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(71) Applicant: **Magneti Marelli S.p.A.**
20011 Corbetta (MI) (IT)

(72) Inventors:
- **CUCINOTTA, Francesco**
  I-20011 Corbetta (Milano) (IT)
- **COSTA, Daniele**
  I-20011 Corbetta (Milano) (IT)

(74) Representative: **Crovini, Giorgio**
Buzzi, Notaro & Antonielli d'Oulx S.r.l.
Via Maria Vittoria, 18
10123 Torino (IT)

(54) TELEMATIC BOX DEVICE FOR MOTOR VEHICLES

(57) Described herein is a telematic-box device for motor vehicles that comprises a module for connection to mobile-communication networks (50), a satellite location module (40), and a sensor (70; 71) configured for detecting the acceleration and braking parameters of the motor vehicle. The device (10) comprises autonomous supply means, of the type including a rechargeable accumulator (17') integrated in the telematic box (10) and a microcontroller module (11) configured for managing at least the module for connection to mobile-communication networks (50), the satellite location module (40), and the sensor (70; 71), it being possible to set the microcontroller module (31), the module for connection to mobile-communication networks (50), the satellite location module (40), and the sensor (70; 71) selectively between an active-operation mode and one or more reduced-operation modes in which they implement saving of energy as compared to the active-operation mode.

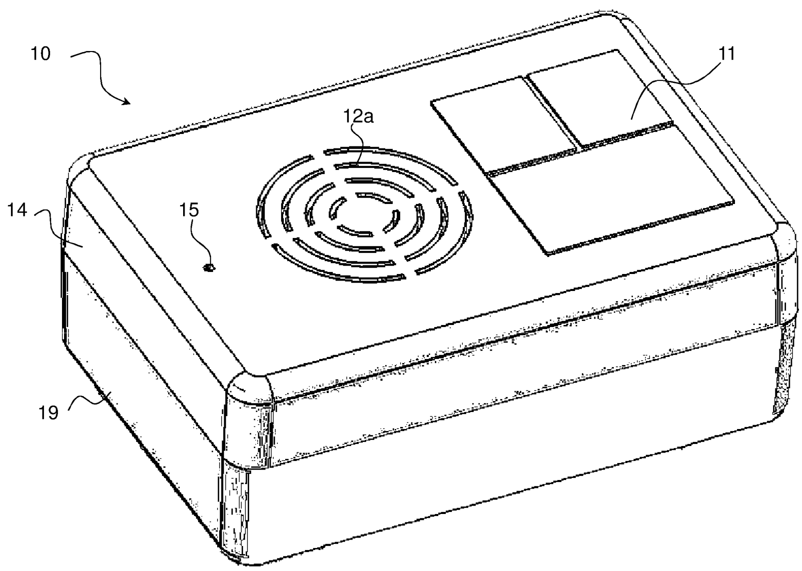


Fig. 1

EP 3 021 290 A1

Description

[0001] The present invention relates to a telematic-box device for motor vehicles that comprises a module for connection to mobile-communication networks, a satellite location module, and a sensor configured for detecting the acceleration and braking parameters of the motor vehicle.

[0002] In the automotive sector, telematic-box devices for motor vehicles are known. The telematic box is in general an electronic control unit that integrates a telephone module for connection to the cellular communication networks, a module for multiconstellation satellite location (for example, GPS, Galileo, GLONASS), and a triaxial accelerometer for detecting the acceleration and braking parameters of the vehicle.

[0003] The possibility of detecting simultaneously the position and operating data of the vehicle and of sending and receiving information from outside thanks to the mobile-communication module, for example GSM, enables the telematic box to perform different functions and applications of location, safety, and info-mobility and enables the vehicle and the driver to gain access to services linked to smart management of mobility. The telematic box may be used, for example, as black box for insurance services, management of fleets, tracking of vehicles, infologistics, car pooling, e-call, i.e., automatic emergency calls in the event of accident or turning-over of the vehicle, e-toll, i.e., telematic payment of tolls or other road services, remote diagnosis, i.e., remote monitoring of operation of the vehicle that enables a central infrastructure to identify possible failures or faults, as well as acquisition of information, for example on car parks, CTZs, traffic, and road conditions.

[0004] The above telematic-box device, on account of its high energy consumption, is normally connected, via wiring, to the battery of the motor vehicle. This, however, leads to drawbacks in its installation on the vehicle.

[0005] The object of the present invention is to provide an improved device that will enable a greater freedom of installation of the telematic-box device on the motor vehicle.

[0006] According to the present invention, the above object is achieved thanks to a device as well as to a corresponding method having the characteristics recalled specifically in the ensuing claims.

[0007] The invention will now be described with reference to the annexed drawings, which are provided purely by way of non-limiting example and in which:

- Figure 1 is a schematic perspective view of a device described herein;
- Figure 2 is an exploded view of the device of Figure 1;
- Figures 3A and 3B are circuit diagrams of the electronic parts and the parts for supply of the device of Figure 1;
- Figure 4 is a diagram representing a method for managing energy implemented by the devices described herein;
- Figure 5 is a schematic perspective view of an alternative embodiment of the device described herein;
- Figure 6 is an exploded view of the device of Figure 5;
- Figure 7 represents a principle circuit diagram of the power-supply parts of the device of Figure 5;
- Figure 8 illustrates a flowchart of a procedure for acquisition of measurements implemented by the device of Figure 1 or Figure 5;
- Figure 9 represents a flowchart of a detection procedure implemented by the device of Figure 1 or Figure 5; and
- Figure 10 illustrates a state diagram of an installation procedure of the device of Figure 1 or Figure 5.

[0008] In brief, the solution according to the invention regards a telematic-box device for motor vehicles comprising autonomous supply means, of the type including a rechargeable accumulator, sized for supplying autonomously energy for a given time, this given time differing according to the application and the conditions of use.

[0009] The device comprises a module for connection to mobile-communication networks, a satellite location module, and a sensor configured for detecting the acceleration and braking parameters of the motor vehicle, where the microcontroller module is configured for managing at least the module for connection to mobile-communication networks, the satellite location module, and the sensor, it being possible to set the aforesaid microcontroller module, module for connection to mobile-communication networks, satellite location module, and sensor selectively in an active-operation mode and in one or more reduced-operation modes in which they implement saving of energy as compared to the active-operation mode.

[0010] In variant embodiments, this rechargeable accumulator is associated, in a relationship of energy exchange, with a solar panel integrated in the telematic box and sized for supplying energy for a given time in the absence of collection of solar energy by the solar panel, this given time differing according to the application and the particular conditions of use.

[0011] In various embodiments, a method for managing energy is provided, which comprises procedures for managing energy that depend upon design parameters of hardware components of the telematic box. This method enables the telematic box to support the main functions for a time range comparable to that of telematic boxes connected in wired mode to the power supply of the motor vehicle.

[0012] In various embodiments, the telematic-box device is configured for being installed on the windscreen of the vehicle. This is favoured by the absence of connection wiring, in particular dedicated and protected wiring, with the motor vehicle, whether for power supply or for other purposes.

[0013] In various embodiments, the telematic-box device comprises a microcontroller module configured for acquiring data of the acceleration and braking sensor and for carrying out operations of analysis on the data acquired from the sensor.

[0014] In various embodiments, the sensor configured for detecting the acceleration and braking parameters of the motor vehicle is configured for storing samples detected in buffers of its own and for notifying via interrupts to the microcontroller that a number of samples in these buffers has reached a given threshold, and the microcontroller module is configured for acquiring data of the sensor by activating, upon reception of the above notification, transfer of data.

[0015] In various embodiments, the microcontroller is configured for using a DMA (Direct Memory Access) controller of its own to gain access to the buffer of the sensor and remains in the reduced-operation mode for the entire duration of data transfer from the buffer.

[0016] In various embodiments, the microcontroller is configured for carrying out an operation of crash detection, which comprises carrying out, at regular time intervals, the operation of analysis on a stored set of data detected by the sensor configured for detecting the acceleration and braking parameters so as to detect possible crash events.

[0017] In various embodiments, the microcontroller is configured, in the case where the operation of analysis identifies a crash event, for storing for a time interval prior to the event and a time interval after the event, the data detected by the sensor.

[0018] The configurations described above of the microcontroller and of the acceleration and braking sensor enable measurements and detections to be made, in particular detection of crash events, with a very low energy consumption, with evident advantages for an autonomous-supply device, both as regards the device in itself and in the framework of the energy-management method referred to above.

[0019] In various embodiments, the telematic-box device may in any case comprise a connection for external supply, for example for connection to the electric power supply of the motor vehicle, in particular a micro-USB connector.

[0020] Illustrated in Figure 1 is a perspective view of a telematic-box device 10 that comprises a keypad 11 and output openings 12a for a speaker 12.

[0021] Figure 2 is an exploded view of the telematic-box device 10, which comprises from the top down:

- the keypad 11;
- light guides 13;
- a top half-shell 14;
- a filter 15a for an aeration hole 15, the filter 15a being obtained via a disk of waterproof material that is, however, transpirant to prevent condensation phenomena;
- the speaker 12;
- a printed circuit 16 comprising a telematic-box electronic module 30;
- a rechargeable battery 17, for example an NiMh 3xAAA battery, or else a lithium battery;
- a solar panel 18, for example a solar panel made of monocrystalline silicon;
- a bottom half-shell 19, provided with a window 19a so as to enable the light to reach the panel 18; and
- fixing screws 20 for fixing the bottom half-shell 19 to the top half-shell 14 to form a closed box.

[0022] Figure 3A illustrates in detail the telematic-box electronic module 30.

[0023] The telematic-box electronic module 30 comprises a microcontroller 31. Designated by 40 is a satellite location module, in particular a GPS module, which is associated to a GPS antenna 41, via a linear amplification module 41a. The location module 40 sends via a serial port (UART - Universal Asynchronous Receiver-Transmitter) to the microprocessor 31 information regarding position, state of reception of the signal, etc.

