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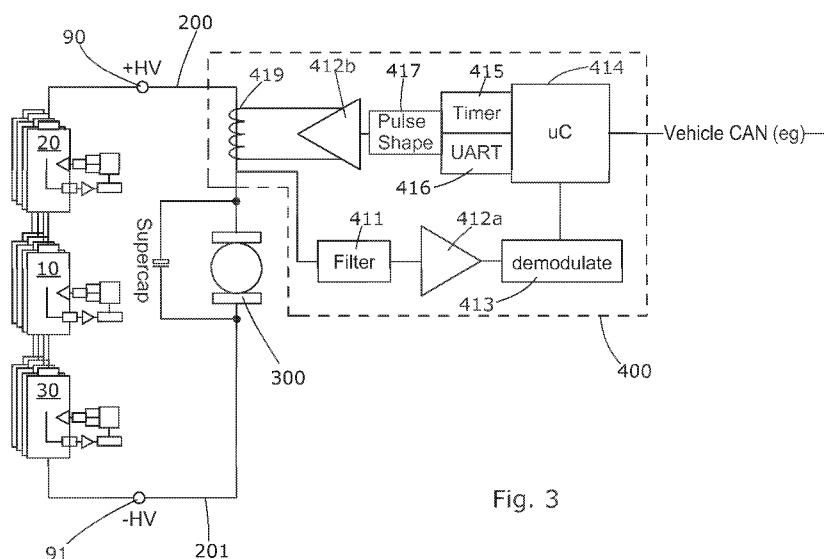


Fig. 3

(57) Abstract: A battery comprising: a positive battery terminal; a negative battery terminal; a plurality of battery cells, each having an anode and a cathode and each connected through a network of electrical connections to the positive and negative terminals, and a monitoring system which is arranged to produce a signal dependent upon at least one parameter of at least one part of the battery and to communicate that signal across the network of connections such that the information can be extracted by monitoring one or more of the voltage and current flowing in the battery terminals.

BATTERY CONDITION MONITORING

This invention relates to improvements in batteries and systems for battery monitoring, especially the monitoring of the condition of the battery which comprises
5 a large battery cell array.

A battery may be defined as one cell, or a collection of electrochemical cells, each of which convert stored chemical energy into electrical energy and so produces an output voltage across its terminals. Within the meaning of this application the term battery
10 refers to a collection of cells, and the term cell refers to a single cell within that collection. A battery will also include many other components, including a housing and where more than one cell is present may also include one or more electrically conductive connections, typically of copper, that connect the cells together electrically and optionally also connects them together thermally.

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Batteries are known using a wide variety of electrochemical cells, but at the time of writing one of the best known and most widely used cells is the lithium-ion cell. The cells are suitable for recharging and are widely used in consumer electronics. One of their key features is a high energy to weight ratio. Recently they have been used for
20 high-load applications, and are used as a source of power for electric vehicles.

A known problem with lithium-ion batteries, and indeed a wide variety of similar battery cells, is that they can overheat if too high a current is drawn. Heat is produced at the anode, and increases as the rate of draw of current increases. This can lead to
25 thermal runaway if the temperature of the battery is allowed to reach too high a level.

To provide enough power for an electric vehicle a battery will have a very large number of cells, often many hundreds or even thousands of cells. This makes it difficult to monitor the temperature of the battery, where it is desirable to monitor the
30 temperature of every cell in the battery to ensure that the cells are not at risk of thermal runaway.

For small batteries with only a few cells it is known to provide a temperature monitoring circuit in which two or more temperature sensors are placed in contact
35 with the battery cells and connected through a rigid lead-frame to a monitoring circuit.

This circuit monitors the temperature, by providing an actual temperature reading or a temperature dependent warning in the event of overheating. It is also valuable to monitor the terminal voltage of the cell.

5

Electric vehicle batteries are constructed from many thousands of cells. One embodiment of these cells is to construct a collection of cells in parallel to increase the capacity and connect sets of these larger cells in series to achieve the desired terminal voltage. For example, a battery may consist of collections of 10-20 cells in parallel, with around 100 of these collections in series. The current practise is to monitor the collections in groups (of approximately 10) and have several battery monitoring units.

For ease of reference, a cell in the rest of this application can be inferred to include a collection of individual cells connected in parallel to form a single larger capacity cell.

For large batteries it has been proposed to provide a plurality of voltage and temperature sensors which are each powered by the cell they are monitoring and connected by a transmitter to a receiver to form a sensor network. In the event that a sensor detects a significant change in temperature or the terminal voltage a message is transmitted across the network.

An object of the present invention is to provide an effective system for monitoring the condition of a battery which comprises multiple cells.

According to a first aspect the invention provides a battery comprising:
a positive battery terminal;
a negative battery terminal;
a plurality of battery cells, each having an anode and a cathode and each connected through a network of electrical connections to the positive and negative terminals, and a monitoring system which is arranged to produce a signal dependent upon at least one parameter of at least a part of the battery and to communicate that signal across the network of connections such that the information can be extracted by monitoring one or more of the voltage and current flowing to/from the battery terminals.

The present invention uses the pre-existing network of connections within a multi-cell battery to transmit a signal dependent upon at least one parameter of the part of the battery to the terminals of the battery from which it can be extracted using a suitable monitoring device, thus eliminating the need for a separate wireless network to carry the information as known from the prior art. The monitoring system may therefore be located, at least in part, internally to the battery alongside or within the network of connections.

10 The at least one parameter may comprise the temperature of the part of the battery, or the voltage present at a point on that part of the battery. For instance, the voltage may be the voltage across a cell or cells, or the voltage representative of an output of the cell, in the battery where the part of the battery comprises a cell or cells. The monitoring means may produce one signal which carries both voltage and temperature information, or two signals, with one carrying temperature information and the other voltage information.

