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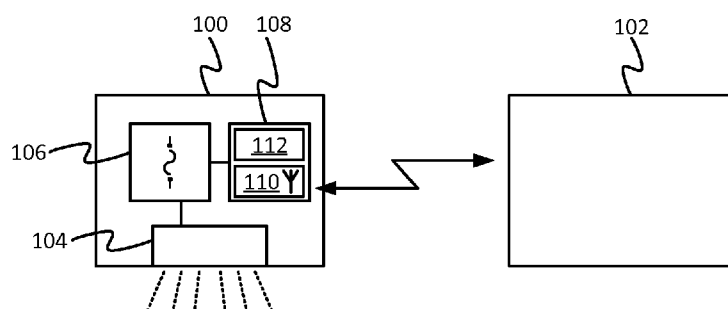
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(54) Title: CONTROLLING THE POWER CONSUMED BY A COMMUNICATIONS MODULE

Figure 1

(57) Abstract: An illumination device comprising an illumination source, a communications module and a power supply for powering the illumination source and communications module. In a standby mode, the power to the communications module is restricted to a standby power limit. The illumination device further comprises an energy buffer arranged to buffer the energy supplied from the power supply to the communications module during the standby mode. A controller of the communications module is configured to adapt the scheduling of communication operations in dependence on a measure or estimate of the amount of energy currently stored in the energy buffer, at least by delaying one or more of the communication operations which require more than the standby power limit to perform until the energy measured or estimated to be stored in the energy buffer is great enough to perform these one or more communication operations without exceeding the standby power limit.



Controlling the power consumed by a communications module

TECHNICAL FIELD

The present disclosure relates to an illumination device comprising both an illumination source for performing the main function of the device, and a communications module for communicating with another node such as a wireless access point..

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BACKGROUND

Connected lighting refers to a system of one or more luminaires which are controlled not by (or not only by) a traditional electrical on-off or dimmer circuit, but rather by using a data communications protocol via a wired or more often wireless connection, e.g. a wired or wireless network. Typically, the luminaires, or even individual lamps within a luminaire, may each be equipped with a wireless receiver or transceiver for receiving lighting control commands from a lighting control device (and optionally also for sending status reports to the lighting control device using the wireless networking protocol). The lighting control device may take the form of a user terminal, e.g. a portable user terminal such as a smartphone, tablet, laptop or smart watch; or a static user terminal such as a desktop computer or wireless wall-panel. In such cases the lighting control commands may originate from an application running on the user terminal, either based on user inputs provided to the application by the user through a user interface of the user terminal (e.g. a touch screen or point-and-click interface), and/or based on an automatized function of the application. The user equipment may send the lighting control commands to the luminaires directly, or via an intermediate device such as a wireless router, access point or lighting bridge.

The growth in wireless personal communications and penetration of smart user devices (e.g. phones, tablets and watches) is expected to widen adoption of wireless lighting control. Current practice in this application domain is based on a hybrid of such communication technologies, e.g. ZigBee & Wi-Fi, or 6LowPAN & Wi-Fi, where a protocol bridge handles the cross-over. I.e. the bridge translates between the wireless access technology used by the user terminal (e.g. Wi-Fi) and the wireless access technology used by the illumination device (e.g. ZigBee or 6LowPAN).

In order to connect a device to a wireless network, the device needs to connect to a suitable wireless access node, sometimes also referred to as a wireless access point.

Connecting a device to the wireless access node involves a process to setup a network between the device and the node, or to join a pre-existing network, whereby the device is associated with an access node. This process comprises an exchange of wireless messages between the device and the node, in which the device listens for a beacon comprising the ID, the device sends a request to the node requesting to connect the device to the network, the device sends the node its own ID, and the node authenticates the device based on a cryptographic signatures sent from the device and the node. Once the node has authenticated the device and registered the device's ID as being connected to the network, and once the device has registered the node's ID as the access point via which it connects to the network, then the device has successfully connected to the network. Optionally, if a higher level of security is imposed, then the process may also require the device to authenticate the access node based on a cryptographic signature sent from the node to the device. Alternatively, only a one-way authentication is required for the node to authenticate the device before the device can successfully connect to the network.

SUMMARY

An illumination device may be required to communicate with another node such as an access point even when it is in a standby mode, i.e. even when the illumination source itself is turned off. For example it may be desirable to enable a wireless luminaire to go through the Wi-Fi network setup or network joining process whilst in standby. However, due to environmental and/or economic considerations, the standby power consumption (the power consumed when the illumination source is switched off) is often required to be limited to within a certain predetermined maximum. On the other hand, during certain phases of communication such as network setup or joining, a communications protocol such as Wi-Fi may in fact draw more power than the standby limit. For instance, Wi-Fi is not currently used by luminaires due to the relatively high power requirements of Wi-Fi compared to the standby power restrictions typically imposed upon luminaires (hence the need for a bridge and a second protocol such as ZigBee or 6LowPAN in conventional systems). Similar considerations may apply in relation to other devices having integrated communications capability, such as a wireless sensor unit.

To address such issues or similar, the present disclosure provides an energy buffer and adaptive delaying mechanism to throttle the performance of one or more

communications tasks during a phase such as network set-up or joining a network, so as to keep the power consumed by the communications below the standby power limit.

According to one aspect disclosed herein, there is provided a device comprising: a load; a communications module comprising a communications interface and a controller configured to communicate via the communications interface with an external node external to said device; a power supply arranged to supply power to the communications module and to the load when the device is in an operational mode, and to supply power to the communications module but not the load when the device is in a standby mode, wherein the power supply is arranged to restrict the supplied power to no more than a predetermined standby power limit during the standby mode; and an energy buffer arranged to buffer energy from the power supplied from the power supply to the communications module during the standby mode, by storing up the energy and at times releasing the stored energy to the communications module at a greater rate than supplied by the power supply; wherein the controller is configured to perform a series of communication operations involved in and/or relating to the communication via the communications interface; and wherein the controller is configured to adapt a schedule of said communication operations in dependence on a measure or estimate of the amount of energy currently stored in the energy buffer, at least by delaying one or more of the communication operations which require more than the standby power limit to perform until the energy measured or estimated to be stored in the energy buffer is great enough to perform said one or more communication operations without exceeding the standby power limit; and wherein the one or more communication operations which the controller is configured to schedule and perform comprise cryptographic calculations and wherein the controller is further configured to split cryptographic calculations into urgent and non-urgent security calculations, wherein the urgent security calculations are performed when required or as soon as possible thereafter when the energy stored allows and the non-urgent ones are performed at a later stage.

The communication operations may for example comprise one, more or all of: an operation of transmitting a signal to the external node, an operation of receiving a signal from the external node, and/or a listening operation (wherein the listening operation may comprise listening for a signal from the external node and/or checking for absence of any other data traffic on a same channel prior to transmitting from the device to the external node).

In embodiments the controller may be further configured to adapt a rate at which at least one other of the communication operations is performed in dependence on the

energy measured or estimated to be stored in the energy buffer. This may comprise adapting the data rate of one or more of the transmission operations, and/or adapting the processing rate of one or more of the cryptographic calculations. Alternatively or additionally, the controller may be further configured to switch off the communications interface so as not to transmit, receive or listen for any signals while one or both of said cryptographic calculations are being performed.

Such embodiments advantageously enable the transmission and/or cryptographic calculation to be stretched out over time so as to consume less energy per unit time (i.e. lower power), thus reducing the degree of energy buffering required.

In embodiments, the device may be configured to boost the power supplied by the power supply, when in the operational mode, beyond the standby power limit plus the power drawn by the load.

In embodiments, the device may further comprise an energy monitor configured to measure the energy stored in the energy buffer, the controller being configured to perform said adaptation based on the energy measured by the energy monitor to be stored in the energy buffer.

Alternatively, the controller may be configured to estimate the energy stored in the energy buffer based on a charge rate and a time elapsed, the controller being configured to perform said adaptation based in the energy estimated by the controller to be stored in the energy buffer.

In embodiments the device may be an illumination device, in which case the load comprises an illumination source.

In embodiments, the energy buffer may comprise a capacitor or rechargeable battery.

In embodiments, the communications interface may be a wireless communications interface, said communications may be wireless communications, and said series of communications operations may be operations involved in and/or relating to said wireless communications.

In embodiments, said external node is a wireless access node for connecting the device to a wireless network, said series of communication operations which the controller is configured to perform being operations for establishing a connection with the wireless access node in order for the device to connect to said network.

In embodiments the wireless communications interface may be a Wi-Fi interface, the wireless communications may be Wi-Fi communications, and said series of

communications operations may be operations involved in and/or relating to said Wi-Fi communications.

Advantageously, in embodiments the techniques disclosed herein enable Wi-Fi to be used directly by an illumination device such as a luminaire or lamp without the need for a bridge and second protocol such as ZigBee or 6LowPAN, by reducing the power consumed by the Wi-Fi network joining process to within the standby power limit of the illumination device.