[0024] Designated by 50 is a module for communication with a mobile-communication network, in particular a GSM modem, associated to a mobile communications antenna 51 of the internal type. The communication module 50 is interfaced in signal-exchange relationship with the microcontroller 31 to enable transmission and reception of signals, in particular on a port 31a that is preferably a UART port. The communication module 50 may comprise a SIM (Subscriber Identity Module) 50a, or also SIMs on-chip. Designated by 52 is an audio connector, in particular with HMI (Human Machine Interface), to enable sending at output, in particular through an audio amplifier 52a, of the audio signals of the communication module 50, for example to the speaker, and reception at input for example of audio signals coming from a microphone so as to be able to implement voice communication services. The communication module 50 is supplied by a reduced voltage VR, in particular 3.8 V, which is raised, in the example described, via a boost conversion circuit 50c.

[0025] Designated by 60 is a second short- or medium-range wireless communication module, in particular a Bluetooth LE (Low Energy) module with a corresponding Bluetooth antenna 61.

[0026] Designated by 70 is a set of movement and impact sensors, which comprises an accelerometer 71 of the triaxial type, with an output range of +-16g. The set of movement sensors 70 is represented as also comprising two elements that in various embodiments may be optional, namely, a gyroscope 72 and a 24-g accelerometer 73, which needs need to be power supplied. The set of sensors 70, in particular the accelerometer 71 communicates with the microcontroller 31 via an interface bus 31c, which is in particular an SPI (Serial Peripheral Interface) bus.

[0027] Designated by 80 is an input port connected to a USB interface 31e of the microcontroller 31. Designated by 90 is a flash memory associated to the microcontroller 31, in particular through the SPI bus 31c.

[0028] A main connector 100, of which four pins are illustrated even though normally there are six of them, enables access from outside to GPIO (General-Purpose Input/Output) ports 31b of the microcontroller 31 following upon the signal Key In, generated by insertion of the key in the dashboard, as well as to a 1-Wire bus 101 (optional) implemented through a UART port 31a for 1-Wire bus, and comprises a safety latch/low-side output relay, for example for an engine-blocking function, governed by the GPIO interface 31b of the microcontroller 31. Using the 4-pin main connector 100 it is possible to connect, in the telematic-box electronic module 30, the battery voltage V_{BAT} of the vehicle. The 1-Wire bus is used, for example, for diagnostics or for communication to peripheral devices. This connector 100 may not be present in variant embodiments with solar panel, but is present in the battery-powered embodiment of Figures 5-7.

[0029] Designated by 110 is a JTAG connector for access via a JTAG port 31d, as well as via a UART 31a, to carry out tests on the microcontroller 31. The microcontroller 31 moreover drives a buzzer 111, for issuing signals through the speaker 12, and a LED 112, which enables lighting of the keypad 11 from inside through the light guides 13. The LED 112 and the buzzer 111 are mounted and managed only in the voiceless version (without HMI).

[0030] Designated moreover by 31g is an I2C-bus port, whereas designated by 31f is an input of an analog-to-digital converter, sent to which are signals representing parameters PK regarding the battery 17, such as the battery temperature and the indicator of the battery level of the module 122, described in what follows. Other signals are then sent to the GPIO ports 31b, such as interrupts generated by the acceleration sensor 71 or by the gyroscope 72, whereas, through GPIO outputs 31b, the microcontroller 31 controls, for example, operation of a battery charger 130 and of a battery-control module 131 described with reference to Figure 3B. The GPIO outputs 31b are used, for example, for enabling recharging from the solar panel or from USB, and for enabling the 1-Wire interface.

[0031] Figure 3B illustrates a supply portion 30a of the telematic-box electronic module 30, which comprises on one side the backup battery pack 17, connected through a battery connector 121, along which there may be inserted a connection with a battery-level indicator 122, to a linear regulator 123, which is a low-consumption linear regulator (quiescent current < 1 μA) for supplying a regulated supply voltage Vcc, and to a battery charger 130. The battery charger 130 comprises an input 130a for 5-V USB supply and optionally a connection, via a DC-DC converter 132, to the battery voltage V_{BAT} of the motor vehicle. Also inserted along the connection to the backup battery pack 17 is a battery-control module 131, which measures parameters PK of the battery 17, such as the temperature, and supplies them to the analog-to-digital inputs 31f and to the GPIO interfaces 31b of the microcontroller 31. On this line the 3.8-V reduced voltage VR is also picked up.

[0032] Furthermore, the battery pack 17 is charged by the solar panel 18, which, via a solar-panel connector 151 is connected to a converter 140 for sending a charging voltage to the backup battery pack 120. The converter 140 is a device based upon an operation of a switching type with integrated MPPC (Maximum Power Point Controller) control for optimizing the energy supplied by the solar panel.

[0033] In variant embodiments, the telematic-box device described herein may comprise other types of autonomous supply means, other than the solar panel. In particular, in alternative embodiments of the device described herein, the telematic-box device may comprise only a primary battery, preferably rechargeable, but may not comprise the panel 18.

[0034] Figure 5 illustrates in this regard a perspective view of a telematic-box device 10' that comprises a substantially C-shaped top lid 14', which, with a bottom lid 19' having a complementary C-shape, forms a substantially cubical box, when the two lids 14' and 19' are assembled together. Present on the top lid 14' is a window 13a for a light guide 13, visible in the exploded view of Figure 6 of the telematic-box device 10', which comprises from the top down:

- the top lid 14';
- a light guide 13';
- a printed circuit 16' comprising a telematic-box electronic module 30'; the light guide 13 is positioned for conveying light from LEDs present on the printed circuit 16';
- a rechargeable battery 17', for example an NiMh 3xAAA battery, or else a lithium battery;
- the bottom lid 19'; and
- fixing screws 20' for fixing the bottom lid 19 to the top lid 14' on the sides to obtain a closed cubical box, or, in variant embodiments, a parallelepipedal box.

[0035] The rechargeable battery or accumulator 17' is sized for supplying autonomously energy for a given time, this given time differing according to the application and conditions of use.

[0036] The telematic-box electronic module 30' substantially corresponds to the telematic-box electronic module 30 described with reference to Figure 3A. The telematic-box electronic module 30' substantially has the same components as those represented in Figure 3A and described with reference to Figure 3A. The telematic-box electronic module 30' has, instead, a supply portion 30a' that differs in part from the supply portion 30a represented in Figure 3B. This supply portion 30a' of the telematic-box electronic module 30' is represented in Figure 6.

[0037] Figure 6 illustrates the supply portion 30a' of the telematic-box electronic module 30'. The components that have functions corresponding to those of Figure 3B are designated by the same reference numbers. The supply portion hence comprises a rechargeable battery 17', connected through the battery connector 121, along which there may be inserted a connection with the battery-level indicator 122, to the linear regulator 123, which is a low-consumption linear regulator (quiescent current < 1 pA) for supplying a regulated supply voltage Vcc, and to the battery charger 130. The battery charger 130 comprises an input 130a for 5-V USB supply and optionally the connection, via DC-DC converter 132, to the battery voltage V_{BAT} of the motor vehicle. Also inserted along the connection to the rechargeable battery 17' is a battery-control module 131, which measures parameters PK of the battery 17', such as the temperature, and supplies them to the analog-to-digital inputs 31f and to the GPIO interfaces 31b of the microcontroller 31. On this line the 3.8-V reduced voltage VR is also picked up.

[0038] Operation of the telematic-box electronic module 30', apart from the fact that it has a rechargeable battery instead of the solar panel, is similar to that of that of the telematic-box electronic module 30, and the components, such as the microcontroller 31, the location module 40, the communication module 50, the wireless module 61, and the set of sensors 70, have the same characteristics; in particular, they each comprise at least one active mode, in which they are fully operative, and one or more reduced modes, in which they operate with reduced functionality.

[0039] Described in detail in what follows are aspects of operation of the different modules, in particular with reference to energy saving. These aspects are common both to the embodiment of telematic-box device 10 with solar panel 18 described with reference to Figures 1-3, and to the embodiment of telematic-box device 10' with just the rechargeable battery 17' described with reference to Figures 5-7.

[0040] For simplicity of exposition, reference will be made to just the components of the telematic-box device 10, but it is clear that the description may also refer to the components of the telematic-box device 10' that have equivalent function.

[0041] The microcontroller 31, of an EFM32GG type manufactured by Energy Micro, is configured for operating at different clock frequencies. Since the consumption in general rises with the clock frequency, by varying this frequency energy consumption can be controlled. In particular, the microcontroller 31 is configured for having a plurality of operating modes, five in the example described herein, which make it possible to enable a decreasing number of peripheral functions, starting from an active mode or run mode (EM0), where the microcontroller 31 is fully operative, to a first reduced mode EM1, a second reduced mode EM2, a third reduced mode EM3, and finally a fourth reduced mode EM4, where progressively fewer functions are enabled. The consumption of the microcontroller decreases or increases according to the operating mode selected.

[0042] By way of example, in the first reduced mode EM1, the CPU of the microcontroller 31 is in sleep mode, but the peripherals are available, including the DMA controller, the PRS (Peripheral Reflex System), and the memory system. In the second reduced mode EM2, which is a deep-sleep mode, the high-frequency oscillator of the microcontroller 31 is deactivated and a lower-frequency oscillator, in particular a 32.768-kHz oscillator, is used, and specific low-energy peripherals (LCD, RTC, LETIMER, PCNT, WDOG, LE UART, I2C, ACMP, LESENSE, OPAMP, USB) remain available. The third reduced mode EM3 (stop mode) and the fourth reduced mode EM4 (shutoff mode) have even fewer functions.

[0043] Appearing by way of example in Table 1 are, in the first column, the clock frequency f in megahertz of the microcontroller 31, and, in the remaining columns, the five operating modes, from EM0 to EM4. Appearing in the rows are the consumption levels in microwatts.

