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(54) **ELECTRONIC DEVICES WITH GAZE DETECTION CAPABILITIES**

(76) Inventors: **Andrew Hodge**, Palo Alto, CA (US); **Michael Rosenblatt**, Campbell, CA (US)

Correspondence Address:
Treyz Law Group
870 Market Street, Suite 984
SAN FRANCISCO, CA 94102 (US)

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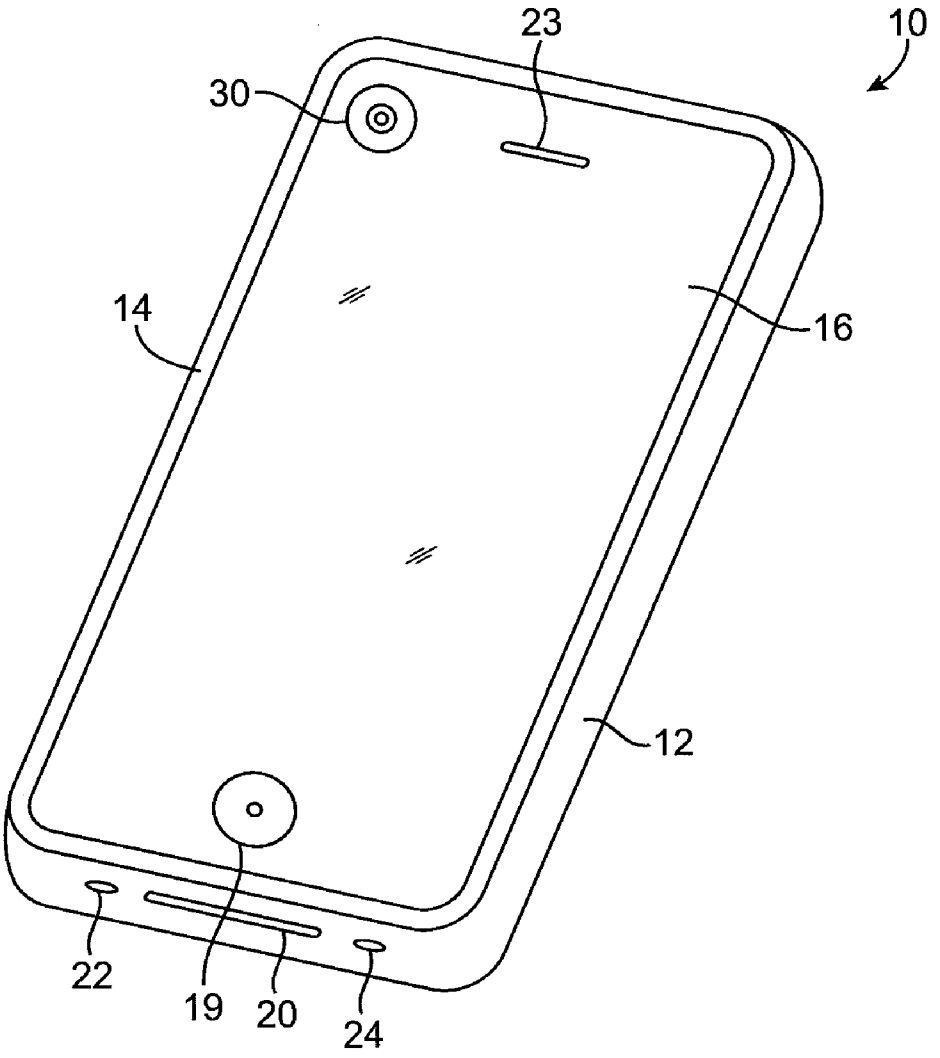
(57) **ABSTRACT**

An electronic device may have gaze detection capabilities that allow the device to detect when a user is looking at the device. The electronic device may implement a power management scheme using the results of gaze detection operations. When the device detects that the user has looked away from the device, the device may dim a display screen and may perform other suitable actions. The device may pause a video playback operation when the device detects that the user has looked away from the device. The device may resume the video playback operation when the device detects that the user is looking towards the device. Gaze detector circuitry may be powered down when sensor data indicates that gazed detection readings will not be reliable or are not needed.



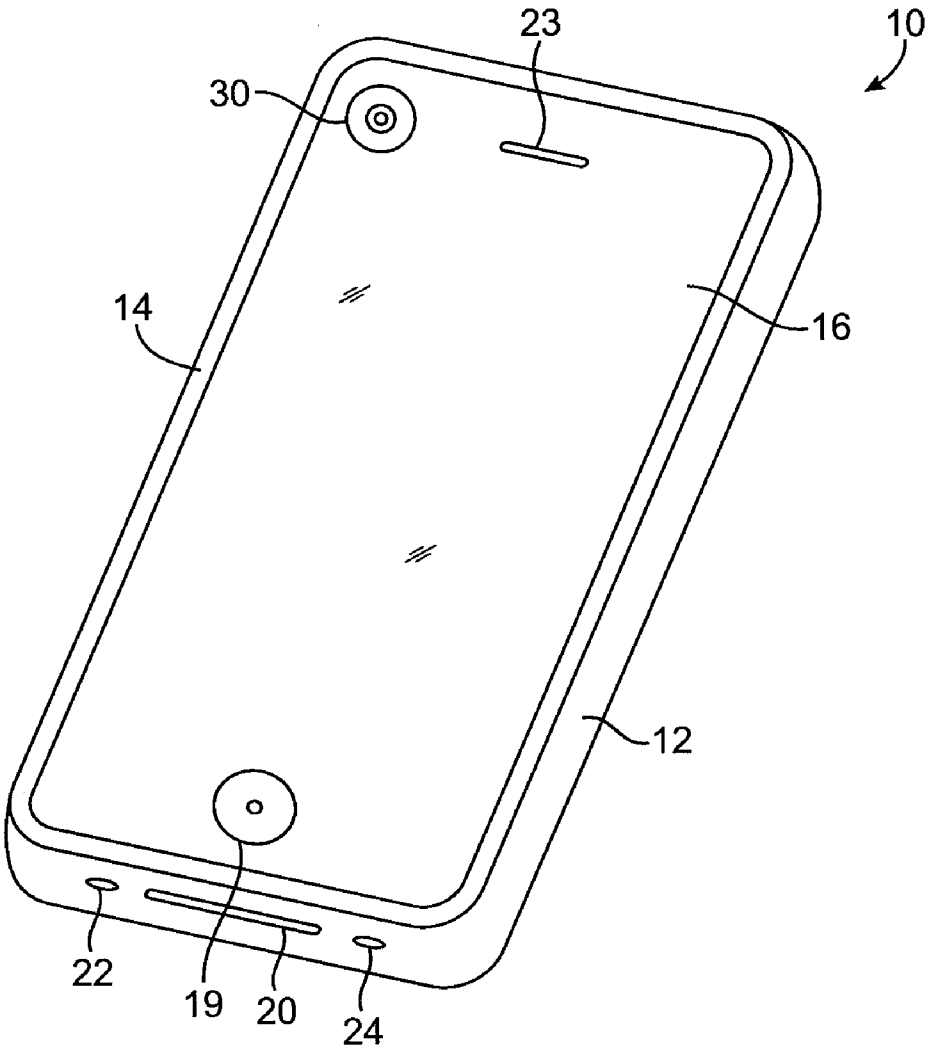


FIG. 1

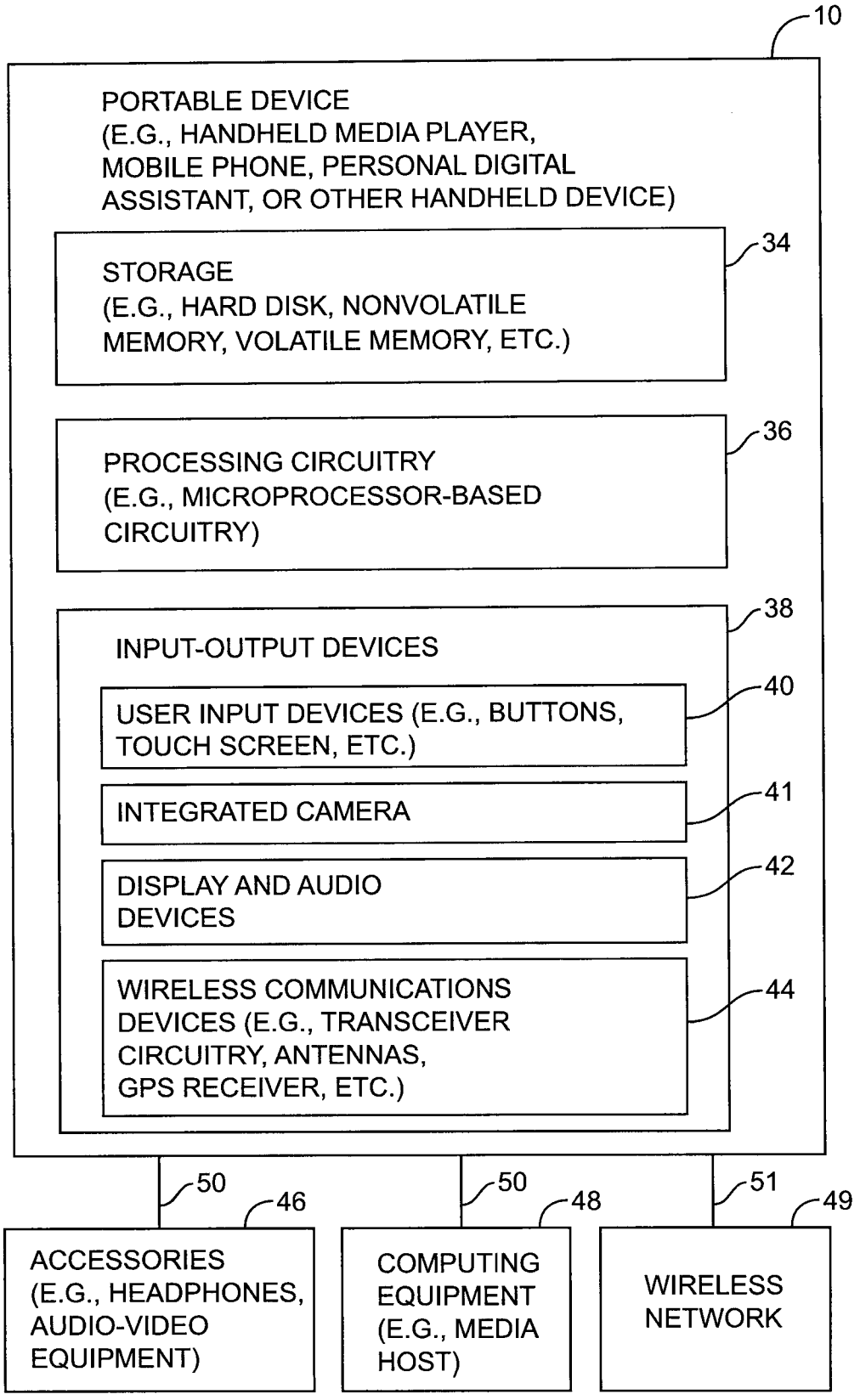

10
PORTABLE DEVICE
(E.G., HANDHELD MEDIA PLAYER,
MOBILE PHONE, PERSONAL DIGITAL
ASSISTANT, OR OTHER HANDHELD DEVICE)
STORAGE
(E.G., HARD DISK, NONVOLATILE
MEMORY, VOLATILE MEMORY, ETC.)
34
PROCESSING CIRCUITRY
(E.G., MICROPROCESSOR-BASED
CIRCUITRY)
36
INPUT-OUTPUT DEVICES
38
USER INPUT DEVICES (E.G., BUTTONS,
TOUCH SCREEN, ETC.)
40
INTEGRATED CAMERA
41
DISPLAY AND AUDIO
DEVICES
42
WIRELESS COMMUNICATIONS
DEVICES (E.G., TRANSCEIVER
CIRCUITRY, ANTENNAS,
GPS RECEIVER, ETC.)
44
50
46
ACCESSORIES
(E.G., HEADPHONES,
AUDIO-VIDEO
EQUIPMENT)
50
48
COMPUTING
EQUIPMENT
(E.G., MEDIA
HOST)
51
49
WIRELESS
NETWORK

