US 20230079485A1

(19) **United States**

(12) **Patent Application Publication**

Kim et al.

(10) **Pub. No.: US 2023/0079485 A1**

(43) **Pub. Date: Mar. 16, 2023**

(54) **SELF-RETRACTING DISPLAY DEVICE AND TECHNIQUES FOR PROTECTING SCREEN USING DROP DETECTION**

(71) Applicant: **APPLE INC.**, CUPERTINO, CA (US)

(72) Inventors: **Hoon Sik Kim**, San Jose, CA (US); **Michael B. Wittenberg**, San Francisco, CA (US)

(73) Assignee: **APPLE INC.**, CUPERTINO, CA (US)

(21) Appl. No.: **17/649,787**

(22) Filed: **Feb. 2, 2022**

Related U.S. Application Data

(60) Provisional application No. 63/244,131, filed on Sep. 14, 2021.

Publication Classification

(51) **Int. Cl.**

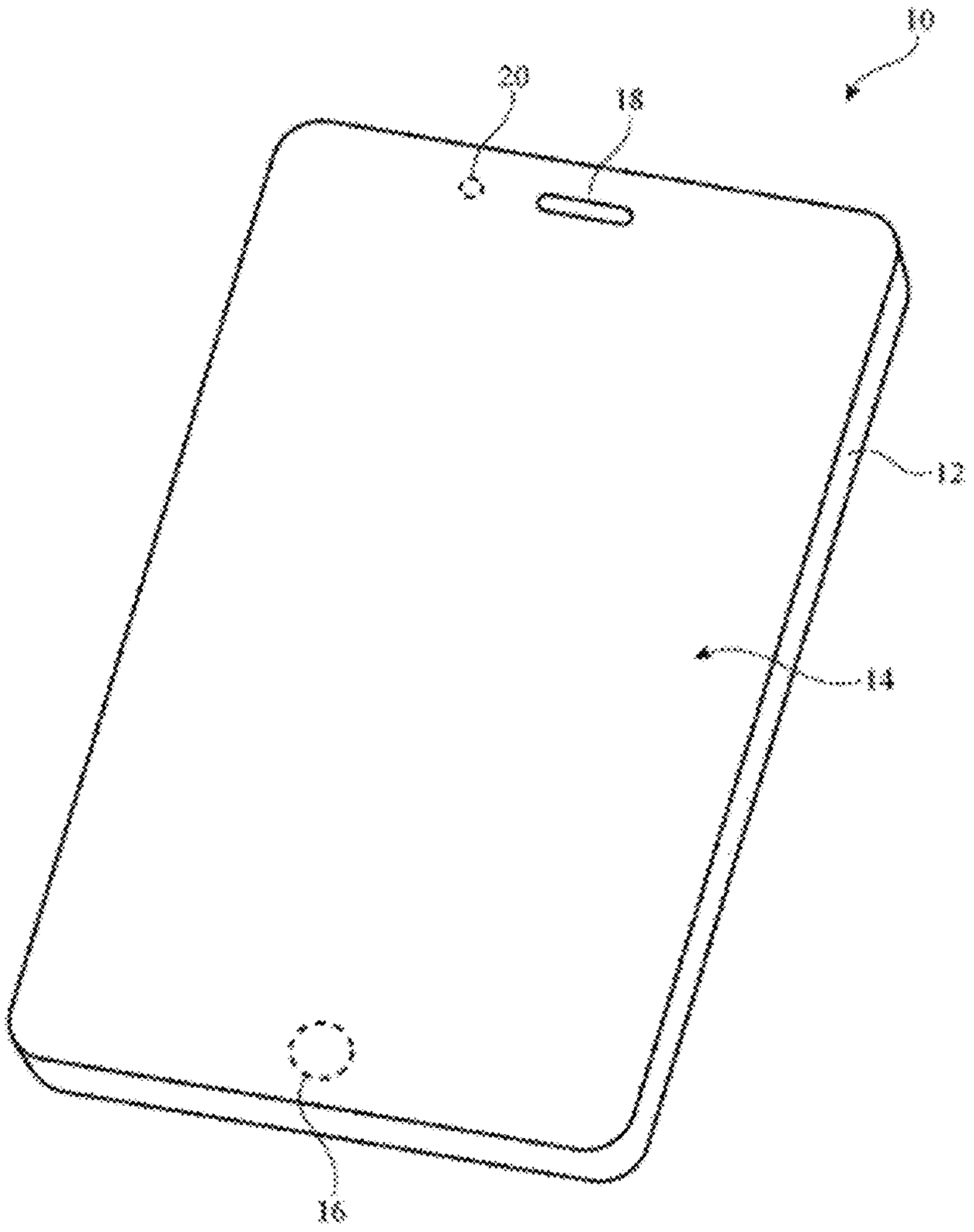
G06F 1/16	(2006.01)
G09F 9/33	(2006.01)

(52) **U.S. Cl.**

CPC ***G06F 1/1652*** (2013.01); ***G06F 1/1681*** (2013.01); ***G06F 1/1679*** (2013.01); ***G09F 9/335*** (2021.05); *G06F 2200/1633* (2013.01); *G06F 2200/1637* (2013.01)

(57) **ABSTRACT**

In some aspects, mobile devices with foldable and rollable displays can use a sensor to detect vertical acceleration with respect to the ground to determine if the mobile device has been dropped. If the sensor detects that the mobile device has been dropped the foldable device can fold or retract at least partially to afford protection from the fragile display from striking the ground. Even folding the display to an angle less the 180 degrees can afford some protection because the mobile device can strike edges of the mobile device instead of the display itself. In various embodiments, a rollable device can retract the display if predetermined acceleration limits are exceeded.



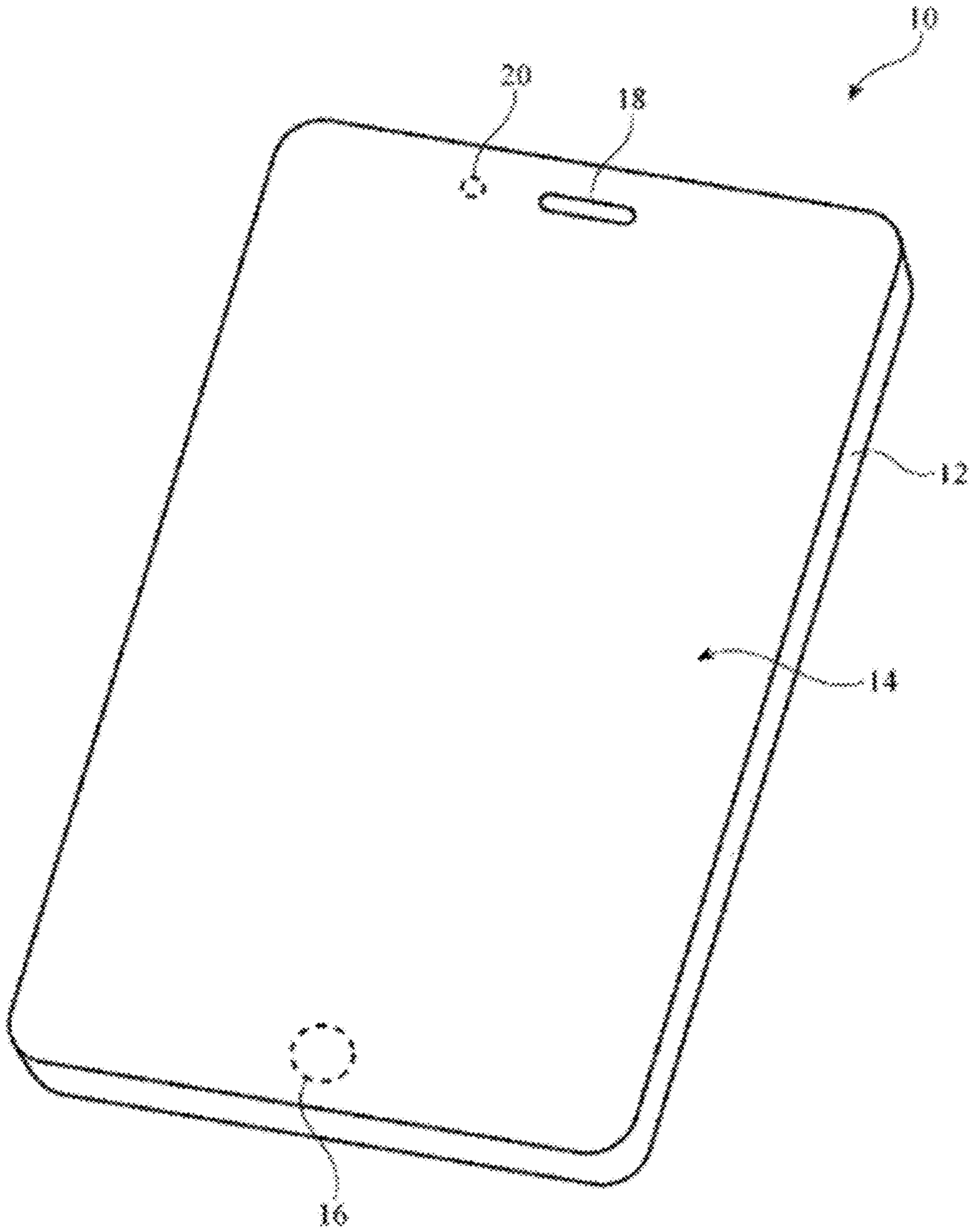


FIG. 1

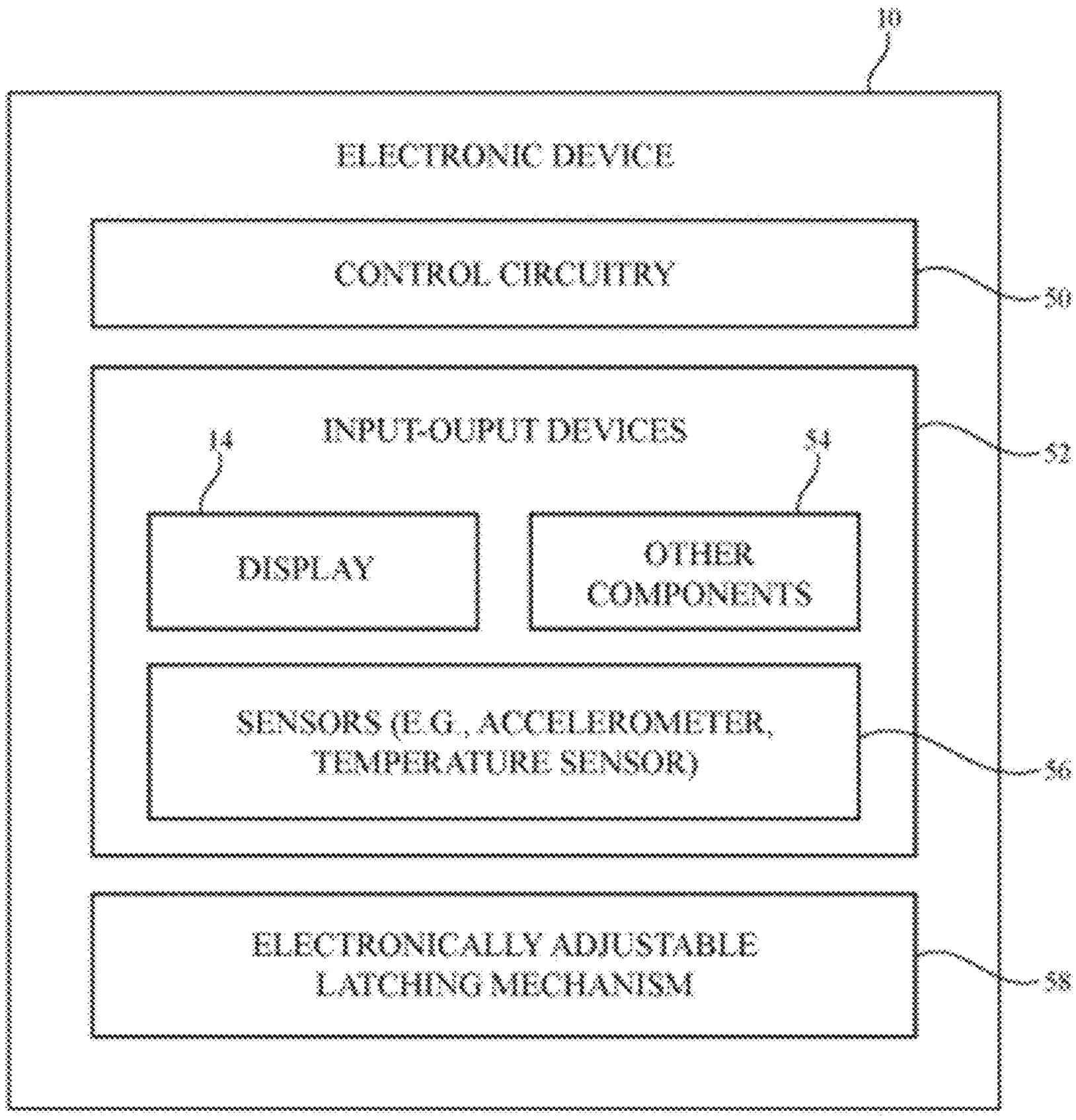

10
ELECTRONIC DEVICE
CONTROL CIRCUITRY
50
INPUT-OUPUT DEVICES
52
14
54
DISPLAY
OTHER COMPONENTS
SENSORS (E.G., ACCELEROMETER, TEMPERATURE SENSOR)
56
ELECTRONICALLY ADJUSTABLE LATCHING MECHANISM
58

