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Innovation, Science and Economic Development Canada
Canadian Intellectual Property Office

CA 3055152 A1 2015/04/16

(21) 3 055 152

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(22) Date de dépôt/Filing Date: 2014/10/08
(41) Mise à la disp. pub./Open to Public Insp.: 2015/04/16
(62) Demande originale/Original Application: 2 998 037
(30) Priorité/Priority: 2013/10/09 (GB1317851.2)
(51) Cl.Int./Int.Cl. *A24F 47/00* (2006.01), *B01D 1/00* (2006.01)

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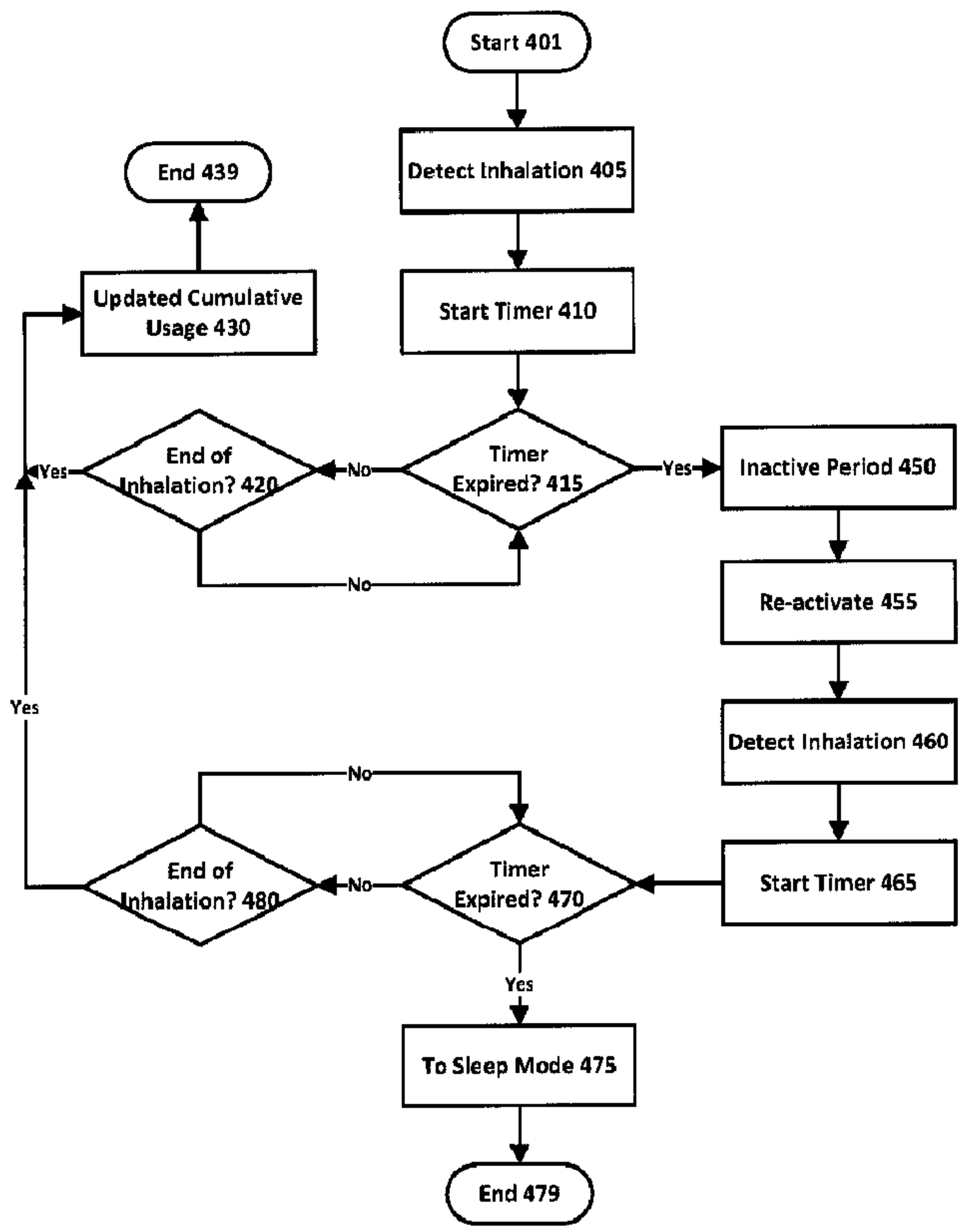
(54) Titre : SYSTEME DE DISTRIBUTION DE VAPEUR ELECTRONIQUE
(54) Title: ELECTRONIC VAPOUR PROVISION SYSTEM



(57) Abrégé/Abstract:
An electronic vapour provision system includes a vaporiser for vaporising liquid for inhalation by a user of the electronic vapour provision system. The electronic vapour provision system also includes a power supply comprising a cell or battery for supplying

(57) **Abrégé(suite)/Abstract(continued):**
power to the vaporiser and a control unit for controlling the supply of power from the power supply to the vaporiser. The control unit has a sleep mode where no power is supplied to the vaporiser and a user mode where power is available for supply to the vaporiser. The control unit reverts from user mode to sleep mode after a predetermined amount of time of inactivity in user mode and/or after the vaporiser has been disengaged from the power supply.

ABSTRACT

An electronic vapour provision system includes a vaporiser for vaporising liquid for inhalation by a user of the electronic vapour provision system. The electronic vapour provision system also includes a power supply comprising a cell or battery for supplying power to the vaporiser and a control unit for controlling the supply of power from the power supply to the vaporiser. The control unit has a sleep mode where no power is supplied to the vaporiser and a user mode where power is available for supply to the vaporiser. The control unit reverts from user mode to sleep mode after a predetermined amount of time of inactivity in user mode and/or after the vaporiser has been disengaged from the power supply.

ELECTRONIC VAPOUR PROVISION SYSTEM

This application is divided from Canadian Patent Application Serial No. 2998037 which is divided from Canadian Patent Application Serial No. 2,922,280 filed on October 8, 2014.

Field

The present disclosure relates to electronic vapour provision systems such as electronic nicotine delivery systems (e.g. e-cigarettes).

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Background

Electronic vapour provision systems such as e-cigarettes generally contain a reservoir of liquid which is to be vaporised, typically nicotine. When a user inhales on the device, a heater is activated to vaporise a small amount of liquid, which is therefore inhaled by the user.

The use of e-cigarettes in the UK has grown rapidly, and it has been estimated that there are now over a million people using them in the UK.

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Summary

In one aspect, there is described an electronic vapour provision system including: a vaporiser for vaporising liquid for inhalation by a user of the electronic vapour provision system; a power supply comprising a cell or battery for supplying power to the vaporiser; and a control unit for controlling the supply of power from the power supply to the vaporiser, the control unit having a sleep mode where no power is supplied to the vaporiser and a user mode where power is available for supply to the vaporiser, whereby the control unit reverts from user mode to sleep mode after a predetermined amount of time of inactivity in user mode and/or after the vaporiser has been disengaged from the power supply.

The electronic vapour provision systems may include a pressure drop or air flow sensor for monitoring inhalation by a user through the electronic vapour provision system. The control unit may be for detecting the start and end of inhalation based on readings from the sensor. The control unit may be configured to monitor the cumulative period of inhalation (Ti) over a predetermined window (Tw), and transfer the electronic vapour provision system to a sleep mode if the cumulative period (Ti) exceeds a predetermined threshold (Th).

The control unit may be further configured to monitor the period of inhalation. If the period of inhalation exceeds a first threshold render the electronic vapour provision system inactive for a predetermined period, render the electronic vapour provision system active after the predetermined period has expired, and monitor the period of the next inhalation such that if the period of the next inhalation exceeds a second threshold transfer the electronic vapour provision system to a sleep mode.

The electronic vapour provision system as described above may further include a pressure drop or air flow sensor for monitoring inhalation by a user through the electronic vapour provision system. The control unit may be for detecting the start and end of inhalation based on readings from the sensor. The control unit may be configured to monitor the period of inhalation. If the period of inhalation exceeds a first threshold render the electronic vapour provision system inactive for a predetermined period, render the electronic vapour provision system active after the predetermined period has expired, and monitor the

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period of the next inhalation, such that if the period of the next inhalation exceeds a second threshold transfer the electronic vapour provision system to a sleep mode.

The electronic vapour provision system may also include a pressure drop or air flow sensor for monitoring inhalation by a user through the electronic vapour provision system. The control unit may be for detecting the start and end of inhalation based on readings from the sensor. The control unit may be configured to detect the start of inhalation when the sensor reading departs by more than a first threshold from a previous reading and detect the end of inhalation when the sensor reading departs by less than a second threshold from the previous reading. The first threshold may be greater than the second threshold.

The period of inactivity may be varied depending on the desired configuration of the system. For example, the period of inactivity may be greater than 4, 5, or 6 minutes. Other embodiments may use different values for the period of inactivity, for example, depending on the desired configuration of the system.

Where the system is transferred to sleep mode, it may be transferred back to user mode either by disengaging and re-engaging the vaporiser with the power supply, or by re-engaging the vaporiser with the power supply (if previously disengaged).

These and other aspects are apparent from the present disclosure as read as a whole. Therefore, the disclosure is not to be restricted to specific paragraphs, but extends to combinations of the disclosures presented in the whole document. For example, an electronic vapour provision system may be provided in accordance with the present disclosure which includes any one or more of the various aspects described above (or features therefrom).

Brief Description of the Drawings

Figure 1 is a schematic (exploded) diagram of an e-cigarette in accordance with some embodiments of the disclosure.

Figure 2 is a schematic diagram of the main functional components of the body of the e-cigarette of Figure 1 in accordance with some embodiments of the disclosure.

Figure 3 is a schematic diagram showing various modes or states of the e-cigarette of Figures 1 and 2 in accordance with some embodiments of the disclosure.