Table 1

f (MHz)	EM0	EM1	EM2	EM3	EM4
32	6400	1600	1.1	0.9	0.02
28	5628	1456			
21	4263	1113			
14	2856	784			
11	2277	627			
6.6	1399.2	409.2			
1.2	292.8	136.8			

[0044] Furthermore, as has been mentioned, also particular peripherals of the microcontroller 31 are considered in the energy budget, in particular interfaces, specifically USART and UART serial interfaces of the communication module 50, interfaces such as the SPI of the accelerometer 71, interfaces such as the LE UART low-energy interface of the location module 40, and other modules such as a timer, the PRS, an RTC (Real-Time Counter), and a DMA.

[0045] The accelerometer 71 is in turn configurable as regards consumption, via different operating modes, comprising:

- an active measurement mode, in which the accelerometer 71 carries out measurements at full sampling rate, i.e., 400 Hz (power consumption: 140 μW);
- a first reduced mode, or low-power mode, where the internal sampling rate is reduced at the expense of a higher noise level (power consumption: 90 μW);
- a second reduced mode, or auto-sleep mode, where it switches into sleep mode during periods of inactivity; in these periods of inactivity acquisition data rates below 12.5 Hz (power consumption: 23 μW), for example 10 Hz, are exploited; and
- a third reduced mode, or standby mode, where no measurement are made (power consumption: 0.1

μW).

[0046] It should be noted that the accelerometer 71 or in general the sensors of the set 70 may be used according to self-calibration procedures that enable the telematic-box device 10 to be placed in any position, for example according to the self-calibration procedures for inertial sensors described in the patent application No. EP 2 469 229 B1, filed in the name of the present applicant.

[0047] The GSM communication module 50 has different operating modes, for example:

an active mode, which may envisage a mode of activation of the mobile communication, in particular GSM (GSM-ON mode), or a mode of activation of the mobile communication according to a variant of the GSM standard, in particular GPRS (GPRS-ON mode);

a first reduced-operation mode of minimum operation (idle mode); and

a second mode where the module 50 is completely off (power-off or switched-off mode).

[0048] The GSM communication module 50 may be switched off (first mode) via hardware (by supplying power to specific pins, in the GL865 or GL868 Telit modems, in particular, to a pin VBATT_PA and not to the battery pin VBATT of the module 50) or via software (command AT#SYSHALT in the modems referred to).

[0049] In the idle mode, the GSM communication module 50 is fully operative, but does not receive or transmit any datum. For the active mode, GSM-ON mode, i.e., with the GSM communication active, or, GPRS-ON mode, i.e., with the GPRS communication active, the current consumption may then vary according to communication sub-modes, such as GSM900 or DCS1800, or GPRS classes, e.g., GPRS class 1 or GPRS class 10.

[0050] As regards the satellite location module 40, the receiver, which, in the example, is of a UBlox type, supports two main operating modes as regards consumption levels:

- a first, active, mode, or continuous mode, with continuous operation; during a cold start, the acquisition engine is set for carrying out scanning of all the satellites; after a position has been calculated and a sufficient number of satellites have been acquired, the acquisition engine is turned off; a tracking engine then enters into operation, which tracks the satellites acquired and acquires other available satellites; cold start refers conventionally, in the framework of the GPS navigation, to the condition where the location module substantially does not have any information and needs to acquire the positions of all the satellites and compute the GPS lock; instead, hot start refers to the condition where the location device has in memory information, amongst which the last position calculated, the satellites in view, the almanac employed, and UTC time and tries to lock on the satellites themselves, calculating a new position on the basis of the previous information; and
- a second, reduced, or power-save mode: in this mode the overall energy consumption is reduced by switching different parts of the location module 40 between on and off states; there are two operating sub-modes for this second mode:

  o cyclic-tracking operation (when acquisitions of positions in short periods, 1-10 s, are required); and

  o ON/OFF operation (when acquisitions of positions in periods longer than 10 s are required).

[0051] In ON/OFF operation, the location module 40 switches between operations of start/navigation and low activity or no activity of the system. In cyclic-tracking operation, the location module 40 does not switch off completely, but is a low-power tracking mode is maintained to reduce consumption. The location module 40 cannot be used in power-save mode when it is configured for receiving GLONASS signals.

[0052] Also the wireless module 61 supports different consumption modes, such as a start-up mode, a sleep mode, a module-initialization mode, and a scanning mode. These modes are generally known in the context of Bluetooth modules. The chip of the wireless module is in general of a 2.4-GHz Bluetooth Low-Energy compliant type.

[0053] Hence, the device according to the invention comprises a microcontroller 31, a location module 40, a communication module 50, and a set of sensors 70, which each comprise at least one active mode, in which they are fully operative, and one or more reduced modes, in which they operate with reduced functionality. Additionally, also the wireless module 61, where present, may present the aforesaid active mode and reduced modes.

[0054] In this framework, the telematic-box device described herein is configured for managing the aforesaid microcontroller 31, location module 40, communication module 50, and set of sensors 70 by switching them between the respective active mode and the respective one or more reduced modes according to switching schemes that are able to bring about an overall energy saving for the device 10 so that they can operate on the basis of the energy supplied by the autonomous supply means, which are of the type comprising a rechargeable accumulator, the battery 17, associated in a relationship of energy exchange with the solar panel 18 integrated in the telematic box 10.

[0055] As regards the set of movement sensors 70, it is envisaged to optimize the energy consumption of the accelerometer 71, at the same time preserving the performance thereof.

[0056] To obtain better performance of the accelerometer, the accelerometer 71 must be used, for measuring acceleration, in the active mode, or measurement mode, described above. The low-power and auto-sleep reduced modes are not preferably used by the device proposed herein, since the low-power mode implies reduction of the resolution of the sensor in so far as it reduces the internal sampling rate, whereas the auto-sleep mode does not envisage acquision of samples during the periods of inactivity, thus causing loss of samples.

[0057] Consequently, the device according to the invention is configured for achieving energy saving by managing the microcontroller 31, rather than by managing the set of sensors 70, in particular the accelerometer 71, during measurement. As illustrated with reference to Figure 4, that is, the accelerometer 71 is used for carrying out measurement in the active mode, whereas, when the measurement is not made, it is kept in the second, sleep, mode.

[0058] In various embodiments, the microprocessor 31 may obtain a single measurement sample from the accelerometer 71 or else, preferably, a plurality of these measurement data or samples. In this case, the accelerometer 71, like the model ADX345L used in the embodiment provided by way of example, is provided with an internal FIFO memory, or internal buffer, which is able to store the aforesaid plurality of samples, in particular up to 31 samples. In addition, in various embodiments, the accelerometer 71 is configured for notifying to the microcontroller 31 that the number of samples stored has reached a threshold N_a, of a programmable type. This notification event, via a full-buffer interrupt IFB, may be used as trigger for activating transfer via DMA controller, as represented in greater detail with reference to Figure 8. In this way, the microcontroller 31 remains in a low-consumption state throughout transmission of the data. In a preferred embodiment, it is envisaged to configure the accelerometer 71 for operating in the active mode at 400 Hz and for storing in its own FIFO memory sixteen consecutive samples (threshold programmed at twenty-eight samples) so that the microcontroller 31 will receive samples every 70 ms.

[0059] In addition to the selection of active and reduced operating modes of the modules, the energy-management method may envisage selection of specific procedures of use of given modules of the telematic box 10.

[0060] In various embodiments, the microcontroller 31 is configured for a procedure of acquisition via interrupts designated by the reference number 200 in the flowchart of Figure 8, where the microcontroller 31 is configured for acquiring the acceleration data (or data of other sensors in the set 70), not via, for example, a polling on the SPI bus 31c shared with the accelerometer 71, which is also a possible acquisition mode, but rather by operating via interrupts, to save on the CPU cycles that are normally used for accessing the SPI data buffer in the accelerometer 71 and possibly for setting the CPU of the microcontroller 31 in the first reduced mode, or sleep mode (for example, EM1 in the EMG32GG microcontroller). In greater detail, in a step 210, it is envisaged that the accelerometer 71, in measurement mode, for example low-power reduced mode, stores in the SPI buffer a number equal to the threshold N_a of acceleration data or samples measured.

[0061] The accelerometer 71 is configured (step 220) for verifying whether this buffer is full, i.e., whether it has reached the threshold N_a, and notifying the microprocessor 31 of this condition via a respective full-buffer interrupt IFB.

[0062] The microprocessor 31, upon reception of the full-buffer interrupt IFB generated by the accelerometer 71, exits, in a step 230, the reduced mode, for example typically the second reduced mode EM2, and enters the active mode EM0 to enable DMA transfer, whereas the accelerometer 71 enters the active measurement mode at 400 Hz, if it is not already in this mode.

[0063] There then follows a procedure of transfer of the data 240 from the SPI buffer of the accelerometer 31 to the microprocessor 31. In a preferred embodiment, once the microcontroller 31 has entered the active mode EM0 upon reception of the full-buffer interrupt IFB, it remains there only for the time necessary for activating, in a step 243, a DMA controller of its own for enabling access to the buffers of the SPI interface 31c. In this way, in a step 245, the microcontroller 31 can return into the first reduced mode, the sleep mode EM1, and remain there for the entire duration of transfer into the microprocessor 31 of the acceleration data from the SPI bus managed by the DMA controller within this step 245. This enables the microprocessor 245 not to be activated for transmission or reception of each individual byte (assuming that the transmission and reception buffers of the microcontroller 31 are one-byte buffers, as in the case of the EMG32GG microcontroller presented by way of example herein).

[0064] At the end of the data-transfer procedure 240, the microprocessor 31 may possibly go, if an enabling condition 248 is verified, to a step of analysis 250, where it enters the active mode EM0 and carries out analysis of the set of acceleration data transferred. Otherwise, the acquisition procedure 200 restarts from step 210.

[0065] The above analysis of step 250 may in general establish, according to a given criterion, as explained more fully also with reference to the intervals 640 of Figure 4, whether the N_a acceleration data acquired from the buffer of the accelerometer 71 identify the occurrence of specific events, for example crash events. The enabling condition 248 may be set so that the microprocessor 31 carries out this step of analysis 250, not at each transfer cycle 220-240, but rather according to a given multiple N_c of the time corresponding to the transfer cycle. As explained in detail hereinafter, the operation of analysis 250 with crash detection is carried out, in particular, according to a given multiple N_c of the transfer cycle. Of course, in various embodiments, the condition block 248 may not be present, and the operation of analysis 250 is carried out at each instance of execution of the acquisition procedure 200.