FIG. 2

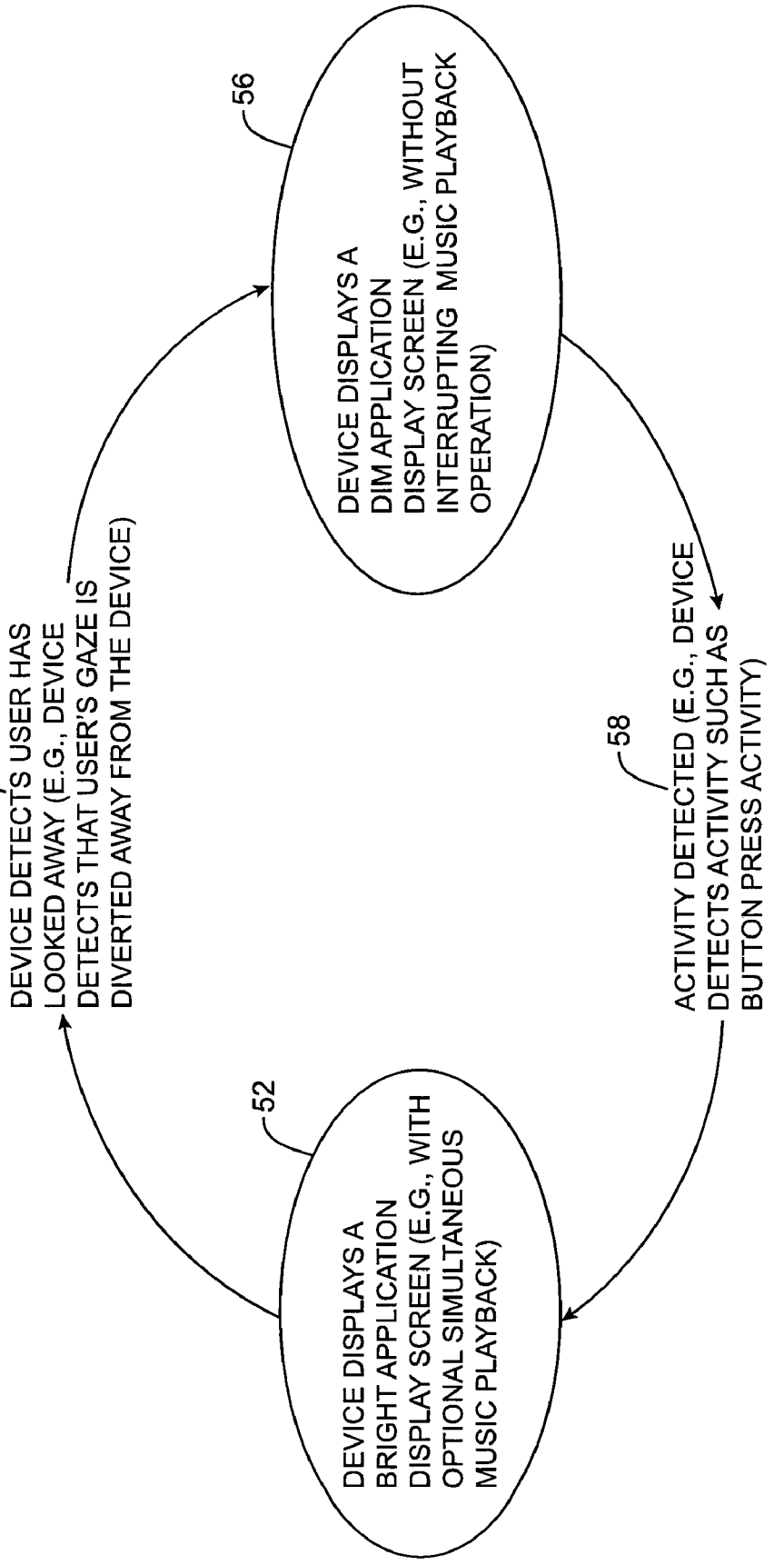

52
DEVICE DISPLAYS A BRIGHT APPLICATION DISPLAY SCREEN (E.G., WITH OPTIONAL SIMULTANEOUS MUSIC PLAYBACK)
54
DEVICE DETECTS USER HAS LOOKED AWAY (E.G., DEVICE DETECTS THAT USER'S GAZE IS DIVERTED AWAY FROM THE DEVICE)
56
DEVICE DISPLAYS A DIM APPLICATION DISPLAY SCREEN (E.G., WITHOUT INTERRUPTING MUSIC PLAYBACK OPERATION)
58
ACTIVITY DETECTED (E.G., DEVICE DETECTS ACTIVITY SUCH AS BUTTON PRESS ACTIVITY)

FIG. 3

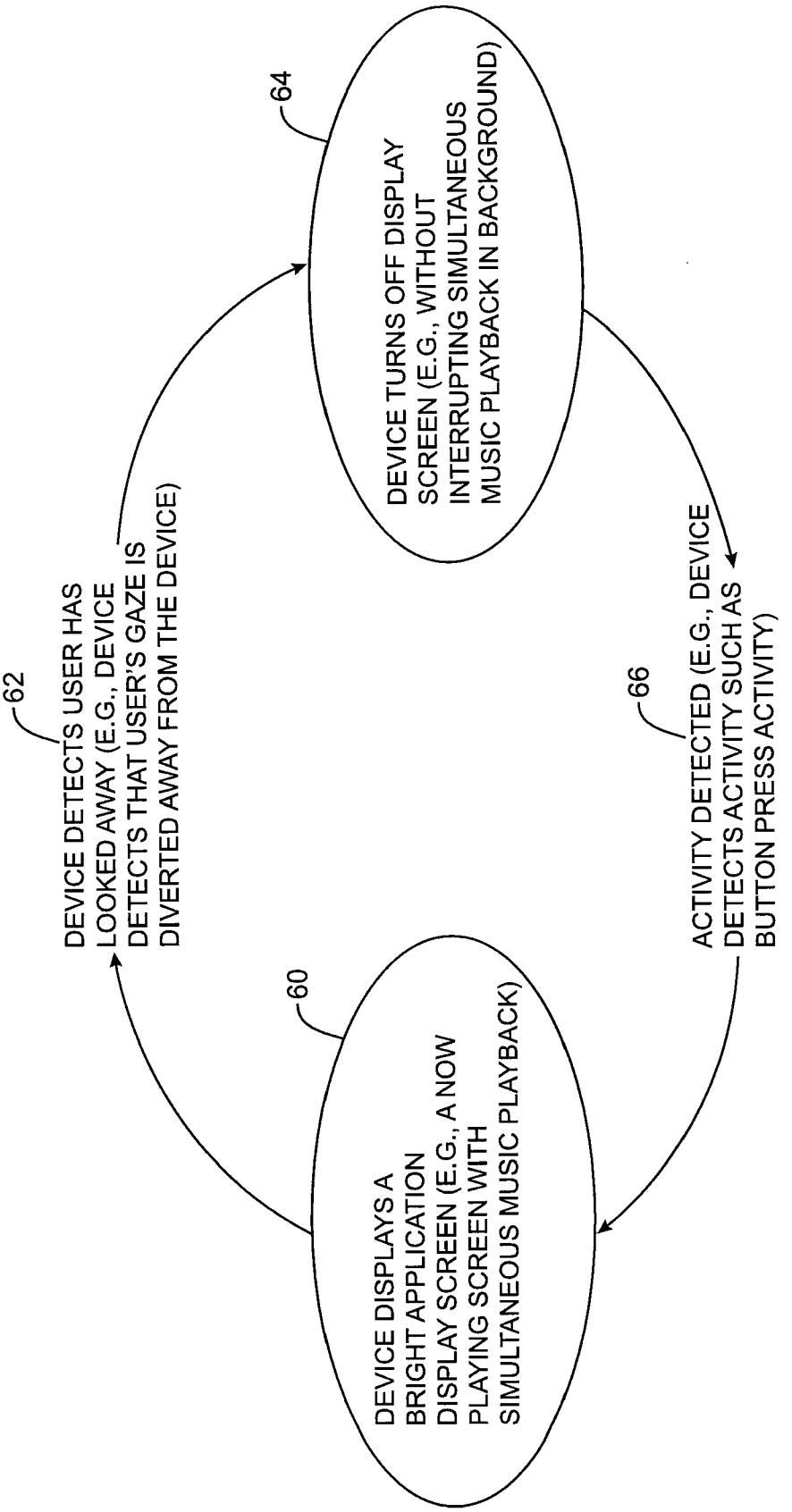

64
DEVICE TURNS OFF DISPLAY SCREEN (E.G., WITHOUT INTERRUPTING SIMULTANEOUS MUSIC PLAYBACK IN BACKGROUND)
62
DEVICE DETECTS USER HAS LOOKED AWAY (E.G., DEVICE DETECTS THAT USER'S GAZE IS DIVERTED AWAY FROM THE DEVICE)
66
ACTIVITY DETECTED (E.G., DEVICE DETECTS ACTIVITY SUCH AS BUTTON PRESS ACTIVITY)
60
DEVICE DISPLAYS A BRIGHT APPLICATION DISPLAY SCREEN (E.G., A NOW PLAYING SCREEN WITH SIMULTANEOUS MUSIC PLAYBACK)

FIG. 4

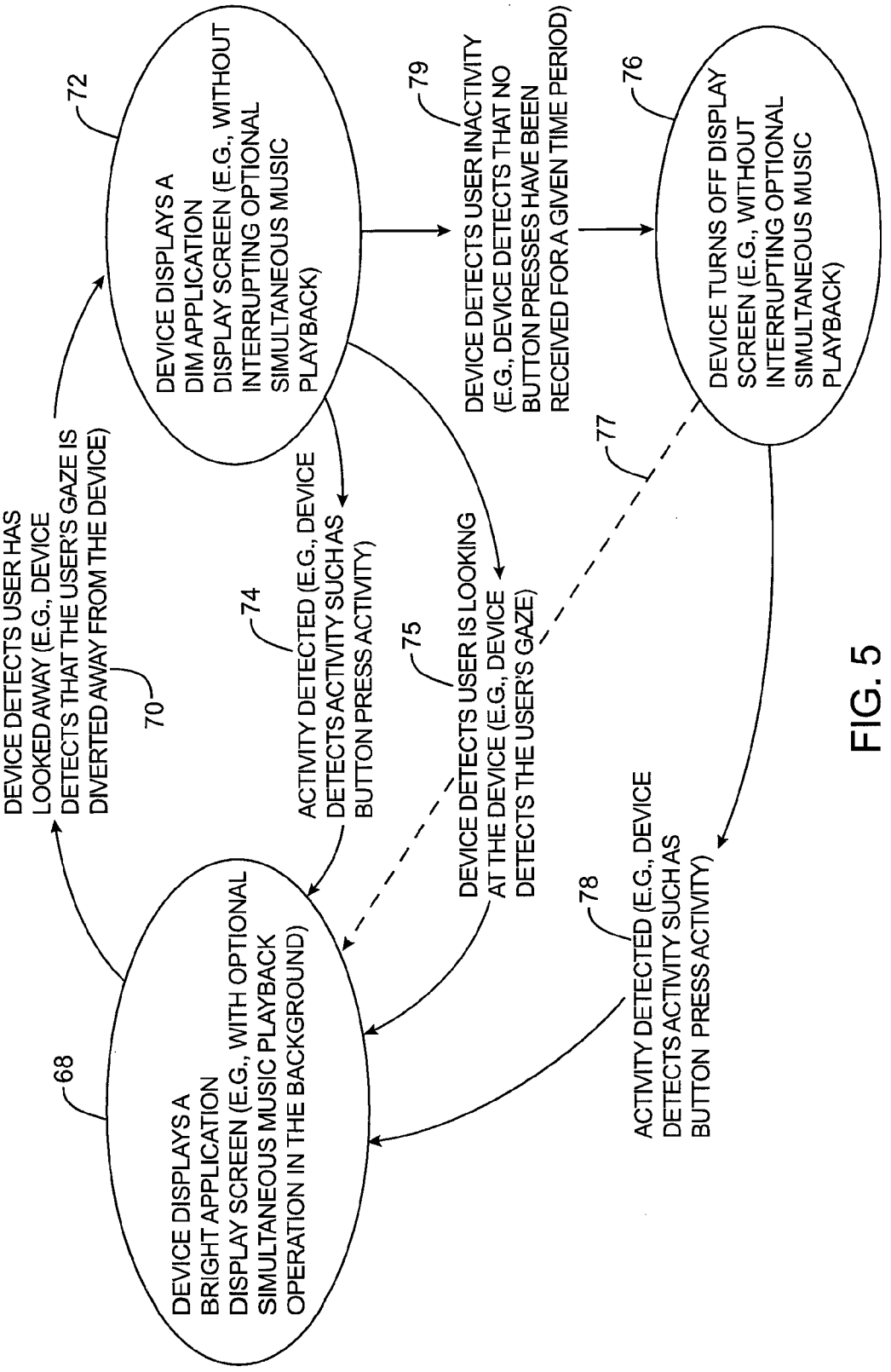

72
DEVICE DISPLAYS A DIM APPLICATION DISPLAY SCREEN (E.G., WITHOUT INTERRUPTING OPTIONAL SIMULTANEOUS MUSIC PLAYBACK)
79
DEVICE DETECTS USER INACTIVITY (E.G., DEVICE DETECTS THAT NO BUTTON PRESSES HAVE BEEN RECEIVED FOR A GIVEN TIME PERIOD)
76
DEVICE TURNS OFF DISPLAY SCREEN (E.G., WITHOUT INTERRUPTING OPTIONAL SIMULTANEOUS MUSIC PLAYBACK)
DEVICE DETECTS USER HAS LOOKED AWAY (E.G., DEVICE DETECTS THAT THE USER'S GAZE IS DIVERTED AWAY FROM THE DEVICE)
70
74
ACTIVITY DETECTED (E.G., DEVICE DETECTS ACTIVITY SUCH AS BUTTON PRESS ACTIVITY)
75
DEVICE DETECTS USER IS LOOKING AT THE DEVICE (E.G., DEVICE DETECTS THE USER'S GAZE)
77
78
ACTIVITY DETECTED (E.G., DEVICE DETECTS ACTIVITY SUCH AS BUTTON PRESS ACTIVITY)
68
DEVICE DISPLAYS A BRIGHT APPLICATION DISPLAY SCREEN (E.G., WITH OPTIONAL SIMULTANEOUS MUSIC PLAYBACK OPERATION IN THE BACKGROUND)