Figure 4 is a flowchart illustrating a method for helping to protect against potential abuse of the device of Figures 1 and 2 in accordance with some embodiments of the disclosure.

Figure 5 is a flowchart illustrating a method detecting the start and end of inhalation in the device of Figure 1 and 2 in accordance with some embodiments of the disclosure.

Figure 6 is a schematic diagram of the power regulation system within the e-cigarette of Figures 1 and 2 in accordance with some embodiments of the disclosure.

Figure 7A illustrates how the power regulation system of Figure 6 changes the duty cycle to maintain a constant average power level in accordance with some embodiments of the disclosure.

Figure 7B is a schematic graph showing the variation of of duty cycle in relation to the measured or tracked voltage of the cell in accordance with some embodiments of the disclosure.

Detailed Description

As described above, the present disclosure relates to an electronic vapour provision system, such as an e-cigarette. Throughout the following description the term "e-cigarette" is used; however, this term may be used interchangeably with electronic vapour provision system.

Figure 1 is a schematic (exploded) diagram of an e-cigarette 10 in accordance with some embodiments of the disclosure (not to scale). The e-cigarette comprises a body 20, a cartridge 30 and a vaporiser 40. The cartridge includes an internal chamber containing a reservoir of nicotine and a mouthpiece 35. The cartridge reservoir may be a foam matrix or any other structure for retaining the nicotine until such time that it is required to be delivered to the vaporiser. The body 20 includes a re-chargeable cell or battery to provide power to

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the e-cigarette 10 and a circuit board for generally controlling the e-cigarette. The vaporiser 40 includes a heater for vaporising the nicotine and further includes a wick or similar device which transports a small amount of nicotine from the reservoir in the cartridge to a heating location on or adjacent the heater. When the heater receives power from the battery, as controlled by the circuit board, the heater vaporises the nicotine from the wick and this vapour is then inhaled by a user through the mouthpiece.

The body 20 and the vaporiser 40 are detachable from one another, but are joined together when the device 10 is in use, for example, by a screw or bayonet fitting (indicated schematically in Figure 1 as 41A and 21A). The connection between the body and vaporiser provides for mechanical and electrical connectivity between the two. When the body is detached from the vaporiser, the electrical connection 21A on the body that is used to connect to the vaporiser also serves as a socket for connecting a charging device (not shown). The other end of the charging device can be plugged into a USB socket to re-charge the cell in the body of the e-cigarette. In other implementations, the e-cigarettte may be provided with a cable for direction connection between the electrical connection 21A and a USB socket.

The body is provided with one or more holes (not shown in Figure 1) for air inlet. These holes connect to an air passage through the body to an air outlet provided as part of connector 21A. This then links to an air path through the vaporiser 40 and the cartridge 30 to the mouthpiece 35. The cartridge 30 and the vaporiser 40 are attached in use by connectors 41B and 31B (again shown schematically in Figure 1). As explained above, the cartridge includes a chamber containing a reservoir of nicotine, and a mouthpiece. When a user inhales through the mouthpiece 35, air is drawn into the body 20 through one or more air inlet holes. This airflow (or the resulting change in pressure) is detected by a pressure sensor, which in turn activates the heater to vaporise the nicotine from the cartridge. The airflow passes from the body, through the vaporiser, where it combines with the nicotine vapour, and this combination of airflow and nicotine vapour then passes through the cartridge and out of the mouthpiece 35 to be inhaled by a user. The cartridge 30 may be detached from the vaporiser 40 and disposed of when the supply of nicotine is exhausted (and then replaced with another cartridge).

It will be appreciated that the e-cigarette 10 shown in Figure 1 is presented by way of example, and various other implementations can be adopted. For example, in some embodiments, the cartridge 30 and the vaporiser 40 may be provided as a single unit (generally referred to as a cartomiser), and the charging facility may connect to an additional or alternative power source, such as a car cigarette lighter.

Figure 2 is a schematic diagram of the main functional components of the body 20 of the e-cigarette 10 of Figure 1 in accordance with some embodiments of the disclosure.

These components may be mounted on the circuit board provided within the body 20, although depending on the particular configuration, in some embodiments, one or more of the components may instead be accommodated in the body to operate in conjunction with the circuit board, but is/are not physically mounted on the circuit board itself.

The body 20 includes a sensor unit 60 located in or adjacent to the air path through the body 20 from the air inlet to the air outlet (to the vaporiser). The sensor unit includes a pressure sensor 62 and temperature sensor 63 (also in or adjacent to this air path). The body further includes a Hall effect sensor 52, a voltage reference generator 56, a small speaker 58, and an electrical socket or connector 21A for connecting to the vaporiser 40 or to a USB charging device.

The microcontroller 55 includes a CPU 50. The operations of the CPU 50 and other electronic components, such as the pressure sensor 62, are generally controlled at least in part by software programs running on the CPU (or other component). Such software programs may be stored in non-volatile memory, such as ROM, which can be integrated into the microcontroller 55 itself, or provided as a separate component. The CPU may access the ROM to load and execute individual software programs as and when required. The microcontroller 55 also contains appropriate communications interfaces (and control software) for communicating as appropriate with other devices in the body 10, such as the pressure sensor 62.

The CPU controls the speaker 58 to produce audio output to reflect conditions or states within the e-cigarette, such as a low battery warning. Different signals for signalling different states or conditions may be provided by utilising tones or beeps of different pitch and/or duration, and/or by providing multiple such beeps or tones.

As noted above, the e-cigarette 10 provides an air path from the air inlet through the e-cigarette, past the pressure sensor 62 and the heater (in the vaporiser), to the mouthpiece 35. Thus when a user inhales on the mouthpiece of the e-cigarette, the CPU 50 detects such inhalation based on information from the pressure sensor. In response to such a detection, the CPU supplies power from the battery or cell 54 to the heater, which thereby heats and vaporises the nicotine from the wick for inhalation by the user.

Figure 3 is a schematic diagram showing various modes or states of the e-cigarette 10 of Figures 1 and 2 in accordance with some embodiments of the disclosure. The device has three modes, namely shelf mode 301, sleep mode 302, and user mode 303. One motivation for the different modes is to help extend cell lifetime – thus shelf mode uses less power from the battery than sleep mode, which in turn uses less power from the cell than user mode. The Hall sensor 52 is responsible for switching from shelf mode to sleep mode, while the CPU 50 is generally responsible for switching the device between sleep mode and user mode (and vice versa) according to predefined triggers. These changes in state may be confirmed by appropriate beeps or tones from the speaker 58.

The device is in shelf mode when in its original packaging (not shown) – hence it remains in shelf mode prior to purchase by a consumer (end user). In shelf mode, the device is largely inactive apart from the Hall effect sensor 52, which draws a very small current (approximately 3μAmp in some implementations). Since the cell 54 generally has a capacity of over 100 mAmp hours, the device can remain powered in shelf mode for up to four years or more.

The packaging is arranged to have a magnet located close to the Hall sensor. When the device is removed from the packaging, the Hall sensor detects the change (reduction) in magnetic field arising as the device is distanced from the magnet. In one embodiment, the Hall sensor 52 responds to this change by providing power to the microcontroller 55, which then becomes operational. This has the effect of switching the device from shelf mode 301 into sleep mode 302. Note that once the device has switched out of shelf mode, it may be possible for the device to be returned to shelf mode if it is placed back in the packaging containing the magnet, depending upon the particular implementation.

The body further includes a capacitor (not shown in Figure 2) which is electrically connected to the electrical socket or connector 21A. In the original packaging, the vaporiser 40 is detached from the body 20. In this configuration, with the body 20 not attached to the vaporiser (or the USB charging device), the electrical socket 21A presents an open circuit to the capacitor, which therefore maintains its charge for a relatively substantial period of time. However, if the vaporiser 40 is connected to the electrical socket 21A, this presents a conductive path through which the capacitor is able to discharge very quickly.

When a user wishes to operate the device, the vaporiser is joined to the body. Every two seconds in sleep mode the CPU arranges for the capacitor to be charged up. If the capacitor discharges rapidly (in just a small fraction of a second), the CPU determines that the body is now connected to the vaporiser. This triggers the CPU to switch the device from sleep mode 302 to user mode 303. Alternatively, if the capacitor does not discharge within a predetermined time (much less than two seconds), this indicates that the body is still separated from the vaporiser, and hence the user is not able to operate the device. Accordingly, in this latter case, the CPU maintains the device in sleep mode, and waits for another two second interval before charging up the capacitor again to test for any new connectivity to the vaporiser.

It will be appreciated that the two second interval is a balance between (i) not charging the capacitor too frequently, which would reduce battery lifetime, and (ii) ensuring that if a user does prepare the device for use (by connecting the vaporiser to the body), then the device is active by the time the user inhales to provide the vaporised nicotine. In other implementations, a different interval may be adopted, depending upon the properties and intended usage pattern of the device in question.

There are various routes or triggers for the CPU 50 to switch the device back from user mode 303 to sleep mode 302. One trigger is if the user disengages the vaporiser 40 from the body 20 – this would typically indicate that the user has finished using the e-cigarette 10 for the time being. Another trigger is if the user has not inhaled for a predetermined time, such as five minutes (see below for a description of how such inhalation is detected). This helps to ensure that the device is not left in an active state for too long, for example, in a situation in which a user becomes distracted while using the device, and moves away to do something else without separating the body from the vaporiser. If the CPU does transition the device to sleep mode 302 while the vaporiser is still connected to the body, then in order to return to user mode 303, a user must first disengage the vaporiser from the body and then re-engage the vaporiser with the body. (This can be regarded as a form of resetting the device). Placing the device in sleep mode if it has been inactive for this predetermined period of time also helps to reduce power consumption, as well as to restrict usage of the device by unintended parties.