[0066] As regards the satellite location module 40, in order to save energy, a procedure of use is envisaged where the module is set in the first, power-save, reduced mode, ON/OFF sub-mode. In a preferred way, a refresh period of 10 s is adopted.

[0067] A procedure of use of the microcontroller 31 envisages setting it in one of the reduced-operation modes, in particular preferably in the second reduced-operation mode, EM2. The microcontroller 31e is in switched on in the active mode (EM0) whenever the GNSS receiver of the satellite location module 40 starts to send NMEA (National Marine Electronics Association) strings on the LE UART port. The mean consumption is 5.7 mA. In various embodiments, the satellite location module 40 may also send binary strings.

[0068] In particular, there are two modes of carrying out data transfer from the GNSS module of the satellite location module 40 to the microprocessor 31:

- standard mode: the DMA port is used; during transfer of the data string, the microprocessor 31 is in the first reduced mode EM1; at the end of the string, processing of the data is carried out with the microprocessor 31 in the active mode (EM0); and
- alternative mode: transfer is managed in base interrupt mode; during reception of the individual byte, the microprocessor 31 is in the second reduced-operation mode EM2; at the end of reception of the string, the microprocessor 31 passes into the active mode EM0 for saving the datum.

[0069] The consumption of the device proposed may be further reduced using the DMA controller of the microcontroller 31 and a timeout interrupt on the reception pin of the LE UART port necessary for switching on the microcontroller 31 after a new NMEA or UBX message has been received.

[0070] Furthermore, to reduce the time necessary for carrying out parsing of the NMEA strings, i.e., the time spent in the operating mode, or active mode, EM0, which has the highest consumption, in various embodiments, the GNSS information is recovered via binary messages envisaged by the UBX protocol (proprietary protocol of UBlox).

[0071] The procedures so far described are operating procedures of the specific modules of the device proposed.

[0072] The telematic-box device 10 described with reference to Figures 1, 2, 3A, and 3B is configured mainly for carrying out the following operations:

- detection and tracking of the position of the motor vehicle to which it is associated, with a periodicity of at least a quarter of a mile or less, on the basis of the acquisition of GNSS signals, via the satellite location module 40;
- detection of a crash involving the motor vehicle (described hereinafter with reference to Figure 9); this detection is carried out, in particular, according to the procedure 200 illustrated in Figure 8, on a time window comprising a given number equal to the threshold N_a of acceleration samples acquired by the set of sensors 70, in particular the acceleration sensor 71; these N_a samples are examined with criteria in themselves known for identifying the occurrence of a crash event involving the motor vehicle; for instance, a criterion for identifying a crash event may entail verifying whether the acceleration signal undergoes oscillations higher than a given threshold for a given time interval; aspects of this operation of crash detection are presented in greater detail with reference to time intervals 640 in the diagram of Figure 4 and, in particular, as has been said, with reference to the flowchart of Figure 9;
- communication of data in wireless mode via the communication module with a mobile-communication network 50, comprising for example transmission of state data and alarm events (movement of the motor vehicle outside a given geo-fence, crash events, pressing of emergency buttons, etc.);
- voice communication services through a mobile-telephone network, once again through the module for communication with a mobile-communication network 50;
- odometer function (calculation of mileage covered by the vehicle); in this operating modality, as in others described herein, the accelerometer 71 can be used as virtual key on, detecting the movement of the vehicle to start the odometer or other function; aspects of this function are presented in greater detail with reference to time intervals 640 in the diagram of Figure 4;
- functions of detection of vehicle driving style, for example using the method described in the patent No. EP 2 469 477 B1, filed in the name of the present applicant.

[0073] Figure 4 presents a diagram representing a method for managing the device proposed herein.

[0074] Designated by 500 is a bar representing the cycle of use of the telematic-box device 10, i.e., a sequence of time intervals during which a respective procedure is carried out for setting the operating modes of the aforesaid microcontroller 31, location module 40, communication module 50, and acceleration sensor 71. This bar preferably represents a 24-hour cycle, from a start-of-cycle time t_i, corresponding to 0.00 hours, to an end-of-cycle time t_f, corresponding to 23.59 hours. Each time segment indicated on the bar 500 represents one of the above time intervals.

[0075] Hence, following upon the start-of-cycle time t_i, a location-initialization procedure 505 is first carried out, where the cold GPS fix is performed, i.e., an procedure of cold acquisition of the satellites, for a given duration of a few minutes. During this initialization procedure 505 of cold GPS fix:

the microcontroller 31 operates in the second reduced mode EM2;
the satellite location module 40 operates in the active mode;
the accelerometer 71 is in the reduced-operation mode, in particular the second, auto-sleep, mode at 10 Hz, awaiting wake up; and
the communication module 50 is in the second, power-off or switched-off, mode.

[0076] Designated, instead, by 510 is a plurality of trip periods, or "key on" periods, which start, that is, from when the dashboard of the vehicle is switched on. In the case where the key-on signal indicating switching-on of the dashboard of the vehicle is not available, the device can be configured, as has been mentioned, for getting information from the accelerometer 71, which operates as virtual key, according to what is described, for example, in the patent application No. EP 2 469 229 B1, filed in the name of the present applicant. The above trip periods 510 are illustrated in detail in the underlying bar 600 and will be described in what follows.

[0077] The trip periods 510 may, of course, have be in variable number and have a variable arrangement in time over the 24-hour cycle, according to the use of the vehicle.

[0078] Designated, instead, by 520 is a daily procedure of data transmission via the communication module 50, which preferably envisages also an operation of reception of SMS messages, in addition to the ones envisaged in the procedure 620 of the trip periods 510 described in what follows. This transmission procedure 520 in general envisages transmitting vehicle data, for example recorded by the set of sensors 70, but also data of the motor-vehicle control unit, to remote centres, for purposes of diagnosis of the state of operation of the vehicle and of the engine, of tracking, and other functions mentioned previously.

[0079] During this daily data-transmission procedure 520:

the microcontroller 31 operates in the active mode;
the satellite location module 40 is off in the first, power-save, reduced mode, ON/OFF sub-mode; in particular, if the vehicle is moving, it is in ON/OFF sub-mode; otherwise, it is OFF;
the accelerometer 71 is in reduced-operation mode, in particular the second, auto-sleep, mode at 10 Hz, awaiting wake up; and
the communication module 50 is in the active mode.

[0080] The above daily data-transmission procedure 520, as illustrated in Figure 4, is carried out preferably immediately prior to the end-of-cycle time t_f.

[0081] In the bar 500, between the time intervals corresponding to the procedures 505, 510, and 520 that have just been described, intervals 515 are represented, in particular appearing in white, where the device 10 is as a whole in sleep mode. In these sleep intervals 515, for example:

the microcontroller 31 is set in the second reduced mode, or sleep mode EM2;
the satellite location module 40 is off in the first, power-save, reduced mode, in the OFF state; the ON/OFF sub-mode is in fact active only when the vehicle is travelling;
the accelerometer 71 is in reduced-operation mode, in particular the second, auto-sleep, mode at 10 Hz, awaiting wake up; and
the communication module 50 is set in the second, power-off or witched-off, mode.

[0082] With reference to the time bar 600, the trip periods 510 are now described in detail. Designated by tk_i is a start-of-trip time, corresponding insertion of the key in key-on position of the dashboard. Immediately after this start-of-trip time tk_i, a key-activation procedure 605 is carried out whenever there is a change of the position of the key, in particular from key on to key off, and vice versa.

[0083] During this key-activation procedure 605, which corresponds to switching-on or switching-off of the vehicle dashboard, in particular of the control unit, the following settings are envisaged:

the microcontroller 31 is set fully operative and operates in the active mode, for example EM0;
the satellite location module 40 is set fully operative and operates in its active mode;
the accelerometer 71 is set fully operative, i.e., in the active or measurement mode at 400 Hz; and
the communication module 50 is set in the second, power-off or sitched-off, mode.

[0084] Duration of the key-activation procedure 605 is appoximately 30 s.

[0085] As appears in the bar 600, the key-activation procedure 605 precedes an end-of-trip time tk_f, i.e., when the key is brought into the key-off position; the key-activation procedure 605 is carried out, at the end of which there is the end-of-trip time tk_f, i.e., the end of the time segment corresponding to this procedure 605.

[0086] Designated by 610 is a hot-fix procedure of the location module.

[0087] During this procedure:

the microcontroller 31 is set in the first reduced mode or carries out buffering of the GPS data;
the satellite location module 40 operates in its own active mode;
the accelerometer 71 is set fully operative, i.e., in the active or measurement mode at 400 Hz; and
the communication module 50 is set in the second,

power-off or switched-off, mode.

[0088] As illustrated in Figure 4, the hot-fix procedure 610 is carried out a plurality of times during the trip period 510, in particular at regular intervals 615.

[0089] Designated by 620 is a procedure for controlling reception of messages, in particular SMS messages. During this procedure 620:

the microcontroller 31 is set in the first reduced mode or in the active mode;
the satellite location module 40 is off in the first, power-save, reduced mode, ON/OFF sub-mode, in the OFF state;
the accelerometer 71 is set fully operative, i.e., in the active mode or measurement mode at 400 Hz; and
the communication module 50 is in the active mode.

[0090] As illustrated in Figure 4, the procedure for controlling reception of the messages 620 is carried out a plurality of times during the trip period 510, in particular at regular intervals 630.