The part of the battery whose temperature and/or voltage the signal from the monitoring means is dependent on may comprise one or more of the following:

- 20 (a) one cell of the battery;
- (b) a plurality of cells, which may or may not be adjacent in the battery, the signal optionally representing an average of the temperature of all of the cells in that part or the temperature of at least one of the cells in that part of the battery;
- (c) one or more of the electrical connections within the battery which are thermally connected to one or more of the cells;
- 25 (d) a structural or non-structural member, within the battery or forming part of the battery housing, which is thermally connected to one or more cells.

The battery may be divided into more than one part, each part being monitored by a respective temperature monitoring means. The components of one part may be shared as components of another part, for example, a common electrical connection or common cell.

It is known, for instance, to provide electrical connections in the form of thermally conductive, and electrically conductive, tracks or cables, and the temperature of a part

of the track or cable will provide an indication of the temperature of the cell or cells connected to the track or cable.

5 The network of electrical connections may comprise a set of conductive cables which connect the cells terminals to the battery terminals, typically with all cells connected in parallel, although another possible implementation would be a collection of series connected cells, each of said collections being connected in parallel. Alternatively or additionally the electrical connections may comprise a lead-frame on which conductive tracks are provided. A mix of lead-frame tracks and conductive cables
10 could be provided. They may comprise copper tracks.

Where the monitoring system monitors temperature, the temperature monitoring system may comprise a temperature monitoring circuit including a temperature transducer which produces an output signal dependent upon the temperature of at least
15 part of a cell, a processor which generates a signal which is modulated with a component dependent upon the output of the temperature sensor, and a coupling means which couples the modulated signal onto the battery connection network so as to modulate the current/voltage flowing in the network of connections.

20 Where the temperature monitoring means is associated with a part of the battery including more than one cell, the temperature of each cell in that part may be measured and transmitted within the signal, or may be measured but only an average transmitted. The temperature of all the cells in that part may be measured and only a subset of the measurements transmitted, so as to allow for the rejection of obviously
25 spurious measurements. The temperature of the cell may be measured directly or the temperature may be measured indirectly.

Where the monitoring system monitors voltage, the voltage monitoring system may comprise a voltage-measuring circuit which produces an output signal dependent on
30 the voltage of the cell, , a processor which generates a signal which is modulated with a component dependent upon the output of the voltage sensor, and a coupling means which couples the modulated signal onto the battery connection network so as to modulate the current or voltage flowing in the network of connections.

The coupling means may couple the modulated signal to the battery connection network in a non-invasive way. It may comprise an inductive type or capacitive type coupler, in which energy is coupled to the network using inductive or capacitive energy transfer.

5

The temperature monitoring circuits may modulate the voltage or current flowing in the network of connectors, although a current modulation scheme is preferred as it is likely to be simpler to implement.

10 The coupling means may modulate the signal pre-existing on the network of connections with a signal in which the temperature and voltage dependent information is contained using a binary phase-shift keyed or frequency-shift keyed encoding scheme.

15 Alternatively it may be arranged to modulate a signal onto the network using a continuous wave modulation scheme. The signal may be arranged to include a portion in which the presence of a carrier wave represents a dominant bit of a signal and absence represents a recessive bit. As described hereinafter this can be used to ensure that there are no conflicts between signals on the network and that the signals are
20 managed in a predictable way.

In a most preferred arrangement, the temperature and/or voltage monitoring means may use a scheme in which the encoded information coupled to the network comprises a first portion indicating the priority of the signal, a second portion representing the
25 encoded signal information, and a third portion containing data suitable for use in error checking and perhaps also, in some arrangements, correction. An additional portion containing a unique identifier for each cell may also be provided. Each portion may include dominant and recessive bits of information. Each portion may comprise one or more bytes of information.

30

The sensors may produce an output signal which is indicative of the temperature and/or voltage or a warning signal to indicate a change which is of interest. For example, a signal may be coupled to the network if the voltage of the cell exceeds a static temperature threshold, or the temperature exceeds a predetermined maximum
35 rate of change, or a combination of one or both of these with other data related to the

cell. Alternatively the "Spanish Inquisition Protocol" as described in Goldsmith, D., and Brusey, J. (2010) 'The 'Spanish inquisition' protocol: Model-based transmission reduction for wireless sensor networks'. *Proceedings of IEEE Sensors*, 'IEEE Sensors'. Held 01-04 Sep 2010 in Hawaii, USA can be used to provide low-bandwidth updates of the continuous
5 state of the cell being monitored.

The temperature and voltage monitoring system may comprise a plurality of temperature and voltage sensors, each associated with a respective cell, each producing an output signal dependent upon the temperature and voltage (or respective
10 histories) of the respective cell, and each associated with a processor which generates a signal which is modulated with a component dependent upon the output of the temperature sensor, and a coupling means which couples the modulated signal onto the battery connection network so as to modulate the current/voltage flowing in the network of connections.

15 Some measure dependent upon the temperature and voltage of each cell of the battery, may therefore be extracted for every cell at the battery terminals.

Each temperature monitoring circuit may be assigned a unique (to that battery or
20 globally) identifier, which may be contained in the identifier encoding portion of any coupled signal.

Alternatively, or additionally, the priority may be set according to the value of the output of the temperature sensor. For example, a severely overheating cell may
25 therefore gain a high priority compared with a cell at a normal temperature.

The processor associated with a temperature and voltage sensor may comprise a microprocessor device, coupled to an area of memory. The system may include a clock or timer connected to the processor.

30 The temperature and voltage monitoring system (and preferably each temperature monitoring circuit) may further include a decoupling means connected to the network of electrical connections, preferably non-invasively, which is adapted to detect signals that have been modulated onto the battery connector network.