Further triggers for switching from user mode 303 to sleep mode 302 are provided to help prevent potential abuse of the device. One such trigger monitors the total period of inhalation (say Ti) within a given window (of duration say Tw). If the value of Ti is seen to be unusually large, then the CPU transitions the device to sleep mode. In some implementations, Tw is fixed, for example at 30 second, 40 or 50 seconds. If the total cumulative period of inhalation (Ti) then exceeds a given threshold (Th) (say 10 or 20 seconds) during this window, the sleep mode is triggered. For example, the device might transition to sleep mode if the period of inhalation (Ti) within the last 40 seconds (representing the window, Tw) exceeds the threshold (Th) of 15 seconds.

One way of viewing this trigger is that it monitors an average level of usage (Ti/Tw) by assessing cumulative usage over a period corresponding to multiple inhalations (puffs) of the device, and signals a potential abuse if this average exceeds a given threshold (Th/Tw). It will be appreciated that other implementations may adopt different approaches for determining whether the average or cumulative level of usage represents a potential abuse, and for triggering accordingly.

Another trigger for helping to protect against potential abuse of the device in some embodiments is illustrated by the flowchart of Figure 4. The processing, which is generally managed by the CPU 50, commences with detection of the start of inhalation (405), which starts a timer running from zero (410). The CPU now waits for one of two potential inputs: (a) detecting the end of inhalation (420); or (b) the timer reaching a first predefined threshold (410)(say 3, 3.5 or 4 seconds). If the end of the inhalation occurs before the timer reaches the threshold, then processing terminates with no further action (439), apart from updating the cumulative usage information (430). In this case, the processing for the next inhalation will commence again at the start (401) of the flowchart of Figure 4.

However, if the timer reaches the first predefined threshold before detecting the end of the inhalation, then the CPU automatically shuts off the supply of nicotine vapour by cutting power to the heater. This prevents the user from inhaling further nicotine vapour from the device. The CPU also restarts the timer to wait for a second predefined interval or delay (which may be the same as the first predefined threshold), say 3, 3.5 or 4 seconds. During this time, the CPU maintains the device effectively in an inactive state (450), in that even if the user inhales, this does not trigger the production of nicotine vapour (unlike normal operation of the device). After the time period corresponding to the predefined interval has passed, the CPU in effect re-activates the device (455), so that now normal operation is resumed, in that if the user inhales, this does trigger the CPU to switch on the heater to produce nicotine vapour. However, in response to detecting such a further inhalation (460), the CPU starts the timer again (465), and determines (470) whether the duration of this further inhalation exceeds a second predefined threshold (which may the same as the first predefined threshold), say 3, 3.5 or 4 seconds. This determination is analogous to the situation with the first inhalation, in that the CPU is waiting to see which occurs first – the end of the inhalation (480) or the timer reaching the second predefined threshold (470). If the former occurs first, the duration of the further inhalation is within the second predefined threshold. In this case, processing terminates with no further action, apart from updating the cumulative usage (430), and the processing for the next inhalation will commence again at the start of the flowchart of Figure 4.

However, if the timer reaches the second predefined threshold prior to the end of the inhalation, then this is regarded as a further indication of abuse, since there have now been two successive inhalations which exceed their respective thresholds. In this situation, the CPU returns the device to sleep mode (475). It will be appreciated that in this situation, further operation of the device is prevented until the device has been returned to user mode by disengaging the vaporiser 40 from the body 20 and then re-engaging the vaporiser with the body.

The processing of Figure 4 helps to protect against potential abuse of the device in accordance with a two-tier approach, in that there is one sanction against an excessive duration for a single inhalation (an enforced period of inactivity corresponding to the second, predefined interval before the device can be used again), and a further sanction if the first inhalation of excessive duration is then followed directly by a second inhalation of excessive duration (namely, an enforced requirement to separate and re-join the vaporiser and the body before the device can be used again).

In some embodiments, the operations of Figure 4 not only may help to prevent potential abuse of the device, but they also may help to protect against over-heating by generally limiting the period for which the CPU 50 provides continuous power to the heater to no more than the first predefined threshold. Such over-heating might otherwise potentially occur, for example, if the device failed to detect the end of an inhalation by a user, or if the device was placed in an environment that somehow simulated a prolonged inhalation.

Figure 5 is a flowchart illustrating a method for the device of Figures 1 and 2 to detect the start and end of an inhalation in accordance with some embodiments of the disclosure. This method is initiated (501) when the device enters into user mode. The CPU obtains a pressure reading (510) from the pressure sensor multiple (e.g. 5, 8, 9, 10 or 12) times per second. In some implementations, the pressure sensor and the temperature sensor are provided in a single combined unit (integrated circuit device) - this allows the pressure sensor to adjust the pressure reading to a constant temperature value, thereby removing (at least reducing) pressure variations caused by fluctuations in temperature in the pressure readings supplied to the CPU. In other implementations, the pressure and temperature readings may be provided separately to the CPU, which performs its own adjustment or correction of the pressure readings to accommodate any changes in temperature. Other implementations might not have a temperature sensor, in which case the pressure readings would be used directly, without compensation for any variation in temperature.

After the first pressure reading has been acquired, this is saved as an ambient pressure value (515). The CPU also starts a timer T1 (520) which expires after a predetermined time period, say 2, 3 or 4 seconds. The CPU now waits for one of two events. The first event is expiry of the timer (535). In this case, the CPU updates the ambient pressure value (530) to match the most recent pressure reading, resets the timer (520), and repeats the process. Accordingly, absent any other activity, the CPU updates the ambient pressure on a regular basis corresponding to said predetermined time period of the timer T1. In addition, the CPU also compares each newly detected pressure reading (which continue to be obtained (540)) with the current value stored for the ambient pressure (545). If the new pressure reading is below the stored value for the ambient pressure by more than a first predefined amount (threshold TH1), this triggers the second event, namely detection of the start of inhalation (550). Note that the first predefined amount (threshold TH1) may be specified as an absolute or relative difference with respect to the ambient pressure. For example, depending on the particular device, the first predefined amount might be a drop in pressure of (one of) 200, 300 of 400 Pascals, or a percentage drop of 0.2%, 0.3% or 0.4% compared with the (stored) ambient value.

In one implementation, whenever the ambient pressure value is updated at operation 530, the system determines a first trigger pressure value based on the ambient pressure value minus the first predefined amount (threshold TH1). The test at operation 545 to detect the start of inhalation can then check whether the pressure detected at operation 540 is below this first trigger pressure value. If so, the detected pressure represents a drop in pressure greater than the threshold TH1, thereby leading to a positive outcome from operation 545, corresponding to the start of inhalation. One advantage of this approach is that a direct comparison between the detected pressure and the first trigger pressure can be performed quickly and easily to detect the start of inhalation. Other implementations may adopt a different approach to perform this detection, although the end result is the same. For example, each detected pressure might first be subtracted from the current ambient pressure, and the onset of inhalation would then be detected if the result of this subtraction is greater than the threshold T1.

Assuming that the drop in pressure from the current ambient value exceeds the first predefined amount (TH1) at operation 545, the CPU determines that inhalation has commenced. The CPU then supplies power to the vaporiser to vaporise nicotine from the wick into the airflow caused by the inhalation. In addition, the CPU increases the rate at which a pressure sensor reading is obtained (575), say to 20-30 times per second, and sets one or more timers to perform the monitoring described above (see Figure 4) to track both the duration of this particular inhalation, and also to update the cumulate level of usage over the specified window (Tw). The CPU also continues to update the ambient pressure value 565 whenever the timer T1 expires, and to reset this timer as appropriate (570).

The CPU determines that inhalation has terminated (580) when the pressure sensor reading returns to within a second predefined amount (threshold TH2) from the currently stored ambient pressure value. Similar to the first predefined amount (TH1), the second predefined amount (TH2) may be specified as an absolute or relative difference with respect to the ambient pressure. For example, depending on the particular device, the second predefined amount might be a drop in pressure of (one of) 80, 100 or 120 Pascals, or a percentage drop of 0.08%, 0.1% or 0.12%. Similar to the first predefined amount (TH1), in some implementations, whenever the ambient pressure value is updated at operation 530, the system may determine a second trigger pressure value based on the ambient pressure value minus the second predefined amount (threshold TH2). The test at operation 580 to detect the start of inhalation can then check whether the pressure detected at operation 575 has now risen to be greater than this second trigger pressure value. If so, the detected pressure represents a drop in pressure which is now less than the threshold TH2, thereby leading to a positive outcome from operation 580, representing the end of inhalation. Once the termination of inhalation has been determined (585), the CPU can switch off power to the heater, and reset any timers used in the monitoring processes described above.

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Having two separate thresholds (TH1, TH2) for determining (i) the start of inhalation, and (ii) the end of inhalation provides greater flexibility and reliability than just having a single threshold for determining whether or not inhalation is currently in progress. In particular, the threshold for detecting the start of inhalation can be raised somewhat (corresponding to a greater pressure drop from ambient). This helps to provide improved robustness in the detection of inhalation (as opposed, for example, to undesired triggering with respect to changes in environmental conditions, which would then lead to unnecessary heating, and hence consumption of power from the cell and nicotine from the reservoir). Similarly, having a lower threshold for detecting the end of inhalation (a smaller pressure drop from ambient) helps to provide a better measurement of the actual length of inhalation, which is useful for monitoring against potential abuse of the device as described above. For example, it has been found that the latter part of a draw (inhalation) tends to produce a lower pressure drop from ambient, hence if the second threshold (TH2) were not reduced compared with the first threshold (TH1) (corresponding to a lesser pressure drop from ambient), the device would tend to determine that inhalation had terminated while the user was, in fact, still drawing on the device, albeit at a lower level to create a smaller pressure drop.