According to another aspect disclosed herein, there is provided a method of operating a device comprising a load and a communications module, the communications module being for communicating with an external node external to said device; the method comprising: in an operational mode of the device, supplying power from a power supply to the communications module and the load; in a standby mode of the device, supplying power from a supply power to the communications module but not the load, wherein the supplied power is restricted to no more than a predetermined standby power limit during the standby mode; buffering energy from the power supplied from the power supply to the communications module during the standby mode, by storing up the energy and at times releasing the stored energy to the communications module at a greater rate than supplied from the power supply; performing a series of communication operations involved in and/or relating to the communication with the external node; and adapting a scheduling of said communication operations in dependence on a measure or estimate of the amount of energy currently stored in the energy buffer, at least by delaying one or more of the communication operations which require more than the standby power limit to perform until the energy measured or estimated to be stored in the energy buffer is great enough to perform said one or more communication operations without exceeding the standby power limit; and wherein the one or more communication operations which the controller schedules and performs comprise cryptographic calculations and the method further comprises: splitting cryptographic calculations into urgent and non-urgent security calculations, , wherein the urgent security calculations are performed when required or as soon as possible thereafter when the energy stored allows and the non-urgent ones are performed at a later stage.

According to another aspect disclosed herein, there is provided computer program product stored on a computer-readable storage, characterized in that it comprises program code instructions for implementing the method described hereinabove.

In embodiments the method may further comprise steps in accordance with the functionality of any of the device features described herein, or the computer program may be further configured to operate a device with any of the functionality described herein.

5 BRIEF DESCRIPTION OF THE DRAWINGS

To assist understanding of the present disclosure and to show how embodiments may be put into effect, reference is made by way of example to the accompanying drawings in which:

Figure 1 is a schematic block diagram of an illumination device
10 communicating with a wireless access point,

Figure 2 is a timing diagram showing an example sequence of communication related operations,

Figure 3 is a schematic block diagram of an illumination device configured to adapt the timing of its communication related operations in dependence on a buffered energy
15 level,

Figure 4 is a timing diagram showing an example adaptation of the sequence of communicating operations of Figure 2,

Figure 5 is a timing diagram showing another example adaptation of the sequence of communicating operations of Figure 2,

Figure 6 is a timing diagram showing yet another example adaptation of the sequence of communicating operations of Figure 2,

Figure 7 is another schematic block diagram of an illumination device, and

Figure 8 is a flow chart showing a process for managing the rate of energy consumed by an illumination device.

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DETAILED DESCRIPTION OF EMBODIMENTS

Despite the wide-spread adoption and various advantages of Wi-Fi for wireless networking, the high power consumption of Wi-Fi is restricting its deployment in power-constrained applications, such as lighting and sensing applications. Particularly in
30 lighting systems, the tight stand-by power regulations are creating a barrier for entry. The standard power-save Wi-Fi operation can be employed in the presence of low data traffic and if supported by the access point (AP) and Wi-Fi stations (e.g. luminaires). However, in the presence of heavy Wi-Fi data traffic, the power-save mode becomes ineffective. Furthermore, during the network setup or joining process, the power-save mode cannot be activated. The

following provides a solution to enable use of Wi-Fi in low-power applications during the network setup or joining process or in the presence of heavy Wi-Fi traffic. Described are a number of adaptive Wi-Fi packet operations combined with the employment an energy buffer to manage the rate of energy consumption. Specifically, the Wi-Fi packet transmission and reception timings are adapted based on the status of the energy buffer.

Figure 1 illustrates a system comprising an illumination device 100 and a wireless access node 102, sometimes also referred to as a wireless access point. The system enables a wireless user terminal such as a laptop, tablet, smartphone or smart watch to communicate with the illumination device 100. The illumination device 100 may take the form of a luminaire or even an individual lamp within a luminaire. The wireless access point 102 may take the form of a node separate from the user terminal, such as a wireless home router. Alternatively the wireless access point 102 may be the user terminal itself. Either way, when the illumination device 100 establishes a wireless connection with the wireless access point 102, it forms or joins a wireless network comprising the device 100, the user terminal, and optionally one or more other devices such as one or more other illumination devices and/or one or more sensor units (not shown). This enables the user terminal to control the illumination device 100 (and optionally the one or more other devices) via the wireless network. For instance this control may be to switch on and off the illumination emitted by the illumination device 100, dim the illumination up and down, and/or change the colour of the emitted illumination. Alternatively or additionally, the wireless network enables the user terminal to receive status reports from the illumination device 100 (and optionally from the one or more other devices) via the wireless network. For instance such status reports may comprise a report of a fault, or of burning hours to date.

In embodiments disclosed herein, the illumination device 100 is configured to connect to the access point 102 using Wi-Fi, and thus communicate with the user terminal directly via Wi-Fi (whereas conventionally the user terminal would have to connect to a bridge via Wi-Fi, which connects onwards to the illumination device via a second wireless networking protocol such as ZigBee or 6LowPAN, with the bridge converting commands from the user terminal from Wi-Fi to the second protocol to be forwarded to the illumination device, and converting reports from the illumination device from the second protocol to Wi-Fi to be forwarded to the user terminal).

As shown in Figure 1, the illumination device 100 comprises an illumination source 104, a power supply 106, and a communications module 108. The illumination source 104 comprises one or more illumination sources, also referred to as lamps. An illumination

source or lamp as referred to herein is an element which, when powered by a suitable power supply 106, emits illumination for illuminating an environment occupied by one or more human users, allowing the users to see features of the environment and/or obstacles within the environment, such as to enable the users to find their way about. In embodiments the (or
5 each) lamp may take the form of an LED-based lamp comprising one or more LEDs (typically a string or array of LEDs). Alternatively the (or each) lamp may take another form, e.g. an incandescent lamp such as a filament bulb or a gas discharge lamp such as a fluorescent tube.

The communications module 108 comprises a communications interface 110,
10 comprising a radio frequency (RF) transceiver for transmitting and receiving RF signals to and from the wireless access point 102, including signals for establishing the connection between the illumination device 100 and the wireless access point. The communications module 108 further comprises a communications controller 112 which is configured to conduct the communications with the wireless access point 102 via the wireless interface
15 110. The controller 112 may also be configured to perform one or more related operations, such as a cryptographic calculation to authenticate the access point 102, and/or to authenticate the illumination device 100 to the access point 102. The communications controller 112 may be implemented in the form of software stored on a memory of the illumination device 100 (the memory comprising one or more memory units employing one
20 or more memory media), and arranged to run on a processor of the illumination device 110 (the processor comprising one or more processing units). Alternatively it is not excluded that the controller 112 may be implemented in the form of dedicated hardware circuitry, or configurable or reconfigurable circuitry such as a PGA (programmable gate array) or FPGA (field programmable gate array), or any combination of hardware and software.

25 The power supply 106 is arranged to be able to supply power to both the illumination source 104 and the communications module 108 (e.g. to the processor upon which the software implementing the communications module is run). N.B. the power supply 106 is not necessarily the source of the power. Rather, in embodiments the power supply is configured to receive power from a source such as the mains, and pass this power on to the
30 illumination source 104 and communication module 108 (conditioning the received power to be suitable for powering the illumination source and communication source if not already suitable for this). Details of power supplies for illumination sources and communications modules will, in themselves, be familiar to a person skilled in the art.

The illumination device 100 is operable to switch between an operational mode (operational state) and a standby mode (standby state). When the illumination device 100 is in the standby state, power is supplied from the power supply 106 to the communications module 108 in order to power the communications module to communicate with external nodes such as the access point 102, and to perform any related computations such as cryptographic calculations for authentication purposes. However, in the standby mode, power is not supplied from the power supply 106 to the illumination source 104, the illumination source 104 thereby being switched off so that it does not emit illumination. Further, in the standby mode the power supply 106 is limited to outputting no more than a certain predetermined power limit (i.e. no more than a certain amount of energy per unit time). For instance this may be a limit set by a regulatory body in a jurisdiction in which the illumination device 100 is intended to be used, or it may be a limit set by the system designer for ecological or economical reasons.

In the operational mode, power is supplied from the power supply 106 to both the illuminations source 104 and the communications module 108, in order to both power the illumination source 104 to emit its illumination and to power the communications module 108 to perform its communications and related computations. In embodiments no specific limit is placed on the power supplied by the power supply. Alternatively there may be a limit, but a substantially higher one than in the standby state.

The illumination device 100 may be configured to be placed in the standby state whenever the illumination source 104 is switched to the off state (i.e. not emitting illumination), for instance because a user has selected through the wireless user terminal to switch off the illumination. In this case the user terminal sends a command to the wireless communications module 108 on the illumination device 100 via the wireless network established via the wireless access point 102, instructing that the illumination source 104 be switched off. The command is received by the controller 112 via the wireless interface 110. In response the controller 112 controls the power supply 106 to switch to the standby state, cutting off the power to the illumination source 104 and therefore turning off the illumination. Conversely, when the user selects on the user terminal to turn the illumination on, the user terminal sends a command to the communications module 108 on the illumination device 100 via the network established using the wireless access point 102. The controller 112 receives this command via the wireless interface 110 and in response controls the power supply 106 to switch to the operational state, thereby turning on the illumination source 104.