[0091] In the bar 600 between the time intervals corresponding to the procedures 605, 610, and 620 that have just been described, trip intervals 640 are represented, in particular appearing in white, where the device 10 is as a whole set in run mode, in particular, for making measurements via sensors, whereas the location and communication functions are disabled. In these trip intervals 640, for example:

the microcontroller 31 is set in the second reduced mode EM2, or carries out buffering of the data of the accelerometer 71;
the satellite location module 40 is off in the first, power-save, reduced mode, ON/OFF sub-mode, in the OFF state;
the accelerometer 71 is set fully operative, i.e., in the active mode or measurement mode at 400 Hz; acceleration data are transferred from the buffer, or the internal FIFO memory, of the accelerometer 71 to the microcontroller 31 preferably according to the low-consumption procedure 200 illustrated in Figure 8; in this context, the microcontroller 31 passes to the first mode EM1 only during data transfer via DMA (step 245), whereas if there is no other activity regarding other processes it remains in the second reduced mode EM2; and
the communication module 50 is set in the second, power-off or switched-off, mode.

[0092] In the intervals 640, one or both of the following two operations are moreover carried out:

(i) crash-detection function, represented schematically in Figure 9 and designated by the reference number 300, where:

the microcontroller 31 periodically acquires the acceleration data, for example via the procedure 200 of acquisition via interrupt;
at regular time intervals, for example multiples Nc of cycles of transfer of acceleration data within the buffer of the accelerator 71, the microcontroller 31 is configured for analysing 250, according to one of the procedures cited previously, a set of a number N_a of acceleration samples present in the RAM buffer so as to apply criteria for detecting possible crash events; at each cycle of analysis, which corresponds to step 250 of Figure 8 and takes place, for example, every 70 ms and has a duration of a few microseconds, the microcontroller 31 passes to to active mode EM0 and then, if there is no other activity regarding other processes, returns to the second reduced mode EM2; and
if, in step 310, the acceleration-analysis algorithm in the microcontroller 31 detects a crash or minicrash event CE (a minicrash event is identified, for example, for acceleration values above a minicrash threshold, but below the threshold that identifies a crash; minicrash is hence an anomalous accelerometric event but with an intensity such as not to be considered a crash), then the microcontroller 31 is configured for storing (in a step 320) in a further buffer contained in a flash memory the acceleration and position data for a given number N_p of seconds before the event and a given number N_d of seconds after the event; the values of N_p and N_d are parameterized and are typically 3 s and 7 s, respectively; and

(ii) virtual-odometer function: at regular intervals (from ten seconds to one minute) the microcontroller 31, by using the data position stored in the SPI buffer, updates the calculation of the virtual odometer; during this step, the microprocessor 31 passes to the active mode EM0 and then, if there is no other activity regarding other processes, returns to the second reduced mode EM2.

[0093] The telematic-box device 10 described herein comprises two stages of life, with reference to the state diagram of Figure 10, a first stage of life 800, in which the device 10 is not installed, in so far as, for example, it is still in the warehouse or on the shelf, or in some other non-installed condition, and a second stage 900, in which the telematic-box device 10 is installed and operative.

[0094] The keypad 11 comprises, for example, a user button, pressing or release of which is denoted by the action UB, and a disconnection switch, pressing or release of which is denoted by the action DS.

[0095] In particular, following upon the production step, i.e., the state or step designated by 805 in Figure 10, the device 10 is in the transport-mode state 810, also referred to as low-consumption transport mode, in which no operation is performed by the device 10 itself. The device 10 is configured for passing, when a specific user button of the keypad 11 is pressed (action UB) and subsequently released, into a state 820 of verification of activation. If, in the state 820, the disconnection switch is in the pressed condition (action denoted by DS) and an activation message is received from a server with which the device 10 is in communication, the device 10 goes into a self-installation state 830, in which it carries out self-installation, which comprises, for example, the aforementioned steps of self-calibration that enable location of the telematic-box device 10 in any position, for example according to the self-calibration procedures for inertial sensors described in the patent application No. EP 2 469 229 B1, filed in the name of the present applicant; otherwise, control returns to the transport-mode step 810. If operation in the self-installation state 830 is successful (signal or action CY), the device 10 is installed and control passes to the second stage 900, where it is installed or operative, specifically in an operating state or mode 910. Otherwise (signal CN), control passes to a state 840, where the remote server is notified that installation, for example calibration, has been unsuccessful, and the device 10 passes in any case to the second stage 900.

[0096] At this point, from the operative state 910 there are two possibilities according to the selection of pressing action on the buttons of the keypad 11, the user button UB and the disconnection switch DS:

- if the disconnection switch DS is released, this means that in a step 920 the device 10 is cut off and a notification 940 is sent to the server; then the device 10 returns into the transport mode (step 810);
- if the user button UB is pressed again, the device 10 starts to gather crash/SOS data in a state 920 and sends them to the server via the notification 940, and then returns into the operative mode 910.

[0097] Hence, from what has been described above, the advantages of the solution proposed emerge clearly.

[0098] The telematic-box device, via the use of modules that can operated in reduced mode and procedures of use of these modules and of management in a period of time, in particular, over the twenty-four-hour cycle, is able to operate autonomously, without it having to be connected, via wiring, to the battery of the motor vehicle. This enables a greater freedom of installation of the telematic-box device on the motor vehicle.

[0099] It is emphasised that the fact that the telematic-box device 10 of Figure 1 or 10' of Figure 5 is configured for carrying out an acquisition procedure 200 or a crash-detection function 300, as has been described, constitutes in itself an important aspect of the solution described herein, irrespective of whether these procedures are included in the process 500 of management of the device proposed, on account of the low consumption that the use itself of the above procedures 200 and 300 entails for the telematic-box device 10, 10', which is particularly advantageous in an autonomously supplied device.

[0100] Inclusion of these procedures 200 and 300 in the context of the process 500 of management of the device, or more specifically in the context of the trip period 510, or even more specifically of the trip time interval 640 leads to further advantages in terms of power consumption.

Claims

1. A telematic-box device for motor vehicles, which comprises a module for connection to mobile-communication networks (50), a satellite location module (40), and a sensor (70; 71) configured for detecting the acceleration and braking parameters of the motor vehicle, said device being **characterized in that** it comprises autonomous supply means, of the type including a rechargeable accumulator (17') integrated in said telematic box (10) and a microcontroller module (31) configured for managing at least said module for connection to mobile-communication networks (50), said satellite location module (40), and said sensor (70; 71), it being possible to set said microcontroller module (31), said module for connection to mobile-communication networks (50), said satellite location module (40), and said sensor (70; 71) selectively between an active-operation mode and one or more reduced-operation modes in which they implement saving of energy as compared to the active-operation mode.

2. The device according to Claim 1, **characterized in that** said microcontroller module (31) is configured to acquire (200), via a given interrupt procedure, data of the sensor (70; 71) configured for detecting the acceleration and braking parameters of the motor vehicle and to carry out operations of analysis (250) on the data acquired from said sensor (70; 71).

3. The device according to Claim 2, **characterized in that** said sensor (70; 71) configured for detecting the acceleration and braking parameters of the motor vehicle is configured for storing samples detected in its own buffers and for notifying (220) via interrupt (IFB) to the microcontroller (31) that a number of samples in said buffers has reached a given threshold (N_a), and **in that** said microcontroller module (31) is configured for acquiring (200) data of the sensor (70; 71) by activating data transfer (240), upon reception of said notification (IFB).

4. The device according to Claim 3, **characterized in that** said microcontroller (31) is configured for using a DMA (Direct Memory Access) controller of its own for gaining access to the buffer of the sensor (70; 71), remaining in reduced-operation mode (EM1) for

the entire duration of transfer of data from said buffer.

5. The device according to any one of the preceding claims, **characterized in that** said microcontroller (31) is configured for carrying out a crash-detection operation (300) that comprises carrying out, at regular time intervals (N_c), said operation of analysis (250) on a stored set (N_a) of data detected by the sensor (70; 71) configured for detecting the acceleration and braking parameters, so as to detect any possible crash events (CE).

6. The device according to Claim 5, **characterized in that** said microcontroller (31) is configured, in the case where the operation of analysis (250) identifies a crash event (CE), for storing for a time interval (N_p) prior to the event and a time interval (N_d) after the event, in particular via said DMA controller, the data detected by the sensor (70; 71).

7. The device according to any one of the preceding claims, **characterized in that** said microcontroller module (31) is configured for carrying out a time sequence (500) of time intervals associated to respective procedures of setting of operating modes for its own operation and for operation of the module for connection to mobile-communication networks (50), the satellite location module (40), and the sensor (70; 71), in particular said time sequence having start (t_i) and end (t_f) corresponding to the start and end of a day.

8. The device according to Claim 7, **characterized in that** said time sequence (500) comprises setting procedures associated to trip periods (510) of the motor vehicle and setting procedures associated to periods of inactivity (515) of the motor vehicle.

9. The device according to Claim 8, **characterized in that** said time sequence further comprises one or more setting procedures associated to periods (505) of initialization of the location module (40) and one or more setting procedures associated to periods (520) of transmission of data via said communication module (50).

10. The device according to Claim 8, **characterized in that** it comprises a setting procedure associated to a period (505) of initialization of the location module (40) at the start (t_i) of the time sequence (500) and a setting procedure associated to a period (520) of transmission of data via said communication module (50) at the end (t_f) of the time sequence (500).

11. The device according to Claim 7, **characterized in that** said setting procedures associated to trip periods (510) comprise a respective time sequence (600) of procedures of setting of the operating mode comprising setting procedures associated to intervals (640) where measurements are carried out.

12. The device according to Claim 11, **characterized in that** said intervals (640) where measurements are carried out comprise said function (300) for detecting crash events (CE).

13. The device according to Claim 12, **characterized in that** said time sequence (600) of procedures of setting of the operating mode further comprises setting procedures (610) for hot initialization of the location module (40) carried out periodically according to a first period (615) and setting procedures for reception of messages (620) carried out periodically according to a second period.

14. The device according to Claim 13, **characterized in that** said trip period (610) is defined between a first time (tk_i) where the vehicle is started, in particular the key-on action, and a second time (tk_f) where the vehicle is started, at said first time and said second time said respective time sequence (600) further comprising a specific setting procedure (605) including setting in the active mode for a given time duration the microcontroller (31), the location module (40), and the sensor (71).