As illustrated in Figure 2, the e-cigarette 10 of Figures 1 and 2 is powered by a re-chargeable cell 54. In practice, the voltage output of such cells tends to decline as they discharge, for example, from about 4.2V when fully charged, down to about 3.6V just before being fully discharged. Since the power output across a given heating resistor R goes with V^2/R, this implies that there would generally be a corresponding drop in power output such that the final operational power output (at a voltage of 3.6V) is only 73% of the initial power output (at a voltage of 4.2V). This change in power supplied by the cell 54 to the heater in the vaporiser 40 may impact the amount of nicotine vaporised (and hence inhaled by a user).

Figure 6 is a schematic depiction of a part of the power regulation system for the e-cigarette of Figures 1 and 2 in accordance with some embodiments of the disclosure. The power regulation system includes a voltage reference device 56, which provides a consistent (known) output voltage level (Vr), irrespective of variations in the output voltage (Vc) of the re-chargeable cell 54. The power regulation system further comprises a voltage divider comprising two resistors, R1, R2, which receives and divides the output voltage (Vc) in known fashion in accordance with the relative size (resistance) of resistors R1 and R2. The midpoint of the voltage divider 610 is used to take an output voltage (Vdiv).

The CPU 50 receives the voltage Vdiv from the voltage divider and the reference voltage (Vr) from the voltage reference device 56. The CPU compares these two voltages and based on Vr is able to determine Vdiv. Furthermore, assuming that the (relative) resistances of R1 and R2 are known, the CPU is further able to determine the cell output voltage (Vc) from Vdiv. This therefore allows the CPU to measure (track) the variation in voltage output (Vc) from the cell 54 as the cell discharges.

Figure 7 illustrates how in some embodiments of the disclosure, the power regulation system of the e-cigarette 10 uses a form of pulse-width modulation to compensate for the variation in voltage. Thus rather than the CPU 50 providing continuous electrical power to the heater in the vaporiser 40, the electrical power is supplied instead as a series of pulses at regular intervals, in effect, as a rectangular or square wave. Assuming that each pulse has an "on" duration of Dp, and a pulse is supplied every period of Di (referred to as the pulse interval or interval duration), then the ratio of the pulse duration to the interval duration, Dp/Di, is known as the duty cycle. If Dp=Di then the duty cycle is one (or 100%), and the CPU in effect provides a continuous voltage. However, if the duty cycle is less than 1, the CPU alternates periods of providing electrical power with periods of not providing electrical power. For example, if the duty cycle is 65%, then each voltage pulse has a duration representing 65% of the interval duration, and no voltage (or power) is supplied for the remaining 35% of the interval.

If we consider a signal level which provides power P for a duty cycle of 1 (i.e. continuous supply), then the average amount of power provided when the duty cycle is reduced below 1 is given by P multiplied by the duty cycle. Accordingly, if the duty cycle is 65% (for example), then the effective power rate becomes 65% of P.

Figure 7A illustrates two different rectangular waves, one shown in solid line, the other shown in dashed line. The pulse interval or period (Di) is the same for both waves. The output shown in solid line has a pulse duration (width) of T1 and a power output when on, i.e. an instantaneous power level, of P1. The duty cycle of this solid line output is T1/Di, to give an average power output of P1xT1/Di. Likewise, the output shown in dashed line has a pulse duration (width) of T2 and an instantaneous power output when on of P2. The duty cycle of this solid line output is T2/Di, to give an average power output of P2xT1/Di.

Figure 7A also indicates in dotted line the average power output (P(ave)), which is the same for both outputs (solid and dashed line). This implies that (P1xT1/Di)=(P2xT1/Di). In other words, assuming that the pulse interval (Di) is maintained constant, then the average power output is constant provided that the pulse duration (T) varies inversely with the (instantaneous) power output (P), so that PxT is also a constant.

In accordance with some embodiments of the disclosure, the power regulation system of the e-cigarette 10 implements a pulse-width modulation scheme such as shown in Figure 7A to provide the vaporiser heater with an approximately constant power level. Thus the power regulation system of Figure 6 allows the CPU 50 to track the current voltage output level from the cell 54. Based on this measured voltage output level, the CPU then sets an appropriate duty cycle for controlling power to the vaporiser heater to compensate for variations in the voltage output level from the cell 54, thereby providing the vaporiser heater with an approximately constant (average) power level. Note that the pulse interval is chosen to be sufficiently short (typically <<1 second) such that it is much smaller than the thermal response time of the heater. In other words, the "off" portions of each pulse are short enough that the heater does not cool significantly during this period. Therefore, the heater provides in effect a constant heat source for vaporising the nicotine, based on the average received power level, with no significant modulation in heat output at the timescale of individual pulse intervals.

Figure 7B illustrates in schematic form the mapping from the (measured) voltage output level to duty cycle. When the cell 54 provides its lowest output voltage (3.6V), the duty cycle is set to 1 (the maximum possible value). When the cell 54 provides its highest output voltage (4.2V), the duty cycle is set to ~0.73. Figure 7B also illustrates schematically the duty cycle for intervening voltages, such that the duty cycle (equivalent to pulse duration for a fixed pulse interval) varies inversely with power output (which is proportional to V^2 for a fixed heater resistance). It will be appreciated that the precise variation of duty cycle with voltage shown in Figure 7B is by way of example only, and may vary according to the details of any given implementation.

As a consequence of the pulse-width modulation scheme described above, the CPU 50 is able to maintain the average power output supplied from cell 54 to the vaporiser heater at an approximately constant level, despite variations in the output voltage level from cell 54. This helps to provide a more consistent heating effect, and hence a more consistent level of nicotine vaporisation and therefore inhalation for a user.

Although the e-cigarette described herein comprises three detachable sections, namely the body, cartridge and vaporiser, it will be appreciated that other e-cigarettes may comprise a different number of sections. For example, some e-cigarettes are supplied as a single (unitary) complete device, and cannot be separated at all into different sections, while other e-cigarettes may comprise two sections, in effect, combining the vaporiser described herein with a liquid reservoir, forming a cartomiser. In addition, the e-cigarette described herein comprises multiple features, such as pulse-width modulation for providing a more consistent power level, threshold setting for reliable monitoring of inhalation duration, monitoring cumulative inhalation and/or checking against successive inhalations of excessive length to help protect against abuse, and reverting to sleep mode after a period of inactivity to help protect the device. However, it will be appreciated that some electronic vapour provision system may only have some (or one) of these features, which may be provided in any combination as desired.

In order to address various issues and advance the art, this disclosure shows by way of illustration various embodiments in which the claimed invention(s) may be practiced. The advantages and features of the disclosure are of a representative sample of embodiments only, and are not exhaustive and/or exclusive. They are presented only to assist in understanding and to teach the claimed invention(s). It is to be understood that advantages, embodiments, examples, functions, features, structures, and/or other aspects of the disclosure are not to be considered limitations on the disclosure as defined by the claims or limitations on equivalents to the claims, and that other embodiments may be utilised and modifications may be made without departing from the scope of the claims. Various embodiments may suitably comprise, consist of, or consist essentially of, various combinations of the disclosed elements, components, features, parts, steps, means, etc other than those specifically described herein. The disclosure may include other inventions not presently claimed, but which may be claimed in future.

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EMBODIMENTS IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. An electronic vapour provision system including:

a vaporiser for vaporising liquid for inhalation by a user of the electronic vapour provision system;

a power supply comprising a cell or battery for supplying power to the vaporiser; and

a control unit for controlling the supply of power from the power supply to the vaporiser, the control unit having a sleep mode where no power is supplied to the vaporiser and a user mode where power is available for supply to the vaporiser, whereby the control unit reverts from user mode to sleep mode after a predetermined amount of time of inactivity in user mode and/or after the vaporiser has been disengaged from the power supply.

2. The electronic vapour provision system according to claim 1, wherein the control unit reverts from user mode to sleep mode after a predetermined amount of time of inactivity in user mode, for example for greater than 4 minutes.

3. The electronic vapour provision system according to claim 1 or 2, wherein the control unit is transferred back to user mode by disengaging and re-engaging the vaporiser with the power supply.

4. The electronic vapour provision system according to any one of claims 1 to 3, wherein the control unit reverts from user mode to sleep mode after the vaporiser has been disengaged from the power supply.

5. The electronic vapour provision system according to claim 4, wherein the control unit is transferred back to user mode by re-engaging the vaporiser with the power supply.

6. The electronic vapour provision system according to any one of claims 1 to 5, wherein the electronic vapour provision system further includes a capacitor configured to be electrically connected to the vaporiser, and wherein the control unit is configured to charge the capacitor after a predetermined time has elapsed, and monitor the discharge of the capacitor to determine whether the vaporiser is electrically connected to the capacitor.

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7. The electronic vapour provision system according to claim 6, wherein the predetermined time is two seconds.

8. The electronic vapour provision system according to claim 6 or 7, wherein the control unit is configured to revert back to user mode if the capacitor discharges in a period of time shorter than the predetermined time.

9. The electronic vapour provision system according to any one of claims 1 to 8, wherein the electronic vapour provision systems includes a pressure drop or air flow sensor for monitoring inhalation by a user through the electronic vapour provision system; and

wherein the control unit is for detecting the start and end of inhalation based on readings from the sensor;

wherein the control unit is configured to:

monitor the cumulative period of inhalation (Ti) over a predetermined window (Tw); and

transfer the electronic vapour provision system to a sleep mode if the cumulative period (Ti) exceeds a predetermined threshold (Th).

10. The electronic vapour provision system according to claim 9, wherein the control unit is further configured to:

monitor the period of inhalation;

if the period of inhalation exceeds a first threshold:

render the electronic vapour provision system inactive for a predetermined period;

render the electronic vapour provision system active after the predetermined period has expired;

monitor the period of the next inhalation such that if the period of the next inhalation exceeds a second threshold:

transfer the electronic vapour provision system to a sleep mode.