As mentioned previously, the growth in wireless personal communications and penetration of smart devices (phones, tablets, watches, etc.) is expected to widen adoption of wireless lighting control. Current practice in this application domain is based on hybrid communication technologies, e.g. ZigBee & Wi-Fi, or 6LowPAN & Wi-Fi, where a protocol bridge handles the cross-over. However, an obstacle in the way of providing a Wi-Fi-only lighting network is the high power consumption of Wi-Fi operations.

For instance, according to EU regulations, the stand-by power consumption for a lighting device, i.e. when the lighting device is OFF, needs to be limited to 500 mW. Or it may be desirable to place an even lower limit on the power consumption, e.g. 150 mW, in order to be even more environmentally friendly.

In comparison, the typical current consumption figures for a Wi-Fi device under different operations are listed in the table below. By way of example, the table shows the typical power consumption data for a RS9110-N-11-02 802.11b/g/n module, using a single point 3.3V, and with a transmit power at the antenna of 15dBm.

Mode	Conditions	Module Current
Standard Operational Modes – 2.4GHz		
Data Transfer – Transmit TCP	1Mbps throughput	19mA
Data Transfer – Transmit TCP	2Mbps throughput	30mA
Data Transfer – Transmit TCP	22Mbps throughput	200mA
Data Transfer – Receive TCP	1Mbps throughput	17mA
Data Transfer – Receive TCP	2Mbps throughput	24mA
Data Transfer – Receive TCP	22Mbps throughput	149mA
Listen	Receive mode, with no active packet reception in progress	110mA

Standby	Remaining connected to the access point, in power-save mode, with DTIM=3, beacon interval of 200ms	1.10mA
Sleep	Not connected to an access point, but ready to connect upon driver command. The module can transition to any active mode in less than 2.5ms.	0.52mA

Derived from the above table, the transmit and receive mode power consumption figures at 22 Mbps are 660 mW ($= 200\text{mA} * 3.3\text{V}$) and 492 mW ($= 149\text{mA} * 3.3\text{V}$), respectively. Although not shown in the table, some Wi-Fi chipsets also operate at 54 Mbps or higher data rates, leading to higher currents and power consumptions.

Even if the Wi-Fi device is not making any active packet transmission and receptions, it is still listening to the channel and consumes significant amount of power. To deal with this unnecessary power consumption, there is a standardized power-save operation, which allows a Wi-Fi device to go to the state of doze while not actively engaged in transmitting or receiving a packet. In the state of doze, the power consumption of the Wi-Fi is almost negligible as also specified by the above table. Each device in the power-save mode regularly wakes up to receive the beacons from the access point and retrieve the incoming packets that are buffered by the access point.

If such a power-save operation is supported by the access point after the network connection is established between the access point and the Wi-Fi device in the power-save mode, and if the network data traffic is quite low, then the average power consumption of the device can be significantly reduced.

However, when there is heavy data traffic in the Wi-Fi network, such a power-save operation becomes ineffective. Moreover, during the network setup or joining process in which a device establishes the secure connection with the access point, no power-save operation can be supported by the access point. Moreover, during the network setup or joining process, multiple packets are exchanged between the access point and the device with about ten round-trip of handshake messages for authentication and association purposes, along with some computationally intensive security calculations such as hash computations and public-key operations. The entire process can last from several seconds to more than ten seconds. Hence, the network setup or joining process has a high power consumption. It is in fact also a critical process for Wi-Fi connectivity, guarding the entry of Wi-Fi connectivity.

It would be desirable to reduce the power consumption (energy consumed per unit time) of the Wi-Fi network setup or joining process so as to keep it within the power consumption limit of the power supply 106 of an illumination device 100 in a standby mode, e.g. within the 500mW limit of EU regulations. That is, even if the total energy consumed is the same, it would be desirable to reduce the instantaneous rate of energy consumption to within the standby power limit of the power supply 106 so as to enable the adoption of Wi-Fi technology directly into the illumination device 100, rather than requiring a second technology such as 6LowPAN and ZigBee plus a bridge between this second technology and the Wi-Fi communications employed by the user terminal.

Figure 2 depicts a typical current consumption profile of a process of authenticating and associating a Wi-Fi device to a Wi-Fi access point. The process comprises a plurality of listening periods 200a in which the device listens for packets from the access point and verifies the absence of any other data traffic on the channel prior to its own transmissions. The process also comprises a plurality of transmission periods 200b in which the device transmits packets to the access point, a plurality of reception periods 200c in which the device receives packets from the access point. Further, and the process comprises at least one security calculation period 200d in which the device performs a security calculation as necessary to perform the authentication process with the access point. The security process comprises at least the access point authenticating the device, because the access point is the gateway for a device to connect to the network. Under higher security requirements, it may also be required for the device to authenticate the access point. During the security calculation period, the device also continues to listen for packets from the access point. In embodiments, elliptic curve cryptography (ECC) may be used as the underlying ciphersuite for authentication, as is generally used for constrained environments. Typical figures for the duration and power consumption of the various periods of listening, receiving, transmitting and calculating 200a-200d are shown in Figure 2. Different modes of this process take more than 100 mA of current and last up to 10s.

The peak current that is provided by a power supply 106 of the illumination device 100 is limited in such a way that the total stand-by power (i.e. when the light is OFF) is kept below the set limit. That is, the power supply 106 is configured with a physical limit on the power it can supply when in the standby mode. This limit may be a hard physical limit in that the power supply 106 cannot supply any power higher than this; or it may be a soft physical limit in that power supply 106 will not work properly above the limit according to its specifications, although it may not necessarily stop working completely or immediately if

one was to attempt to draw power beyond the limit. Further, the limit may either be an inherent limitation on the capability of the power supply 106, or it may be an intentional result of a power-limiting circuitry explicitly added to the power supply 106 to throttle the power during the standby mode (e.g. for environmental reasons). In addition, in embodiments the power supply 106 may effectively be limited to about 70% when converting from AC mains voltage (e.g., 230V) to the DC low Wi-Fi supply voltage (3.3V), in which case the actual available power is even lower than what is set by the standby regulation. Furthermore, the total stand-by power budget also covers power that is dissipated in the main driver of the light source 104 as well.

Consequently, straight-forward operation of a Wi-Fi module would not be possible under such stringent stand-by power restrictions.

Figure 3 shows an arrangement for addressing this issue or similar. As shown in Figure 3, the illumination device 100 is adapted to include an energy buffer 300 disposed between the power supply 106 and the wireless communications module (e.g. Wi-Fi module) 108. The energy buffer 300 may take the form of a rechargeable battery or a capacitor such as a super capacitor. In embodiments the illumination device 100 is also equipped with an energy monitor 302 arranged to measure the amount of energy currently stored in the energy buffer 300 and to provide this measurement to the controller 112. Alternatively the controller 112 may be configured to estimate the amount of energy currently stored in the energy buffer 300 based on information on the charge rate of the buffer 300, on the power drawn by the various communications operations 200a-200d, and on the duration of these operations.

The energy buffer 300 is arranged to buffer the energy supplied from the power supply 106 to the communications module 108 in the standby mode, i.e. to temporarily hold back some or all of the energy from the power supplied by the power supply 106 so that it can then be released to the communications module 108 at a temporarily greater rate than the standby power limit of the power supply 106, without drawing more than the standby power limit from the power supply 106 itself at any moment in time. The controller 112 is configured so as, in dependence on the amount of energy measured by the energy monitor 302 or estimated by the controller 112 to be currently stored in the energy buffer 300, to: (a) control the build-up and release of energy from the energy buffer 300 and (b) to adapt the timing of the communications and related operations performed by the controller 112, e.g. to adapt the timing of the operations 200a-200d involved in the network set-up or joining processed; such that overall the rate of energy consumed by the communications module 108 does not exceed the standby limit of the power supply 106. In embodiments, the controller

112 may also be configured to reduce the rate of data transmission of one or more of the transmission operations 200b, and/or to reduce the processing rate of one or more of the security calculations 200d, in order to reduce the instantaneous power required by the communications module 108 during these operations and thereby reduce degree of energy buffering required.

In embodiments, the illumination device 100 thus enables Wi-Fi operations under tightly constrained stand-by power scenarios. The energy buffer 300 is designed to provide the high peak current needed during Wi-Fi operations. The amount of energy stored in the energy buffered 300 is monitored and/or estimated, and one or more of the following are adapted based on the status of the energy buffer 300: (i) Wi-Fi packet transmissions timing, and/or one or more other transmission parameters such as transmission data rate and/or RF transmission power; (ii) Wi-Fi packet reception timing; and/or (iii) the power consumption during security calculations. The Wi-Fi mode may be switched to standby based on the status of the energy buffer 300, and advance knowledge of upcoming Wi-Fi operation(s). Such upcoming Wi-Fi operations may be: (I) security calculations of either the device 100 itself or the node 102 it communicates with; (II) upcoming receive operations, and the retransmission timings of the communication partner; and/or (III) number of exchanges still to be done in order to conclude a process such as network set-up or joining.

