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(54) **ACCELEROMETER-BASED CONTROL OF WEARABLE DEVICES**

(75) Inventors: **King-Wah Walter Yeung**, Davis, CA (US); **Wei-Wei Vivian Yeung**, Davis, CA (US)

Correspondence Address:
Enbiomedic
P.O. Box 407
Davis, CA 95617-0407 (US)

(73) Assignee: **ENBIOMEDIC**, Davis, CA (US)

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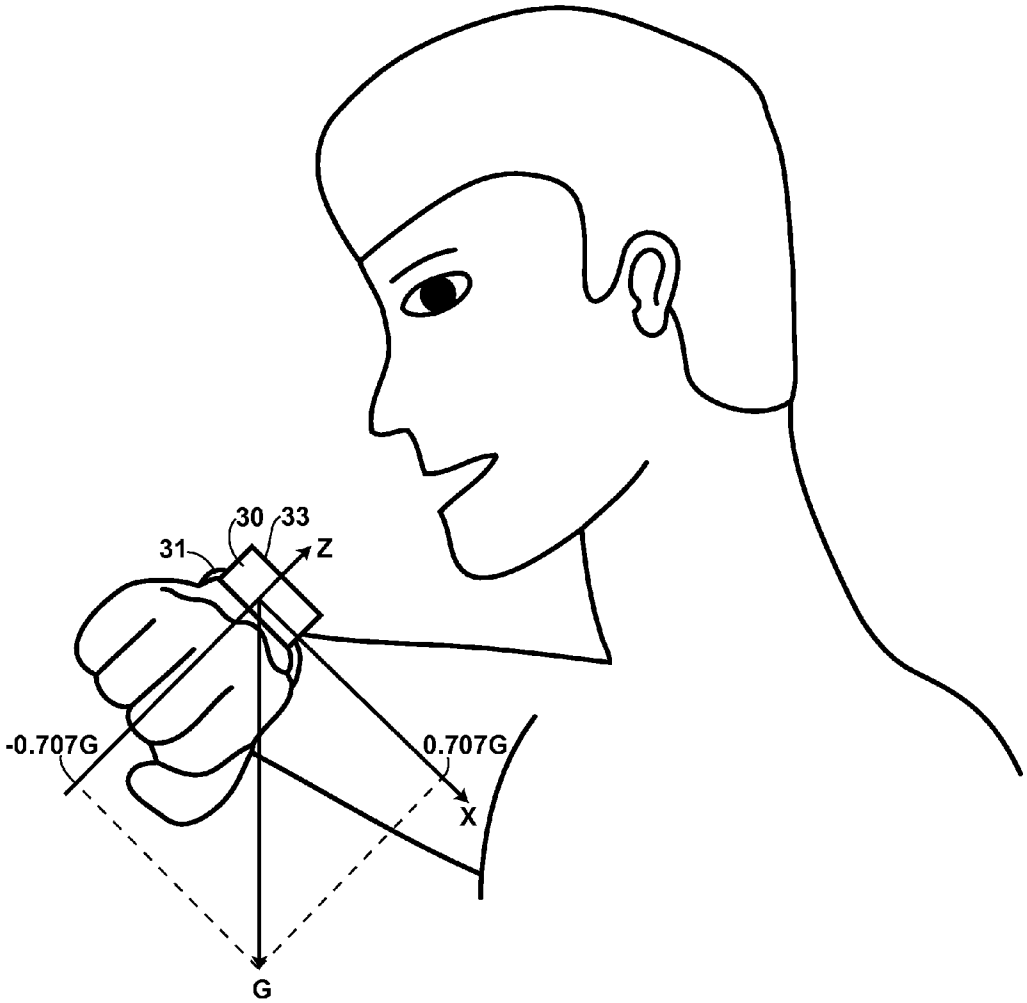
(57) **ABSTRACT**

Accelerometer-based orientation and/or movement detection for controlling wearable devices, such as wrist-worn audio recorders and wristwatches. A wrist-worn audio recorder can use an accelerometer to detect the orientation and/or movement of a user's wrist and subsequently activate a corresponding audio-recorder function, for instance recording or playback. A wearable device with a vibration mechanism can use this method to remind a user of an undesirable movement such as restless leg movement. Likewise, a talking wristwatch can use this method to activate audio reporting of time when a user moves or orients his or her wrist in close proximity to his or her ear. In such applications, and many others, accelerometer-based control of the wearable device offers significant advantages over conventional means of control, particularly in terms of ease of use and durability.



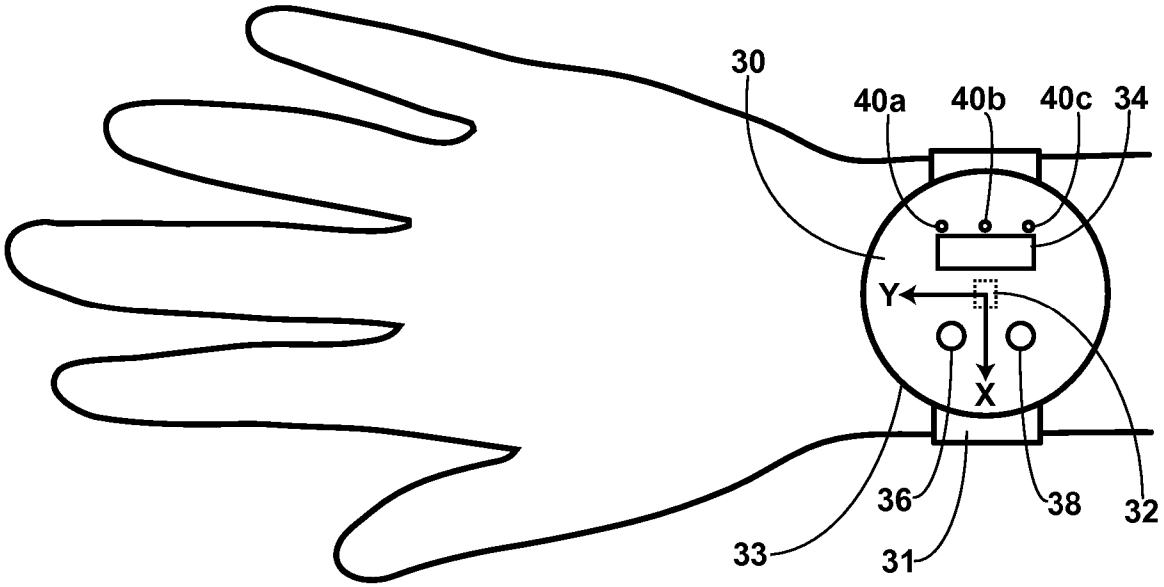


FIG. 1

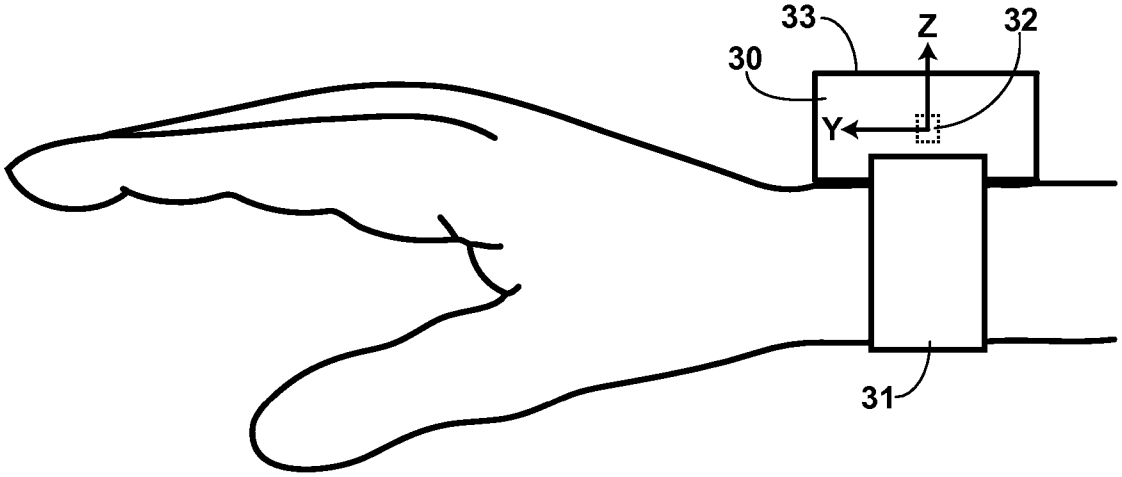


FIG. 2

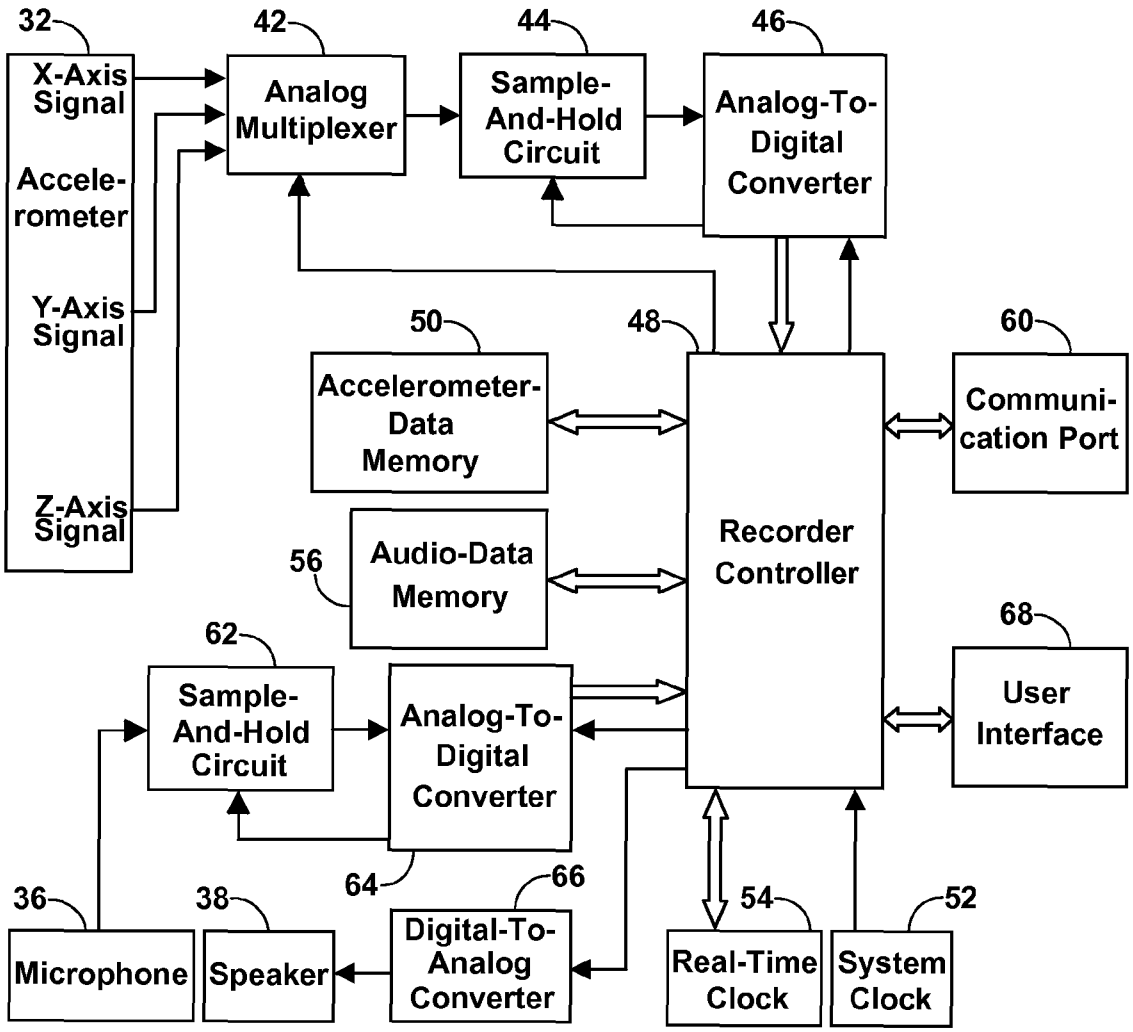

32
X-Axis Signal
Accele-rometer
Y-Axis Signal
Z-Axis Signal
42
Analog Multiplexer
44
Sample-And-Hold Circuit
46
Analog-To-Digital Converter
50
Accelerometer-Data Memory
48
Recorder Controller
60
Communi-cation Port
56
Audio-Data Memory
62
Sample-And-Hold Circuit
Analog-To-Digital Converter
64
68
User Interface
36
Microphone
38
Speaker
66
Digital-To-Analog Converter
54
Real-Time Clock
52
System Clock