FIG. 5

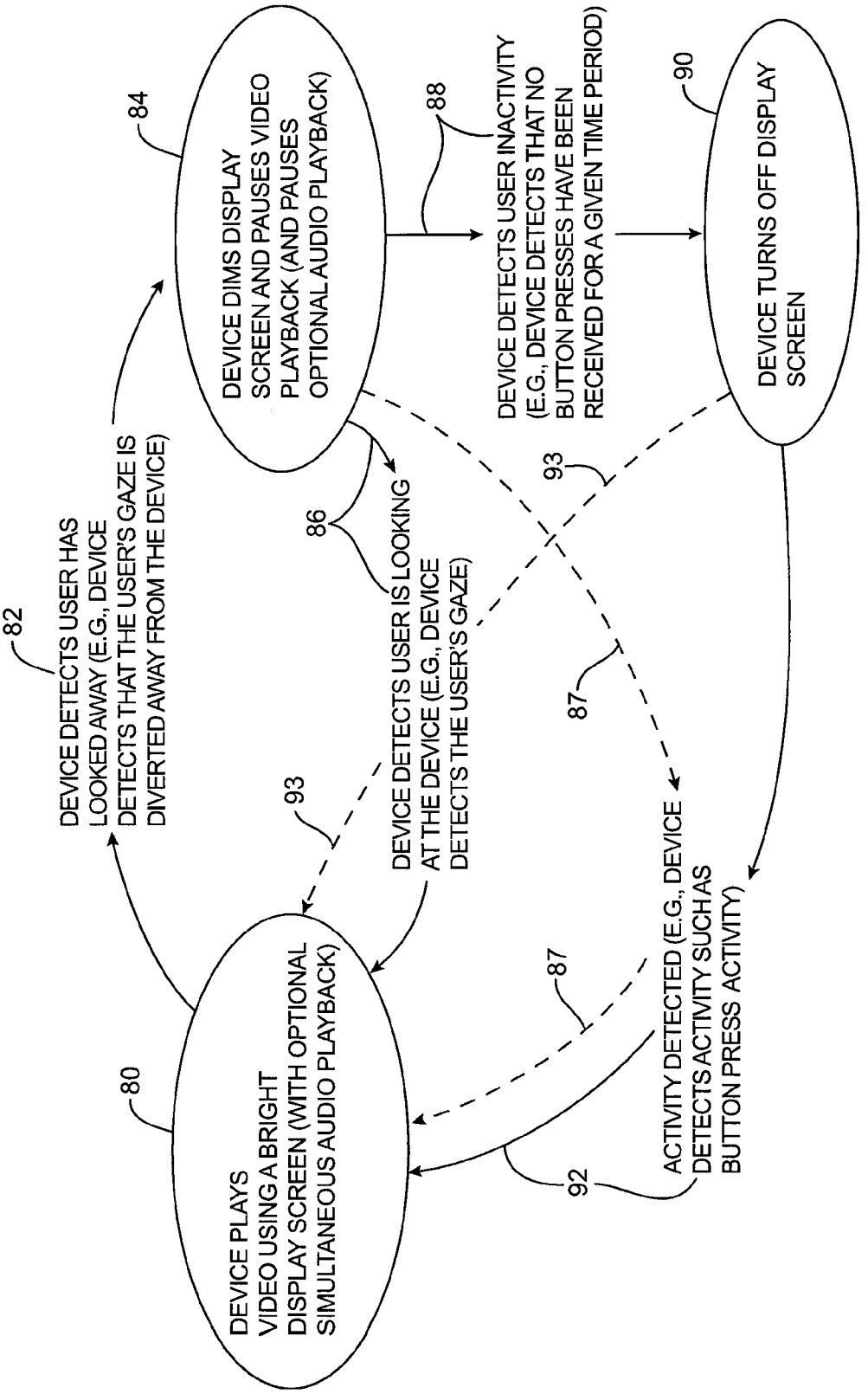

DEVICE PLAYS VIDEO USING A BRIGHT DISPLAY SCREEN (WITH OPTIONAL SIMULTANEOUS AUDIO PLAYBACK)
80
DEVICE DIMS DISPLAY SCREEN AND PAUSES VIDEO PLAYBACK (AND PAUSES OPTIONAL AUDIO PLAYBACK)
84
DEVICE TURNS OFF DISPLAY SCREEN
90
DEVICE DETECTS USER HAS LOOKED AWAY (E.G., DEVICE DETECTS THAT THE USER'S GAZE IS DIVERTED AWAY FROM THE DEVICE)
82
DEVICE DETECTS USER IS LOOKING AT THE DEVICE (E.G., DEVICE DETECTS THE USER'S GAZE)
86
DEVICE DETECTS USER INACTIVITY (E.G., DEVICE DETECTS THAT NO BUTTON PRESSES HAVE BEEN RECEIVED FOR A GIVEN TIME PERIOD)
88
ACTIVITY DETECTED (E.G., DEVICE DETECTS ACTIVITY SUCH AS BUTTON PRESS ACTIVITY)
92
87
93
87
93

FIG. 6

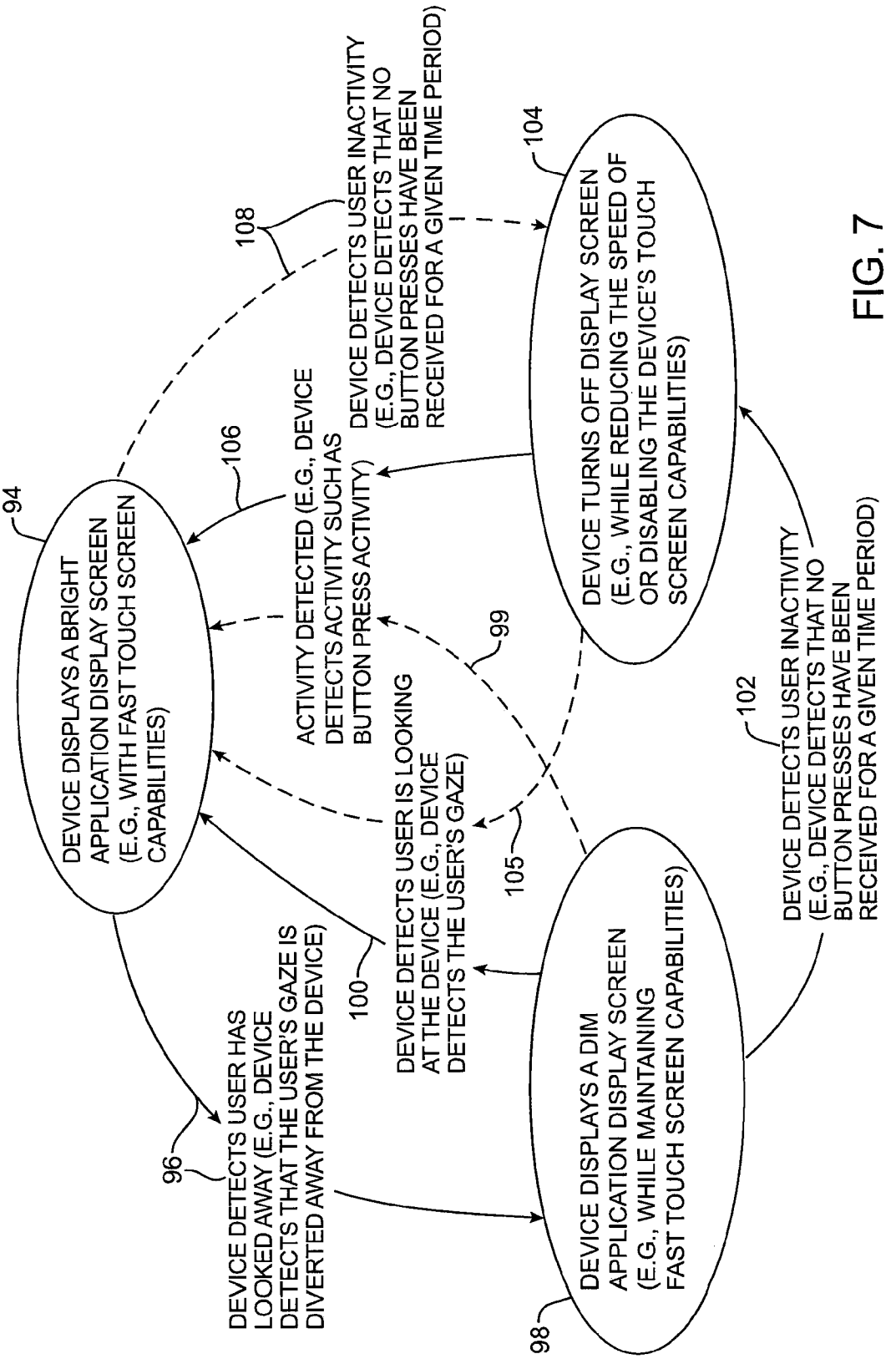

94
DEVICE DISPLAYS A BRIGHT APPLICATION DISPLAY SCREEN (E.G., WITH FAST TOUCH SCREEN CAPABILITIES)
96
DEVICE DETECTS USER HAS LOOKED AWAY (E.G., DEVICE DETECTS THAT THE USER'S GAZE IS DIVERTED AWAY FROM THE DEVICE)
98
DEVICE DISPLAYS A DIM APPLICATION DISPLAY SCREEN (E.G., WHILE MAINTAINING FAST TOUCH SCREEN CAPABILITIES)
100
DEVICE DETECTS USER IS LOOKING AT THE DEVICE (E.G., DEVICE DETECTS THE USER'S GAZE)
102
DEVICE DETECTS USER INACTIVITY (E.G., DEVICE DETECTS THAT NO BUTTON PRESSES HAVE BEEN RECEIVED FOR A GIVEN TIME PERIOD)
104
DEVICE TURNS OFF DISPLAY SCREEN (E.G., WHILE REDUCING THE SPEED OF OR DISABLING THE DEVICE'S TOUCH SCREEN CAPABILITIES)
105
99
106
ACTIVITY DETECTED (E.G., DEVICE DETECTS ACTIVITY SUCH AS BUTTON PRESS ACTIVITY)
108
DEVICE DETECTS USER INACTIVITY (E.G., DEVICE DETECTS THAT NO BUTTON PRESSES HAVE BEEN RECEIVED FOR A GIVEN TIME PERIOD)

FIG. 7

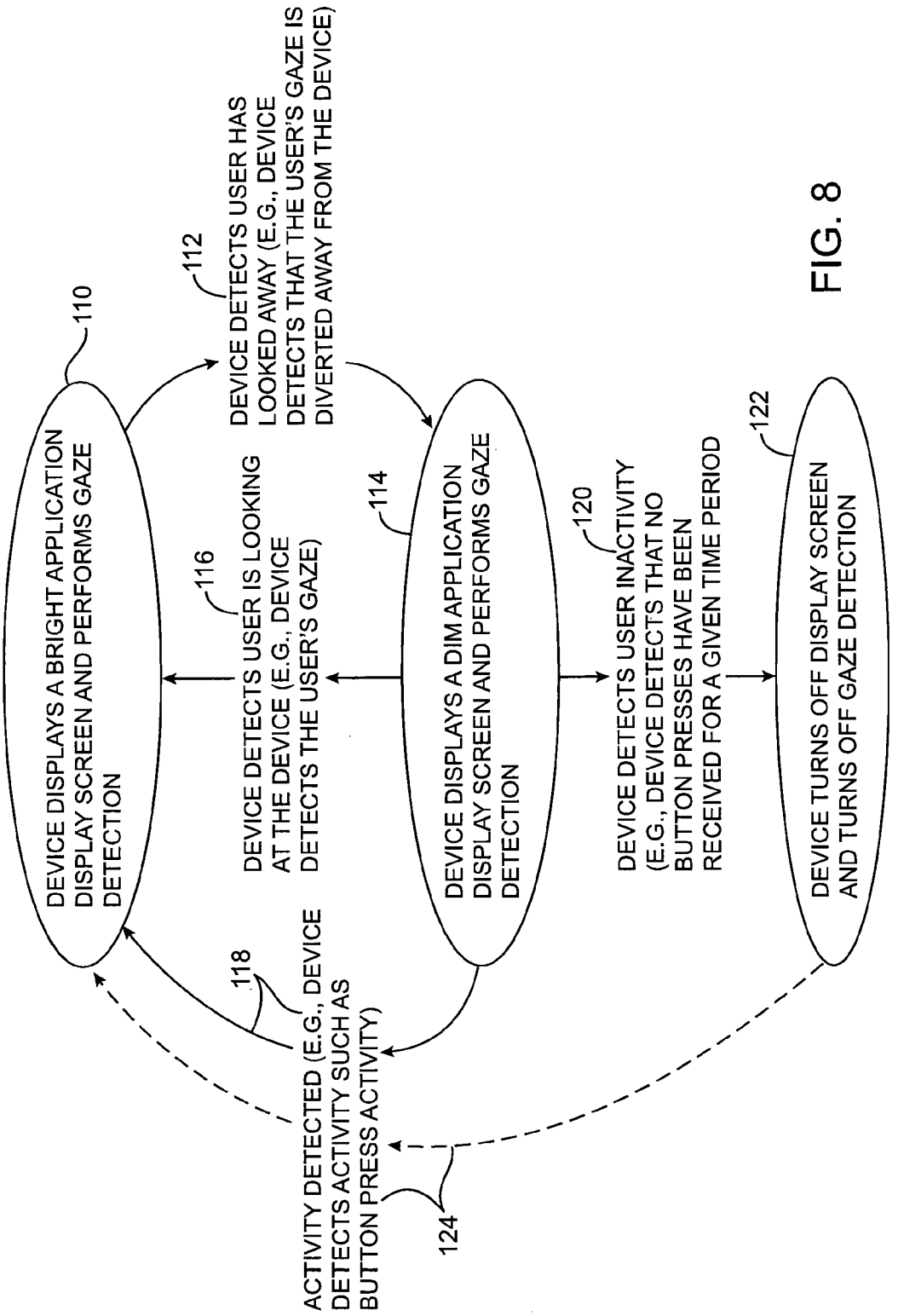

DEVICE DISPLAYS A BRIGHT APPLICATION DISPLAY SCREEN AND PERFORMS GAZE DETECTION
110
DEVICE DETECTS USER HAS LOOKED AWAY (E.G., DEVICE DETECTS THAT THE USER'S GAZE IS DIVERTED AWAY FROM THE DEVICE)
112
DEVICE DETECTS USER IS LOOKING AT THE DEVICE (E.G., DEVICE DETECTS THE USER'S GAZE)
116
DEVICE DISPLAYS A DIM APPLICATION DISPLAY SCREEN AND PERFORMS GAZE DETECTION
114
DEVICE DETECTS USER INACTIVITY (E.G., DEVICE DETECTS THAT NO BUTTON PRESSES HAVE BEEN RECEIVED FOR A GIVEN TIME PERIOD
120
DEVICE TURNS OFF DISPLAY SCREEN AND TURNS OFF GAZE DETECTION
122
ACTIVITY DETECTED (E.G., DEVICE DETECTS ACTIVITY SUCH AS BUTTON PRESS ACTIVITY)
118
124