Instead of a traditional arrangement where the power is directly fed from a power supply to the Wi-Fi module 108, an additional component in the form of the energy buffer 300 is included. The role of the energy buffer 300 is to store energy as well as to regulate the voltages for the Wi-Fi module 108. At the same time, the remaining energy level inside the energy buffer 300 is measured or estimated and further employed to adapt Wi-Fi operations, such as exemplified shortly.

The energy buffer 300 can be realized in the form of a storage capacitor or a rechargeable battery. The storage size is dimensioned to be able to bridge the gap between high burst current demand of Wi-Fi module 108 and the limited current from the power supply 106. The buffer 300 is charged if the energy flow from the power supply 106 is higher than that drawn to the Wi-Fi module 108. Otherwise, the buffer 300 is discharged. The rate of charging and discharging depends on the supply and consumption currents.

The level of stored energy can be measured by measuring the voltage across the storage capacitor and combining it with the capacitance size. Alternatively in the case of a rechargeable battery, a battery meter can be used. As another alternative, based on knowledge of the current consumption of each Wi-Fi operation mode and also the time schedule for

different operation modes, it is also possible for the controller 112 to estimate the stored energy without measurement and to adjust the Wi-Fi operations accordingly.

The arrangement thus enables Wi-Fi operation under tightly constrained stand-by power scenarios. The energy buffer 300 provides the high peak current needed during Wi-Fi listen, compute, receive and transmit modes, and the controller 112 implements an energy-buffer management scheme that is aligned to the Wi-Fi MAC protocol operation, taking into account the operation mode of the illumination device 100.

Figure 7 illustrates further detail of an example implementation. The power supply 106 is arranged to receive power from a power line 702 such as a mains power line. The power supply 106 comprises an LED driver 704 arranged so as, in the operational mode, to convert a portion of the power received from the power line 702 into a form suitable for driving the illumination source 104, which in this embodiment takes the form of at least LED-based lamp comprising a string or array of LEDs. The power supply 106 further comprises a current-limited power supply 706 arranged so as, in the operational mode, to convert a portion of the power supplied from the power line 702 into a form suitable for powering the communications module 108, which in embodiments takes the form of a Wi-Fi module. Further, the current-limited power supply 706 arranged so as, in the standby mode, to convert the power supplied from the power line 702 into a form suitable for powering the communications module 108 but with a predetermined limit placed on the supplied current.

The current-limited power supply 706 generates a first voltage (V_1) and current (I_1), which are interfaced to the Wi-Fi module 108 which draws a third current (I_3) at voltage (V_3). The current-limited power supply 706 provides the first voltage (V_1) and current (I_1) to the energy buffer 300, which is arranged to buffer the energy from the first voltage (V_1) and current (I_1), and to output the buffered energy in the form of a second, intermediate voltage (V_2) and current (I_2). The illumination device 100 further comprises a voltage regulator 710, and the energy buffer 300 is arranged to provide the intermediate voltage (V_2) and current (I_2) to the voltage regulator 100. Following the voltage regulation, the communications module 108 draws the power from the voltage regulator 710 in the form of the third voltage (V_3) and current (I_3). The energy buffer 300 and a voltage regulator 710 provide the translation between the two power domains. The intermediate voltage (V_2) and current (I_2) depend on the actual circuit implementation.

The communications controller 112 of the communications module 108 comprises a power manager 708 to monitor the level of stored energy (ESENSE) in the energy buffer 300. The power manager 708 is also configured to monitor the status

(WSTATUS) of the wireless interface 110, e.g. Wi-Fi interface. Further, the illumination device 100 comprises an illumination source controller 712 (implemented in software or hardware or any combination thereof) arranged to control the illumination source 104 via the driver 704, based on control signals (LCONTROL) received via the wireless interface 110, and optionally to report information (LDATA) concerning the illumination source 104 and/or its driver 704 via the wireless interface 110. The energy manager 708 is coupled to the illumination source controller 712 in order to monitor the status (LSTATUS) of the illumination source 104 to determine the current operating mode of the illumination source. Based on these monitored statuses, the power manager 708 controls the wireless interface 110 to operate in a corresponding mode (MODE).

A flow chart of a process for managing the energy-adaptive Wi-Fi operation is shown in Figure 8. In embodiments the process may be implemented by the energy manager 708, or more generally by the communications controller 112. This energy-adaptive mode is activated if the illumination device 100 is in stand-by mode; otherwise, normal Wi-Fi operation can be maintained by activating a boost command (PBOOST) sent to the current-limited power supply 706, to get more power from the power supply unit 106 during the operational mode. In the latter case, since the illumination device 100 is ON, the power drawn by Wi-Fi operation has (relatively) very little influence on the overall power consumption. When the illumination device 100 is OFF on the other hand, the standby mode is activated in which case the current-limited power supply 106 provides a limited current output and the energy-buffer management process take over the control. If a certain task cannot be relaxed (e.g., by decreasing data rate or system clock frequency), it is postponed until the energy storage in the buffer 300 is charged to a sufficient level.

Referring to Figure 8, the method begins at step 800. Then at step 802 it is determined whether the illumination source 104 is turned OFF. If not (the illumination source 104 is ON), the method proceeds to step 804 where the power from the power supply 106 is boosted, and then to step 806 where the Wi-Fi operations are performed powered by the boosted power. The method then returns to the start.

If on the other hand it is determined at step 802 that the illumination source 104 is OFF, then the method proceeds to step 808 where the energy stored in the energy buffer 300 is measured or estimated. The method then proceeds to step 810 where the next Wi-Fi operation to be performed is estimated (e.g. an operation of 200a listening for a packet, 200b transmitting a packet, 200c receiving a packet, or 200d performing a security calculation such as an ECC). At step 812 it is determined, based on the measure or estimate

of the energy stored in the buffer 300, whether there is sufficient energy to perform the Wi-Fi operation in question. If so, the method proceeds to step 814 where the operation is performed. The method then loops back to the start.

If on the other hand it is determined at step 812 that there is insufficient energy in the buffer 300 to perform the next operation 200, then the method proceeds to step 816 where it is determined whether the operation in question can be relaxed (by reducing the transmission rate for a transmission operation 200b or reducing the processing rate for a security calculation 200d) and whether doing so will allow the operation to be performed using the energy currently in the buffer plus the energy to be received from the power supply over the duration of the operation. If so, the method proceeds to step 818 where the operation is adjusted accordingly (by reducing the data transmission rate if a transmission operation or reducing the processing rate of a security calculation). The method then proceeds to step 814 where the operation is performed, and then the method loops back to the start.

If however it is determined at step 818 that the next operation 200 cannot be relaxed (e.g. it is a listen operation 200a or receive operation 200c, or it is a transmission operation 200b or a security operation 200d but there is insufficient energy available to perform it), then the method proceeds to step 820 where the operation in question is instead postponed while the energy buffer 300 continues to charge. Once there is enough energy available in the buffer to allow the operation to be performed, the controller 112 controls the energy buffer to release its stored energy to the communications module 108 in order to perform the operation. The method then loops back to the start.

The details of each process and decision in the flow chart depend on the status of the Wi-Fi MAC protocol. Figures 4-6 show some example schemes that may be deployed in the power management process to adjust the Wi-Fi operation without affecting the overall behaviour.

Figure 4 illustrates the adaptation of Wi-Fi packet transmissions 200b in accordance with embodiments disclosed herein. This involves lowering the transmit data rate (e.g., from 22 Mbps to 2 Mbps) to reduce the peak current requirement. This is done when the stored energy level is lower than what is needed for high data. There is a corresponding increase in transmission duration which is still acceptable from communication performance point of view. The listening mode which consumes about 110 mA is interrupted to allow the energy buffer to charge to a level high enough for the subsequent transmit session. This is possible since the cryptographic processing takes place via explicit handshake events that tolerate eventual delays of acknowledgements.

For instance, during the network connection setup process, the remaining energy level inside the buffer 300 is monitored (or estimated). The lower timing diagram in Figure 4 shows the updated current consumption profile is, in comparison to the non-adapted profile as shown in the upper timing diagram.

5 Consider then the scenario where the next Wi-Fi operation is to transmit a packet 200b. If it is measured or estimated that the stored energy in the buffer 300 is not sufficient to carry on the upcoming transmit operations, then the communications controller 112 switches off the Wi-Fi transceiver 100 completely in order to charge the buffer 300 at a higher current and therefore rate, until there is enough power, or when the buffer is full. By
10 this approach, sufficient charge is accumulated to perform the transmit operation 200b.

The transmission operation 200b can also be optimized by adjusting the transmission rate and therefore power level, taking into account the various upcoming operations 200 involved in the network setup of joining process. The peak power is thus reduced. Hence less power buffering is needed, to ensure a smooth network connection
15 process.

By these adaptive Wi-Fi transmission strategies, there is no risk of disrupting the Wi-Fi authentication and association process. In the same time, sufficient energy is guaranteed to undertake the Wi-Fi transmissions.