35

The temperature and voltage monitoring system may be arranged to read the detected signals and use the information contained in the detected signals to control the timing of the transmission of the temperature dependent modulating signals onto the network. For instance, the processor may cause the temperature monitoring means only to
5 transmit signals onto the network when the detected signal satisfies one or more predefined tests.

These tests may include a test of priority, whereby a signal will not be coupled to the network at a time when a signal from another temperature monitoring device of the
10 battery with a higher priority is already present on the network.

The decoupling means may comprise a non-invasive decoupling device, of the inductive or capacitive type.

15 The processor of the (or each) temperature monitoring circuit, i.e. associated with each cell, may draw power from a respective cell. Alternatively it may be provided with its own dedicated power source such as a small long life battery or capacitor.

Where dedicated battery power sources are provided, it is important that the current
20 drawn in monitoring temperature and sending any required signals across the network is minimised. Care should therefore be taken during the selection of the signal transmission strategy and also the type of signals being transmitted.

The system may therefore employ a protocol such as the "Spanish Inquisition
25 Protocol" described earlier. Although described in the context of wireless networks, the teachings can be readily transferred to the hard-wired network of the battery of the present invention.

According to a second aspect the invention provides a system for monitoring at least
30 one parameter of at least one part of a battery according to the first aspect of the invention, the system comprising:

a monitor connected directly or indirectly to the network of conductors, the monitor being arranged to extract from the network the parameter dependent signals which have previously been coupled to the network by the monitoring system of the battery.

The monitoring system may monitor temperature and/or voltage.

The monitor may be connected to the network of connectors internal to the battery, or may be connected to the battery terminals or to a wire, cable or other conductor which
5 is connected to the battery terminals, i.e. the monitor is located external of the battery. It may therefore form a part of the battery or may be separate from the battery.

The monitor may further be adapted to couple request signals onto the network of electrical connections (either directly or onto cables coupled to the battery terminals),
10 which include information identifying a cell from which temperature dependent information is required by the monitor. It may therefore include a request generating means which generates requests. This may generate requests periodically, perhaps polling all cells in turn over a time and then repeating, or may request information in accordance with known information about the manner and/or environment in which
15 the battery is being operated.

The monitor may include means for measuring the current being drawn from the battery, or for receiving a signal indicative of the drawn current from a current measuring circuit, and may determine which cells, or how when to poll the cells,
20 dependent on the current drawn. For instance, at times of high draw there is a higher risk of overheating so it is more useful to poll the cells than at times of low draw.

In an alternative, the monitor may be adapted to couple acknowledgment signals onto the network of connections in response to extracting a signal from the network which
25 has been sent by a temperature monitoring circuit. The monitor may therefore include a means for generating acknowledgement signals. It may generate signals which encode the identity of the circuit to which the acknowledgement is being sent, perhaps previously extracted from the signal on the network.

30 There will now be described, by way of example only, several embodiments of the present invention with reference to the accompanying drawings of which:

Figure 1 is a general overview of an example of a complete battery and associated monitoring system in accordance with the present invention in a typical automotive
35 application;

Figure 2 is an overview of the circuitry common located at each battery cell of the battery in the system of Figure 1;

- 5 **Figure 3** is an overview of the circuitry common to each of the monitors in the system of Figure 1; and

Figure 4 is general view of an alternative complete battery and associated monitoring system that may be provided within the scope of the invention.

10

A battery monitoring system 100 is illustrated in Figure 1. The system encompasses the components shown within the dashed line in Figure 1. It comprises a battery 1, which may have many hundreds or thousands of electrochemical cells. The battery can be considered to be divided into a number of smaller parts 1,2,3,4,5,6 and 7. Each
15 part may comprise one or more cells of the battery, although it is possible within the scope of the invention for a part to include no cells.

In this example, each part of the battery comprises a single cell and as shown there are seven cells 10, 20, 30,40,50,60 and 70. Each cell has a positive and negative terminal
20 and the terminals of the cells are interconnected through a network of electrical connections 80 to positive and negative battery terminals 90, 91. The electrical connections in this example comprise heavy gauge conductive copper tracks. The battery 1 is connected through a battery wiring loom, perhaps as simple as a single heavy duty electrical cable 200,201 which is connected to a respective one of the
25 terminals. The cables 200,201 are in turn connected to a motor 300 or other electrical load which draws power from the battery 1.

Each part of the battery, in this example each cell 10,20,30,40,50,60,70, is associated with an individual temperature and voltage monitoring circuit
30 110,120,130,140,150,160,170, 1001 and each circuit includes a temperature sensor and voltage sensor, by which we mean a device which produces an output dependent upon the actual temperature of at least part of the cell and the voltage of said cell. Circuitry included in the monitoring circuit associated with each part of the battery, i.e. with each cell, generates a signal within which the battery cell temperature and
35 voltage is encoded and this signal is coupled onto the network and hence onto the

cables 200,201 by a coupling means. Of course, in a modification only temperature or voltage may be monitored, or different sensors which monitor other parameters may be provided.

- 5 The system further includes a monitor 400 which decouples the signals from one of the cables, or any other convenient point in the circuit and from these determines the transmitted temperature information. In the event that this indicates a fault or a risk of a fault, the monitor outputs a suitable warning signal. As shown the monitor is provided with a link to a CAN type bus, whereby the warning signal can be
10 transmitted across the CAN bus.

The system may be fitted to an alternative fuel vehicle, as so-called "hybrid" or a full electric vehicle, in which case the battery 1 will typically provide power to one or more electric motors 300. The monitor may then be fitted to the chassis of the vehicle
15 at a convenient point where the battery wiring can be accessed.

Where the electrical load connected to the terminals of the battery drive through cables is electrically "noisy" such as a heavy duty electric motor, it will generate electrical noise in the cables and in turn in the electrical connections within the
20 battery. This noise will typically vary in frequency up to 1MHz or so after which the noise power density will fall off rapidly. The signals coupled to and decoupled from the network of connections must therefore be suitable for reliably being extracted from the noise.

