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(54) NON-INTRUSIVE AMBIENT LIGHT SENSOR FOR FRONTLIGHT CONTROL

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G01J 1/44 (2006.01)

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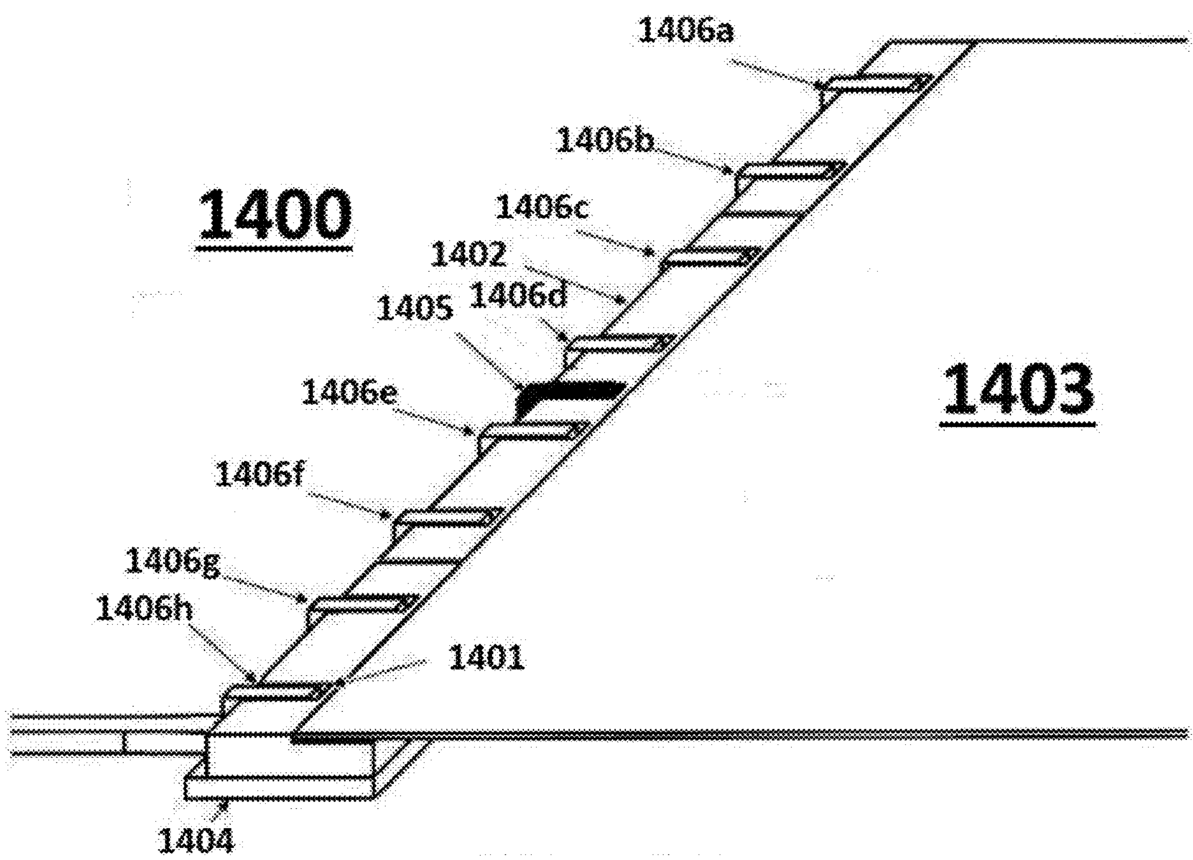
(57) **ABSTRACT**

Embodiments of the invention provide a frontlight switch comprising an ambient light sensor system configured to detect ambient light levels received into a lightguide associated with the display on a tablet device. The ambient light sensor system may be configured to detect when ambient light levels are above or have fallen below a level where a user will be able to read the device screen and switch on or off the frontlight. The ambient light sensor may reside in the frontlight in the same layer as the LEDs associated with the frontlight, thus eliminating the need for separate light openings in the device.