FIG. 8

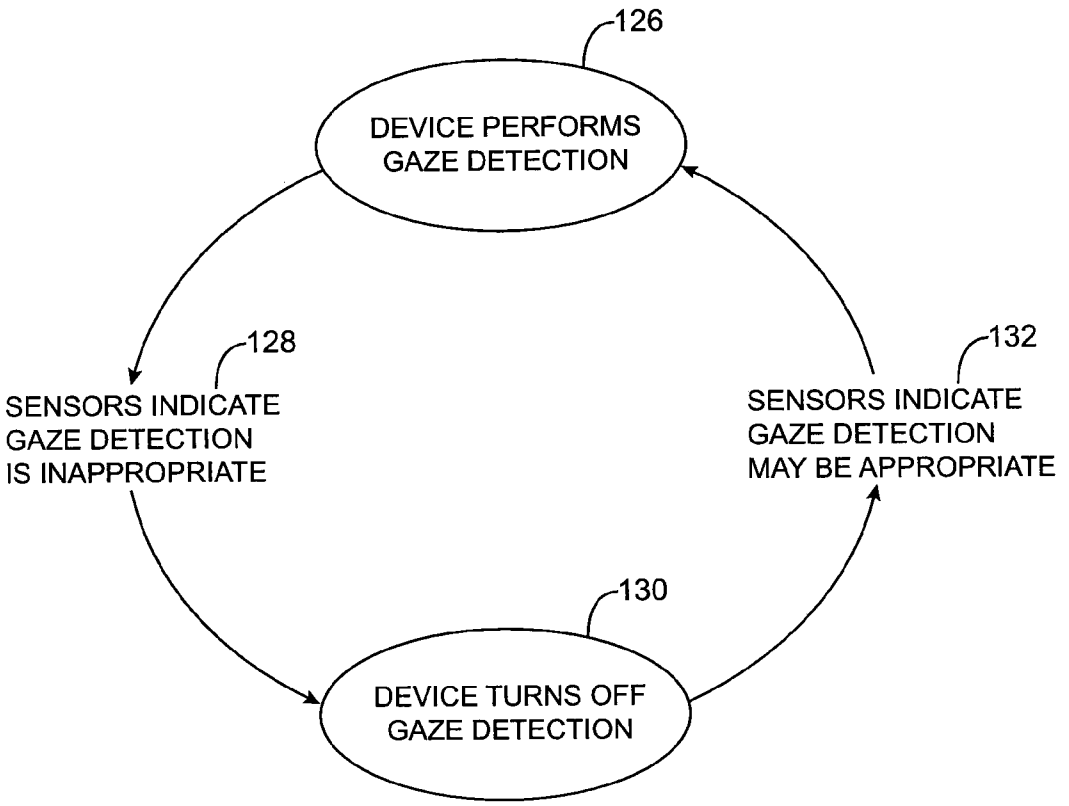

126
DEVICE PERFORMS GAZE DETECTION
128
SENSORS INDICATE GAZE DETECTION IS INAPPROPRIATE
132
SENSORS INDICATE GAZE DETECTION MAY BE APPROPRIATE
130
DEVICE TURNS OFF GAZE DETECTION

FIG. 9

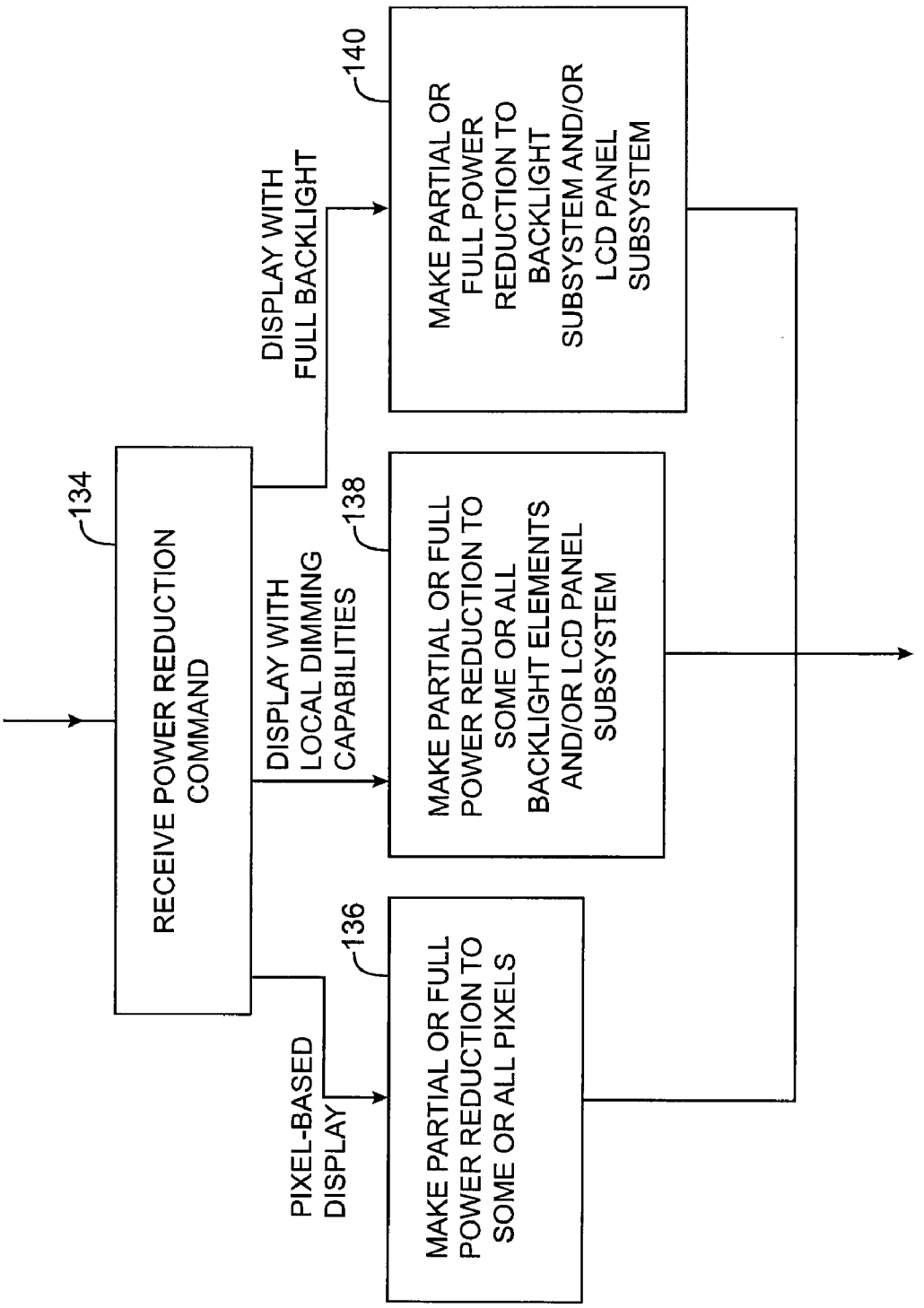

134
RECEIVE POWER REDUCTION COMMAND
DISPLAY WITH FULL BACKLIGHT
DISPLAY WITH LOCAL DIMMING CAPABILITIES
PIXEL-BASED DISPLAY
136
MAKE PARTIAL OR FULL POWER REDUCTION TO SOME OR ALL PIXELS
138
MAKE PARTIAL OR FULL POWER REDUCTION TO SOME OR ALL BACKLIGHT ELEMENTS AND/OR LCD PANEL SUBSYSTEM
140
MAKE PARTIAL OR FULL POWER REDUCTION TO BACKLIGHT SUBSYSTEM AND/OR LCD PANEL SUBSYSTEM

FIG. 10

ELECTRONIC DEVICES WITH GAZE DETECTION CAPABILITIES

BACKGROUND

[0001] This invention relates generally to electronic devices, and more particularly, to electronic devices such as portable electronic devices that have gaze detection capabilities.

[0002] Electronic devices such as portable electronic devices are becoming increasingly popular. Examples of portable devices include handheld computers, cellular telephones, media players, and hybrid devices that include the functionality of multiple devices of this type. Popular portable electronic devices that are somewhat larger than traditional handheld electronic devices include laptop computers and tablet computers.

[0003] To satisfy consumer demand for small form factor portable electronic devices, manufacturers are continually striving to reduce the size of components that are used in these devices. For example, manufacturers have made attempts to miniaturize the batteries used in portable electronic devices.

[0004] An electronic device with a small battery has limited battery capacity. Unless care is taken to consume power wisely, an electronic device with a small battery may exhibit unacceptably short battery life. Techniques for reducing power consumption may be particularly important in wireless devices that support cellular telephone communications, because users of cellular telephone devices often demand long "talk" times.

[0005] Conventional portable electronic devices use various techniques for reducing their power consumption. Because display screens in electronic devices can consume relatively large amounts of power, power conservation techniques in portable electronic devices with display screens typically involve turning off the display screens at particular times. Unfortunately, conventional power conservation techniques may turn off display screens at inappropriate times, thereby interfering with a user's ability to interact with a device. Conventional techniques may also leave display screens on at inappropriate times, wasting valuable battery power.

[0006] It would therefore be desirable to be able to provide improved ways in which to conserve power in electronic devices.

SUMMARY

[0007] An electronic device is provided that may have gaze detection capabilities. One or more gaze detection sensors such as a camera may be used by the electronic device to determine whether a user's gaze is directed towards the electronic device (e.g., whether the user of the electronic device is looking at the electronic device). In particular, the electronic device may use gaze detection sensors to determine whether or not the user is looking at a display portion of the electronic device.

[0008] In an illustrative embodiment, the electronic device may have power management capabilities that are used to help conserve power. The electronic device may operate in two or more operating modes. One operation mode may be used to optimize performance. Another operating mode may help to extend battery life. The electronic device may use results from gaze detection operations to determine an appropriate mode in which to operate the electronic device.

[0009] For example, the electronic device may operate in an active mode when the electronic device determines, using gaze detection sensors, that the user's gaze is directed towards the electronic device and may operate in one or more standby modes when the device determines that the user's gaze is not directed towards the electronic device. When the electronic device is operating in one of the standby modes, circuitry and components such as a display screen, touch screen components, gaze detection components, and a central processing unit or CPU in the electronic device may be powered down or operated in a low-power mode to minimize power consumption in the electronic device.

[0010] With one suitable arrangement, when the electronic device is in the active mode and detects that the user has looked away from the device, the electronic device may dim or turn off a display screen. If desired, the electronic device can dim the display screen to a standby brightness level after the device has determined that the user has looked away from the device. After a given period of time has elapsed in which no user input has been received by the electronic device, the electronic device can turn off the display screen to conserve power. When the electronic device detects that the user's gaze is directed towards the electronic device, the electronic device may enter the active mode and return the display screen to an active brightness level (e.g., turn on the display screen or brighten the display screen to the active brightness level).

[0011] If desired, the electronic device may be performing an operation, while in the active mode, that is uninterrupted when the electronic device switches to operating in one of the standby modes. For example, the electronic device may be performing a music playback operation while in the active mode and, when the electronic device detects the user's gaze is not directed towards the electronic device, the electronic device may enter one of the standby modes without interrupting the music playback operation.

[0012] With one suitable arrangement, the electronic device may interrupt an operation when the electronic device begins operating in one of the standby mode. For example, the electronic device may be performing a video playback operation while in the active mode. In this example, when the electronic device detects that the user's gaze is no longer directed towards the electronic device, the electronic device may enter one of the standby modes, dim the display screen that was being used for the video playback operation, and pause the video playback operation. If desired, the electronic device may resume the video playback operation when it detects that the user has redirected their gaze towards the electronic device (e.g., towards the video screen).

[0013] In an illustrative embodiment, the electronic device may use readings from sensors such as proximity sensors, ambient light sensors, and motion sensors such as accelerometers to determine whether or not to perform gaze detection operations. For example, the electronic device may suspend gaze detection operations whenever a proximity sensor, ambient light sensor, or accelerometer indicates that gaze detection operations are inappropriate (e.g., because of an object in close proximity with the electronic device, insufficient ambient light for gaze detection sensors to detect the user's gaze, excessive vibration which may degrade the performance of gaze detection sensors, etc.).

[0014] An advantage of powering down the display is that a powered down display can help to prevent information on the display from being viewed by an unauthorized viewer. It may

therefore be helpful to turn off a display when the lack of a user's gaze indicates that the user is not present to guard the device.

[0015] Further features of the invention, its nature and various advantages will be more apparent from the accompanying drawings and the following detailed description of the preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. **1** is a perspective view of an illustrative portable electronic device that may have gaze detection capabilities in accordance with an embodiment of the present invention.

[0017] FIG. **2** is a schematic diagram of an illustrative portable electronic device that may have gaze detection capabilities in accordance with an embodiment of the present invention.

[0018] FIG. **3** is a state diagram of illustrative operating modes of an illustrative electronic device with gaze detection capabilities in accordance with an embodiment of the present invention.

[0019] FIG. **4** is a state diagram of illustrative operating modes of an illustrative electronic device with gaze detection capabilities during a music playback operation in accordance with an embodiment of the present invention.