Figure 5 shows the adaptation of Wi-Fi packet receptions 200c in accordance
20 with further embodiments disclosed herein. The bottom timing diagram in Figure 5 illustrates the updated current consumption profile based on the proposed adaptation of Wi-Fi packet receptions, compared to the non-adapted profile as shown in the upper timing diagram.

Similar to the adaption strategy for Wi-Fi packet transmission, it is also possible to undertake an adaptive Wi-Fi packet reception strategy. Consider the scenario
25 where the next Wi-Fi operation is to receive a packet 200c. If the stored power in the energy buffer 300 is not sufficient to execute the upcoming receive operation, the communications controller 112 can switch off the Wi-Fi receiver 110 in order to charge the buffer 300 at a higher current and therefore speed.

Preferably, the sleeping duration here should not be larger than the duration of
30 the number of expected retransmissions from the access point 102 combined with the random channel access time. Further, this sleeping time should preferably be more conservative when close to finishing the Wi-Fi connection setup process, e.g. no sleeping for the last hand-shake packet exchange to increase reliability. Sleeping longer can be allowed if the communications controller 112 knows that the access point 102 needs to do some calculation

before responding, or is busy with a Radius server for authentication purposes. In embodiments, the controller 112 may enable this feature on condition that the link quality is high enough to have a high packet success probability for one of the re-transmissions.

Figure 6 shows adaptation of the power consumption during security calculations 200d in accordance with yet further embodiments of the present disclosure. In the original (non-adapted) current consumption profile shown in the top timing diagram, while the device is performing cryptographic security calculations (e.g. ECC calculations), the RF transceiver 110 is still on. This is in fact unnecessary since no Wi-Fi packet exchange is expected during such security calculations. Hence as shown in the lower timing diagram, in 10 embodiments the communications controller 112 is configured to switch off the RF transceiver 110 during this time, to reduce the buffered power discharge, and provide additional power charge to the energy buffer 300.

In embodiments, the controller 112 may also be configured to undertake the security calculations (e.g. hash calculations) at a lower processing clock rate in order to 15 reduce the power consumption. If the handshake process may be disrupted due to the long security calculation time, the communications controller 112 may further split the security calculations into urgent ones necessary for the next handshake process and non-urgent ones. The controller 112 may then further distribute the non-urgent security calculations to different time slots instead of a continuous time block. A concrete way to achieve this 20 distribution is by delaying the certificate verification of the key agreement parameters to a later stage and instead performing the key agreement calculations immediately; i.e. when required and the energy budget allows and/or as after the moment when required, but as soon as possible as the energy budget allows. The certificate verification can be performed at a later stage (but before any data can be trusted based on the initial key agreement). This 25 allows for enough time for energy buffering before the certificate verification calculations without delaying the sending of key agreement messages to the access point 102.

According to the various embodiments discussed above, there have therefore been provided techniques for the combined operation of an energy storage component 300 and the Wi-Fi operation in which the usual execution of Wi-Fi tasks is relaxed and/or 30 postponed depending on the state of the illumination device 100 and the energy buffer 300. The illumination source 100 uses a current-limited power supply that guarantees standby regulations (thus no need to hard disconnect it from the mains), but nonetheless by means of the energy buffer 300, the power supply can in effect be requested to release more energy briefly in such a way that the performance does not degrade. Further, in embodiments, the

current-limited power supply may occasionally be requested more energy (e.g. via the BOOST control signal) when the Wi-Fi operations demand it.

The disclosed techniques can be applied in any context where there power is restricted, e.g. either due to stand-by power regulations or the energy source has a limited capacity (e.g. scavenging from solar, or due to a maximum current of a battery).

It will be appreciated that the above embodiments have been described by way of example only.

For instance, while the above has been described in terms of an illumination device, the techniques described herein can also be applied to powering other loads having an associated wireless communication module. For example the device may take the form of a sensor unit such as a presence sensor, the load being a sensor such as an active ultrasound sensor, passive infrared sensor or camera.

Further, the applicability of the above-described techniques is not limited to Wi-Fi. Other wireless protocols may also consume more power than the standby power limit of any given illumination device or other device, and therefore may also benefit from a power-slowdown as disclosed herein. Note also that the term "access point" as referred to herein does not necessarily have to limit to a Wi-Fi access point. Further, although the above has been described in terms of wireless communications, similar techniques can also be applied in relation to wired communications.

Further, the disclosed techniques are not limited to use in a network setup or joining process, and more generally may apply in relation to any exchange of messages or related processing operations.

Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single processor or other unit may fulfil the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. A computer program may be stored/distributed on a suitable medium, such as an optical storage medium or a solid-state medium supplied together with or as part of other hardware, but may also be distributed in other forms, such as via the Internet or other wired or wireless telecommunication systems. Any reference signs in the claims should not be construed as limiting the scope.

CLAIMS:

1. An illumination device (100) comprising:
 - an illumination source (104);
 - a communications module (108) comprising a communications interface (110)and a controller (112) configured to communicate via the communications interface with an
5 external node (102) external to said device;
 - a power supply (106) arranged to supply power to the communications module and to the illumination source when the device is in an operational mode, and to supply power to the communications module but not the illumination source when the device is in a standby mode, wherein the power supply is arranged to restrict the supplied power to no
10 more than a predetermined standby power limit of the illumination device during the standby mode; and
 - an energy buffer (300) arranged to buffer energy from the power supplied from the power supply to the communications module during the standby mode, by storing up the energy and at times releasing the stored energy to the communications module at a
15 greater rate than supplied by the power supply;
 - wherein the controller is configured to perform a series of communication operations involved in and/or relating to the communication via the communications interface;
 - wherein the controller is configured to adapt a schedule of said communication
20 operations in dependence on a measure or estimate of the amount of energy currently stored in the energy buffer, at least by delaying one or more of the communication operations which require more than the standby power limit to perform until the energy measured or estimated to be stored in the energy buffer is great enough to perform said one or more communication operations without exceeding the standby power limit; and
 - 25 wherein the one or more communication operations which the controller (112) is configured to schedule and perform comprise cryptographic calculations and wherein the controller is further configured to split cryptographic calculations into urgent and non-urgent security calculations, wherein:
 - the urgent security calculations are performed when required or as soon as

possible thereafter when the energy stored allows and

- the non-urgent ones are performed at a later stage.

2. The device of claim 1, wherein the controller (112) is further configured to adapt a rate at which at least one other of the communication operations is performed in dependence on the energy measured or estimated to be stored in the energy buffer (300).

3. The illumination device of claim 1 or 2, wherein the communication operations which the controller (112) is configured to schedule and perform comprise one, more or all of:

- an operation of transmitting a signal to the external node,
- an operation of receiving a signal from the external node, and/or
- an operation of listening for a signal from the external node and/or checking for absence of any other data traffic on a same channel prior to transmitting from the illumination device to the external node.

4. The illumination device of claim 1 or 2, wherein said cryptographic calculations comprise one or both of:

- a cryptographic calculation to authenticate the external node (102) based on a signal received from the external node, and/or
- a cryptographic calculation to authenticate said illumination device (100) to the external node based on a signal transmitted from the illumination device to the external node.

5. The illumination device of claim 4, wherein the controller (112) is further configured to switch off the communications interface (110) so as not to transmit, receive or listen for any signals while one or both of said cryptographic calculations are being performed.

6. The illumination device of any preceding claim, wherein the controller (112) is configured to boost the power supplied by the power supply (106), when in the operational mode, beyond the standby power limit plus the power drawn by the illumination source (104).

7. The illumination device of any preceding claim, wherein the illumination device further comprises an energy monitor (302) configured to measure the energy stored in the energy buffer (300), the controller (112) being configured to perform said adaptation based on the energy measured by the energy monitor to be stored in the energy buffer.

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8. The illumination device of any of claims 1 to 6, wherein the controller (112) is configured to estimate the energy stored in the energy buffer based on a charge rate and a time elapsed, the controller being configured to perform said adaptation based in the energy estimated by the controller to be stored in the energy buffer.

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9. The illumination device of any preceding claim, wherein the energy buffer comprise a capacitor or rechargeable battery.

10. The illumination device of any preceding claim, wherein the communications interface (110) is a wireless communications interface, the communications which the controller (112) is configured to perform via said wireless interface being wireless communications, and said series of communications operations being operations involved in and/or relating to said wireless communications.

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11. The illumination device of claim 10, wherein the wireless communications interface (110) is a Wi-Fi interface, the wireless communications which the controller (112) is configured to perform via said wireless interface being Wi-Fi communications, and said series of communications operations being operations involved in and/or relating to said Wi-Fi communications.

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12. The illumination device of claim 10 or 11, wherein said external node is a wireless access node for connecting the illumination device to a wireless network, said series of communication operations which the controller (112) is configured to perform being operations for establishing a connection with the wireless access node in order for the illumination device to connect to said network.

