(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
6 March 2014 (06.03.2014)

(10) International Publication Number
WO 2014/035119 A2

(51) International Patent Classification: Not classified

(21) International Application Number: PCT/KR2013/007682

(22) International Filing Date: 27 August 2013 (27.08.2013)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
13/595,119 27 August 2012 (27.08.2012) US
10-2013-0088382 26 July 2013 (26.07.2013) KR

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KN, KP, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,

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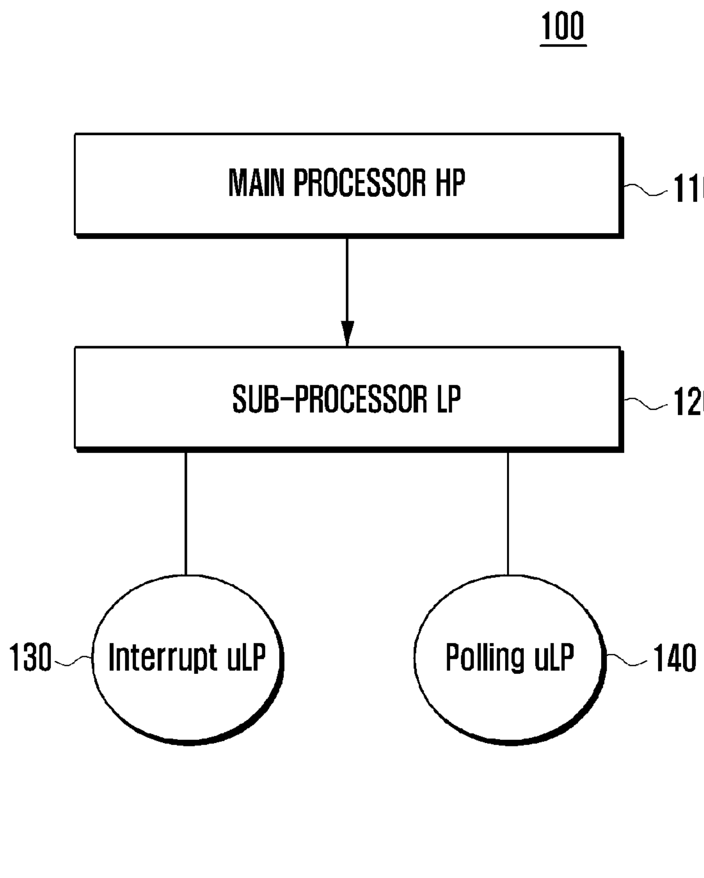
(54) Title: AN APPARATUS AND METHOD FOR WAKING UP A PROCESSOR



(57) Abstract: An apparatus and method for waking up a main processor (MP) in a low power or ultra-low power device preferably includes the MP, and a sub-processor (SP) that utilizes less power than the MP to monitor ambient conditions than the MP, and may be internalized in the MP. The MP and SP can remain in a sleep mode while an interrupt sensor monitors for changes in the ambient environment. A sensor is preferably an interrupt-type sensor, as opposed to polling-type sensors conventionally used to detect ambient changes. The MP and SP may remain in sleep mode, as a low-power or an ultra-low power interrupt sensor operates with the SP being in sleep mode, and awakens the SP via an interrupt indicating a detected change. The SP then wakes the MP after comparing data from the interrupt sensor with values in storage or with another sensor.

WO 2014/035119 A2

MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

Description

Title of Invention: AN APPARATUS AND METHOD FOR WAKING UP A PROCESSOR

Technical Field

[1] The present invention relates generally to a method and apparatus for waking-up an electronic device. More particularly, although not exclusively, the present invention relates to a low-power wake-up method and apparatus for waking-up an electronic device having a sensor, thereby reducing battery power utilized by the portable device and facilitating a return of the electronic device to operation from a sleep mode.

Background Art

[2] In order to save power, which is of particular importance to battery powered devices, conventionally a "sleep mode" has been utilized, which is typically entered when the electronic device has been in an idle state for a predetermined amount of time. Herein, a sleep mode of an electronic device may be regarded as a first mode or state in which the electronic device operates at a lower power level than when the electronic device is in a second (e.g. normal, non-sleep, awake or operational) mode or state. In the second mode, the electronic device is typically fully operational. In the first mode, one or more components of the electronic device are typically operated with reduced power, powered down, or deactivated to lower power consumption relative to the second mode, but typically resulting in reduced operability and/or reduced performance.

[3] Battery usage in portable electronic devices is critical. A few examples of the many types of devices where battery usage is critical include, but are not limited to, cell phones, smart phones, tablets, personal digital assistants (PDAs), portable music players, etc. Furthermore, there continues to be a need to provide more functionality, while at the same time reducing battery power usage.

[4] Conventional devices may dim the brightness of the display, or may cause the display to go blank, after a period of time of non-usage to conserve energy.

[5] For example, with regard to computers, a sleep mode is typically defined as an energy-saving standby condition of the computer, wherein the computer can be re-activated by an external stimulus, for example touching the keyboard. For example, when a goes into sleep mode, the and are typically shut down. Once awakened (e.g. by being sent a specific signal), the returns to its former operating state.

[6] Moreover, in the case of portable electronic devices, a sleep mode may be operated in many different types of devices, for example smartphones, tablets, music players, Personal Digital Assistant (PDAs), just to name a few possibilities.

[7] Many mobile terminals (e.g. smartphones) typically default to a sleep mode when not

used, unless actively performing certain tasks. When there are no active user interactions, for example screen touches, some or all components, for example a central processor, may be powered down unless an application (app) instructs the operating system to keep the device, or certain components thereof, fully powered on.

[8] Moreover, a number of background operations may need to be performed while the device (e.g. mobile phone) is idle. In one example, a user may need a device to automatically update an email folder by checking with a remote server. To prevent the mobile phone from going to sleep during such an operation, device (e.g. smartphone) manufacturers often make application programming interfaces (APIs) available to app developers. A developer may insert an API into one or more apps to instruct the mobile phone to stay awake long enough to perform necessary operations.

[9] In a typical portable device (e.g. smartphone), an Application Processor (AP) is kept in a sleep state when the device is in a sleep state. In order to wake up the device, conventional systems require the user to provide a physical input, for example press a power button or an unlock button.

[10] Using a sleep mode or sleep state saves battery power, particularly when compared with leaving a device in a fully operational mode or state while idle, and advantageously permits the user to avoid having to reset programming codes or wait for an electronic device to reboot. In wireless electronic devices, for example portable mobile terminals, tablets, etc., which often seek out networks and have to provide passwords (or have passwords provided to them) to obtain access upon being rebooted or reset, the use of sleep mode is preferable to a rather cumbersome and slow process or rebooting.

[11] However, to return an electronic device to an operational mode (e.g. wake mode) from a sleep mode requires an action to be undertaken by the user. For example, a power button or an unlock icon must be pressed, which is slow and sometimes awkward, especially when trying to quickly perform an action on the electronic device. Even in the case of the electronic device providing a virtual keypad, an unlock icon must be touched, swiped or spread in order to restore the electronic device to an operational mode, meaning that the user is inconvenienced by being required to contact a button of the device, or slide their finger along a screen.

[12] Some conventional attempts to solve some of the shortcomings mentioned above include providing a luminance sensor or a camera. However, in such cases the application processor (AP) cannot go into sleep mode and must always be in an operating mode in order to monitor and process sensed data from the sensor or camera. This type of monitoring requires a high amount of power consumption, as it is impossible to control the sensor by the AP directly when the AP is asleep.

[13] Recently, the use of a lower-power processor for processing only the sensing data has

been configured into devices. However, the lower-power processor processes data from the sensor using a polling-type technique, and must be maintained in an awake state, using significant amounts of power.

[14] With regard to conventional attempts to address the above-discussed issues, U.S. Pat. Appln. Pub. No. 20100313050 discloses that a sensor processor system selects a power profile to be applied to an application processor system based on sensed data, and instructs a power management controller to apply the selected power profile to the application processor system. There are two processors used for low-power sensing that wakes up the AP when the sensed data meets a condition.

[15] However, a significant drawback with the technique described in U.S. Pat. Appln. Pub. No. 2010/0313050 is that the sensor processor always operates to monitor an ambient environment using a polling-type sensor without using a sleep mode. The sensor processor applies the power profile to the application processor system (software, S/W, type).

[16] Another conventional attempt to improve the art is described in U.S. Pat, Appln. Pub. No. 2009/0259865, wherein an electronic device includes a circuit configured to operate when a main processor is in a sleep mode. The circuit comprises at least one low-power processor and a sensor. However, the low-power processor in this conventional system always operates without being in sleep mode, in order to be able to monitor an ambient environment via a polling-type sensor.

[17] Accordingly, there is a need in the art for a system, apparatus and method that permits additional components to be in a sleep mode, and yet provides ambient monitoring of a device, and that permits the device to switch back to an operating mode from sleep mode quickly, without requiring a user to press buttons or touch a display screen.

Disclosure of Invention

Technical Problem

[18] It is an aim of certain embodiments of the present invention to address, solve, mitigate or obviate, at least partly, at least one of the problems and/or disadvantages associated with the prior art, for example one or more of the above-mentioned problems and/or disadvantages. Certain embodiments of the present invention aim to provide at least one of the advantages described below.

Solution to Problem

[19] The present invention is defined by the appended claims. The skilled person will appreciate that the present invention is not limited to the specific embodiments described herein.

[20] In accordance with an aspect of the present invention, there is provided a method

according to claim 1.

[21] In accordance with another aspect of the present invention, there is provided an apparatus according to claim 2.

[22] In accordance with another aspect of the present invention, there is provided a method for changing a power mode of a first processor (e.g. high-power main processor) in an electronic device, the method comprising the steps of: monitoring, by a sensor (e.g. ultra-low power interrupt sensor), for a predetermined condition (e.g. sensed motion of the device or another object) when a second processor (e.g. low-power sub-processor) is in a first power mode (e.g. sleep mode); sending, by the sensor, an interrupt signal to the second processor upon occurrence of the predetermined condition; entering, by the second processor, a second power mode (e.g. awake mode) upon receiving the interrupt signal; determining, by the second processor, that a value corresponding to the output of the sensor satisfies a numerical condition; and, if the output of the sensor satisfies the numerical condition, outputting, by the second processor, a signal for controlling the first processor to enter the second power mode from the first power mode.

[23] In accordance with another aspect of the present invention, there is provided an apparatus for changing a power mode of a first processor (e.g. high-power main processor) in an electronic device, the apparatus comprising: a second processor (e.g. low-power sub-processor) configured for operating in at least a first power mode (e.g. sleep mode) and a second power mode (e.g. awake mode); a sensor (e.g. an ultra-low power interrupt sensor) for monitoring for a predetermined condition (e.g. sensed motion of the device or another object) when the second processor is in the first power mode, and for sending an interrupt signal to the second processor upon occurrence of the predetermined condition; wherein the second processor is configured for entering the second power mode upon receiving the interrupt signal, determining that a value corresponding to the output of the sensor satisfies a numerical condition, and, if the output of the sensor satisfies the numerical condition, outputting a signal for controlling the first processor to enter the second power mode from the first power mode.

[24] Another aspect of the present invention provides a computer program comprising instructions arranged, when executed, to implement a method and/or apparatus, in accordance with any one of the above-described aspects. A further aspect provides machine-readable storage storing such a program.