[0020] FIG. **5** is a state diagram of illustrative operating modes of an illustrative electronic device with gaze detection capabilities and activity detection capabilities in accordance with an embodiment of the present invention.

[0021] FIG. **6** is a state diagram of illustrative operating modes of an illustrative electronic device with gaze detection capabilities during a video playback operation in accordance with an embodiment of the present invention.

[0022] FIG. **7** is a state diagram of illustrative operating modes of an illustrative electronic device with gaze detection and touch screen input capabilities in accordance with an embodiment of the present invention.

[0023] FIG. **8** is a state diagram of illustrative operating modes of an illustrative electronic device with gaze detection capabilities in accordance with an embodiment of the present invention.

[0024] FIG. **9** is a state diagram of illustrative operating modes of an illustrative electronic device with gaze detection capabilities and sensors such as environment sensors in accordance with an embodiment of the present invention.

[0025] FIG. **10** is a flow chart of illustrative steps involved in reducing power to displays in an electronic device in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION

[0026] The present invention relates generally to electronic devices, and more particularly, to electronic devices such as portable electronic devices that have gaze detection capabilities.

[0027] With one suitable arrangement, an electronic device with gaze detection capabilities may have the ability to determine whether a user's gaze is within a given boundary without resolving the specific location of the user's gaze within that boundary. The electronic device, as an example, may be able to detect whether a user's gaze is directed towards a display associated with the device. With another suitable arrangement, an electronic device may have gaze tracking capabilities. Gaze tracking capabilities allow the electronic device to determine not only whether or not a user's gaze is directed towards a display associated with the device but also which portion of the display the user's gaze is directed towards.

[0028] An electronic device may be used to detect a user's gaze and adjust its behavior according to whether or not the user's gaze is detected. For example, the electronic device may be able to detect whether or not the user is looking at the device and adjust power management settings accordingly. With one suitable arrangement, the electronic device may delay turning device components off (e.g., components which would otherwise be turned off as part of a power management scheme) while the user's gaze is directed towards the device and the electronic device may accelerate the shutdown of device components when the user's gaze is not detected. For example, when the user's gaze is detected, a device with a display may keep the display at normal brightness rather than dimming the display and, when the device detects the user is no longing looking at the device, the device may dim or turn off the display. This type of arrangement may be especially beneficial in situations in which the user is not actively controlling the electronic device (e.g., the user is not pressing buttons or supplying touch screen inputs) but is still interacting with the electronic device (e.g., the user is reading text on the display, watching video on the display, etc.). An advantage of turning off the display when the user is not looking at the display is this may help prevent unauthorized users from viewing information on the display, thereby enhancing device security.

[0029] Electronic devices that have gaze detection capabilities may be portable electronic devices such as laptop computers or small portable computers of the type that are sometimes referred to as ultraportables. Portable electronic devices may also be somewhat smaller devices. Examples of smaller portable electronic devices include wrist-watch devices, pendant devices, headphone and earpiece devices, and other wearable and miniature devices. With one suitable arrangement, the portable electronic devices may be wireless electronic devices.

[0030] The wireless electronic devices may be, for example, handheld wireless devices such as cellular telephones, media players with wireless communications capabilities, handheld computers (also sometimes called personal digital assistants), global positioning system (GPS) devices, and handheld gaming devices. The wireless electronic devices may also be hybrid devices that combine the functionality of multiple conventional devices. Examples of hybrid portable electronic devices include a cellular telephone that includes media player functionality, a gaming device that includes a wireless communications capability, a cellular telephone that includes game and email functions, and a portable device that receives email, supports mobile telephone calls, has music player functionality, and supports web browsing. These are merely illustrative examples.

[0031] An illustrative portable electronic device in accordance with an embodiment of the present invention is shown in FIG. **1**. User device **10** may be any suitable electronic device such as a portable or handheld electronic device. Device **10** of FIG. **1** may be, for example, a handheld electronic device that supports 2G and/or 3G cellular telephone and data functions, global positioning system capabilities or other satellite navigation capabilities, and local wireless communications capabilities (e.g., IEEE 802.11 and Bluetooth®) and that supports handheld computing device functions such

as internet browsing, email and calendar functions, games, music player functionality, etc.

[0032] Device **10** may have a housing **12**. Display **16** may be attached to housing **12** using bezel **14**. Display **16** may be a touch screen liquid crystal display (as an example). Display **16** may have pixels that can be controlled individually in connection with power consumption adjustments. For example, in an organic light emitting diode (OLED) display, power can be reduced by making full and/or partial brightness reductions to some or all of the pixels. Display **16** may be formed from a panel subsystem and a backlight subsystem. For example, display **16** may have a liquid crystal display (LCD) panel subsystem and a light emitting diode or fluorescent tube backlight subsystem. In backlight subsystems that contain individually controllable elements such as light emitting diodes, the brightness of the backlight elements may be selectively controlled. For example, the brightness of some of the backlight elements may be reduced while the other backlight elements remain fully powered. In backlight subsystems that contain a single backlight element, the power of the single element may be partially or fully reduced to reduce power consumption. It may also be advantageous to make power adjustments to the circuitry that drives the LCD panel subsystem.

[0033] Display screen **16** (e.g., a touch screen) is merely one example of an input-output device that may be used with electronic device **10**. If desired, electronic device **10** may have other input-output devices. For example, electronic device **10** may have user input control devices such as button **19**, and input-output components such as port **20** and one or more input-output jacks (e.g., for audio and/or video). Button **19** may be, for example, a menu button. Port **20** may contain a 30-pin data connector (as an example). Openings **22** and **24** may, if desired, form speaker and microphone ports. Speaker port **22** may be used when operating device **10** in speakerphone mode. Opening **23** may also form a speaker port. For example, speaker port **23** may serve as a telephone receiver that is placed adjacent to a user's ear during operation. In the example of FIG. **1**, display screen **16** is shown as being mounted on the front face of handheld electronic device **10**, but display screen **16** may, if desired, be mounted on the rear face of handheld electronic device **10**, on a side of device **10**, on a flip-up portion of device **10** that is attached to a main body portion of device **10** by a hinge (for example), or using any other suitable mounting arrangement.

[0034] A user of electronic device **10** may supply input commands using user input interface devices such as button **19** and touch screen **16**. Suitable user input interface devices for electronic device **10** include buttons (e.g., alphanumeric keys, power on-off, power-on, power-off, and other specialized buttons, etc.), a touch pad, pointing stick, or other cursor control device, a microphone for supplying voice commands, or any other suitable interface for controlling device **10**. Buttons such as button **19** and other user input interface devices may generally be formed on any suitable portion of electronic device **10**. For example, a button such as button **19** or other user interface control may be formed on the side of electronic device **10**. Buttons and other user interface controls can also be located on the top face, rear face, or other portion of device **10**. If desired, device **10** can be controlled remotely (e.g., using an infrared remote control, a radio-frequency remote control such as a Bluetooth® remote control, etc.).

[0035] If desired, device **10** may contain sensors such as a proximity sensor and an ambient light sensor. A proximity sensor may be used to detect when device **10** is close to a user's head or other object. An ambient light sensor may be used to make measurements of current light levels.

[0036] Device **10** may have a camera or other optical sensor such as camera **30** that can be used for gaze detection operations. Cameras used for gaze detection may, for example, be used by device **10** to capture images of a user's face that are processed by device **10** to detect where the user's gaze is directed. Camera **30** may be integrated into housing **12**. While shown as being formed on the top face of electronic device **10** in the example of FIG. **1**, cameras such as camera **30** may generally be formed on any suitable portion of electronic device **10**. For example, camera **30** may be mounted on a flip-up portion of device **10** that is attached to a main body portion of device **10** by a hinge or may be mounted between the flip-up portion of device **10** and the main body portion of device **10** (e.g., in the hinge region between the flip-up portion and the main body portion such that the camera can be used regardless of whether the device is flipped open or is closed). Device **10** may also have additional cameras (e.g., device **10** may have camera **30** on the top face of device **10** for gaze detection operations and another camera on the bottom face of device **10** for capturing images and video).

[0037] If desired, the gaze detection functions of camera **30** may be implemented using an optical sensor that has been optimized for gaze detection operations. For example, camera **30** may include one or more light emitting diodes (LED's) and an optical sensor capable of detecting reflections of light emitted from the LEDs off of the users' eyes when the users are gazing at device **10**. The light emitting diodes may emit a modulated infrared light and the optical sensor may be synchronized to detect reflections of the modulated infrared light, as an example. In general, any suitable gaze detection image sensor and circuitry may be used for supporting gaze detection operations in device **10**. The use of camera **30** is sometimes described herein as an example.

[0038] A schematic diagram of an embodiment of an illustrative portable electronic device such as a handheld electronic device is shown in FIG. **2**. Portable device **10** may be a mobile telephone, a mobile telephone with media player capabilities, a handheld computer, a remote control, a game player, a global positioning system (GPS) device, a laptop computer, a tablet computer, an ultraportable computer, a hybrid device that includes the functionality of some or all of these devices, or any other suitable portable electronic device.

[0039] As shown in FIG. **2**, device **10** may include storage **34**. Storage **34** may include one or more different types of storage such as hard disk drive storage, nonvolatile memory (e.g., flash memory or other electrically-programmable-read-only memory), volatile memory (e.g., battery-based static or dynamic random-access-memory), etc.

[0040] Processing circuitry **36** may be used to control the operation of device **10**. Processing circuitry **36** may be based on a processor such as a microprocessor and other suitable integrated circuits. With one suitable arrangement, processing circuitry **36** and storage **34** are used to run software on device **10**, such as gaze detection applications, internet browsing applications, voice-over-internet-protocol (VOIP) telephone call applications, email applications, media playback applications, navigation functions, map functions, operating system functions, power management functions, etc. Processing circuitry **36** and storage **34** may be used in implementing suitable communications protocols. Communications protocols that may be implemented using processing

circuitry **36** and storage **34** include internet protocols, wireless local area network protocols (e.g., IEEE 802.11 protocols—sometimes referred to as Wi-Fi®), protocols for other short-range wireless communications links such as the Bluetooth® protocol, protocols for handling 3G communications services (e.g., using wide band code division multiple access techniques), 2G cellular telephone communications protocols, etc. If desired, processing circuitry **36** may operate in a reduced power mode (e.g., circuitry **36** may be suspended or operated at a lower frequency) when device **10** enters a suitable standby mode.

[0041] Input-output devices **38** may be used to allow data to be supplied to device **10** and to allow data to be provided from device **10** to external devices. Display screen **16**, camera **30**, button **19**, microphone port **24**, speaker port **22**, and dock connector port **20** are examples of input-output devices **38**. In general, input-output devices **38** may include any suitable components for receiving input and/or providing output from device **10**. For example, input-output devices **38** can include user input-output devices **40** such as buttons, touch screens, joysticks, click wheels, scrolling wheels, touch pads, key pads, keyboards, microphones, etc. A user can control the operation of device **10** by supplying commands through user input devices **40**. Input-output device **38** may include sensors such as proximity sensors, ambient light sensors, orientation sensors, proximity sensors, and any other suitable sensors.

[0042] Input-output devices **38** may include a camera such as integrated camera **41** (e.g., a camera that is integrated into the housing of device **10**) and camera **30** of FIG. **1**. Cameras such as camera **41** and camera **30** may be used as part of a gaze detection system. For example, camera **41** may be used by device **10** to capture images that are processed by a gaze detection application running on processing circuitry **36** to determine whether or not a user's gaze is directed towards the device. Cameras such as camera **41** and camera **30** may, if desired, be provided with image stabilization capabilities (e.g., using feedback derived from an accelerometer, orientation sensor, or other sensor).

[0043] Display and audio devices **42** may include liquid-crystal display (LCD) screens or other screens, light-emitting diodes (LEDs), and other components that present visual information and status data. Display and audio devices **42** may also include audio equipment such as speakers and other devices for creating sound. Display and audio devices **42** may contain audio-video interface equipment such as jacks and other connectors for external headphones and monitors.

[0044] Wireless communications devices **44** may include communications circuitry such as radio-frequency (RF) transceiver circuitry formed from one or more integrated circuits, power amplifier circuitry, passive RF components, antennas, and other circuitry for handling RF wireless signals. Wireless signals can also be sent using light (e.g., using infrared communications).

[0045] Device **10** can communicate with external devices such as accessories **46**, computing equipment **48**, and wireless network **49**, as shown by paths **50** and **51**. Paths **50** may include wired and wireless paths. Path **51** may be a wireless path. Accessories **46** may include headphones (e.g., a wireless cellular headset or audio headphones) and audio-video equipment (e.g., wireless speakers, a game controller, or other equipment that receives and plays audio and video content), a peripheral such as a wireless printer or camera, etc.

[0046] Computing equipment **48** may be any suitable computer. With one suitable arrangement, computing equipment **48** is a computer that has an associated wireless access point (router) or an internal or external wireless card that establishes a wireless connection with device **10**. The computer may be a server (e.g., an internet server), a local area network computer with or without internet access, a user's own personal computer, a peer device (e.g., another portable electronic device **10**), or any other suitable computing equipment.

[0047] Wireless network **49** may include any suitable network equipment, such as cellular telephone base stations, cellular towers, wireless data networks, computers associated with wireless networks, etc.

[0048] A device such as device **10** that has gaze detection capabilities may use gaze detector data in implementing a power management scheme. As an example, device **10** may operate in multiple modes to conserve power and may utilize gaze detection operations to assist in determining an appropriate mode in which to operate.

[0049] With one suitable arrangement, the operational modes of device **10** may include modes such as an active mode, a partial standby mode, and a full standby mode. In these and other operational modes, device **10** may adjust the brightness of display **16** and may turn display **16** on or off whenever appropriate in order to conserve power. For example, display **16** may be at an active brightness when device **10** is in the active mode, a standby brightness when device **10** is in the partial standby mode, and may be turned off when device **10** is in the full standby mode. The standby brightness may be somewhat dimmer than the active brightness. Generally, the power consumption of display **16** and therefore device **10** will be reduced when the brightness of display **16** is reduced and when display **16** is turned off.