FIG. 2

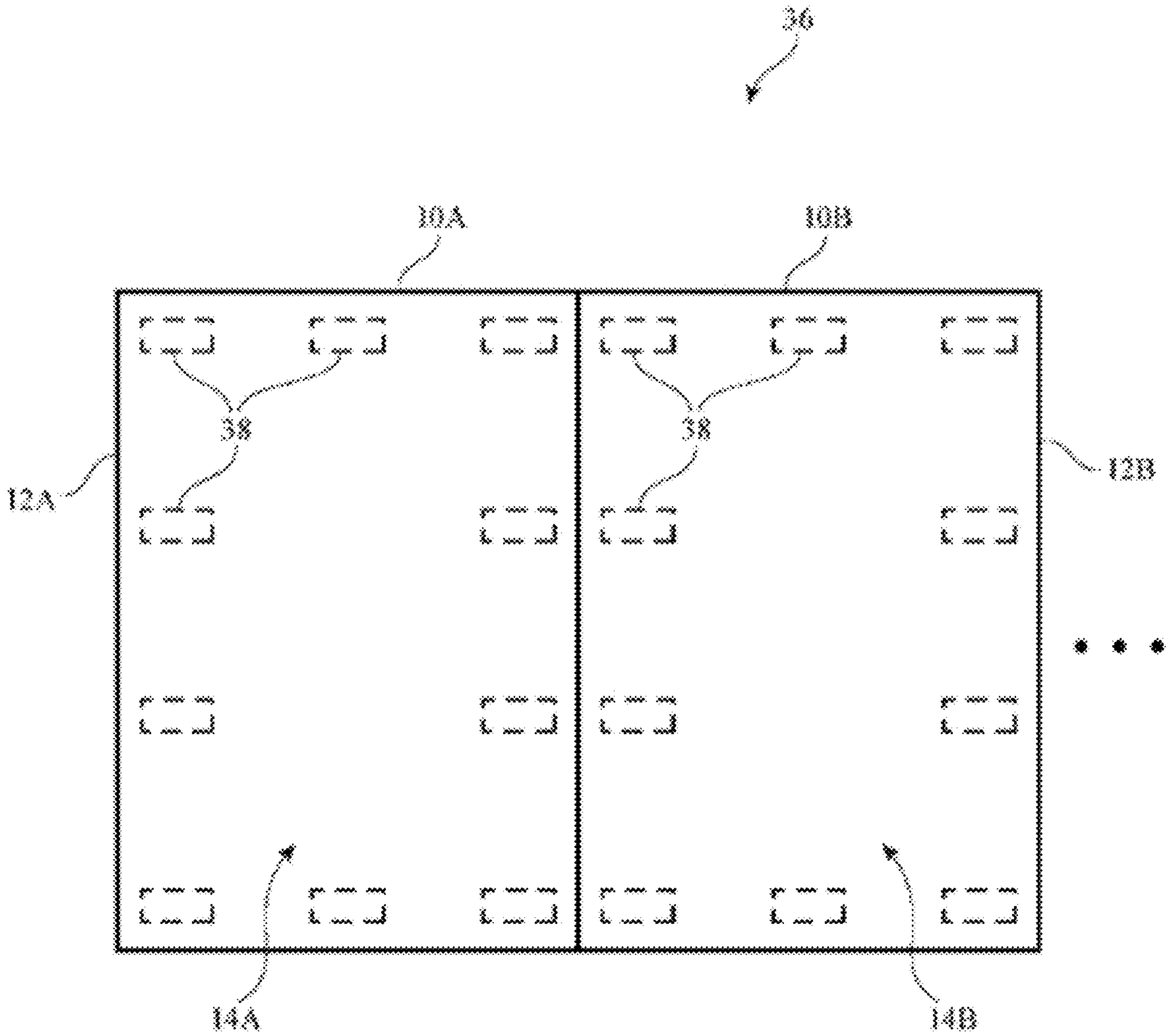


FIG. 3

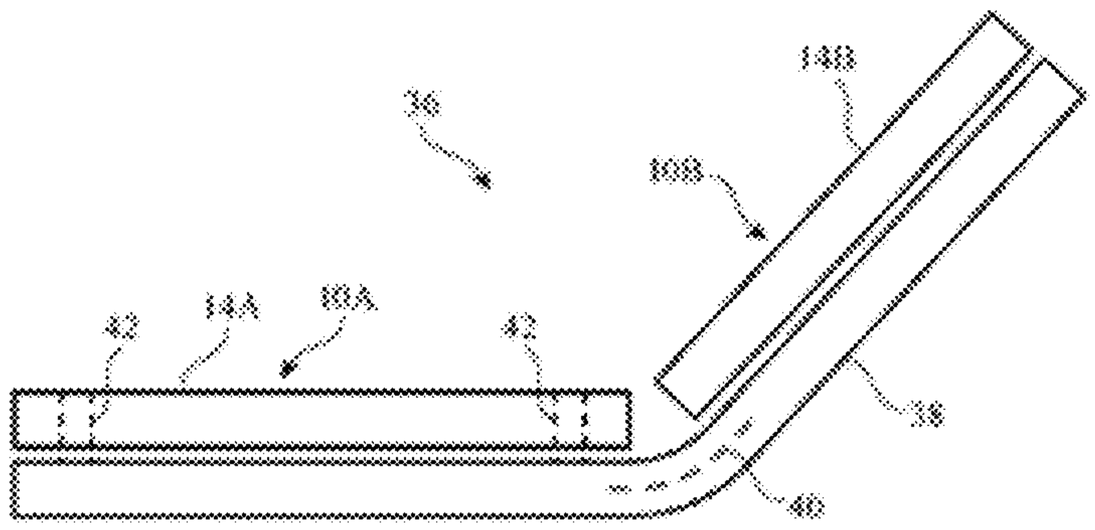


FIG. 4

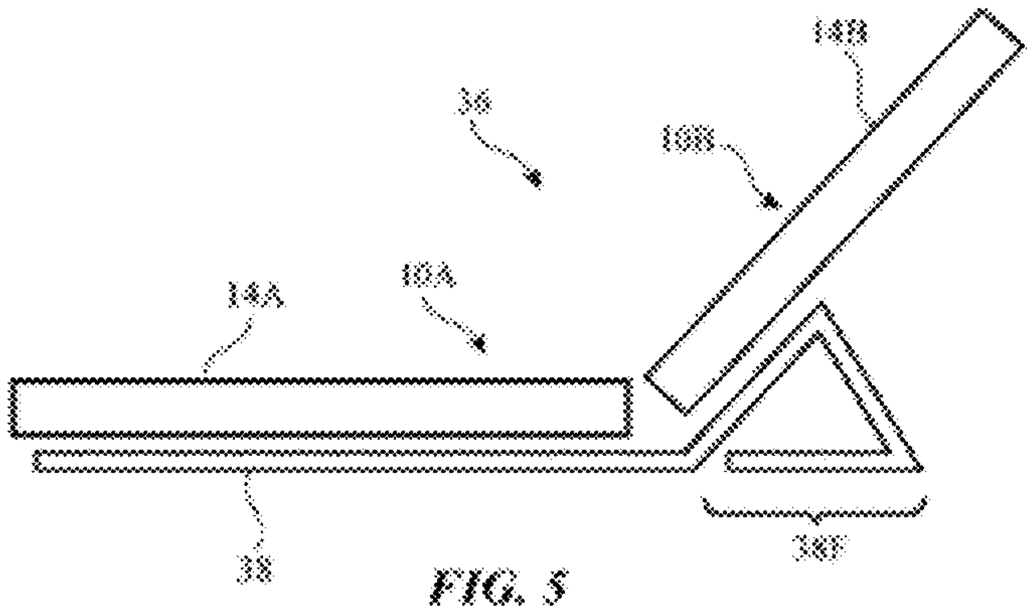


FIG. 5

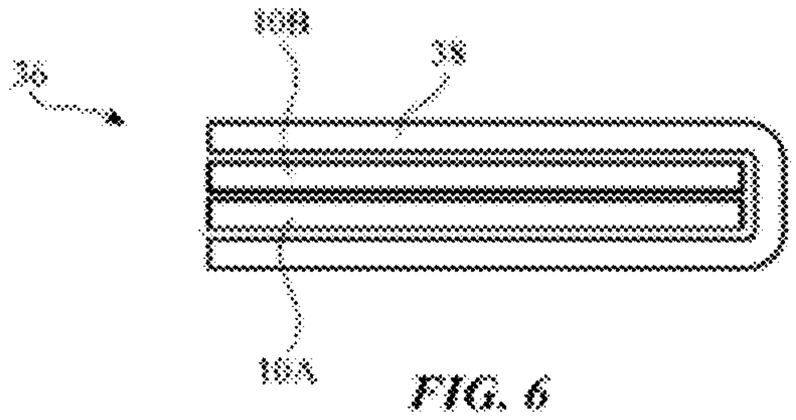


FIG. 6

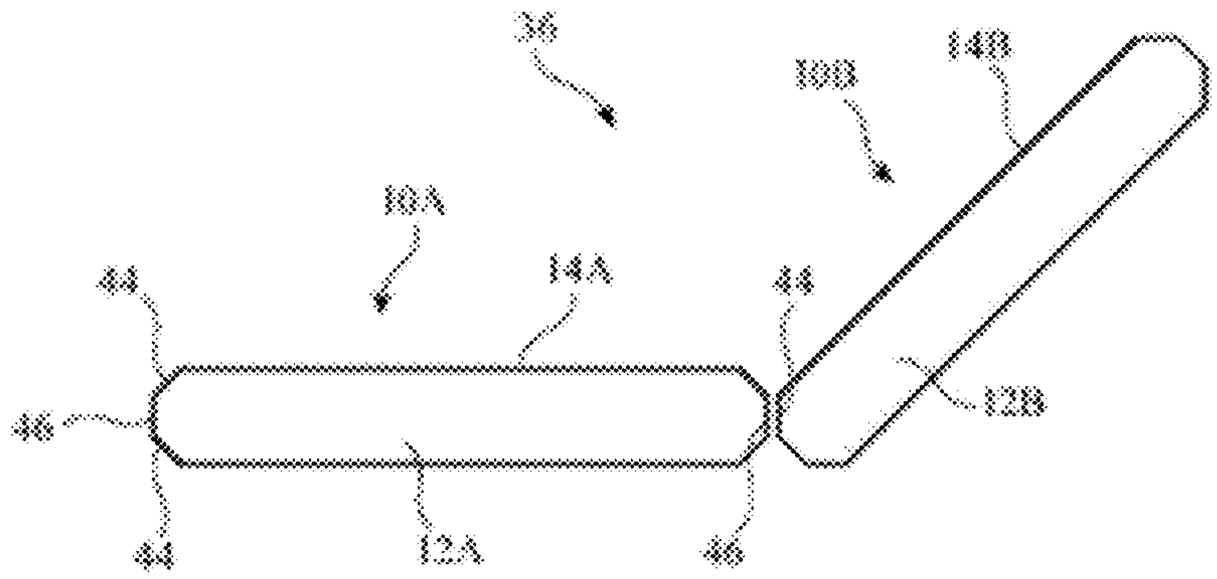


FIG. 7

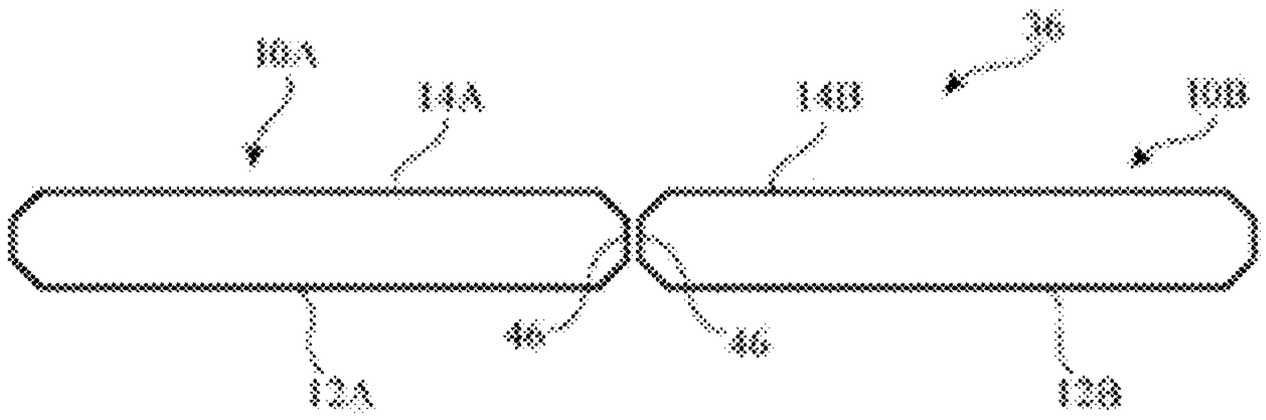


FIG. 8

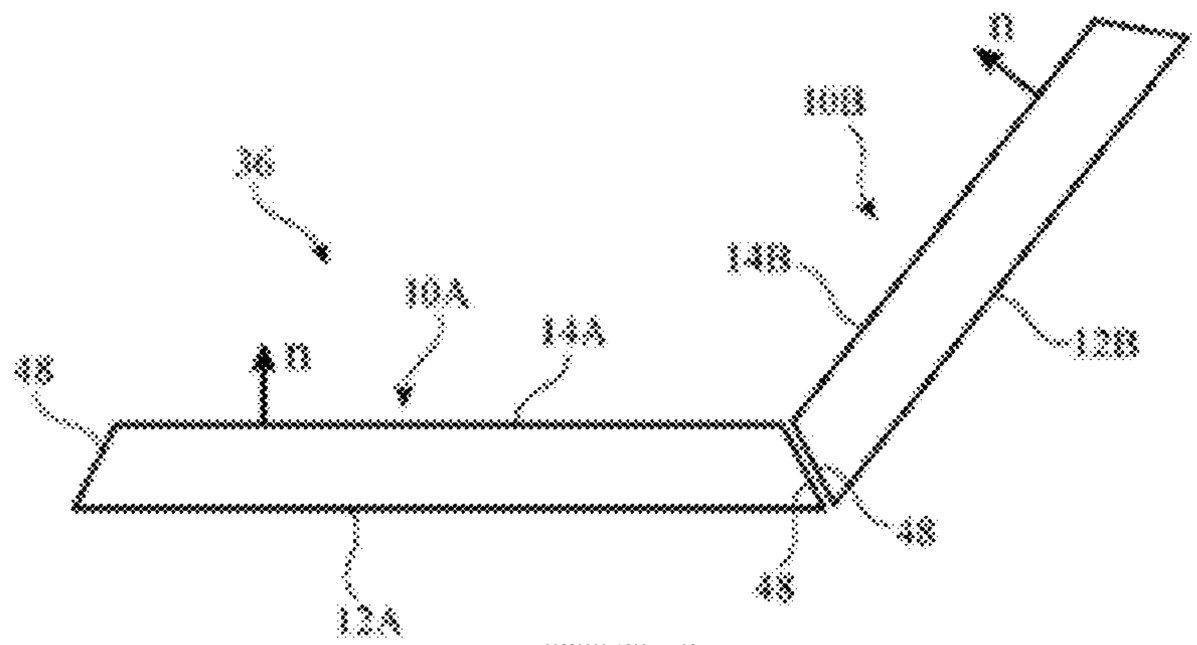


FIG. 9

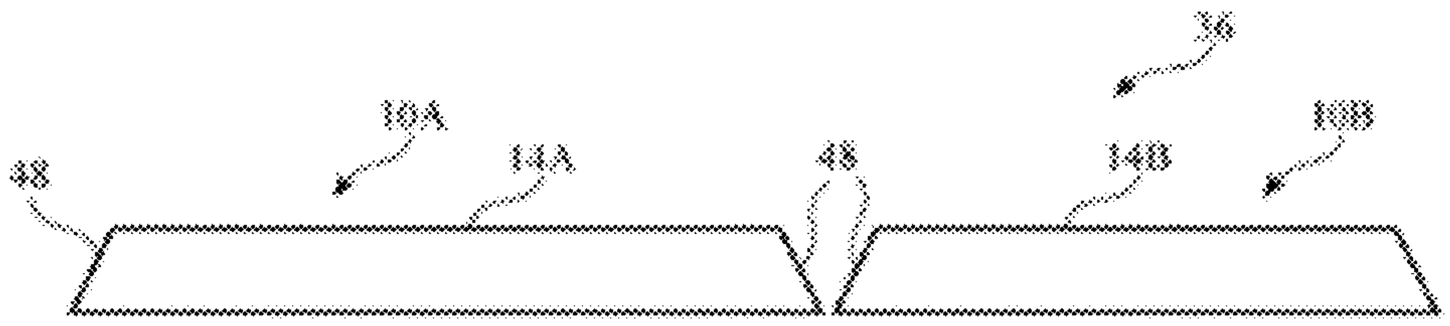


FIG. 10

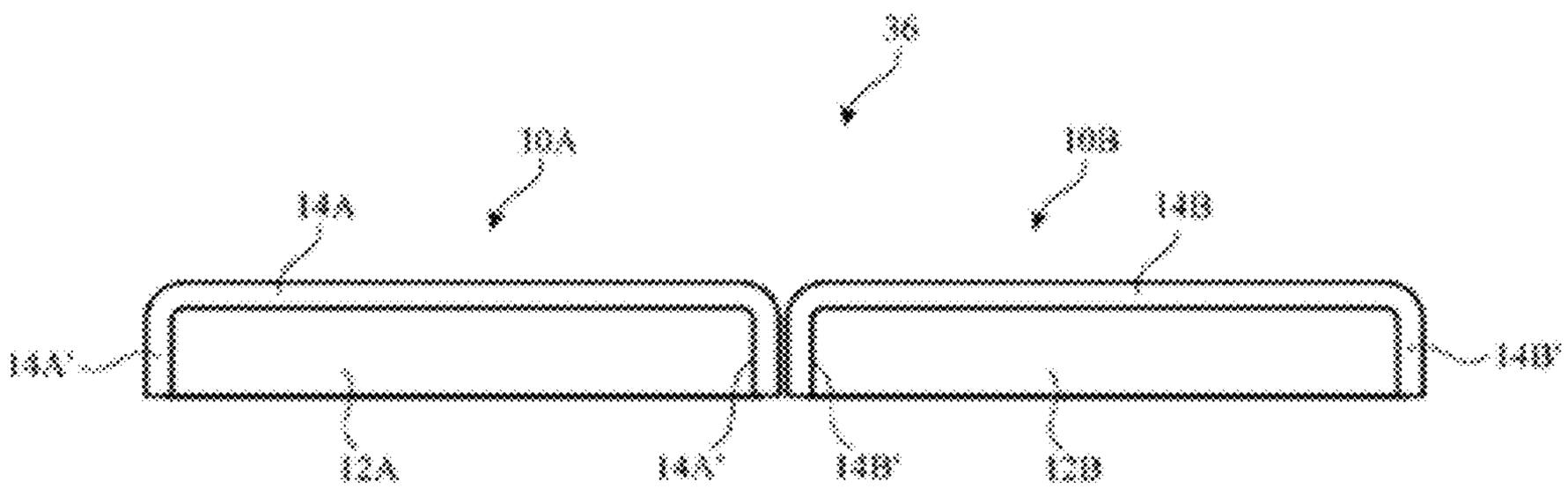

36
10A
10B
14A
14B
14A'
14B'
12A
14A"
14B"
12B

FIG. 11

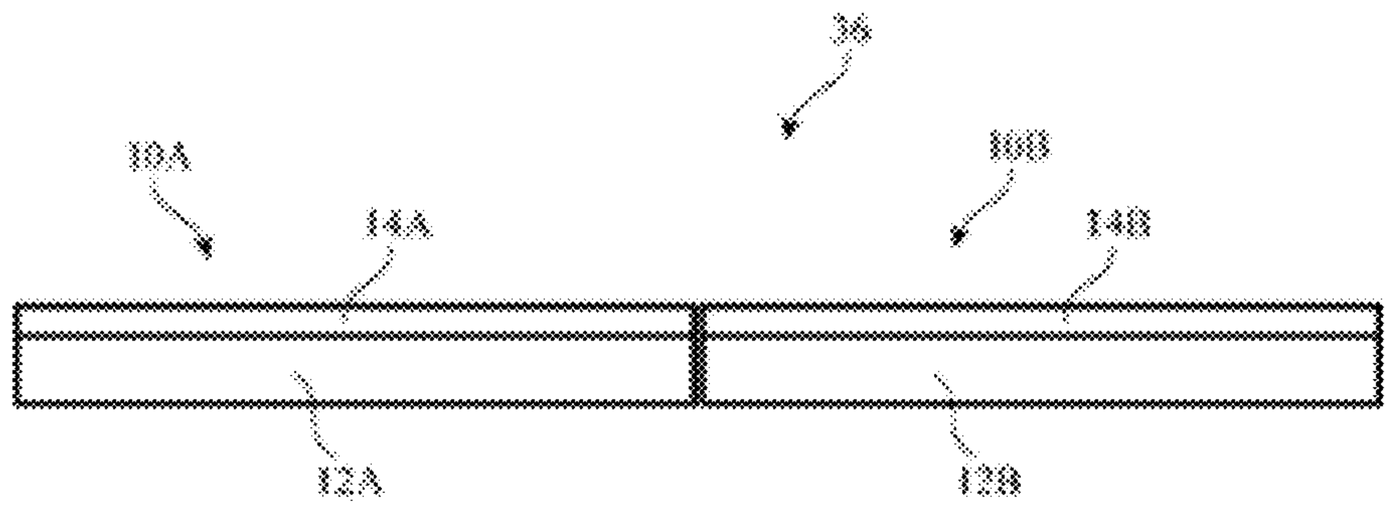

36
10A
10B
14A
14B
12A
12B

FIG. 12

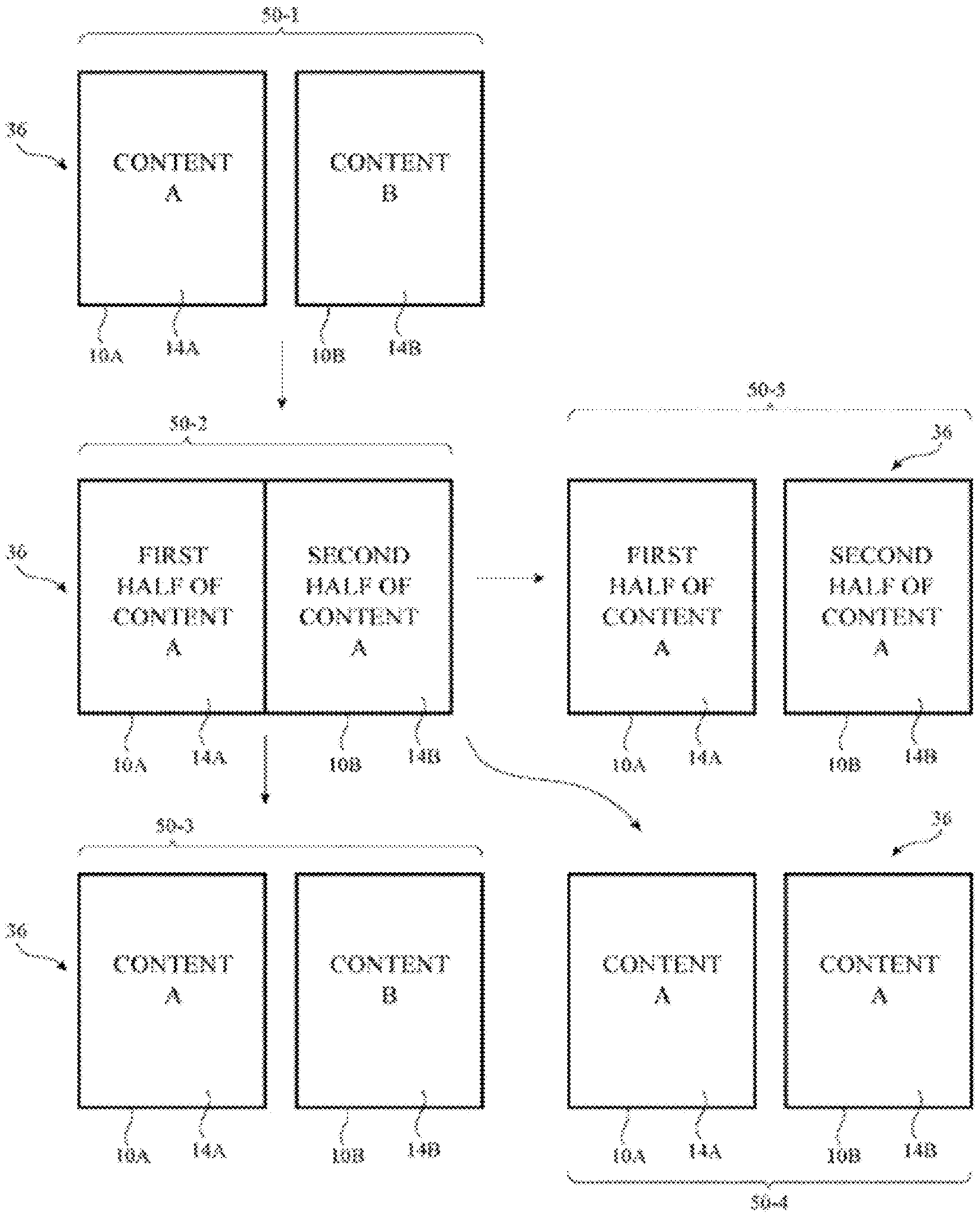

50-1
36
CONTENT A
CONTENT B
10A
14A
10B
14B
50-2
36
FIRST HALF OF CONTENT A
SECOND HALF OF CONTENT A
10A
14A
10B
14B
50-3
36
CONTENT A
CONTENT B
10A
14A
10B
14B
50-3
36
FIRST HALF OF CONTENT A
SECOND HALF OF CONTENT A
10A
14A
10B
14B
36
CONTENT A
CONTENT A
10A
14A
10B
14B
50-4

FIG. 13

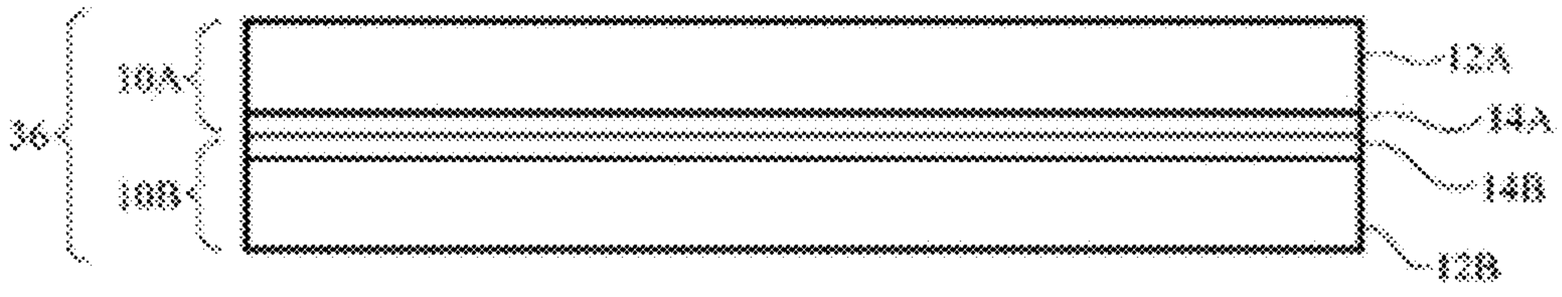


FIG. 14

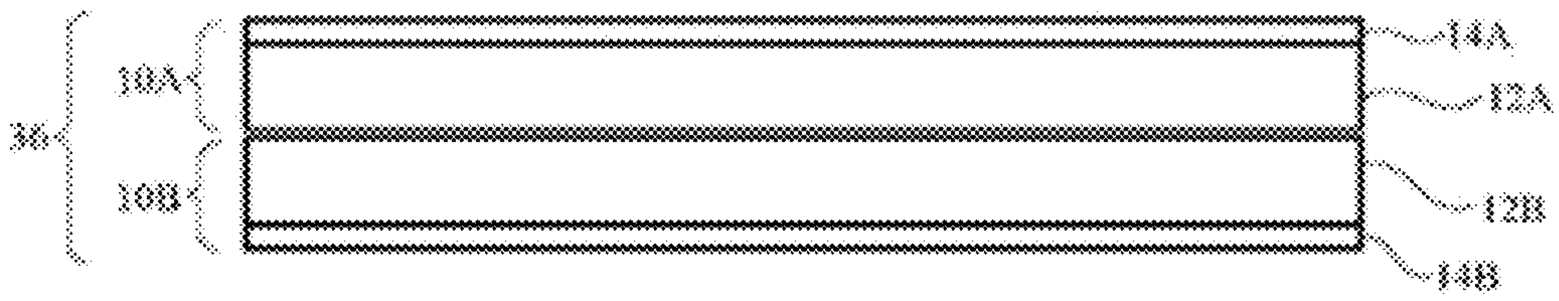


FIG. 15

FIG. 16

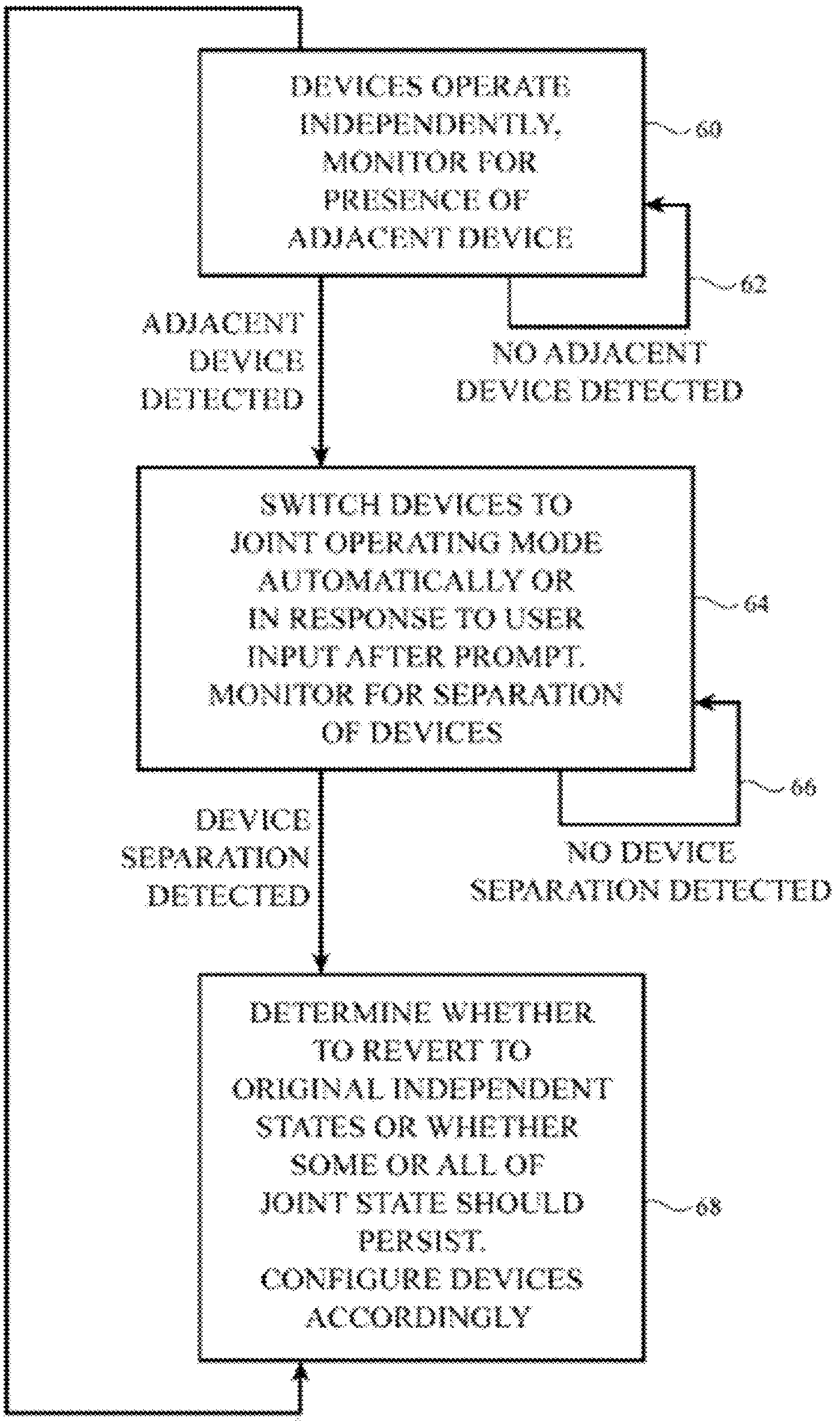

DEVICES OPERATE INDEPENDENTLY, MONITOR FOR PRESENCE OF ADJACENT DEVICE
60
62
ADJACENT DEVICE DETECTED
NO ADJACENT DEVICE DETECTED
SWITCH DEVICES TO JOINT OPERATING MODE AUTOMATICALLY OR IN RESPONSE TO USER INPUT AFTER PROMPT. MONITOR FOR SEPARATION OF DEVICES
64
66
DEVICE SEPARATION DETECTED
NO DEVICE SEPARATION DETECTED
DETERMINE WHETHER TO REVERT TO ORIGINAL INDEPENDENT STATES OR WHETHER SOME OR ALL OF JOINT STATE SHOULD PERSIST. CONFIGURE DEVICES ACCORDINGLY
68