Advantageous Effects of Invention

[25] Exemplary embodiments of the present invention provide an apparatus and method for waking up a main processor in an ultra-low power device. In an exemplary embodiment, the apparatus includes a main processor, and a sub-processor that utilizes

less power than the main processor, and may be internalized in the main processor. An exemplary embodiment comprises at least one sensor, wherein the sensor comprises an interrupt-type sensor (as opposed to, for example, a polling-type sensor).

[26] One of the many advantages provided by embodiments of the present invention is that both the main processor and the sub-processor can remain in a sleep mode, since a low-power or an ultra-low power sensor can operate while the sub-processor is in the sleep mode, and only awaken after receiving an interrupt signal from the interrupt sensor indicating that a change has been detected.

[27] In addition, embodiments of the present invention also permit a return from sleep mode to an operating mode by a user gesture, for example a wave of the hand. Also, in certain embodiments, the device may be awakened from a sleep mode in many other ways, for example by shaking the device, or by moving a stylus pen arranged along an exterior of the device.

[28] Other aspects, advantages, and salient features of the invention will become apparent to those skilled in the art from the following detailed description, which, taken in conjunction with the annexed drawings, disclose exemplary embodiments of the invention.

Brief Description of Drawings

[29] The above and other exemplary aspects, and features and advantages of certain exemplary embodiments and aspects of the present invention will become more apparent from the following detailed description taken in conjunction with the accompanying drawings, in which:

[30] FIG. 1 shows a block diagram of an exemplary depiction of an apparatus according to an exemplary embodiment of the invention;

[31] FIG. 2A shows a flowchart illustrating an exemplary operation for gesture sensing according to an exemplary embodiment of the invention;

[32] FIG. 2B shows a flowchart illustrating an exemplary operation for gesture sensing according to an exemplary aspect of the invention;

[33] FIG. 3A shows a flowchart illustrating an exemplary operation of a feedback voice input based on device's motion according to an exemplary embodiment of the invention;

[34] FIG. 3B is an exemplary overview of an AP Processor to Hub Processor Protocol according to an exemplary embodiment of the present invention;

[35] FIG. 3C is an example of a message frame that can be used with an AP to Hub Protocol according to an exemplary embodiment of the present invention;

[36] FIG. 3D is an example of an AP processor communicating with a second processor hub, according to an AP to Hub protocol that can be used with embodiments of the present invention;

[37] FIG. 3E shows a flowchart illustrating an exemplary operation of a feedback voice input based on a wakeup from the sleep mode by audio data detection according to another exemplary aspect of the invention;

[38] FIG. 3F shows a flowchart illustrating an exemplary operation of a feedback voice input based on a wakeup from the sleep mode by audio data detection according to another exemplary aspect of the invention; FIG. 4 shows a flowchart illustrating exemplary operation of a signature unlock based on stylus movement according to an exemplary embodiment of the invention;

[39] FIG. 5 shows a current profiling example according to an exemplary embodiment of the invention; and

[40] FIG. 6 shows an example of a wireless device embodying the present invention.

[41] It is to be understood, however, that the drawings are designed solely for purposes of illustration and should not be interpreted as limiting the scope of the invention, as defined by the appended claims. Moreover, the drawings are not necessarily drawn to scale and, unless otherwise indicated, they are merely intended to conceptually illustrate the structures in exemplary embodiments of the present invention, including at least one of a low power processor and an ultra-low power sensor for monitoring at least one of signals, commands, inputs, and changes in an environment. As will become more apparent from the following detailed description, in exemplary embodiments, the circuit wakes up the main processor responsive to one of the low power processor and the ultra-low power interrupt sensor.

Best Mode for Carrying out the Invention

[42] The following description of exemplary embodiments of the present invention, with reference to the accompanying drawings, is provided to assist in a comprehensive understanding of the present invention, as defined by the claims. The description includes various specific details to assist in that understanding but these are to be regarded as merely exemplary. Accordingly, those of ordinary skill in the art will recognize that various changes and modifications of the embodiments described herein can be made without departing from the scope of the invention. For example, the drawings illustrated are only schematic and are non-limiting. In the drawings, for illustrative purposes, the size of some of the elements may be exaggerated and not drawn to a particular scale.

[43] The terms and words used in the following description and claims are not limited to the bibliographical meanings, but, are merely used by the inventor to enable a clear and consistent understanding of the invention. Accordingly, it should be apparent to those skilled in the art that the following description of exemplary embodiments of the present invention is provided for illustration purpose only and not for the purpose of

limiting the invention as defined by the appended claims.

[44] The same or similar components may be designated by the same or similar reference numerals although they may be illustrated in different drawings. Detailed descriptions of structures, constructions, functions or processes known in the art may be omitted for clarity and conciseness, and to avoid obscuring the subject matter of the present invention.

[45] Throughout the description and claims of this specification, the singular encompasses the plural unless the context otherwise requires. In particular, it is to be understood that the singular forms “a,” “an,” and “the” include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to “an object” includes reference to one or more of such objects.

[46] Throughout the description and claims of this specification, the terms “comprising” and “contain”, and variations of these terms, mean “including but not limited to”, and are not intended to (and do not) exclude other moieties, additives, components, integers, elements or steps. Hence, the term “comprising” should not be interpreted as being restricted to the items listed thereafter; it does not exclude other elements or steps, and so the scope of the expression “a device comprising items A and B”should not be limited to devices consisting only of components A and B. This expression signifies that, relevant components of the device include A and B.

[47] Furthermore, the terms “first”, “second”, “third” and the like, if used in the description and in the claims, are provided for distinguishing between similar elements and not necessarily for describing a sequential or chronological order. It is to be understood that the terms so used are interchangeable under appropriate circumstances (unless clearly disclosed otherwise) and that exemplary embodiments of the invention, including those described herein, may be operated in sequences and/or arrangements other than those described or illustrated herein. It is understood that, in certain circumstances, two logical or functional elements designated with the same name but distinguished by different numbers (e.g. “first processor” and “second processor”) may be implemented by, or integrated within, a single physical element.

[48] Features, integers, characteristics, compounds, chemical moieties or groups described in conjunction with a particular aspect, embodiment or example of the present invention are to be understood to be applicable to any other aspect, embodiment or example described herein, unless incompatible therewith.

[49] It will be also be appreciated that, throughout the description and claims of this specification, language in the general form of “X for Y” (where Y is some action, activity or step and X is some means for carrying out that action, activity or step) encompasses means X adapted or arranged specifically, but not exclusively, to do Y.

[50] To aide in an understanding of the present invention, the skilled person should un-

derstand and appreciate that the terms "main processor" and sub-processor" are terminologies used for understanding exemplary embodiments of the present invention, but that other equivalent terms can be interchangeably used in place of main processor and sub-processor having the same meaning.

[51] For example, to aid the skilled person, the term "main processor", can be regarded herein as interchangeable with any one of the terms "application processor", "AP" , "first processor", and "processor 1", which are all used herein to refer to the same processor 110 that is shown in FIG. 1. For example, a processor (e.g. a “high-power” processor) having a first operating power level can be referred to as a main processor, or an application processor. The first operating power level may be an operating power that is greater than or equal to a first threshold.

[52] A processor (e.g. a “low-power” processor) having a second operating power level (the second operating power level being lower than the first operating power level) may be referred to as a sub-processor, or a sensing processor. The second operating power level may be an operating power that is lower than the first threshold. The second operating power level may also be an operating power that is greater than or equal to a second threshold (the second threshold being lower than the first threshold). The main processor (or application processor) is typically considered as high-power relative to the low-power sub-processor (or sensing processor).

[53] In addition, the term "sub-processor", can be regarded herein as interchangeable with any one of the terms "sensing processor", "MCU", "second processor", "processor 2", "Sensor Hub (Processor)", MCU (Micro Controller Unit", which are all used herein to refer to the same processor 120 that is shown in FIG. 1. Herein, the term “ultra-low power processor” may refer to any of the above.

[54] Herein, the term "ultra-low power" refers to a third operating power level that is lower than the second operating power level. The third operating power level may be an operating power that is lower than the second threshold.

[55] For example, the skilled person will understand and appreciate that, in certain exemplary embodiments, the term "ultra-low power" used in connection with a component (e.g. a processor or sensor) may refer to a component (e.g. processor or sensor) operating at power consumption values using less than approximately 1mA, for example in the Arange(e.g.1-999A),orlower. That is, in certain embodiments, the expression "ultra-low power level" may refer to power consumption at a level less than approximately 1mA.

[56] In addition, the skilled person will also understand and appreciate that, in certain exemplary embodiments, the term "low power" used in connection with a component (e.g. processor or sensor) may refer to a component (e.g. processor (e.g. sub-processor) or sensor) operating in the 1-10mA range.

[57] In addition, the skilled person will also understand and appreciate that, in certain exemplary embodiments, the term "high power" used in connection with a component (e.g. processor or sensor) may refer to a component (e.g. processor (e.g. main-processor) or sensor) operating above 10mA.

[58] In certain exemplary embodiments, the first threshold may be 10mA and the second threshold may be 1mA. The skilled person will understand that other values may be used in various embodiments.

[59] In some embodiments, the first, second and/or third operating power levels may have certain numerical relationships with each other. For example, the second operating power level may be at least a certain factor (e.g. 5 or 10) lower than the first operating power level, and/or the third operating power level may be at least a certain factor (e.g. 5 or 10) lower than the second operating power level or at least a certain factor (e.g. 25 or 100) lower than the first operating power level. Similarly, the first and second thresholds may have a certain numerical relationship to each other (e.g. at least a certain factor difference). Other numerical relationships are possible.

[60] In certain exemplary embodiments, the apparatus may comprise a wireless communication device, for example a mobile communication terminal, a cellphone, smart phone, tablet, Personal Digital Assistant (PDA), notebook, netbook, etc., just to name a few possible non-limiting examples of devices.

[61] FIG. 1 shows a block diagram of an exemplary depiction of an apparatus 100 according to an exemplary embodiment of the invention that includes a main processor (e.g. a high power, HP, processor) in the form of, for example, an application processor, a sub-processor 120 (e.g. a low power, LP, processor) that receives information from one or more sensors, for example an interrupt sensor 130 (e.g. an ultra-low power, uLP, sensor) and a polling sensor 140 (that may or may not be ultra-low power).

[62] The sub-processor 120 may operate at a low power or ultra-low power, and can remain in a sleep mode along with the main processor 110 because of the use of an interrupt sensor 130. As discussed herein above, a conventional apparatus uses only a polling sensor that requires at least one of the main processor and the sub-processor to remain fully operational to be able to cause the device to change from a sleep mode to an operational mode.

[63] The interrupt sensor 130 operates at ultra-low power levels and sends an interrupt signal to the sub-processor 120 when a predetermined condition is sensed. The predetermined condition may be, for example, a user waiving their hand in front of the display, shaking the device, or moving a piece of the device, for example shifting a position of a stylus 475 (FIG. 4) or part of the cover. In addition, the interrupt sensor 130 may also comprise a pressure sensor, such as n audio sensor including but not

limited to a microphone that senses acoustic pressure in the form of sound waves (audio data), and the microphone is active at ultra-low power levels and detects audio data the while the main processor 110 and the sub-processor 120 are asleep. In embodiments of the present invention, the interrupt sensor 130 is operable while the sub-processor 120 is in a sleep mode (e.g. a mode in which power consumption is lower than when in a normal operating mode). However, in certain embodiments the polling sensor 140 requires the sub-processor to be in an awake mode or operating mode (not in sleep mode).