[0050] Consider, as an example, the scenario of FIG. **3**. In mode **52** of FIG. **3**, device **10** is in an active mode. In general, it is generally desirable for device **10** to be in the active mode whenever a user is actively interacting with device **10**. In particular, it is desirable for display **16** to be at the active brightness level whenever the user's gaze is directed towards display **16**.

[0051] When device **10** is in the active mode, a display such as display **16** may be turned on and may display an appropriate screen such as an application display screen at the active brightness level. The active brightness level may be a configurable brightness level. For example, device **10** may receive input from a user to adjust the active brightness level. In general, the active brightness level may be adjusted anywhere between the maximum brightness and minimum brightness level display **16** is capable of.

[0052] If desired, device **10** may be performing a music playback operation when device **10** is in the active mode. In the example of FIG. **3**, the music playback operation may be occurring in the background of the operation of device **10** (e.g., device **10** may be performing the music playback operation while display **16** and user input device **40** are used by the user to perform additional tasks such as writing an e-mail, browsing the web, etc.).

[0053] While device **10** is in the active mode, device **10** may be performing gaze detection operations. For example, when device **10** is in the active mode, device **10** may be capturing images using camera **30** or other image sensing components at regular intervals and maybe analyzing the images using gaze detection software. Based on this analysis, the device can determine whether the user's gaze is directed towards device **10** and display **16**. When device **10** is performing gaze detection operations, device **10** may be capturing images used

for the gaze detection operations at any suitable interval such as thirty times per second, ten times per second, twice per second, once per second, every two seconds, every five seconds, upon occurrence of non-time-based criteria, combinations of these intervals, or at any other suitable time.

[0054] As illustrated by line **54**, when device **10** detects that the user has looked away, device **10** may dim display screen **16** and may enter partial standby mode **56**. Device **10** may detect that the user has diverted their gaze away from device **10** and display **16** using a gaze detection sensor such as camera **30** and gaze detection software running on the hardware of device **10**. If desired, gaze detection processing may be offloaded to specialized gaze detection circuitry (e.g., circuitry in a gaze detection chip or a camera controller).

[0055] In mode **56**, device **10** is in a partial standby mode. In the partial standby mode, the brightness level of display **16** may be reduced from an active brightness level to a standby brightness level to reduce the power consumption of device **10**. When device **10** enters a standby mode such as the partial standby mode, some operations running on device **10** may be suspended or stopped and some operations may continue running. For example, a music playback operation may continue when device **10** enters one of its standby modes while a web browsing application may be suspended. With this type of arrangement, when a user of device **10** is listening to music through the device while browsing the web on display **16**, device **10** can dim display **16** to conserve power whenever the user looks away from display **16** while continuing to play back the music that the user is listening to without interruption.

[0056] As illustrated by line **58**, when device **10** detects activity, device **10** may brighten display screen **16** and may enter active mode **52**. Device **10** may enter active mode **52** in response to user activity such as button press activity received through a button such as button **19** and in response to other activity such as network activity (e.g., activity received through a wired or wireless communications link). In this type of arrangement, device **10** will enter the active mode whenever a user resumes interacting with device **10**.

[0057] As illustrated by FIG. **4**, device **10** may implement a power management scheme that turns off display **16** based on gaze detection data. In particular, device **10** may turn off display **16** when the device detects that the user is not looking at display **16** (e.g., rather than merely dimming display **16** as in the example of FIG. **3**).

[0058] In mode **60**, device **10** is in an active mode. While device **10** is in the active mode, device **10** may perform gaze detection operations. Because device **10** is in the active mode, display **16** may be at an active brightness level. With one suitable arrangement, when device **10** is in active mode **60**, device **10** may be displaying a screen with display **16** that is of interest to the user but which does not demand the user's constant attention. For example, when device **10** is in mode **60**, device **10** may be displaying a screen such as a now playing screen associated with a music playback operation or a telephone information screen associated with a telephone operation (e.g., a new incoming call, a new outgoing call, an active call, etc.). The now playing screen may, for example, include information about the music playback operation such as a track name, album name, artist name, elapsed playback time, remaining playback time, album art, etc. and may include on-screen selectable options (e.g., when display **16** is a touch-screen display) such as play, pause, fast forward, rewind, skip ahead (e.g., to another audio track), skip back, stop, etc. A telephone information screen might include information about a telephone operation such as a current call time, the telephone number associated with a telephone call, a contact name associated with the telephone call, and an image associated with the telephone call and may include on-screen selectable options such as a keypad to enter a telephone number, a call button, an end call button, a hold button, a speakerphone button, a mute button, an add call button, a contacts button, etc.

[0059] As illustrated by line **62**, when device **10** detects that the user has looked away from display **16**, device **10** may turn off display **16** and may enter standby mode **64**. When device **10** is in standby mode **64**, device **10** may continue to perform background operations such as a music playback operation that was occurring before device **10** entered standby mode **64** (e.g., before device **10** detected that the user's gaze was diverted away from display **16**). Because the application screen displayed in mode **60** is of secondary importance to the user, device **10** may turn off display **16** completely when the user looks away without disrupting the user. For example, when a user is listening to an audio track and is also viewing information associated with the audio track on a now playing screen, device **10** can turn off display **16** when the user looks away, while continuing an audio playback operation. The user's primary use of device **10** (listening to music) is not interrupted, even though the secondary use of device **10** (viewing the now playing screen) has been halted.

[0060] In mode **64**, device **10** is in a standby mode. In standby mode **64**, display **16** may be turned off by device **10** to conserve power. When device **10** enters standby mode **64**, suitable components of device **10** may be powered down (if desired). For example, in mode **64**, the power consumption of processing circuitry **36** may be reduced (e.g., by operating fewer processor cores, by reducing the computing frequency of circuitry **36**, etc.). With one suitable arrangement, an operation such as a music playback operation or a telephone call may continue when device **10** is in mode **64**.

[0061] As illustrated by line **66**, when device **10** detects activity such as user activity, device **10** may enter active mode **60** and turn on display **16**. Device **10** may enter active mode **60** in response to any suitable activity such as button press activity, network activity, and gaze detection activity (e.g., when device **10** detects that the user has directed their gaze towards device **10**).

[0062] As shown in the example of FIG. **5**, device **10** may implement a power management scheme that is responsive to gaze detection data and other input data (e.g., user input, network input, etc.). In the power management scheme illustrated in FIG. **5**, device **10** can switch between an active mode, a partial standby mode, and a standby mode. Device **10** may power down hardware components and suspend or slow down software operations depending on the mode in which device **10** is operating. For example, when device **10** is in either of the standby modes, device **10** may reduce the number of processing cores utilized by circuitry **36** and/or may reduce the processing frequency (clock rate) of circuitry such as circuitry **36**. With one suitable arrangement, device **10** may turn display **16** on at an active brightness level in the active mode, dim display **16** to a standby brightness level in the partial standby mode, and turn display **16** off in the standby mode.

[0063] In mode **68**, device **10** is in an active mode. While device **10** is in the active mode, device **10** may perform gaze detection operations. Display **16** may be at the active bright-

ness level while device **10** is in active mode **68**. In mode **68**, device **10** may be displaying an application display screen such as a home page, a music playback application screen, a web browsing application screen, an email application screen, etc. If desired, device **10** may also be performing a music playback operation while in mode **68** (e.g., device **10** may be performing the music playback operation as a background process as device **10** displays the application display screen).

[0064] When device **10** detects that the user has looked away from display **16** (e.g., using a gaze detection sensor such as camera **30**), device **10** may dim display **16** and enter partial standby mode **72**, as illustrated by line **70**.

[0065] In mode **72**, device **10** is in a partial standby mode. In partial standby mode **72**, device **10** may dim display **16** to a partial standby brightness level to conserve power and, if desired, may place other components such as processing circuitry, wireless transceiver circuitry, etc. in a standby mode to conserve power. Certain operations may continue when device **10** enters mode **72**. For example, a music playback operation or a telephone call may continue uninterrupted when device **10** enters mode **72**.

[0066] Device **10** may perform gaze detection operations while in mode **72**. For example, device **10** may continually capture images using camera **30** at regular intervals and may analyze the captured images using gaze detection software to determine whether the user's gaze has returned to device **10** and display **16**. If desired, the rate at which device **10** captures and processes images for gaze detection operations while in mode **72** may be reduced relative to the rate at which gaze detection images are captured and processed while device is in an active mode such as mode **68** (e.g., device **10** may capture images at a rate of once every 100 milliseconds, 250 milliseconds, 500 milliseconds, 1 second, etc. in mode **72** and once every 50 milliseconds, 125 milliseconds, 250 milliseconds, 500 milliseconds, etc. in mode **68**).

[0067] Device **10** may switch from partial standby mode **72** to active mode **68** whenever appropriate. For example, when device **10** detects that a user's gaze is directed towards display **16**, device **10** may enter an active mode such as mode **68** (e.g., as illustrated by line **75**) and may brighten display **16** to the active brightness level. Device **10** may also enter active mode **68** when device **10** detects activity such as user activity received through a button such as button **19** and network activity received through a wired or wireless communications link (e.g., as illustrated by line **74**). In general, device **10** will enter active mode **68** whenever a user resumes interacting with device **10** or device **10** needs to respond to network activity. Because device **10** enters active mode **68** when device **10** detects that the user's gaze is directed towards display **16** (e.g., as illustrated by line **75**), the user of device **10** need not press a button or provide other input to awaken device **10** from the partial standby state. Instead, device **10** can automatically awaken (e.g., switch to active mode **68**) when device **10** detects that the user has directed their gaze towards display **16**.

[0068] If desired, device **10** may operate in a standby mode such as standby mode **76** in which display **16** is turned off. For example, when device **10** is operating in partial standby mode **72** and no user activity is detected for a given period of time (e.g., within a period of time such as one second, two seconds, . . . , ten seconds, twenty seconds, thirty seconds, etc.), device **10** may enter standby mode **76** and turn off display **16**. Device **10** may enter standby mode **76**, as illustrated by line **79**, after device **10** detects that the user has looked away (e.g., as illustrated by line **70**) and after a given period of user inactivity has elapsed following the device's detection that the user looked away.

[0069] In standby mode **76**, device **10** may operate with display **16** turned off. Device **10** may place suitable components into standby. For example, device **10** may turn wireless transceiver circuitry off, reduce the power consumption of processing circuitry such as circuitry **36** (e.g., by turning off selected processing cores or lowering clock rates), turn off sensors such as proximity sensors, ambient light sensors, and accelerometers, and may suspend or power down any other suitable components. If desired, certain operations may continue when device **10** enters and operates in standby mode **76**. For example, a music playback operation or a telephone call may continue uninterrupted when device **10** enters mode **76**.

[0070] With the arrangement of FIG. **5**, as long as device **10** detects that the user's gaze is directed at the device (e.g., the user is looking at display **16**), device **10** may remain in active mode **68**. Device **10** may remain in active mode **68** even when no other user activity is received (e.g., when the user is not pressing a button such as button **19** or providing user input through a touch screen such as touch screen display **16**). This type of arrangement may be beneficial when a user is utilizing device **10** without providing user input and would be inconvenienced by device **10** implementing power management techniques. Device **10** can override power management schemes such as dimming a display screen based on results of gaze detection operations. For example, when device **10** detects a user's gaze and is presenting the user with text or video through display **16**, device **10** may override power management instructions that could otherwise reduce the power of display **16** to ensure that display **16** is not dimmed or turned off even though the user has not provided direct user input.

[0071] If desired, device **10** may continue to perform gaze detection operations when operating in standby mode **76**. As illustrated by dashed line **77**, device **10** may switch from standby mode **76** to active mode **68** whenever device **10** detects that a user's gaze is once again directed towards display **16**.

[0072] As illustrated by line **78**, when device **10** detects activity, device **10** may switch from mode **76** to active mode **68** (e.g., device **10** may turn on display **16** to the active brightness level). As an example, device **10** may enter active mode **68** in response to user activity such as button press activity received through a button such as button **19** and in response to other activity such as network activity (e.g., activity received through a wired or wireless communications link).

[0073] As illustrated in FIG. **6**, device **10** may implement a power management scheme that utilizes gaze detection capabilities while executing a video playback operation (e.g., while playing video for a user). In the scheme illustrated by FIG. **6**, device **10** can operate in an active mode (mode **80**), a pause standby mode (e.g., a partial standby mode such as mode **84**), and a standby mode (mode **90**). With one suitable arrangement, device **10** may be performing a video playback operation for a user when the device is in the active mode, device **10** may pause the video playback operation and dim an associated display screen when the user looks away from the device and the device enters the pause standby mode, and device **10** may turn off the display screen (e.g., the screen used for the video playback operation) if the user does not

look back towards the device within a given period of time and no other user activity is detected.

[0074] In active mode **80**, device **10** is active. While device **10** is in the active mode, device **10** may perform gaze detection operations (e.g., using camera **30** and processing circuitry **36** to detect whether or not a user is gazing at display **16**). While in mode **80**, device **10** may perform a video playback operation. For example, device **10** may display video on display **16** and may play audio associated with the video through a speaker such as speaker **22** or through a headphone accessory such as accessory **46**. Display **16** may display the video at an active brightness level (e.g., display **16** may be at a relatively bright display level).

[0075] When device **10** detects that the user has looked away from display **16** (e.g., using a gaze detection sensor such as camera **30**), device **10** may dim display **16** and enter pause standby mode **84** as illustrated by line **82**. As part of entering pause standby mode **84**, device **10** may pause the video playback operation of mode **80**. Generally, when device **10** pauses the video playback operation, device **10** will also pause an accompanying audio playback associated with the video playback operation. The user may, if desired, configure whether device **10** pauses the audio.

