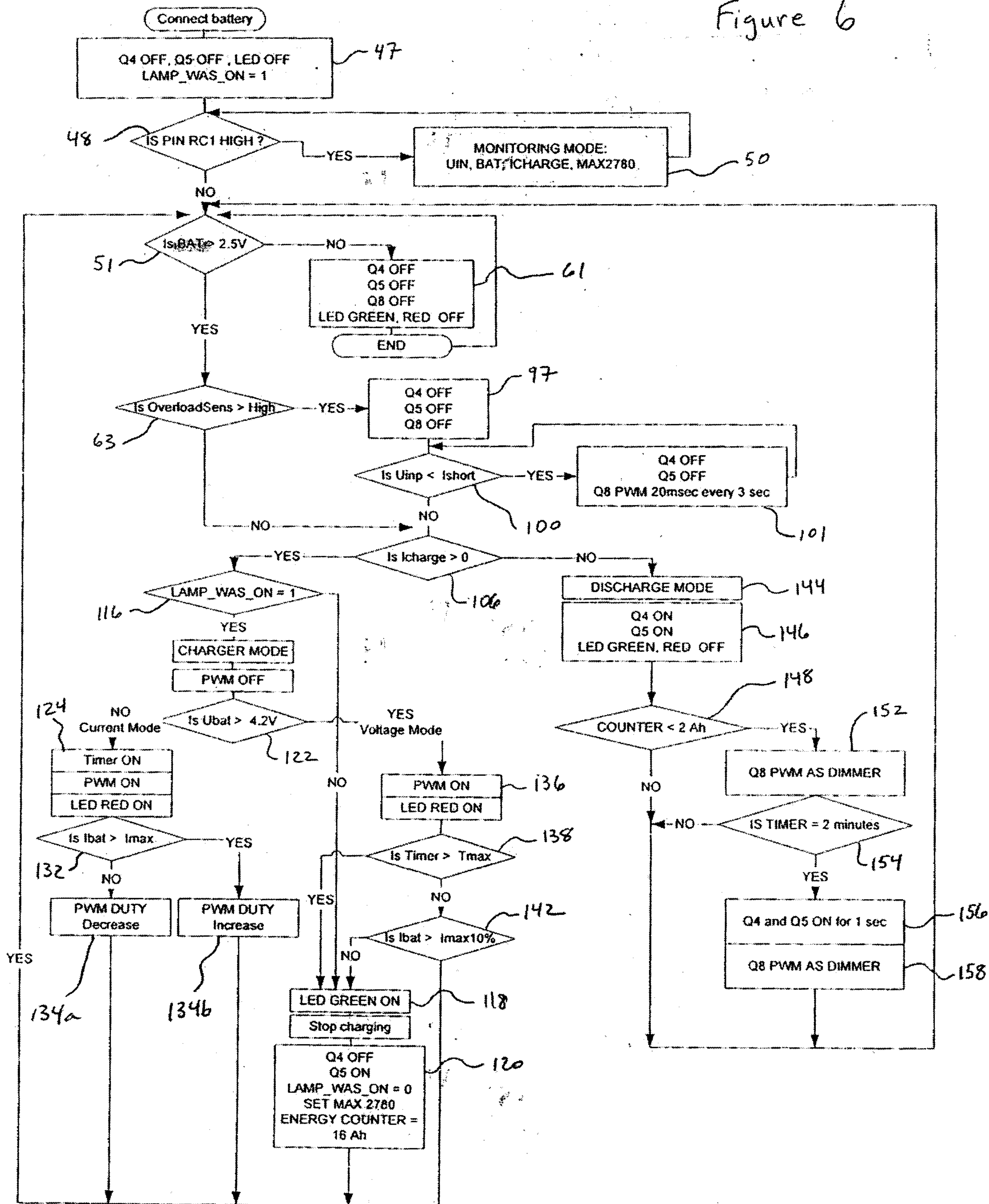


Figure 5