[64] FIG. 2A shows a flowchart illustrating an exemplary operation for gesture sensing according to an exemplary aspect of the invention.

[65] At step 200a, the main processor 110 and sub-processor 120 are in sleep mode. At steps 210a and 220a, an interrupt sensor 130 (for example, an infrared (IR) sensor) detects or senses gestures occurring within a certain distance (e.g. proximity distance) of the electronic device, for example with the proximity distance from a display or touchscreen of the electronic device. The proximity distance may be, for example, 10-15cm in some exemplary embodiments. The skilled person will appreciate that embodiments of the present invention are not limited to using a specific distance, so long as the sensor can recognize the wave of the user's hand or other gesture.

[66] At step 230a, the sub-processor 120 is awakened by the interrupt signal sent from the interrupt sensor 130. Alternatively or additionally, at step 240a an accelerometer may detect the device being shaken or waived, thereby causing the sub-processor 120 to be awakened.

[67] At step 250a, the sub-processor determines whether or not the sensed data from the interrupt sensor 130 is valid, for example by comparing the data value(s) with a table in storage. Herein, sensed data may be regarded as valid if a value corresponding to, or derived from, the sensor output satisfies a numerical condition, for example (i) is greater than a threshold, (ii) is lower than a threshold, or (iii) falls within a range of values. For example, if a value corresponding to the output of a motion sensor exceeds a threshold, this may indicate that more than a certain amount of motion has been sensed by the motion sensor. Thus, in this example, sensed data may be regarded as valid if more than a certain amount of motion is sensed.

[68] In addition, a polling sensor 130 can be optionally included so that when the mobile device is placed in a case or bag, the interrupt sensor does not unintentionally operate. Accordingly, the sub-processor wakes up due to the interrupt from the interrupt sensor, and the main processor wakes up when 1) sensing data of the interrupt sensor is valid (e.g. within a valid range) or 2) when sensing data of the polling sensor is valid (e.g. within a valid range), with 1) or 2) being determined by the sub-processor at step 250a.

[69] After determining by the sub-processor 120 that the data is valid, for example, by

being in a valid range, or having exceeded a predetermined threshold, the sub-processor 120 at step 260a then wakes the main processor 110, which in turn at step 270a provides feedback to the user, in the form of, for example, unlocking the screen, prompting the user, making the display operable, showing a home screen, etc.

[70] In an exemplary embodiment of the present invention, the predetermined threshold may be a particular value wherein, if the output (e.g. sensor data) is greater than or equal to the particular value, the sub-processor determines that the wake up condition(s) is/are satisfied. In addition, or alternatively, there may be a range of values received from the sensor that are predetermined as satisfying a wakeup condition. For example, the predetermined range may be a microvoltv(or microamp) range,or any other suitable range (e.g.milliamp,*m*a,range) that is within the capability of the sub processor to distinguish between values received from the sensor so ass certain a valid range. Furthermore, any suitable predetermined threshold may be used. The skilled person will appreciate that the present invention is not limited to the specific examples described.

[71] FIG. 2B shows a flowchart illustrating an exemplary operation for audio sensing while the main processor and sub-processor are asleep according to an exemplary aspect of the invention.

[72] At step 200b, the main processor 110 and sub-processor 120 are in sleep mode. At steps 210b and 220b, an audio sensor 130 (including but not limited to a microphone) detects audio (sound) within a valid range for a predetermined threshold.

[73] At step 230, the sub-processor 120 is awakened by the interrupt signal sent from the interrupt sensor 130. Alternatively, at step 240b a polling sensor may optionally additionally collect data to determine whether sound is being received that is within a valid range (for example, a certain pitch, sound pressure (in dB), sound intensity, etc.).

[74] At step 250b, the sub-processor determines whether or not the sensed data from the interrupt sensor 130 is valid by comparing the value with a table in storage.

[75] Accordingly, with regard to the example of FIG. 2B, the sub-processor wakes up due to the interrupt from the interrupt sensor, and the main processor wakes up when 1) sensing data of the interrupt sensor is within valid range or 2) when sensing data of the polling sensor is within the valid range, with 1) or 2) being determined by the sub-processor at step 250.

[76] After determining by the sub-processor 120 that the data is valid, for example, by being in a valid range, or has reached a predetermined threshold, the sub-processor 120 at step 260b then wakes the main processor 110, which in turn at step 270b provides feedback to the user, in the form of, for example, unlocking the screen, prompting the user, making the display operable, showing a home screen, etc. According to an exemplary aspect of the present invention, the predetermined threshold could be a

particular value which if the output is greater than or equal to, is determined by the sub-processor as satisfying the wake up condition(s). In addition, there can be a range of range of values received from the sensor that are predetermined as satisfying a wakeup condition, that being provided only for purposes of illustration and not for limiting the appended claims, such as, for example a microvoltμV(or microamp μA) range. Any other such range (e.g.mA) that is within the capability of the sub-processor to distinguish between values received from the sensor so as to ascertain avalid range or predetermined threshold are within the spirit ands cope of the claimed invention.

[77] Fig.3A shows a flowchart illustrating an exemplary operation of a feedback voice input based on a device's motion according to an exemplary embodiment of the invention. This particular exemplary embodiment starts at step 300 with the main processor and sub-processor being asleep. A motion detector detects motion at step 310, by sensing the predetermined condition (which in this example is the device being shaken or waved) at step 320, and the interrupt signal is sent to the sub-processor 120 to wake up the sensing processor at step 330. Then the sub-processor at step 340 determines whether or not the sensed data is valid, by comparing with values in storage to determine if the data is within a valid range or has exceeded a predetermined threshold, for example. Upon determining that the sensed data from the interrupt sensor is valid, then at step 350 the sub-processor 120 wakes up the main processor 110. The main processor can be fully operable and wait, for example, for a voice input (step 360), and based on the determined voice input, can either unlock the display screen or execute a function or application (step 370).

[78] An exemplary protocol between the main processor and sub-processor is discussed herein in relation to certain exemplary embodiments. The protocol for transmitting data is in accordance with the main processor and sub-processor's active or sleep state.

[79] As shown in FIG. 3B, while the main processor is active, an exchange occurs between a main processor and a sub-processor according to a HUB protocol. First, a hub interrupt is sent by the main processor to the sub-processor, and wherein the main processor starts to send length information (e.g. data length information) to the sub-processor. In turn, the sub-processor sends an acknowledgement back to the main processor. At this point, the hub (sub-processor) sets the control right and AP sleep information.

[80] With continued reference to FIG. 3B, it can be seen that the sub-processor keeps varying states between active and sleep. When a situation arises where the main processor needs to be awakened, an AP interrupt id is sent from the sub-processor to the main processor. Once the main processor is awakened, the main processor remains in an active state and starts to send information to the sub-processor. In turn, the sub-processor indicates to the main processor the data length to send. Next the main

processor starts to read a message from sub-processor, which can comprise sensor data and sub-processed data.

[81] FIG. 3C shows an example of a main processor to sub-processor (i.e. AP to Hub) Protocol Message Frame that can be used in an exemplary embodiment of the present invention.

[82] Referring now to FIG. 3C, it is shown that an exemplary frame can be 8 bytes, with a command field commanded by the AP (main processor) to the Hub (sub-processor), a sensor number field specifying a particular sensor, a data type showing the content of the operand being transmitted, a data size field providing the actual data that follows. Each of the aforementioned parts of the message frame can be 1 byte in length, and the data and status can be 4 bytes each so as to total 8 bytes, for example.

[83] FIG. 3D shows another example of an AP (main processor) to Hub (sub-processor) Protocol according to a non-limiting exemplary embodiment of the present invention. These actions are similar to what is shown in FIG 3B while the AP is in the active mode.

[84] FIG. 3E shows a flowchart illustrating an exemplary operation of a feedback voice input based on a wakeup from the sleep mode by audio data detection according to another exemplary aspect of the invention. This particular exemplary embodiment, in which the ultra lower power sensor 130 is a pressure sensor such as an audio sensor or a microphone, starts at step 300e with the main processor and sub-processor being asleep. An audio sensor including but not limited to a microphone operable while the main processor and sub-processor are asleep, receives audio data (sound pressure) at step 310e. It is determined at step 320e that audio data is detected, and the interrupt signal is sent to the sub-processor 120 to wake up the sensing processor at step 330e. Then the sub-processor at step 340 determines whether or not the sensed data is valid, by comparing with values in storage to determine if the data is within a valid range or has reached a predetermined threshold, for example. Upon determining that the sensed data from the interrupt sensor is valid, then at step 350e the sub-processor 120 wakes up the main processor 110. The main processor can be fully operable and wait, for example, for a voice input (step 360e), and based on the determined voice input, can either unlock the display screen or execute a function or application (step 370e). For further purposes of illustration and not to limit the claimed invention, exemplary protocol between the main processor and sub-processor is discussed herein. The protocol for transmitting is in accordance with the main processor and sub-processor's active or sleep state.

[85] FIG. 3F shows a flowchart illustrating an exemplary operation of a feedback voice input based on a wakeup from the sleep mode by audio data detection according to another exemplary aspect of the invention.

[86] This particular exemplary embodiment, in which the ultra lower power sensor 130 is an audio sensor or a microphone, starts at step 300f with the main processor being asleep and sub-processor being awake. An audio sensor including but not limited to a microphone operable while the main processor are asleep, and sub-processor are awake, receives audio data (sound pressure) at step 310f. It is determined at step 320f that audio data is detected, and the interrupt signal is sent to the sub-processor. Then the sub-processor at step 330f determines whether or not the sensed data is valid, by comparing with values in storage to determine if the data is within a valid range or has reached a predetermined threshold, for example. The sub-processor may control to unlock the display screen the electronic device when the voice is detected.

[87] Upon determining that the sensed data from the interrupt sensor is valid, then at step 340f the sub-processor 120 wakes up the main processor 110. The main processor can be fully operable and wait, for example, for a voice command input (step 350f), and based on the determined voice command input, execute a function or application (step 360f). that is, the sensor according to the present invention, when the sub processor is awakened, sends a sensed signal and sensing data to the sub-processor, the sub processor may determines that the received sensed signal from the senor has sensing data received from the sensor changing in the predetermined condition.

[88] FIG. 4 shows a flowchart illustrating exemplary operation of a signature unlock based on stylus movement according to an exemplary embodiment of the invention.

[89] With reference to FIG. 4, at step 400, the main processor and sub-processor are in sleep mode. At step 410, the presence of a stylus pen 475 is monitored to determine whether the stylus pen has been removed from a holder on the electronic device. At step 420, when it is determined that the stylus pen is removed, sub-processor wakes up at 430 and a non-input timer may be activated. If at step 440, the non-input timer has expired, the main processor and sub-processor go back to sleep mode, otherwise, at step 450 it is determined whether a signature (e.g. a signature written by the user on a touch screen of the electronic device) is valid (e.g. by comparing to a pre-stored signature), and if so, then main processor wakes up, and the display LCD is turned on and unlocked (step 460).

[90] FIG. 5 shows a current profiling example according to an exemplary embodiment of the invention. In this particular non-limiting example, The X axis represents time, and the Y-axis represents current consumption which may be of the order of milliamps (㎃)ormicroamps(㎂),forexample.