FIG. 3

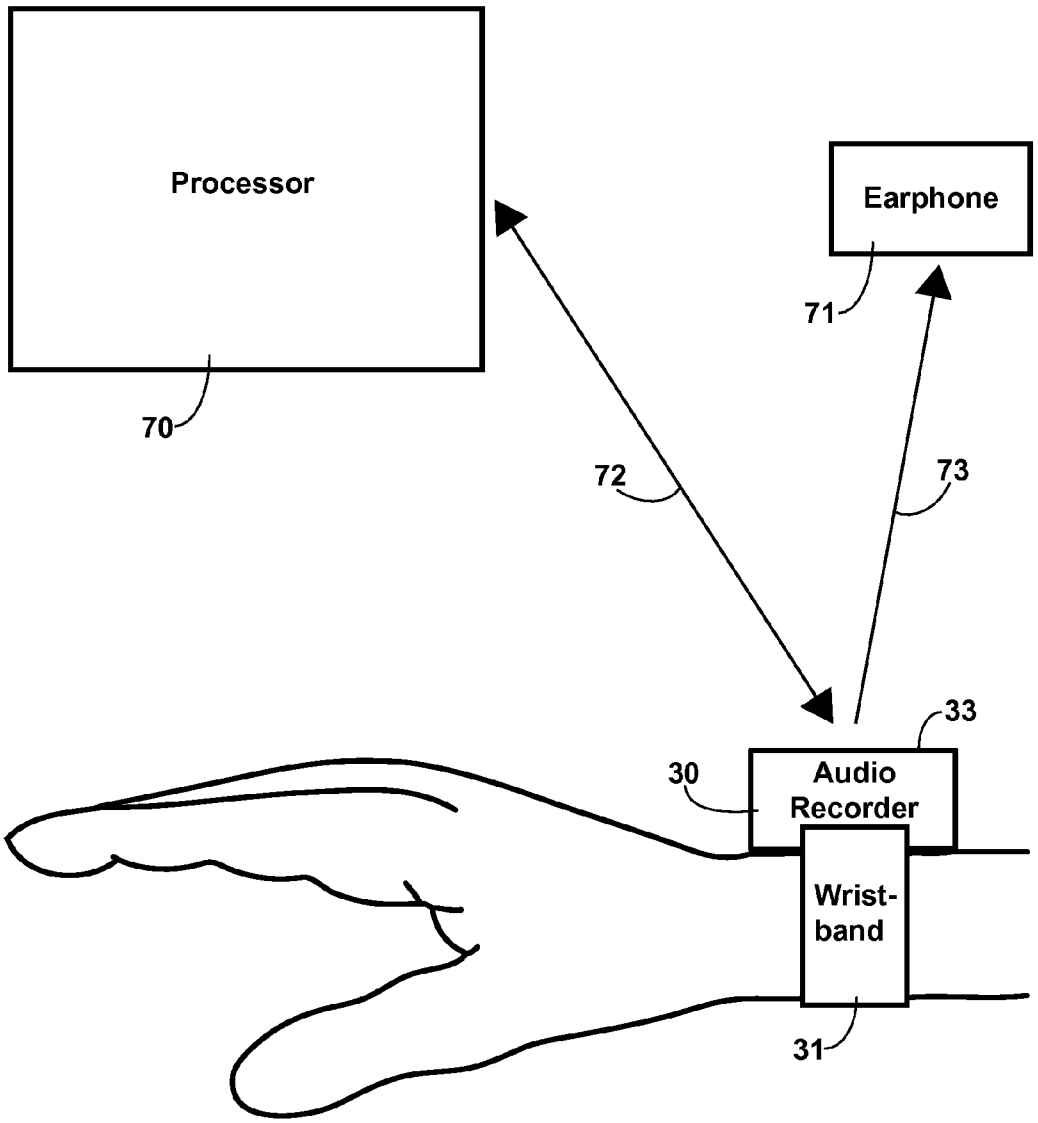

Processor
70
Earphone
71
72
73
33
30
Audio
Recorder
Wrist-
band
31

FIG. 4

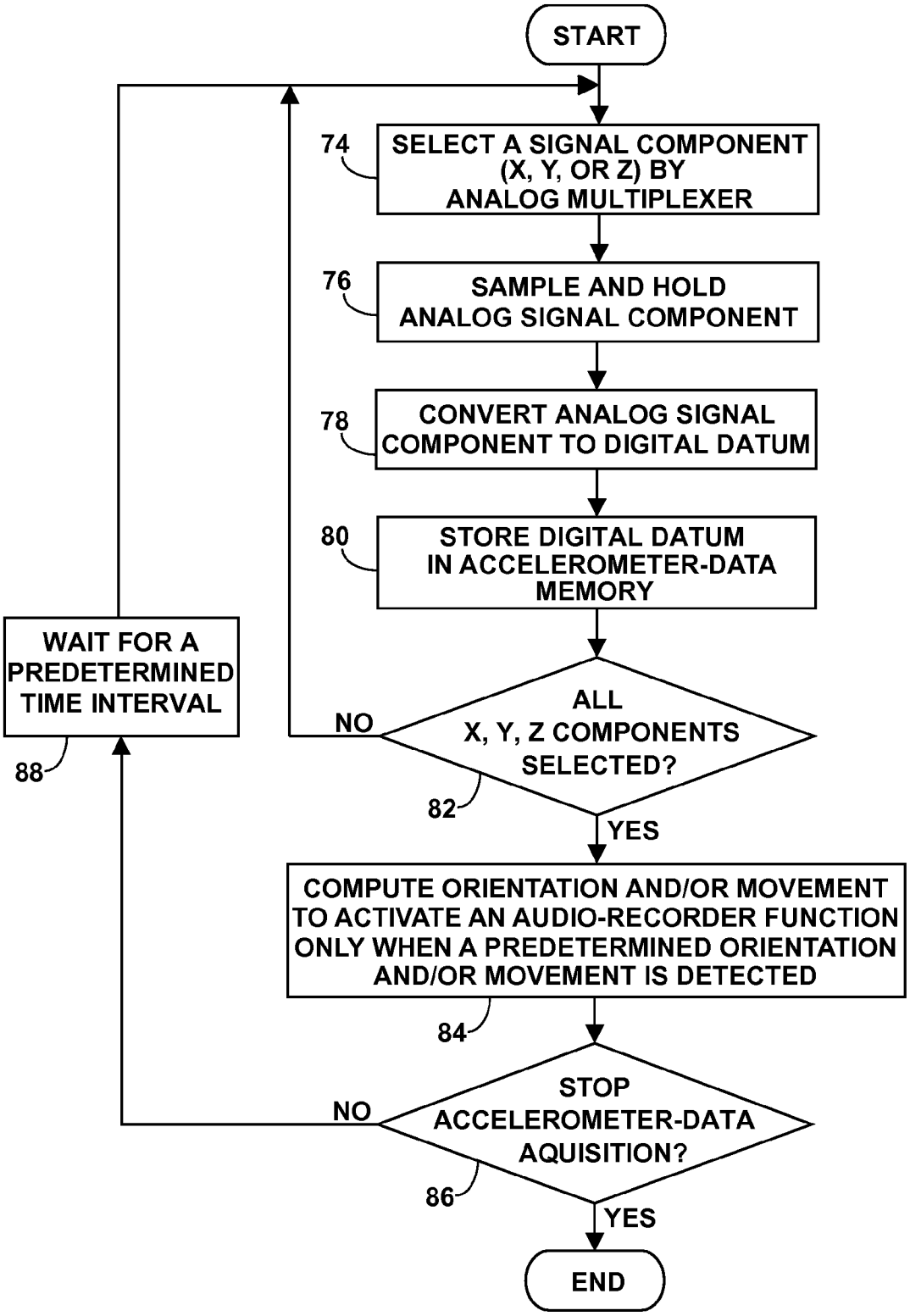

START
74
SELECT A SIGNAL COMPONENT (X, Y, OR Z) BY ANALOG MULTIPLEXER
76
SAMPLE AND HOLD ANALOG SIGNAL COMPONENT
78
CONVERT ANALOG SIGNAL COMPONENT TO DIGITAL DATUM
80
STORE DIGITAL DATUM IN ACCELEROMETER-DATA MEMORY
WAIT FOR A PREDETERMINED TIME INTERVAL
88
NO
ALL X, Y, Z COMPONENTS SELECTED?
82
YES
COMPUTE ORIENTATION AND/OR MOVEMENT TO ACTIVATE AN AUDIO-RECORDER FUNCTION ONLY WHEN A PREDETERMINED ORIENTATION AND/OR MOVEMENT IS DETECTED
84
NO
STOP ACCELEROMETER-DATA AQUISITION?
86
YES
END