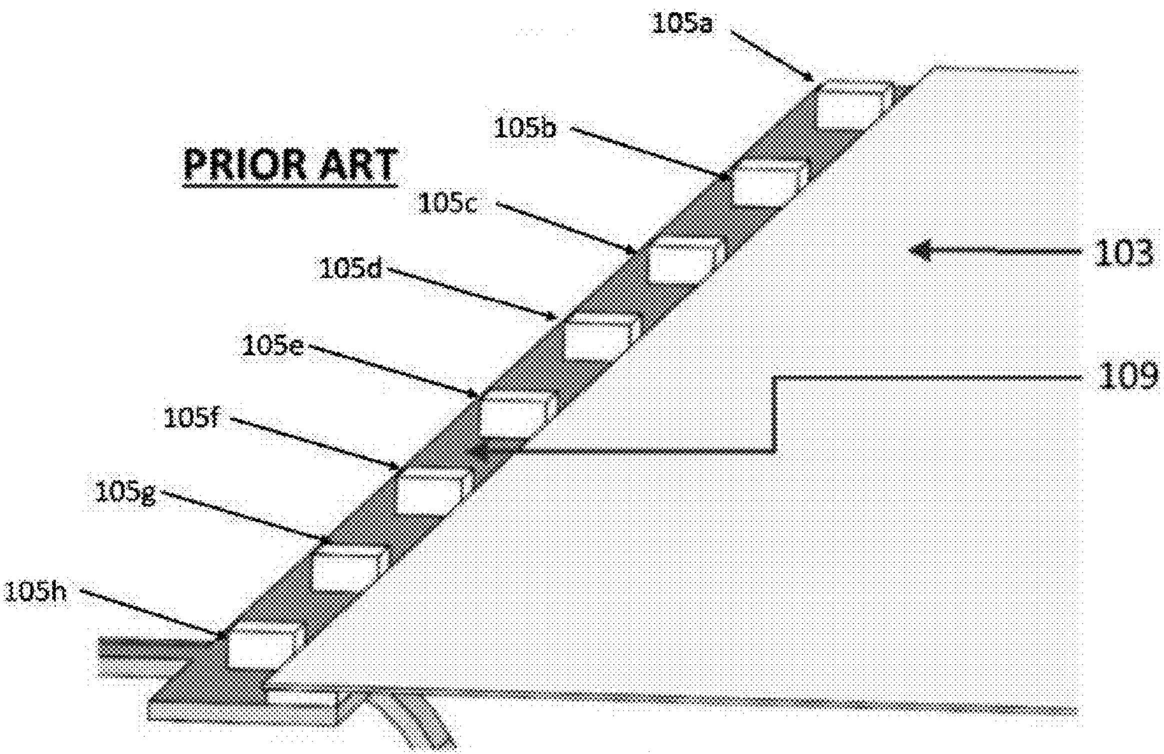

PRIOR ART
105a
105b
105c
105d
105e
105f
105g
105h
103
109

FIG. 1

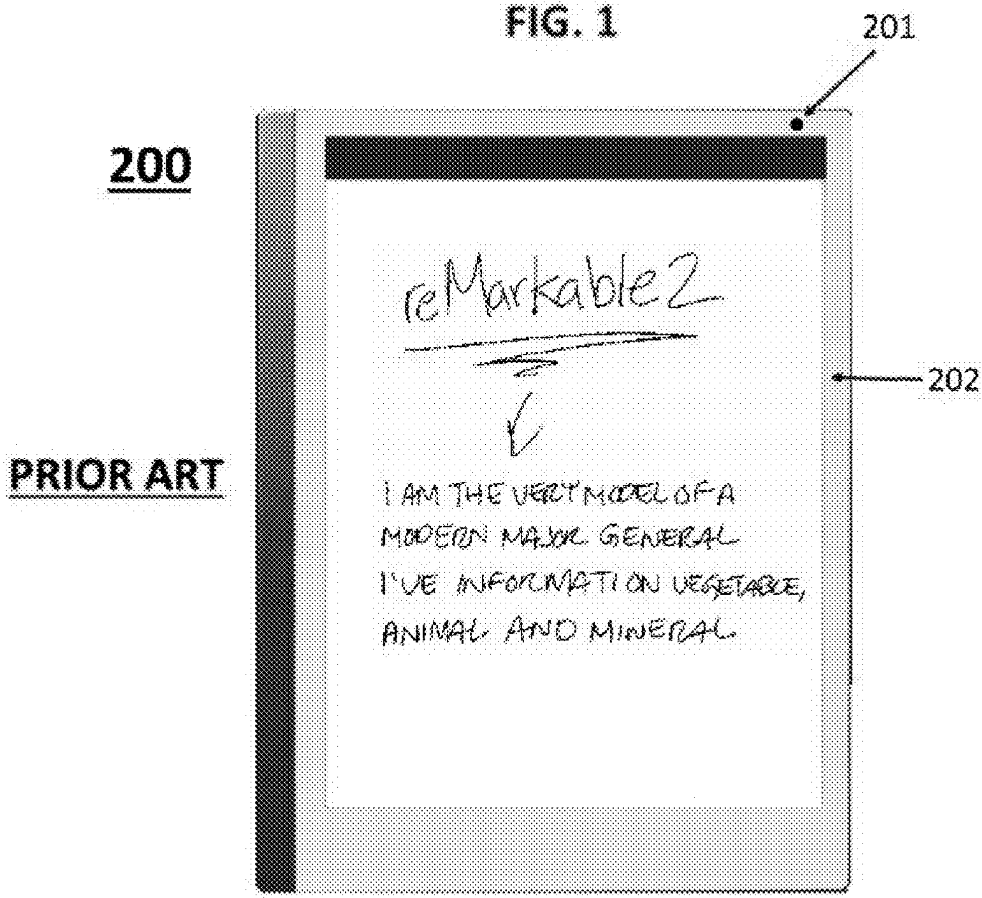

200
PRIOR ART
201
202
reMarkable2
I AM THE VERY MODEL OF A
MODERN MAJOR GENERAL