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13. A method of operating an illumination device (100) comprising an illumination source (104) and a communications module (108), the communications module (108) being for communicating with an external node (102) external to said illumination

device; the method comprising:

in an operational mode of the illumination device, supplying power from a power supply (106) to the communications module and the illumination source;

in a standby mode of the illumination device, supplying power from a supply power to the communications module but not the illumination source, wherein the supplied power is restricted to no more than a predetermined standby power limit of the illumination device during the standby mode;

buffering energy from the power supplied from the power supply to the communications module during the standby mode, by storing up the energy and at times releasing the stored energy to the communications module at a greater rate than supplied from the power supply;

performing a series of communication operations involved in and/or relating to the communication with the external node; and

adapting a schedule of said communication operations in dependence on a measure or estimate of the amount of energy currently stored in the energy buffer, at least by delaying one or more of the communication operations which require more than the standby power limit to perform until the energy measured or estimated to be stored in the energy buffer is great enough to perform said one or more communication operations without exceeding the standby power limit; and

wherein the one or more communication operations which the controller (112) schedules and performs comprise cryptographic calculations and the method further comprises:

splitting cryptographic calculations into urgent and non-urgent security calculations, wherein:

- the urgent security calculations are performed when required or as soon as possible thereafter when the energy stored allows and
- the non-urgent ones are performed at a later stage.

14. A computer program product stored on a computer-readable storage, characterized in that it comprises program code instructions for implementing a method according to claim 13 when run on one or more processing units.

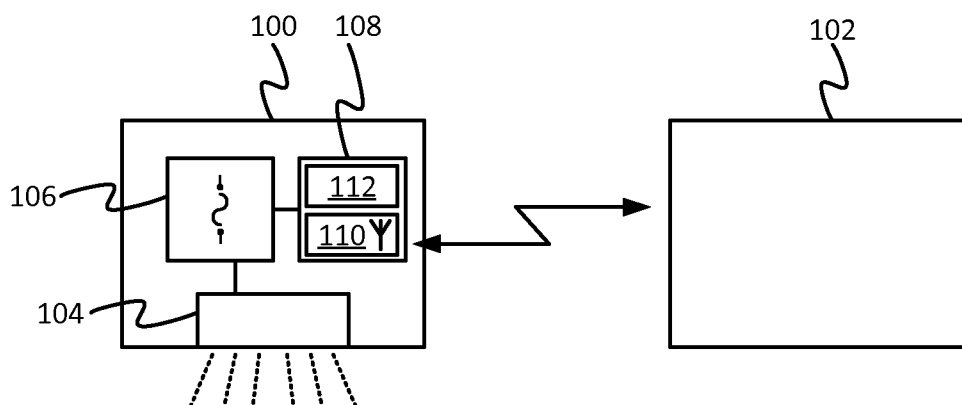
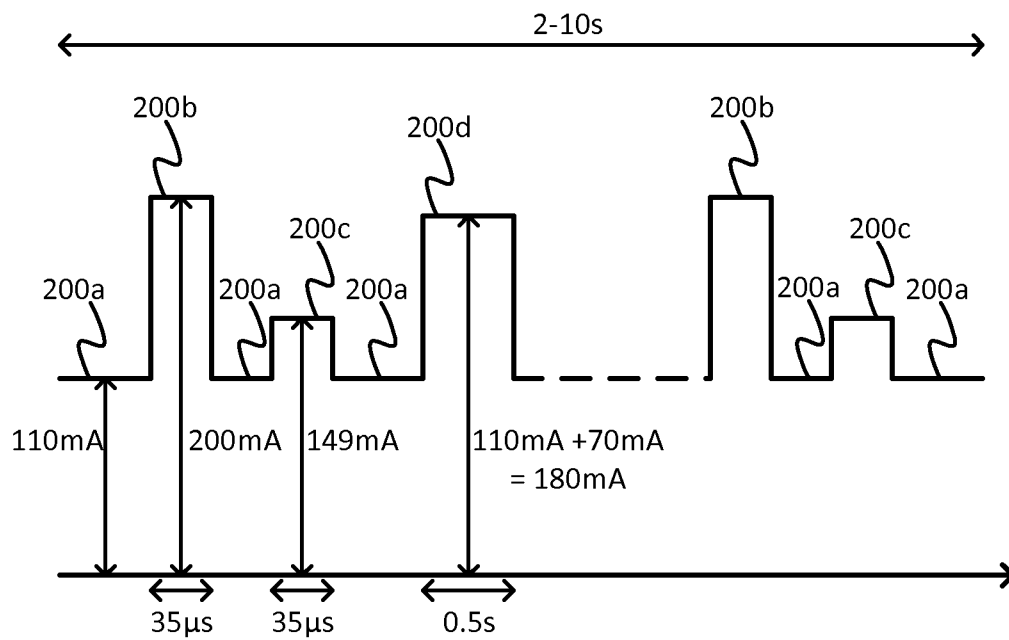
Figure 1Figure 2