FIG. 17

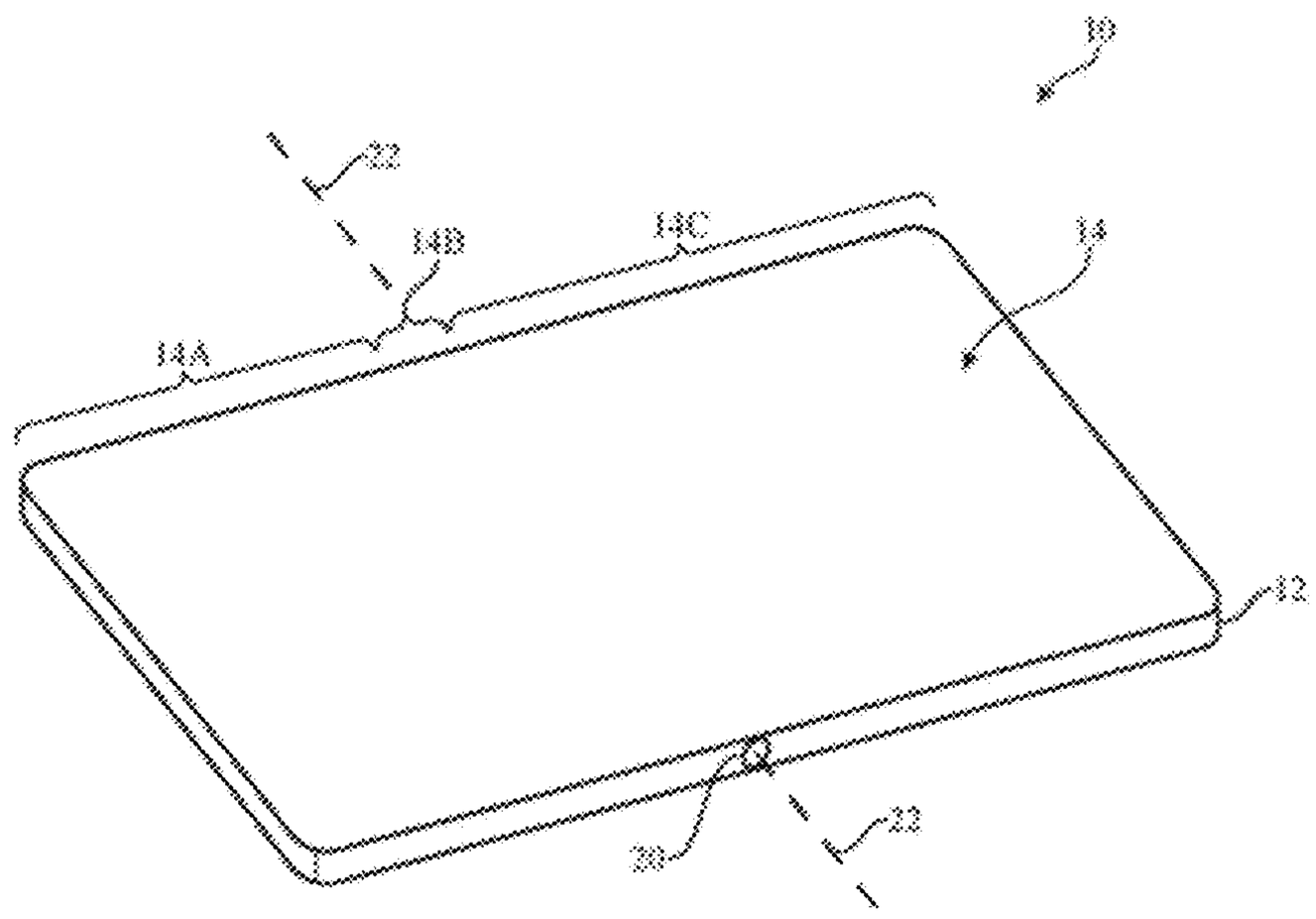


FIG. 18

FIG. 19

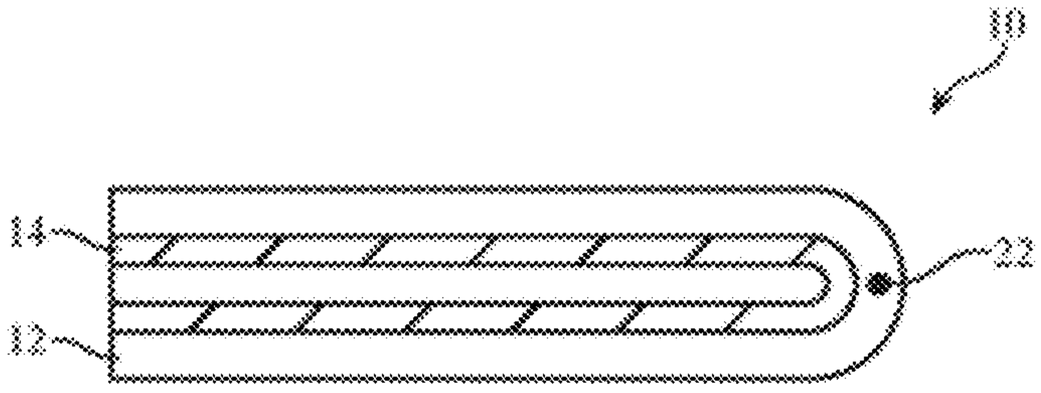


FIG. 20

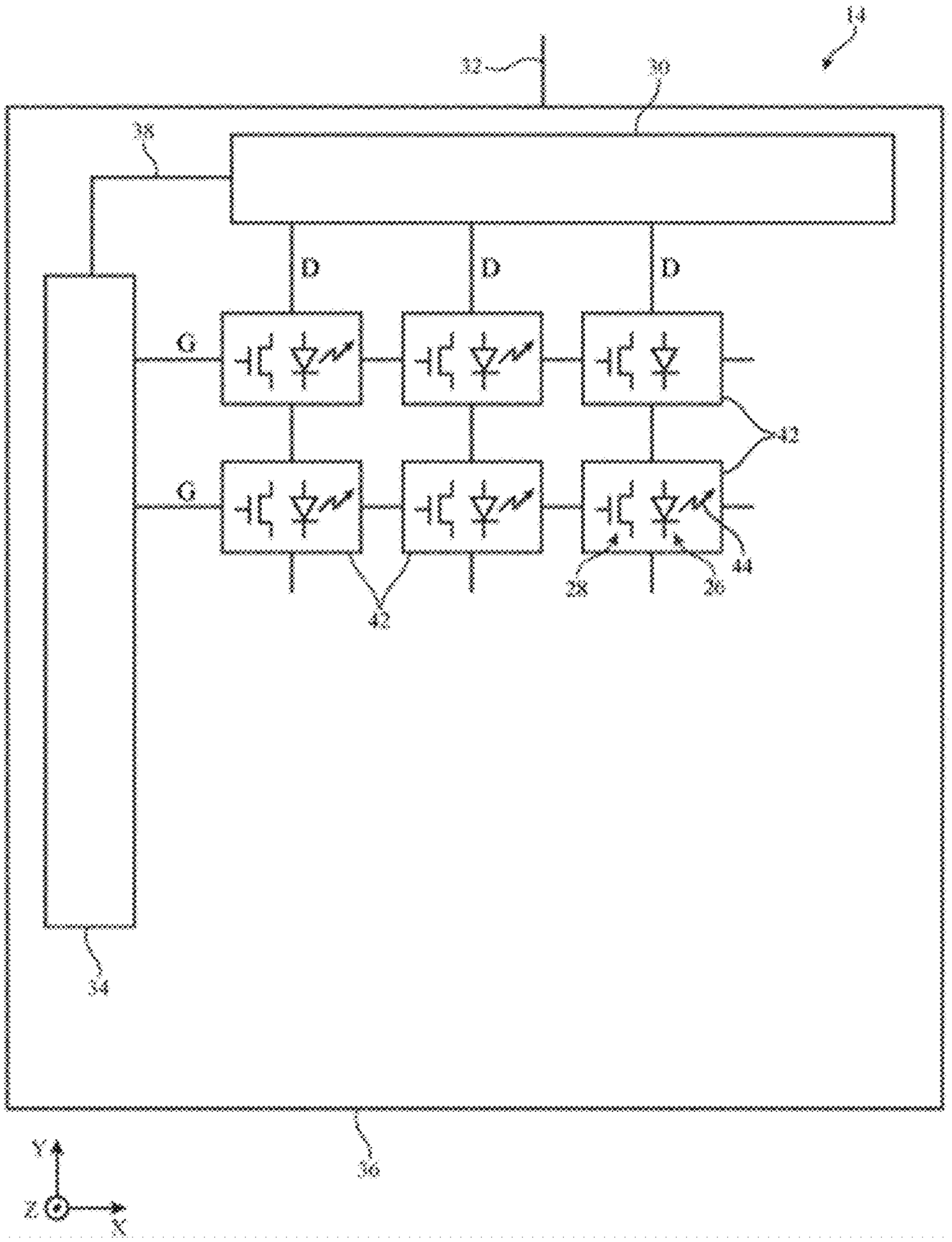


FIG. 21

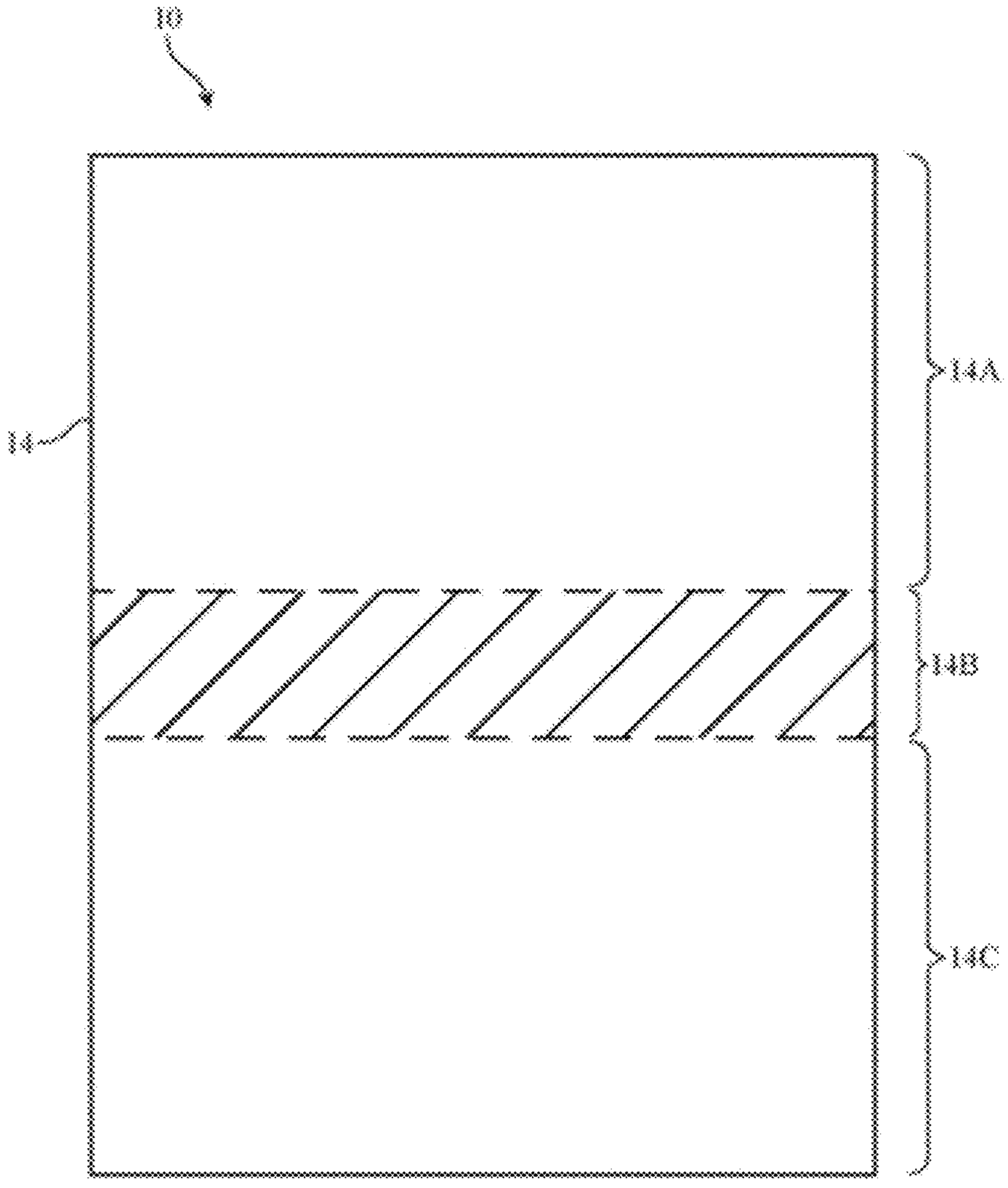


FIG. 22

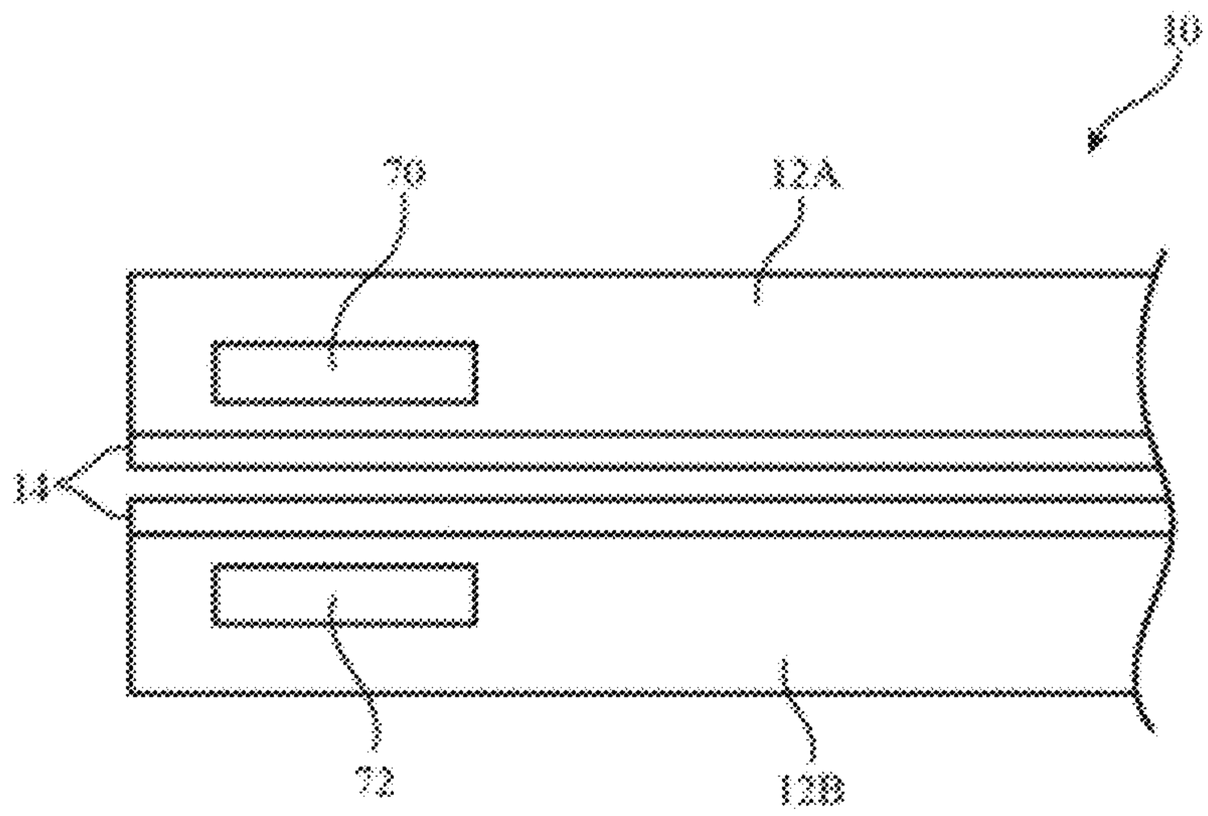


FIG. 23

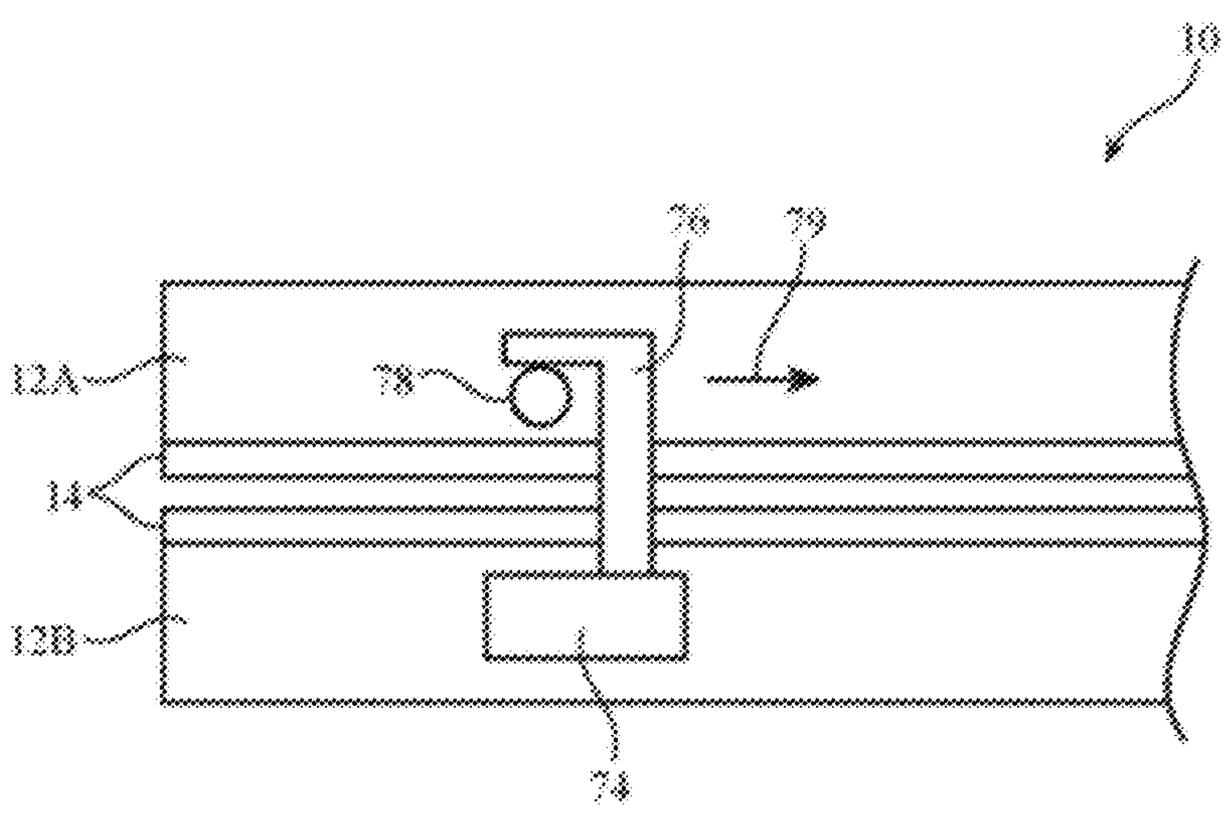


FIG. 24

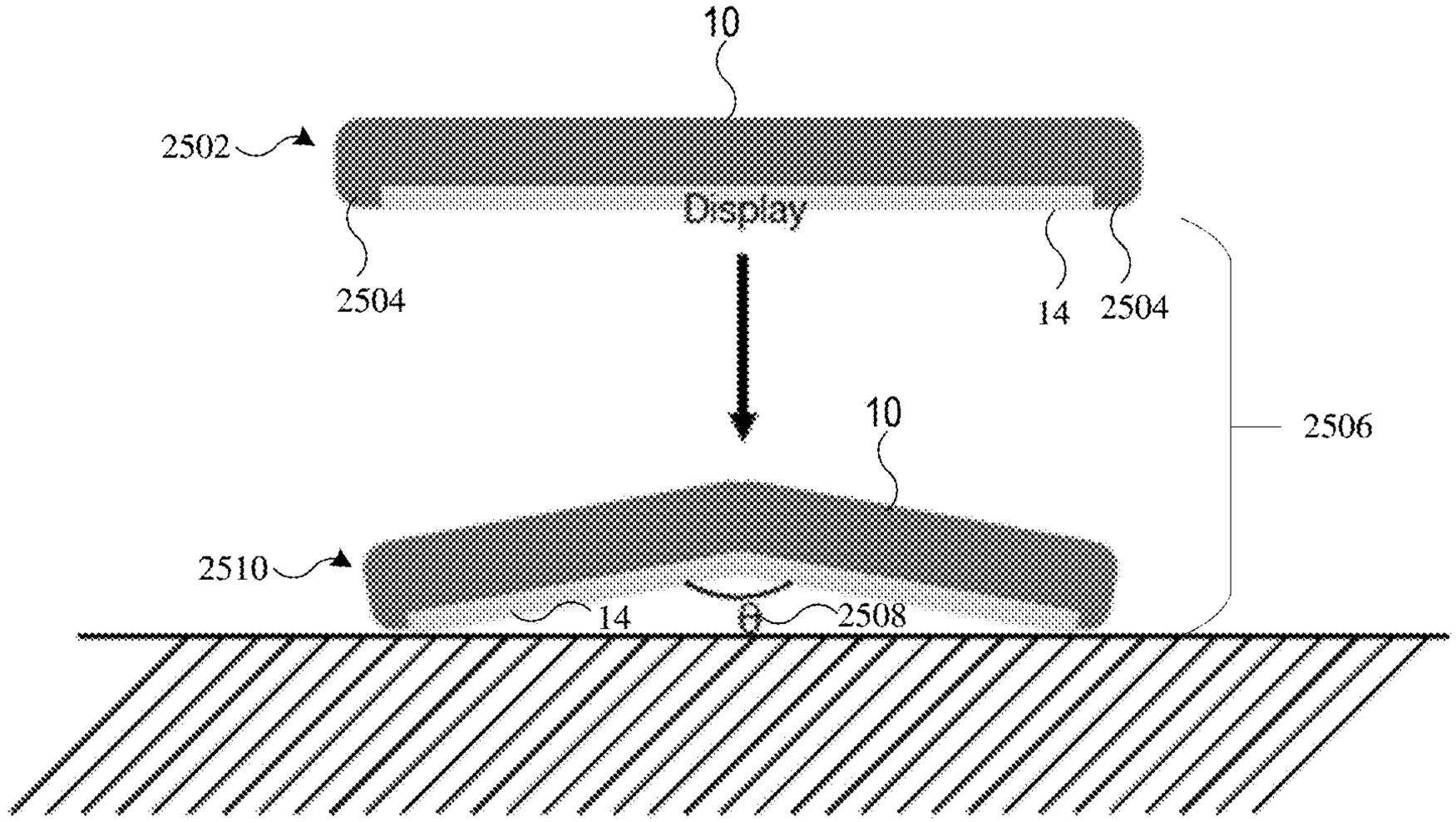


FIG. 25

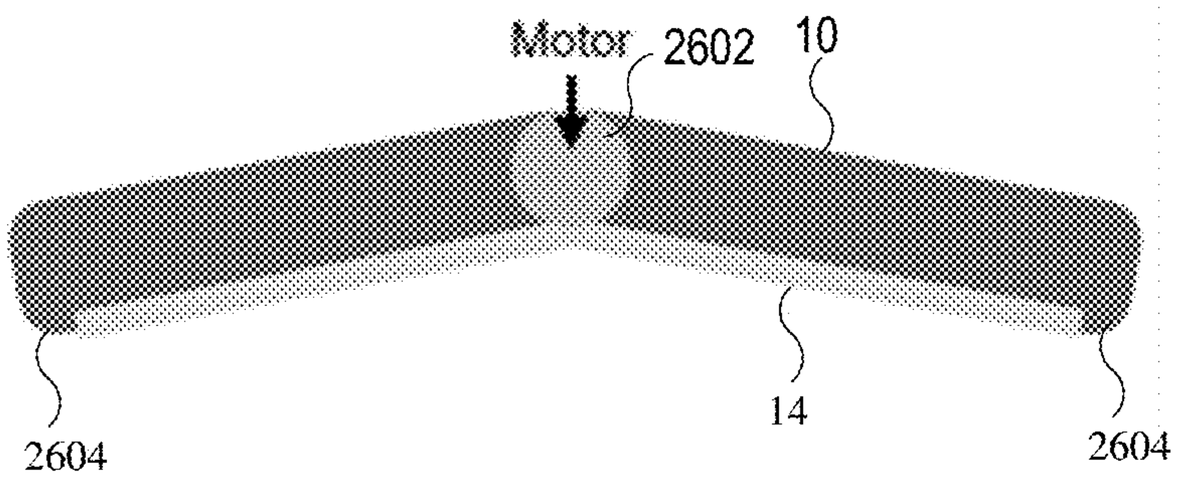


FIG. 26A

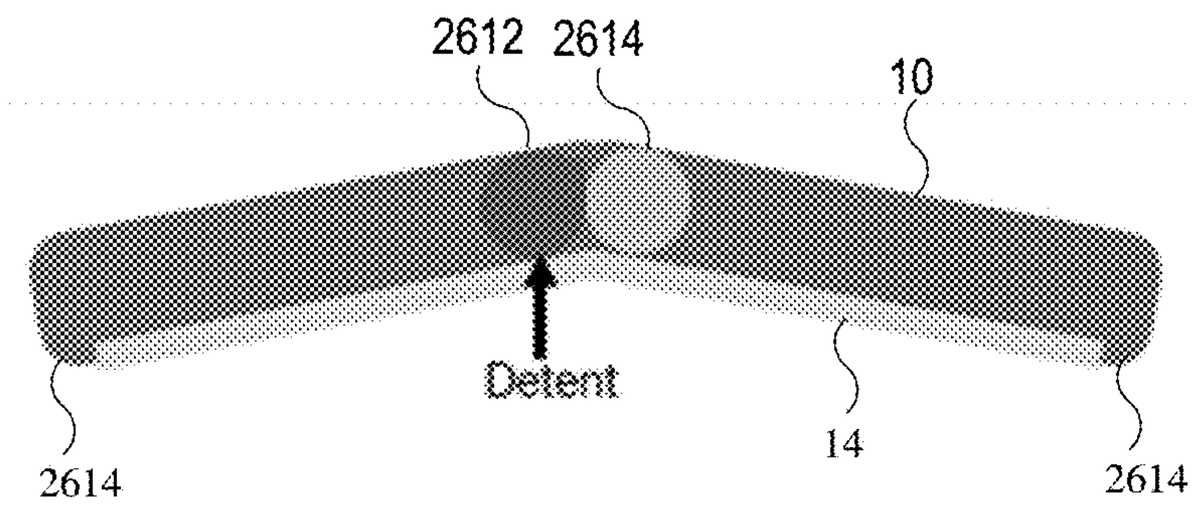


FIG. 26B

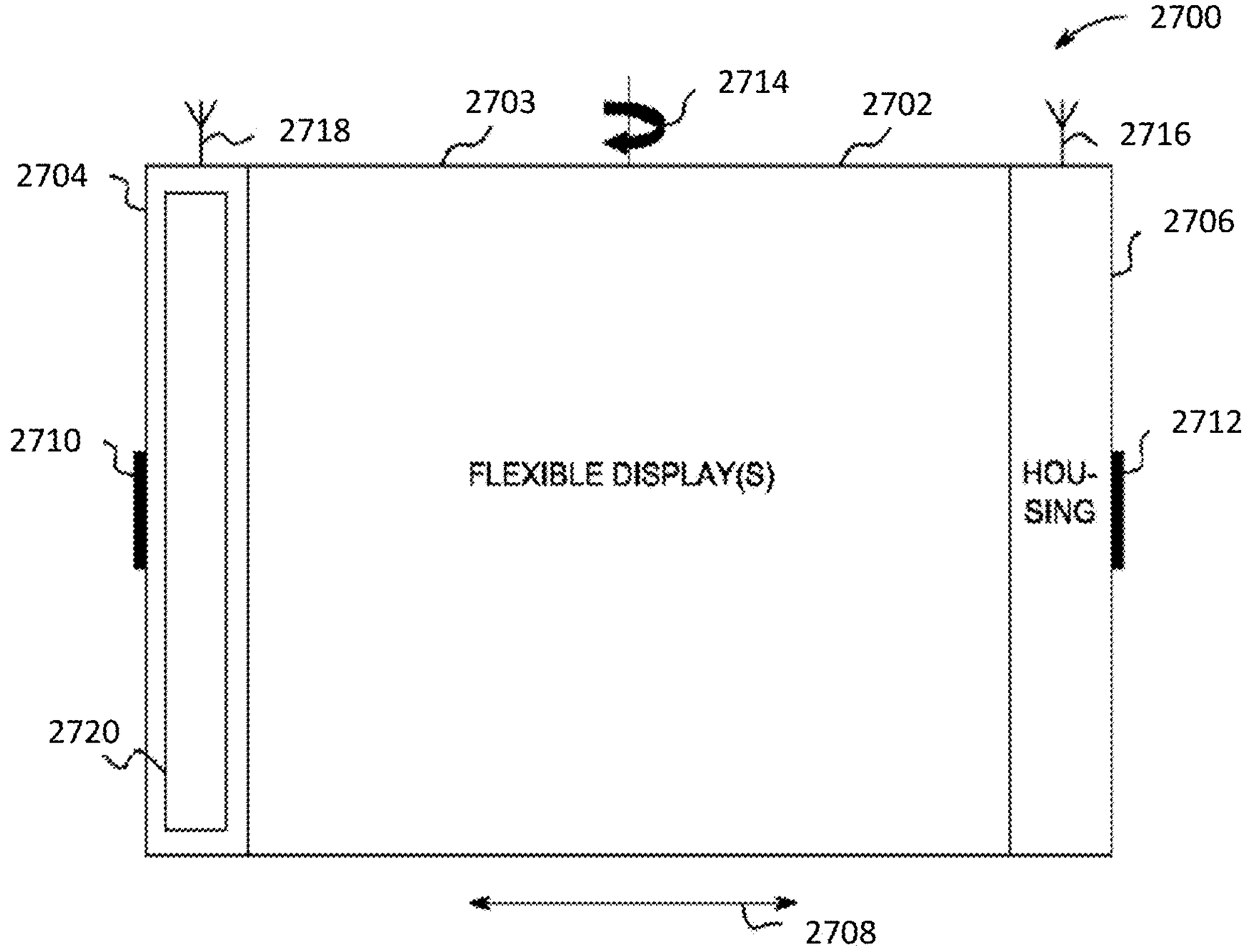

2700
2718
2703
2714
2702
2716
2704
2706
2710
FLEXIBLE DISPLAY(S)
HOU-
SING
2712
2720
2708

FIG. 27

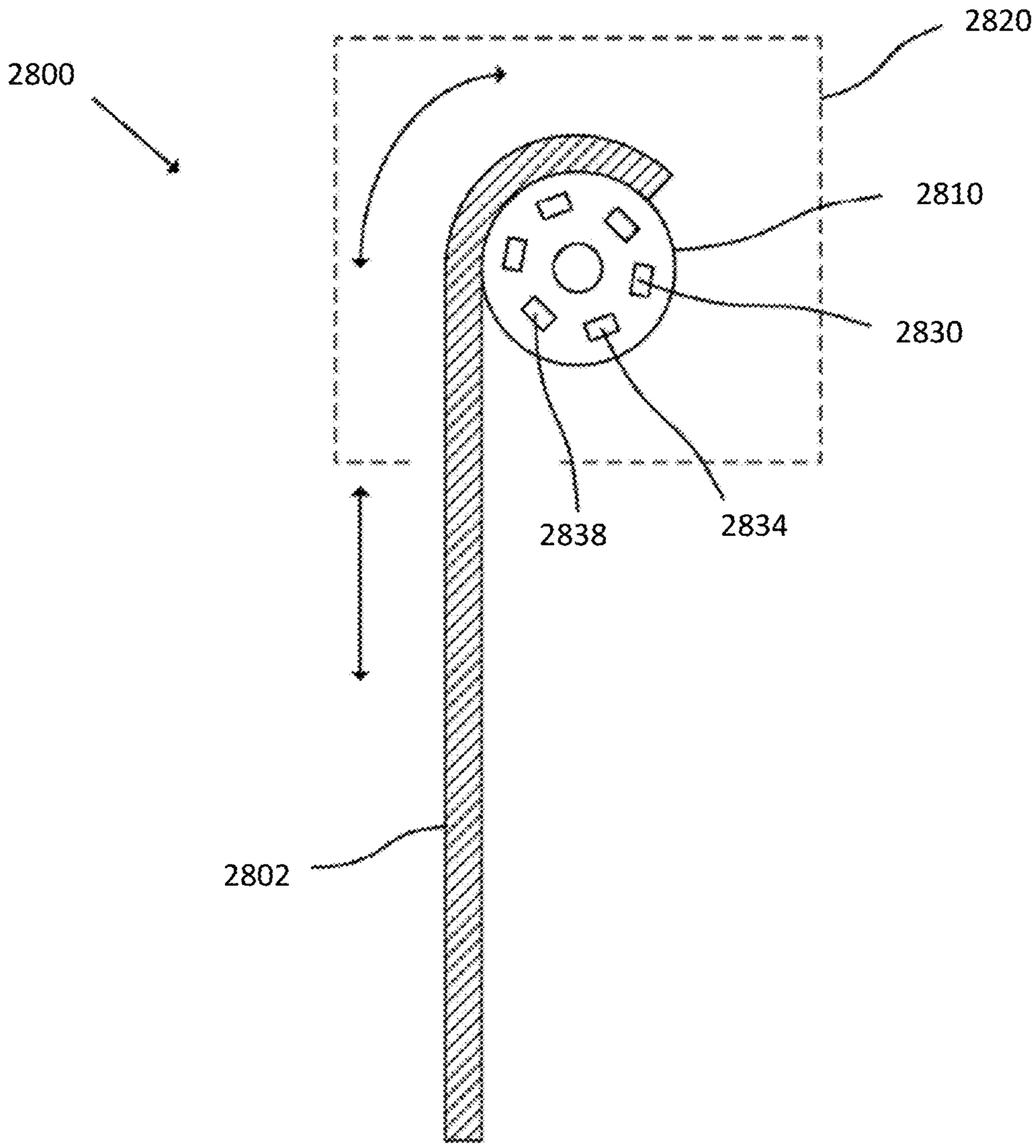


FIG. 28

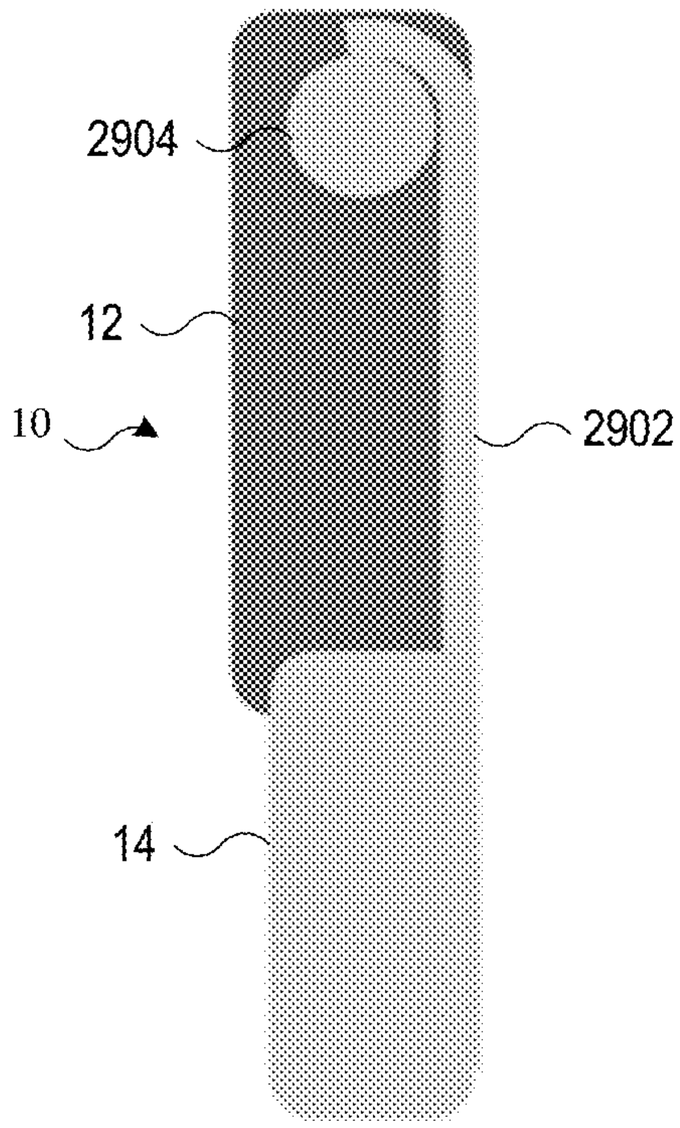


FIG. 29

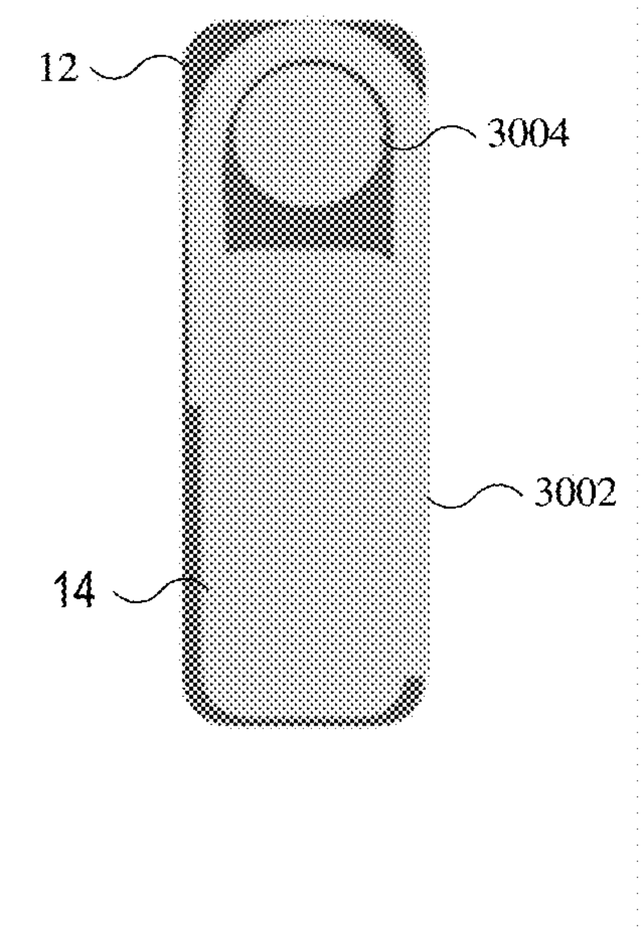


FIG. 30

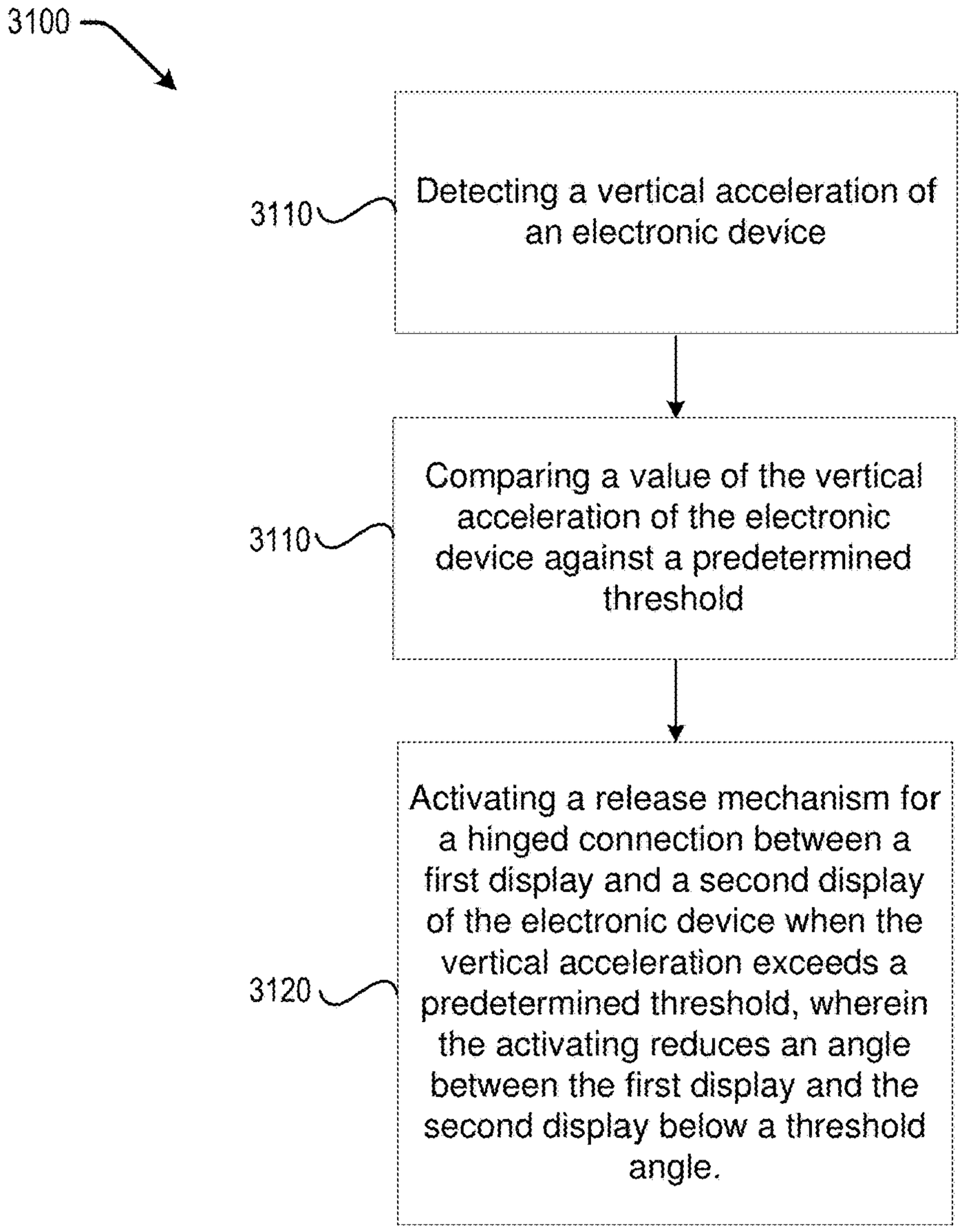

3100
3110
Detecting a vertical acceleration of an electronic device
3110
Comparing a value of the vertical acceleration of the electronic device against a predetermined threshold
3120
Activating a release mechanism for a hinged connection between a first display and a second display of the electronic device when the vertical acceleration exceeds a predetermined threshold, wherein the activating reduces an angle between the first display and the second display below a threshold angle.

FIG. 31

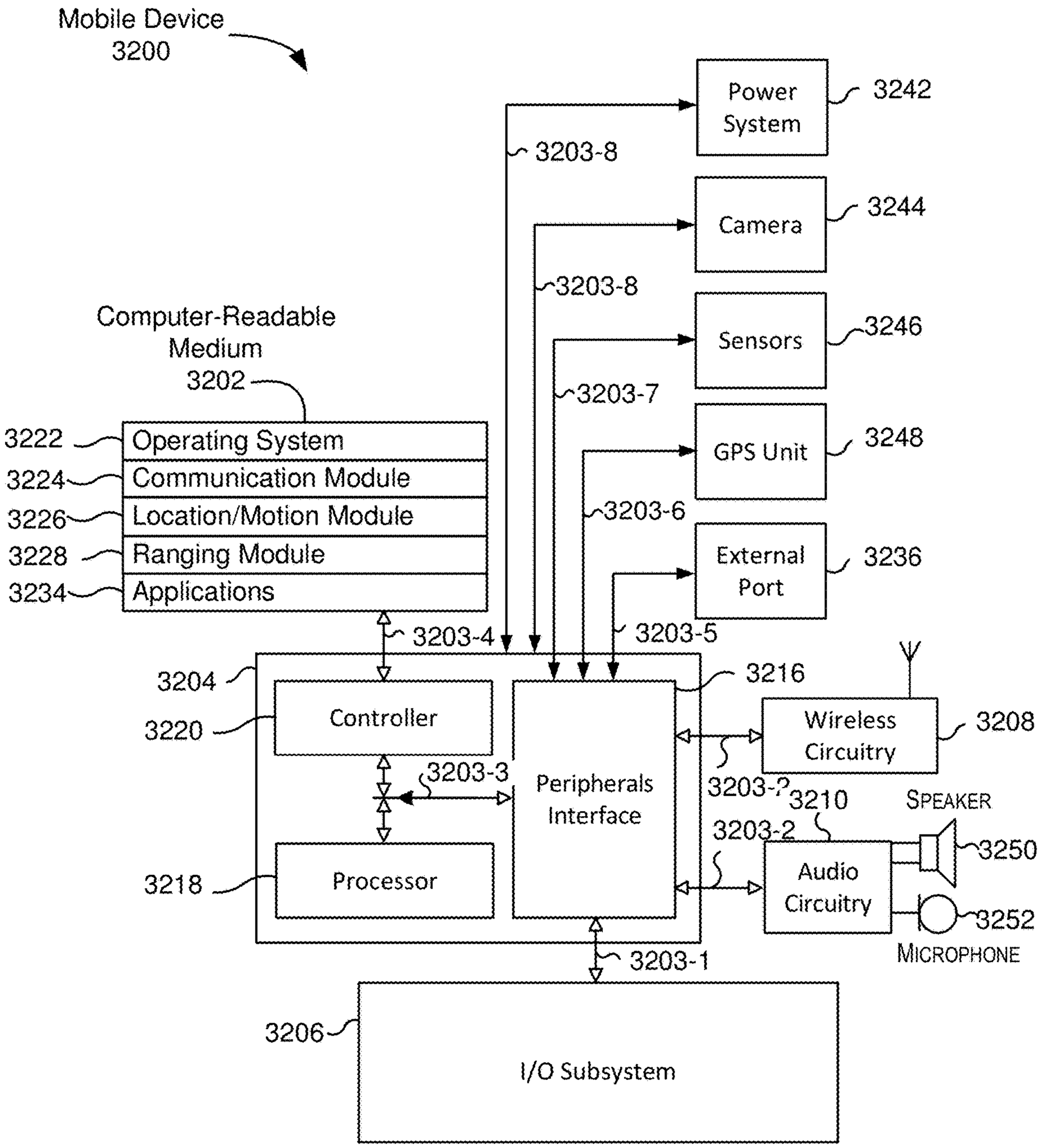

Mobile Device
3200
Computer-Readable Medium
3202
3222
Operating System
3224
Communication Module
3226
Location/Motion Module
3228
Ranging Module
3234
Applications
3204
Controller
3220
3218
Processor
Peripherals Interface
3216
Power System
3242
Camera
3244
Sensors
3246
GPS Unit
3248
External Port
3236
Wireless Circuitry
3208
Audio Circuitry
3210
SPEAKER
3250
3252
MICROPHONE
3203-1
3203-2
3203-3
3203-4
3203-5
3203-6
3203-7
3203-8
3206
I/O Subsystem

FIG. 32

SELF-RETRACTING DISPLAY DEVICE AND TECHNIQUES FOR PROTECTING SCREEN USING DROP DETECTION

CROSS-REFERENCES TO RELATED APPLICATIONS

[0001] This application claims priority to and the benefit of U.S. Provisional Patent Application No. 63/244,131, filed Sep. 14, 2021, entitled "Self-Retracting Display Device And Techniques For Protecting Screen Using Drop Detection" hereby incorporated by reference it in their entirety and for all purposes.

BACKGROUND

[0002] Mobile devices with thin-screen displays may be vulnerable if the display strikes the ground after dropping. Certain foldable displays and rollable displays can be especially vulnerable due to use of ultra-thin glass displays which can be especially vulnerable. It would be advantageous to detect when a device is falling to implement protection features to

BRIEF SUMMARY

[0003] Mobile devices with foldable and rollable displays can use a sensor to detect vertical acceleration (e.g., acceleration with respect to the ground) to determine if the mobile device has been dropped. If the sensor detects that the mobile device has been dropped the foldable device can retract at least partially to afford protection from the fragile display from striking the ground. Even folding the display to an angle less the 180 degrees can afford some protection because the mobile device can strike edges of the mobile device instead of the display itself. In various embodiments, a rollable device can retract the display if predetermined acceleration limits are exceeded.

[0004] In an aspect an electronic device can include a first display coupled to a second display via a hinged connection. In various embodiments, the first display and the second display can each be portions of a foldable display. The sensor used to detect vertical acceleration can be an accelerometer (e.g., as part of an inertial measure unit (IMU)). If the vertical acceleration exceeds a predetermined threshold, a release mechanism operating with a hinged connection can be used to reduce the angle between the first display and the second display below a threshold angle when the predetermined acceleration threshold is exceeded. In various embodiments, the threshold angle can be less than 180 degrees.

[0005] In various embodiments, the release mechanism can include a motorized hinge. In other embodiments, the release mechanism can include a mechanical hinge with a spring-loaded detent.

[0006] The first display or the second display can be a light emitting diode display such as an organic light emitting diode display.

[0007] In an aspect, an electronic device can include a foldable display coupled on one edge of the foldable device to a roller. The electronic device can include an acceleration sensor configured to detect a vertical acceleration of the electronic device exceeding a predetermined vertical acceleration threshold. The acceleration sensor can be an inertial measurement unit. The electronic device can include a release mechanism operating with the roller to automatically retract the foldable display on the roller when the detected vertical acceleration exceeds a predetermined acceleration threshold.

[0008] In various embodiments, the release mechanism comprises a motorized hinge. In other embodiments, the release mechanism comprises a mechanical hinge with a spring-loaded detent.

[0009] In various embodiments the foldable display can include a substrate including a first side and a second side, a first wiring layer on the first side, an array of LEDs on and in electrical contact with the first wiring layer on the first side of the substrate, and a second wiring layer on the second side of the substrate. The array of LEDs can include both inorganic LEDs and organic LEDs. The foldable display can include a plurality of interconnects extending between and electrically connecting the first wiring layer to the second wiring layer.

[0010] In various embodiments, the foldable display can include an array of microchips connected with the first wiring layer to drive the array of LEDs. Each microchip can be connected with a corresponding plurality of LEDs.

[0011] In an aspect, a method can include detecting a vertical acceleration of an electronic device. The method can include comparing a value of the vertical acceleration of the electronic device against a predetermined threshold. The method can include activating a release mechanism for a hinged connection between a first display and a second display of the electronic device when the vertical acceleration exceeds a predetermined threshold, wherein the activating reduces an angle between the first display and the second display below a threshold angle.

[0012] In various embodiments, the release mechanism comprises a motorized hinge. In various embodiments, the release mechanism comprises a mechanical hinge with a spring-loaded detent.

[0013] In various embodiments, the threshold angle is less than 180 degrees. In various embodiments, the first display or the second display is an organic light emitting diode display. The first display and the second display can each comprise regions of a foldable display.