[91] As shown in FIG. 5, the IR gesture sensor (interrupt sensor) consumes at 317.5uA of current. The sub-processor in this example consumes about 3.2mA when awakened due to the IR gesture sensor sensing a change in the ambient condition. Within about 330ms (milliseconds) of waking up, the sub-processor may wake up the main

processor to perform a function, and upon doing so, the sub-processor goes back to sleep. The main processor consumes considerably more current than the sub-processor. Also, in the example of FIG. 5, it is shown that the accelerometer can cause the main processor to wake up within 180 ms.

[92] FIG. 6 shows one possible example of a wireless device embodying the present invention. The skilled person will understand and appreciate that many different types of both wired and wireless devices can embody the present invention. Some non-limiting examples include smartphone, tablet, PDA, music player, etc. just to name a few examples. A controller includes the main processor 610 and a codec 617. The controller communicates with sensing processor 620. The interrupt sensor 630. which may be an audio sensor or microphone that operates when main processor are asleep and the polling sensor 640 are shown schematically, but their actual proximity to the controller may be different than shown.

[93] Touch screen 655 permits display and entry of data. Storage device 685 is in communication with the controller, and comprises a non-transitory machine readable medium.

[94] Auxiliary input 675 can be any suitable type of input, for example a keyboard or a mouse. The wireless communication unit, although shown as a single box in Figure 5, may comprise any number of different hardware modules

[95] for communication, for example for transmitting and receiving in short range communication such as Near Field Communication, Bluetooth, WLAN, 802.11, RF communications, etc.

[96] In embodiments of the invention, the ambient environment (e.g. the environment or volume surrounding the device or the physical state of the device) is monitored by an interrupt sensor, so that the sub-processor and the main processor (e.g. application processor) can remain together in sleep mode. Embodiments of the present invention provide an advantage of saving power. Embodiments of the present invention also provide an advantage of increased user convenience since there is no requirement to push a button to activate/convert the device from a sleep mode back to a normal operating mode.

[97] In certain embodiments, the sensing of a swiping near the device is sufficient to awake the device from sleep mode. Alternatively or additionally, in certain embodiments, shaking or waving the device also restores the device to a normal operating state by waking it up.

[98] It will be appreciated that embodiments of the present invention (e.g. methods and apparatus) can be realized in the form of hardware, software or any combination of hardware and software. For example, the above-described embodiments can be implemented in hardware, firmware or as software or computer code that can be stored in a recording medium such as a CD ROM, an RAM, a floppy disk, a hard disk, or a

magneto-optical disk or computer code downloaded over a network originally stored on a remote recording medium or a non-transitory machine readable medium and to be stored on a local recording medium, so that the embodiments described herein can be rendered in such software that is stored on the recording medium using a general purpose computer, or a special processor or in programmable or dedicated hardware, such as, flash, an ASIC or FPGA.

[99] As would be understood by the skilled person, the computer, the processor, microprocessor controller or the programmable hardware may include memory components, e.g., RAM, ROM, Flash, etc. that may store or receive software or computer code that, when accessed and executed by the computer, processor or hardware, implement the processing methods described herein. In addition, it would be recognized that when a general purpose computer accesses code for implementing the processing described herein, the execution of the code transforms the general purpose computer into a special purpose computer for executing the processing described herein.

[100] It will be appreciated that the storage devices and storage media are embodiments of machine-readable storage that are suitable for storing a program or programs comprising instructions that, when executed, implement embodiments of the present invention. Accordingly, embodiments provide a program comprising code for implementing apparatus or a method as claimed in any one of the claims of this specification and a machine-readable storage storing such a program. Still further, such programs may be conveyed

[101] electronically via any medium such as a communication signal carried over a wired or wireless connection and embodiments suitably encompass the same.

[102] While the invention has been shown and described with reference to certain exemplary embodiments thereof, it will be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the scope of the invention, as defined by the appended claims.

Claims

[Claim 1] A method of waking up a main processor in an ultra-low power electronic device, said, method comprising:
monitoring for a predetermined condition by an sensor when a sub-processor that controls the sensor is in a sleep mode;
sending by the sensor an sensed signal to the sub-processor upon sensing a change in the predetermined condition being monitored, said sub-processor being configured to wake up from sleep mode upon receiving the sensed signal and evaluate data received from the sensor;and
wherein when the sub-processor determines that the data received from the sensor has reached a predetermined threshold value or is within a predetermined range of validity, the sub-processor sending a signal to wake up a main processor that is coupled to the sub-processor.

[Claim 2] The method according to claim 1, wherein the sensor is interrupt type.

[Claim 3] The method according to claim 1, wherein the sensor comprises a microphone that senses sound received that is within a predetermined range or has reached a predetermined threshold value.

[Claim 4] The method according to claim 1, wherein the sensor comprises at least one of a microphone, piezoelectric sensor, pressure sensor, motion sensor, IR gesture sensor, accelerometer, gyro sensor that is active by an ultra-low power while main processor are in sleep mode.

[Claim 5] The method according to claim 1, wherein the predetermined condition being monitored comprises a voice that received through the microphone.

[Claim 6] The method according to claim 5, wherein after the voice is detected and the sub processor is awakened, unlocking the electronic device.

[Claim 7] The method according to claim 1, wherein after the main processor is awakened, operating the electronic device after determining receipt of a voice command.

[Claim 8] The method according to claim 1, wherein the sensor, when the sub processor is awakened, sends a sensed signal and sensing data to the sub-processor, the sub processor determines that the received sensed signal from the senor has sensing data received from the sensor changing in the predetermined condition.

[Claim 9] An ultra-low power wake up apparatus comprising:
a sub-processor including an interface for communicating with a main

processor, said sub-processor having at least a sleep mode and an operating mode;
an sensor in communication with the sub-processor, said sensor monitors a predetermined condition when the sub-processor is in the sleep mode;
wherein said sensor sends an sensed signal to the sub processor upon sensing a change in the condition being monitored, said sub-processor being configured to wake up from the sleep mode and evaluate data provided from the sensor; and
wherein said sub-processor being further configured to send a signal over the communication interface to wake up the main processor when the sub-processor determines that the data received from the sensor is at a predetermined threshold value or within a predetermined range of validity.

[Claim 10] the apparatus according to claim 9, wherein the sensor operates at an ultra-low power level; and/or
wherein the sub-processor operates at one of a low power level and an ultra-low power level; and/or
wherein the sub-processor operates at a power level that is less than a power level at which the main processor operates; and/or
wherein the sub-processor operates at a power level that is higher than a power level of the sensor.

[Claim 11] the apparatus according to claim 9 , wherein monitoring for the predetermined condition comprises one or more of:
monitoring for a gesture;
motion sensing;
monitoring for a voice;
monitoring for the electronic device being shaken or waved;
monitering for a voice that received through the microphone;
monitoring an ambient environment of the apparatus, and wherein the sensor monitors the ambient environment either periodically or continuously;
monitoring an ambient environment of the apparatus, and wherein the sensor comprises an infrared (IR) gesture sensor that senses a gesture as a change in the ambient environment;
monitoring an ambient environment of the apparatus, and wherein the sensor comprises an microphone that senses a voice sound as a change in the ambient environment;

monitoring an ambient environment of the apparatus, and wherein the interrupt sensor comprises a motion sensor that senses a motion as a change in the ambient environment; and
sensing a change in position of a stylus arranged partially within a holder or on a surface of the apparatus.

[Claim 12] The apparatus according to claim 9, wherein after motion is detected and the main processor is awakened, the electronic device is unlocked or operated after determining receipt of a voice command.

[Claim 13] The apparatus according to claim 9, wherein the sub-processor comprises a sensing processor, and both the main processor and the sensing processor are configured to go into a sleep mode until the sensor senses a change in the ambient environment and wakes the sensing processor, and the sensing processor wakes up the main processor when the sensing processor determines that the data received from the sensor has reached a predetermined threshold value or is within a predetermined range of validity.

[Claim 14] The apparatus according to claim 9, wherein an sensor comprising a polling sensor is in communication with the sub-processor to determine whether to wake the main processor when sensing data of the polling sensor is within a valid range.

[Claim 15] The apparatus according to claim 14, wherein the polling sensor operates only when the sub-processor is in the operating mode after being awakened by the interrupt sensor.

[Claim 16] The apparatus according to claim 15, wherein the polling sensor comprises an accelerometer.

[Claim 17] The method or apparatus of claim 9, wherein the sub-processor is internalized in the main processor.

[Claim 18] The apparatus of claim 11, wherein a gesture proximity to be sensed by the IR gesture sensor is less than 15cm.

[Claim 19] The apparatus according to claim 9, wherein the sub-processor utilizes 1/5th or less than an operating power of the main processor.

[Claim 20] The apparatus according to claim 9, wherein the main processor comprises an application processor; and/or
wherein the sub-processor comprises one of a sensing processor, a sensor hub, and a Micro Controller Unit (MCU).

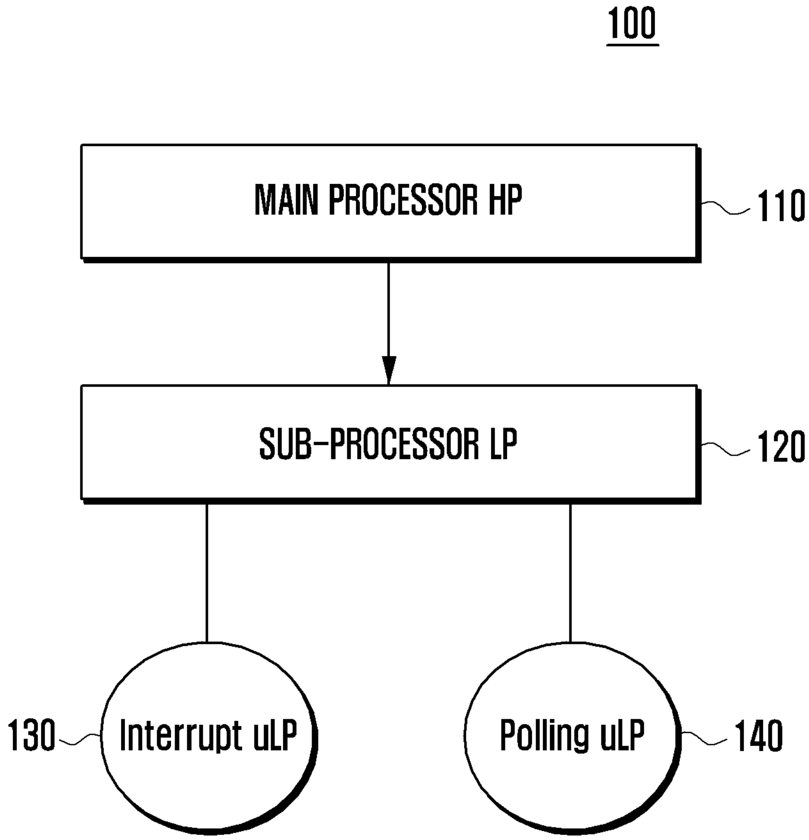
[Claim 21] The apparatus according to claim 20, wherein the application processor includes a sleep mode and an operating mode, and wherein both the application processor and the sub-processor are configured to go into a sleep mode until the sensor senses a change in the ambient environment and wakes the sub-processor.