11. The electronic vapour provision system according to any one of claims 1 to 8, further including:

a pressure drop or air flow sensor for monitoring inhalation by a user through the electronic vapour provision system; and

wherein the control unit is for detecting the start and end of inhalation based on readings from the sensor, wherein the control unit is configured to:

monitor the period of inhalation;

if the period of inhalation exceeds a first threshold:

render the electronic vapour provision system inactive for a predetermined period;

render the electronic vapour provision system active after the predetermined period has expired;

monitor the period of the next inhalation such that if the period of the next inhalation exceeds a second threshold:

transfer the electronic vapour provision system to a sleep mode.

12. The electronic vapour provision system according to any one of claims 1 to 11, the electronic vapour provision system including:

a pressure drop or air flow sensor for monitoring inhalation by a user through the electronic vapour provision system; and

wherein the control unit is for detecting the start and end of inhalation based on readings from the sensor;

wherein the control unit is configured to:

detect the start of inhalation when the sensor reading departs by more than a first threshold from a previous reading; and

detect the end of inhalation when the sensor reading departs by less than a second threshold from the previous reading;

wherein the first threshold is greater than the second threshold.

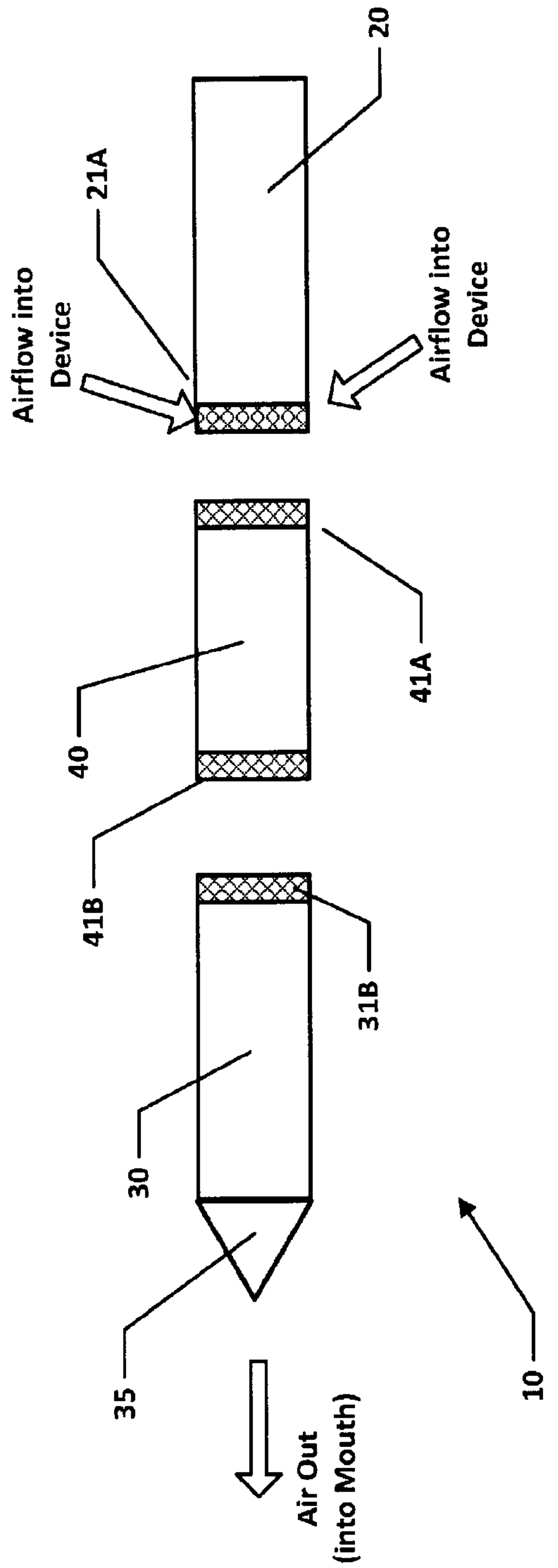

Figure 1

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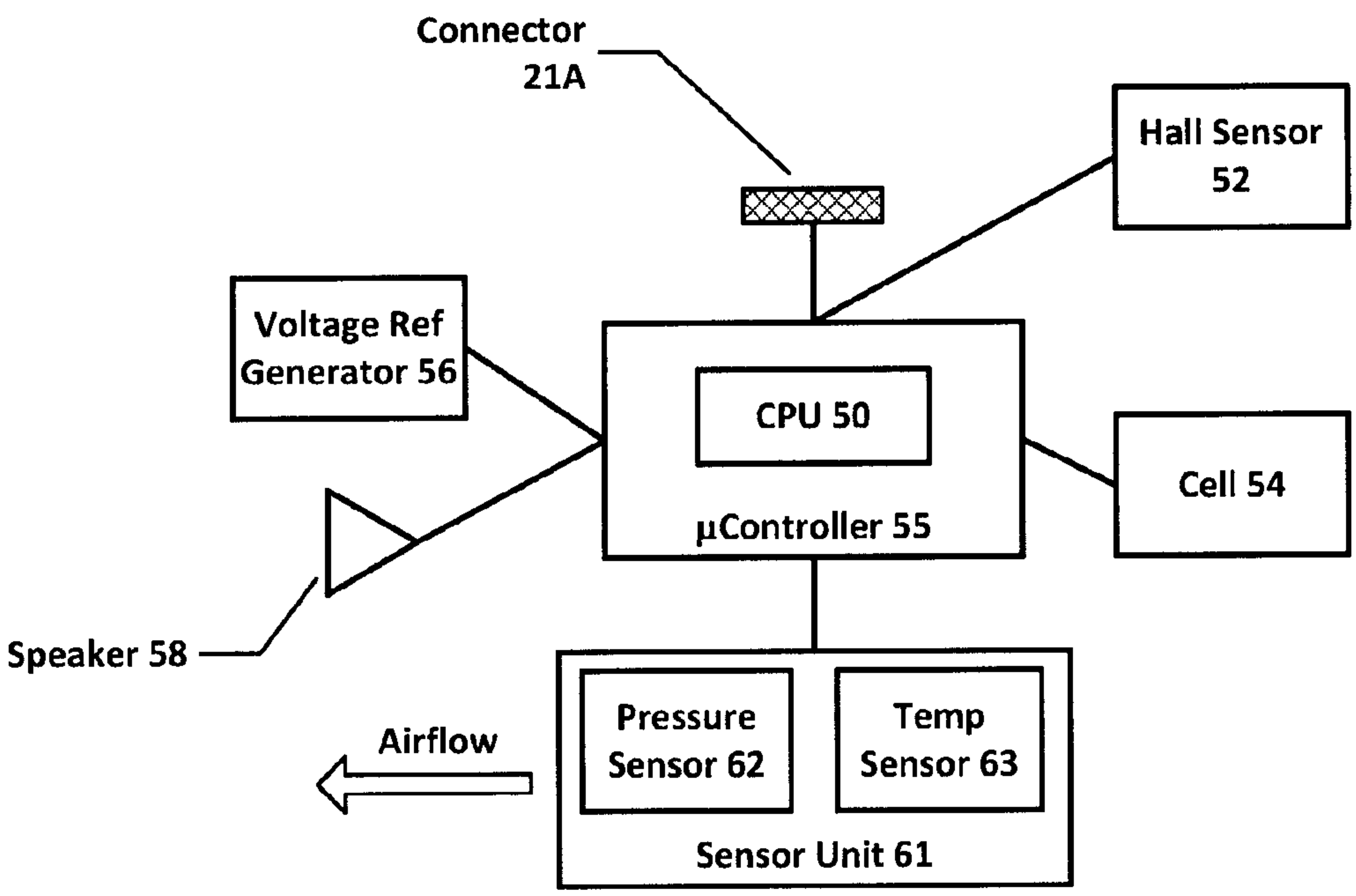