15. The device according to Claim 1, **characterized in that** the location module (40) is configured for operating in ON/OFF power-save mode, and the microcontroller (31) is configured for operating in a reduced mode and for passing into the active mode (EM0) whenever the location module (40) sends location strings on a low-consumption interface of said location module (40).

16. A method for managing energy of a telematic-box device for motor vehicles that implements the operations performed by the telematic-box device for motor vehicles according to any one of Claims 1 to 14.

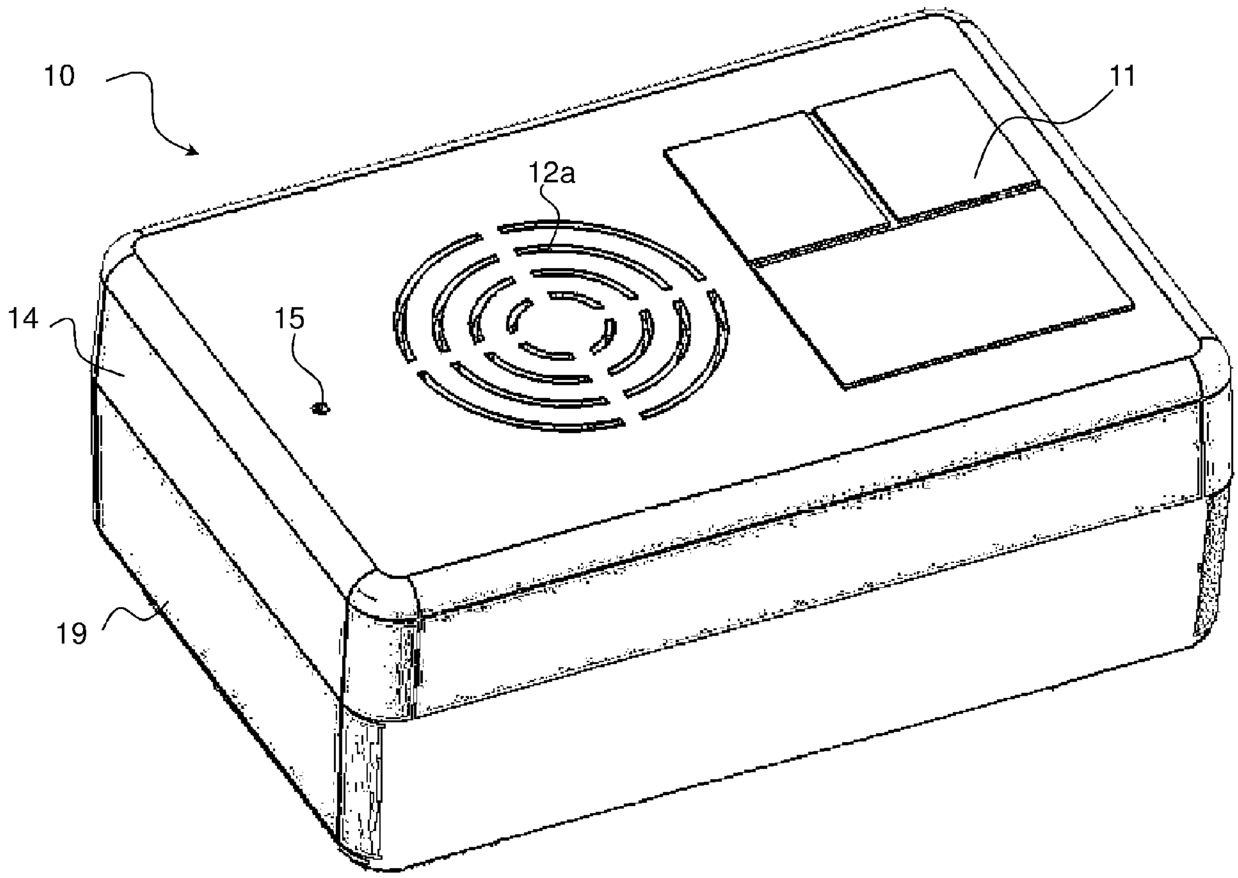


Fig. 1

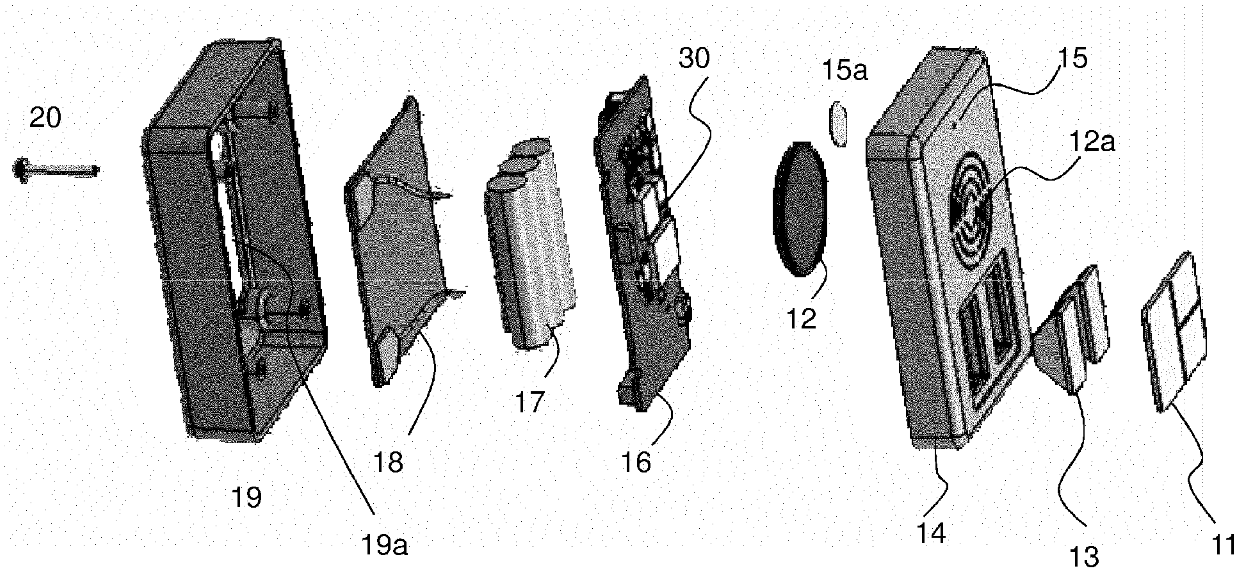
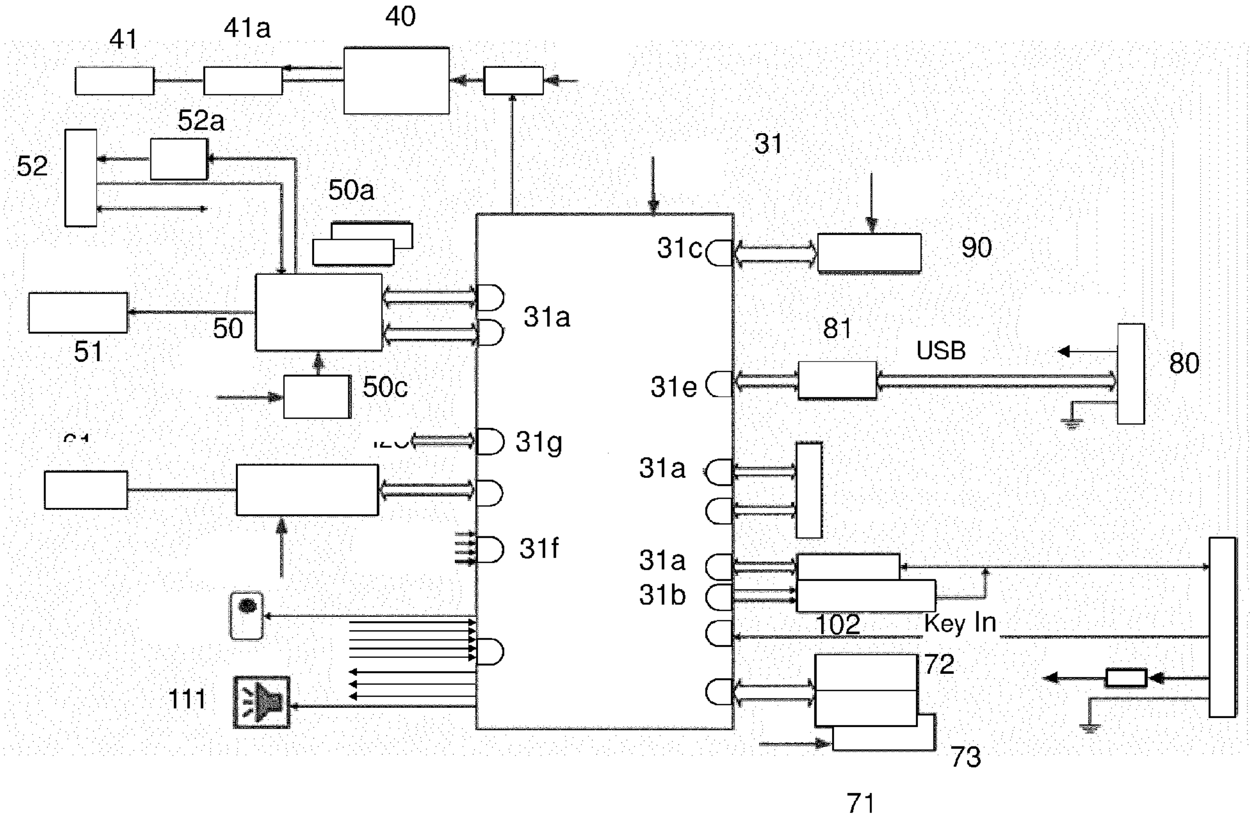


Fig. 2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31f
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31b
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Key In
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111
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71