[Claim 22] The apparatus according to claim 20, wherein the sensor is configured to operate at an ultra-low power level and senses whether a change in the predetermined condition being monitored occurs, and the sensor sends an interrupt to the sub-processor upon detection of the change in the predetermined condition being monitored.

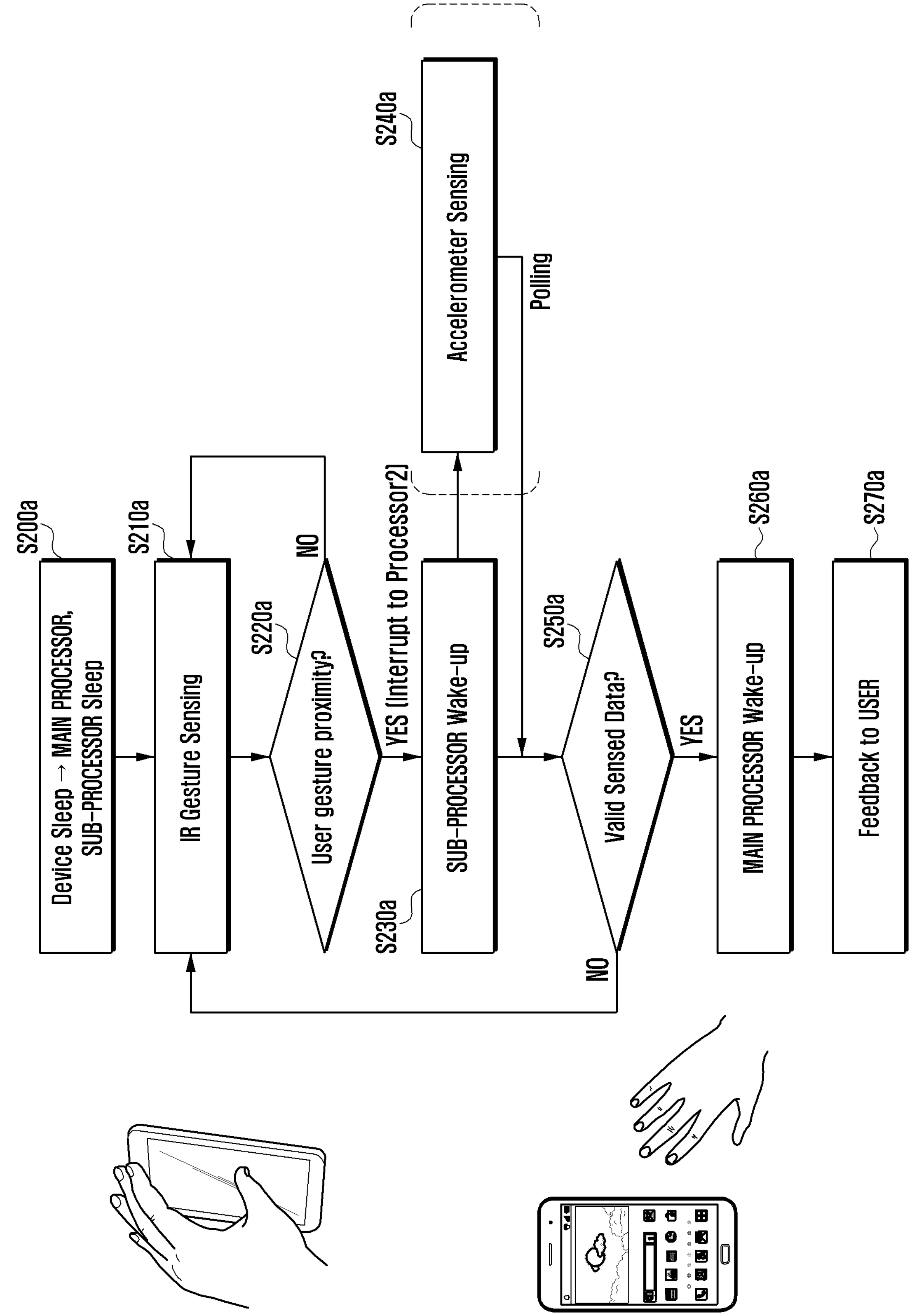
[Claim 23] TThe apparatus according to claim 20, further comprising an additional sensor in communication with the sub-processor,
herein the sub-processor compares an output of the interrupt sensor with an output of the additional sensor to determine whether to wake the main processor via the communication interface between the sensing processor and the main processor.

[Claim 24] The method or apparatus of any preceding claim, wherein said apparatus or electronic device comprises a portable communication terminal configured for wireless communication, and optionally wherein the apparatus comprises:
a controller including the main processor and the sub-processor;
a non-transitory memory;
an RF communication unit coupled to the controller;
a touchscreen;
a network communication unit; and
wherein the sensor sends the sensed signal to the main processor upon detecting a change in the ambient environment of the portable communication terminal.

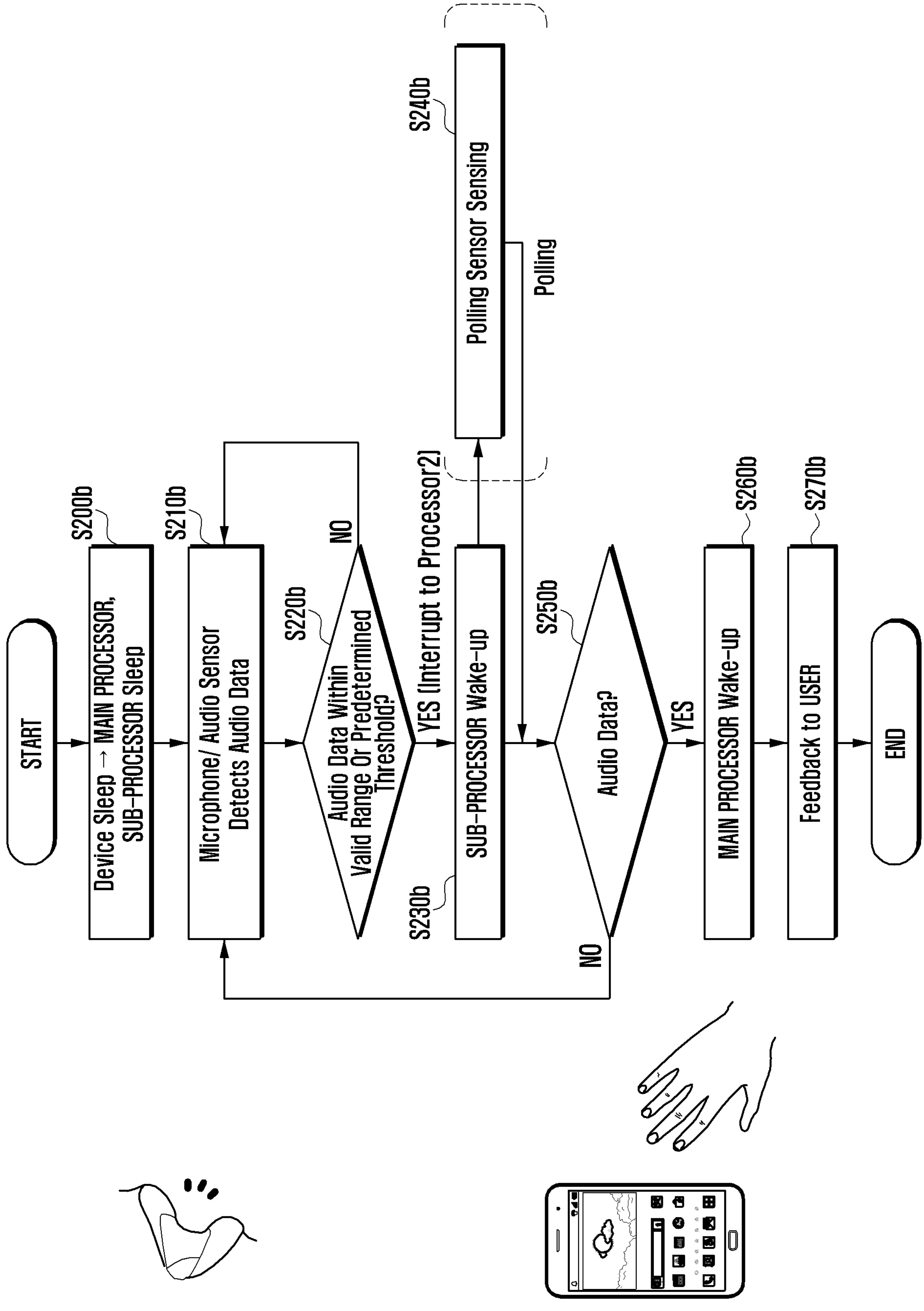
[Fig. 1]


100
MAIN PROCESSOR HP
110
SUB-PROCESSOR LP
120
130
Interrupt uLP
Polling uLP
140

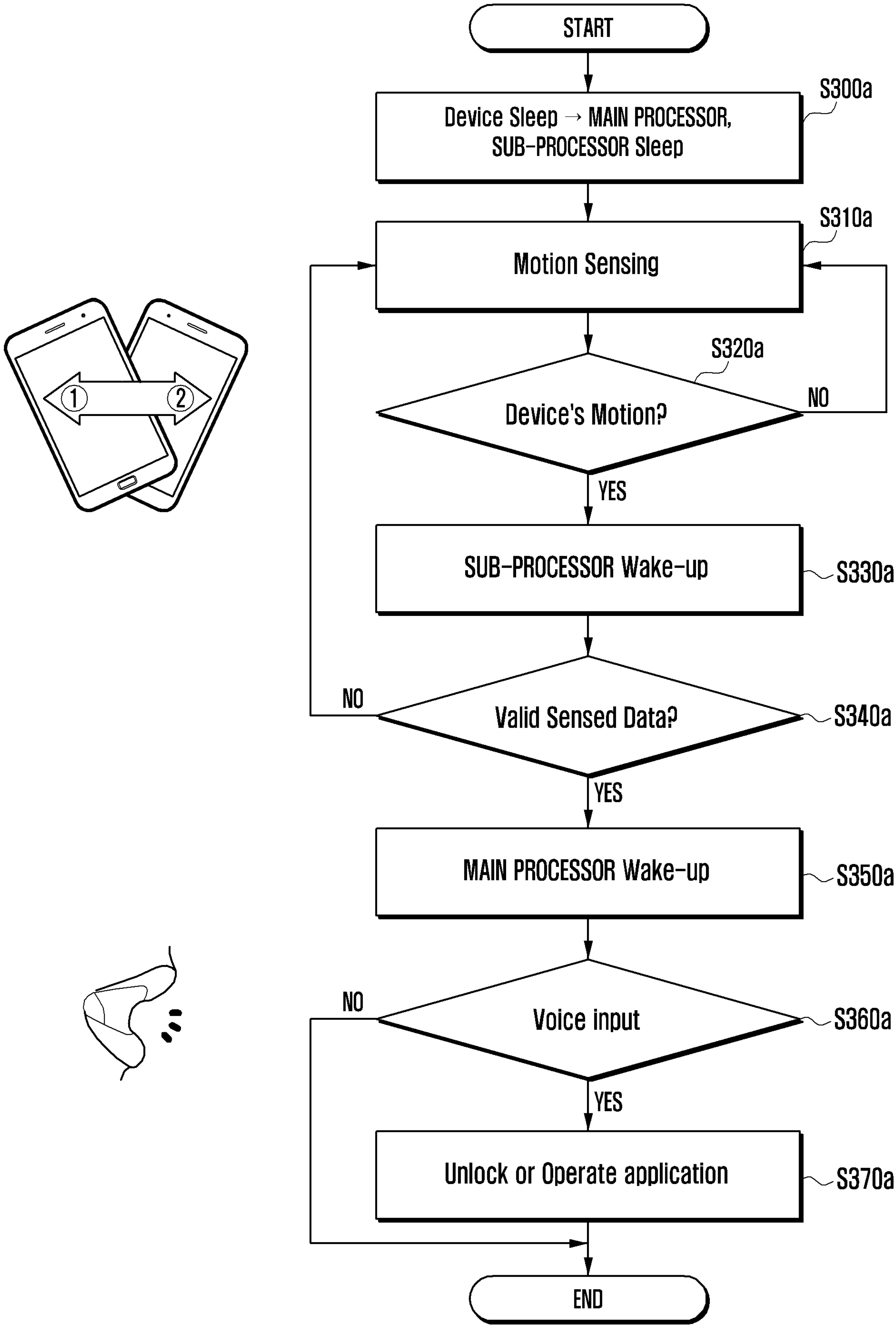
[Fig. 2a]