- 25 The applicant has appreciated that it is possible to modulate either the current or the voltage flowing in the cables connected to the battery terminals (or connector elsewhere to the electrical circuit) at a frequency of (say) a few MHz, with a very small overlaid signal to enable communication to be established. In this invention this is used to monitor the temperature of the cells of the battery.

30

Figure 2 is an illustration of a typical temperature and voltage monitoring circuit 110 associated with one cell 10 of the battery, the other monitoring circuits being the same. The monitoring circuits together form a temperature and voltage monitoring system for all the cells of the battery.

35

An inductive type decoupler, or perhaps a hardwired connection 111 is provided which produces an output dependent on the current or change in current following in the part of the network of connections adjacent the cell 10. The output of the hardwired provides a measure of the voltage of the part of the battery being monitored, and this is fed directly to a microcontroller where it is used to derive the voltage parameter signal. This voltage may also be overlaid with modulated signals from the other monitoring circuits of the battery (where provided) but these will typically be of much lower magnitude, or may be removed by filtering (not shown) as they will be of a higher frequency than that of interest.

10

The output signal from the connection is also passed through a filter 111 which removes the drivetrain noise from the signal – it is matched to the transmission used. This is followed by a first amplifier 112a and a demodulator 113, which allows the microcontroller (uC) 114 to read the bits being transferred from the network. In one embodiment, if the bits received are not the same as the bits transmitted onto the network by the temperature monitoring circuit 110, this means a collision has occurred on the network. The device transmitting dominant bits will “override” the recessive bits, and will therefore carry on regardless. The device(s) who have been overridden will back-off and retry. This is similar bus arbitration mechanism to that used in CAN. This is known as “CSMA/CR with non-destructive bitwise arbitration”.

20

The circuit 110 also includes a timer 115 and UART in the microcontroller 116 which are used to generate a modulated CW signal to be applied the network (in other embodiments with other modulation schemes, other circuitry may be required). The signal is then passed through a pulse shaper 117 which then limits the bandwidth of the signals transmitted to minimise electromagnetic interference. Finally the signal is passed through a second amplifier 112b to an inductive coil 119 which is used to couple the signal onto the network of connections within the battery.

25

The receive filter 111 in this embodiment is a band-pass filter centred around the carrier frequency (say 5MHz) of the signals carried by the network of connections, an amplifier and a simple half-wave rectifier/envelope detector to demodulate into the micro port pin. The diode demodulator produces the "envelope" which is a square wave of the form of the data which was transmitted. The transmit side could be a microcontroller timer for the carrier frequency, gated with the UART output to

30

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generate the pulses for the bits, followed by a differential driver into a coupling onto the battery “wire”.

5 The temperature in this example is measured using any standard temperature measurement transducer 118 which outputs a signal to the microcontroller 114. The voltage is measured directly or indirectly (possibly via some scaling means) by the microcontroller.

10 Figure 3 is an illustration of a typical monitor of the system of Figure 1. The parts are essentially the same as those of the temperature sensing circuit described above and shown in Figure 2. A hardwired connection is provided which produces an output dependent on the current or change in current following in the part of the network of connections adjacent the monitor. The output signal from the connection is passed through a filter 411 which removes the drivetrain noise from the signal – it is matched
15 to the transmission used. This is followed by a first amplifier 412a and a demodulator 413, which allows the microcontroller (uC) 414 to read the bits being transferred from the network. The monitor 400 also includes a timer 415 and UART in the microcontroller 416 which are used to generate a modulated CW signal to be applied the network (again in other embodiments with other modulation schemes, other
20 circuitry may be required). The signal is then passed through a pulse shaper 417 which then limits the bandwidth of the signals transmitted to minimise electromagnetic interference. Finally the signal is passed through a second amplifier 412b to an inductive coil 419 which is used to couple the signal onto the network of connections within the battery. The transmitted signals may be used to request information from
25 specific cells in the battery.

It is envisaged that the system could be arranged to transmit and read signals to/from the battery wiring loom using one, or a combination, of different strategies (not all “at once” necessarily), the common link being a preferred non-physical coupling of
30 signals to and from the network of electrical connections or other part of the battery circuit:

Strategy 1) A Req-ack strategy– In this strategy the monitor applies a signal to the network requesting the temperature of a specific cell. Each temperature monitoring
35 circuit has a unique identifier, so it can determine whether or not the associated cell is

the one that has been requested by decoupling the request from the network. It will then send a response encoding the temperature of the associated cell.

5 Strategy 2) A periodic transmission strategy – In this scheme the temperature monitoring circuit associated with each cell will periodically couple a signal encoding its temperature onto the network. Care has to be taken that only one signal is transmitted at once, by selection of the transmission times (perhaps synchronised to a global clock) or that the signals can co-exist on the network.

10 Strategy 3) An event driven strategy – In this strategy the temperature monitoring circuits will only couple a signal to the network when a significant event, such as a large change in temperature, occurs.

For an embodiment that falls within strategy 1), the access is mediated by the monitor,
15 so only one slave will attempt to transmit at any one time.

For an embodiment that falls within strategy 2) and/or strategy 3) the monitor will require multiple access to the signals on the network, which will require the temperature monitoring circuits to mediate amongst themselves. Two potential
20 solutions are Carrier sense multiple access collision detection (CSMA)/CD (like Ethernet), or a collision recovery CSMA/CR solution. The latter is preferred as it avoids retransmits when collisions occur, and reduces the total bandwidth required. It allows high-priority messages to continue transmitting through a collision.