FIG. 5

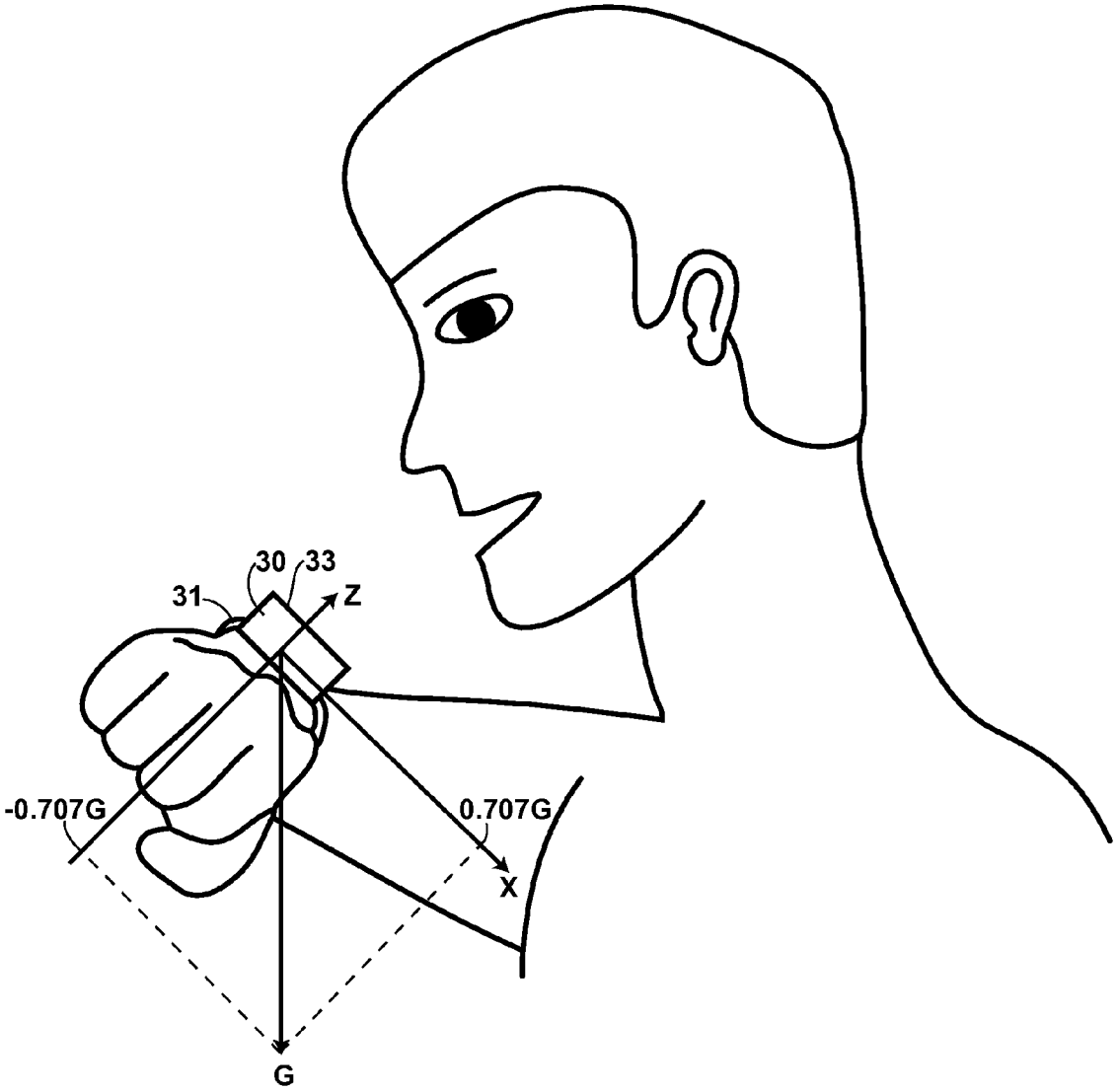


FIG. 6

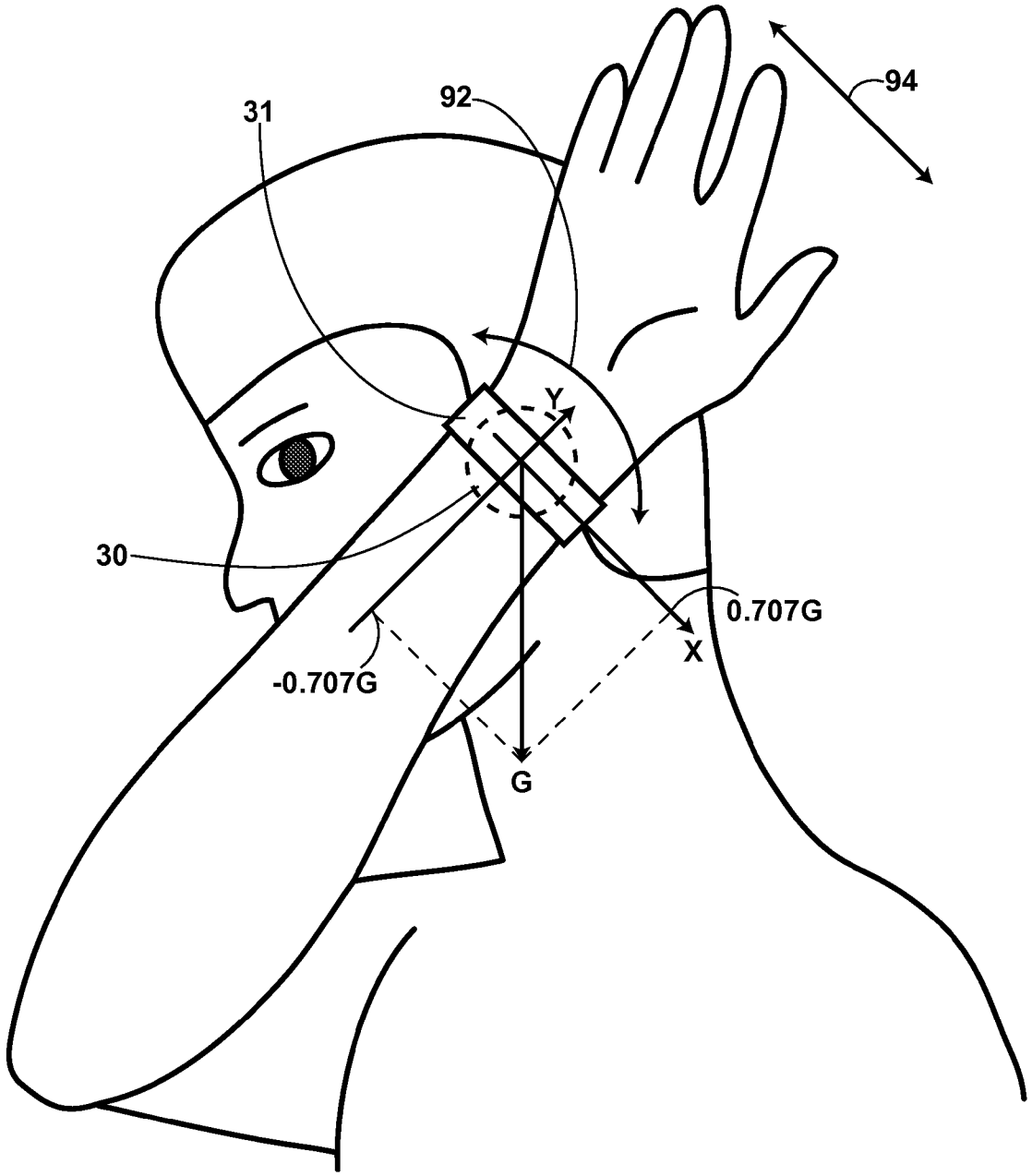


FIG. 7

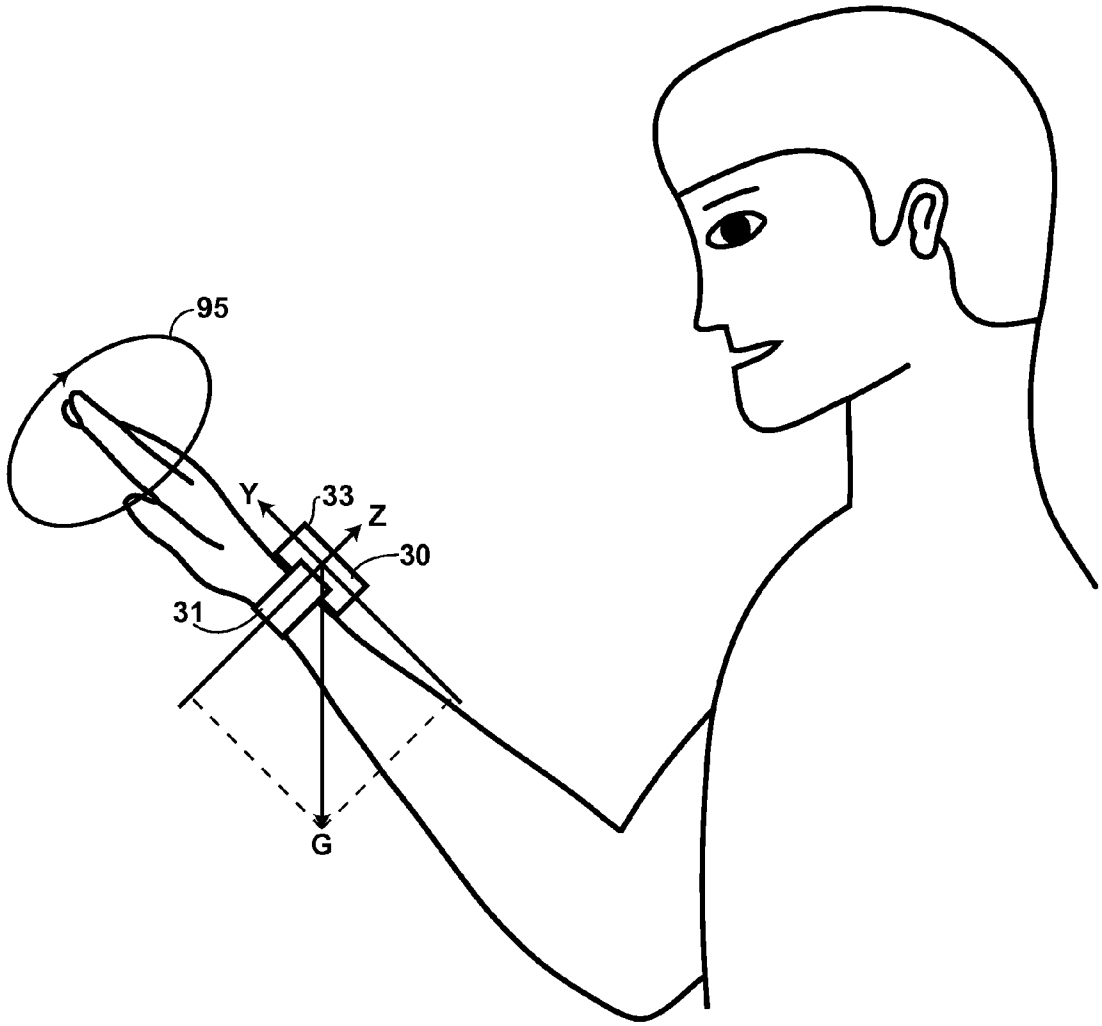


FIG. 8

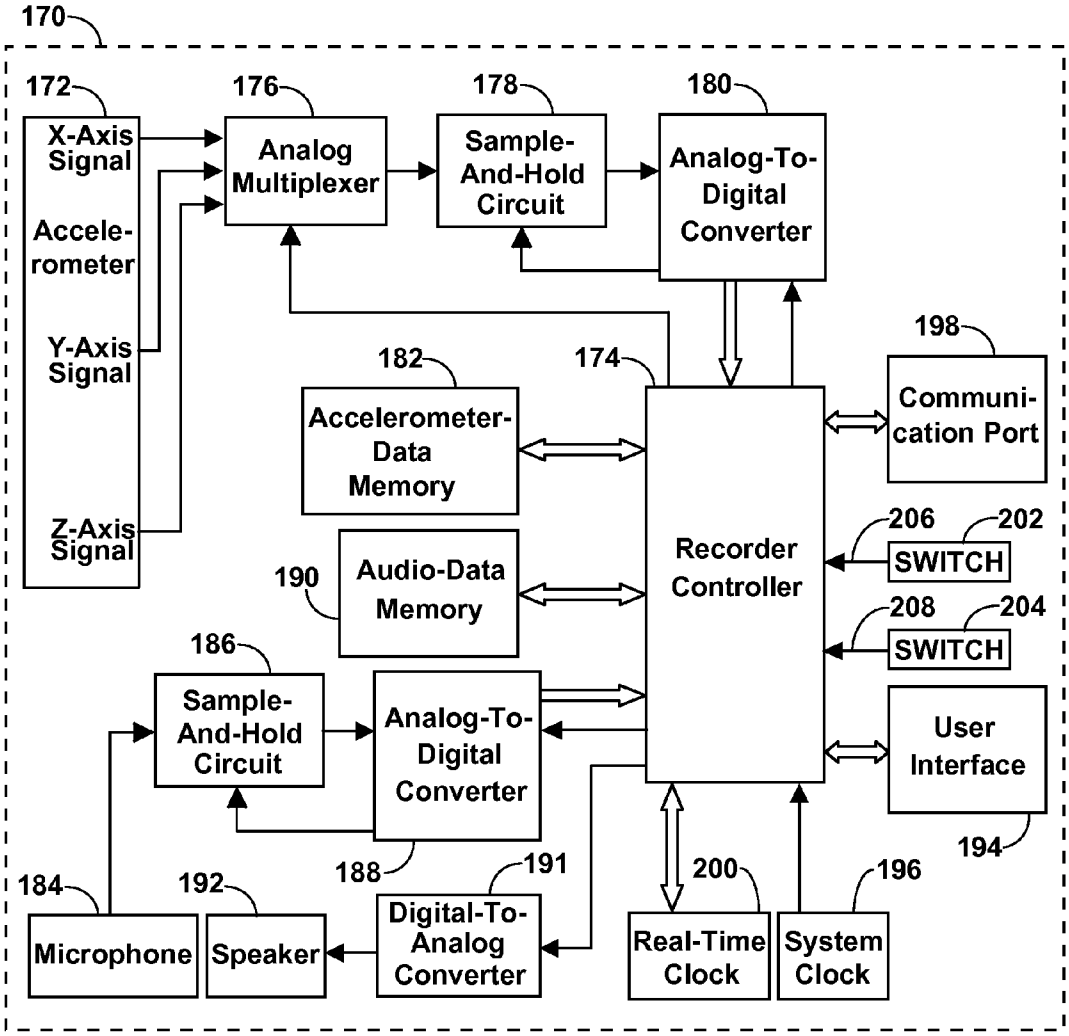

170
172
X-Axis Signal
Accele-rometer
Y-Axis Signal
Z-Axis Signal
176
Analog Multiplexer
178
Sample-And-Hold Circuit
180
Analog-To-Digital Converter
182
Accelerometer-Data Memory
174
Recorder Controller
198
Communi-cation Port
206
202
SWITCH
190
Audio-Data Memory
208
204
SWITCH
186
Sample-And-Hold Circuit
Analog-To-Digital Converter
User Interface
194
188
191
184
192
200
196
Microphone
Speaker
Digital-To-Analog Converter
Real-Time Clock
System Clock

FIG. 9

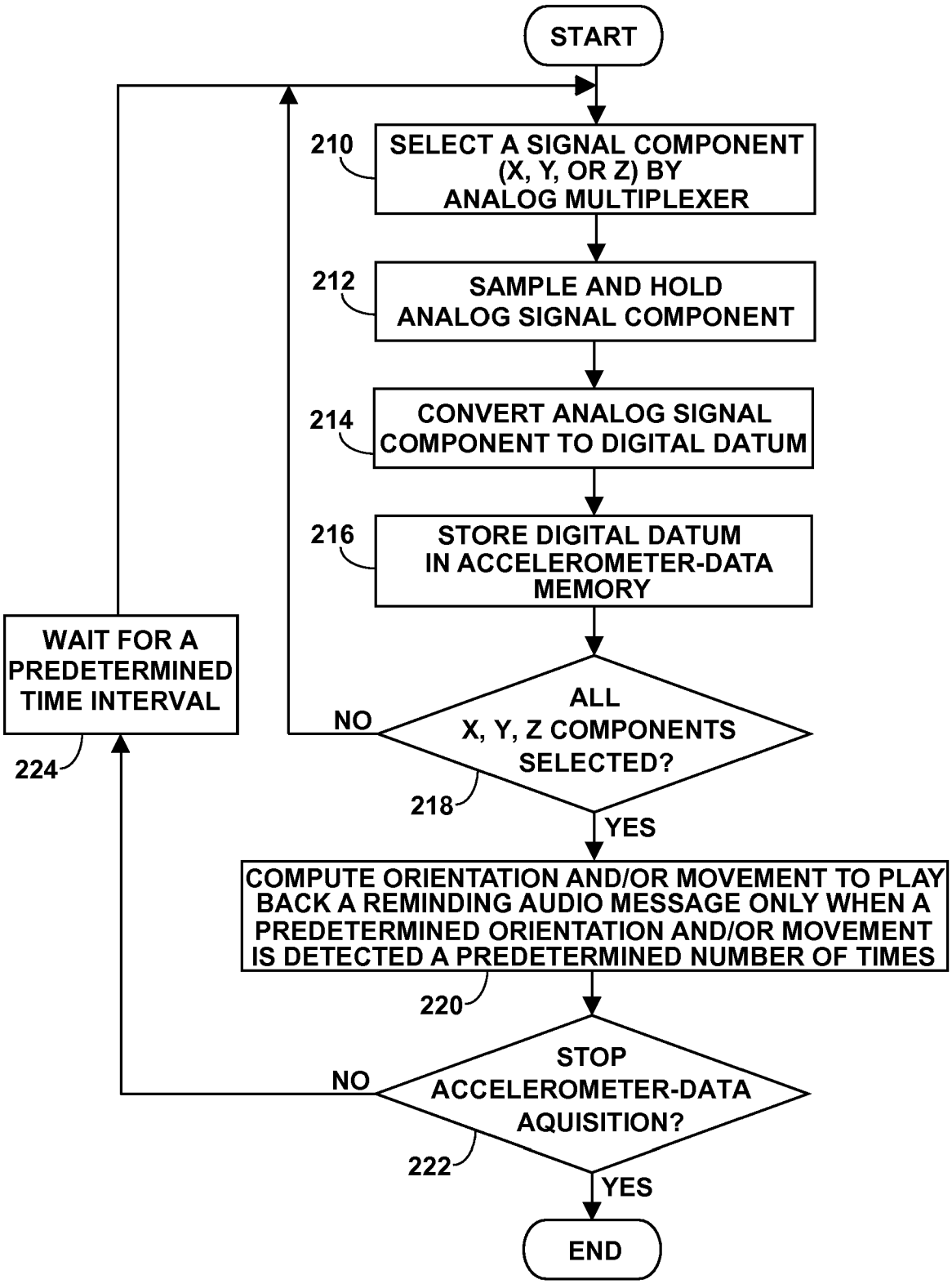

START
210
SELECT A SIGNAL COMPONENT (X, Y, OR Z) BY ANALOG MULTIPLEXER
212
SAMPLE AND HOLD ANALOG SIGNAL COMPONENT
214
CONVERT ANALOG SIGNAL COMPONENT TO DIGITAL DATUM
216
STORE DIGITAL DATUM IN ACCELEROMETER-DATA MEMORY
ALL X, Y, Z COMPONENTS SELECTED?
NO
YES
218
WAIT FOR A PREDETERMINED TIME INTERVAL
224
COMPUTE ORIENTATION AND/OR MOVEMENT TO PLAY BACK A REMINDING AUDIO MESSAGE ONLY WHEN A PREDETERMINED ORIENTATION AND/OR MOVEMENT IS DETECTED A PREDETERMINED NUMBER OF TIMES
220
STOP ACCELEROMETER-DATA AQUISITION?
NO
YES
222
END