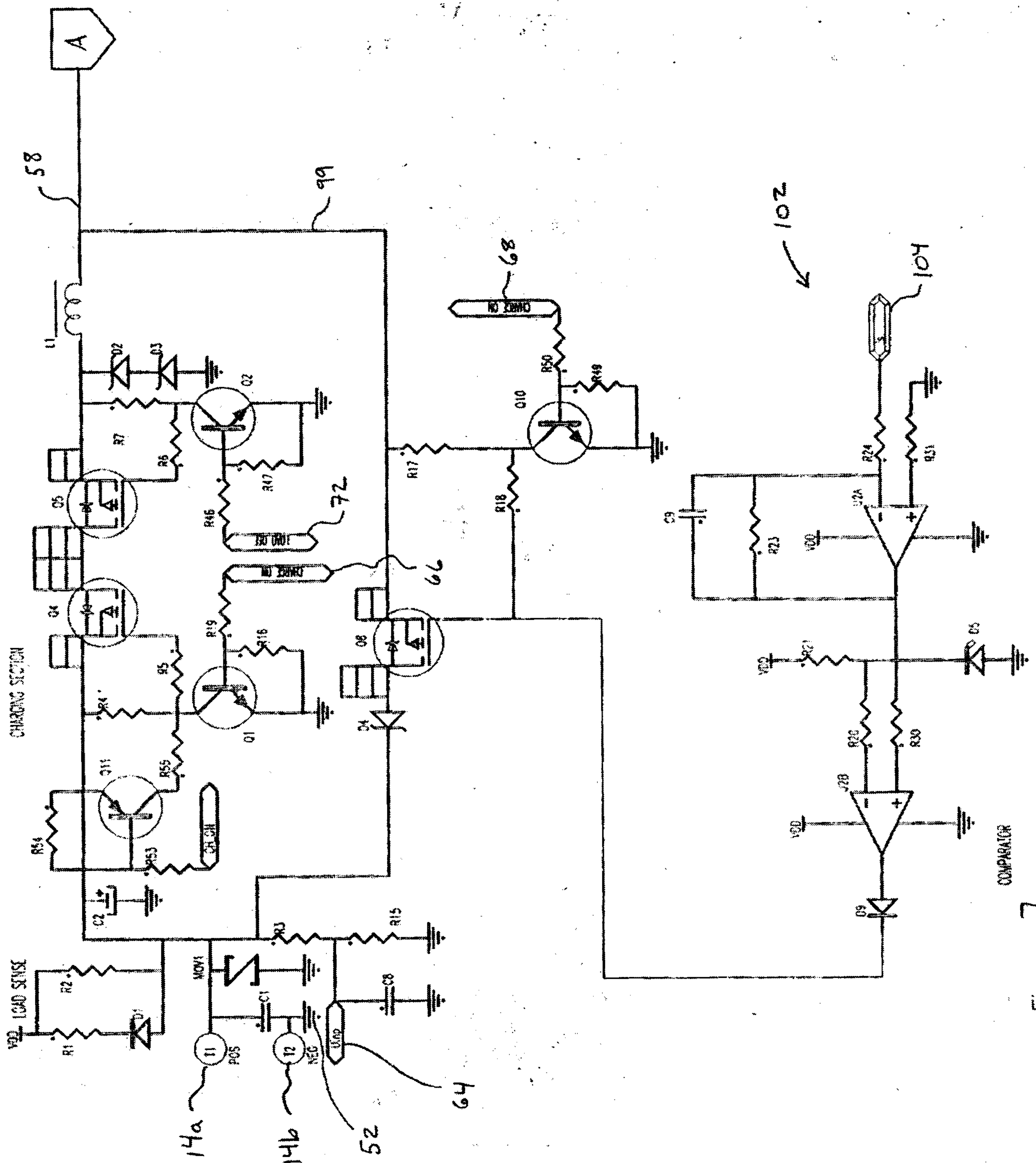


Figure 7