Device Sleep → MAIN PROCESSOR, SUB-PROCESSOR Sleep
S200a
IR Gesture Sensing
S210a
User gesture proximity?
S220a
NO
YES (Interrupt to Processor2)
SUB-PROCESSOR Wake-up
S230a
Accelerometer Sensing
S240a
Polling
Valid Sensed Data?
S250a
YES
NO
MAIN PROCESSOR Wake-up
S260a
Feedback to USER
S270a

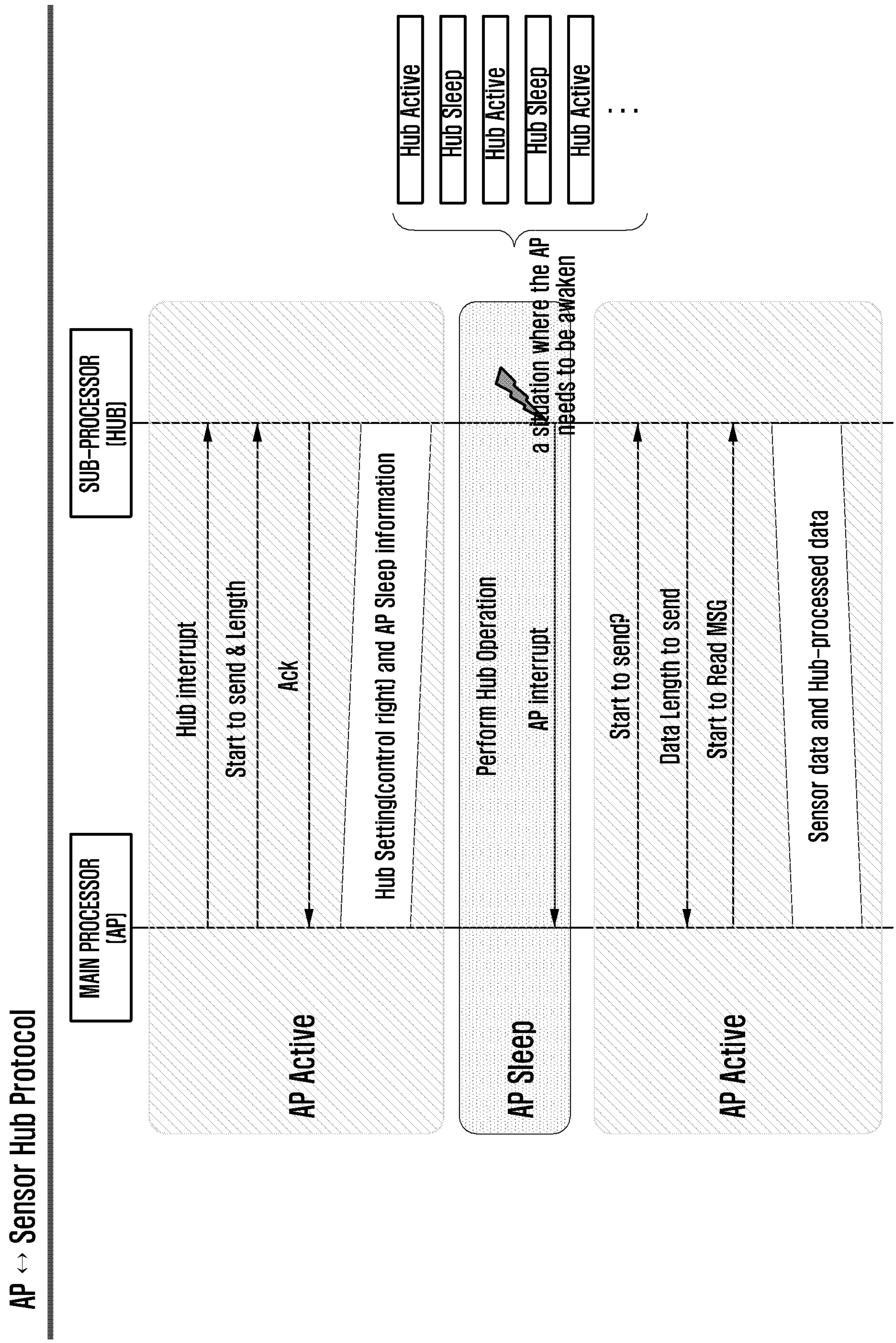
[Fig. 2b]


START
S200b
Device Sleep → MAIN PROCESSOR, SUB-PROCESSOR Sleep
S210b
Microphone/ Audio Sensor Detects Audio Data
S220b
Audio Data Within Valid Range Or Predetermined Threshold?
NO
YES (Interrupt to Processor2)
S230b
SUB-PROCESSOR Wake-up
S240b
Polling Sensor Sensing
Polling
S250b
Audio Data?
NO
YES
S260b
MAIN PROCESSOR Wake-up
S270b
Feedback to USER
END

[Fig. 3a]

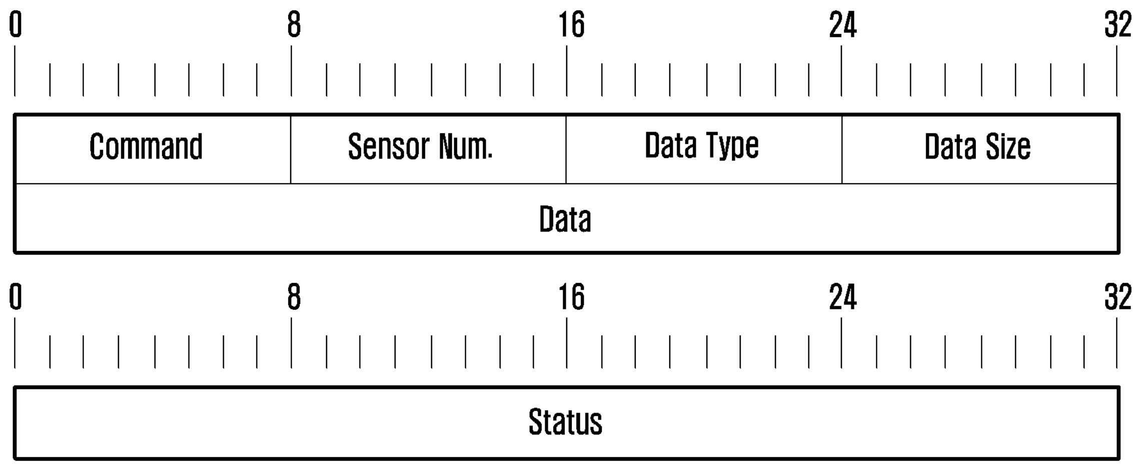

START
Device Sleep → MAIN PROCESSOR, SUB-PROCESSOR Sleep
S300a
Motion Sensing
S310a
Device's Motion?
S320a
NO
YES
SUB-PROCESSOR Wake-up
S330a
Valid Sensed Data?
S340a
NO
YES
MAIN PROCESSOR Wake-up
S350a
Voice input
S360a
NO
YES
Unlock or Operate application
S370a
END
1
2

[Fig. 3b]


AP ↔ Sensor Hub Protocol
MAIN PROCESSOR (AP)
SUB-PROCESSOR (HUB)
AP Active
Hub interrupt
Start to send & Length
Ack
Hub Setting(control right) and AP Sleep information
AP Sleep
Perform Hub Operation
AP interrupt
a situation where the AP needs to be awaken
Hub Active
Hub Sleep
Hub Active
Hub Sleep
Hub Active
...
AP Active
Start to send?
Data Length to send
Start to Read MSG
Sensor data and Hub-processed data

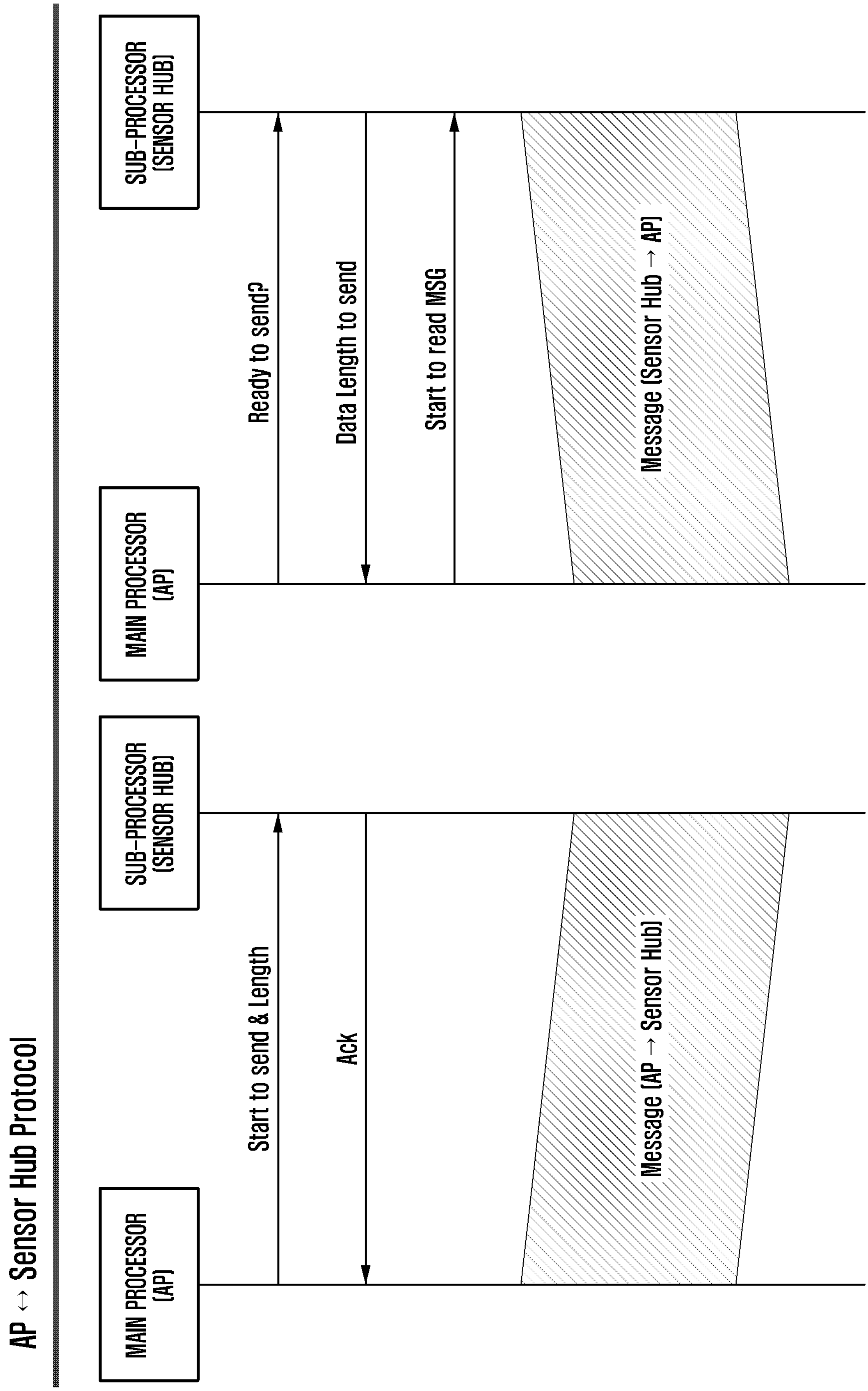
[Fig. 3c]