FIG. 10

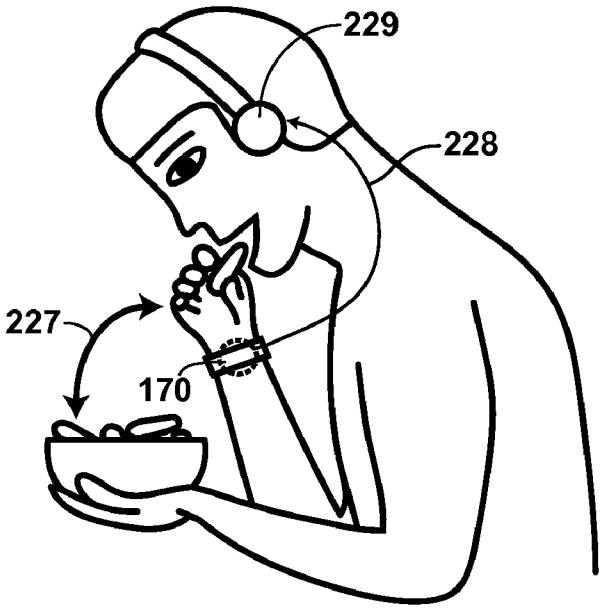


FIG. 11

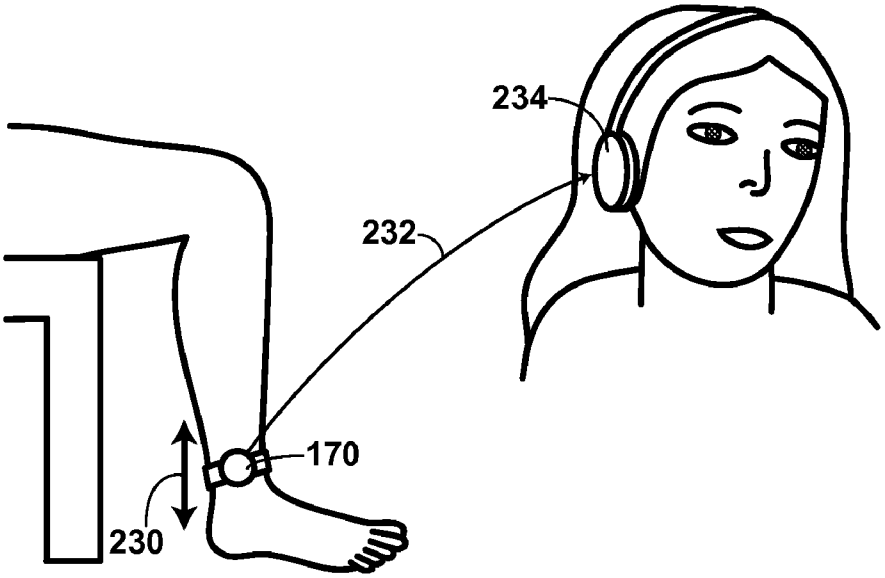


FIG. 12

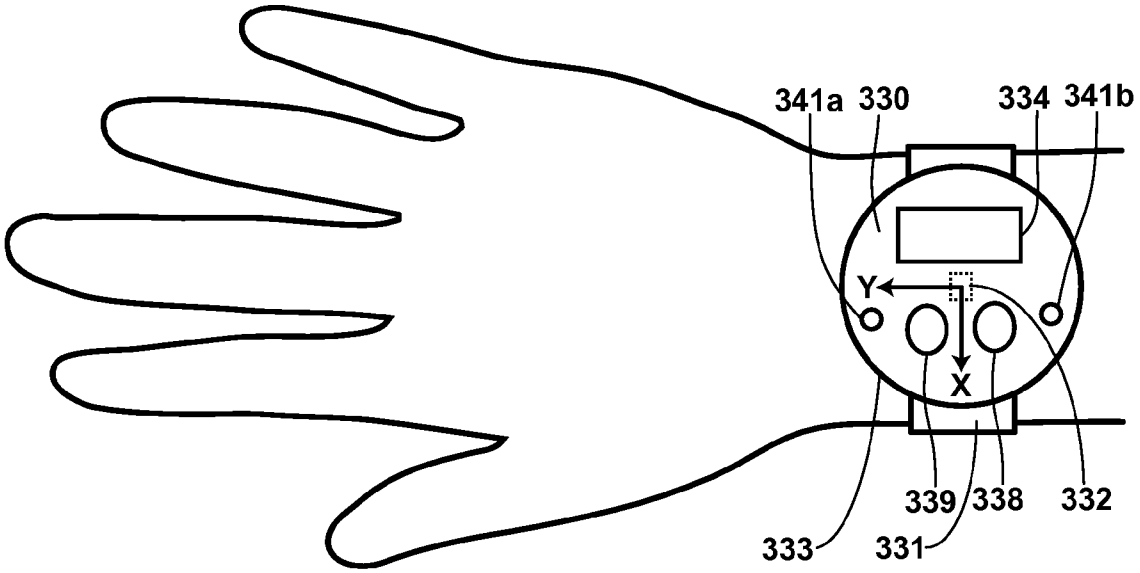


FIG. 13

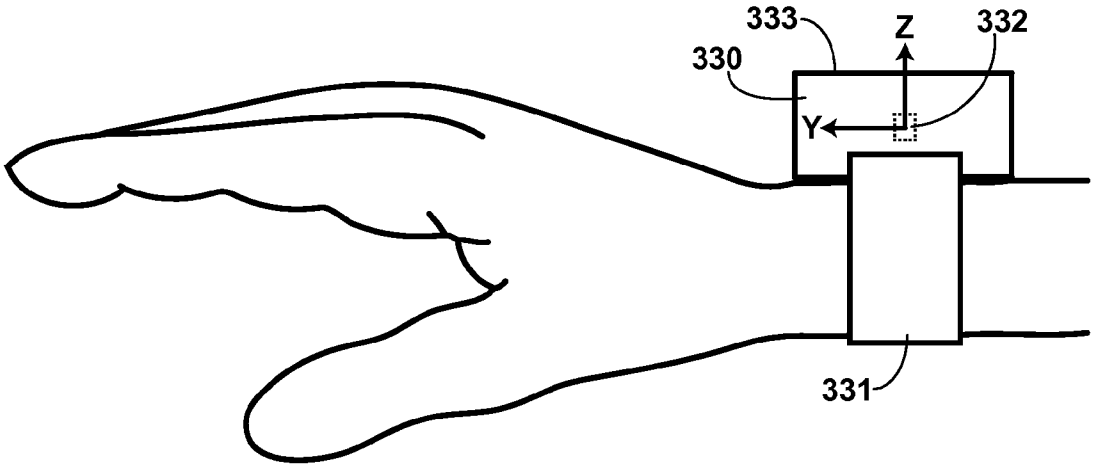


FIG. 14

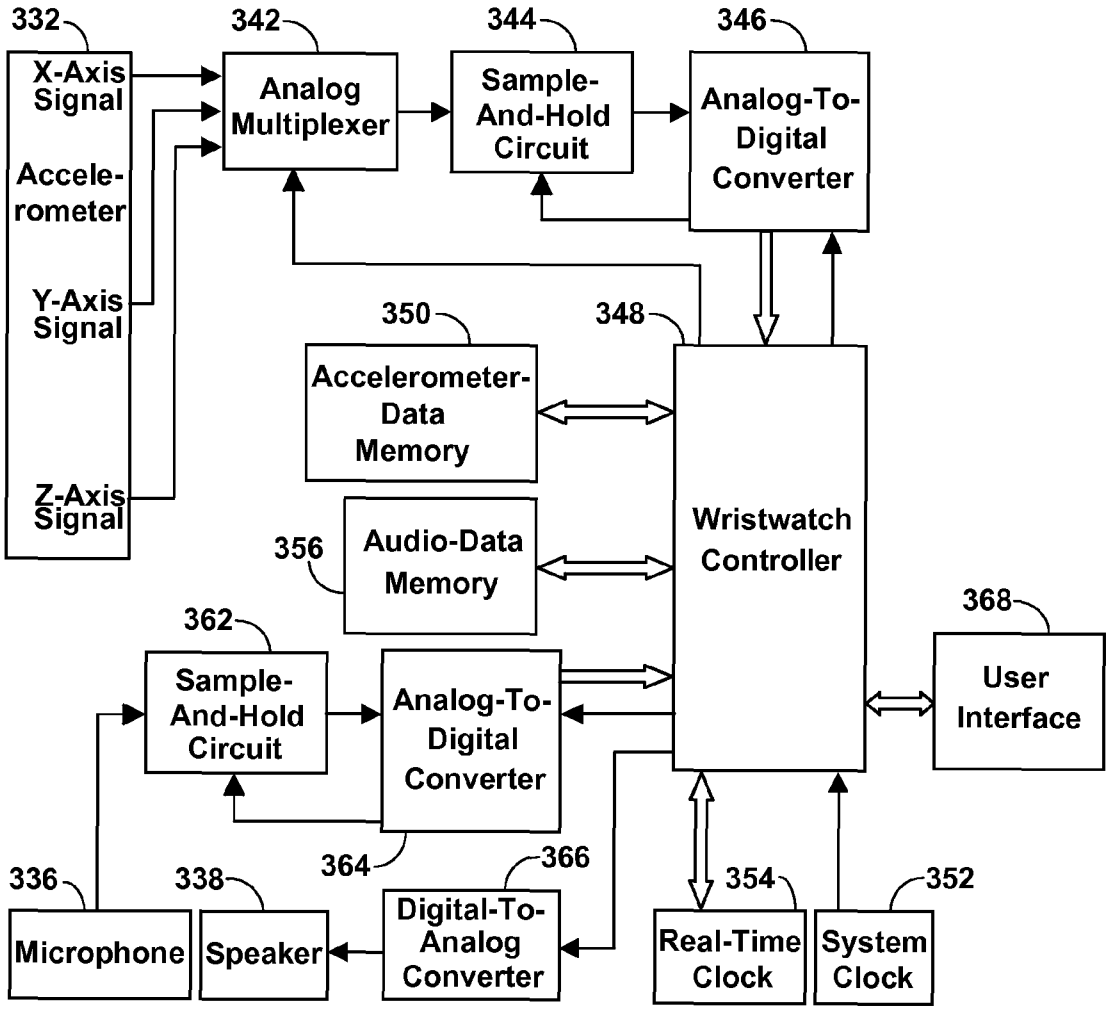

332
X-Axis Signal
Accele-rometer
Y-Axis Signal
Z-Axis Signal
342
Analog Multiplexer
344
Sample-And-Hold Circuit
346
Analog-To-Digital Converter
350
Accelerometer-Data Memory
348
Wristwatch Controller
356
Audio-Data Memory
362
Sample-And-Hold Circuit
Analog-To-Digital Converter
364
368
User Interface
336
Microphone
338
Speaker
366
Digital-To-Analog Converter
354
Real-Time Clock
352
System Clock

FIG. 15

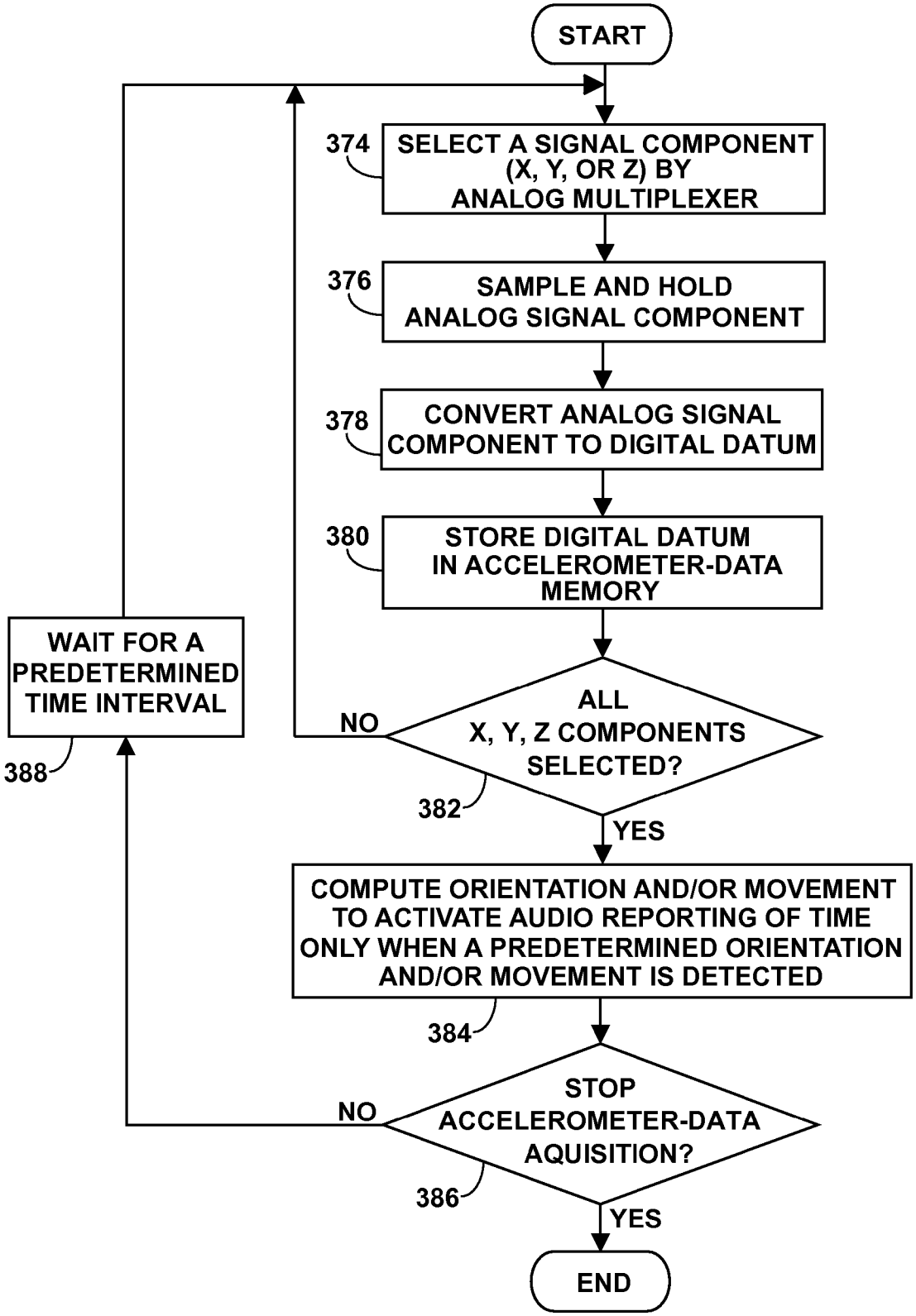

START
374
SELECT A SIGNAL COMPONENT (X, Y, OR Z) BY ANALOG MULTIPLEXER
376
SAMPLE AND HOLD ANALOG SIGNAL COMPONENT
378
CONVERT ANALOG SIGNAL COMPONENT TO DIGITAL DATUM
380
STORE DIGITAL DATUM IN ACCELEROMETER-DATA MEMORY
WAIT FOR A PREDETERMINED TIME INTERVAL
388
NO
ALL X, Y, Z COMPONENTS SELECTED?
382
YES
COMPUTE ORIENTATION AND/OR MOVEMENT TO ACTIVATE AUDIO REPORTING OF TIME ONLY WHEN A PREDETERMINED ORIENTATION AND/OR MOVEMENT IS DETECTED
384
NO
STOP ACCELEROMETER-DATA AQUISITION?
386
YES
END