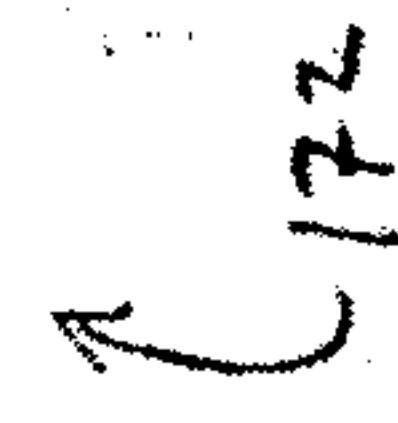
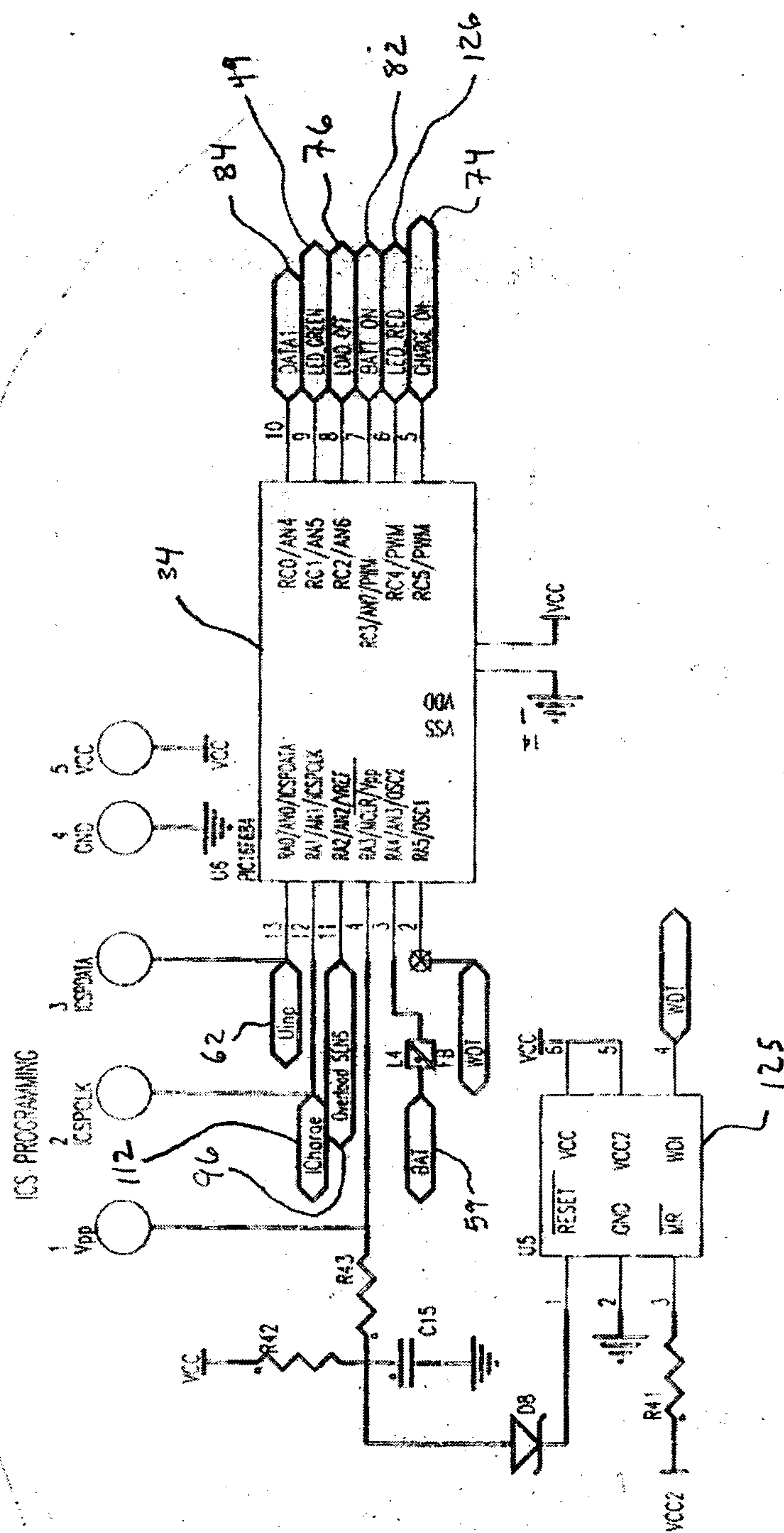