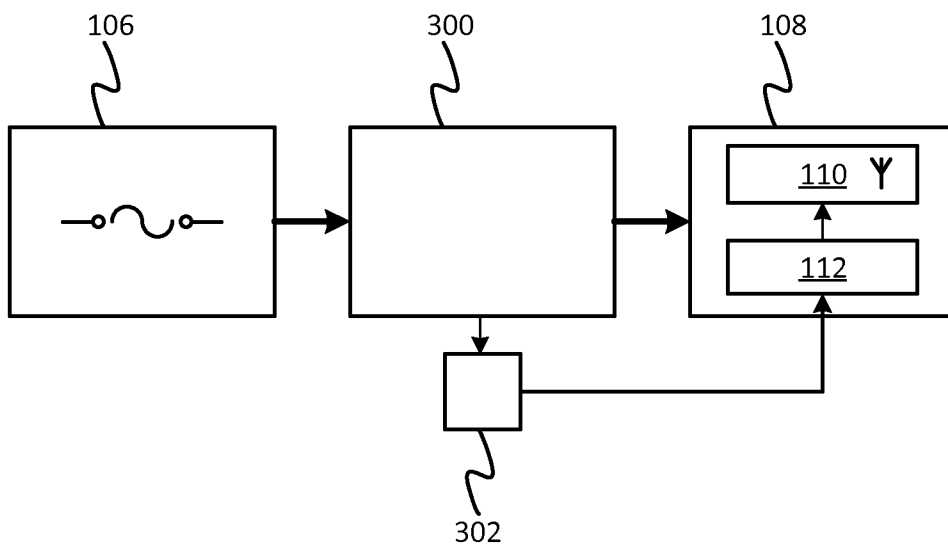
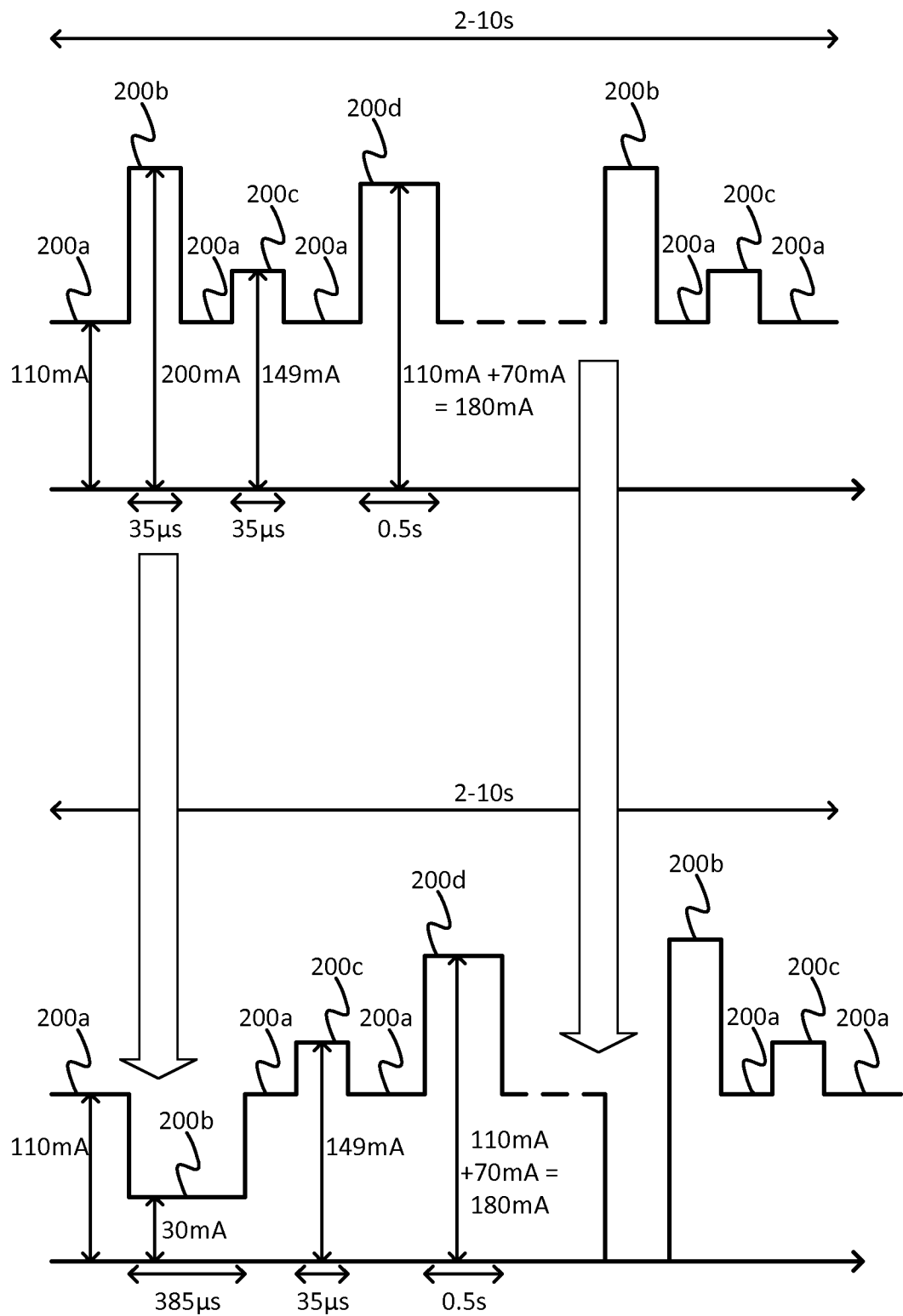
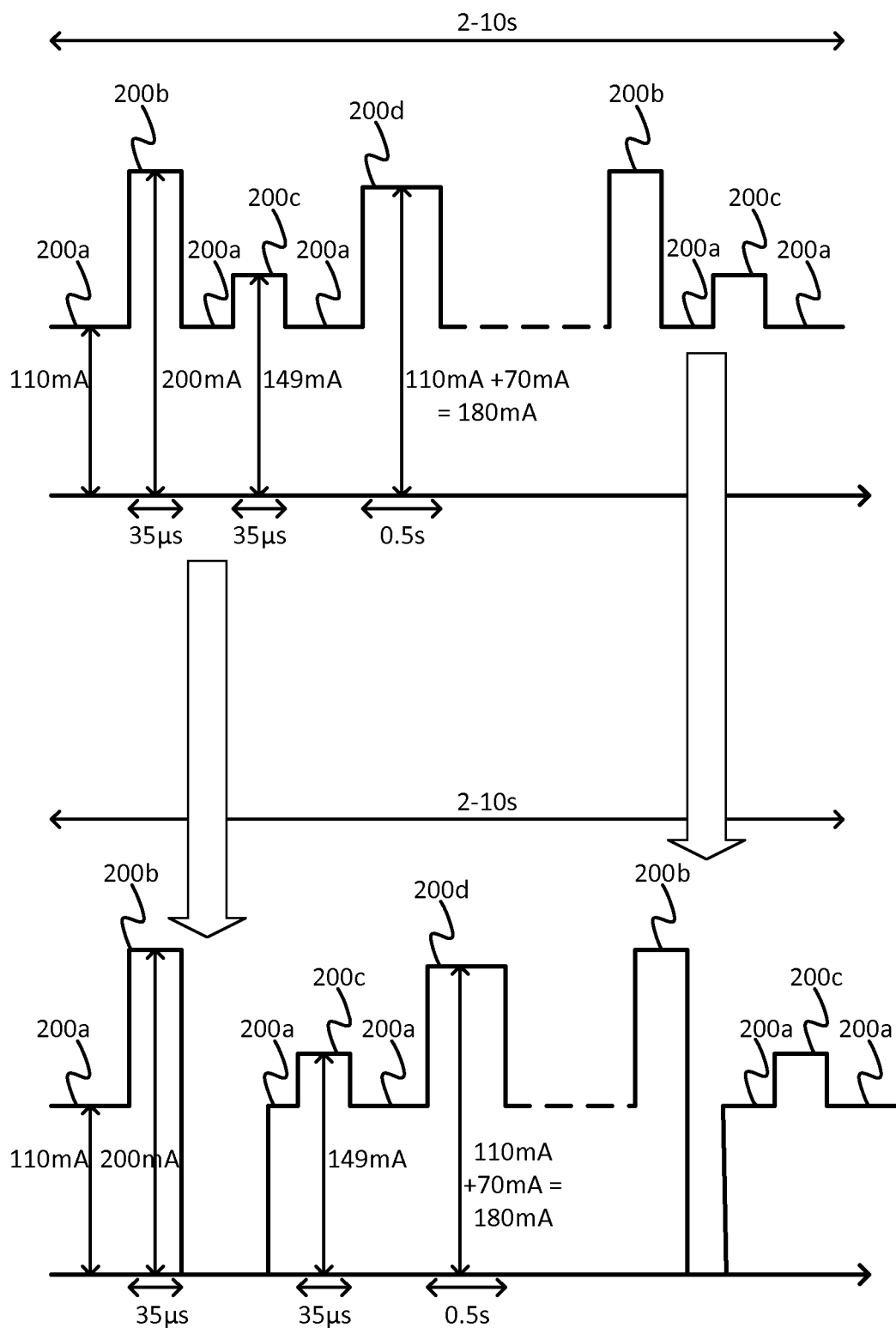
Figure 3