FIG. 16

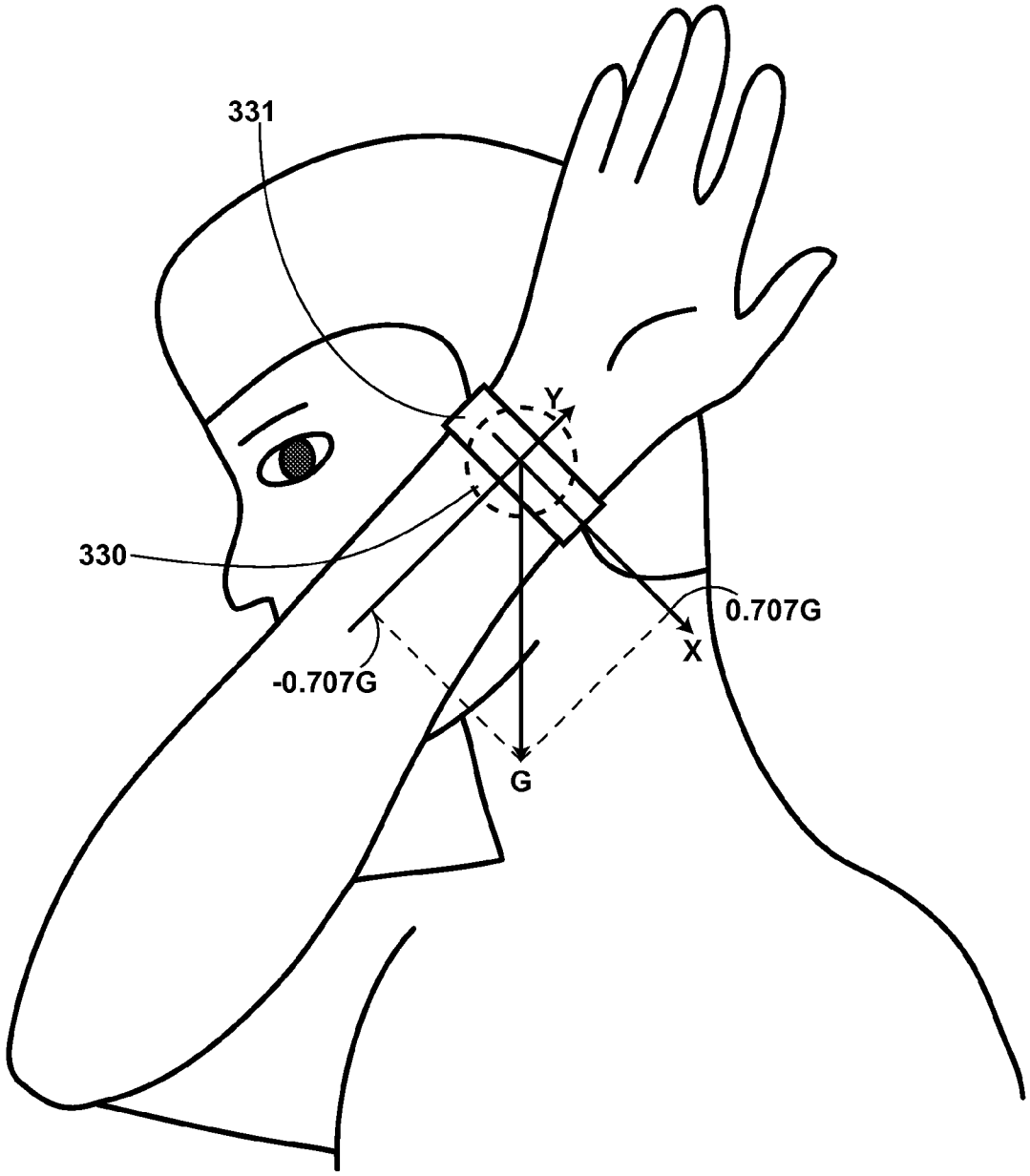


FIG. 17

ACCELEROMETER-BASED CONTROL OF WEARABLE DEVICES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of provisional application Ser. No. 61/008,504, filed Dec. 19, 2007 by the present inventors.

FEDERALLY SPONSORED RESEARCH

[0002] Not Applicable

SEQUENCE LISTING OR PROGRAM

[0003] Not Applicable

BACKGROUND

[0004] 1. Field

[0005] This application relates to using accelerometer-based orientation and/or movement sensing to control wearable devices, such as wrist-worn audio recorders and wristwatches.

[0006] 2. Prior Art

[0007] Wrist-worn audio recorders can serve a wide range of uses, from recording memos and meetings for professionals to documenting dietary intake and physical activity for health-conscious individuals and chronicling a child's first words and actions for parents. Furthermore, recorded audio messages can be played back at preset times to remind or alert a user, as disclosed in U.S. Pat. No. 5,511,046 to Vanderpal (1996).

[0008] These wrist-worn audio recorders, wristwatches, and related devices are generally controlled through one or more of the following means: electromechanical switches, voice activation, and motion activation.

[0009] Switches are commonly used to control functions such as audio recording and playback on devices like electronic wristwatches (as described in U.S. Pat. No. 4,717,261 to Kita et al. (1988)) and, more recently, wrist-worn watch/MP3 players (for example, the Xonix MP3 recorder watches manufactured by Xonix Electronic Watch Co., Ltd., Zhuhai, China). They are also used to report the time in talking watches. However, these switches are often small, difficult to operate, and not very reliable, which may lead to premature failure of the audio recorder or talking watch. In addition, using switches can be inconvenient for recording many brief personal messages, because the user has to remember to turn the audio recorder on and off in order to record each message.

[0010] Voice-activated recording mechanisms offer more convenience since they facilitate convenient recording of personal messages only when the user wants to record, without relying on the user's active attention to physically turn the audio reorder on and off during a recording session. However, irrelevant audio signals in the surrounding can still turn on a voice-activated mechanism.

[0011] Finally, motion activation has also been used to operate wristwatches. U.S. Pat. No. 3,939,640 to Kahn (1976) describes using a motion-activated switch inside a wristwatch to turn on or off the illumination of a wristwatch display. A free-rolling heavy ball within the container of the switch strikes a spring to cause conduction of electrical current when the wrist rotates rapidly. Additionally, U.S. Pat. No. 4,115,995 to Brien (1978) discloses using a motion-activated switch secured within a wristwatch to set the display on the wristwatch (i.e. to a desired time and date), where quick snaps of the wrist dislodge a metal ball from a magnet and cause conduction of electrical current through the ball. Although these motion-activated switches can be used to turn on and off a wrist-worn device, such as an audio recorder, the rapid motion required to close the electrical switches is unnatural and can cause muscle strain, especially after many repeated actions. Furthermore, it is difficult to add more control functions to a wrist-worn device using only these simple motion-activated on-off switches.

[0012] The aforementioned mechanisms for controlling wrist-worn devices leave much to be desired in terms of ease of use and durability. Accelerometer-based methods would offer advantages in these senses, since control can be automatically activated through a user's natural movements, and the user does not need to directly interact with the electromechanical parts of the accelerometer.

[0013] In recent years, accelerometers produced with low-cost MEMS (micro-electro-mechanical systems) technology have been used for movement and orientation sensing. For example, the wristwatch described in U.S. Pat. No. 6,513,532 B2 to Mault et al. (2003) uses an accelerometer and a button-controlled audio recorder to monitor physical activity and record dietary consumption, respectively, and U.S. Pat. No. 6,956,564 B1 to Williams (2005) discloses a portable hand-held computer that incorporates two single-axis accelerometers for display control and gesture recognition with small fingertip switches for recording speech notes. In the field of animal behavior monitoring, U.S. Pat. No. 7,246,033 B1 to Kudo (2007) and U.S. Pat. No. 6,263,836 B1 to Hollis (2001) describe the use of accelerometers to monitor pet activity and train dogs, respectively, and both incorporate an audio recorder for recording and playback of a human's voice. However, all of the above accelerometer applications require conventional switches to operate audio recording, so that there still exists a need for the application of accelerometer technology to control recording, playback, time reporting, and other functionality in wrist-worn devices.

SUMMARY

[0014] The use of accelerometer-based orientation and movement sensing to control wearable devices, such as wrist-worn audio recorders and wristwatches, is illustrated through three embodiments.

[0015] In accordance with a first embodiment, a wrist-worn audio recorder comprises an accelerometer for sensing the orientation and/or movement of the audio recorder. In this embodiment, the audio recorder activates audio recording only when it is in a predetermined orientation and/or after it has completed a predetermined movement. Different predetermined orientations and/or movements (i.e. sequences of accelerometer data) of the audio recorder can be used to activate other functions of the recorder, such as playback, rewinding, or fast forwarding.

[0016] In accordance with a second embodiment, a wrist-worn audio recorder comprises an accelerometer for sensing the orientation and/or movement of the audio recorder. In this embodiment, a reminding audio message can be recorded in accordance with the first embodiment or in any other manner. When the audio recorder is worn on a wrist, a leg, or another part of the body, it plays back a reminding audio message after it detects a predetermined orientation and/or movement a predetermined number of times.

[0017] In accordance with a third embodiment, a wristwatch comprises an accelerometer for sensing the orientation and/or movement of the wristwatch. In this embodiment, the watch gives an audio report of the time after it detects a predetermined orientation and/or movement.

[0018] Although the above embodiments take the form of wrist-worn devices, the methods and apparatus they illustrate can be extended to wearable devices in general, by one skilled in the art and without departing from the spirit and scope of the invention.

DRAWINGS—FIGURES

[0019] FIG. **1** shows a front view of a wrist-worn audio recorder incorporating a three-axis accelerometer in accordance with the first embodiment, illustrating the X- and Y-axes of the accelerometer.

[0020] FIG. **2** shows a side view of the wrist-worn audio recorder of FIG. **1**, illustrating the Y- and Z-axes of the accelerometer.

[0021] FIG. **3** is a schematic block diagram of the wrist-worn audio recorder of FIG. **1**, in accordance with the first embodiment.

[0022] FIG. **4** is a view of the wrist-worn audio recorder in accordance with the first embodiment, schematically illustrating communication between the audio recorder and a processor, and between the audio recorder and an earphone.

[0023] FIG. **5** is a flow diagram illustrating the orientation and/or movement detection operation of a recorder controller of the wrist-worn audio recorder, in accordance with the first embodiment.

[0024] FIG. **6** is a graphical illustration of a possible orientation of the wrist-worn audio recorder for activating audio recording, in accordance with the first embodiment.

[0025] FIG. **7** is a graphical illustration of a possible orientation of the wrist-worn audio recorder for activating playback, in accordance with the first embodiment.

[0026] FIG. **8** is a graphical illustration of possible movements of the wrist-worn audio recorder for activating rewinding and fast forwarding, in accordance with the first embodiment.

[0027] FIG. **9** is a schematic block diagram of a wrist-worn audio recorder, in accordance with the second embodiment.

[0028] FIG. **10** is a flow diagram illustrating the orientation and/or movement detection operation of a recorder controller of the wrist-worn audio recorder, in accordance with the second embodiment.

[0029] FIG. **11** is a graphical illustration of using a wrist-worn audio recorder to remind the user of eating too many snacks, in accordance with the second embodiment.

[0030] FIG. **12** is a graphical illustration of using a wrist-worn audio recorder to sense restless leg movement of the user and transmit a reminding audio message to the caregiver of the user, in accordance with the second embodiment.

[0031] FIG. **13** shows a front view of a wristwatch incorporating a three-axis accelerometer in accordance with the third embodiment, illustrating the X- and Y-axes of the accelerometer.

[0032] FIG. **14** shows a side view of the wristwatch of FIG. **13**, illustrating the Y- and Z-axes of the accelerometer.

[0033] FIG. **15** is a schematic block diagram of the wristwatch of FIG. **13**, in accordance with the third embodiment.

[0034] FIG. **16** is a flow diagram illustrating the orientation and/or movement detection operation of a wristwatch controller of the wristwatch, in accordance with the third embodiment.

[0035] FIG. **17** is a graphical illustration of a possible orientation of the wristwatch for activating audio time reporting, in accordance with the third embodiment.

DETAILED DESCRIPTION—FIGS. 1, 2, 3, AND 4—FIRST EMBODIMENT

[0036] The use of accelerometer-based orientation and/or movement sensing to control a wearable device is illustrated in a first embodiment with a wrist-worn audio recorder. The wrist-worn audio recorder incorporates an accelerometer for sensing the orientation and/or movement (i.e. either orientation or movement or both) of the audio recorder, and it is activated to record audio messages only when it is in a predetermined orientation and/or after it has completed a predetermined movement. In this embodiment we describe the predetermined orientation and/or movement to be the natural orientation and/or movement for the user to record personal audio messages, so that the user does not need to actively remember to turn the audio recorder on and off, but the predetermined orientation and/or movement can be any other orientation and/or movement. The wrist-worn audio recorder may usually also contain a real-time clock, so that the recorder can provide additional time-keeping function, and in this case the recorded audio data can be synchronized with other time-stamped data, such as video data or accelerometer data from other devices.

[0037] FIG. **1** shows a front view of a wrist-worn audio recorder **30** incorporating a three-axis accelerometer **32** inside a housing **33** of audio recorder **30**. Three-axis accelerometer **32** is commonly also called a triaxial accelerometer, and it senses acceleration in the three orthogonal axes X, Y, and Z. In FIG. **1**, the accelerometer **32** is illustrated by a dotted outline, and the Z-axis points out of the figure. Wristband **31** secures audio recorder **30** on top of the user's right wrist (although audio recorder **30** could also be secured on top of the user's left wrist). A display **34** on the front surface of audio recorder **30** shows the time of day (hours, minutes, seconds), the date (month, date, day), or the current status (recording, playback, etc.) of audio recorder **30**. Alternatively, the hands for the hours, minutes, and seconds of an analog wristwatch may be used to show the time of day, in place of display **34**. Wrist-worn audio recorder **30** can function without a real-time clock, although the inclusion of a real-time clock enables time-stamping of the recorded audio data and facilitates data archiving, data searching, or time synchronization of the data with time-stamped data from other devices.

[0038] A microphone **36** is used for audio recording, and a speaker **38** is used for playing back the recorded audio data. When audio recorder **30** is activated for audio recording, indicators **40***a*, **40***b*, **40***c* at the front of housing **33** may be used to inform the user whether the recording is started at the beginning, the end, or somewhere in the middle of the audio-data record. Recording audio data at the beginning or between the beginning and the end of the audio-data record will overwrite previously recorded audio data. Recording at the end is the usual mode of audio recording and will append additional audio data to the end of the audio-data record. Indicators **40***a*, **40***b*, **40***c* can be miniature LEDs (light-emitting diodes), and flashing of an indicator can be used to signal the user that audio recording is in process. Alternatively, the functions of

indicators **40***a,* **40***b,* **40***c* can be incorporated into display **34**, so that separate indicators **40***a,* **40***b,* **40***c* are not needed.