Figure 8



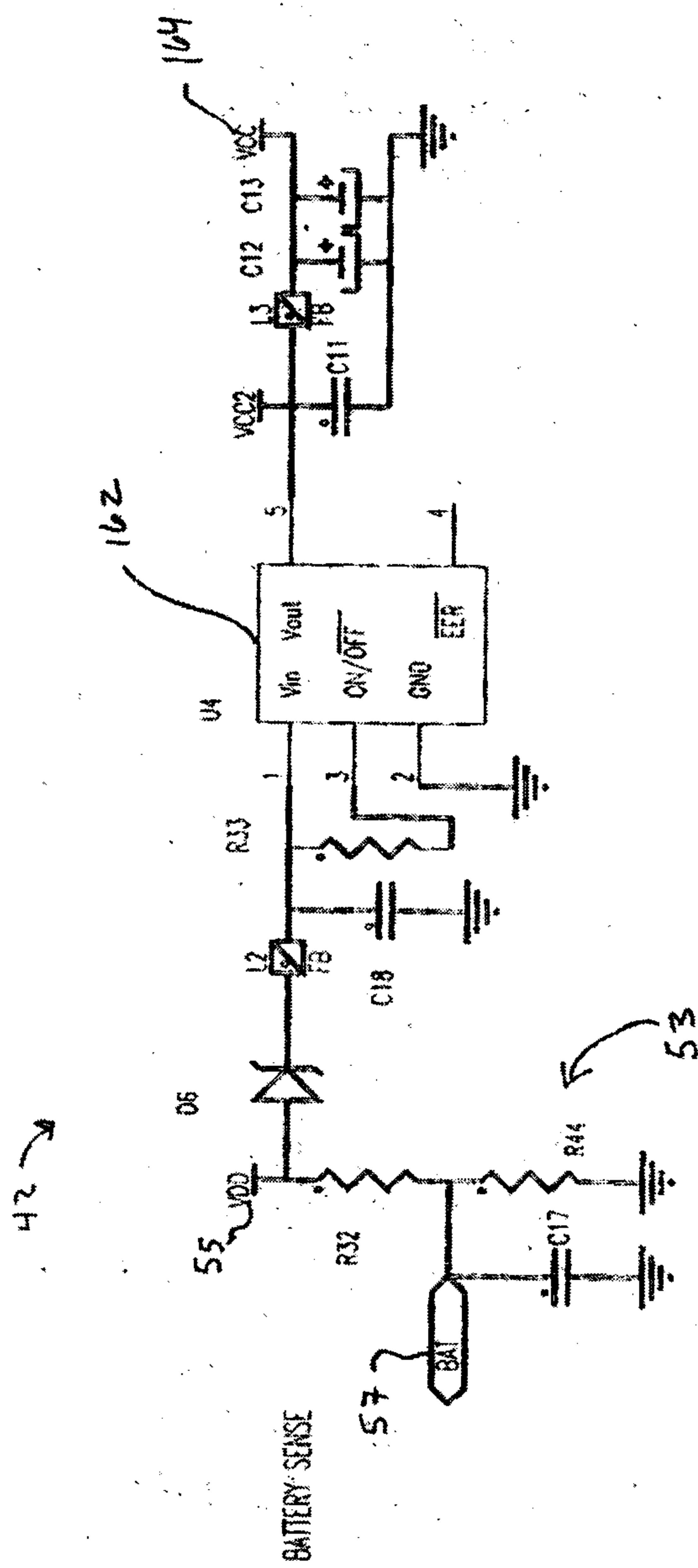


Figure 10