Figure 2

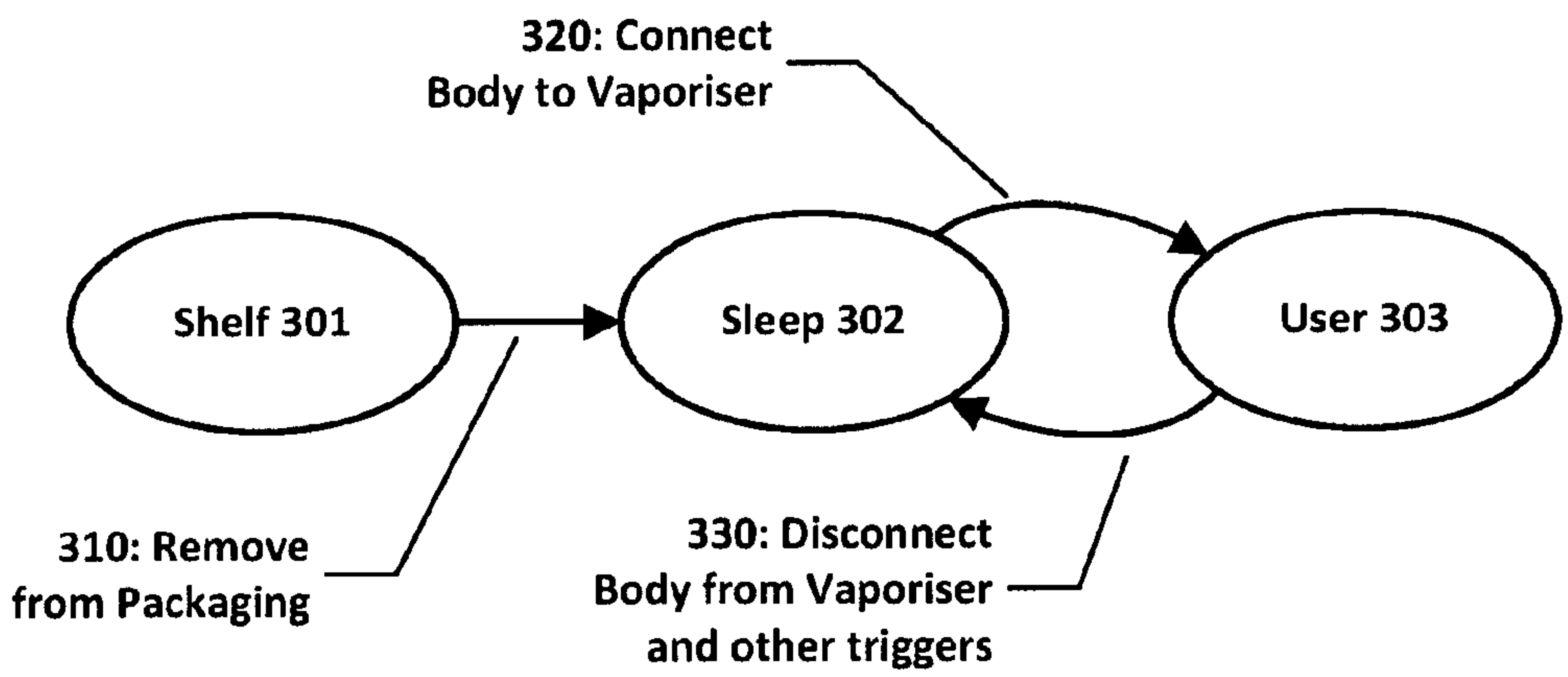


Figure 3

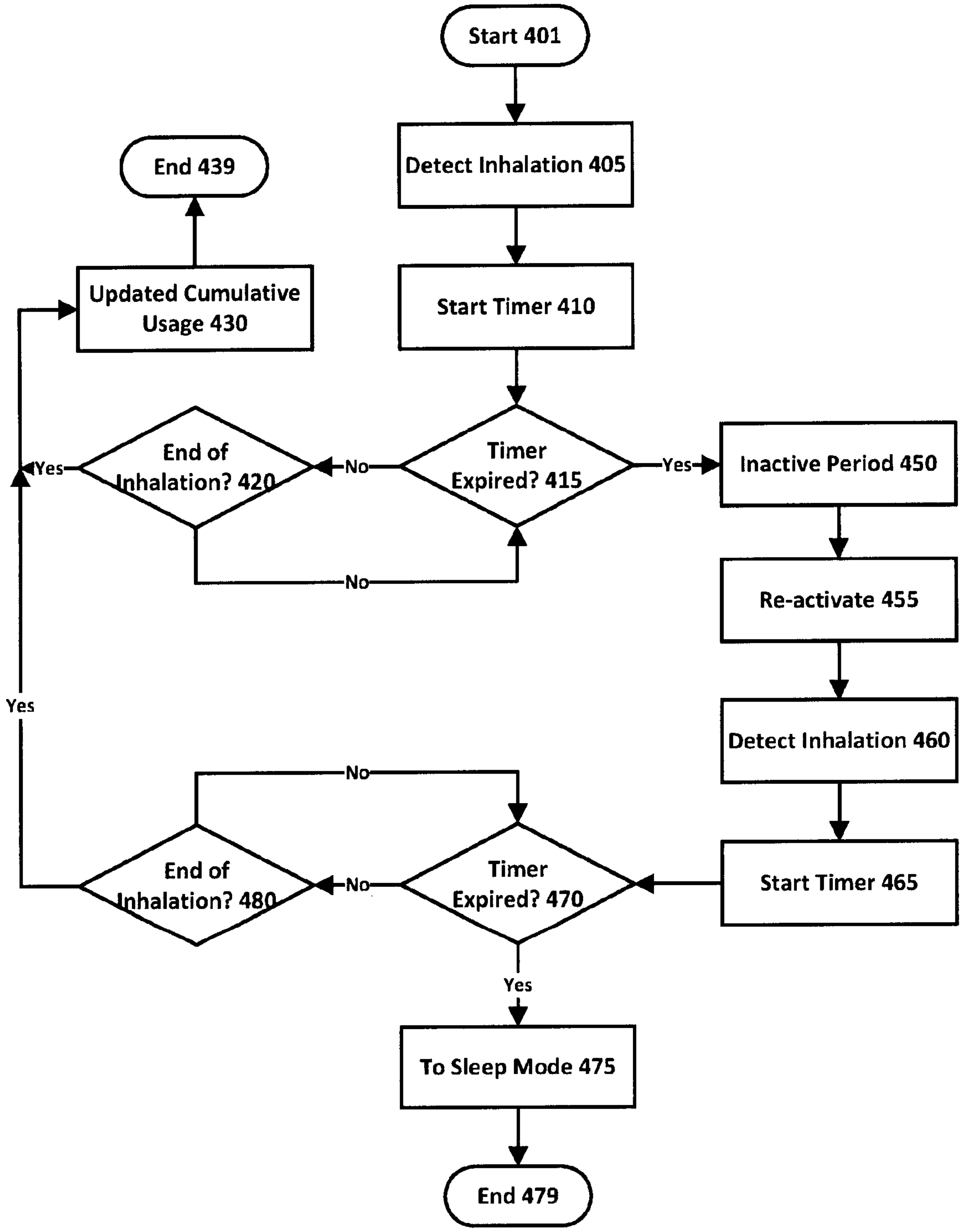
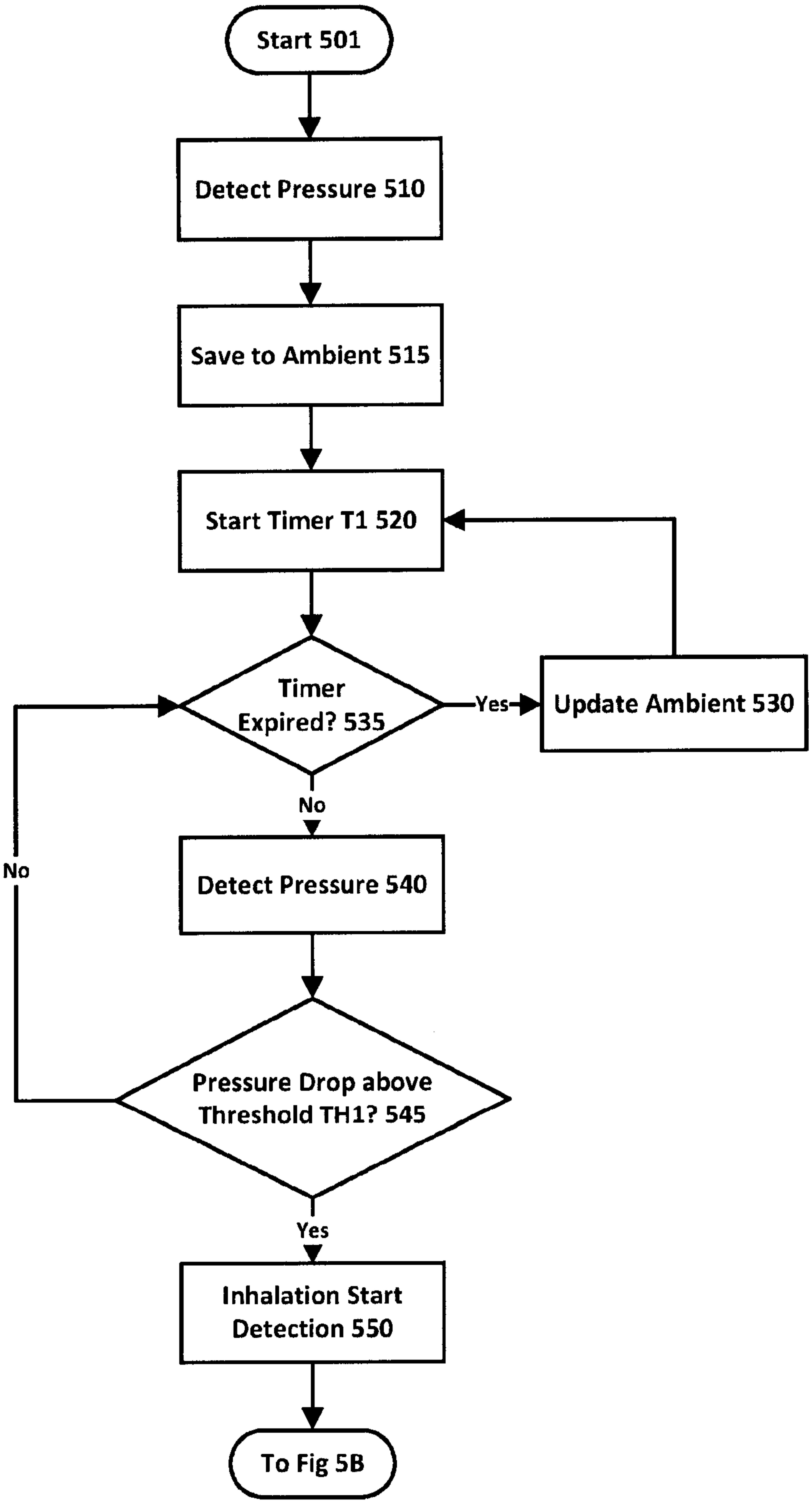

Start 401
Detect Inhalation 405
Start Timer 410
Timer Expired? 415
Yes
Inactive Period 450
Re-activate 455
Detect Inhalation 460
Start Timer 465
No
End of Inhalation? 420
Yes
Updated Cumulative Usage 430
End 439
No
Timer Expired? 470
No
End of Inhalation? 480
No
Yes
Yes
To Sleep Mode 475
End 479

Figure 4



Start 501
Detect Pressure 510
Save to Ambient 515
Start Timer T1 520
Timer Expired? 535
Yes
Update Ambient 530
No
Detect Pressure 540
No
Pressure Drop above Threshold TH1? 545
Yes
Inhalation Start Detection 550
To Fig 5B