[0039] FIG. **2** shows a side view of wrist-worn audio recorder **30** with accelerometer **32** (illustrated by a dotted outline) mounted inside housing **33** to sense the orientation and/or movement of audio recorder **30**. Audio recorder **30** is secured on top of the wrist, using wristband **31**, and the X-axis points out of the figure. Three-axis accelerometers such as accelerometer **32** may be constructed with MEMS (micro-electro-mechanical systems) technology using capacitance measurement to determine the amount of acceleration, and they are available from Freescale Semiconductor, Inc., of Austin, Tex., or other companies. The X-, Y-, and Z-axis signals from a three-axis accelerometer provide information about the accelerometer's movement (which may be determined by a sequence of accelerometer data, for example), and can also be separated into components of the vertical gravitational acceleration G to determine orientation when the accelerometer is at rest, so that a three-axis accelerometer can serve as both an orientation and movement sensor. In this way, audio recorder **30** uses the X-, Y-, and Z-axis acceleration signals of accelerometer **32** to detect specific orientations and/or movements of audio recorder **30** and subsequently activate the corresponding audio-recorder functions. For example, if the user stretches his or her arm out forwards, with the palm of his or her hand facing vertically downwards, accelerometer **32** (as illustrated in FIG. **2**) will sense an acceleration of −9.8 meter/sec^2 (the gravitational acceleration G is 9.8 meter/sec^2 vertically downward) along its Z-axis, because the Z-axis is pointing vertically upward in this orientation. The acceleration signals are zero along its X- and Y-axes, because they are orthogonal to the direction of G. Likewise, an acceleration of 9.8 meter/sec^2 (i.e. G) will be sensed along the accelerometer's Z-axis if the palm is facing upwards instead. Other orientations of the wrist will produce acceleration signals with different signs and magnitudes in the X-, Y-, and Z-axis components of accelerometer **32**, and the orientation can be computed using standard vector analysis.

[0040] FIG. **3** is a schematic block diagram of wrist-worn audio recorder **30** (FIG. **1**). Each of the X-, Y- and Z-axis analog signal components of accelerometer **32** is selected by an analog multiplexer **42** at predetermined time intervals, under the control of a recorder controller **48**. Recorder controller **48** also activates an analog-to-digital converter **46**, which uses a sample-and-hold circuit **44** to sample and hold the selected analog signal component. Analog-to-digital converter **46** converts the sampled analog signal component to the corresponding digital datum and sends the digital datum to recorder controller **48**, which stores the digital datum in an accelerometer-data memory **50**. Although FIG. **3** shows that accelerometer **32** senses accelerometer signal components in three orthogonal axes, accelerometer **32** may sense signal components in a different number of axes for detection of different predetermined orientations and/or movements. Sample-and-hold circuit **44** and analog-to-digital converter **46** are not required for an accelerometer that produces digital output data for the signal components, and analog multiplexer **42** should be replaced with a digital multiplexer in this case. Furthermore, if accelerometer **32** is a single-axis accelerometer that produces only one signal component, the analog or digital multiplexer is not needed.

[0041] A system clock **52** provides the operation timing for recorder controller **48**, which is usually a microprocessor. Recorder controller **48** can be configured to perform mathematical computation, logic operation, timer function, storing and retrieving data using an audio-data memory **56** and accelerometer-data memory **50**, and reading and sending data through a communication port **60**, etc., as well known in the art. A real-time clock **54** provides time-keeping function, and recorder controller **48** can also use real-time clock **54** to time-stamp each section of recorded audio message. In certain designs, real-tine clock **54** is derived from system clock **52**, so that a dedicated real-time clock **54** is not required.

[0042] A user records audio messages into microphone **36**, and the analog audio signal from microphone **36** is converted to digital audio data by a sample-and-hold circuit **62** and an analog-to-digital converter **64**. Recorder controller **48** stores the digital audio data in audio-data memory **56**, and it can subsequently send the digital audio data to a digital-to-analog converter **66** for playback from speaker **38**. Through communication port **60**, recorder controller **48** can also send the recorded audio data to a processor (not shown in FIG. **3**) for data archiving, data searching, or time synchronization of the data with other time-stamped data, or to an earphone (not shown in FIG. **3**) for playback. Audio-data memory **56** and accelerometer-data memory **50** can be RAM (random-access memory), flash memory, removable memory cards, or other types of digital memory. A user interface **68**, which includes display **34** (FIG. **1**), indicators **40***a,* **40***b,* **40***c* (FIG. **1**), and switches if necessary (not shown in FIG. **1**), facilitates communication between audio recorder **30** and the user.

[0043] Communication port **60** facilitates communication between audio recorder **30** and a processor (not shown in FIG. **3**), such as a personal computer, and can send recorded audio data to the processor for playback, data archiving, data searching, or time synchronization of the data with other time-stamped data. Communication port **60** also facilitates transmission of recorded audio data to an earphone (not shown in FIG. **3**) for playback. Communication port **60** can be a wired or wireless USB (Universal-Serial-Bus) port, a Bluetooth® (a digital wireless protocol) wireless communication port, or any other wired or wireless communication port.

[0044] FIG. **4** illustrates communication between audio recorder **30** and a processor **70** through a communication link **72**, which can be a wired or wireless data link. Communication link **72** can be used to transmit data between audio recorder **30** and processor **70**, or for other uses such as sending clock-setting commands from processor **70** to audio recorder **30** to set real-time clock **54** (FIG. **3**) of audio recorder **30** to an accurate real-time clock reading. Audio recorder **30** can also transmit recorded audio data to an earphone **71** through a wired or wireless data link **73**, such as a Bluetooth® data link. Processor **70** can be a personal computer, a PDA, a cellular phone, or another digital device. Although FIG. **4** shows audio recorder **30**, with housing **33**, secured to the right wrist by wristband **31**, audio recorder **30** can communicate with processor **70** and earphone **71** without being secured to a wrist.

[0045] Speech recognition of recorded speech notes is useful in applications such as recording food intake or physical activity, because it minimizes the time and inconvenience otherwise involved if the user needs to manually enter this food and activity data into a processor such as processor **70** to analyze his or her energy balance or fitness status. In these cases, either recorder controller **48** (FIG. **3**) can perform the speech recognition, or it can send the audio data to processor **70** for processor **70** to perform the speech recognition. If audio recorder **30** performs the speech recognition, then the

time-stamped text messages (obtained from speech recognition of time-stamped audio data) can be stored in audio-data memory **56** (FIG. **3**) along with other audio data and sent to processor **70** at a later time.

Detection Operation—FIGS. 5, **6**, **7**, and **8**

[0046] FIG. **5** is a flow diagram illustrating the orientation and/or movement (i.e. sequence of acceleration data) detection operation of recorder controller **48** (FIG. **3**). In FIG. **5**, after analog multiplexer **42**, under the control of recorder controller **48**, selects an acceleration signal component (X, Y, or Z) at step **74**, recorder controller **48** activates analog-to-digital converter **46** (FIG. **3**) to use sample-and-hold circuit **44** (FIG. **3**) to sample and hold the selected signal component at step **76**. At step **78**, analog-to-digital converter **46** converts the sampled analog signal component to its corresponding digital datum and sends the digital datum to recorder controller **48**, which stores the digital datum in accelerometer-data memory **50** (FIG. **3**) at step **80**. At step **82**, recorder controller **48** repeats this process for the next accelerometer signal component, until the X, Y, and Z signal components have all been selected. If audio recorder **30** does not move too fast over each cycle of accelerometer-data acquisition, the acquired and stored X, Y, and Z signal data in each cycle are approximately simultaneous. Alternatively, separate data acquisition subsystems, each including a sample-and-hold circuit and an analog-to-digital converter, can be used for each of the three accelerometer-signal components to obtain more precisely simultaneous X, Y, and Z accelerometer signal data. At step **84**, recorder controller **48** uses the data stored in accelerometer-data memory **50** to compute the orientation and/or movement of audio recorder **30** and activates an audio-recorder function, such as audio recording, playback, or rewinding (the operation of the audio-recorder function is not illustrated in FIG. **5**), only if a predetermined orientation and/or movement is detected. At step **86**, if the user does not stop the accelerometer-data acquisition, recorder controller **48** waits for a predetermined time interval at step **88** and then returns to step **74** to repeat the above process.

[0047] FIG. **6** illustrates a possible orientation of audio recorder **30** during audio recording, with audio recorder **30** secured on top of the wrist, using wristband **31**. The user naturally positions audio recorder **30** in front of his or her mouth (typically within 8 inches of the mouth, for example), with the front surface of housing **33** of audio recorder **30** facing the mouth. In this specific orientation of audio recorder **30**, the Y component of the gravitational acceleration G is small (the Y-axis points away from the figure and is nearly horizontal). Since the angle between the X-axis and the direction of the gravitational acceleration G is about 45 degrees, the X component of the gravitational acceleration G is approximately G cosine 45°, which is equal to 0.707 G, as illustrated in the vector diagram in FIG. **6**. Similarly, the angle between the Z-axis and the gravitational acceleration G is about 135°, so that tile Z component of the gravitational acceleration G is G cosine 135°, which is −0.707 G. Recorder controller **48** (FIG. **3**) detects this combination of X, Y, and Z signal components to activate audio recording. Alternatively, and for more robust detection, recorder controller **48** can use a machine learning algorithm or other suitable method to detect a predetermined movement, such as the natural movement of lifting the arm upwards from a resting position (i.e. from the side of the body or from in front of the lower end of the torso) and tilting the wrist towards the mouth to activate audio recording.

[0048] In the first embodiment, the audio recording function of audio recorder **30** turns on automatically when the user positions audio recorder **30** in a predetermined orientation, such as the natural orientation for recording shown in FIG. **6**, and/or after audio recorder **30** has completed a predetermined movement, and an indicator (**40***a*, **40***b*, or **40***c* shown in FIG. **1**) simultaneously turns on to inform the user that he or she may begin audio recording. A voice-activated mechanism can be added to minimize accidental activation, so that recording is activated only when audio recorder **30** is in the predetermined orientation and/or has completed the predetermined movement and the user begins talking to it. In addition, recorder controller **48** (FIG. **3**) of audio recorder **30** can be designed to take the user's position or posture into consideration, so that it activates audio recording after sensing any in a range of signal outputs from accelerometer **32**. This range may encompass, for example, audio recorder **30**'s natural recording orientation in front of the mouth (as shown in FIG. **6**) for a range of user postures from standing upright (the posture illustrated in FIG. **6**) to lying down. Using these same concepts, recorder controller **48** can also be designed to detect the natural recording orientation of audio recorder **30** for a user who wears audio recorder **30** on the other side (i.e. the bottom) of the wrist. In all cases, the audio recording is stopped as soon as the user moves audio recorder **30** away from the predetermined orientation, so that recording of irrelevant audio information is minimized without requiring the user to consciously turn off the audio recording. Furthermore, a different type of accelerometer, such as a two-axis (also called biaxial) or a single-axis (also called uniaxial) accelerometer, or a combination of the same or different types of accelerometers, can also be used to detect a predetermined orientation of audio recorder **30**, instead of using a three-axis accelerometer as illustrated here.

[0049] FIG. **7** illustrates a possible orientation of audio recorder **30** for activating playback of recorded audio data when audio recorder **30** is secured on the top of the right wrist by wristband **31**. The user simply positions audio recorder **30** (illustrated by a dotted circle in FIG. **7**) close to his or her ear, with the front surface of housing **33** (not shown in FIG. **7**) of audio recorder **30** facing the ear. In this predetermined orientation of audio recorder **30**, the sound volume of speaker **38** (FIGS. **1** and **3**) is automatically adjusted to the appropriate level for listening to the recorded audio data in close proximity. The Z accelerometer signal component of the gravitational acceleration G here is almost zero (the Z-axis points into the figure and is nearly horizontal). Since the angle between the accelerometer X-axis and the direction of the gravitational acceleration G is about 45 degrees, the X accelerometer signal component of G is approximately G cosine 45°, which is equal to 0.707 G, as illustrated in the vector diagram in FIG. **7**. Similarly, the angle between the accelerometer Y-axis and the gravitational acceleration G is about 135°, so that the Y accelerometer signal component is approximately G cosine 135°, which is −0.707 G. After sensing this combination of accelerometer signal components, recorder controller **48** (FIG. **3**) of audio recorder **30** activates playback of a section of audio recording before the end of the audio-data record through speaker **38**. A proximity sensor (not shown in FIG. **3**), such as a capacitive, pyroelectric, pressure-sensitive, or electrical-conductive sensor, can be

added to minimize accidental activation, so that playback only begins when audio recorder **30** is in this predetermined orientation and in close proximity (within 3 inches, for example) of or in contact with the skin of the ear or around the ear. Besides the orientation illustrated in FIG. **7**, recorder controller **48** can also be designed to activate playback after detecting an orientation where the user positions audio recorder **30** close to his or her other ear for listening, where the user wears audio recorder **30** on the other side (i.e. the bottom) of the wrist, or where the user positions audio recorder **30** towards the ear of another person. When audio recorder **30** is playing back the audio-data record, the user can use predetermined patterns of wrist and arm movement to activate rewinding or fast forwarding as discussed below.

[0050] In FIG. **7**, rotating of the wrist (and audio recorder **30**) back and forth in a direction **92** in front of the ear (the rotating movement of the wrist is illustrated by the arrows at each end of direction line **92**) produces a pattern of X- and Z-axis accelerometer signal changes while the Y-axis accelerometer signal remains essentially unchanged, because the angle between the Y-axis and the vertically downward direction of the gravitational acceleration G is nearly constant during this movement. Recorder controller **48** (FIG. **3**) can detect these predetermined signal changes to activate rewinding for a short duration. Record controller **48** can also detect several back-and-forth rotations of the wrist in direction **92** in close succession to activate rewinding for a much longer duration. Likewise, moving the wrist side-to-side in a direction **94** in front of the ear (the side-to-side movement of the wrist is illustrated by having an arrow at each end of direction line **94**) produces a pattern of X- and Y-axis accelerometer signal changes while the Z-axis accelerometer signal component remains essentially unchanged, because the angle between the Z-axis and the vertically downward direction of gravitational acceleration G is nearly constant during this movement (the Z-axis points into the page and is nearly horizontal). Recorder controller **48** can detect these predetermined signal changes to activate fast forwarding for a short duration. Recorder controller **48** can also detect multiple side-to-side movements of the wrist in direction **94** in close succession to activate fast forwarding for a much longer duration. Similarly, recorder controller **48** can be designed to detect other movements of the wrist and arm to activate rewinding or fast forwarding. In all these cases, machine-learning algorithms can be used for more accurate and robust detection of predetermined movements from accelerometer signals.