[0014] A better understanding of the nature and advantages of embodiments of the present disclosure may be gained with reference to the following detailed description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. **1** is a perspective view of an illustrative electronic device in accordance with an embodiment.

[0016] FIG. **2** is a schematic diagram of an illustrative electronic device in accordance with an embodiment.

[0017] FIG. **3** is a diagram of a pair of adjacent electronic devices in accordance with an embodiment.

[0018] FIG. **4** is a side view of a pair of electronic devices supported by a bendable case with an internal hinge structure in accordance with an embodiment.

[0019] FIG. **5** is a side view of a pair of electronic devices supported by a folded case in accordance with an embodiment.

[0020] FIG. **6** is a side view of a pair of electronic devices in a case that has been folded back on itself in accordance with an embodiment.

[0021] FIG. **7** is a cross-sectional side view of a pair of illustrative electronic devices with beveled housing sidewalls that have been joined at a desired angle with respect

to each other using magnetic attraction and the angled surfaces of the sidewalls in accordance with an embodiment.

[0022] FIG. **8** is a cross-sectional side view of the pair of electronic devices with beveled housing sidewalls of FIG. **7** in a planar configuration in accordance with an embodiment.

[0023] FIG. **9** is a cross-sectional side view of a pair of illustrative electronic devices with angled housing sidewalls that have been joined at a desired angle with respect to each other using magnetic attraction in accordance with an embodiment.

[0024] FIG. **10** is a cross-sectional side view of the pair of illustrative electronic devices of FIG. **9** in a planar orientation in accordance with an embodiment.

[0025] FIG. **11** is a cross-sectional side view of a pair of adjacent electronic devices each of which has a display that covers housing sidewalls in accordance with an embodiment.

[0026] FIG. **12** is a cross-sectional side view of a pair of adjacent electronic devices each of which has a display that is borderless along at least its left and right edges in accordance with an embodiment.

[0027] FIG. **13** is a diagram showing how a system with multiple electronic devices may present content to a user in various contexts in accordance with an embodiment.

[0028] FIG. **14** is a cross-sectional side view of a system in which two devices are in a face-to-face configuration in accordance with an embodiment.

[0029] FIG. **15** is a cross-sectional side view of a system in which two devices are in a back-to-back configuration in accordance with an embodiment.

[0030] FIG. **16** is a cross-sectional side view of a system in which two devices are in a back-to-front configuration in accordance with an embodiment.

[0031] FIG. **17** is a flow chart of illustrative operations involved in using multiple electronic devices in accordance with an embodiment.

[0032] FIG. **18** is a perspective view of an illustrative electronic device having a display in accordance with an embodiment.

[0033] FIG. **19** is a first cross-sectional side view of electronic devices with flexible displays in accordance with an embodiment.

[0034] FIG. **20** is a second cross-sectional side view of electronic devices with flexible displays in accordance with an embodiment.

[0035] FIG. **21** is a diagram of an illustrative display with an array of light-emitting pixels in accordance with an embodiment.

[0036] FIG. **22** is a display in which pixels overlapping a bend axis have been illuminate to heat the portion of the display overlapping the bend axis in accordance with an embodiment.

[0037] FIG. **23** is a cross-sectional side view of a portion of an electronic device with an electrically adjustable magnetic latching mechanism in accordance with an embodiment.

[0038] FIG. **24** is a cross-sectional side view of a portion of an electronic device with an illustrative electrically adjustable mechanical latching mechanism in accordance with an embodiment.

[0039] FIG. **25** is an exemplary embodiment of a device with a foldable display incorporating display protective features.

[0040] FIG. **26**A is an exemplary embodiment of a device with a motorized release mechanism.

[0041] FIG. **26**B is an exemplary embodiment of a device with a spring-loaded detent release mechanism.

[0042] FIG. **27** is a diagram of a device having one or more electronic flexible screens.

[0043] FIG. **28** is schematic cross-sectional side view illustration of a system including a flexible display panel secured to a spool in accordance with an embodiment of the invention.

[0044] FIG. **29** illustrates an exemplary device with a rollable display in which the display is extended.

[0045] FIG. **30** illustrates an exemplary device with a rollable display in which the display is retracted.

[0046] FIG. **31** is a flowchart of an example process associated with techniques to protect a display of an electronic device.

[0047] FIG. **32** is a block diagram of an example electronic device.

[0048] Like reference, symbols in the various drawings indicate like elements, in accordance with certain example implementations. In addition, multiple instances of an element may be indicated by following a first number for the element with a letter or a hyphen and a second number.

DETAILED DESCRIPTION

[0049] Modern mobile devices can include foldable or rollable displays. In various embodiments, the foldable display can include two screens coupled together via a hinged connection that can be operated together to form a larger display. In various embodiments, the display can be constructed from flexible materials that can be flexed about a bend axis.

[0050] An illustrative electronic device of the type that may be used in a system with multiple electronic devices is shown in FIG. **1**. Electronic device **10** may be a computing device such as a laptop computer, a computer monitor containing an embedded computer, a tablet computer, a cellular telephone, a smart phone, a media player, or other handheld or portable electronic device, a smaller device such as a wrist-watch device, a pendant device, a headphone or earpiece device, a device embedded in eyeglasses or other equipment worn on a user's head, or other wearable or miniature device, a television, a computer display that does not contain an embedded computer, a gaming device, a navigation device, an embedded system such as a system in which electronic equipment with a display is mounted in a kiosk or automobile, equipment that implements the functionality of two or more of these devices, or other electronic equipment. In the illustrative configuration of FIG. **1**, device **10** is a portable device such as a smart phone, cellular telephone, media player, tablet computer, or other portable computing device. Other configurations may be used for device **10** if desired. The example of FIG. **1** is merely illustrative.