AP ↔ Sensor Hub Protocol – Message Frame

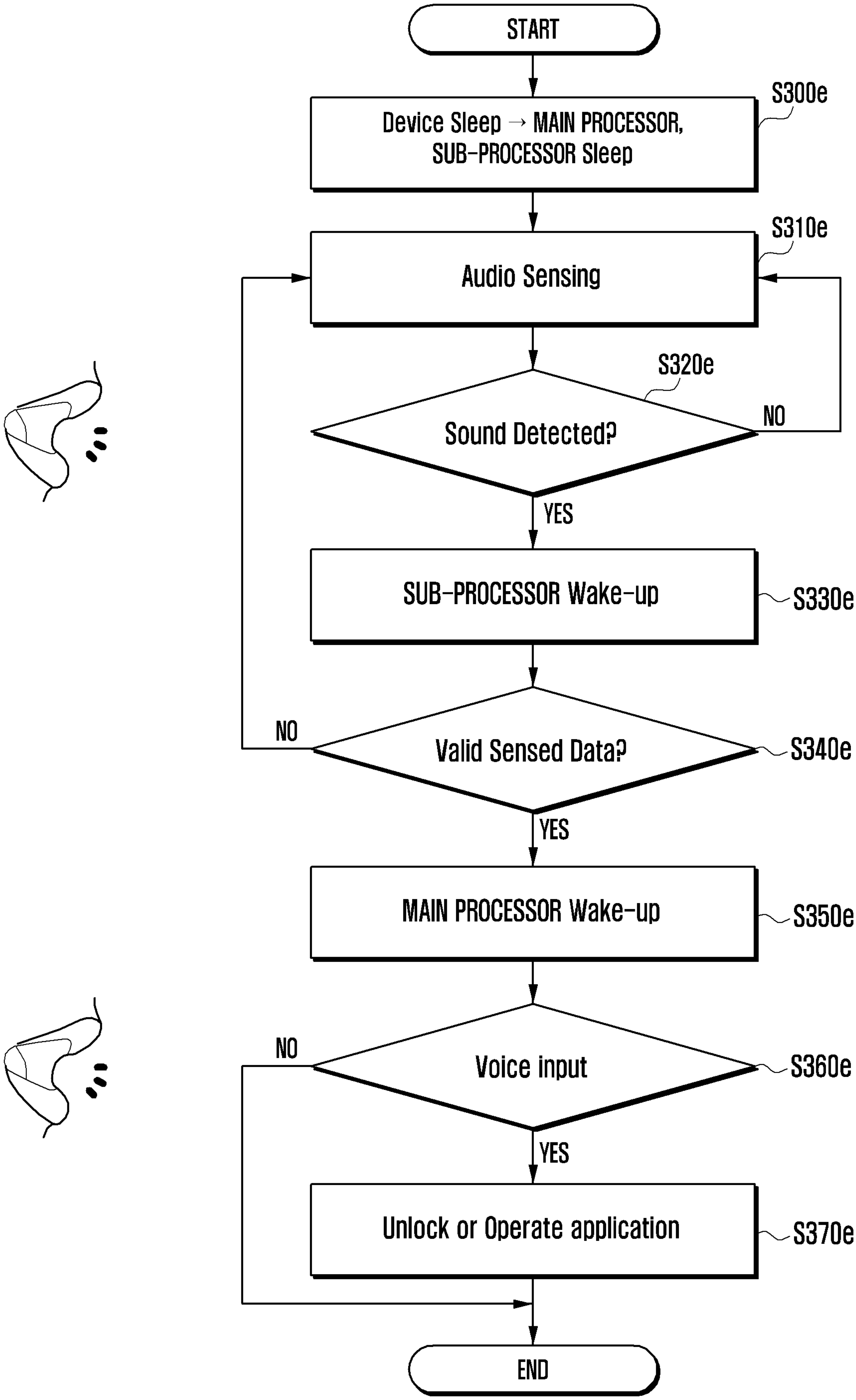


Field	Size	Description
Command	1byte	operation commanded by the AP to the Hub
Sensor Num.	1byte	sensor number field specifying a particular sensor
Data Type	1byte	shows the content of the operand being transmitted
Data Size	1byte	size of the actual data that follows
Data	4byte	the actual operand
Status	4byte	current status information of AP/Hub

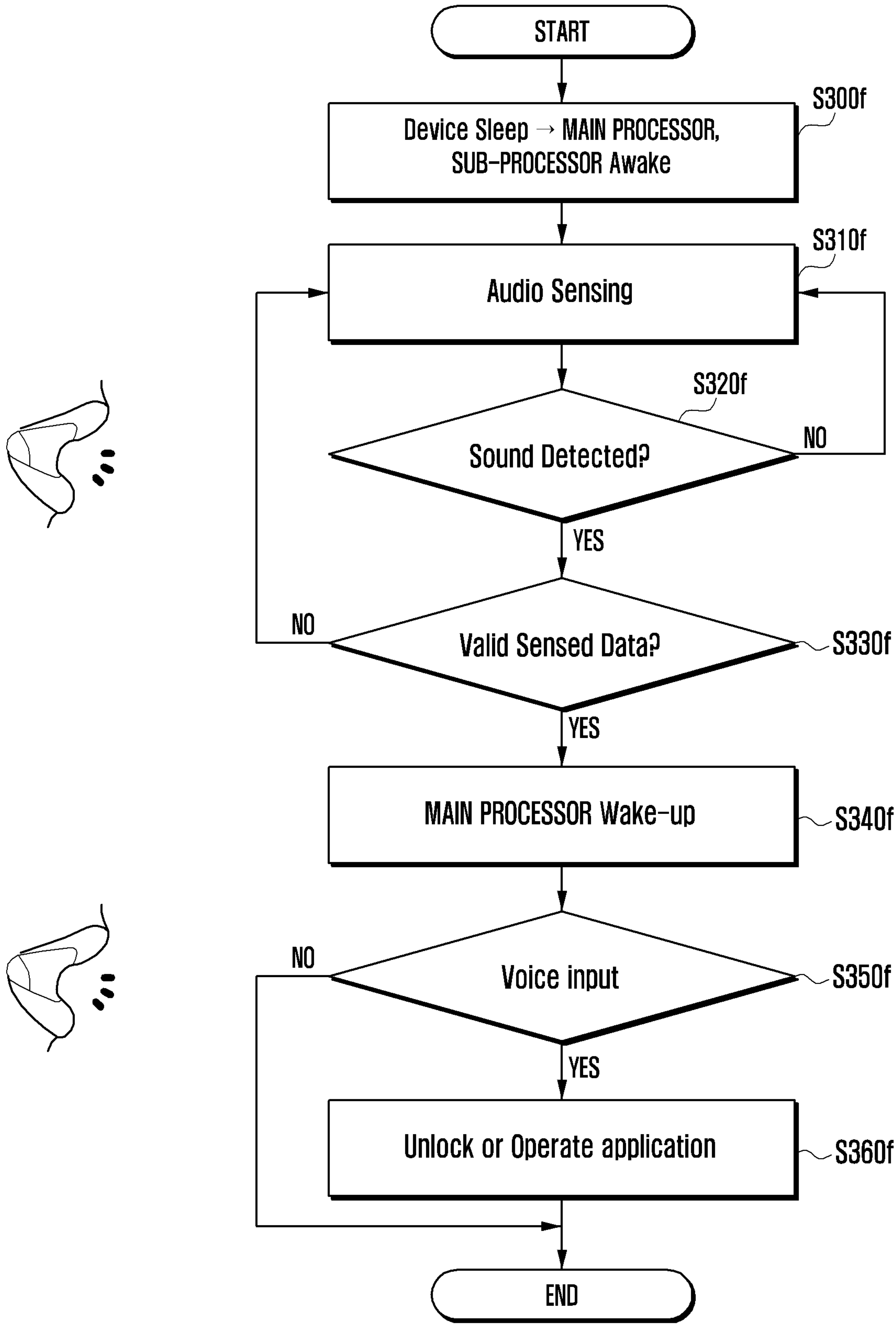
[Fig. 3d]


AP ↔ Sensor Hub Protocol
MAIN PROCESSOR (AP)
SUB-PROCESSOR (SENSOR HUB)
Start to send & Length
Ack
Message (AP → Sensor Hub)
MAIN PROCESSOR (AP)
SUB-PROCESSOR (SENSOR HUB)
Ready to send?
Data Length to send
Start to read MSG
Message (Sensor Hub → AP)