[0051] For the case illustrated in FIG. **7**, playback stops as soon as audio recorder **30** is moved away from the predetermined orientation in close proximity of the ear, and an indicator (**40***a*, **40***b*, or **40***c* in FIG. **1**) informs the user whether the playback stopped at the beginning, the end, or somewhere in the middle of the audio-data record. As in a typical audio recorder, starting audio recording before the end of tile audio-data record will overwrite previously stored audio data. When the audio data stored in audio recorder **30** is digital, as discussed above, and each section of recorded audio message is time-stamped by real-time clock **54** (FIG. **3**), rewinding and fast forwarding can be accomplished almost instantly.

[0052] FIG. **8** illustrates some other possible movements of the wrist and the forearm (and hence of audio recorder **30**) for activating rewinding and fast forwarding of audio recorder **30**. Audio recorder **30**, with housing **33**, is secured on top of the wrist here using wristband **31**. In FIG. **8**, the user positions his forearm at an angle of about 135 degrees between the forearm and the vertically downward direction of the gravitational acceleration G. Counterclockwise circular movement of the wrist (and also the hand and forearm) along a path **95** (in the direction of the arrow) produces a pattern of Y- and Z-axis accelerometer signal changes while the X-axis accelerometer signal component of the gravitational acceleration G is small, because the X-axis points away from the figure and is nearly horizontal. Recorder controller **48** (FIG. **3**) can detect these predetermined signal changes to activate rewinding all the way to the beginning of the audio-data record, and an indicator (**40***a*, **40***b*, or **40***c* in FIG. **1**) turns on to inform the user of this action. Likewise, recorder controller **48** can detect clockwise circular movement of the wrist and forearm along path **95** (in the opposite direction of the arrow) to activate fast forwarding all the way to the end of the audio-data record, and a different indicator (**40***a*, **40***b*, or **40***c* in FIG. **1**) turns on to inform the user of this action. To minimize accidental activation of these audio-recorder functions by normal daily activities, recorder controller **48** can be designed to activate an audio-recorder function such as recording or playback only after audio recorder **30** remains in a static position for a predetermined period of time after a predetermined wrist and arm movement pattern has been detected.

DETAILED DESCRIPTION—FIGS 9—SECOND EMBODIMENT

[0053] The use of accelerometer-based orientation and/or movement sensing in a second embodiment for controlling a wearable electronic device is illustrated with a wearable audio recorder in FIG. **9**, which is a block diagram of the audio recorder. The audio recorder of the second embodiment incorporates an accelerometer for sensing the orientation and/or movement (i.e. sequence of acceleration data) of the audio recorder, and a predetermined orientation and/or movement of the audio recorder activates playback of a reminding message. The reminding messages can be audio messages (i.e. voice messages, musical sounds, songs, alarms, or computer generated audio tones or messages) recorded in accordance with the first embodiment or in any other way, or they can be non-audio, such as vibration of the audio recorder.

[0054] In FIG. **9**, a wrist-worn audio recorder **170** incorporates a three-axis accelerometer **172** for sensing the orientation and/or movement of audio recorder **170**, and two switches **202**, **204** for recording and verifying a reminding audio message. A recorder controller **174** plays back a reminding audio message when a predetermined orientation and/or movement of audio recorder **170** is detected. Each of the X, Y and Z analog signal components of accelerometer **172** is selected by an analog multiplexer **176** at predetermined time intervals, under the control of a recorder controller **174**. Recorder controller **174** also activates an analog-to-digital converter **180**, which uses a sample-and-hold circuit **178** to sample and hold the selected analog signal component. Analog-to-digital converter **180** converts the sampled analog signal component to the corresponding digital datum and sends the digital datum to recorder controller **174**, which stores the digital datum in an accelerometer-data memory **182**.

[0055] A microphone **194** is used for recording a reminding audio message when the user activates switch **202** to cause signal **206** at an input of record controller **174** to change from logic low to logic high (or vice versa). Under the control of recorder controller **174**, the analog audio signal from microphone **184** is converted to digital audio data by a sample-and-hold circuit **186** and an analog-to-digital converter **188**, and

the digital audio data of the reminding audio message is stored in an audio-data memory **190**. Audio-data memory **190** and accelerometer-data memory **182** can be RAM (random-access memory), flash memory, removable memory cards, or other types of digital memory. When recorder controller **174** detects a predetermined orientation and/or movement of audio recorder **170** a predetermined number of times, it sends the reminding audio message for the predetermined orientation and/or movement from audio-data memory **190** to a digital-to-analog converter **191** and a speaker **192** for playback. Tile user can also verify (i.e. manually use a switch to play back) a recorded reminding audio message by activating switch **204** to cause signal **208** at an input of record controller **174** to change from logic low to logic high (or vice versa). Additional switches may be used for recording and verifying more reminding audio messages. Instead of playing back a reminding audio message through speaker **192**, recorder controller **174** can send the reminding audio message to an earphone or a processor (not shown in FIG. **9**) through a communication port **198**, or vibrate the audio recorder if a vibration mechanism (not shown in FIG. **9**) is incorporated.

[0056] Communication port **198** facilitates wired or wireless communication between the audio recorder **170** and a processor, such as a personal computer or an earphone. Communication port **198** can be a wired or wireless USB port, a Bluetooth® wireless communication port, or any other wired or wireless communication port. Although FIG. **9** shows that accelerometer **172** senses accelerometer signal components in three orthogonal axes X, Y, and Z, accelerometer **172** may sense accelerometer signal components in a different number of axes to detect different predetermined orientations and/or movements. Sample-and-hold circuit **178** and analog-to-digital converter **180** are not required for an accelerometer that produces digital output data for the accelerometer signal components, and analog multiplexer **176** should be replaced with a digital multiplexer in this case. Furthermore, if accelerometer **172** is a single-axis accelerometer that produces only one signal component, the analog or digital multiplexer is not needed.

[0057] A user interface **194**, which usually includes a display, LED indicators, and conventional switches, facilitates communication between audio recorder **170** and the user. A system clock **196** provides the operation timing for recorder controller **174**, which is usually a microprocessor. Recorder controller **174** can be configured to perform mathematical computation, logic operation, timer function, storing and retrieving data using audio-data memory **190** and accelerometer-data memory **182**, and reading and sending data through communication port **198**, etc., as well known in the art. A real-time clock **200** provides time-keeping function, although audio recorder **170** can function without a real-time clock. In certain designs, real-time clock **200** is derived from system clock **196**, so that a dedicated real-time clock **200** is not required.

[0058] In FIG. **9**, two switches **202**, **204** are used for recording and verifying a reminding audio message. Instead of switches **202**, **204**, accelerometer **172** may also be used to record a reminding audio message. For example, audio recorder **170** may activate recording after using accelerometer **172** to detect that it is in a predetermined orientation, as discussed in the first embodiment, or that it has completed a predetermined movement of the wrist, such as rotating the wrist (and thus audio recorder **170**, located on the wrist) back and forth three times in close succession while audio recorder **170** is in front of the mouth (as illustrated in FIG. **6**). If audio recorder **170** is also used as a regular audio recorder, the recorded reminding audio messages may be stored in a dedicated location of audio-data memory **190**, so that they will not be overwritten by other recorded audio data. Furthermore, reminding audio messages can be recorded in audio recorder **170** during the manufacturing process of audio recorder **170** or received from a computer through communication port **198**.

[0059] In the second embodiment, a recorded reminding audio message can be played back to remind the user of a predetermined type of physical activity, especially an undesired type of physical activity. For example, recorder controller **174** can be designed to detect the pattern of changes of X, Y, and Z accelerometer signal components produced by the wrist and arm movement of a user's hand when he or she puts snacks into his or her mouth, provided that the user wears audio recorder **170** on the wrist to detect such movement. When the wrist movement is repeated a predetermined number of times in a preset time window, recorder controller **174** activates playback of a reminding audio message to warn the user that he or she is eating too many snacks. With real-time clock **200** incorporated in audio recorder **170**, recorder controller **174** can also be designed to play back a reminding audio message only when such repeated wrist movement is detected during the usual snack time of the user. In another example, wrist-worn audio recorder **170** can play back a different reminding audio message when the user has not moved his or her wrist (and audio recorder **170** on the wrist) very much over a period of time because of inactivity, such as when the user is watching television. This reminding audio message can help remind the user to stay active to prevent obesity, for instance.

[0060] After reminding messages are stored in audio-data memory **190** of audio recorder **170**, audio recorder **170** can be attached to any part of the user's body, such as the waist or one of the lower extremities, to detect physical activity or inactivity there. For example, when audio recorder **170** is attached to the leg of a user who has restless leg syndrome, audio recorder **170** can play back a reminding audio message to the user when his or her leg is moving restlessly. Instead of playing back a reminding audio message through speaker **192**, recorder controller **174** can also send the message to a wireless earphone (not shown in FIG. **9**) such as a Bluetooth® earphone, through communication port **198**, or activate a vibration mechanism (not shown in FIG. **9**) if one is incorporated, so that the user is not embarrassed by unwanted people hearing the reminding audio message.

Detection Operation—FIGS. 10, **11**, and **12**

[0061] FIG. **10** is a flow diagram illustrating the orientation and/or movement detection operation of recorder controller **174** (FIG. **9**) for playing back a reminding audio message when a predetermined orientation and/or movement of audio recorder **170** (FIG. **9**) is detected a predetermined number of times. In FIG. **10**, after analog multiplexer **176** (FIG. **9**), under the control of recorder controller **174**, selects an accelerometer signal component (X, Y, or Z) at step **210**, recorder controller **174** activates analog-to-digital converter **180** to use sample-and-hold circuit **178** (FIG. **9**) to sample and hold the accelerometer signal component at step **212**. At step **214**, analog-to-digital converter **180** converts the sampled analog signal to the corresponding digital datum and sends the digital datum to recorder controller **174**, which stores the digital

datum in accelerometer-data memory **182** (FIG. **9**) at step **216**. At step **218**, recorder controller **174** repeats this process for the next accelerometer signal component, until the X, Y, and Z accelerometer signal components have all been selected. If audio recorder **170** does not move too fast over each cycle of accelerometer-data acquisition, the acquired and stored X, Y, and Z signal data in each cycle are approximately simultaneous. Alternatively, separate data acquisition subsystems, each including a sample-and-hold circuit and an analog-to-digital converter, can be used for each of the three accelerometer-signal components to obtain more precisely simultaneous X, Y, and Z accelerometer signal data. At step **220**, recorder controller **174** uses the data stored in accelerometer-data memory **182** to compute the orientation and/or movement of audio recorder **170** to playback a reminding audio message if the orientation and/or movement matches a predetermined orientation and/or movement for a predetermined number of times. At step **222**, if the user does not stop accelerometer-data acquisition, recorder controller **174** waits for a predetermined time interval at step **224** and then returns to step **210** to repeat the above process.

[0062] FIG. **11** is a graphical illustration of using audio recorder **170** (behind the right wrist in FIG. **11**, and illustrated by a dotted outline) to remind a user of eating too many snacks. When the user puts snacks into his or her mouth, recorder controller **174** (FIG. **9**) of audio recorder **170** worn on the wrist detects the pattern of accelerometer signal changes of the X, Y, and Z components produced by a wrist movement **227** (the alternating movement of the wrist is illustrated by the arrows at each end of direction line **227**). When wrist movement in direction **227** is repeated a predetermined number of times in a preset time window, recorder controller **174** activates playback of a reminding audio message to remind the user that he or she might be eating too many snacks. In FIG. **11**, recorder controller **174** sends the reminding audio message through communication port **198** (FIG. **9**) and the corresponding communication link **228** (wired or wireless) to an earphone **229**, such as a Bluetooth® earphone, worn by the user, although recorder controller **174** may also play back the reminding audio message through speaker **192** (FIG. **9**) or vibrate audio recorder **170** if a vibrate mechanism (not shown in FIG. **9**) is incorporated. Alternatively, recorder controller **174** may send the reminding audio message to a wireless earphone worn by another person (not shown in FIG. **11**), such as the parent of a child or the caregiver of an elderly, instead of the child or the elderly who wears audio recorder **170**. Furthermore, recorder controller **174** can use real-time clock **200** (FIG. **9**) to enable playback of a reminding audio message only when wrist movement **227** is detected a predetermined number of times during a predetermined time window, such as during the usual snack time for the person who wears audio recorder **170**.

[0063] FIG. **12** is a graphical illustration of using audio recorder **170** to play back a reminding audio message when restless leg movement is detected. After an appropriate reminding audio message has been recorded in audio recorder **170**, audio recorder **170** is attached to the user's right lower leg, as illustrated in FIG. **12**. When the user moves his or her right leg restlessly in a direction **230** (the alternating movement of the leg is illustrated by the arrows at each end of direction line **230**), recorder controller **174** (FIG. **9**) detects the pattern of accelerometer signal changes of the X, Y, and Z components produced by the leg movement in direction **230**. When leg movement in direction **230** is repeated a predetermined number of times in a predetermined time window, recorder controller **174** activates playback of the reminding audio message. Recorder controller **174** sends the reminding audio message through communication port **198** (FIG. **9**) and the corresponding communication link **232** (wired or wireless) to an earphone **234** (a Bluetooth® earphone, for example) worn by another person, such as the parent of a child or the caregiver of an elderly, instead of the child or the elderly who wears audio recorder **170** on his or her right lower leg. Alternatively, recorder controller **174** may play back the reminding audio message through speaker **192** (FIG. **9**), send the reminding audio message to an earphone worn by the person who wears audio recorder **170** on his or her right lower leg, or vibrate audio recorder **170** if a vibrate mechanism (not shown in FIG. **9**) is incorporated. Furthermore, recorder controller **174** can use real-time clock **200** (FIG. **9**) to enable playback of the reminding audio message only when leg movement is detected a predetermined number of times during a predetermined time window, such as during the usual rest time for the person who wears audio recorder **170**.