25 Strategy 3) will preferably also include a means for acknowledgement of transmission (ACK) from the monitor back to the temperature monitoring circuit that sent a signal to allow retries if a critical message is lost – 2) may require this. In the case of 1) the monitor can actively request a re-transmission

30 Strategies 2) and 3) therefore require much simpler receiving circuitry at the temperature monitoring circuits of each cell (just detecting an ACK from the monitor) 1) requires a true “data carrying” link across the network of connections.

Having chosen which signal strategy is to be used, the applicant has appreciated that
35 the system can apply the signals to the wiring loom in a variety of different forms,

depending on the configuration of the temperature monitoring circuit associated with each cell. A non-exhaustive list of preferred signal types is as follows:

For strategy 1) it is possible to use binary phase-shift keying (BPSK) or frequency-shift keying (FSK) for encoding information in the coupled signals carried on the network. In one arrangement it is proposed to use BPSK for the signals sent from the temperature monitoring circuits to the monitor (higher bandwidth), and FSK- which is easier to demodulate- for the request signals sent from the monitor to the temperature monitoring circuits.

10

Strategy 1) is only of benefit if the controller has enough knowledge to request data from the cells at lower rates than Strategy 2) would otherwise have them periodically transmit as. This is because the request messages will use valuable bandwidth on the bus, so for frequent updates, it becomes more efficient simply to allow the cells to transmit on a regular cycle.

15

For strategies 2) and 3), it is possible to use a continuous wave (CW) modulation scheme to encode signals sent from the temperature monitoring circuits, whereby the presence of a carrier indicates a dominant bit (in CAN terminology), and the absence of a carrier indicates a recessive bit. This is much less bandwidth efficient than the, previously suggested FSK and BPSK schemes, but is much simpler to implement. For strategy 3 where only infrequent event updates are used, the bandwidth requirements are much lower than for strategy 1) or 2).

20

Figure 4 shows an alternative arrangement of a battery 900 and monitoring apparatus. Where the same components used in the first embodiment are used with this battery the same reference numerals have been used for clarity.

25

The battery comprises a housing and a plurality of cells 601-608, of which 8 are shown. The battery is split up conceptually into 4 parts 500, 510, 520, 530, each part comprising two of the eight cells. All the cells are connected electrically to electrical connection 800 which comprises a rigid copper lead frame. Each of the parts is supported by a thermally conductive support member 920, 930, 940, 950 that is molded into the housing 910. Each part also includes a temperature monitoring circuit

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700,710,720,703 which produces a signal indicative of the temperature of each respective part of the battery 900.

5 For three of the parts 520, 530,540 the temperature monitoring circuit monitors the temperature of a part of the electrical connection 800 closest the respective cells. Because the thermal conductivity of the electrical connection is high, and because it is relatively massive compared with the cells, the temperature of the electrical connector provides a reasonable indication of the temperature of the cell or cells connected to it.

10 In this alternative arrangement, one part 510 of the battery 900 the temperature of the support part provides an indication of the temperature of the supported cells, and the temperature monitoring circuit provides an output signal indicative of the temperature of the support part and transmits it along the electrical connections of the battery to the terminals.

15

Of course, many other arrangements of battery may be provided and the two illustrated embodiments should not be considered to be limiting to the scope of the protection sought, which is defined by the claims.

CLAIMS

1. A battery comprising:
a positive battery terminal;
5 a negative battery terminal;
a plurality of battery cells, each having an anode and a cathode and each connected through a network of electrical connections to the positive and negative terminals, and a monitoring system which is arranged to produce a signal dependent upon at least one parameter of at least one part of the battery and to communicate that signal across the
10 network of connections such that the information can be extracted by monitoring one or more of the voltage and current flowing in the battery terminals.
2. A battery according to claim 1 in which the network of electrical connections comprises one or more of a set of conductive cables which connect the cells terminals
15 to the battery terminals and a lead frame on which conductive tracks are provided.
3. A battery according to claim 1 or claim 2 in which the part of the battery comprises one or more of the following: a single cell; a plurality of cells; a portion of electrical connection thermally connected to at least one cell, and a non-structural or
20 structural member that is thermally connected to one or more cells.
4. A battery according to claim 1,2 or 3 in which the parameter monitored by the monitoring system comprises at least one of temperature and voltage.
- 25 5. A battery according to claim 1, 2, 3 or 4 in which the monitoring system comprises a plurality of monitoring circuits, each associated with a respective part of the battery and each comprising a transducer which produces an output signal dependent upon the temperature and/or voltage of at least part of an associated cell, a processor which generates a signal which is modulated with a component dependent
30 upon the output of the sensor(s), and a coupling means which couples the modulated signal onto the battery connection network so as to modulate the current/voltage flowing in the network of connections.
6. A battery according to claim 5 in which the coupling means is arranged to
35 couple the modulated signal to the battery connection network in a non-invasive way.

7. A battery according to claim 4 or claim 5 in which the temperature and/or voltage monitoring circuits in use modulate the voltage or current flowing in the network of connectors.

5

8. A battery according to claim 5,6 or 7 in which the coupling means is arranged to modulate the signal pre-existing on the network of connections with a signal in which the temperature and/or voltage dependent information is contained using a binary phase-shift keyed or frequency-shift keyed encoding scheme or using a continuous wave modulation scheme.

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9. A battery according to claim 8 in which the signal includes a portion in which the presence of a carrier wave represents a dominant bit of a signal and absence represents a recessive bit.

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10. A battery according to claim 8 or claim 9 in which the temperature monitoring circuit uses a scheme in which the encoded information coupled to the network comprises a first portion indicating the priority of the signal, a second portion representing the encoded temperature dependent information, and a third portion containing data suitable for use in error checking and/or correction.

20

11. A battery according to claim 10 in which the signal further includes an additional portion containing a unique identifier for each cell.

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12. A battery according to any one of claims 5 to 11 in which the temperature transducer produces an output signal which is indicative of the temperature or a warning signal to indicate a thermal change which is of interest.