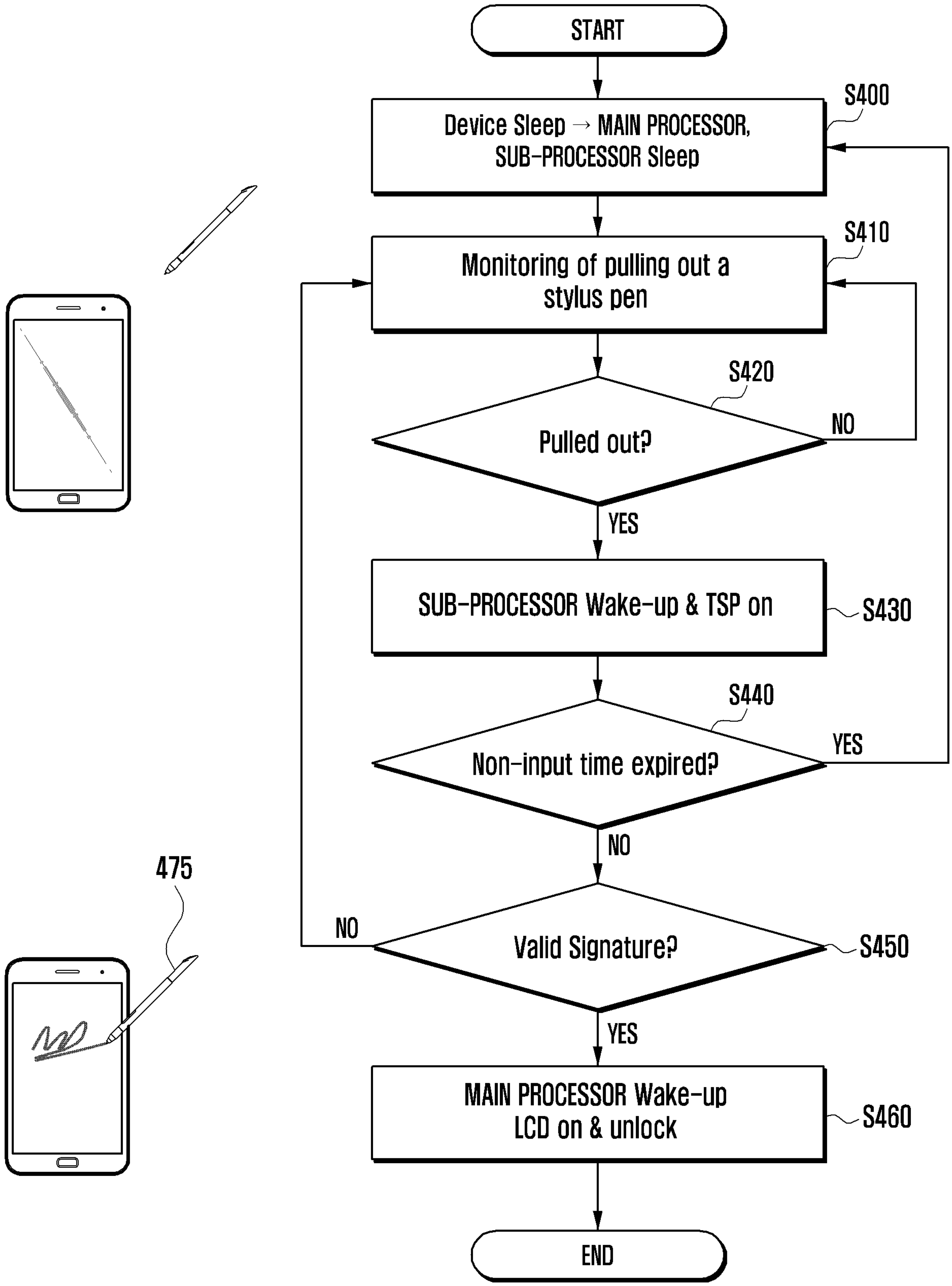
[Fig. 3e]


START
Device Sleep → MAIN PROCESSOR, SUB-PROCESSOR Sleep
S300e
Audio Sensing
S310e
Sound Detected?
S320e
NO
YES
SUB-PROCESSOR Wake-up
S330e
Valid Sensed Data?
S340e
NO
YES
MAIN PROCESSOR Wake-up
S350e
Voice input
S360e
NO
YES
Unlock or Operate application
S370e
END

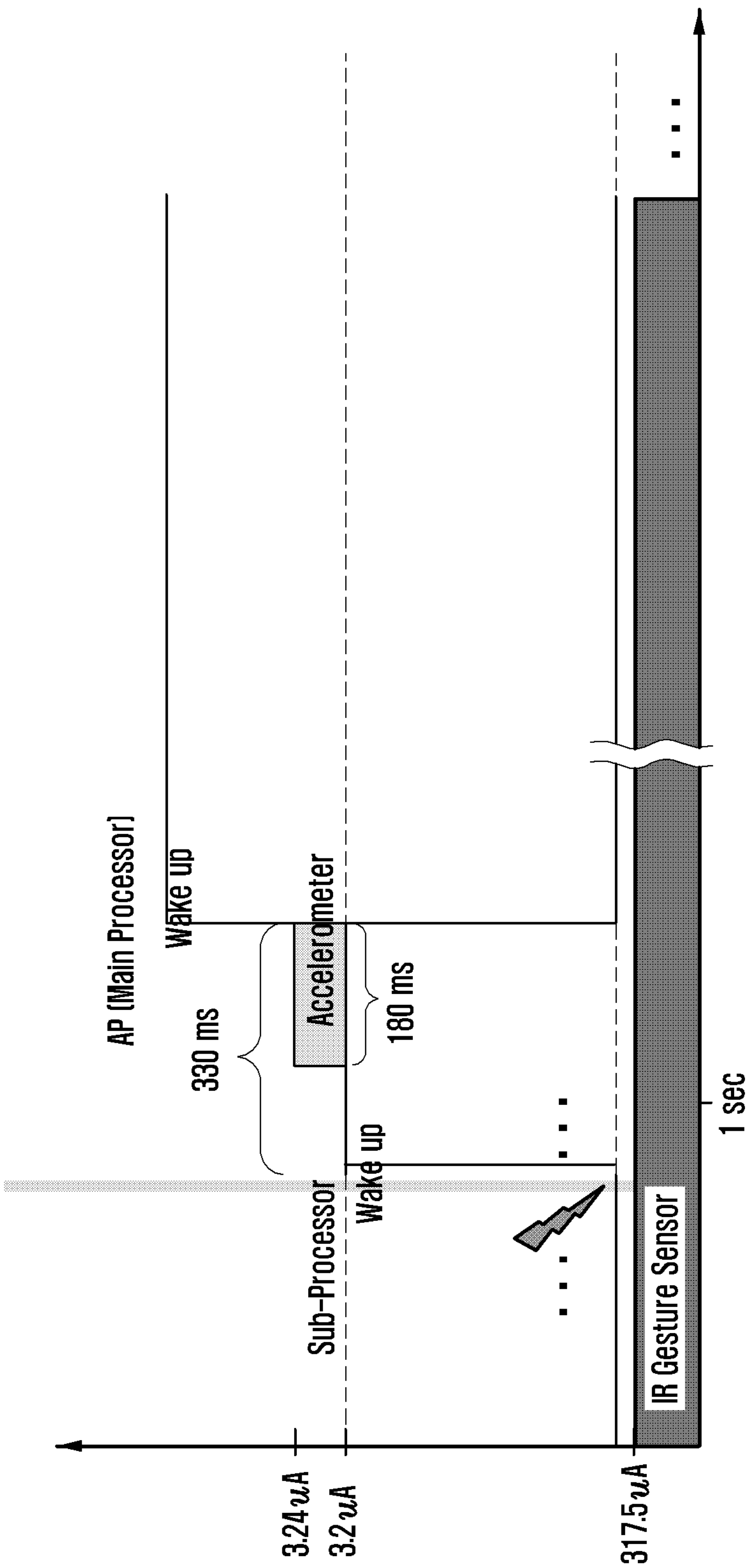
[Fig. 3f]


START
Device Sleep → MAIN PROCESSOR, SUB-PROCESSOR Awake
S300f
Audio Sensing
S310f
Sound Detected?
S320f
NO
YES
Valid Sensed Data?
S330f
NO
YES
MAIN PROCESSOR Wake-up
S340f
Voice input
S350f
NO
YES
Unlock or Operate application
S360f
END

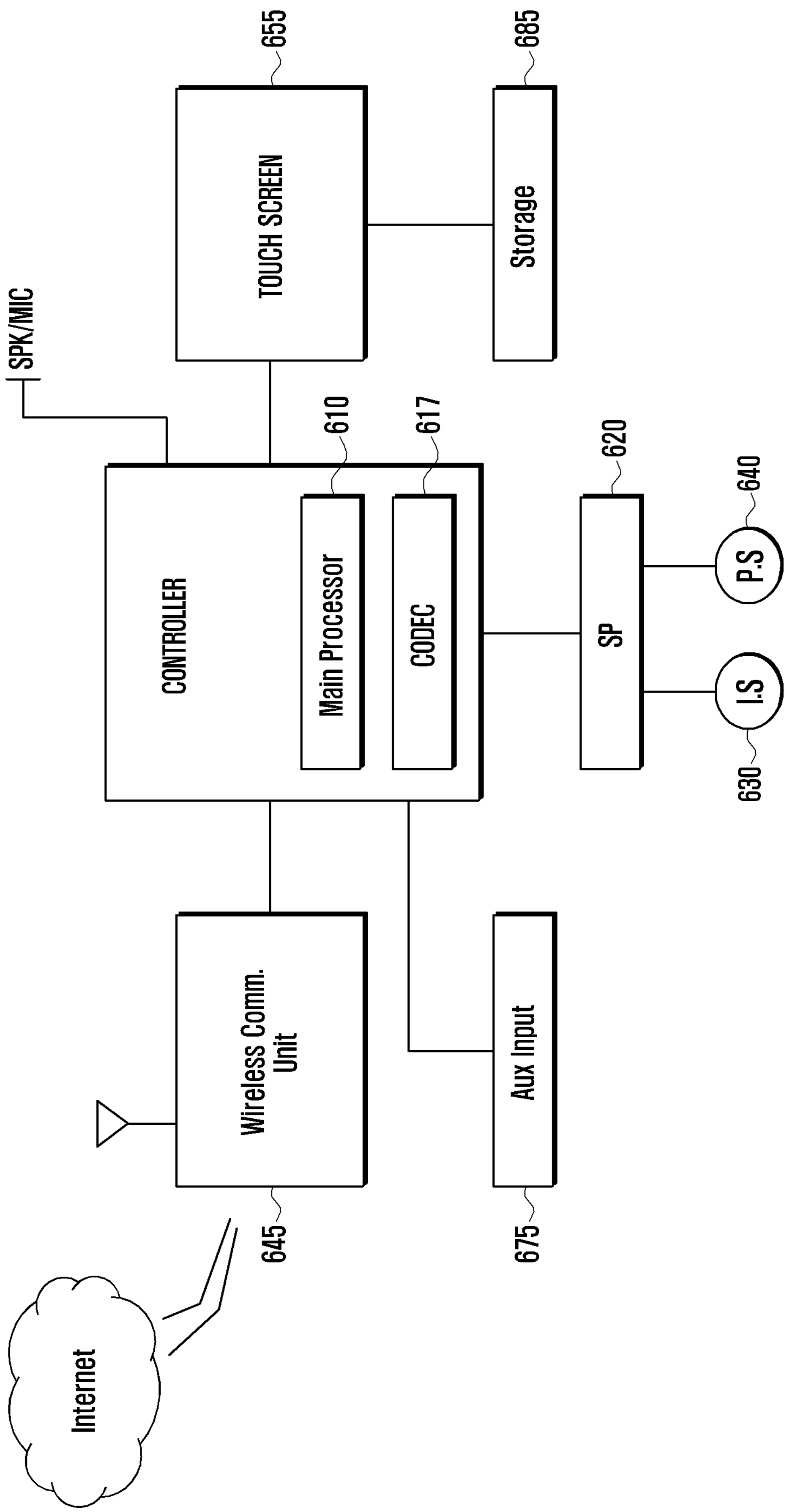
[Fig. 4]


START
Device Sleep → MAIN PROCESSOR, SUB-PROCESSOR Sleep
S400
Monitoring of pulling out a stylus pen
S410
Pulled out?
S420
NO
YES
SUB-PROCESSOR Wake-up & TSP on
S430
Non-input time expired?
S440
YES
NO
Valid Signature?
S450
NO
YES
MAIN PROCESSOR Wake-up LCD on & unlock
S460
END
475

[Fig. 5]


AP (Main Processor)
Wake up
Accelerometer
330 ms
180 ms
Sub-Processor
Wake up
1 sec
IR Gesture Sensor
3.24uA
3.2uA
317.5uA

[Fig. 6]


655
TOUCH SCREEN
685
Storage
SPK/MIC
610
617
CONTROLLER
Main Processor
CODEC
620
SP
640
P.S
I.S
630
Wireless Comm.
Unit
Aux Input
645
675
Internet