[0076] In mode **84**, device **10** is in a pause standby mode. In pause standby mode **84**, device **10** may dim display **16** to a pause standby brightness level (e.g., a partial standby brightness level) to conserve power. The video playback operation of mode **80** may be paused while device **10** is in mode **84**. If desired, device **10** may place components such as processing circuitry and wireless transceiver circuitry in a standby mode while device **10** is in mode **84** (e.g., by turning off unused CPU cores or reducing clock rates).

[0077] With one suitable arrangement, device **10** may be performing gaze detection operations while in pause standby mode **84**. For example, device **10** may capture images using camera **30** at regular intervals and may analyze the images using gaze detection software to continually monitor whether the user's gaze has returned to device **10** and display **16**.

[0078] Device **10** may switch from pause standby mode **84** to mode **80** whenever appropriate. For example, whenever device **10** detects that a user's gaze is once again directed towards display **16**, device **10** may enter an active mode such as mode **80** (e.g., as illustrated by line **86**), brighten display **16** to the active brightness level, and resume the video playback operation. Device **10** may also enter mode **80** when device **10** detects activity such as user activity received through a button such as button **19** or network activity received through a wired or wireless communications link (e.g., as illustrated by dashed line **87**). In general, device **10** will enter mode **80** whenever a user resumes interacting with device **10**.

[0079] Because device **10** enters mode **80** when it detects that the user's gaze is directed towards display **16** (e.g., as illustrated by line **86**), the user of device **10** need not press a button or provide other input to awaken device **10** from the pause standby state and resume the video playback operation of mode **80**. Instead, device **10** can automatically awaken itself (e.g., switch to mode **80**) and resume the video playback operation when the user directs their gaze towards display **16**.

[0080] If desired, device **10** may operate in a standby mode such as standby mode **90** in which display **16** is turned off. For example, when device **10** is operating in pause standby mode **84** and no user activity is detected for a given period of time (e.g., within a period of time such as one second, two seconds, . . . , ten seconds, twenty seconds, thirty seconds, etc.), device **10** may enter standby mode **90** and turn off display **16**. Because standby mode **90** involves a lower power state for device **10** then pause standby mode **84**, mode **90** may sometimes referred to as full standby mode. As illustrated by line **88** in FIG. **6**, device **10** may enter full standby mode **90** after device **10** detects that the user has looked away (e.g., as illustrated by line **82**) and after a given period of user inactivity has elapsed following the device's detection that the user looked away.

[0081] In standby mode **90**, device **10** may operate with display **16** turned off. Device **10** may also place other suitable components into standby (e.g., wireless circuitry, etc.).

[0082] With the arrangement of FIG. **6**, as long as device **10** detects that the user's gaze is directed at the device (e.g., the user is looking at display **16**), device **10** may remain in active mode **80** and video playback operation can continue (e.g., until the video is completed or the operation is stopped). Device **10** may remain in mode **80** even when no other user activity is being received (e.g., when the user is not pressing a button such as button **19** or providing user input through a touch screen such as touch screen display **16**). This type of arrangement may be beneficial when a user is viewing a video on display **16** of device **10** without providing user input and would be inconvenienced if device **10** were to attempt to conserve power by dimming the video screen. Device **10** can pause the video playback operation when the user temporarily looks away and can then resume operation when the user returns their gaze to device **10**. This allows the user of device **10** to automatically pause a video without having to provide direct user input (e.g., without selecting a pause button). The video can be paused simply by looking away from a video display such as display **16**.

[0083] If desired, device **10** may continue to perform gaze detection operations when operating in standby mode **90**. As illustrated by dashed line **93**, device **10** may switch from standby mode **90** to active mode **80** and resume the video playback operation of mode **80** when device **10** detects that a user's gaze is again directed towards display **16**.

[0084] As illustrated by line **92**, when device **10** detects activity, device **10** may switch from mode **90** to active mode **80** (e.g., device **10** may turn on display **16** to the active brightness level). As an example, device **10** may enter active mode **80** in response to user activity such as button press activity received through a button such as button **19** and in response to other activity such as network activity (e.g., activity received through a wired or wireless communications link).

[0085] If desired, device **10** may automatically resume a video playback operation when the device switches to active mode **80** from a standby mode such as pause standby mode **84** or full standby mode **90**. With another suitable arrangement, device **10** may present the user with an option such as an on-screen selectable option to resume the video playback operation when the device switches to active mode **80**.

[0086] Device **10** may have touch screen capabilities and may implement a power management scheme using gaze detection capabilities to control the device's touch screen capabilities. With this type of scheme, which is illustrated by FIG. **7**, device **10** can switch between an active mode, a partial standby mode, and a standby mode.

[0087] Touch screen functions can be adjusted to conserve power. For example, display **16** may be a touch screen display that can operate at varying speeds (e.g., a fast speed and a slow speed) or with varying levels of functionality (e.g., general

touch sensitivity, localized touch sensitivity, and gesture-capable touch sensitivity). These features can be adjusted based on gaze detection data.

[0088] With one suitable arrangement, touch screen display **16** may operate at a first frequency (e.g., at a relatively high speed) when device **10** is in active mode **94** and a second frequency (e.g., a relatively low speed) when device **10** is in standby mode **104**. The frequency of touch screen display **16** may be the frequency at which the touch screen scans for user input (e.g., once every 10 milliseconds, 50 milliseconds, 100 milliseconds, 200 milliseconds, etc.).

[0089] If desired, touch screen display **16** may operate at a first level of functionality when device **10** is in mode **94** and at a second level of functionality when device **10** is in mode **104**. For example, when device **10** is in active mode **94**, touch screen display **16** may be configured to sense the location of user input within the area of display **16**. Device **10** may also be configured to sense user inputs such as multi-touch user inputs and gestures such as swipe gestures and swipe and hold gestures while in mode **94**. In contrast, when device **10** is in standby mode **104**, touch screen display **16** may be configured such that display **16** can sense general user input such as the presence or absence of contact without being able to resolve the location of the input. The power consumption of display **16** may be reduced when display **16** is configured in this way.

[0090] In mode **94**, device **10** is in an active mode. While device **10** is in the active mode, device **10** may perform gaze detection operations. Touch screen display **16** may be operating at a relatively high frequency (e.g., in the high power mode) while device **10** is in active mode **94**. With another suitable arrangement, touch screen display **16** may be operating at or near its maximum capability (e.g., touch screen display **16** may be configured to sense the location of user inputs and to sense user inputs such as multi-touch inputs and gestures). Display **16** may also be displaying an application display screen (e.g., a home page, a telephone application information page, a media player screen, etc.) at an active brightness level.

[0091] When device **10** detects that the user has looked away from display **16** (e.g., using a gaze detection sensor such as camera **30**), device **10** may dim display **16** and enter partial standby mode **98**, as illustrated by line **96**.

[0092] In mode **98**, device **10** is in a partial standby mode. In partial standby mode **98**, device **10** may dim display **16** to a partial standby brightness level to conserve power and may retain the touch screen capabilities of display **16**. (Alternatively, touch screen capabilities can be reduced in mode **98**.)

[0093] Device **10** may switch from partial standby mode **98** to active mode **94** whenever appropriate. For example, when device **10** detects that a user's gaze is directed towards display **16**, device **10** may enter an active mode such as mode **94** (e.g., as illustrated by line **100**) and may brighten display **16** to the active brightness level. Device **10** may also enter active mode **94** when device **10** detects user activity (e.g., as illustrated by dashed line **99**). In arrangements in which the touch screen capabilities of display **16** remain at the active mode level when device **10** is in mode **98**, display **16** may be able to receive location specific user inputs (e.g., inputs specific to a particular portion of display **16**) while device **10** is in mode **98**.

[0094] If desired, device **10** may operate in a full standby mode such as standby mode **104** in which display **16** is turned off and the touch screen capabilities of display **16** are reduced. As an example, when device **10** is operating in partial standby mode **98** and no user activity is detected for a given period of time, device **10** may enter standby mode **104**. Device **10** may enter standby mode **104** as illustrated by line **102** after device **10** detects that the user has looked away (e.g., as illustrated by line **96**) and after a given period of user inactivity has elapsed following the device's detection that the user has looked away.

[0095] With another suitable arrangement, device **10** may enter standby mode **104** directly from active mode **94** when no user activity is detected for a configurable period of time (e.g., as illustrated by dashed line **108**). Device **10** may enter standby mode **104** even when device **10** detects that a user's gaze is directed towards display **16**. If desired, the time period of user inactivity required before device **10** enters mode **104** directly from mode **94** (e.g., when a user's gaze is still directed towards device **10**) may be longer than the time period of user inactivity required before device **10** enters mode **104** from mode **98** (e.g., when the user's gaze is not directed towards device **10**). For example, the inactivity period associated with the mode transition of line **108** may be one minute or more while the inactivity period associated with the mode transition of line **102** may be thirty seconds or less.

[0096] In standby mode **104**, device **10** may operate with a display portion of display **16** turned off. The display portion of display **16** and a touch screen portion of display **16** may be powered and configured independently. In mode **104**, device **10** may reduce the touch screen capabilities of the touch screen portion of display **16** (e.g., by reducing the frequency at which touch screen display **16** scans for user input, by configuring display **16** such that user inputs can only be sensed generally, by disabling the touch screen capabilities of display **16**, etc.).

[0097] If desired, device **10** may continue to perform gaze detection operations when operating in standby mode **104**. As illustrated by dashed line **105**, device **10** may switch from standby mode **104** to active mode **94** when device **10** detects that a user's gaze is directed towards display **16**.

[0098] As illustrated by line **106**, device **10** may also switch from mode **104** to active mode **94** when activity is detected (e.g., device **10** may turn on display **16** to the active brightness level and restore the touch screen capabilities of display **16** to the active capability level).

[0099] If desired, power can be further conserved by reducing the power consumption of components such as a processor, wireless communications circuitry, etc. while in full standby mode **104** and/or partial standby mode **98**. For example, when device **10** is placed in full standby mode **104** or partial standby mode **98**, the clock frequency for the clock that is used to operate processing circuitry **36** (e.g., a microprocessor) may be reduced. The number of processor cores that are active in processing circuitry **36** may also be reduced. Some or all of wireless communications circuitry **44** may be placed in a low-power state or turned off. The amount of additional circuitry that is powered down when device **10** enters modes **98** and **104** may be the same or, if desired, relatively more circuitry may be powered down in full standby mode **104** than in partial standby mode **98**.

[0100] In configurations in which device **10** has additional components, some or all of these components can be selectively powered down. Device **10** may have additional power down modes in which different numbers of these components have been placed in low-power states. Any suitable criteria

may be used to determine when to switch device **10** between these modes. For example, gaze detection data, user input data, and/or sensor data may be used to determine an appropriate mode in which to operate device **10**. Components that may be powered down in this way include proximity sensors, light sensors such as an ambient light sensor, cameras, motions sensors such as accelerometers, audio circuits, radio-frequency transceiver circuitry, radio-frequency amplifiers, audio amplifiers, serial and parallel port communications circuits, thermal sensors, touch-screen input devices, etc.

[0101] As illustrated by FIG. **8**, device **10** can implement a power management scheme in which gaze detection circuitry is turned on or off or is otherwise adjusted in real time. In the scheme illustrated by FIG. **8**, device **10** can switch between an active mode, a partial standby mode, and a standby mode.

[0102] The gaze detection capabilities of device **10** can be adjusted to conserve power depending on the mode in which device **10** is operating. For example, device **10** may perform gaze detection operations by taking images using camera **30** or other imaging circuitry at a first rate while in an active mode and at a second rate that is less than the first rate while in a standby mode. If desired, device **10** may suspend gaze detection operations while in standby. When the gaze detection operations of device **10** are slowed down (e.g., performed at the second rate) or suspended, device **10** may consume a reduced amount of power.

[0103] In mode **110**, device **10** is in an active mode. While device **10** is in the active mode, device **10** may perform gaze detection operations. For example, device **10** may perform gaze detection operations by taking images at a given rate to search for a user's gaze (e.g., once every 100 milliseconds, 200 milliseconds, 250 milliseconds, 500 milliseconds, 1 second, 2 seconds, etc.). These images may then be analyzed to determine whether the user of device **10** is looking at device **10**. Display **16** may simultaneously display an application display screen (e.g., a home page, a telephone application information page, a media player screen, etc.) at an active brightness level.

[0104] When device **10** detects that the user has looked away from display **16** (e.g., using a gaze detection sensor such as camera **30**), device **10** may dim display **16** and enter partial standby mode **114** as illustrated by line **112**.

[0105] In mode **114**, device **10** is in a partial standby mode. In partial standby mode **114**, device **10** may dim display **16** to a partial standby brightness level to conserve power. If desired, device **10** may also reduce the speed at which images are captured for gaze detection operations in device **10** (e.g., to a lower multiple of the rate at which gaze detection images were captured in mode **110** such as one-half, one-quarter, etc. of the rate in mode **110**).

[0106] Device **10** may switch from partial standby mode **114** to active mode **110** whenever appropriate. For example, when device **10** detects that a user's gaze is directed towards display **16**, device **10** may enter an active mode such as mode **110** (e.g., as illustrated by line **116**) and may brighten display **16** to the active brightness level. Device **10** may also enter active mode **110** when device **10** detects user activity (e.g., as illustrated by line **118**).

[0107] If desired, device **10** may operate in a full standby mode such as standby mode **122** in which display **16** is turned off and the gaze detection capabilities of device **10** are also turned off (e.g., camera **30** is turned off). As an example, when device **10** is operating in partial standby mode **114** and no user activity is detected for a given period of time, device **10** may enter standby mode **122**. Device **10** may enter standby mode **122** as illustrated by line **120** after device **10** detects that the user has looked away (e.g., as illustrated by line **116**) and after a given period of user inactivity has elapsed following the device's detection that the user has looked away.