Figure 5A

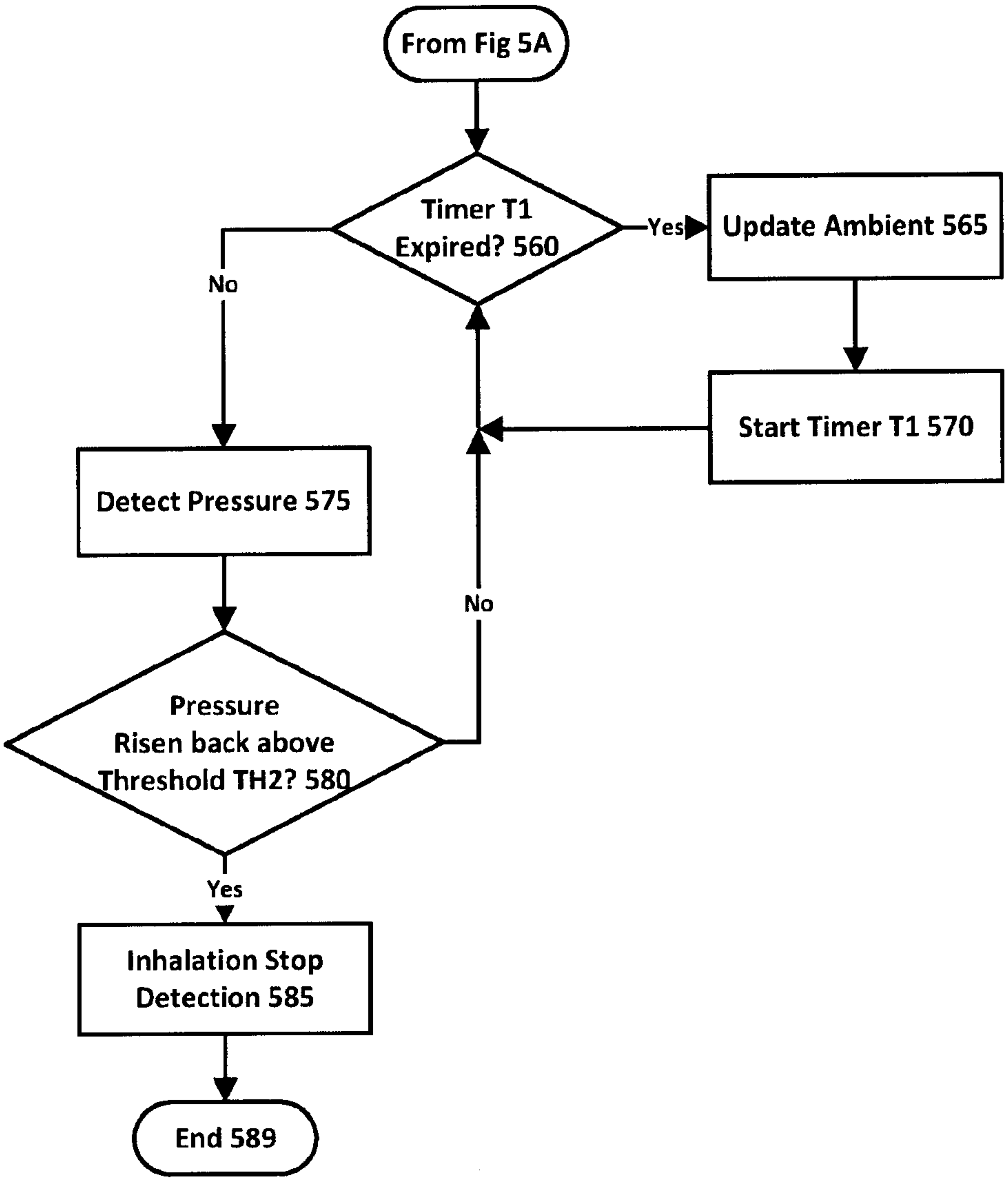

From Fig 5A
Timer T1
Expired? 560
Yes
Update Ambient 565
No
Start Timer T1 570
Detect Pressure 575
No
Pressure
Risen back above
Threshold TH2? 580
Yes
Inhalation Stop
Detection 585
End 589

Figure 5B

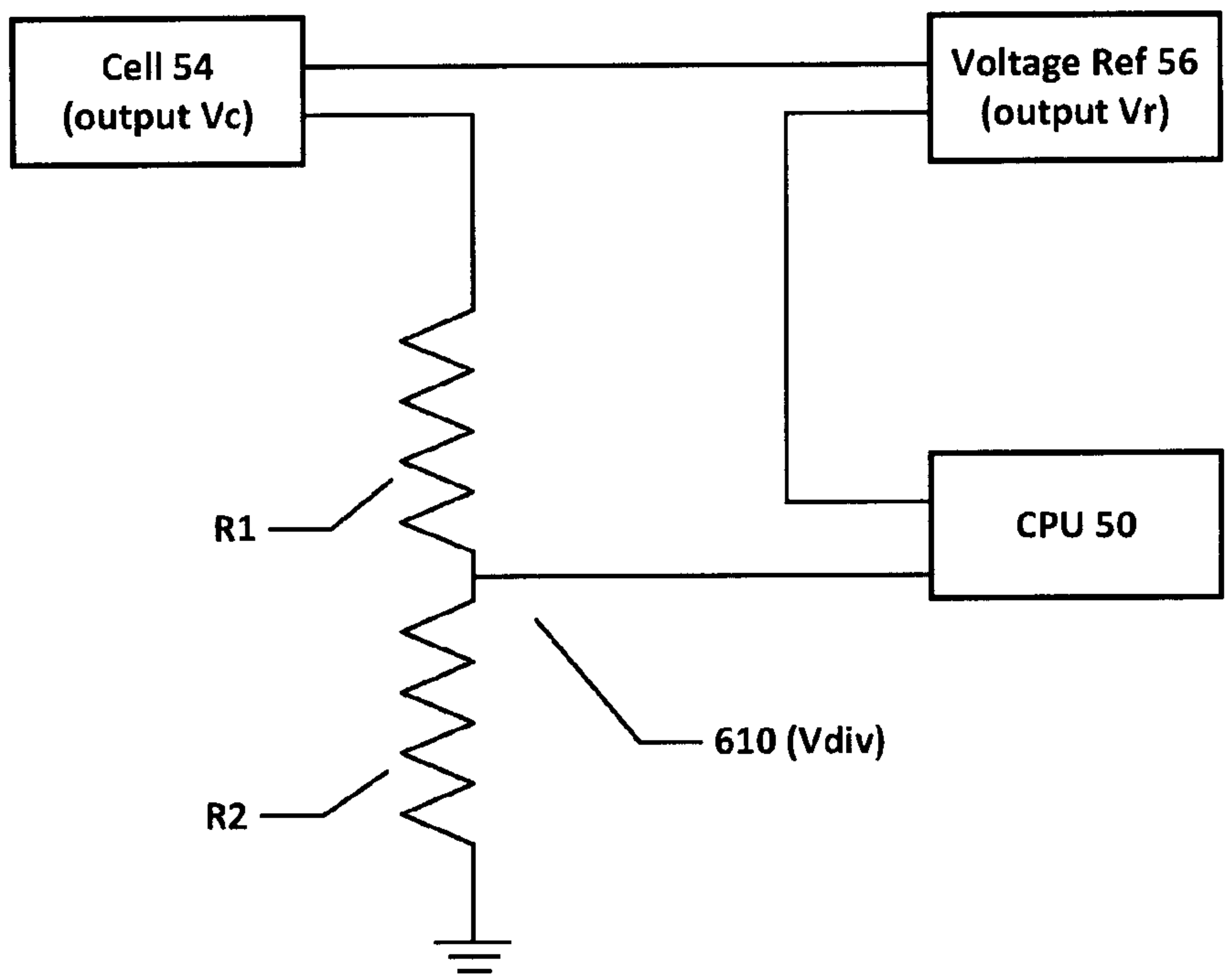


Figure 6

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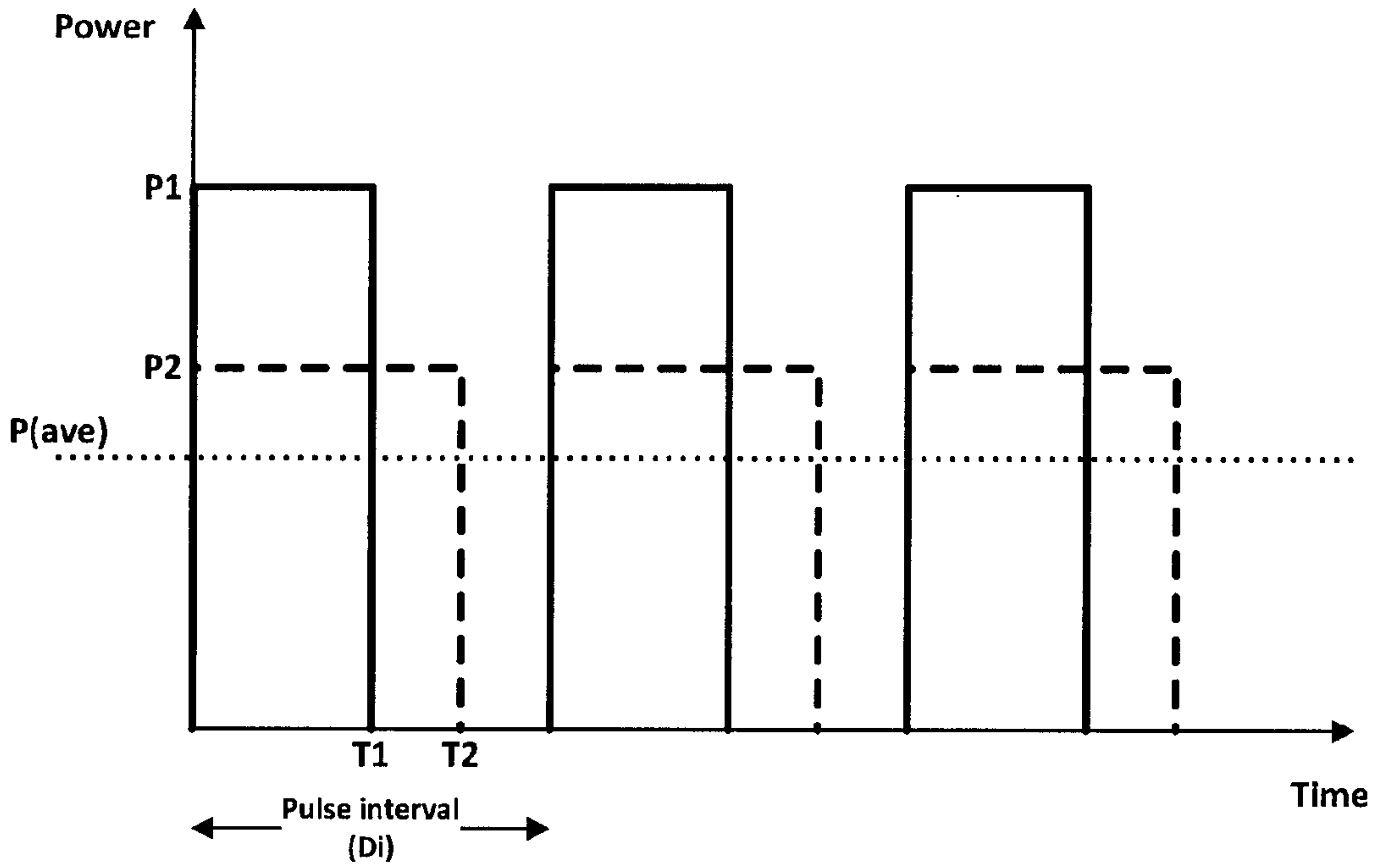