Figure 4



4/7

Figure 5

5/7

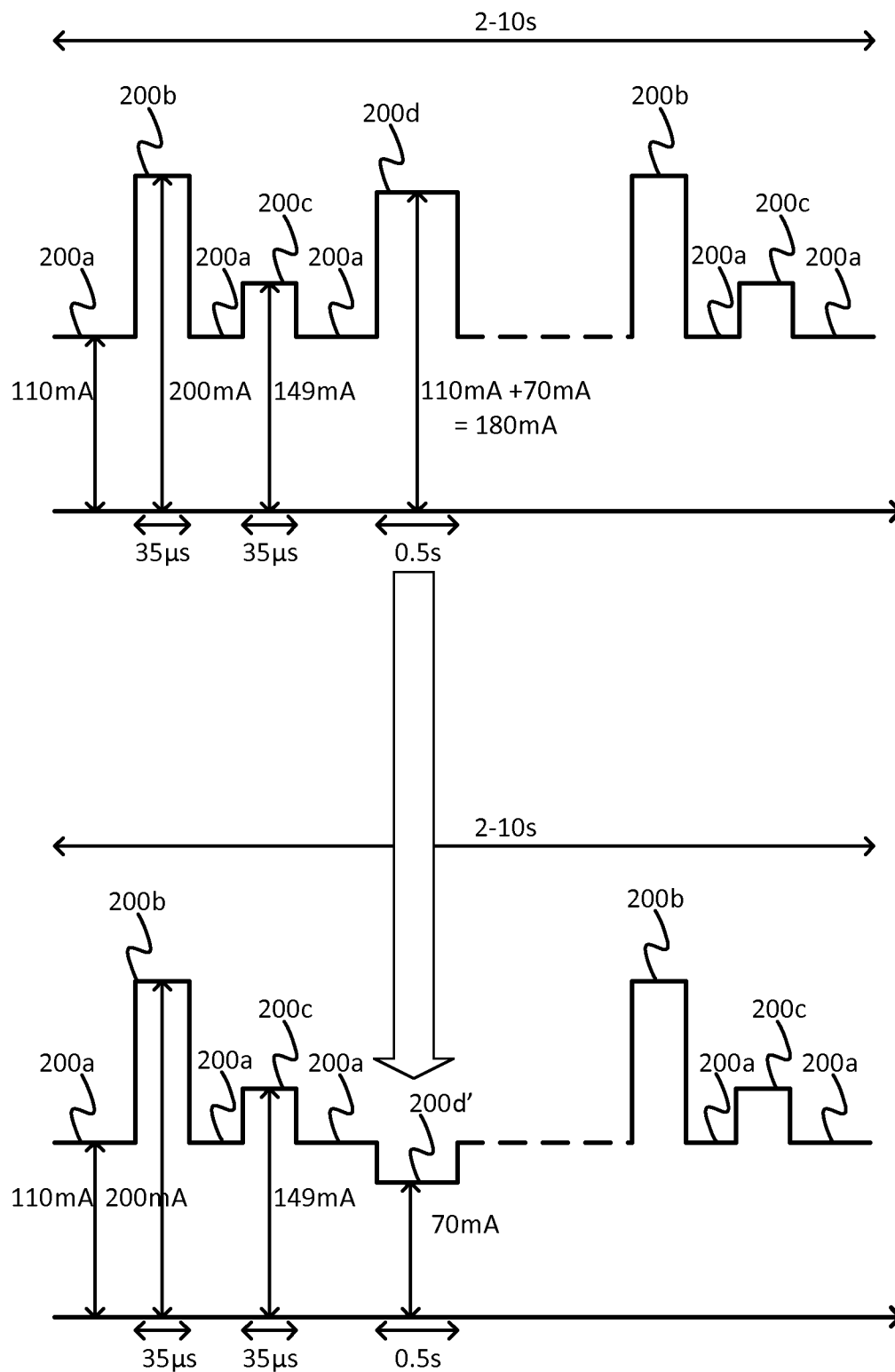
Figure 6

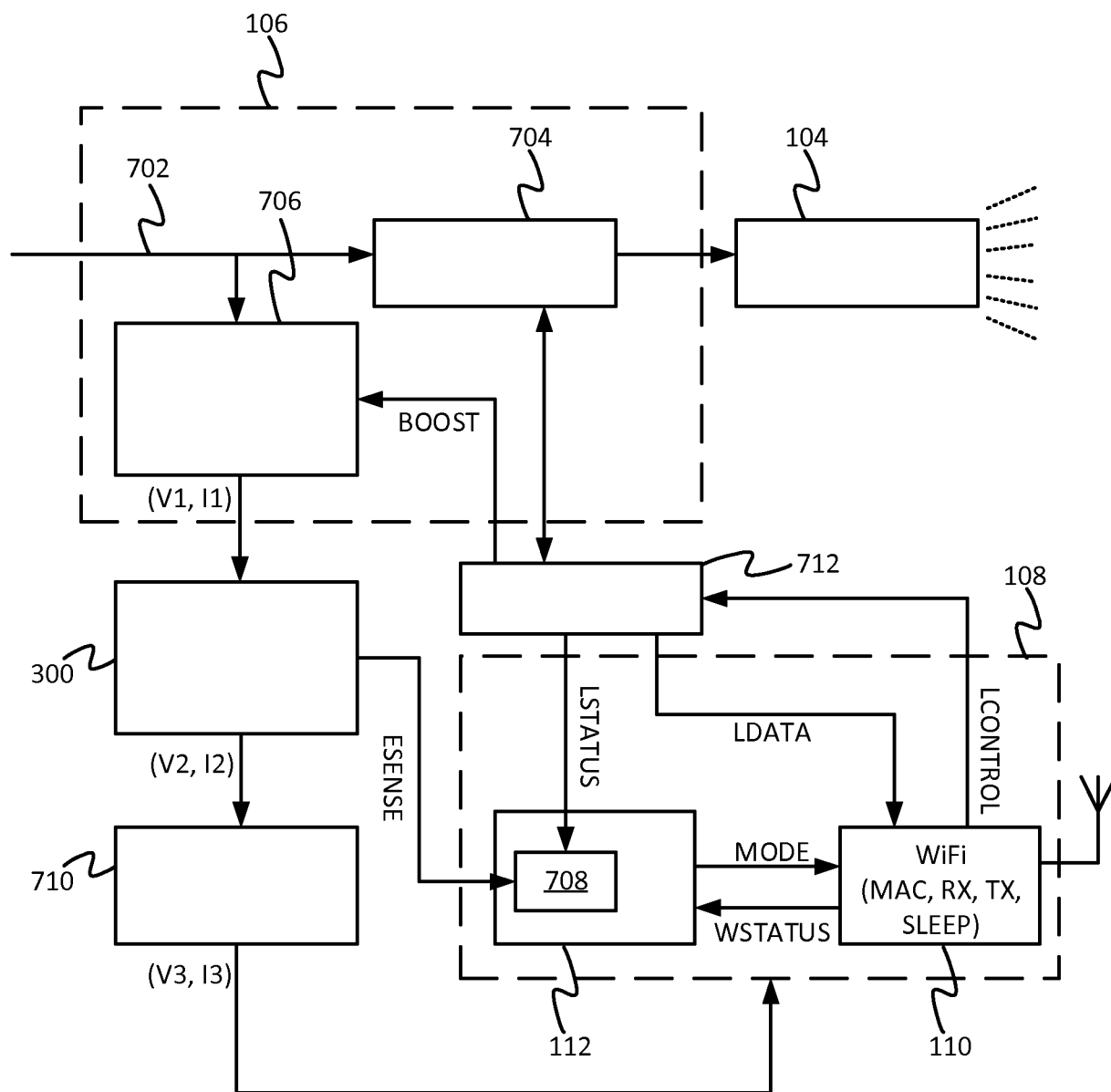
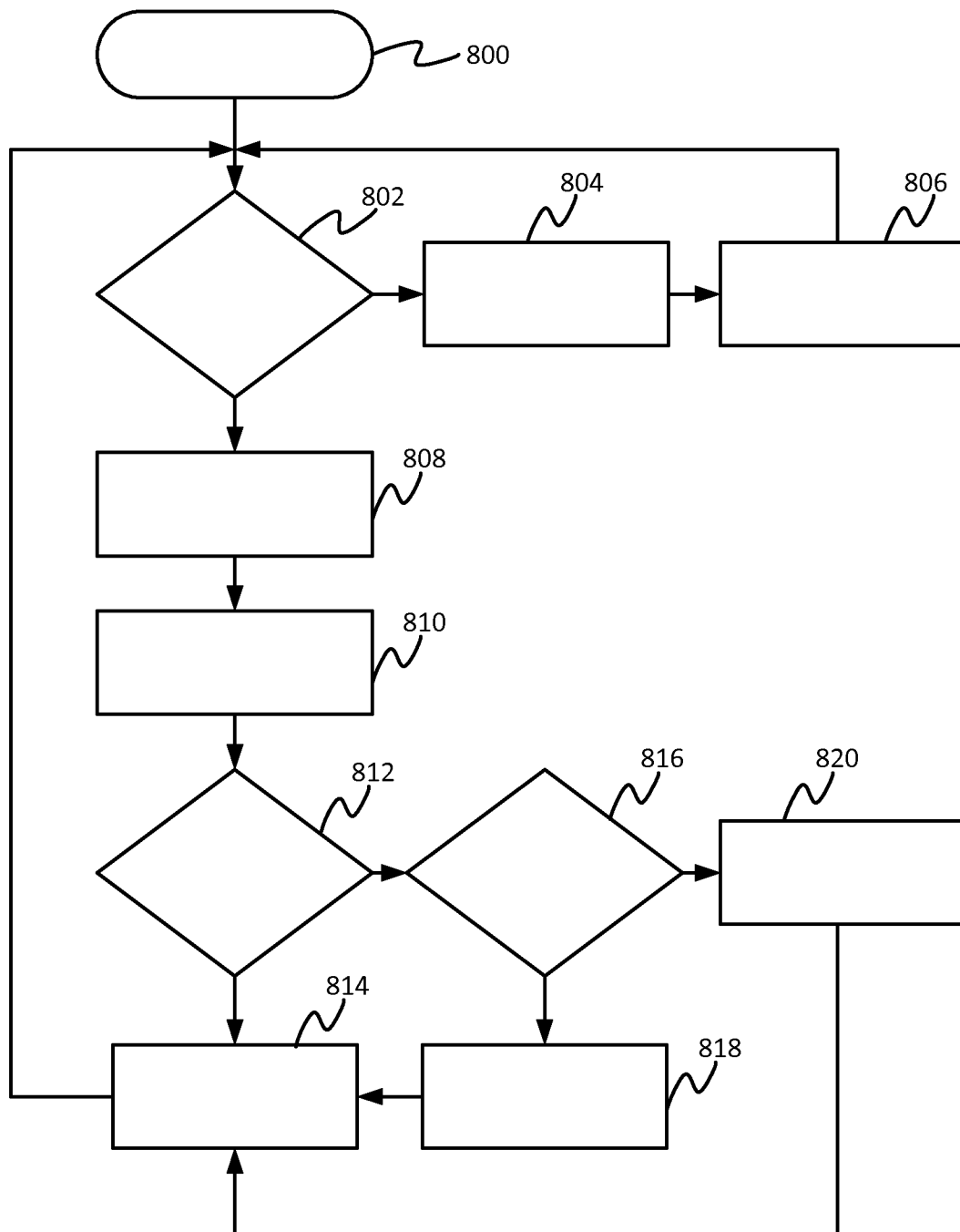
Figure 7

Figure 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/079872

A. CLASSIFICATION OF SUBJECT MATTER
INV. H05B37/02
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)
H05B

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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 1 202 145 A1 (FOXBORO CORP [US]) 2 May 2002 (2002-05-02) paragraphs [0002] - [0004], [0018], [0028], [0039], [0047], [0048], [0070] - [0072], [0098] - [0101], [0108] - [0111]; claims 1-3,31-33; figures 7-16 -----	1-14
A	EP 2 928 045 A1 (NIKO NV [BE]) 7 October 2015 (2015-10-07) paragraphs [0013], [0042]; claims 1,2; figure 1 -----	1,13,14
A	WO 02/082618 A1 (MICROCHIP TECH INC [US]) 17 October 2002 (2002-10-17) page 5, line 8 - page 13, line 29; claim 1; figure 1 -----	1,13,14



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

8 January 2018

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12/01/2018

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2017/079872

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1202145	A1	02-05-2002	DE 60018072 D1 17-03-2005
			DE 60018072 T2 29-12-2005
			EP 1202145 A1 02-05-2002
			US 2002065631 A1 30-05-2002
			US 2007229255 A1 04-10-2007
			US 2010061733 A1 11-03-2010

EP 2928045	A1	07-10-2015	NONE

WO 02082618	A1	17-10-2002	AT 310330 T 15-12-2005
			DE 60207396 D1 22-12-2005
			DE 60207396 T2 03-08-2006
			EP 1374366 A1 02-01-2004
			TW 564343 B 01-12-2003
			WO 02082618 A1 17-10-2002