Fig. 3A

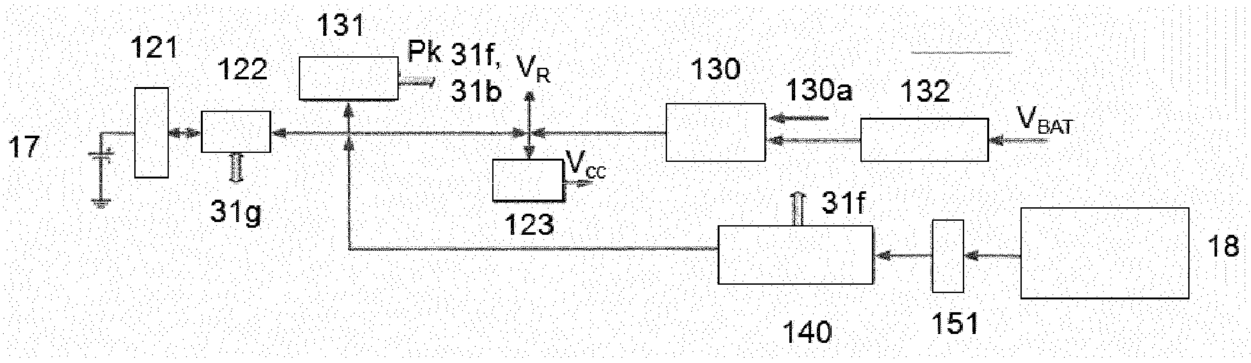
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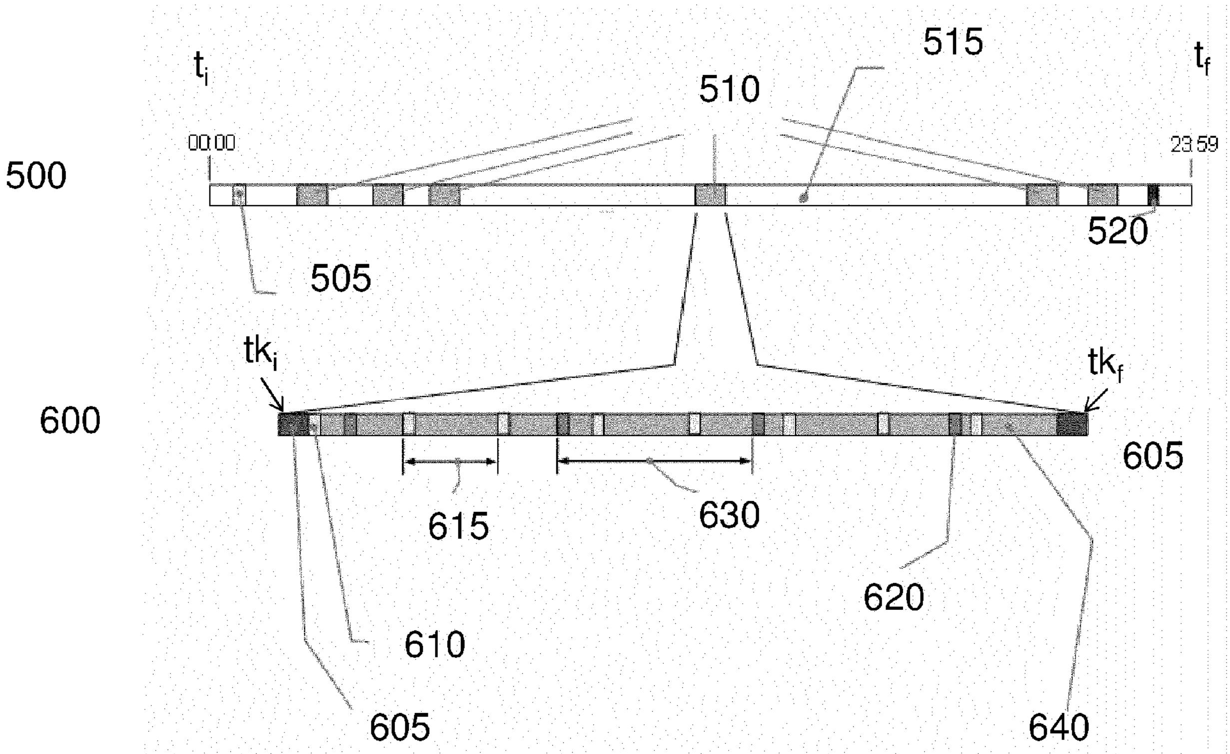
Fig. 3B



t_i
515
t_f
510
00:00
23:59
500
520
505
tk_i
tk_f
600
605
615
630
620
610
605
640

Fig. 4

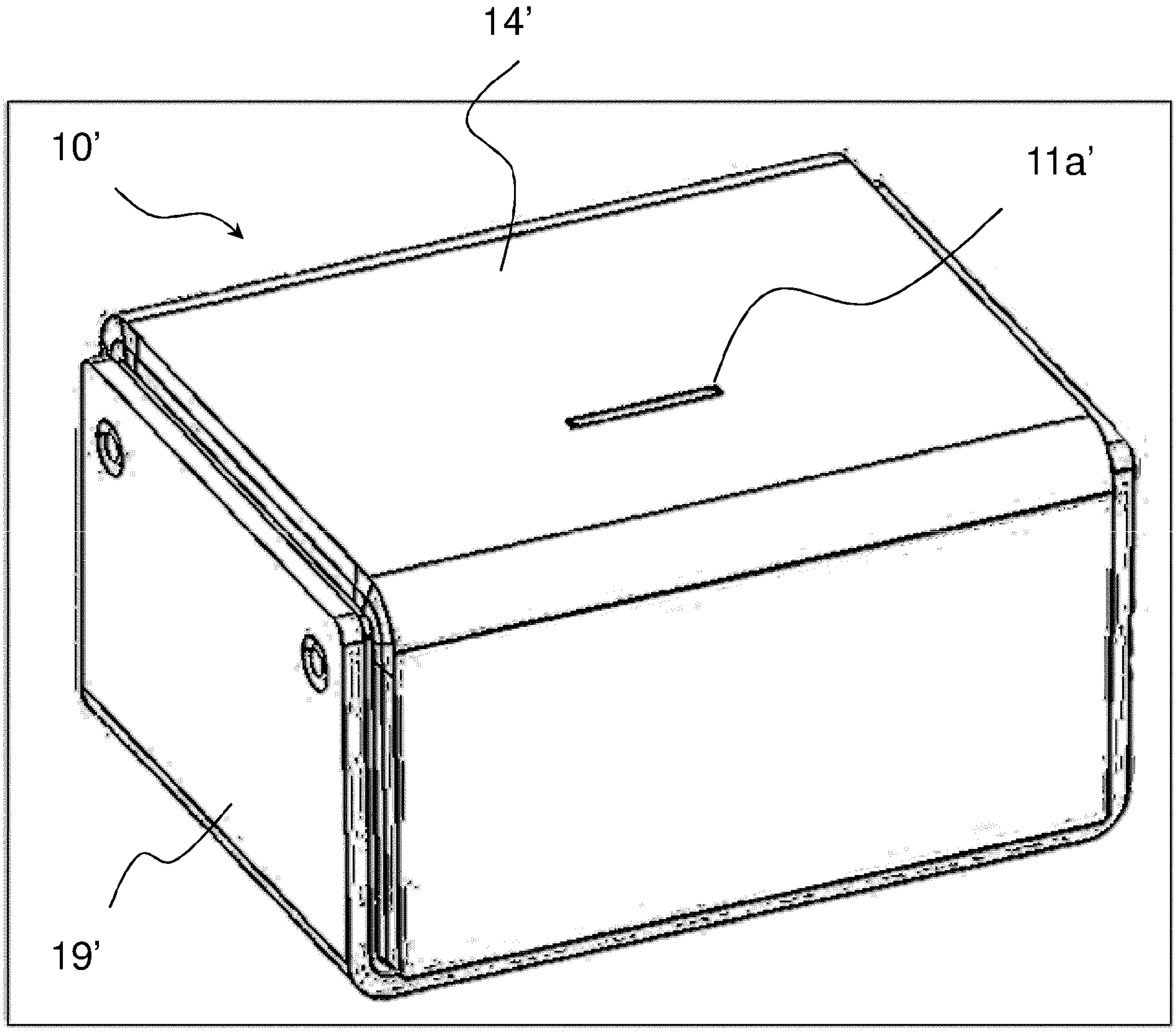
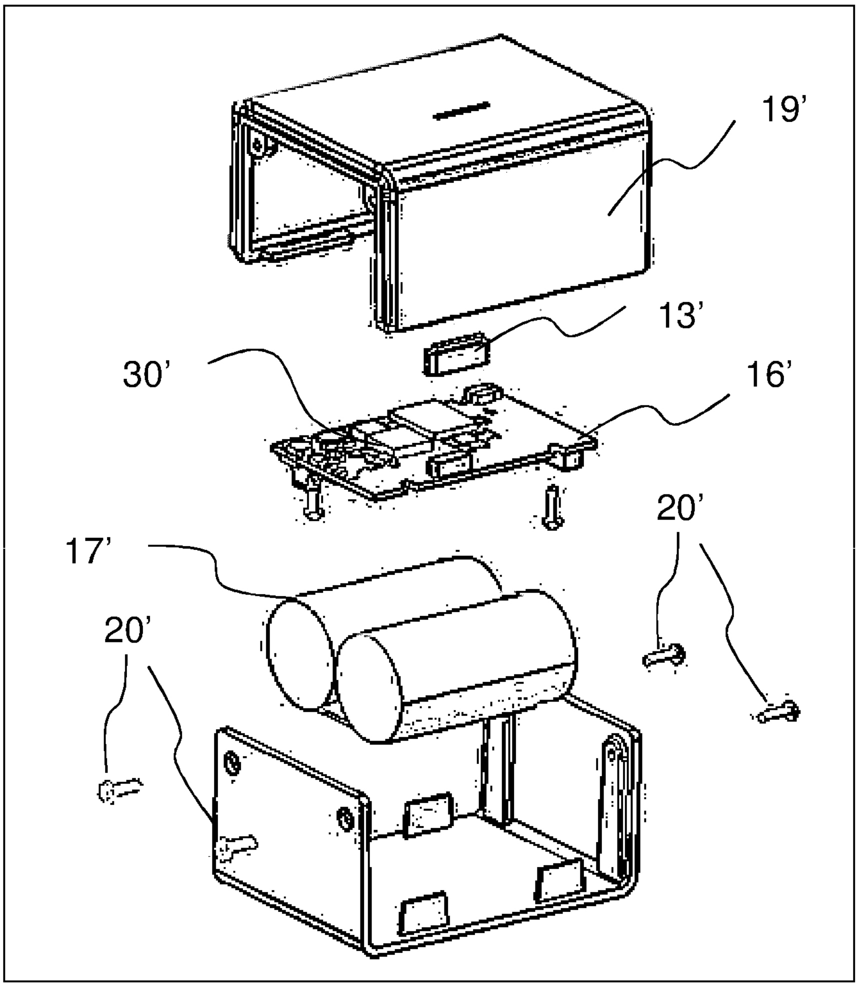