[0051] In the example of FIG. **1**, device **10** has opposing front and rear faces and peripheral sidewalls that run around the periphery of device **10**. Device **10** includes a display such as display **14** on the front face of device **10** mounted in housing **12**. Housing **12**, which may sometimes be referred to as an enclosure or case, may be formed of plastic, glass, ceramics, fiber composites, metal (e.g., stainless steel, aluminum, etc.), other suitable materials, or a combination of any two or more of these materials. Housing **12** may be

formed using a unibody configuration in which some or all of housing **12** is machined or molded as a single structure or may be formed using multiple structures (e.g., an internal frame structure, one or more structures that form exterior housing surfaces, etc.). Housing **12** may have vertical sidewalls, curved sidewalls, sidewalls with one or more beveled (angled) portions, sidewalls that are uncovered by display **14**, sidewalls that are partly or fully covered by portions of display **14**, and/or other suitable sidewall structures. The rear face of device **10** may be covered with housing **12**. Configurations in which a display such as display **14** is formed on the rear face of housing **12** (e.g., in addition to display **14** on the front face of device **10**) may also be used.

[0052] Display **14** may be a touch screen display that incorporates a layer of conductive capacitive touch sensor electrodes or other touch sensor components (e.g., resistive touch sensor components, acoustic touch sensor components, force-based touch sensor components, light-based touch sensor components, etc.) or may be a display that is not touch-sensitive. Capacitive touch screen electrodes may be formed from an array of indium tin oxide pads or other transparent conductive structures.

[0053] Display **14** may include an array of display pixels formed from liquid crystal display (LCD) components, an array of electrophoretic display pixels, an array of plasma display pixels, an array of organic light-emitting diode display pixels or other light-emitting diodes, an array of electrowetting display pixels, or display pixels based on other display technologies.

[0054] Display **14** may be protected using a display cover layer such as a layer of transparent glass or clear plastic. Openings may be formed in the display cover layer. For example, an opening may be formed in the display cover layer to accommodate optional speaker port **18**. Openings may also be formed in housing **12** to form communications ports (e.g., an audio jack port, a digital data port, etc.), to form openings for buttons, etc. If desired, a touch sensor, fingerprint sensor, dome-switch button or other input device such as input device **16** may be formed on the front face of device **10** (e.g., within an opening in the display cover layer, under the display cover layer in a configuration in which the display cover layer does not contain any button openings, etc.).

[0055] Display **14** may have an active area and an inactive area. The active area may, as an example, be formed in a rectangular central portion of the front face of device **10**. The active area contains pixels that display images for a user of device **10**. Inactive border regions (areas without pixels) may be formed along one or more of the edges of the active area. For example, the active area may be bordered on the left and right and top and bottom by inactive display areas. In other configurations, the active area of display **14** may cover all of the front face of device **10**, may cover the front face of device **10** and some or all of the sidewalls of device **10**, may have inactive borders at the upper and lower ends of device **10** while being borderless along the left and right edges of device **10**, or may have other layouts.

[0056] Components such as light sensors (e.g., light-sensors in proximity sensors, ambient light sensors, etc.), cameras (e.g., digital image sensors that capture images), status indicator lights (e.g., light-emitting diodes), and other components may be mounted under windows in display **14** such as windows **20** or other portions of device **10**. Sensors such as proximity sensor light sensors may be mounted under a layer of visible-light-blocking and infrared-light-transparent material. Sensors such as ambient light sensors and other components that use visible light such as cameras and status indicator lights may be mounted under windows that are transparent to visible light. Light-based components such as these may also be mounted on the rear face of device **10**, on device sidewalls, or in other portions of structures of device **10**.

[0057] A schematic diagram of an illustrative electronic device such as device **10** of FIG. **1** is shown in FIG. **2**. As shown in FIG. **2**, electronic device **10** may have control circuitry **50**. Control circuitry **50** may include storage and processing circuitry for supporting the operation of device **10**. The storage and processing circuitry may include storage such as hard disk drive storage, nonvolatile memory (e.g., flash memory or other electrically-programmable-read-only memory configured to form a solid state drive), volatile memory (e.g., static or dynamic random-access-memory), etc. Processing circuitry in control circuitry **50** may be used to control the operation of device **10** (e.g., to process sensor signals and other input and to control adjustable components such as a display, a heating element, etc.). The processing circuitry may be based on one or more microprocessors, microcontrollers, digital signal processors, baseband processors, power management units, audio chips, application specific integrated circuits, etc.

[0058] Input-output circuitry in device **10** such as input-output devices **52** 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. As shown in FIG. **2**, input-output devices **52** may include display **14**. Display **14** may be a touch screen that incorporates a two-dimensional touch sensor or may be insensitive to touch. A two-dimensional touch sensor for display **14** may be formed from an array of capacitive touch electrodes touch sensor or other touch sensor components (e.g., force sensors, resistive touch sensors, acoustic touch sensors, optical sensors, etc.).

[0059] Input-output devices **52** may include sensors **56**. Sensors **56** may include a capacitive proximity sensor, a light-based proximity sensor, a magnetic sensor, a force sensor such as a force sensor that gathers user input, a touch sensor for gathering user touch input, a temperature sensor, a pressure sensor, an ambient light sensor, a microphone or other sound sensor that gathers ambient noise measurements and user input such as voice commands, sensors for gathering data on device position and motion such as inertial measurement units that include accelerometers, compasses, and/or gyroscopes, and/or other sensors.

[0060] Input-output devices **52** may also include other components **54** such as buttons, joysticks, scrolling wheels, touch pads, key pads, keyboards, speakers, tone generators, vibrators, cameras, light-emitting diodes and other status indicators, data ports, etc. A user can control the operation of device **10** by supplying user input commands through input-output devices **52** and may receive status information and other output from device **10** using the output resources of input-output devices **52**.

[0061] Input-output devices **28** may include status-indicator lights (e.g., light-emitting diodes), light-emitting diodes for providing camera flash illumination and other light, buttons, joysticks, scrolling wheels, key pads, keyboards, audio components **34** such as microphones and speakers (e.g., an ear speaker located at an upper end of device **10** and/or one or more speaker-phone speakers at an opposing

lower end of device **10** or elsewhere in device **10** that are used to play audio when device **10** is being held away from a user's head), tone generators, haptic devices such as vibrators, cameras such as camera **30** (e.g., front-facing and/or rear-facing cameras), sensors **32**, displays such as display **14**, and other input-output components that gather input and provide output from device **10**. Input-output devices **28** (e.g., sensors **32**) may include touch sensors (e.g., stand-alone touch sensors for touch sensitive buttons and track pads and/or touch sensor panels that overlap display **14** and are used in gathering touch screen input from a user as selectable on-screen options are displayed on display **14**). Sensors **32** may also include light sensors, orientation sensors (e.g., accelerometers, gyroscopes, compasses, and/or other components that can detect device motion and/or device orientation such as device orientation relative to the Earth), resistance sensors (e.g., sensors that can detect contact by a conductive sidewall of another device or other external object), switch-based sensors, capacitance sensors, proximity sensors (e.g., a capacitive proximity sensor and/or a light-based proximity sensor such as an infrared proximity sensor that makes proximity sensor measurements by emitting infrared light from an infrared light-emitting diode and measuring corresponding reflected light using an infrared light detector), magnetic sensors, force sensors (e.g., force sensors based on a capacitive force sensing arrangement, strain gauges, piezoelectric force sensors, and/or other transducers that convert force into electrical signals), gas pressure sensors (e.g., sensors for measuring air pressure), gas sensors (e.g., carbon dioxide sensors), particulate sensors, moisture sensors, a connector port sensor or other sensor that determines whether first device **10** is mounted in a dock, and other sensors and input-output components.

[0062] Control circuitry **50** may be used to run software on device **10** such as operating system code and applications. During operation of device **10**, the software running on control circuitry **50** may display images on display **14** (e.g., video, still images such as text, alphanumeric labels, photographs, icons, other graphics, etc.) using an array of pixels in display **14**. In self-heating arrangements, control circuitry **50** can use display **14** to display patterns of light (e.g., images or other patterns of light) that heat portion **14**B of display. For example, control circuitry **50** can direct the pixel array in display **14** to illuminate some or all of the pixels in portion **14**B so that heat generated by the illuminated pixels will heat portion **14**B.

[0063] Control circuitry **50** may be configured to execute instructions for implementing desired control and communications operations in device **10** and systems including multiple devices such as device **10**. For example, control circuitry **22** may be used in processing sensor data, processing user input, processing information received via wireless communications circuitry, and/or other information to determine when to operate device **10** in an independent mode or in a joint operating mode with other devices and to determine which capabilities device **10** and/or other devices should be provided with during these operating modes.

[0064] Control circuitry **50** may perform these operations using hardware (e.g., dedicated hardware or circuitry) and/or software code (e.g., code that runs on the hardware of device **10** such as control circuitry **50**). Software code may be stored on non-transitory computer readable storage media (e.g., tangible computer readable storage media). The software code may sometimes be referred to as software, data, program instructions, instructions, or code. The non-transitory computer readable storage media may include non-volatile memory such as non-volatile random-access memory (NVRAM), one or more hard drives (e.g., magnetic drives or solid state drives), one or more removable flash drives or other removable media, other computer readable media, or combinations of these computer readable media or other storage. Software stored on the non-transitory computer readable storage media may be executed on the processing circuitry of control circuitry **50** during operation.

[0065] In some configurations for device **10**, device **10** may include an electrically adjustable latching mechanism such as latching mechanism **58**. Latching mechanism **58** may be engaged when it is cold and portion **14**B is therefore sensitive to bending stress (e.g., when adhesive or other materials in portion **14**B have become stiff from the cold and susceptible to damage if flexed). By engaging latching mechanism whenever portion **14**B is cold to prevent device **10** from being unfolded, undesired damage to portion **14**B can be avoided. Latching mechanism **58** may be disengaged when the temperature of portion **14**B is sufficiently high to avoid damage during bending.

[0066] Device **10** may have input-output circuitry **24**. Input-output circuitry **24** may be configured to gather input from users, external devices, and the surrounding environment and may be configured to supply output to users, external devices, and the surrounding environment. As shown in FIG. **2**, input-output circuitry **24** may include communications circuitry **26** and input-output devices **28**.

[0067] Communications circuitry **26** may include transceiver circuitry (transmitters and/or receivers) for supporting wired and wireless communications. For example, communications circuitry **26** may support data communications between device **10** and another electronic device over a serial or parallel data path. Device **10** may have communications ports (e.g., Universal Serial Bus ports, etc.) for receiving mating data cables. The data cables can be used to carry data between device **10** and other electronic equipment (e.g., peer devices, etc.).

[0068] Communications circuitry **26** may include also wireless communications circuitry for communicating wirelessly with external equipment. The wireless communications circuitry may include radio-frequency (RF) transceiver circuitry formed from one or more integrated circuits, power amplifier circuitry, low-noise input amplifiers, passive RF components, one or more antennas, transmission lines, and other circuitry for handling RF wireless signals. Wireless signals can also be sent using light (e.g., using infrared communications).

[0069] Communications circuitry **26** may include radio-frequency transceiver circuitry for handling various radio-frequency communications bands. For example, circuitry **26** may include transceiver circuitry that transmits and receives data in 2.4 GHz and 5 GHz bands for Wi-Fi® (IEEE 802.11) communications and the 2.4 GHz Bluetooth® communications band. Circuitry **26** may include cellular telephone transceiver circuitry for handling wireless communications in frequency ranges such as a low communications band from 700 to 960 MHz, a midband from 1710 to 2170 MHz, and a high band from 2300 to 2700 MHz or other communications bands between 700 MHz and 2700 MHz or other suitable frequencies (as examples). Circuitry **26** may handle voice data and non-voice data. Wireless communications circuitry in circuitry **26** can include circuitry for other

short-range and long-range wireless links if desired. For example, circuitry **26** may include millimeter wave communications circuitry (e.g., circuitry for supporting 60 GHz communications and communications in other millimeter wave bands), circuitry for receiving television and radio signals, paging system transceivers, near field communications (NFC) circuitry, etc. Circuitry **26** may also include global positioning system (GPS) receiver equipment for receiving GPS signals at 1575 MHz or for handling other satellite positioning data. In WiFi® and Bluetooth® links and other short-range wireless links, wireless signals are typically used to convey data over tens or hundreds of feet. In cellular telephone links and other long-range links, wireless signals are typically used to convey data over thousands of feet or miles.

[0070] Communications circuitry **26** may include one or more antennas. These antennas may be located at one or both ends of device **10**, along the sides of device **10**, at the corners of device **10**, in the middle of the rear face of device **10**, and/or at other locations within housing **12**. Antennas for device **10** may be formed using any suitable antenna types. For example, antennas in circuitry **26** may include antennas with resonating elements that are formed from loop antenna structures, patch antenna structures, inverted-F antenna structures, slot antenna structures, planar inverted-F antenna structures, helical antenna structures, hybrids of these designs, etc. Different types of antennas may be used for different bands and combinations of bands. For example, one type of antenna may be used in forming a local wireless link antenna and another type of antenna may be used in forming a remote wireless link antenna. Device **10** may include impedance sensors (e.g., impedance measurement circuitry that measures the impedance of antennas and/or other radio-frequency components in circuitry **26**). These sensors may be used by the control circuitry of device **10** in detecting when external objects are in the vicinity of device **10** (e.g., when part of device **10** is being held in the hand of a user, when part of device **10** such as an edge of device **10** is adjacent to another electronic device, etc.).

[0071] Devices such as device **10** can be used in isolation or, when brought into the vicinity of additional devices such as device **10** can be used in joint operating modes. An illustrative system in which two electronic devices have been placed adjacent to each other for use in a joint operating mode is shown in FIG. **3**. As shown in FIG. **3**, system **36** may include multiple electronic devices such as device **10** of FIGS. **1** and **2**. System **36** may, as an example, include a pair of devices, two or more devices, three or more devices, four or more devices, five or more devices, 2-4 devices, fewer than five devices, fewer than four devices, or other suitable number of electronic devices **10**.

[0072] In the example of FIG. **3**, system **36** includes first electronic device **10**A and second electronic device **10**B. Devices **10**A and **10**B may be peer devices (e.g., devices **10**A and **10**B may both be cellular telephones, may both be wristwatch devices, may both be tablet computers, may both be laptop computers, may both be desktop computers, etc.) or devices **10**A and **10**B may be different types of devices. For example, device **10**A may be a tablet computer and device **10**B may be a cellular telephone, device **10**A may be a laptop computer, and device **10**B may be a tablet computer, device **10**A may be a cellular telephone and device **10**B may be a wrist watch device, etc. In some configurations, devices **10**A and **10**B are of the same general type but have individual differences (e.g., devices **10**A and **10**B may be different cellular telephone models). Configurations for system **36** in which devices **10**A and **10**B have the same size and shape may sometimes be described herein as an example. This is however, merely illustrative. Devices **10**A and **10**B may have different shapes (e.g., outlines when viewed from the front that are circular, oval, triangular, hexagonal, rectangular, etc.) and/or may have different sizes (e.g., device **10**A may have a housing **12** and/or a display **14** that is larger or smaller than the housing and/or display of device **10**B, etc.).

[0073] As shown in FIG. **3**, devices **10**A and **10**B may be oriented on a tabletop or other surface so that devices **10**A and **10**B are adjacent (e.g. so that one or more edges of housing **12**A of device **10**A abuts one or more edges of housing **12**B of device **10**B). In the example of FIG. **3**, the right-hand edge of housing **12**A is aligned with and touching a corresponding left-hand edge of housing **12**B, so that display **14**A of device **10**A and display **14**B of device **10**B can effectively form a single larger display and so that other resources of devices **10**A and **10**B can be used together. Other arrangements in which devices **10**A and devices **10**B are placed adjacent to each other (e.g., so that the housing sidewall along the periphery of one device abuts at least some of the housing sidewall along the periphery of another device) can be used, if desired.

[0074] Devices **10**A and **10**B may contain components **38** that are located within housings **12**A and **12**B. Components **38** may be located along one or more edge of devices **10**A and **10**B and/or may be located elsewhere within the housings of devices **10**A and **10**B. For example, one or more components **38** may be located along each peripheral edge of devices **10**A and **10**B so that sensing circuitry associated with components **38** can detect external objects around the periphery of each device (e.g. by making sensor measurements through sidewalls of housing **12** or through other portions of housing **12**). In some configurations, components **38** may make sensor measurements through display **14**.

[0075] If desired, components **38** may include magnetic components such as permanent magnets, electromagnets, and/or magnetic materials such as iron that are attracted to permanent magnets and electromagnets. These magnetic components help hold devices **10**A and **10**B adjacent to each other. If desired, components **38** and/or the housings of devices **10**A and **10**B may include interlocking male and female parts (e.g., pins and holes, interlocking grooves, or other engagement structures) that help hold devices **10**A and **10**B in desired positions relative to each other. Devices **10**A and **10**B may also be supported by removable sleeves, plastic or leather cases, covers that fold or bend, and/or other supporting structures.

[0076] Components **38** may include sensors such as sensors **32** of FIG. **2** for detecting when devices **10**A and **10**B are adjacent to each other. For example, components **38** may include magnetic sensors, force sensors, proximity sensors, antenna impedance sensors, light-based sensors, capacitive sensors, resistive sensors that measure resistance to determine when a metal object such as an electronic device housing is in contact with a given device, switch-based sensors, and/or other sensors that detect when the edge of one device housing abuts at least a portion of an edge of another device housing. Sensors in components **38** may also be configured to operate through the front and rear faces of

the housings for devices **10**A and **10**B (e.g., to detect when devices **10**A and **10**B are overlapping in a front-to-front configuration, a back-to-back configuration, or a front-to-back configuration).

[0077] In general, devices **10** may have any suitable number of components **38** and these components may run along the edges of each device **10** (e.g., on the interior side of a housing sidewall formed from metal, plastic, and/or glass or other materials), and/or may be located at other locations within the interior of the housing for each device **10**). The configurations of FIG. **3** are illustrative.

[0078] Sleeves and other support structures for supporting devices **10**A and **10**B (sometimes referred to herein as covers or cases) may be formed from plastic, metal, fabric, leather or other natural materials, and/or other materials. In some configurations, covers for system **36** may be foldable.

[0079] FIG. **4** is a cross-sectional side view of system **36** in which devices **10**A and **10**B are supported by a foldable support structure such as cover **38**. Cover **38** of FIG. **4** has hinge structures **40** that help hold cover **38** in a desired bent shape (e.g., to support device **10**B at an non-zero angle with respect to device **10**A, so that device **10**A can serve as a touch sensitive virtual keyboard while device **10**B serves as a display for presenting a document or other content to a user, etc.). Hinge structures **40** may be formed from interlocking rotatable structures (e.g., a clutch barrel assembly), may include bendable metal or plastic structures (e.g., bendable strip-shaped members that retain their shape when forced into a particular bent or flat position by a user), or other hinge mechanisms. Hinge structures **40** allow a user to place devices **10**A and **10**B in a planar configuration (e.g., lying flat on a table so that devices **10**A and **10**B and their respective displays lie in a common plane) or in a bent configuration of the type shown in FIG. **4** in which the surface normal of the display of device **10**A is oriented at a non-zero angle with respect to the surface normal of the display of device **10**B and which devices **10**A and **10**B do not lie in a common plane). Attachment structures **42** (e.g., straps, magnets, adhesive, screws or other fasteners, clamps, etc.) may be used in removably attaching devices **10**A and **10**B to cover **38**.

[0080] As shown in the example of FIG. **5**, cover **38** may have a foldable portion such as portion **38**F that can be folded into a shape that supports device **10**B at a non-zero angle with respect to device **10**A. FIG. **6** shows how cover **38** may be folded 180° to allow the front faces of devices **10**A and **10**B to face each other. If desired, covers **38** of FIGS. **5** and **6** may be provided with hinge structures such as hinge structures **40**. Configurations for cover **38** that support three or more devices **10**, that allow devices **10**A and **10**B to be placed into front-to-back and back-to-back configurations, and/or that allow devices **10**A and **10**B to be supported in other orientations relative to each other may also be used. In some arrangements, device **10**A may be coupled to cover **38** while magnetic components are used in oriented device **10**B relative to device **10**A or magnetic components and cover **38** may be used together in other configurations. For example, cover **38** may form a base to which device **10**A may be attached while magnetic components are used in coupling device **10**B to device **10**A at a desired angle (e.g., a non-zero angle).

[0081] FIGS. **7**, **8**, **9**, and **10** show illustrative configurations in which devices **10**A and **10**B are oriented relative to each other using magnetic components (see, e.g., components **38** along the peripheral edges of devices **10**A and **10**B in FIG. **3**). When the edges of the housings of devices **10**A and **10**B are brought together with this type of arrangement, magnetic attraction between magnetic components in respective portions of devices **10**A and **10**B hold devices **10**A and **10**B together. Device housings **12**A and **12**B may have curved sidewalls, flat (vertical) sidewalls, or sidewalls with other suitable cross-sectional profiles.

[0082] In some configurations, the sidewall profile of devices **10**A and **10**B may help orient devices **10**A and **10**B relative to each other while the respective abutting edges of devices **10**A and **10**B are pulled together by magnetic attraction. As shown in FIG. **7**, for example, housings **12**A and **12**B may have beveled sidewalls each of which has two beveled 45° sidewall surfaces **44** and one vertical sidewall surface **46**. In the configuration of FIG. **7**, one of surfaces **46** bears against to one of surfaces **44** (e.g., magnetic attraction from magnetic components in housings **12**A and **12**B couple these surfaces together), so that device **10**B is oriented at 45° relative to device **10**A (e.g., so that device **10**A can serve as a touch sensitive virtual keyboard while device **10**B serves as a display for presenting a document or other content to a user, etc.). In the illustrative configuration of FIG. **8**, one of vertical sidewall surfaces **46** of device **10**A abuts one of vertical sidewall surfaces **46** of device **10**B, so that devices **10**A and **10**B are held in a planar orientation relative to each other.

[0083] In the illustrative arrangement of FIGS. **9** and **10**, device housings **12**A and **12**B have angled (outwardly sloped) sidewall surfaces **48** each of which is oriented at a non-zero angle with respect to surface normal n of displays **14**A and **14**B, respectively. When placed so that sidewall surfaces **48** press against each other and lie in the same plane as shown in FIG. **9**, device **10**B is supported at a non-zero angle with respect to device **10**A. When placed so that sidewall surfaces **48** are not in direct contact, devices **10**A and **10**B may rest side-by-side in the adjacent device configuration of FIG. **10** (e.g., so that displays **14**A and **14**B lie in the same plane).

[0084] Display **14** may cover some or all of the front face of device **10**. If desired, display **14** may have portions that extend over some or all of the sidewalls of housing **12**. As shown in FIG. **11**, for example, display **14** may have left and right edges that fold down over the left and right sidewalls of each device. When placed adjacent to each other as shown in FIG. **11**, abutting sidewall portions **14**A' and **14**B' of displays **14**A and **14**B, respectively, may be disabled. This allows content (e.g., videos, text, and/or other images) to be displayed in a seamless fashion across the exposed front face surfaces of displays **14**A and **14**B. The outermost portions **14**A' and **14**B' of the displays of FIG. **11** (e.g., portion **14**A' on the left of device **10**A and portion **14**B' on the right of device **10**B) may be used to display extended portions of the image displayed on the front faces of devices **10**A and **10**B, may be used to display virtual buttons for system **36**, and/or may be temporarily deactivated.

[0085] In the arrangement of FIG. **12**, displays **14**A and **14**B have borderless configurations, so that images can be displayed seamlessly across displays **14**A and **14**B when devices **10**A and **10**B are adjacent (e.g., when the sidewalls of device housings **12**A and **12**B abut). Other configurations for devices **10**A and **10**B may be used, if desired (e.g., configurations in which one or more edges of display **14** has an inactive border).

[0086] FIG. **13** illustrates how devices **10**A and **10**B may behave when brought together and pulled apart.

[0087] Initially, devices **10**A and **10**B of system **36** may be in an independent operating mode represented by state **50-1**. In state **50-1**, devices **10**A and **10**B are separated by an air gap and are not adjacent to each other. Sensors in components **38** can apply measured sensor signals to predetermined adjacency thresholds (adjacency criteria such as a minimum separation distance, sidewall alignment criteria, angular orientation criteria, etc.) to determine whether devices **10**A and **10**B are adjacent or are separated. When separated as shown in state **50-1**, each device can operate independently. A single user may operate both devices or each device may be operated by a respective user.

[0088] Components **38** may monitor whether devices **10**A and **10**B are adjacent. Wireless communications (e.g., handshaking) between devices **10**A and **10**B to determine whether devices **10**A and **10**B are adjacent and/or other techniques for determining adjacency may also be used. In response to detecting that devices are adjacent, system **36** may transition to a joint (adjacent) operating mode, as illustrated by state **50-2** of FIG. **13**.

[0089] In state **50-2**, some or all of the functions of devices **10**A and **10**B may continue to operate independently. For example, devices **10**A and **10**B may display separate content on their respective displays (e.g. a first web page on device **10**A and a second web page on device **10**B) and/or may play separate audio. At the same time, the joint operating mode may allow at least some of the functions of devices **10**A and **10**B to be shared. As an example, a wireless communications circuit in device **10**A may transmit and receive data for both device **10**A and device **10**B (and this data may be exchanged locally between devices **10**A and **10**B using a wired or wireless link between devices **10**A and **10**B) or measurements from an ambient light sensor in device **10**A may be used in controlling screen brightness in the displays of both devices **10**A and **10**B.

[0090] If desired, devices **10**A and **10**B may operate in a coordinated fashion during the joint mode of state **50-2** so that most or all functions of the devices are coordinated. For example, images that are displayed may be expanded to stretch across displays **14**A and **14**B to provide a user with an expanded display area, stereo audio may be played from a first speaker in device **10**A and a second speaker in device **10**B, touch input may be gathered from displays **14**A and **14**B so that a user can drag on-screen items from display **14**A to display **14**B or can make touch gestures that extend across displays **14**A and **14**B, wireless communications capabilities of devices **10**A and **10**B may be combined to provide enhanced bandwidth and/or additional bands of coverage, etc.