Figure 7A

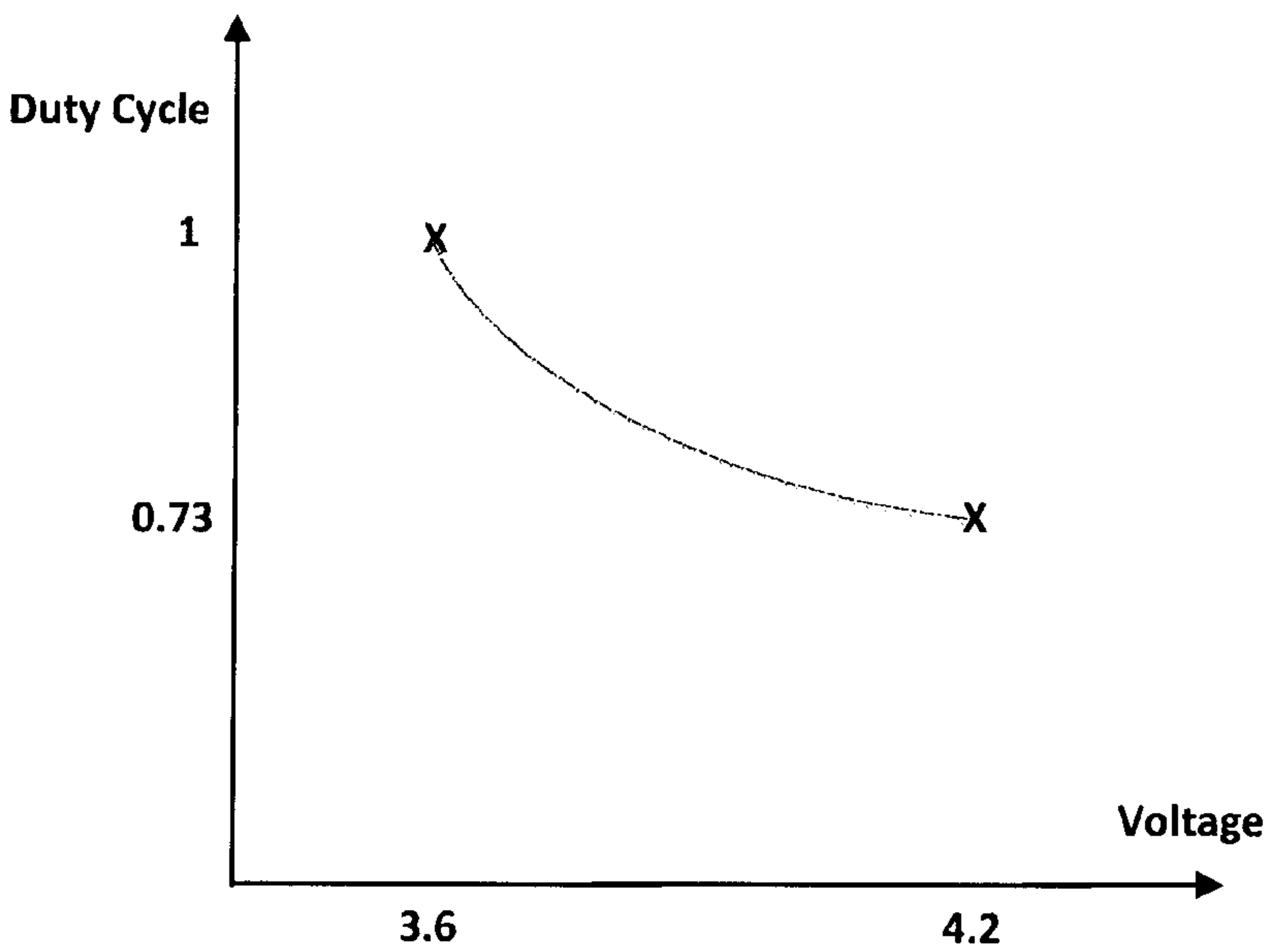
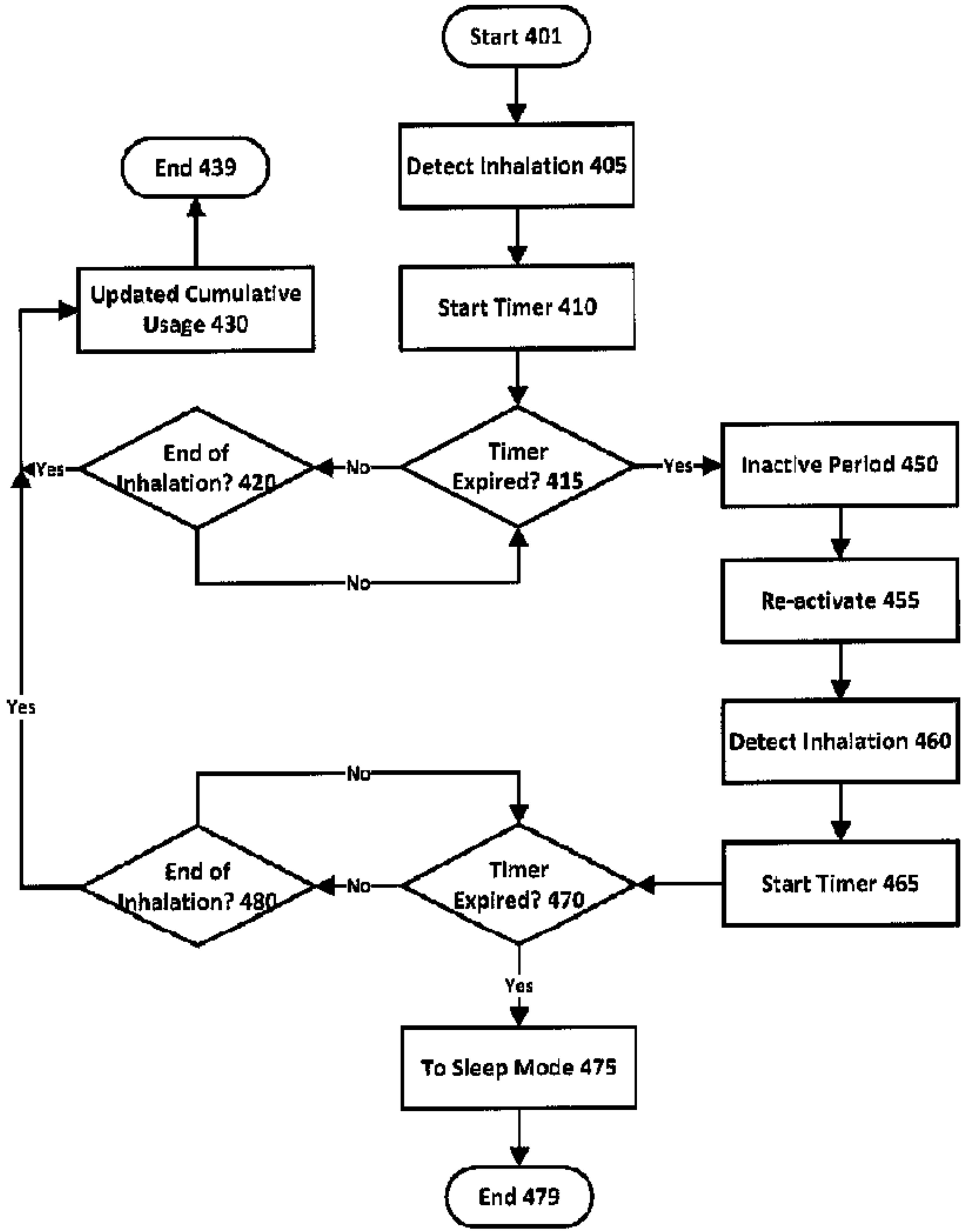


Figure 7B


Start 401
Detect Inhalation 405
Start Timer 410
Timer Expired? 415
Yes
No
Inactive Period 450
Re-activate 455
Detect Inhalation 460
Start Timer 465
End of Inhalation? 420
Yes
No
Updated Cumulative Usage 430
End 439
Yes
No
Timer Expired? 470
No
End of Inhalation? 480
Yes
To Sleep Mode 475
End 479