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13/ A battery according to any one of claims 5 to 12 in which the voltage transducer produces an output signal which is indicative of the voltage or a warning signal to indicate a thermal change which is of interest.

14. A battery according to any one of claim 4 to 13 in which the monitoring circuit associated with each part of the battery further includes a decoupling means connected to the network of electrical connections, preferably non-invasively, which is adapted to detect signals that have been modulated onto the battery connector network.

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15. A battery according to claim 14 in which each monitoring circuit is adapted to read the detected signals and use the information contained in the detected signals to control the timing of the transmission of the temperature dependent modulating signals onto the network.

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16. A system for monitoring a parameter of a battery according to any one of claims 1 to 15, the system comprising:

a monitor connected to a conductor which is connected directly or indirectly to the network of connections of the battery, the monitor being arranged to extract from the network signals dependent on the parameter to be measured which have previously been coupled to the network by the monitoring system of the battery.

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17. A system according to claim 16 in which the monitor is further adapted to couple request signals onto the network of electrical connections (either directly or onto cables coupled to the battery terminals), which include information identifying a cell from which temperature dependent information is required by the monitor.

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18. A battery, or system for monitoring the temperature or voltage of a battery, substantially as described herein with reference to and as illustrated in the accompanying drawings.

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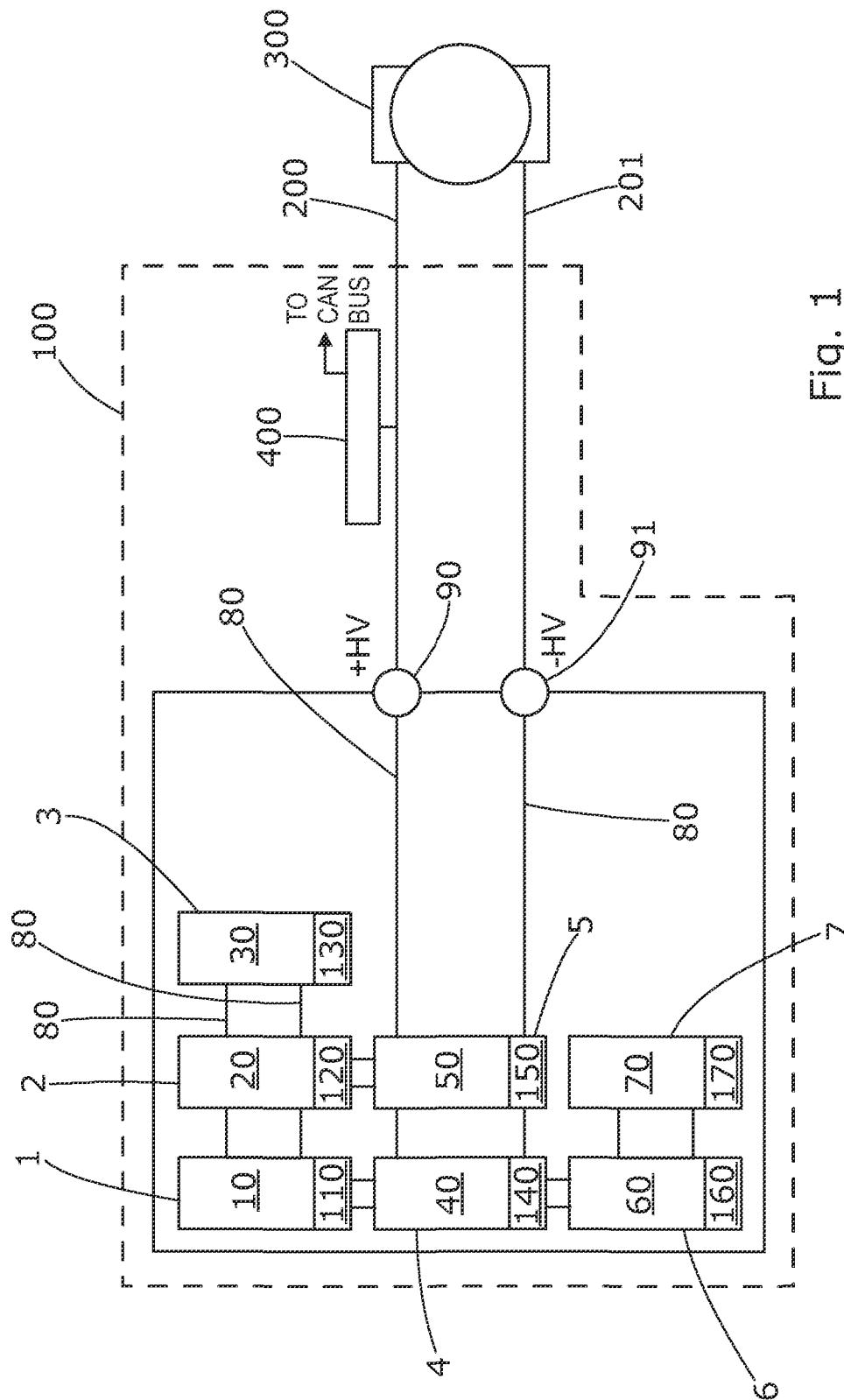