[0091] In some arrangements, devices **10**A and **10**B may be operated in a master-slave (mother/child) configuration. In this type of arrangement, the operation of one device is used in controlling the operation of another device. As an example, device **10**A may display a virtual keyboard for system **36** and device **10**B may display documents or other content that is being controlled by input supplied to the keyboard. Device **10**A may also serve as video controller device, a color picker input area, brush selection area, or other input area for an image editing application that is displaying an edited image on device **10**A, may serve as a game controller pad or video playback controller pad with stop, pause, forward, and reverse button for device **10**B, or may otherwise serve as a touch controller for device **10**B.

[0092] Operations in each of these modes need not be mutually exclusive. For example, devices **10**A and **10**B may initially be operated independently in all respects (state **50-1**). In joint mode (state **50-2**), a first device function (e.g., use of wireless communications circuitry **26** to receive email messages) may remain separate on each device, a second device function (e.g., audio playback) may be shared (e.g., by presenting the audio in a synchronized stereo arrangement in which a speaker in device **10**A provide left channel audio for an audio track while a speaker in device **10**B simultaneously provides right channel audio for the same track), and a third device function (e.g., use of displays **14**A and **14**B) may be implemented using a master-slave arrangement (e.g., device **10**A may use display **14**A as a touch keyboard and device **10**B may use display **14**B as a display to present an edited image or other content to a user).

[0093] With the illustrative configuration of FIG. **13**, devices **10**A and **10**B initially present separate content (respectively, content A and content B) to their respective users (or to a single user of both devices). When placed adjacent to each other so that system **36** operates in joint state **50-2**, content A is presented using both displays **14**A and **14**B, whereas content B is no longer presented. Content A may be, for example, a video whereas content B may be a desktop screen containing an array of selectable icons. A user may be playing the video on device **10**A when device **10**B is brought into contact with device **10**A. When this configuration is detected, devices **10**A and **10**B can operate together to display a first half of content A on device **10**A and a second half of content A on device **10**B. In this way, the user may benefit from an enlarged display area and expanded stereo sound (by using respective speakers in devices **10**A and **10**B to present stereo to the user).

[0094] During joint operating mode (state **50-2**), devices **10**A and/or **10**B may use components **38** (e.g., sensors **32**) and optional handshaking procedures (e.g., messages relayed between devices **10**A and **10**B wirelessly upon detection of adjacency using sensors **32**) to determine whether devices **10**A and **10**B are adjacent. In response to detecting that devices **10**A and **10**B are no longer adjacent, devices **10**A and **10**B may transition to an updated operating mode such as a mode corresponding to one of operating states **50-3**, **50-4**, and **50-5** of FIG. **13**. The behavior of devices **10**A and **10**B after devices **10**A and **10**B are separated (e.g., whether system **36** transitions to state **50-3**, **50-4**, or **50-5**) can depend on the configuration of devices **10**A and **10**B during operating state **36** and/or other criteria.

[0095] Consider, as an example, a first scenario in which devices **10**A and **10**B are displaying a video that stretches across displays **14**A and **14**B in state **50-2**. The video (content A in this example) originated from device **10**A (via streaming or a video stored in storage in the control circuitry of device **10**A). When devices **10**A and **10**B are separated, system **36** transitions to the operating mode of state **50-3**. In state **50-3**, device **10**A continues to display the same video with its audio track, so that the user's viewing of the video is not disrupted. Device **10**B reverts to its original operating mode and displays content B (which may be, for example, a list of selectable icons on a desktop, an email inbox, or other functionality that is potentially specific to device **10**B).

[0096] In a second illustrative scenario, devices **10**A and **10**B transition from state **50-2** to state **50-4** when separated.

In state **50-2**, content for a video is spread across displays **14**A and **14**B. In this example, the content is being watched by two users who decided to share their screens during the joint operating mode of state **50-2**. When the two users need to separate their devices **10**A and **10**B (e.g., for more convenient viewing angles, because the users are departing for different destinations, etc.), both users desire to continue viewing the video. Accordingly, in this second operating scenario, the video (content A) is displayed separately (in its entirety) on each of displays **14**A and **14**B. If the video was initially stored locally on only one of the devices, the video can be transferred to the other device during state **50-2** (e.g., using a local communications link between devices **10**A and **10**B) or that other device can retain access to the video by automatically switching to an on-line video streaming delivery mode when the devices are separated. In scenarios in which the shared content on system **36** of state **50-2** is a website, the website can be displayed separately on both display **14**A and **14**B in state **50-4**.

[0097] In a third illustrative scenario, devices **10**A and **10**B transition from state **50-2** to state **50-5** when separated. The content displayed on displays **14**A and **14**B of system **36** in state **50-2** may correspond to a game with two users. In the combined display arrangement of state **50-2**, a first user's portion of the game (e.g., the first user's game controller and/or a first portion of a game playing space) is displayed on display **14**A, whereas a second user's portion of the game (e.g., the second user's game controller and/or a second portion of the game playing space) is displayed on display **14**B. Upon transitioning to state **50-5**, the first user's game controller and/or the first portion of a game playing space may continue to be displayed on display **14**A, whereas the second user's game controller and/or the second portion of the game playing space is displayed on display **14**B. This allows the two users to continue to play a shared game (perhaps in a mode in which it is desirable for each user's input to their game controller to not be revealed to the opposing user). At a later stage of game play, the users may recombine their devices to revert to state **50-2**. Local wireless communications links or communications links that pass through the internet may be used to allow the first and second user's to play the shared game in state **50-5**.

[0098] In some joint operating modes, devices **10**A and **10**B may be oriented so that they overlap each other in a front-to-front configuration in which their displays overlap and face each other (see, e.g., the arrangement of FIG. **14**), in a back-to-back configuration in which their displays overlap and face away from each other so that their rear faces are facing each other (see, e.g., the arrangement of FIG. **15**), or in a front-to-back configuration in which their displays are facing in the same direction (see, e.g., FIG. **16**). The orientation of devices **10**A and **10**B in these scenarios can be detected by components **38** and operation of devices **10**A and **10**B adjusted accordingly. When, for example, devices **10**A and **10**B are in a front-to-front configuration, displays **14**A and **14**B may be powered down to conserve power. When devices **10**A and **10**B are in a back-to-back configuration, one or both of displays **14**A and **14**B may be active. For example, a display facing up may be on and a display facing down may be turned off. The orientation of devices **10**A and **10**B relative to the Earth may be detected using an accelerometer in device **10**A and/or device **10**B. In a back-to-front configuration, it may be desirable to turn on the exposed display while turning of the covered (downward facing) display. In each of these joint operation modes, devices resources such as audio resources, communications circuitry, sensors, and other input-output circuitry **24** can be shared, if desired. Magnetic components (see, e.g., components **38**) may be used in coupling devices **10**A and **10**B together in overlapping configurations.

[0099] Illustrative operations involved in using multiple devices **10** (e.g., devices **10**A and **10**B) are shown in FIG. **17**. During the operations of block **60**, devices **10**A and devices **10**B may be operated in an independent operating mode (see, e.g., state **50-1** of FIG. **13**). During this mode, device **10**A and/or device **10**B may use components **38** (e.g., sensors **32**) to monitor for adjacency between devices **10**A and **10**B. If desired, output from components **38** in device **10**A and/or device **10**B may be used to initially detect that a sidewall along an edge of device **10**B is adjacent to one of the sidewalls along an edge of device **10**A and this initial detection may be confirmed using wireless communications between devices **10**A and **10**B (sometimes referred to as handshaking, authentication, or acknowledgement). For example, if device **10**A detects the presence of a possible adjacent device, device **10**A can issue a near-field communications request or other wireless request asking adjacent devices to identify themselves. In response, device **10**B can use its sensor(s) **32** to confirm adjacency and can wirelessly provide device **10**A with this information and/or information on the identity of device **10**B and/or other information confirming that device **10**B is authorized and desires to jointly operate with device **10**A. Configurations in which devices **10**A and/or **10**B generate confirmatory patterns of magnetic fields (e.g., a magnetic field produced by device **10**B that is detected by a magnetic sensor in device **10**A), acoustic signals or vibrations (e.g., a sound or vibration that is generated by device **10**B and detected by a microphone or accelerometer in device **10**A), light (e.g., light from a light-emitting diode in device **10**B that is detected by a light detector in device **10**A), and/or other in which devices **10**A and **10**B otherwise generate unidirectional and/or bidirectional localized confirmatory information may also be used in determining adjacency. Simultaneous accelerometer signatures (e.g., simultaneous bumps that are detected by the accelerometers in each device when the devices first contact each other) may also be used as part of an adjacency detection scheme. In general, adjacency between devices **10**A and **10**B can be determined by using data from adjacency detection sensors, receipt of wireless communications from an adjacent device, and/or other operations that take place in one of devices **10**A and **10**B or that take place in both devices **10**A and **10**B. Configurations in which adjacency status information (e.g., sensor readings indicative of device adjacency) is shared between devices **10**A and **10**B (e.g., when adjacency is confirmed when device **10**A detects the presence of device **10**B with a sensor in device **10**A and when device **10**B detects the presence of device **10**A with a sensor in device **10**B) may enhance adjacency detection reliability. In response to determining that devices **10**A and **10**B are not adjacent (from information gathered using one or more of sensors **32** and/or other detection mechanisms), monitoring may continue at block **60**, as indicated by line **62**.

[0100] In response to determining that devices **10**A and **10**B are adjacent (e.g., in response to detection of adjacency by the control circuitry and sensors of either device **10**A or device **10**B or both and/or confirmation using other adja-

cency detection/confirmation mechanisms), devices **10**A and **10**B may transition to a joint operating mode (block **64**). The transition to joint operation may take place automatically or may proceed in response to user confirmation by the user of device **10**A and/or the user of device **10**B that joint operation is desired and authorized. As an example devices **10**A and **10**B may display an on-screen interactive prompt asking each user (e.g., if there are two users) to enter a password and to confirm that joint operation is desired. Devices **10**A and **10**B may then proceed to operate in a joint operating mode, as described in connection with state **50-2** of FIG. **13**.

[0101] In the joint operating mode, one or more resources in device **10**A may be shared with one or more corresponding resources in device **10**B. As an example, graphics circuitry in the control circuitry of each device may be shared so that images can be displayed across a combined display formed from each of the adjacent displays. During image presentation operations, the graphics circuitry (e.g., a graphics processing unit) in one device may, as an example, render content for both displays and may transfer this content to respective display driver circuitry in each device for displaying on the display of that device. A local wireless link between devices **10**A and **10**B can be used to transfer content to be displayed from device **10**A to device **10**B (as an example) or, in some configurations, devices **10**A and **10**B may independently gather their portions of the content to be displayed from an on-line source or other remote source. Local rendering operations performed based on shared information (e.g., when each part of the shared content corresponds to a user's game controller and/or game playing space) may also be used. In some embodiments, content to be displayed across both displays may be divided before graphics rendering operations and a graphics processing unit in each device may handle rendering operations for its portion of the split content. Each device may have its own display driver circuitry coupled to a pixel array in its own display. The display driver circuitry of each device may be used in displaying an appropriate portion of the content for that device on its display.

[0102] As further examples, first and second microphones in devices **10**A and **10**B may be used jointly to capture stereo audio input, first and second cameras in devices **10**A and **10**B respectively may be used to capture stereo (e.g., three dimensional) images, first and second respective cameras may be used to gather user free-space gestures (e.g. using triangulation to gather three-dimensional gesture input), or first and second respective cameras may be used to capture image recognition images of a user's face from first and second respective perspectives. Touch screen functionality may be merged across displays **14**A and **14**B (e.g., to allow icons and other items to be dragged from one display to another, to allow a user touch gesture to extend across multiple displays, to allow a stylus, finger, or other input device to draw a line that extends across multiple displays, etc.). Wireless circuitry in devices **10**A and **10**B may be used jointly (e.g., to double downloading and uploading bandwidth by combining data streams from the two devices), wired circuitry in devices **10**A and **10**B may be used jointly (e.g., to allow multiple accessories to be coupled to system **36**—one of which is coupled to a port in device **10**A and another of which is coupled to a port in device **10**B), and other communications and control functions can be operated jointly.

[0103] If desired, sensors such as ambient light sensors and proximity sensors may be used jointly. For example, if an ambient light sensor in device **10**A is shadowed by a user's hand, readings from an ambient light sensor in device **10**B may be used in adjusting the screen brightness for the combined display formed from displays **14**A and **14**B. Proximity sensor measurements may be gathered from respective proximity sensors in devices **10**A and **10**B (e.g., to determine whether a user is placing the user's ear next to an ear speaker in either device **10**A or device **10**B).

[0104] To conserve power, some circuitry may be disabled in one device while the circuitry of the other device is used for both devices **10**A and **10**B. For example, when devices **10**A and **10**B are used jointly, global positioning system circuitry in one device may be disabled to conserve power while global positioning system circuitry in the other device is enabled to gather satellite navigation system readings.

[0105] Displays **14**A and **14**B may, if desired, use common brightness and color balance (white point) settings so that content appears uniform across displays **14**A and **14**B. Devices **10**A and **10**B can revert to their original settings when separated or can (at least temporarily) retain shared joint operating mode settings.

[0106] Components **38** (e.g., sensors **32**) in devices **10**A and/or **10**B can monitor for device adjacency during the joint operations of block **64**. For example, one or both devices may make sensor measurements to detect when devices **10**A and **10**B are pulled apart and/or wireless communications between devices **10**A and **10**B may be used in determining when devices **10**A and **10**B are no longer adjacent. So long as devices **10**A and **10**B are positioned so that devices **10**A and **10**B are adjacent (e.g., so that the edges of devices **10**A and **10**B abut one another in a side-by-side or overlapping arrangement) and a wired or wireless communications link is supported between devices **10**A and **10**B so that the control circuitry of devices **10**A and **10**B can share information and otherwise operate cooperatively to support joint operation, processing may continue at block **64**, as indicated by line **66**. In response to detecting that devices **10**A and **10**B have been separated, system **36** may transition from a joint operating mode (e.g., state **50-2** of FIG. **13**) to an appropriate separate (independent) operating mode (see, e.g., states **50-3**, **50-4**, and **50-5** of FIG. **13**). During the operations of block **68**, it may be determined which, if any, of the operating settings from the joint state are to persist on each of the separate devices before operation loops back to the independent operations of block **60**. As an example, if devices **10**A and **10**B were jointly displaying a web page during the operations of block **64**, the web page may continue to be displayed on each device after device separation (e.g. each device may display a browser window with the same web page). As another example, if devices **10**A and **10**B were playing stereo music through respective first and second speakers in devices **10**A and **10**B, device **10**A (but not device **10**B) may continue to play the music through its speakers upon device separation. In general, all joint operating parameters may be retained when devices **10**A and **10**B are separated, some joint operating parameters may be retained, or no joint operating parameters may be retained.

[0107] The foregoing is merely illustrative and various modifications can be made to the described embodiments. The foregoing embodiments may be implemented individually or in any combination.

[0108] An illustrative electronic device of the type that may be provided with a flexible display is shown in FIG. **18**. Electronic device **10** may be a computing device such as a laptop computer, a computer monitor containing an embedded computer, a tablet computer, a cellular telephone, a media player, or other handheld or portable electronic device, a smaller device such as a wrist-watch device, a pendant device, a wearable or miniature device of other types, a computer display that does not contain an embedded computer, a computer display that includes an embedded computer, a gaming device, a navigation device, an embedded system such as a system in which electronic equipment with a display is mounted in a kiosk or automobile, equipment that implements the functionality of two or more of these devices, or other electronic equipment. In the illustrative configuration of FIG. **18**, device **10** is a portable device such as a cellular telephone, media player, tablet computer, watch or other wrist device, or other portable computing device. Other configurations may be used for device **10** if desired. The example of FIG. **18** is merely illustrative.

[0109] In the example of FIG. **18**, device **10** includes a display such as display **14** mounted in housing **12**. Housing **12**, which may sometimes be referred to as an enclosure or case, may be formed of plastic, glass, ceramics, fiber composites, metal (e.g., stainless steel, aluminum, etc.), other suitable materials, or a combination of any two or more of these materials. Housing **12** may be formed using a unibody configuration in which some or all of housing **12** is machined or molded as a single structure or may be formed using multiple structures (e.g., an internal frame structure, one or more structures that form exterior housing surfaces, etc.). Housing **12** may have hinge structures such as hinge **20** to allow device **10** to bend about bend axis **22**. Housing **12** may have first and second housing portions that rotate with respect to each other as device **10** is bent (folded) about bend axis **22** using hinge **20** or other flexible structures joining the first and second housing portions.

[0110] Display **14** may be a touch screen display that incorporates a layer of conductive capacitive touch sensor electrodes or other touch sensor components (e.g., resistive touch sensor components, acoustic touch sensor components, force-based touch sensor components, light-based touch sensor components, etc.) or may be a display that is not touch-sensitive. Capacitive touch screen electrodes may be formed from an array of indium tin oxide pads or other transparent conductive structures. A touch sensor may be formed using electrodes or other structures on a display layer that contains a pixel array or on a separate touch panel layer that is attached to the pixel array (e.g., using adhesive). In various embodiments, the on-cell touch sensors can be directly fabricated on top of OLED display panel.

[0111] Display **14** may include pixels formed from liquid crystal display (LCD) components, electrophoretic pixels, microelectromechanical (MEMs) shutter pixels, electrowetting pixels, micro-light-emitting diodes (small crystalline semiconductor die), organic light-emitting diodes (e.g., pixels in a thin-film organic light-emitting diode display), or pixels based on other display technologies. Configurations in which display **14** has an array of light-emitting pixels such as an array of organic light-emitting diode pixels may sometimes be described herein as an example.

[0112] Display **14** may have a portion that overlaps bend axis **22**. To facilitate bending of device **10** about axis **22**, all of display **14** may be formed using flexible structures or at least the portion of display **10** that overlaps bend axis **22** may be formed using flexible structures. A display cover layer or other layer may form the outermost surface of the display. Display layers such these (e.g., display cover layers) may be formed from glass, plastic, and/or other transparent display cover layer structures and may be flexible (at least where these layers overlap bend axis **22** of device **10**).

[0113] As shown in FIG. **18**, for example, display **14** may have three portions such as portions **14**A, **14**B, and **14**C. In portions **14**A and **14**C, display **14** may be flexible or may be rigid (e.g., the pixel array in these areas may be rigid and/or the display cover layer structures in these regions may be rigid). Flexible portion **14**B overlaps bend axis **22** and forms a strip that lies between portions **14**A and **14**C and that extends across the width of the display between opposing edges of the display. To ensure that flexible portion **14**B is sufficiently flexible to allow device **10** to bend about axis **22**, display layers such as a display cover layer for display **14** may be formed from a thin flexible glass or polymer layer that accommodates bending of display **14** about axis **22** and underlying display layers (e.g., a polymer substrate, metal traces, a polarizer layer, a touch sensor layer, adhesive layers, and other conducting and dielectric layers in an organic light-emitting diode pixel array) may also be formed from flexible materials and structures.

[0114] In cold operating environments (e.g., temperatures significantly below room temperature such as temperatures below 10° C., below 0° C., −40° C. to −10° C., or other cold temperatures), materials such as adhesives in flexible portion **14**B may become inflexible. To help avoid damage to flexible portion **14**B when device **10** is bent open or closed about axis **22**, flexible portion **14**B may be heated (e.g., while other portions such as portions **14**A and **14**C of display **14** are not heated or are heated less to conserve energy). Portion **14**B may, for example, be heated by using heat spreading structures that help spread heat from integrated circuits and other components in device **10** to portion **14**B. With another illustrative arrangement, a heating element under portion **14**B may be used to heat portion **14**B. Another illustrative arrangement involves self-heating operations. In a self-heating arrangement, pixels in display **14** are illuminated. For example, the light-emitting diodes in at least those pixels in display **14** that are in portion **14**B may be turned on to produce light and heat. The heat produced by the illuminated pixels can heat portion **14**B (e.g., to room temperature or other suitable temperature that is elevated relative to an initial cold temperature) and help prevent damage to sensitive structures in portion **14**B as portion **14**B is bent about axis **22**. In various embodiments, the heating area may be larger than portion **14**B because the adhesive can be a continuous film under **14**A and **14**C and can stretch and shear during bending/unbending of the display.

[0115] As shown in FIG. **19**, device **10** may be folded (bent by 180° or other suitable amount) about bend axis **22** so that display **14** is visible from the outside of device **10** in its folded state. FIG. **20** shows how device **10** may be folded about bend axis **22** so that display **14** is protected within the interior of device **10**. Device **10** may have flexible structures (e.g., a hinge) to allow outward bending of the type shown in FIG. **19**, to allow inward bending of the type shown in FIG. **20**, or to allow bending of both the type shown in FIG. **19** and the type shown in FIG. **20**. Configurations in which device **10** is flexed by different amounts (e.g., more than 180° or less than 180°) may also be used.

[0116] Display **14** may have a rectangular shape (i.e., display **14** may have a rectangular footprint and a rectangular peripheral edge that runs around the rectangular footprint) or may have other suitable shapes. A top view of circuitry in an illustrative display with a rectangular shape is shown in FIG. **21**. As shown in FIG. **21**, display **14** may have an array of pixels **42** formed on substrate **36**. Substrate **36** may be formed from glass, metal, plastic, ceramic, or other substrate materials. Pixels **42** may receive data signals over signal paths such as data lines D and may receive one or more control signals over control signal paths such as horizontal control lines G (sometimes referred to as gate lines, scan lines, emission control lines, etc.). There may be any suitable number of rows and columns of pixels **42** in display **14** (e.g., tens or more, hundreds or more, or thousands or more). Each pixel **42** may have a light-emitting diode **26** that emits light **44** under the control of a pixel circuit formed from thin-film transistor circuitry such as thin-film transistors **28** and thin-film capacitors). Thin-film transistors **28** may be polysilicon thin-film transistors, semiconducting-oxide thin-film transistors such as indium gallium zinc oxide transistors, or thin-film transistors formed from other semiconductors. Pixels **42** may contain light-emitting diodes of different colors (e.g., red, green, and blue diodes for red, green, and blue pixels, respectively) to provide display **14** with the ability to display color images.

[0117] Display driver circuitry may be used to control the operation of pixels **42**. The display driver circuitry may be formed from integrated circuits, thin-film transistor circuits, or other suitable circuitry. Display driver circuitry **30** of FIG. **21** may contain communications circuitry for communicating with system control circuitry such as control circuitry **50** of FIG. **2** over path **32**. Path **32** may be formed from traces on a flexible printed circuit or other cable. During operation, the control circuitry (e.g., control circuitry **50** of FIG. **2**) may supply circuitry **30** with information on images to be displayed on display **14**.

[0118] To display the images on pixels **42**, display driver circuitry **30** may supply image data to data lines D while issuing clock signals and other control signals to supporting display driver circuitry such as gate driver circuitry **34** over path **38**. If desired, circuitry **30** may also supply clock signals and other control signals to gate driver circuitry on an opposing edge of display **14** or may use display driver circuitry with other layouts. The configuration of FIG. **21** is illustrative.

[0119] Gate driver circuitry **34** (sometimes referred to as horizontal control line control circuitry) may be implemented as part of an integrated circuit and/or may be implemented using thin-film transistor circuitry. Gate lines G (sometimes referred to as horizontal control lines) in display **14** may carry gate line signals (sometimes referred to as scan line signals, emission enable control signals, etc.) for controlling the pixels of each row. There may be any suitable number of control signals per row of pixels **22** (e.g., one or more, two or more, three or more, four or more, etc.).

[0120] Some or all of pixels **42** in the pixel array of display **14** can be illuminated (fully or partially). Turning pixels **42** on in this way creates a pattern of light on display **14**. The pattern of light may include text, icons, a logo or other images, may be a solid or graded block, or may form any other image or abstract pattern (e.g., a solid bright white area, an area of a particular color or pattern of colors, a photograph, etc.). To conserve energy, it may be desirable to only or to primarily illuminate pixels **42** that overlap flexible portion **14**B of display **14**, as shown in FIG. **22**. With this type of arrangement, the pixels in region **14**B may be configured to output light **44** at their maximum intensity.

[0121] FIGS. **23** and **24** show how device **10** may have a latching mechanism that is used to hold housing **12** and device **10** in a closed (folded) configuration when portion **14**B of display **14** is cold. In the example of FIG. **23**, housing **12** has been bent about bend axis **22**, so that end portion (housing structures) **12**A and end portion (housing structures) **12**B of housing **12** face each other. In this example, display **14** has been folded inwardly. Outwardly folding display arrangements may also be used, if desired.

[0122] When housing **12** is folded so that portions **12**A and **12**B are adjacent to each other, the latching mechanism can be engaged (e.g., to prevent damage to display **14** while portion **14**B is cold). When it is desired to release portions **12**A and **12**B and thereby allow device **10** to be opened for use, the latching mechanism can be disengaged.

[0123] The illustrative latching mechanism of FIG. **23** includes first component **70** in device housing portion **12**A and second component **72** in device housing portion **12**B. Components **70** and **72** may interact magnetically when it is desired to hold device **10** in a folded (closed) state. In one illustrative configuration, both of components **70** and **72** are electromagnets. In another illustrative configuration, component **72** may be an electromagnet and component **70** may be a magnetic structure (e.g., a permanent magnet or a magnetic structure formed from iron, ferrite, or other magnetic material). When control circuitry **50** activates the electromagnet(s), housing portion **12**A and housing portion **12**B are held together by magnetic attraction and the user of device **10** will be prevented from unfolding device **10**. When it is desired to disengage the magnetic latching mechanism of FIG. **23**, control circuitry **50** can turn off the control signals (drive current) applied to the electromagnet(s).

[0124] The illustrative latching mechanism of FIG. **24** includes electrically controlled actuator **74** and latch member **76** in housing portion **12**B and a corresponding latch member such as pin **78** in housing portion **12**B. When latch member **76** is placed in the position shown in FIG. **11**, latch member **76** will engage pin **78** and thereby hold portions **12**A and **12**B to each other. When control circuitry **50** uses actuator **74** to move latch member **76** in direction **79**, latch member **76** will disengage from pin **78**, thereby releasing portions **12**A and **12**B so that device **10** can be unfolded by moving these portions away from each other.