DETAILED DESCRIPTION—FIGS. 13, 14, AND 15—THIRD EMBODIMENT

[0064] The use of accelerometer-based orientation and/or movement sensing in a third embodiment for controlling a wearable device is illustrated with a wristwatch. The wristwatch incorporates an accelerometer for sensing the orientation and/or movement of the wristwatch, and a predetermined orientation and/or movement of the wristwatch, such as the user moving it up and towards the ear, activates audio reporting of the time. This accelerometer-based time-reporting function can also be incorporated in other wrist-worn devices such as the voice recorder described in the first embodiment.

[0065] FIG. **13** shows a front view of a wristwatch **330** incorporating a three-axis accelerometer **332** inside a housing **333** of wristwatch **330**. Three-axis accelerometer **332** is commonly also called a triaxial accelerometer, and it senses acceleration in the three orthogonal axes X, Y, and Z. In FIG. **13**, accelerometer **332** is illustrated by a dotted outline, and the Z-axis points out of the page. Wristband **331** secures wristwatch **330** on top of the user's right wrist, although wristwatch **330** could also be secured on top of the user's left wrist. A display **334** on the front surface of wristwatch **330** shows the time of day (hours, minutes, seconds) or date (month, date, day) of wristwatch **330**. Alternatively, the hands for the hours, minutes, and seconds of an analog display may be used to show the time of the day, in place of display **334**. A speaker **338** is used for audio reporting of the time, and buttons **341***a* and **341***b* are used for functional control of the wristwatch, such as re-setting the time or setting an alarm. Microphone **339** allows the user to record personalized audio time components (i.e. "three", "forty", "minutes", "PM", etc.) for use in the audio time reporting, so that the reporting can be in a desired voice or language. Alternatively, standard time components recorded during manufacturing may be used for the audio time reporting. Other button arrangements and watch face displays may also be used.

[0066] FIG. **14** shows a side view of wristwatch **330** with accelerometer **332** (illustrated by a dotted outline) mounted inside housing **333** to sense the orientation and/or movement of wristwatch **330**, and the X-axis points out of the page. Wristwatch **330** is secured on top of the wrist, using wristband **331**. The X-, Y-, and Z-axis signals from a three-axis accelerometer such as accelerometer **332** provide informa-

tion about the accelerometer's movement (which may be determined by a sequence of accelerometer signals, for example), and can also be separated into components of the vertical gravitational acceleration G to determine orientation when the accelerometer is at rest, so that a three-axis accelerometer can serve as both an orientation and movement sensor. In this way, wristwatch **330** uses the X-, Y-, and Z-axis acceleration signals of accelerometer **332** to detect specific orientations and/or movements of wristwatch **330** and subsequently activate the audio time reporting function of wristwatch **330**.

[0067] FIG. **15** is a schematic block diagram of wristwatch **330** (FIGS. **13**, **14**). Each of the X-, Y-, and Z-axis analog signal components of accelerometer **332** is selected by an analog multiplexer **342** at predetermined time intervals, under the control of wristwatch controller **348**. Wristwatch controller **348** also activates an analog-to-digital converter **346**, which uses a sample-and-hold circuit **344** to sample and hold the selected analog signal component. Analog-to-digital converter **346** converts the sampled analog signal component to the corresponding digital datum and sends the digital datum to wristwatch controller **348**, which stores the digital datum in an accelerometer-data memory **350**.

[0068] Audio-data memory **356** stores audio data for each of the time components needed to report time (i.e. "three", "forty", "minutes", "PM", etc.). Alternatively, the wristwatch of the third embodiment can be incorporated with the voice recording function of the first embodiment or a conventional voice recording function to allow personalized recording of each of these audio time components, for example in a different voice or language. In either of these cases, a user records the personalized audio time components into a microphone **336**, and the analog audio signal from microphone **336** is converted to digital audio data by a sample-and-hold circuit **362** and an analog-to-digital converter **364**. Wristwatch controller **348** stores the digital audio data in audio-data memory **356**, and it can subsequently send the digital audio data to a digital-to-analog converter **366** for personalized reporting of time from speaker **338**. Audio-data memory **356** and accelerometer-data memory **350** can be RAM (random-access memory), flash memory, removable memory cards, or other types of digital memory. When wristwatch controller **348** detects a predetermined orientation and/or movement of wristwatch **330** (FIGS. **13**, **14**), such as moving the wristwatch towards the ear, it notes the current time from real-time clock **354** and sends the appropriate audio data (i.e. "two", "fifty", "one," and "PM", for 2:51 PM) from audio-data memory **356** to a digital-to-analog converter **366** and subsequently speaker **338** for audio time reporting to the user.

[0069] Although FIG. **15** shows that accelerometer **332** senses accelerometer signal components in three orthogonal axes X, Y, and Z, accelerometer **332** may sense accelerometer signal components in a different number of axes to detect different predetermined orientations and/or movements. Sample-and-hold circuit **344** and analog-to-digital converter **346** are not required for an accelerometer that produces digital output data for the accelerometer signal components, and analog multiplexer **342** should be replaced with a digital multiplexer in this case. Furthermore, if accelerometer **332** is a single-axis accelerometer that produces only one signal component, the analog or digital multiplexer is not needed.

[0070] A user interface **368**, which usually includes a display **334** (FIG. **13**) and switches (such as switches **341***a*, **341***b* (FIG. **13**) and additional switches if necessary), facilitates communication between wristwatch **330** and the user, and provides a visual display of the time. A system clock **352** provides the operation timing for wristwatch controller **348**, which is usually a microprocessor. Wristwatch controller **348** can be configured to perform mathematical computation, logic operation, timer function, storing and retrieving data using audio-data memory **356** and accelerometer-data memory **350**, etc., as well known in the art. A real-time clock **354** provides time-keeping function.

Detection Operation—FIGS. 16 and 17

[0071] FIG. **16** is a flow diagram illustrating the orientation and/or movement detection operation of wristwatch controller **348** (FIG. **15**) for audio reporting of the time when a predetermined orientation and/or movement of wristwatch **330** (FIGS. **13**, **14**) is detected. In FIG. **16**, after analog multiplexer **342** (FIG. **15**), under the control of wristwatch controller **348**, selects an accelerometer signal component (X, Y, or Z) at step **374**, wristwatch controller **348** activates analog-to-digital converter **346** (FIG. **15**) to use sample-and-hold circuit **344** (FIG. **15**) to sample and hold the accelerometer signal component at step **376**. At step **378**, analog-to-digital converter **346** converts the sampled analog signal to the corresponding digital datum and sends the digital datum to wristwatch controller **348**, which stores the digital datum in accelerometer-data memory **350** (FIG. **15**) at step **380**. At step **382**, wristwatch controller **348** repeats this process for the next accelerometer signal component, until the X, Y, and Z accelerometer signal components have all been selected. If wristwatch **330** does not move too fast over each cycle of accelerometer data acquisition, the acquired and stored X, Y, and Z signal data in each cycle are approximately simultaneous. Alternatively, separate data acquisition subsystems, each including a sample-and-hold circuit and an analog-to-digital converter, can be used for each of the three accelerometer-signal components to obtain more precisely simultaneous X, Y, and Z accelerometer signal data. At step **384**, wristwatch controller **348** uses the data stored in the accelerometer-data memory **350** to compute the orientation and/or movement of wristwatch **330** and activates an audio time reporting function if a predetermined orientation and/or movement is detected. At step **386**, if the user does not stop accelerometer-data acquisition, wristwatch controller **348** waits for a predetermined time interval at step **388** and then returns to step **374** to repeat the above process.

[0072] FIG. **17** illustrates a possible orientation of wristwatch **330** for activating audio reporting of the current time when wristwatch **330** is secured on top of the right wrist by wristband **331**. The user simply positions wristwatch **330** (illustrated by a dotted circle in FIG. **17**) close to his or her ear, with the front surface of housing **333** (not shown in FIG. **17**) of audio recorder **330** facing the ear. In this predetermined orientation of audio recorder **330**, the sound volume of speaker **338** (FIGS. **13** and **15**) is automatically adjusted to the appropriate level for listening to audio time reporting in close proximity. The Z accelerometer signal component of the gravitational acceleration G here is almost zero (the Z-axis points into the page and is nearly horizontal). Since the angle between the accelerometer X-axis and the direction of the gravitational acceleration G is about 45 degrees, the X accelerometer signal component of G is approximately G cosine 45°, which is equal to 0.707 G, as illustrated in the vector diagram in FIG. **17**. Similarly, the angle between the accelerometer Y-axis and the gravitational acceleration G is

about 135°, so that the Y accelerometer signal component is approximately G cosine 135°, which is −0.707 G. After sensing this combination of acceleration signal components, wristwatch controller **348** (FIG. **15**) activates audio time reporting, so that the current time is reported using real-time clock information and standard or personalized time components from audio-data memory **356** (FIG. **15**) through speaker **338**. A proximity sensor (not shown in FIG. **15**), such as a capacitive, pyroelectric, pressure-sensitive, or electrical-conductive sensor, can be added to minimize accidental activation, so that time reporting only occurs when wristwatch **330** is in this predetermined orientation and is in close proximity (within 3 inches, for example) of or in contact with the skin of the ear or around the ear. Besides the orientation illustrated in FIG. **17**, wristwatch controller **348** can also be designed to activate audio time reporting after detecting an orientation where the user positions wristwatch **330** close to his or her other ear for listening, where the user wears wristwatch **330** on the other side (i.e. the bottom) of the wrist, or where the user positions wristwatch **330** toward the ear of another person.

[0073] Although the description above contains many specificities, these should not be construed as limiting the scope of the embodiments but as merely providing illustrations of some of the presently preferred embodiments. For example, the above-described embodiments can be modified by one skilled in the art, especially in the combination of various described features, without departing from the spirit and the scope of the embodiments.

[0074] Thus the scope of the embodiments should be determined by the appended claims and their legal equivalents, rather than by the examples given.

We claim:

1. A method for activating an audio-recorder function of a wearable device, comprising:

(a) acquiring acceleration data of a wearable device; and

(b) using said acceleration data to activate an audio-recorder function of said wearable device.

2. The method according to claim **1** wherein the step of using said acceleration data to activate an audio-recorder function of said wearable device comprises using said acceleration data to compute an orientation of said wearable device to activate an audio-recorder function when said orientation is a predetermined orientation.

3. The method according to claim **2** wherein said audio-recorder function is audio recording, and said predetermined orientation is an orientation of said wearable device in front of the mouth of a user who wears said wearable device on a wrist.

4. The method according to claim **2** wherein said audio-recorder function is playback of recorded audio data, and said predetermined orientation is an orientation of said wearable device in predetermined proximity of a ear of a user who wears said wearable device.

5. The method according to claim **1** wherein the step of using said acceleration data to activate an audio-recorder function of said wearable device comprises using said acceleration data to compute a movement of said wearable device to activate an audio-recorder function when said movement is a predetermined movement.

6. The method according to claim **1** wherein the step of using said acceleration data to activate an audio-recorder function of said wearable device comprises using said acceleration data to compute an orientation and a movement of said wearable device to activate an audio-recorder function when said orientation is a predetermined orientation and said movement is a predetermined movement.

7. The method according to claim **6** wherein said audio-recorder function is audio recording, said predetermined orientation is an orientation of said wearable device in front of the mouth of a user who wears said wearable device on a wrist, and said predetermined movement is a natural movement of said user's wrist wearing said wearable device for said user to move said wearable device to said predetermined orientation in front of the mouth of said user.

8. The method according to claim **6** wherein said audio-recorder function is playback of recorded audio data, said predetermined orientation is an orientation of said wearable device in predetermined proximity of a ear of a user who wears said wearable device on a wrist, and said predetermined movement is a natural movement of said user's wrist wearing said wearable device for said user to move said wearable device to said predetermined orientation of said wearable device in predetermined proximity of said ear of said user.

9. A wearable device, comprising:

(a) a wearable audio recorder;

(b) a three-axis accelerometer for acquiring acceleration data of said wearable audio recorder; and

(c) a detection means for using said acceleration data to activate an audio-recorder function of said wearable audio recorder.

10. The wearable device according to claim **9** wherein said detection means comprises a means for using said acceleration data to compute an orientation of said wearable audio recorder to activate an audio-recorder function when said orientation is a predetermined orientation.

11. The wearable device according to claim **9** wherein said detection means comprises a means for using said acceleration data to compute a movement of said wearable audio recorder to activate an audio-recorder function when said movement is a predetermined movement.

12. The wearable device according to claim **9** wherein said detection means comprises a means for using said acceleration data to compute an orientation and a movement of said wearable audio recorder to activate an audio-recorder function when said orientation is a predetermined orientation and said movement is a predetermined movement.

13. The wearable device according to claim **12** wherein said wearable audio recorder is a wrist-worn audio recorder.

14. The wearable device according to claim **9** wherein said detection means comprises a means for using said acceleration data to compute a movement of said wearable audio recorder to activate playing back of a reminding audio message after said movement matches a predetermined movement a predetermined number of times.

15. The wearable device according to claim **14** wherein said detection means further comprises a vibration mechanism, which vibrates said wearable audio recorder for reminding a user who wears said wearable audio recorder after said movement matches said predetermined movement said predetermined number of times.

16. A talking wristwatch, comprising:

(a) a wristwatch;

(b) an accelerometer for acquiring acceleration data of said wristwatch; and

(c) a detection means for using said acceleration data to activate audio time reporting of said wristwatch.

17. The talking wristwatch according to claim **16** further comprising a means for recording personalized audio time components, so that said personalized audio time components can be used for audio time reporting.

18. The talking wristwatch according to claim **16** wherein said detection means comprises a means for using said acceleration data to compute an orientation of said talking wristwatch to activate audio time reporting when said orientation is a predetermined orientation.

19. The talking wristwatch according to claim **16** wherein said detection means comprises a means for using said acceleration data to compute a movement of said talking wristwatch to activate audio time reporting when said movement is a predetermined movement.

20. The talking wristwatch according to claim **16** wherein said detection means comprises a means for using said acceleration data to compute an orientation and a movement of said talking wristwatch to activate audio time reporting when said orientation is a predetermined orientation and said movement is a predetermined movement.

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