Fig. 1

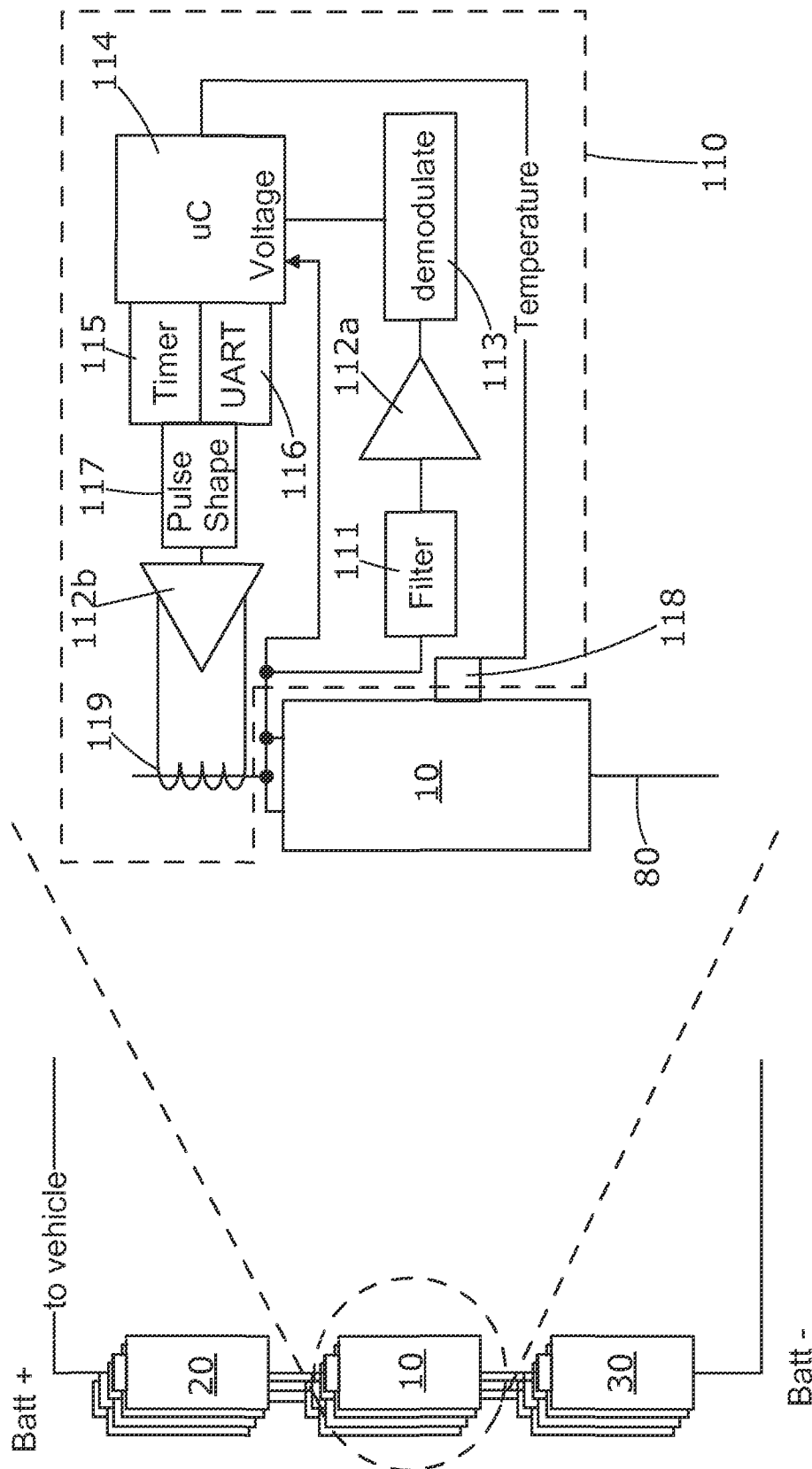


Fig. 2

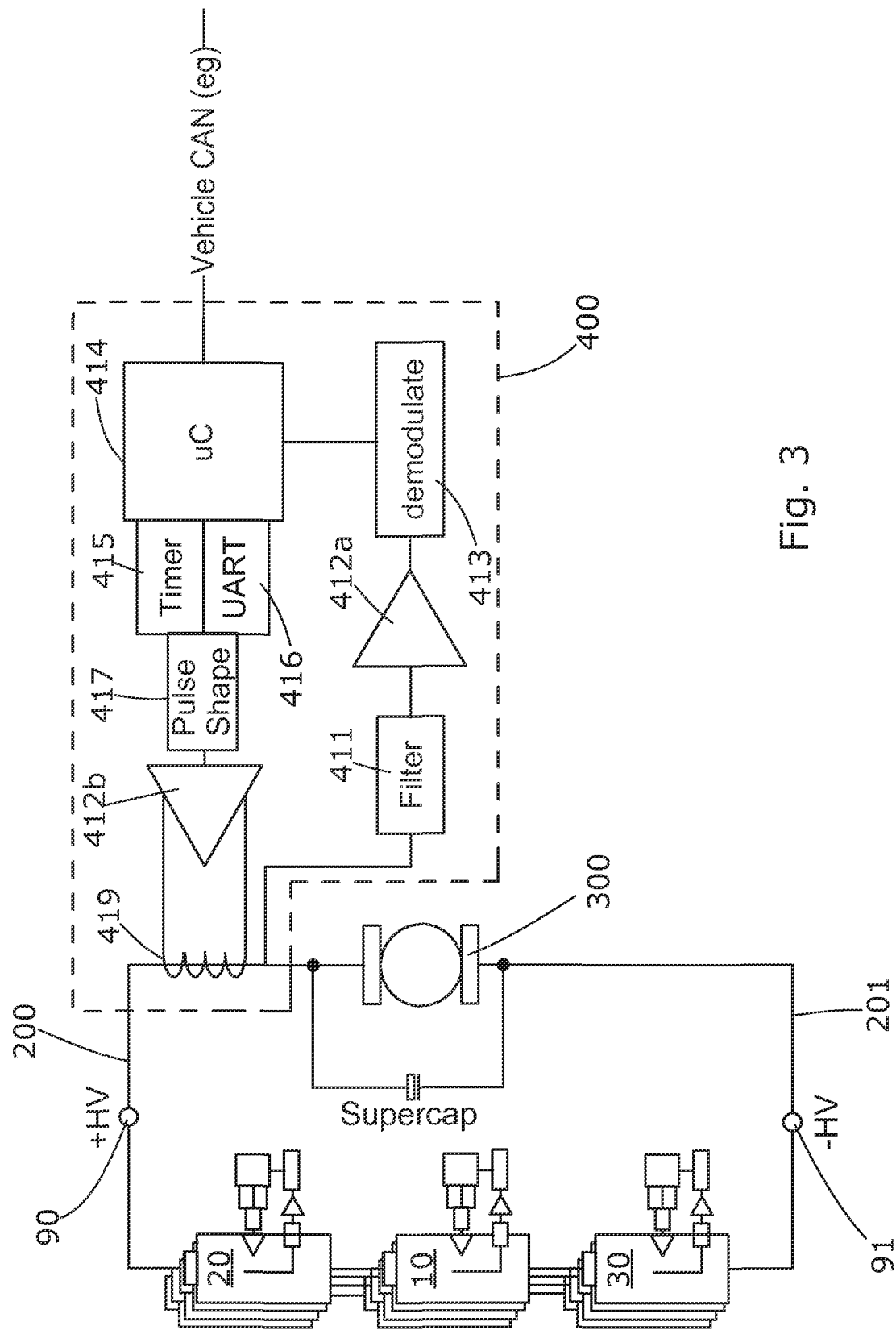
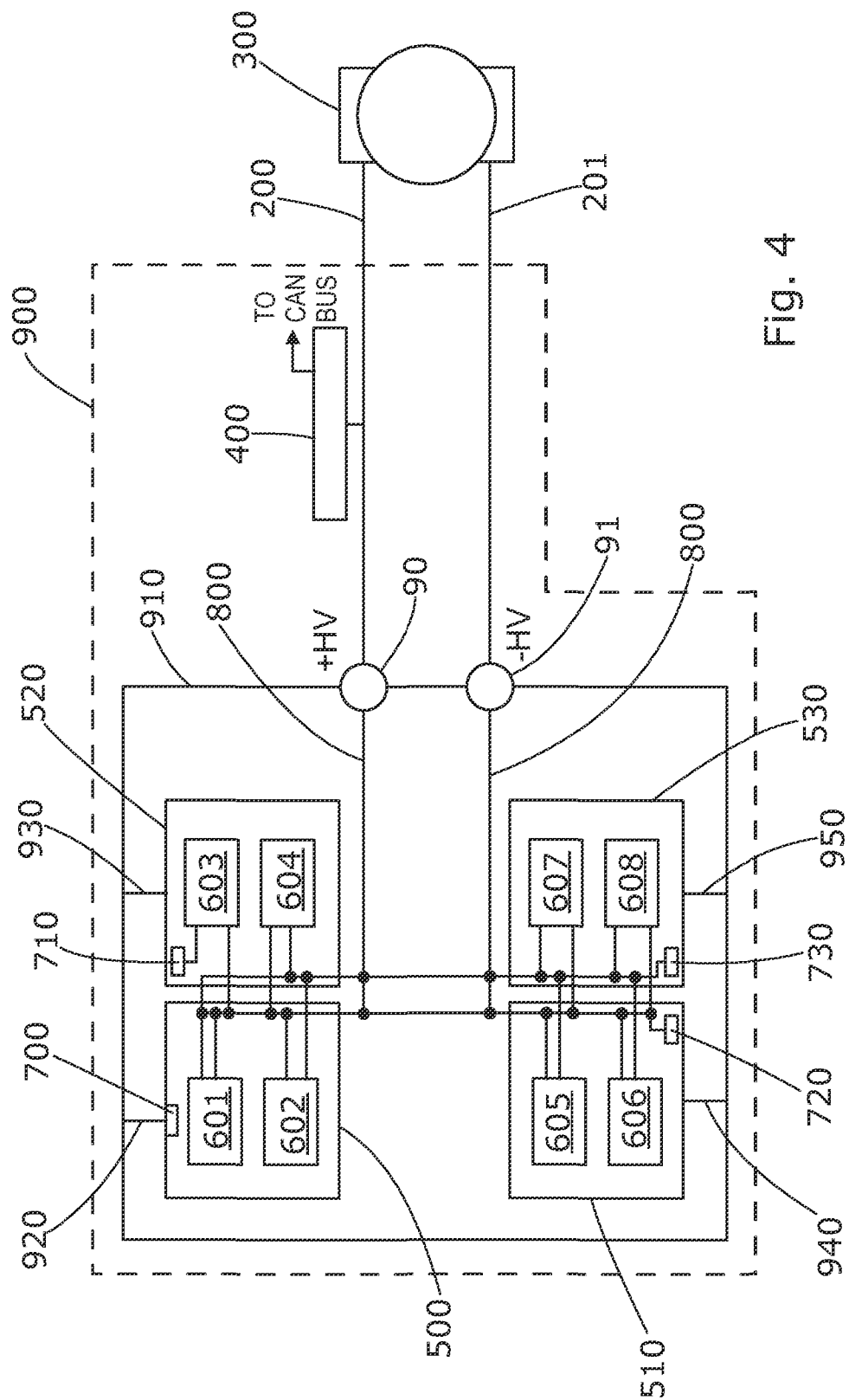


Fig. 3



INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2011/052536

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01M10/48 G01R31/36
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01M G01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2008/118819 A1 (GAMBOA PAUL [US] ET AL) 22 May 2008 (2008-05-22)	18
A	the whole document	1-17
X	US 2010/079146 A1 (KUROSE DAISUKE [JP] ET AL) 1 April 2010 (2010-04-01)	18
A	the whole document	1-17
X	US 2005/077878 A1 (CARRIER DAVE [US] ET AL) 14 April 2005 (2005-04-14)	18
A	the whole document	1-17



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search

29 February 2012

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2011/052536

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