[0125] FIG. **25** illustrates an exemplary depiction of the protective features of the exemplary foldable device. In a first position **1502**, the foldable device **10** is dropped from a height **2504** above the ground. In the first position **1502** the display is unfolded or flat. The device **10** can include edges **2504** around the display **14**. The edges **2504** can be reinforced to be able to withstand forces.

[0126] A sensor in the device **10** senses the acceleration of the device. If the acceleration of the device **10** exceeds a predetermined threshold, protective features are engaged to protect the display **14**. For example, if the device **10** is dropped from a height **2506**, the sensor in the device **10** can detect the acceleration or motion and after a threshold limit is reached the protective features of the device **10** can be engaged. The protective features can include folding the display **14** about the hinge so the angle between either the two displays or two portions of the same display **14** are at an

angle **2508** less than 180 degrees. In this way, in a second position **2510** the device **10** can strike the ground so that the display **14** is protected. The device **10** can strike on the edges **2504** instead of the display **14**, in order for the edges **14** to absorb the forces from the drop.

[0127] FIG. **26**A illustrates a first exemplary depiction of the protective features of the exemplary foldable device. FIG. **26**A illustrates a device **10** with a foldable display **14**. The display can include a motorized hinge **2602** as a release mechanism. The motorized hinge **2602** can include a reverse rotation (e.g., closing) of a motor when a fall is detected. In various embodiments the motorized hinge **2602** can close the display to an angle less than 180 degrees. In various embodiments, the motorized hinge **2602** can close the display **14** completely, depending on the speed of the motor and the height the device **10** is dropped from.

[0128] FIG. **26**B illustrates a second exemplary depiction of the protective features of the exemplary foldable device. FIG. **26**B illustrates a device **10** with a foldable display **14**. The display can include a detent **2612** (e.g., a spring-loaded detent) as a release mechanism. The detent **2612** can work with a mechanical hinge **2614**. The detect can be electro-mechanically released with spring force from the hinge. After the spring-loaded detent is retracted a spring force on the hinge can mechanically cause the device to close, at least partially if the acceleration exceeds a predetermined threshold. The detent can be released when a fall is detected. In various embodiments the detent **2612** can close the display to an angle less than 180 degrees. In various embodiments, the detent **2612** can close the display **14** completely, depending on height the device **10** above the ground.

[0129] The device **10** can collects sensor data regarding the motion of the user. For instance, using the motion sensors (e.g., one or more accelerometers), the device **10** can measure an acceleration experienced by the motion sensors, and correspondingly, the acceleration experienced by the device **10**. Further, using the motion sensors (e.g., one or more compasses or gyroscopes), the device **10** can measure an orientation of the motion sensors, and correspondingly, an orientation of the device **10**. In some cases, the motion sensors can collect data continuously or periodically over a period of time or in response to a trigger event. In some cases, the motion sensors can collect motion data with respect to one or more specific directions relative to the orientation of the device **10**. For example, the motion sensors can collect sensor data regarding an acceleration of the device **10** with respect to the x-axis (e.g., a vector projecting from a side edge of the device **10**, the y-axis (e.g., a vector projecting from a front edge of the **10**, and/or the z-axis (e.g., a vector projecting from a top surface or screen of the mobile device **10**, where the x-axis, y-axis, and z-axis refer to a Cartesian coordinate system in a frame of reference fixed to the device **10** (e.g., a "body" frame).

[0130] As the user moves, the device **10** can use the motion sensors to continuously or periodically collect sensor data regarding an acceleration experienced by the motion sensors with respect to y-axis over a period of time. The resulting sensor data can be presented in the form of a time-varying acceleration signal. In some cases, the acceleration system can obtain acceleration samples at a sample frequency of 800 Hz using the motion sensors, with a sampling bandwidth of 200 Hz. In practice, other sampling frequencies and/or sampling bandwidths are also possible.

[0131] In the example above, the acceleration signal indicates the acceleration experienced by the device **10** with respect to the y-axis of the device. In some cases, the acceleration signal can also indicate the acceleration experienced by the device **10** with respect to multiple different directions. For example, the acceleration signal can include an x-component, a y-component, and a z-component, referring to the acceleration experienced by the device **10** with respect to the x-axis, the y-axis, and the z-axis of the device **10**, respectively. Each component also can be referred as a channel of the acceleration signal (e.g., "x-channel," the "y-channel," and the "z-channel").

[0132] The device **10** can analyze the acceleration signal to determine whether the device **10** has fallen. For instance, if the device **10** has fallen, the device **10** may experience a relatively strong impact (e.g., when the device **10** strikes the ground). Such an impact can be identified based on a magnitude of the acceleration experienced by the device **10** (e.g., the rate of change in the velocity of the mobile device), a magnitude of the jerk experienced by the mobile device (e.g., the rate of change in the acceleration of the mobile device), and an oscillatory behavior of the acceleration experienced by the device **10**. Each of these parameters can be determined using the acceleration signal.

[0133] As an example, the magnitude of the acceleration experienced by the device **10** can be determined, for each channel of the acceleration signal, using the relationship:

$$\text{mag}=\max(\text{abs}(a(n))),$$

where mag is the magnitude of acceleration for that channel, a(n) is the nth sample of the acceleration signal for that channel, and max is the maximum calculated over a sliding window of samples of the acceleration signal, nwindow. In some cases, nwindow can correspond to the number of samples spanning an interval of time of 0.2 seconds or approximately 0.2 second. For example, if the sampling frequency for the acceleration signal is 800 Hz, nwindow can be 160. In practice, other values for nwindow are also possible.

[0134] Alternatively, the magnitude of the acceleration experienced by the device **10** can be determined, for each channel of the acceleration signal, using the relationship:

$$\text{mag}=\max(a(n))-\min(a(n)),$$

where mag is the magnitude of acceleration for that channel, a(n) is the nth sample of the acceleration signal for that channel, max is the maximum calculated over a sliding window of samples nwindow, and min is the minimum calculated over the window of samples the acceleration signal, nwindow. As above, in some cases, nwindow can correspond to the number of samples spanning an interval of time of 0.2 seconds or approximately 0.2 second, though in practice, other values for nwindow are also possible.

[0135] If the acceleration signal includes acceleration measurements with respect to a single direction (e.g., having a single channel, such as a y-channel), the magnitude of the acceleration with respect to that direction can be determined using the relationship above. The resulting value is representative of the magnitude of the acceleration for the acceleration signal. Alternatively, the total energy from all three channels over the window of interest (e.g. nwindow) may be used as the total magnitude of acceleration. For example, one notion of total energy could be computed as:

$$\text{mag}=\sqrt{\max(|x|)^2+\max(|y|)^2+\max(|z|)^2}$$

[0136] If the acceleration signal includes acceleration measurements with respect to multiple directions (e.g., having multiple channels, such as a x-channel, a y-channel, and a z-channel), the magnitude of the acceleration with respect to each direction can be individually determined using the relationship above, resulting in three individual magnitude values (corresponding to the three channels, respectively). The greatest magnitude value can be selected as representative of the magnitude of the acceleration for the acceleration signal. In various embodiments, the threshold vertical acceleration (e.g., z-channel) can be the acceleration forces due to gravity (e.g., 9.8 meters per second per second). In various embodiments, the features will only be triggered in free-fall acceleration or vertical acceleration (i.e., if the device is thrown) to avoid triggering the features when users are riding in a car, a train, or an airplane etc. In various embodiments, the features can be selectively enabled and disabled (e.g., riding a roller coaster while taking a selfie.)

[0137] FIG. **27** is a diagram of a device **200** having one or more electronic flexible screen or display devices **2702**. The one or more electronic flexible screen or display devices **2702** may be configured, manufactured, produced, or assembled based on the descriptions provided in U.S. Patent Publication Nos. 2007-247422, 2007-139391, 2007-085838, or 2006-096392 or U.S. Pat. No. 7,050,835 or WO Publication No. 2007-012899 all herein incorporated by reference as if fully set forth. The one or more electronic flexible screen or display devices **2702** may be configured and assembled using organic light emitting diodes (OLED), liquid crystal displays using flexible substrate technology, flexible transistors, field emission displays (FED) using flexible substrate technology, as desired. In the case for multiple electronic flexible screens or display devices **2702**, rotation **2714** reveals a second electronic flexible screen or display device **2703** on the back of device **2700**.

[0138] Any one of housing members **2704** and **2706** selectively house certain hardware components described in device **2700** such as one or more processors, memory, one or more sensors, and one or more network adapters. In one embodiment of the invention, housing members **2704** and **2706** may each have individual transmitting/receiving antennas **2716** and **2718** for providing spatial and time diversity. One or more electronic flexible screen or display devices **2702** can optionally be configured to collapse **2708** and roll up into housing members **2704** or **2706** for portability. For orientating device **2700** in a circular manner for a presentation or posting on a light post as an advertisement, attachment members **2710** and **2712** may be used. Housing members **2704** and **2706** may be rectangular or cylindrical and provide grasping positions, the ability to position device **2700** upright on a flat surface, or the ability to mount device **2700** on a flat surface, as desired. It is appreciated by one skilled in the art that housing members **2704** and **2706** and one or more electronic flexible screen or display devices **2702** are not drawn to scale. They may have different shapes and dimensions while configured to provide the same functionality provided herewith.

[0139] Still referring to FIG. **27**, in another embodiment device **2700** may optionally have a liquid crystal display (LCD), LED, FED, or OLED display unit **2720**. For this case, when one or more electronic flexible screen or display devices **2072** is collapsed into housing member **2706** adjacent display unit **2720** is still available for displaying content. When one or more electronic flexible screen or display devices **2702** is expanded out of housing member **2704** or **2706**, the combination of display unit **2720** and flexible screen or display devices **2702** provides a larger screen size for a single graphical feed or for having separate graphical feeds or windows in each display unit, as desired. In this configuration, the images displayed on flexible screen or display devices **2702** can be responsive to one or more sensors detecting a bending of flexible screen or display devices **2702**.

[0140] FIG. **28** is schematic cross-sectional side view illustration of a system **2800** including a flexible display panel **2802** secured to a spool **2810** in accordance with an embodiment of the invention. FIG. **28** is a schematic cross-sectional side view illustration of a flexible display panel **2802** including an array of LEDs and microchips in a display area on a front surface of the display substrate in accordance with an embodiment of the invention. In various embodiments, the display panel **2802** can also include an OLED display. The display panel **2802** may be similar to any of the display panels previously described above. In the embodiment illustrated in FIG. **28**, the flexible display panel **2802** is rollable into and out of a housing **2820**. In such an embodiment, rather than locating the driver ICs **2830** additional IC chips **2834** and battery **2838** on the back surface of the display substrate, any combination of these components can be located within the housing **2820**, such as on the spool **2810**. In other embodiments, any of these components may also be located on the back surface of the display substrate. For example, a thin film battery **2838** can be located on the back surface, or a plurality of batteries **2838** can be located on the back surface. Likewise one or more driver ICs **2830** may be located on the back surface to reduce transmission line distance to the microchips.

[0141] FIG. **29** illustrates an exemplary device **10** with a rollable display **14**. The display **14** can be attached to an extension member **2902**. The extension member **2902** is attached to a display **14** at one end and a spool **2904** at the other end. FIG. **29** illustrates the extension member **2902** in the extended position in which the display **14** extends outside the housing **12** of the device **10**. The spool **2904** can include a spring under tension to allow the display to be retracted into the housing **10**.

[0142] FIG. **30** illustrates an exemplary device **10** with a rollable display **14**. Similar to FIG. **29**, the display **14** can be attached to an extension member **3002**. The extension member **3002** is attached to a display **14** at one end and a spool **3004** at the other end. FIG. **30** illustrates the extension member **3002** in the retracted position in which the display **14** is retracted into the housing **12** of the device **10**. The spool **3004** can include a spring under tension to allow the display to be retracted into the housing **10**. In various embodiments, sensors (e.g., IMU sensors) in the device can detect the device **10** being dropped. Up detecting a predetermined acceleration, the release mechanism allows the extension member **3002** to retract the display **14** into the housing **12**.

[0143] FIG. **31** is a flowchart of an example process **3100** associated with techniques to protect a display of an electronic device. In some implementations, one or more process blocks of FIG. **31** may be performed by an electronic device. Additionally, or alternatively, one or more process blocks of FIG. **31** may be performed by one or more components of device **10**, such as control circuitry **50**, sensors **56**, display **14**, and release mechanism **2704**. In various embodiments,

a first display or the second display is an organic light emitting diode display. In various embodiments, the first display and the second display each comprise regions of a foldable display.

[0144] At **3110**, the process **3100** can include detecting a vertical acceleration of an electronic device. The vertical acceleration can be detected by an accelerometer. In various embodiments, the vertical acceleration can be detected by an IMU. The vertical acceleration can be converted to a numerical value. The value for the vertical acceleration can be stored in a memory of the device.

[0145] At block **3120**, the process **3100** can include comparing a value of the vertical acceleration of the electronic device against a predetermined threshold. In various embodiments, a predetermined threshold value of acceleration can be stored in a memory. The processor can compare the detected acceleration value with the predetermined threshold value.

[0146] At block **3130**, the process **3100** can include activating a release mechanism for a hinged connection between a first display and a second display of the electronic device when the value of the vertical acceleration exceeds the predetermined threshold, wherein the activating reduces an angle between the first display and the second display below a threshold angle. In various embodiments, the threshold angle is an angle less than 180 degrees.

[0147] In various embodiments, the release mechanism comprises a motorized hinge. In various embodiments, the release mechanism comprises a mechanical hinge with a spring-loaded detent.

[0148] In various embodiments, a mobile device can include one or more memories and one or more processors in communication with the one or more memories and configured to execute instructions stored in the one or more memories to performing operations of a method described above.

[0149] In various embodiments, a computer-readable medium may store a plurality of instructions that, when executed by one or more processors of a computing device, cause the one or more processors to perform operations of any of the methods described above.

[0150] Although FIG. **31** shows example steps of process **3100**, in some implementations, process **3100** can include additional steps, fewer steps, different steps, or differently arranged steps than those depicted in FIG. **31**. Additionally, or alternatively, two or more of the steps of process **3100** can be performed in parallel.

[0151] FIG. **32** is a block diagram of an example electronic device **3200**. Device **3200** generally includes computer-readable medium **3202**, control circuitry **3204**, an Input/Output (I/O) subsystem **3206**, wireless circuitry **3208**, and audio circuitry **3210** including speaker **3250** and microphone **3252**. These components may be coupled by one or more communication buses or signal lines **3203**. Device **3200** can be any portable electronic device, including a handheld computer, a tablet computer, a mobile phone, laptop computer, tablet device, media player, personal digital assistant (PDA), a key fob, a car key, an access card, a multifunction device, a mobile phone, a portable gaming device, a headset, or the like, including a combination of two or more of these items.

[0152] It should be apparent that the architecture shown in FIG. **32** is only one example of an architecture for device **3200**, and that device **3200** can have more or fewer components than shown, or a different configuration of components. The various components shown in FIG. **32** can be implemented in hardware, software, or a combination of both hardware and software, including one or more signal processing and/or application specific integrated circuits.

[0153] Wireless circuitry **3208** is used to send and receive information over a wireless link or network to one or more other devices' conventional circuitry such as an antenna system, a radio frequency (RF) transceiver, one or more amplifiers, a tuner, one or more oscillators, a digital signal processor, a CODEC chipset, memory, etc. Wireless circuitry **3208** can use various protocols, e.g., as described herein. In various embodiments, wireless circuitry **3208** is capable of establishing and maintaining communications with other devices using one or more communication protocols, including time division multiple access (TDMA), code division multiple access (CDMA), global system for mobile communications (GSM), Enhanced Data GSM Environment (EDGE), wideband code division multiple access (W-CDMA), Long Term Evolution (LTE), Long-term Evolution (LTE)-Advanced, Wi-Fi (such as Institute of Electrical and Electronics Engineers (IEEE) 802.11a, IEEE 802.11b, IEEE 802.11g and/or IEEE 802.11n), Bluetooth, Wi-MAX, voice over Internet Protocol (VoIP), near field communication protocol (NFC), a protocol for email, instant messaging, and/or a short message service (SMS), or any other suitable communication protocol, including communication protocols not yet developed as of the filing date of this document.

[0154] Wireless circuitry **3208** is coupled to control circuitry **3204** via peripherals interface **3216**. Peripherals interface **3216** can include conventional components for establishing and maintaining communication between peripherals and. Voice and data information received by wireless circuitry **3208** (e.g., in speech recognition or voice command applications) is sent to one or more processors **3218** via peripherals interface **3216**. One or more processors **3218** are configurable to process various data formats for one or more application programs **3234** stored on medium **3202**.

[0155] Peripherals interface **3216** couple the input and output peripherals of device **3200** to the one or more processors **3218** and computer-readable medium **3202**. One or more processors **3218** communicate with computer-readable medium **3202** via a controller **3220**. Computer-readable medium **3202** can be any device or medium that can store code and/or data for use by one or more processors **3218**. Computer-readable medium **3202** can include a memory hierarchy, including cache, main memory, and secondary memory. The memory hierarchy can be implemented using any combination of RAM (e.g., Standard Random Access Memory (SRAM), Dynamic Random Access Memory (DRAM), Double Data Random Access Memory (DDRAM), Read only Memory (ROM), FLASH, magnetic and/or optical storage devices, such as disk drives, magnetic tape, CDs (compact disks) and DVDs (digital video discs)). In some embodiments, peripherals interface **3216**, one or more processors **3218**, and controller **3220** can be implemented on a single chip, such as control circuitry **3204**. In some other embodiments, they can be implemented on separate chips.

[0156] Processor(s) **3218** can include hardware and/or software elements that perform one or more processing functions, such as mathematical operations, logical operations, data manipulation operations, data transfer operations,

controlling the reception of user input, controlling output of information to users, or the like. Processor(s) **3218** can be embodied as one or more hardware processors, microprocessors, microcontrollers; field programmable gate arrays (FPGAs), application-specified integrated circuits (ASICs), or the like.

[0157] Device **3200** may include storage and processing circuitry such as control circuitry **3204**. Control circuitry **3204** may include storage such as hard disk drive storage, nonvolatile memory (e.g., flash memory or other electrically-programmable-read-only memory configured to form a solid-state drive), volatile memory (e.g., static or dynamic random-access-memory), etc. Processing circuitry in control circuitry **3204** may be used to control the operation of device **3200**. This processing circuitry may be based on one or more microprocessors, microcontrollers, digital signal processors, baseband processor integrated circuits, application specific integrated circuits, etc.

[0158] Control circuitry **3204** may be used to run software on device **3200**, such as internet browsing applications, voice-over-internet-protocol (VOIP) telephone call applications, email applications, media playback applications, operating system functions, etc. To support interactions with external equipment, control circuitry **3204** may be used in implementing communications protocols. Communications protocols that may be implemented using control circuitry **3204** 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, cellular telephone protocols, multiple-input and multiple-output (MIMO) protocols, antenna diversity protocols, satellite navigation system protocols, millimeter wave communications protocols, IEEE 802.15.4 ultra-wideband communications protocols, etc.

[0159] Device **3200** may include input/output subsystem **3206**. Input/output subsystem **3206** may include input-output devices. Input/output devices may be used to allow data to be supplied to device **3200** and to allow data to be provided from device **3200** to external devices. Input/output devices may include user interface devices, data port devices, and other input-output components. For example, input/output devices may include one or more displays (e.g., touch screens or displays without touch sensor capabilities), one or more image sensors **3244** (e.g., digital image sensors), motion sensors, and speakers **3250**. Input-output device may also include buttons, joysticks, scrolling wheels, touch pads, key pads, keyboards, microphones **3252**, haptic elements such as vibrators and actuators, status indicators, light sources, audio jacks and other audio port components, digital data port devices, light sensors, capacitance sensors, proximity sensors (e.g., a capacitive proximity sensor and/or an infrared proximity sensor), magnetic sensors, and other sensors and input-output components.

[0160] Device **3200** also includes a power system **3242** for powering the various hardware components. Power system **3242** can include a power management system, one or more power sources (e.g., battery, alternating current (AC)), a recharging system, a power failure detection circuit, a power converter or inverter, a power status indicator (e.g., a light emitting diode (LED)) and any other components typically associated with the generation, management and distribution of power in mobile devices.

[0161] In some embodiments, device **3200** includes an image sensor **3244** (e.g., a camera). In some embodiments, device **3200** includes sensors **3246**. Sensors can include accelerometers, compass, gyrometer, pressure sensors, audio sensors, light sensors, barometers, and the like. Sensors **3246** can be used to sense location aspects, such as auditory or light signatures of a location.

[0162] In some embodiments, device **3200** can include a Global Positioning System (GPS) receiver, sometimes referred to as a GPS unit **3248**. A mobile device can use a satellite navigation system, such as the GPS, to obtain position information, timing information, altitude, or other navigation information. During operation, the GPS unit can receive signals from GPS satellites orbiting the Earth. The GPS unit analyzes the signals to make a transit time and distance estimation. The GPS unit can determine the current position (current location) of the mobile device. Based on these estimations, the mobile device can determine a location fix, altitude, and/or current speed. A location fix can be geographical coordinates such as latitudinal and longitudinal information.

[0163] One or more processors **3218** run various software components stored in medium **3202** to perform various functions for device **3200**. In some embodiments, the software components include an operating system **3222**, a communication module **3224** (or set of instructions), a location module **3226** (or set of instructions), a ranging module **3228** that is used as part of ranging operation described herein, and other application programs **3234** (or set of instructions).

[0164] Operating system **3222** can be any suitable operating system, including iOS, Mac OS, Darwin, Quatros Real-Time Operating System (RTXC), LINUX, UNIX, OS X, WINDOWS, or an embedded operating system such as VxWorks. The operating system can include various procedures, sets of instructions, software components, and/or drivers for controlling and managing general system tasks (e.g., memory management, storage device control, power management, etc.) and facilitates communication between various hardware and software components.

[0165] Communication module **3224** facilitates communication with other devices over one or more external ports **3236** or via wireless circuitry **3208** and includes various software components for handling data received from wireless circuitry **3208** and/or external port **3236**. External port **3236** (e.g., universal serial bus (USB), FireWire, Lightning connector, **60**-pin connector, etc.) is adapted for coupling directly to other devices or indirectly over a network (e.g., the Internet, wireless local area network (LAN), etc.).

[0166] Location/motion module **3226** can assist in determining the current position (e.g., coordinates or other geographic location identifiers) and motion of device **3200**. Modern positioning systems include satellite based positioning systems, such as Global Positioning System (GPS), cellular network positioning based on "cell IDs," and Wi-Fi positioning technology based on a Wi-Fi networks. GPS also relies on the visibility of multiple satellites to determine a position estimate, which may not be visible (or have weak signals) indoors or in "urban canyons." In some embodiments, location/motion module **3226** receives data from GPS unit **3248** and analyzes the signals to determine the current position of the mobile device. In some embodiments, location/motion module **3226** can determine a current location using Wi-Fi or cellular location technology. For

example, the location of the mobile device can be estimated using knowledge of nearby cell sites and/or Wi-Fi access points with knowledge also of their locations. Information identifying the Wi-Fi or cellular transmitter is received at wireless circuitry **3208** and is passed to location/motion module **3226**. In some embodiments, the location module receives the one or more transmitter IDs. In some embodiments, a sequence of transmitter IDs can be compared with a reference database (e.g., Cell ID database, Wi-Fi reference database) that maps or correlates the transmitter IDs to position coordinates of corresponding transmitters, and computes estimated position coordinates for device **3200** based on the position coordinates of the corresponding transmitters. Regardless of the specific location technology used, location/motion module **3226** receives information from which a location fix can be derived, interprets that information, and returns location information, such as geographic coordinates, latitude/longitude, or other location fix data.

[0167] Ranging module **3228** can send/receive ranging messages to/from an antenna, e.g., connected to wireless circuitry **3208**. The messages can be used for various purposes, e.g., to identify a sending antenna of a device, determine timestamps of messages to determine a distance of mobile device **3200** from another device. Ranging module **3228** can exist on various processors of the device, e.g., an always-on processor (AOP), a UWB chip, and/or an application processor. For example, parts of ranging module **3228** can determine a distance on an AOP, and another part of the ranging module can interact with a sharing module, e.g., to display a position of the other device on a screen in order for a user to select the other device to share a data item. Ranging module **3228** can also interact with a reminder module that can provide an alert based on a distance from another mobile device.

[0168] Dielectric-filled openings such as plastic-filled openings may be formed in metal portions of housing such as in metal sidewall structures (e.g., to serve as antenna windows and/or to serve as gaps that separate portions of antennas from each other).

[0169] Antennas may be mounted in housing. If desired, some of the antennas (e.g., antenna arrays that may implement beam steering, etc.) may be mounted under dielectric portions of device **3200** (e.g., portions of the display cover layer, portions of a plastic antenna window in a metal housing sidewall portion of housing, etc.). With one illustrative configuration, some or all of rear face of device **3200** may be formed from a dielectric. For example, the rear wall of housing may be formed from glass plastic, ceramic, other dielectric. In this type of arrangement, antennas may be mounted within the interior of device **3200** in a location that allows the antennas to transmit and receive antenna signals through the rear wall of device **3200** (and, if desired, through optional dielectric sidewall portions in housing). Antennas may also be formed from metal sidewall structures in housing and may be located in peripheral portions of device **3200**.

[0170] To avoid disrupting communications when an external object such as a human hand or other body part of a user blocks one or more antennas, antennas may be mounted at multiple locations in housing. Sensor data such as proximity sensor data, real-time antenna impedance measurements, signal quality measurements such as received signal strength information, and other data may be used in determining when one or more antennas is being adversely affected due to the orientation of housing, blockage by a user's hand or other external object, or other environmental factors. Device **3200** can then switch one or more replacement antennas into use in place of the antennas that are being adversely affected.