[0108] In standby mode **122**, device **10** may operate with display **16** turned off and with gaze detection disabled (e.g., turned off). Other circuitry may also be placed in a low-power standby mode (e.g., processing circuitry).

[0109] As illustrated by dashed line **124**, when device **10** detects activity, device **10** may switch from mode **122** to active mode **110** (e.g., device **10** may turn on display **16** to the active brightness level and turn on gaze detection capabilities to determine is a user's gaze is directed towards display **16**).

[0110] With one suitable arrangement, when device **10** detects activity such as user activity, the period of user inactivity detected by device **10** and associated with the mode transition of line **120** may be reset. For example, when device **10** switches from mode **122** to active mode **110** and determines that the user's gaze is not directed towards display **16**, device **10** may switch to mode **114** and the given period of user inactivity associated with the mode transition of line **120** may begin anew.

[0111] The motion of device **10** can be indicative of whether device **10** is being used by a user. If desired, device **10** may use data from an accelerometer or other motion sensor in selecting its mode of operation. For example, when device **10** detects motion above a threshold level with an accelerometer, device **10** may activate gaze detection operations to determine if a user is looking at the device. Device **10** may turn on gaze detection circuitry or may temporarily activate gaze detection operations for a given period of time (e.g., one second, five seconds, etc.) whenever a motion sensor such as an accelerometer detects that a user is shaking device **10** or device **10** is otherwise in motion. With this type of arrangement, device **10** may be in standby mode. When device **10** is picked up by a user, device **10** may detect that the device is in motion using the accelerometer. Device **10** may then activate gaze detection operations and, if the user's gaze is properly detected, may switch to an active mode such as mode **68** in which display **16** is turned on.

[0112] Device **10** may also suspend gaze detection operations when appropriate. For example, when device **10** is receiving user input through an input-output device **38** (e.g., when a user is providing user input through one or more user input devices) or when device **10** has recently received user input, gaze detection operations may be suspended (e.g., camera **30** may be turned off and the execution of gaze detection software may be stopped). In this situation, the presence of user interface activity makes it unnecessary to expend extra power operating the gaze detection circuitry.

[0113] As illustrated by FIG. **9**, device **10** may also use information from environmental sensors such as proximity sensors and ambient light sensors to determine whether or not to perform gaze detection operations. Environmental sensors such as these may, if desired, be used in conjunction with an environmental sensor such as an accelerometer that detects device motion.

[0114] When device **10** is performing gaze detection operations (e.g., when device **10** is operating in a mode such as mode **126**), device **10** may suspend gaze detection operations whenever a sensor in device **10** indicates that gaze detection operations are inappropriate or not needed (e.g., as illustrated by line **128**). With one suitable arrangement, device **10** may

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be able to detect when gaze detection sensors such as camera **30** would be incapable of detecting a user's gaze due to excessive vibration detected by an accelerometer. For example, device **10** may suspend gaze detection operations (e.g., device **10** may switch to operating in mode **130**) in response to signals from the accelerometer in device **10** that indicate the device is shaking or otherwise moving rapidly. In this example, device **10** may switch to mode **130** when the accelerometer detects that the acceleration of device **10** exceeds a given threshold level. In another example, device **10** may be able to detect, using a proximity sensor, that gaze detection operations are inappropriate because an object is in close proximity to device **10** and is blocking the device's gaze detection sensors (e.g., such as when a user places device **10** against their ear and thereby blocks camera **30**). If desired, device **10** may suspend gaze detection operations when an ambient light sensor detects that there is insufficient light in the environment around device **10** for a camera such as camera **30** to capture images in which a user's gaze could be detected. Device **10** may also deactivate a camera associated with gaze detection operations and suspend a gaze detection application running on circuitry **36** when data from one or more sensors in device **10** indicate that gaze detection operations are inappropriate or wasteful of power.

[0115] When device **10** detects that gaze detection operations may be appropriate (e.g., after the sensors no longer indicate that gaze detection operations are inappropriate), device **10** may resume gaze detection operations in mode **126**, as illustrated by line **132**. This type of arrangement may help device **10** to avoid performing gaze detection operations at inappropriate times, while ensuring that the power conserving functionality of the gaze detection circuitry is retained during normal device operation.

[0116] The gaze detection capabilities of device **10** may, if desired, include visual user identification capabilities (e.g., face recognition). In this type of arrangement, device **10** may distinguish between authorized users and unauthorized users based on image sensor data. For example, device **10** may recognize an authorized user and may unlock itself whenever the authorized user is detected by the device's gaze detection circuitry (e.g., camera **30**). If desired, when device **10** detects that the authorized user's gaze has been diverted from device **10**, device **10** may lock itself to prevent unauthorized users from using device **10**. This type of user-specific gaze detection functionality may be used for all gaze detection operations if desired. By making gaze detection specific to particular users, device **10** will not inadvertently transition from standby mode to active mode if a person in the user's vicinity happens to glance at the user's device.

[0117] FIG. **10** shows steps involved in processing a command to reduce the power consumption of display **16**. Power reduction commands may be processed by device **10** based on gaze detection data or any other suitable data.

[0118] As show by step **134**, processing may begin with reception of a power reduction command by the processing circuitry of device **10**.

[0119] Display **16** may be an OLED display or other display that has pixels that may be controlled individually. As shown by box **136**, in this type of situation, device **10** may make partial or full power reduction to some or all of the pixels of display **16** in response to the received power reduction command.

[0120] Display **16** may also be formed from a panel subsystem and a backlight subsystem. For example, display **16** may have a liquid crystal display (LCD) panel subsystem and a light emitting diode or fluorescent tube backlight subsystem. In backlight subsystems that contain individually controllable elements such as light emitting diodes, the brightness of the backlight elements may be selectively controlled. For example, as shown in step **138**, the brightness of some of the backlight elements may be reduced while the other backlight elements remain fully powered.

[0121] In backlight subsystems that contain a single backlight element, the power of the single element may be partially or fully reduced to reduce power consumption (step **140**).

[0122] During the operations of steps **138** and **140**, further power reductions may be made by adjusting circuitry that controls the LCD panel subsystem.

[0123] The foregoing is merely illustrative of the principles of this invention and various modifications can be made by those skilled in the art without departing from the scope and spirit of the invention.

What is claimed is:

1. A method for minimizing power consumption in a portable electronic device that has a display and gaze detection circuitry, the method comprising:

performing a video playback operation in which video is displayed on the display;

with the gaze detection circuitry, determining whether a user's gaze is directed towards the portable electronic device; and

when it is determined that the user's gaze is not directed towards the portable electronic device, pausing the video playback operation.

2. The method defined in claim **1** wherein determining whether the user's gaze is directed towards the portable electronic device comprises determining whether the user's gaze is directed towards the display.

3. The method defined in claim **1** further comprising:

after it has been determined that the user's gaze is not directed towards the portable electronic device, determining whether the user's gaze has returned to the portable electronic device; and

when it has been determined that the user's gaze has returned to the portable electronic device, resuming the video playback operation.

4. The method defined in claim **1** further comprising:

after it has been determined that the user's gaze is not directed towards the portable electronic device, determining whether the user's gaze has returned to the portable electronic device; and

when it has been determined that the user's gaze has returned to the portable electronic device, presenting an on-screen selectable option to resume the video playback operation.

5. The method defined in claim **1** further comprising:

when it has been determined that the user's gaze is not directed towards the portable electronic device, placing the display in an operating mode that reduces power consumption by the display.

6. The method defined in claim **5** wherein the display is at a first brightness level during the video playback operation and wherein placing the display in the operating mode comprises reducing the brightness of the display to a second brightness level.

7. The method defined in claim 6 further comprising:
after it has been determined that the user's gaze is not directed towards the portable electronic device, determining whether the user's gaze has returned to the portable electronic device; and
when it has been determined that the user's gaze has returned to the portable electronic device, increasing the brightness of the display to the first brightness level.

8. The method defined in claim 5 wherein placing the display in the operating mode that reduces power consumption comprises turning off the display.

9. A method for using a portable electronic device having an accelerometer and gaze detection circuitry, the method comprising:
with the accelerometer, determining whether a measured acceleration level for the portable electronic device has exceeded a given threshold value; and
when it has been determined that the acceleration level of the portable electronic device has exceeded the given threshold value, disabling the gaze detection circuitry.

10. The method defined in claim 9 further comprising:
after it has been determined that the acceleration level of the portable electronic device has exceeded the given threshold value, determining whether the acceleration level of the portable electronic device has dropped below a second threshold value; and
when it has been determined that the acceleration level of the portable electronic device has dropped below the second threshold value, enabling the gaze detection circuitry.

11. The method defined in claim 9 wherein the gaze detection circuitry comprises a camera that is used to determine whether the user's gaze is directed towards the portable electronic device and wherein disabling the gaze detection circuitry comprises turning off the camera.

12. A portable electronic device comprising:
an image sensor that captures images of a user; and
circuitry that processes the captured images to determine whether the user is looking at the portable electronic device, wherein the circuitry is configured to suspend captured image processing operations when user activity with the portable electronic device is detected.

13. The portable electronic device defined in claim 12 wherein the circuitry comprises at least one button and wherein the user activity comprises presses of the button by the user.

14. The portable electronic device defined in claim 12 wherein the user activity includes movement of the portable electronic device and wherein the circuitry comprises a sensor that detects the movement of the portable electronic device.

15. The portable electronic device defined in claim 12 further comprising:
a proximity sensor that detects whether any objects are within a given distance of the portable electronic device, wherein the circuitry is configured to suspend captured image processing operations when the proximity sensor detects an object within the given distance.

16. The portable electronic device defined in claim 12 further comprising:
a light sensor that measures a brightness level of ambient light, wherein the circuitry is configured to suspend captured image processing operations when the measured brightness level of ambient light is less than a given brightness level.

17. A portable electronic device comprising:
a display;
an image sensor that captures images of a user;
a user input device that receives input from the user; and
circuitry that processes the captured images to determine whether the user is looking at the portable electronic device, wherein the circuitry is configured to:
power the display at a first brightness level when it is determined that the user is looking at the portable electronic device; and
turn off the display after a given period of time has elapsed in which no input has been received from the user by the user input device, wherein the given period of time begins when it is determined that the user has looked away from the portable electronic device.

18. The portable electronic device defined in claim 17 wherein the circuitry is configured to reduce power to the display so that the display is at a second brightness level during the given period of time in which no input has been received from the user by the user input device.

19. The portable electronic device defined in claim 17 wherein the circuitry is configured to once again power the display at the first brightness level when the user input device receives input from the user.

20. The portable electronic device defined in claim 17 wherein the user input device comprises at least one button and wherein the input from the user comprises presses of the button by the user.

21. The portable electronic device defined in claim 17 wherein the circuitry is configured to suspend captured image processing operations after the given period of time has elapsed.

22. The portable electronic device defined in claim 21 wherein the circuitry is configured to resume captured image processing operations when the user input device receives input from the user.

23. A method for using a portable electronic device having a display, a user input device, and gaze detection circuitry, the method comprising:
with the gaze detection circuitry, determining whether a user's gaze is directed towards the portable electronic device;
when it is determined that the user's gaze is not directed towards the portable electronic device, reducing power to the display; and
when the user input device receives input from a user and power to the display has been reduced, increasing power to the display so that the display is at a first brightness level.

24. The method defined in claim 23 wherein reducing power to the display comprises reducing power to the display so that the display is at a second brightness level that is less than the first brightness level.

25. The method defined in claim 23 wherein reducing power to the display comprises turning off the display.

26. The method defined in claim 23 wherein reducing power to the display comprises reducing power to the display so that the display is at a second brightness level that is less than the first brightness level, the method further comprising:

after a given period of time has elapsed in which no input has been received by the user input device, turning off the display.

27. A portable electronic device comprising:

a display;

an image sensor that captures images of a user; and

circuitry that processes the captured images to determine whether the user is looking at the portable electronic device, wherein the portable electronic device is configured to operate in:

an active mode in which the display is powered at a first brightness level;

a partial standby mode in which the display is powered at a second brightness level that is less than the first brightness level; and

a full standby mode in which the display screen and at least part of the circuitry that processes the captured images are powered down.

28. The portable electronic device defined in claim **27** wherein the portable electronic device is further configured to switch from operating in the active mode to operating in the partial standby mode when the circuitry determines that the user has looked away from the portable electronic device.

29. The portable electronic device defined in claim **27** wherein the portable electronic device is further configured to switch from operating in the partial standby mode to operating in the full standby mode after a given period of time has elapsed in which no input has been received from the user by the user input device.

29. A portable electronic device comprising:

a display;

an image sensor that captures images of a user;

a processor; and

circuitry that processes the captured images to determine whether the user is looking at the portable electronic device, wherein the portable electronic device is configured to operate in:

a first mode in which the display is powered at a first brightness level; and

a second mode in which power to the display and the processor is reduced.

30. The portable electronic device defined in claim **29** wherein the first mode is an active mode, wherein the second mode is a full standby mode in the display is powered down, and wherein the portable electronic device is further configured to operate in a partial standby mode in which the display is powered at a second brightness level that is less than the first brightness level.

31. The portable electronic device defined in claim **29** wherein the processor includes a given number of processing cores, wherein, in the first mode, the processor is configured to operate using the given number of the processing cores, and wherein, in the second mode, the processor is configured to operate using fewer than the given number of the processing cores.

32. The portable electronic device defined in claim **29** wherein the processor is configured to receive a first clock in the first mode and a second clock in the second mode and wherein the first clock has a frequency that is greater than the second clock.

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