Figure 11

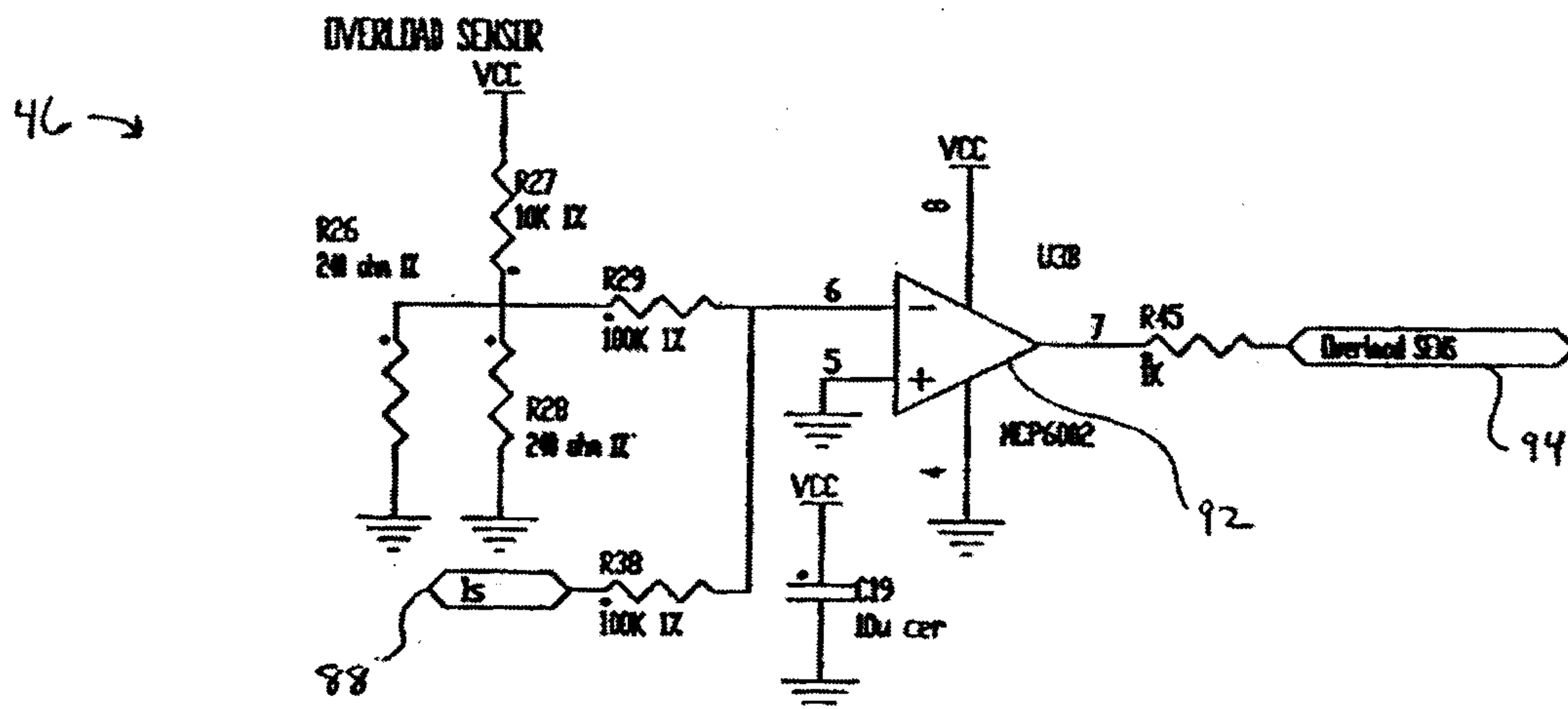