[0171] Antennas may be mounted at the corners of housing, along the peripheral edges of housing, on the rear of housing, under the display cover layer that is used in covering and protecting display on the front of device **3200** (e.g., a glass cover layer, a sapphire cover layer, a plastic cover layer, other dielectric cover layer structures, etc.), under a dielectric window on a rear face of housing or the edge of housing, under a dielectric rear wall of housing, or elsewhere in device **3200**. As an example, antennas may be mounted at one or both ends of device **3200** (e.g., along the upper and lower edges of housing, at the corners of housing, etc.).

[0172] Antennas in device **3200** may include cellular telephone antennas, wireless local area network antennas (e.g., Wi-Fi® antennas at 2.4 GHz and 5 GHz and other suitable wireless local area network antennas), satellite navigation system signals, and near-field communications antennas. The antennas may also include antennas that support IEEE 802.15.4 ultra-wideband communications protocols and/or antennas for handling millimeter wave communications. For example, the antennas may include two or more ultra-wideband frequency antennas and/or millimeter wave phased antenna arrays. Millimeter wave communications, which are sometimes referred to as extremely high frequency (EHF) communications, involve signals at 60 GHz or other frequencies between about 10 GHz and 400 GHz.

[0173] Wireless circuitry in device **3200** may support communications using the IEEE 802.15.4 ultra-wideband protocol. In an IEEE 802.15.4 system, a pair of devices may exchange wireless time stamped messages. Time stamps in the messages may be analyzed to determine the time of flight of the messages and thereby determine the distance (range) between the devices.

[0174] Image sensors **3244** may include one or more visible digital image sensors (visible-light cameras) and/or one or more infrared digital image sensors (infrared-light cameras). Image sensors **3244** may, if desired, be used to measure distances. For example, an infrared time-of-flight image sensor may be used to measure the time that it takes for an infrared light pulse to reflect back from objects in the vicinity of device **3200**, which may in turn be used to determine the distance to those objects. Visible imaging systems such as a front and/or rear-facing camera in device **3200** may also be used to determine the position of objects in the environment. For example, control circuitry **3204** may use image sensors **3244** to perform simultaneous localization and mapping (SLAM). SLAM refers to the process of using images to determine the position of objections in the environment while also constructing a representation of the imaged environment. Visual SLAM techniques include detecting and tracking certain features in images such as edges, textures, room corners, window corners, door corners, faces, sidewalk edges, street edges, building edges, tree trunks, and other prominent features. Control circuitry **3204** may rely entirely upon image sensors **3244** to perform simultaneous localization and mapping, or control circuitry **3204** may synthesize image data with range data from one

or more distance sensors (e.g., light-based proximity sensors). If desired, control circuitry **3204** may use display to display a visual representation of the mapped environment.

[0175] Input-output devices may include motion sensor circuitry **3246**. Motion sensor circuitry **3246** may include one or more accelerometers (e.g., accelerometers that measure acceleration along one, two, or three axes), gyroscopes, barometers, magnetic sensors (e.g., compasses), image sensors (e.g., image sensor **3244**) and other sensor structures. Sensors **3246** may, for example, include one or more microelectromechanical systems (MEMS) sensors (e.g., accelerometers, gyroscopes, microphones, force sensors, pressure sensors, capacitive sensors, or any other suitable type of sensor formed using microelectromechanical systems technology).

[0176] Control circuitry **3204** may be used to store and process motion sensor data. If desired, motion sensors, processing circuitry, and storage that form motion sensor circuitry may form part of a system-on-chip integrated circuit (as an example).

[0177] Input-output devices may include movement generation circuitry. Movement generation circuitry may receive control signals from control circuitry **3204**. Movement generation circuitry may include electromechanical actuator circuitry that, when driven, moves device **3200** in one or more directions. For example, movement generation circuitry may laterally move device **3200** and/or may rotate device **3200** around one or more axes of rotation. Movement generation circuitry may, for example, include one or more actuators formed at one or more locations of device **3200**. When driven by a motion control signal, actuators may move (e.g., vibrate, pulse, tilt, push, pull, rotate, etc.) to cause device **3200** to move or rotate in one or more directions. The movement may be slight (e.g., not noticeable or barely noticeable to a user of device **3200**), or the movement may be substantial. Actuators may be based on one or more vibrators, motors, solenoids, piezoelectric actuators, speaker coils, or any other desired device capable of mechanically (physically) moving device **3200**.

[0178] Some or all of movement generation circuitry such as actuators may be used to perform operations that are unrelated to rotation of device **3200**. For example, actuators may include vibrators that are actuated to issue a haptic alert or notification to a user of device **3200**. Such alerts may include, for example, a received text message alert identifying that device **3200** has received a text message, a received telephone call alert, a received email alert, an alarm notification alert, a calendar notification alert, or any other desired notification. By actuating actuator, device **3200** may inform the user of any desired device condition.

[0179] Motion sensor circuitry may sense motion of device **3200** that is generated by movement generation circuitry. If desired, motion sensor circuitry may provide feedback signals associated with the sensed motion of device **3200** to movement generation circuitry. Movement generation circuitry may use the feedback signals to control actuation of the movement generation circuitry.

[0180] Control circuitry **3204** may use motion sensor circuitry and/or movement generation circuitry to determine the angle of arrival of wireless signals received by device **3200** from another electronic device. For example, control circuitry **3204** may use movement generation circuitry to move device **3200** from one position to another. Motion sensor circuitry may be used to track the movement of device **3200** as it is moved between the different positions. At each position, control circuitry **3204** may receive wireless signals from another electronic device. Control circuitry **3204** may process the received wireless signals together with the motion data from motion sensor circuitry to more accurately determine the position of the other electronic device. The use of motion generation circuitry is merely illustrative, however. If desired, motion sensor circuitry may track movement of device **3200** that is not caused by motion generation circuitry. This may include a user's natural, unprompted movement of device **3200** and/or the user's movement of device **3200** after the user is prompted (by display, audio circuitry **3210**, a haptic output device in device **3200**, or any other suitable output device) to move device **3200** in a particular fashion.

[0181] Other sensors that may be included in input-output devices include ambient light sensors for gathering information on ambient light levels, proximity sensor components (e.g., light-based proximity sensors, capacitive proximity sensors, and/or proximity sensors based on other structures), depth sensors (e.g., structured light depth sensors that emit beams of light in a grid, a random dot array, or other pattern, and that have image sensors that generate depth maps based on the resulting spots of light produced on target objects), sensors that gather three-dimensional depth information using a pair of stereoscopic image sensors, LIDAR (light detection and ranging) sensors, radar sensors, and other suitable sensors.

[0182] Input-output circuitry may include wireless communications circuitry for communicating wirelessly with external equipment. Wireless communications circuitry may include radio frequency (RF) transceiver circuitry formed from one or more integrated circuits, power amplifier circuitry, low-noise input amplifiers, passive RF components, one or more antennas, transmission lines, and other circuitry for handling RF wireless signals. Wireless signals can also be sent using light (e.g., using infrared communications).

[0183] Wireless communications circuitry **3208** may include radio-frequency transceiver circuitry for handling various radio-frequency communications bands. For example, wireless circuitry **3208** may include transceiver circuitry.

[0184] Transceiver circuitry may be wireless local area network transceiver circuitry. Transceiver circuitry may handle 2.4 GHz and 5 GHz bands for Wi-Fi® (IEEE 802.11) communications and may handle the 2.4 GHz Bluetooth® communications band.

[0185] Circuitry may use cellular telephone transceiver circuitry for handling wireless communications in frequency ranges such as a communications band from 700 to 960 MHz, a band from 1710 to 2170 MHz, a band from 2300 to 2700 MHz, other bands between 700 and 2700 MHz, higher bands such as LTE bands 42 and 43 (3.4-3.6 GHz), or other cellular telephone communications bands. Circuitry may handle voice data and non-voice data.

[0186] Millimeter wave transceiver circuitry (sometimes referred to as extremely high frequency transceiver circuitry) may support communications at extremely high frequencies (e.g., millimeter wave frequencies such as extremely high frequencies of 10 GHz to 400 GHz or other millimeter wave frequencies). For example, circuitry may support IEEE 802.11ad communications at 60 GHz. Circuitry may be formed from one or more integrated circuits (e.g., multiple integrated circuits mounted on a common

printed circuit in a system-in-package device, one or more integrated circuits mounted on different substrates, etc.).

[0187] Ultra-wideband transceiver circuitry may support communications using the IEEE 802.15.4 protocol and/or other wireless communications protocols. Ultra-wideband wireless signals may be characterized by bandwidths greater than 500 MHz or bandwidths exceeding 20% of the center frequency of radiation. The presence of lower frequencies in the baseband may allow ultra-wideband signals to penetrate through objects such as walls. Transceiver circuitry may operate in a 2.4 GHz frequency band, a 6.5 GHz frequency band, an 8 GHz frequency band, and/or at other suitable frequencies.

[0188] Wireless communications circuitry may include satellite navigation system circuitry such as Global Positioning System (GPS) receiver circuitry for receiving GPS signals at 3275 MHz or for handling other satellite positioning data (e.g., GLONASS signals at 1609 MHz). Satellite navigation system signals for receiver are received from a constellation of satellites orbiting the earth.

[0189] In satellite navigation system links, cellular telephone links, and other long-range links, wireless signals are typically used to convey data over thousands of feet or miles. In Wi-Fi® and Bluetooth® links at 2.4 and 5 GHz and other short-range wireless links, wireless signals are typically used to convey data over tens or hundreds of feet. Extremely high frequency (EHF) wireless transceiver circuitry may convey signals over these short distances that travel between transmitter and receiver over a line-of-sight path. To enhance signal reception for millimeter wave communications, phased antenna arrays and beam steering techniques may be used (e.g., schemes in which antenna signal phase and/or magnitude for each antenna in an array is adjusted to perform beam steering). Antenna diversity schemes may also be used to ensure that the antennas that have become blocked or that are otherwise degraded due to the operating environment of device **3200** can be switched out of use and higher-performing antennas used in their place.

[0190] Wireless communications circuitry can include circuitry for other short-range and long-range wireless links if desired. For example, wireless communications circuitry **36** may include circuitry for receiving television and radio signals, paging system transceivers, near field communications (NFC) circuitry, etc.

[0191] The one or more applications **3234** on device **3200** can include any applications installed on the device **3200**, including without limitation, a browser, address book, contact list, email, instant messaging, social networking, word processing, keyboard emulation, widgets, JAVA-enabled applications, encryption, digital rights management, voice recognition, voice replication, a music player (which plays back recorded music stored in one or more files, such as MP3 or advanced audio codec (AAC) files), etc.

[0192] There may be other modules or sets of instructions (not shown), such as a graphics module, a time module, etc. For example, the graphics module can include various conventional software components for rendering, animating and displaying graphical objects (including without limitation text, web pages, icons, digital images, animations, and the like) on a display surface. In another example, a timer module can be a software timer. The timer module can also be implemented in hardware. The time module can maintain various timers for any number of events.

[0193] I/O subsystem **3206** can be coupled to a display system (not shown), which can be a touch-sensitive display. The display displays visual output to the user in a GUI. The visual output can include text, graphics, video, and any combination thereof. Some or all of the visual output can correspond to user-interface objects. A display can use LED (light emitting diode), LCD (liquid crystal display) technology, or LPD (light emitting polymer display) technology, although other display technologies can be used in other embodiments.

[0194] In some embodiments, I/O subsystem **3206** can include a display and user input devices such as a keyboard, mouse, and/or trackpad. In some embodiments, I/O subsystem **3206** can include a touch-sensitive display. A touch-sensitive display can also accept input from the user based at least part on haptic and/or tactile contact. In some embodiments, a touch-sensitive display forms a touch-sensitive surface that accepts user input. The touch-sensitive display/surface (along with any associated modules and/or sets of instructions in computer-readable medium **3202**) detects contact (and any movement or release of the contact) on the touch-sensitive display and converts the detected contact into interaction with user-interface objects, such as one or more soft keys, that are displayed on the touch screen when the contact occurs. In some embodiments, a point of contact between the touch-sensitive display and the user corresponds to one or more digits of the user. The user can make contact with the touch-sensitive display using any suitable object or appendage, such as a stylus, pen, finger, and so forth. A touch-sensitive display surface can detect contact and any movement or release thereof using any suitable touch sensitivity technologies, including capacitive, resistive, infrared, and surface acoustic wave technologies, as well as other proximity sensor arrays or other elements for determining one or more points of contact with the touch-sensitive display.

[0195] Further, I/O subsystem **3206** can be coupled to one or more other physical control devices (not shown), such as pushbuttons, keys, switches, rocker buttons, dials, slider switches, sticks, LEDs, etc., for controlling or performing various functions, such as power control, speaker volume control, ring tone loudness, keyboard input, scrolling, hold, menu, screen lock, clearing and ending communications and the like. In some embodiments, in addition to the touch screen, device **3200** can include a touchpad (not shown) for activating or deactivating particular functions. In some embodiments, the touchpad is a touch-sensitive area of the device **3200** that, unlike the touch screen, does not display visual output. The touchpad can be a touch-sensitive surface that is separate from the touch-sensitive display or an extension of the touch-sensitive surface formed by the touch-sensitive display.

[0196] In some embodiments, some or all of the operations described herein can be performed using an application executing on the user's device. Circuits, logic modules, processors, and/or other components may be configured to perform various operations described herein. Those skilled in the art will appreciate that, depending on implementation, such configuration can be accomplished through design, setup, interconnection, and/or programming of the particular components and that, again depending on implementation, a configured component might or might not be reconfigurable for a different operation. For example, a programmable processor can be configured by providing suitable execut-

able code; a dedicated logic circuit can be configured by suitably connecting logic gates and other circuit elements; and so on.

[0197] Any of the software components or functions described in this application may be implemented as software code to be executed by a processor using any suitable computer language such as, for example, Java, C, C++, C#, Objective-C, Swift, or scripting language such as Perl or Python using, for example, conventional or object-oriented techniques. The software code may be stored as a series of instructions or commands on a computer readable medium for storage and/or transmission. A suitable non-transitory computer readable medium can include random access memory (RAM), a read only memory (ROM), a magnetic medium such as a hard-drive or a floppy disk, or an optical medium, such as a compact disk (CD) or DVD (digital versatile disk), flash memory, and the like. The computer readable medium may be any combination of such storage or transmission devices.

[0198] Computer programs incorporating various features of the present disclosure may be encoded on various computer readable storage media; suitable media include magnetic disk or tape, optical storage media, such as compact disk (CD) or DVD (digital versatile disk), flash memory, and the like. Computer readable storage media encoded with the program code may be packaged with a compatible device or provided separately from other devices. In addition, program code may be encoded and transmitted via wired optical, and/or wireless networks conforming to a variety of protocols, including the Internet, thereby allowing distribution, e.g., via Internet download. Any such computer readable medium may reside on or within a single computer product (e.g. a solid state drive, a hard drive, a CD, or an entire computer system), and may be present on or within different computer products within a system or network. A computer system may include a monitor, printer, or other suitable display for providing any of the results mentioned herein to a user.

[0199] As described above, one aspect of the present technology is the gathering, sharing, and use of data available from specific and legitimate sources to improve the delivery to users of invitational content or any other content that may be of interest to them. The present disclosure contemplates that in some instances, this gathered data may include personal information data that uniquely identifies or can be used to contact or locate a specific person. Such personal information data can include demographic data, location-based data, telephone numbers, email addresses, twitter ID's, home addresses, data or records relating to a user's health or level of fitness (e.g., vital signs measurements, medication information, exercise information), date of birth, or any other identifying or personal information.

[0200] The present disclosure recognizes that the use of such personal information data, in the present technology, can be used to the benefit of users. For example, the personal information data can be used to authenticate another device, and vice versa to control which devices ranging operations may be performed. Further, other uses for personal information data that benefit the user are also contemplated by the present disclosure. For instance, health and fitness data may be shared to provide insights into a user's general wellness, or may be used as positive feedback to individuals using technology to pursue wellness goals.

[0201] The present disclosure contemplates that the entities responsible for the collection, analysis, disclosure, transfer, storage, or other use of such personal information data will comply with well-established privacy policies and/or privacy practices. In particular, such entities should implement and consistently use privacy policies and practices that are generally recognized as meeting or exceeding industry or governmental requirements for maintaining personal information data private and secure. Such policies should be easily accessible by users, and should be updated as the collection and/or use of data changes. Personal information from users should be collected for legitimate and reasonable uses of the entity and not shared or sold outside of those legitimate uses. Further, such collection/sharing should occur after receiving the informed consent of the users. Additionally, such entities should consider taking any needed steps for safeguarding and securing access to such personal information data and ensuring that others with access to the personal information data adhere to their privacy policies and procedures. Further, such entities can subject themselves to evaluation by third parties to certify their adherence to widely accepted privacy policies and practices. In addition, policies and practices should be adapted for the particular types of personal information data being collected and/or accessed and adapted to applicable laws and standards, including jurisdiction-specific considerations. For instance, in the US, collection of or access to certain health data may be governed by federal and/or state laws, such as the Health Insurance Portability and Accountability Act (HIPAA); whereas health data in other countries may be subject to other regulations and policies and should be handled accordingly. Hence, different privacy practices should be maintained for different personal data types in each country.

[0202] Despite the foregoing, the present disclosure also contemplates embodiments in which users selectively block the use of, or access to, personal information data. That is, the present disclosure contemplates that hardware and/or software elements can be provided to prevent or block access to such personal information data. For example, in the case of sharing content and performing ranging, the present technology can be configured to allow users to select to "opt in" or "opt out" of participation in the collection of personal information data during registration for services or anytime thereafter. In addition to providing "opt in" and "opt out" options, the present disclosure contemplates providing notifications relating to the access or use of personal information. For instance, a user may be notified upon downloading an app that their personal information data will be accessed and then reminded again just before personal information data is accessed by the app.

[0203] Moreover, it is the intent of the present disclosure that personal information data should be managed and handled in a way to minimize risks of unintentional or unauthorized access or use. Risk can be minimized by limiting the collection of data and deleting data once it is no longer needed. In addition, and when applicable, including in certain health related applications, data de-identification can be used to protect a user's privacy. De-identification may be facilitated, when appropriate, by removing specific identifiers (e.g., date of birth, etc.), controlling the amount or specificity of data stored (e.g., collecting location data a city

level rather than at an address level), controlling how data is stored (e.g., aggregating data across users), and/or other methods.

[0204] Therefore, although the present disclosure broadly covers use of personal information data to implement one or more various disclosed embodiments, the present disclosure also contemplates that the various embodiments can also be implemented without the need for accessing such personal information data. That is, the various embodiments of the present technology are not rendered inoperable due to the lack of all or a portion of such personal information data.

[0205] Although the present disclosure has been described with respect to specific embodiments, it will be appreciated that the disclosure is intended to cover all modifications and equivalents within the scope of the following claims.

[0206] The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense. It will, however, be evident that various modifications and changes may be made thereunto without departing from the broader spirit and scope of the disclosure as set forth in the claims.

[0207] Other variations are within the spirit of the present disclosure. Thus, while the disclosed techniques are susceptible to various modifications and alternative constructions, certain illustrated embodiments thereof are shown in the drawings and have been described above in detail. It should be understood, however, that there is no intention to limit the disclosure to the specific form or forms disclosed, but on the contrary, the intention is to cover all modifications, alternative constructions and equivalents falling within the spirit and scope of the disclosure, as defined in the appended claims.

[0208] The use of the terms "a" and "an" and "the" and similar referents in the context of describing the disclosed embodiments (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The terms "comprising," "having," "including," and "containing" are to be construed as open-ended terms (i.e., meaning "including, but not limited to,") unless otherwise noted. The term "connected" is to be construed as partly or wholly contained within, attached to, or joined together, even if there is something intervening. The phrase "based on" should be understood to be open-ended, and not limiting in any way, and is intended to be interpreted or otherwise read as "based at least in part on," where appropriate. Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of all examples, or exemplary language (e.g., "such as") provided herein, is intended merely to better illuminate embodiments of the disclosure and does not pose a limitation on the scope of the disclosure unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the disclosure. The use of "or" is intended to mean an "inclusive or," and not an "exclusive or" unless specifically indicated to the contrary. Reference to a "first" component does not necessarily require that a second component be provided. Moreover, reference to a "first" or a "second" component does not limit the referenced component to a particular location unless expressly stated. The term "based on" is intended to mean "based at least in part on."

[0209] Disjunctive language such as the phrase "at least one of X, Y, or Z," unless specifically stated otherwise, is otherwise understood within the context as used in general to present that an item, term, etc., may be either X, Y, or Z, or any combination thereof (e.g., X, Y, and/or Z). Thus, such disjunctive language is not generally intended to, and should not, imply that certain embodiments require at least one of X, at least one of Y, or at least one of Z to each be present. Additionally, conjunctive language such as the phrase "at least one of X, Y, and Z," unless specifically stated otherwise, should also be understood to mean X, Y, Z, or any combination thereof, including "X, Y, and/or Z."

[0210] Preferred embodiments of this disclosure are described herein, including the best mode known to the inventors for carrying out the disclosure. Variations of those preferred embodiments may become apparent to those of ordinary skill in the art upon reading the foregoing description. The inventors expect skilled artisans to employ such variations as appropriate, and the inventors intend for the disclosure to be practiced otherwise than as specifically described herein. Accordingly, this disclosure includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the disclosure unless otherwise indicated herein or otherwise clearly contradicted by context.

[0211] All references, including publications, patent applications, and patents, cited herein are hereby incorporated by reference to the same extent as if each reference were individually and specifically indicated to be incorporated by reference and were set forth in its entirety herein.

[0212] Any of the software components or functions described in this application, may be implemented as software code to be executed by a processor using any suitable computer language such as, for example, Java, C++ or Perl using, for example, conventional or object-oriented techniques. The software code may be stored as a series of instructions, or commands on a computer readable medium for storage and/or transmission, suitable media include random access memory (RAM), a read only memory (ROM), a magnetic medium such as a hard-drive or a floppy disk, or an optical medium such as a compact disk (CD) or DVD (digital versatile disk), flash memory, and the like. The computer readable medium may be any combination of such storage or transmission devices.

[0213] Such programs may also be encoded and transmitted using carrier signals adapted for transmission via wired, optical, and/or wireless networks conforming to a variety of protocols, including the Internet. As such, a computer readable medium according to an embodiment of the present invention may be created using a data signal encoded with such programs. Computer readable media encoded with the program code may be packaged with a compatible device or provided separately from other devices (e.g., via Internet download). Any such computer readable medium may reside on or within a single computer program product (e.g. a hard drive or an entire computer system), and may be present on or within different computer program products within a

system or network. A computer system may include a monitor, printer, or other suitable display for providing any of the results mentioned herein to a user.

[0214] The specific details of particular embodiments may be combined in any suitable manner or varied from those shown and described herein without departing from the spirit and scope of embodiments of the invention.

[0215] The above description of exemplary embodiments of the invention has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form described, and many modifications and variations are possible in light of the teaching above. The embodiments were chosen and described in order to best explain the principles of the invention and its practical applications to thereby enable others skilled in the art to best utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated.

[0216] All publications, patents, and patent applications cited herein are hereby incorporated by reference in their entirety for all purposes.

What is claimed is:

1. An electronic device, comprising:

a first display coupled to a second display via a hinged connection;

an acceleration sensor configured to detect a vertical acceleration of the electronic device exceeding a predetermined vertical acceleration threshold; and

a release mechanism operating with the hinged connection to automatically reduce an angle between the first display and the second display below a threshold angle when the predetermined acceleration threshold is exceeded.

2. The electronic device of claim **1**, wherein the release mechanism comprises a motorized hinge.

3. The electronic device of claim **1**, wherein the release mechanism comprises a mechanical hinge with a spring-loaded detent.

4. The electronic device of claim **1**, wherein the threshold angle is less than 180 degrees.

5. The electronic device of claim **1**, wherein the first display or the second display is an organic light emitting diode display.

6. The electronic device of claim **1**, wherein the first display and the second display each comprise regions of a foldable display.

7. The electronic device of claim **1**, wherein the acceleration sensor comprises an inertial measurement unit.

8. An electronic device, comprising:

a foldable display coupled on one edge of the foldable device to a roller;

an acceleration sensor configured to detect a vertical acceleration of the electronic device exceeding a predetermined vertical acceleration threshold; and

a release mechanism operating with the roller to automatically retract the foldable display on the roller when the detected vertical acceleration exceeds a predetermined acceleration threshold.

9. The electronic device of claim **8**, wherein the release mechanism comprises a motorized hinge.

10. The electronic device of claim **8**, wherein the release mechanism comprises a mechanical hinge with a spring-loaded detent.

11. The electronic device of claim **8**, wherein the acceleration sensor comprises an inertial measurement unit.

12. The electronic device of claim **8**, wherein the foldable display comprises:

a substrate including a first side and a second side;

a first wiring layer on the first side;

an array of LEDs on and in electrical contact with the first wiring layer on the first side of the substrate;

a second wiring layer on the second side of the substrate; and

a plurality of interconnects extending between and electrically connecting the first wiring layer to the second wiring layer.

13. The electronic device of claim **12**, further comprising an array of microchips connected with the first wiring layer to drive the array of LEDs.

14. The electronic device of claim **12**, wherein each microchip is connected with a corresponding plurality of LEDs.

15. A method, comprising:

detecting a vertical acceleration of an electronic device;

comparing a value of the vertical acceleration of the electronic device against a predetermined threshold; and

activating a release mechanism for a hinged connection between a first display and a second display of the electronic device when the value of the vertical acceleration exceeds the predetermined threshold, wherein the activating reduces an angle between the first display and the second display below a threshold angle.

16. The method of claim **15**, wherein the release mechanism comprises a motorized hinge.

17. The method of claim **15**, wherein the release mechanism comprises a mechanical hinge with a spring-loaded detent.

18. The method of claim **15**, wherein the threshold angle is less than 180 degrees.

19. The method of claim **15**, wherein the first display or the second display is an organic light emitting diode display.

20. The method of claim **15**, wherein the first display and the second display each comprise regions of a foldable display.

* * * * *