Fig. 5



19'

Fig. 6

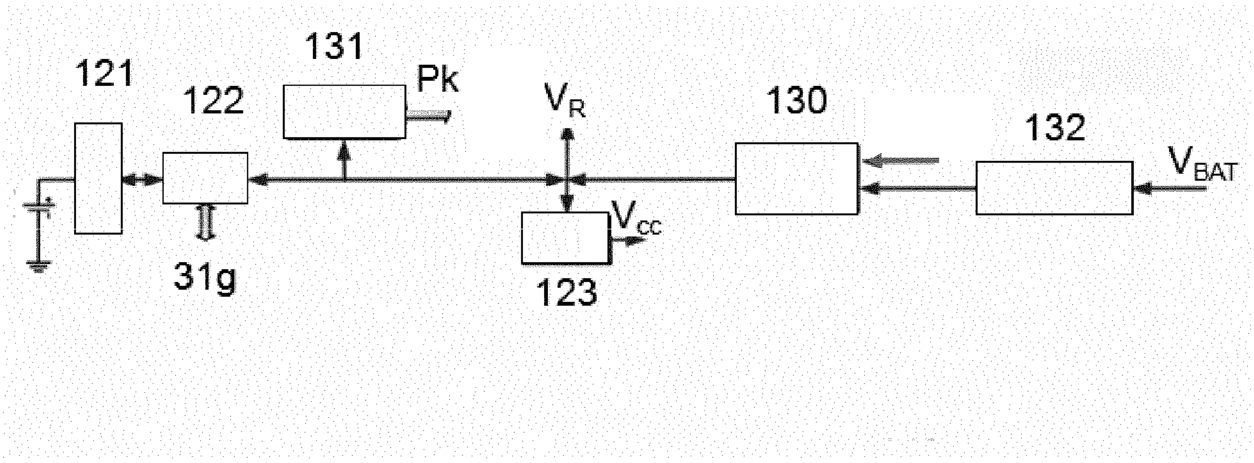
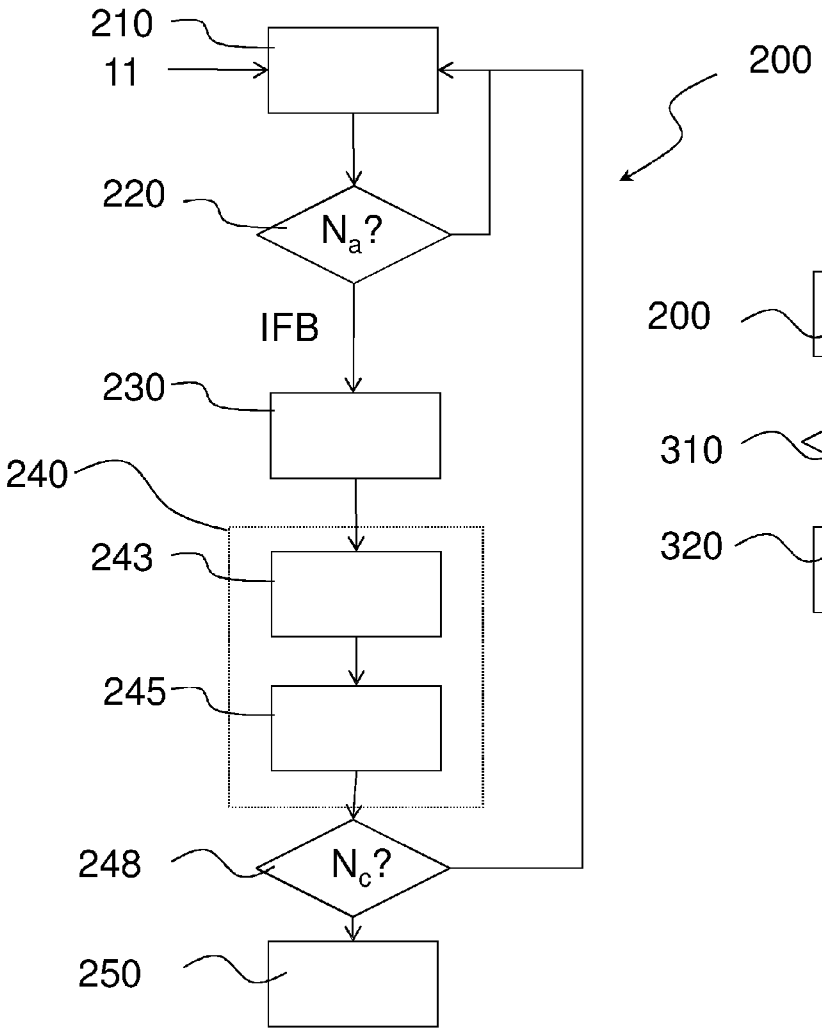


Fig. 7

Fig. 8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N_a?
IFB
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245
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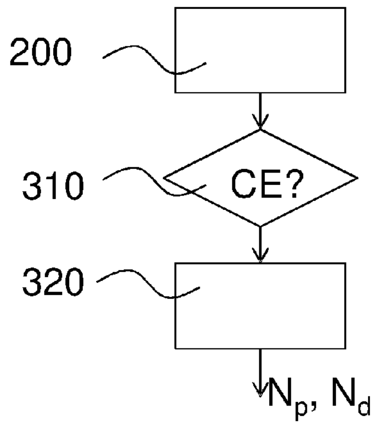
N_c?
250

Fig. 9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CE?
320
N_p, N_d

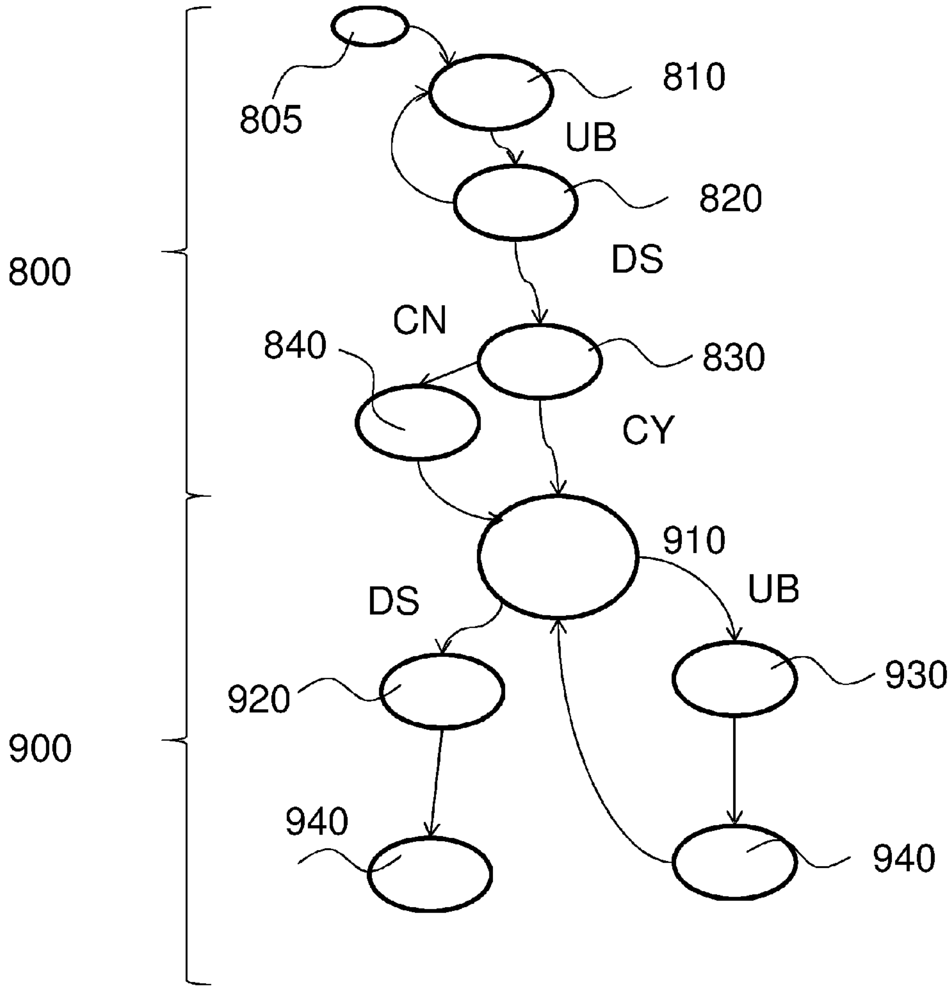

Fig. 10

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EUROPEAN SEARCH REPORT

Application Number
EP 15 19 3692

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2012/197486 A1 (ELLIOTT BRYANT [US]) 2 August 2012 (2012-08-02) * abstract * * * paragraph [0006] - paragraph [0045] * * figures 1-6 * * claims 1-20 *	1-16	INV. G07C5/08
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G07C
G01R

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	8 April 2016	Pañeda Fernández, J

1

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 15 19 3692

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08-04-2016

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REFERENCES CITED IN THE DESCRIPTION

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