Figure 12

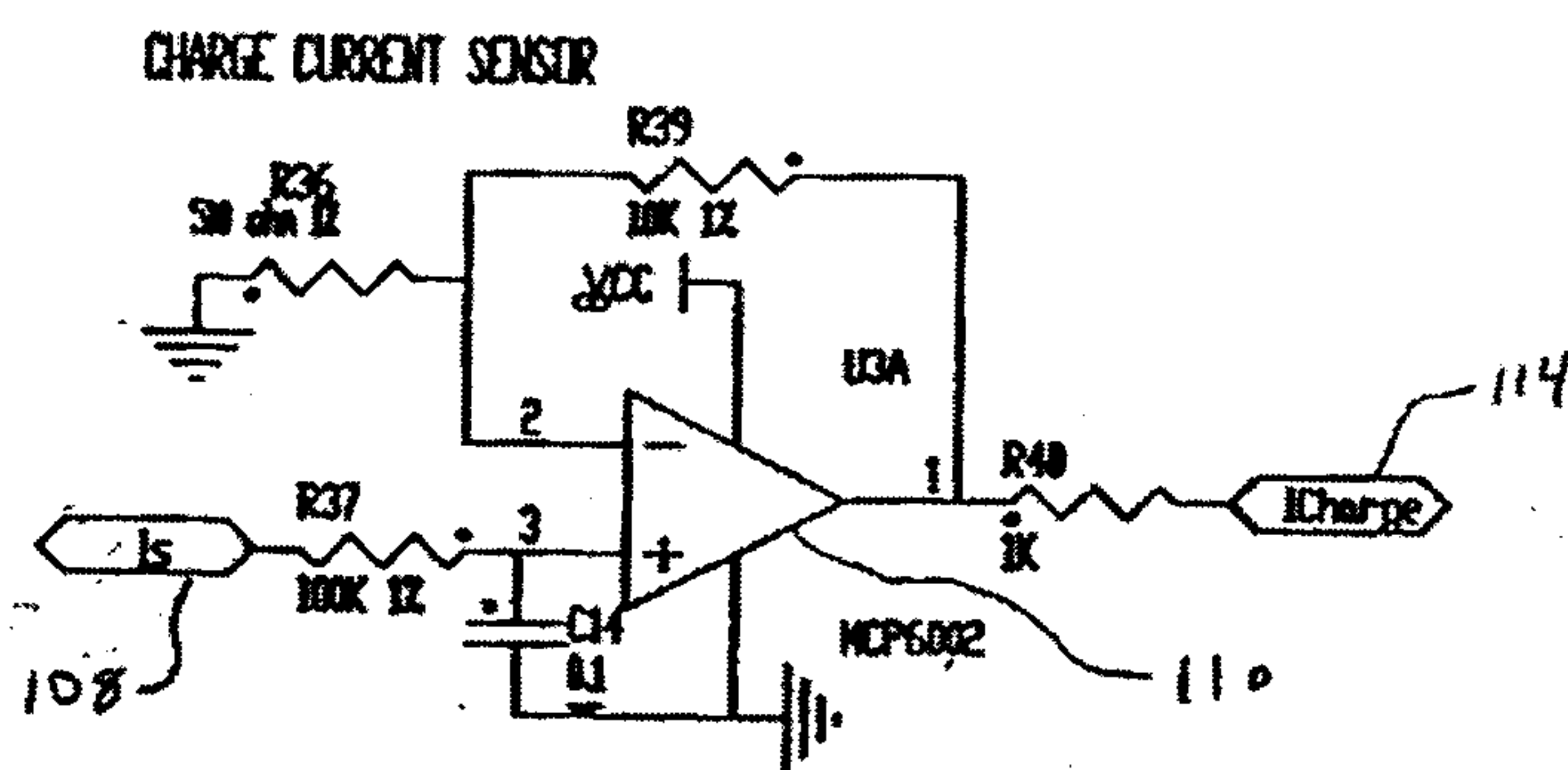


Figure 13