I'VE INFORMATION VEGETABLE,
ANIMAL AND MINERAL

FIG. 2

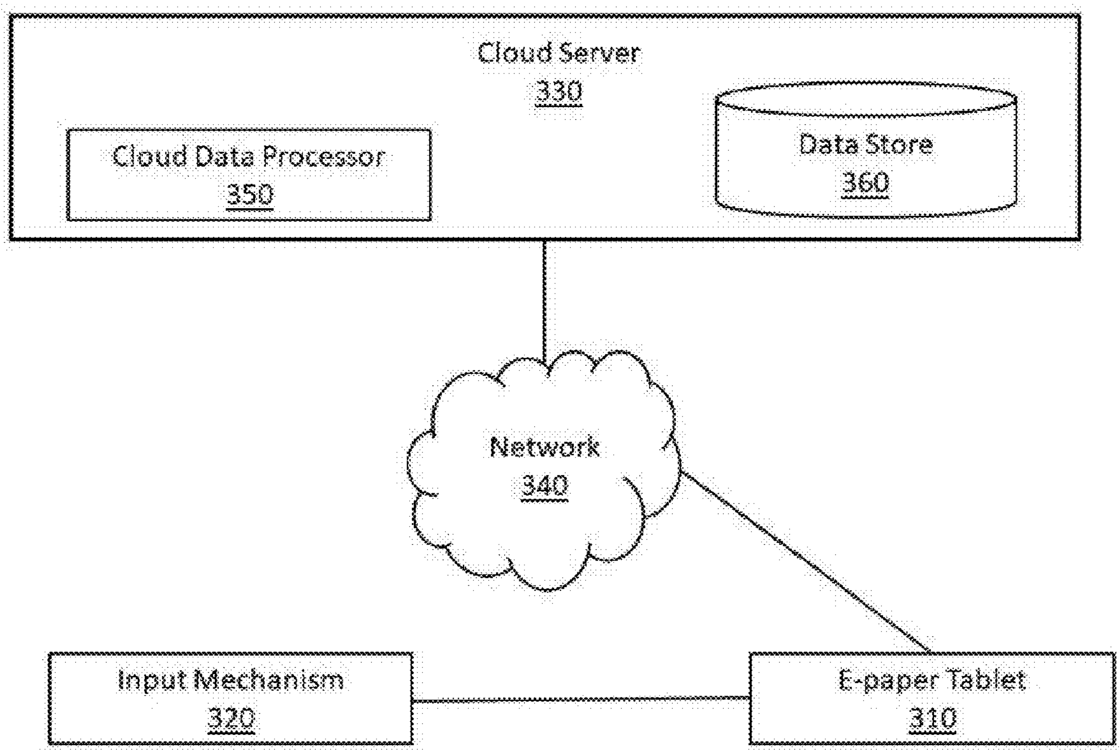

Cloud Server
330
Cloud Data Processor
350
Data Store
360
Network
340
Input Mechanism
320
E-paper Tablet
310

FIG. 3

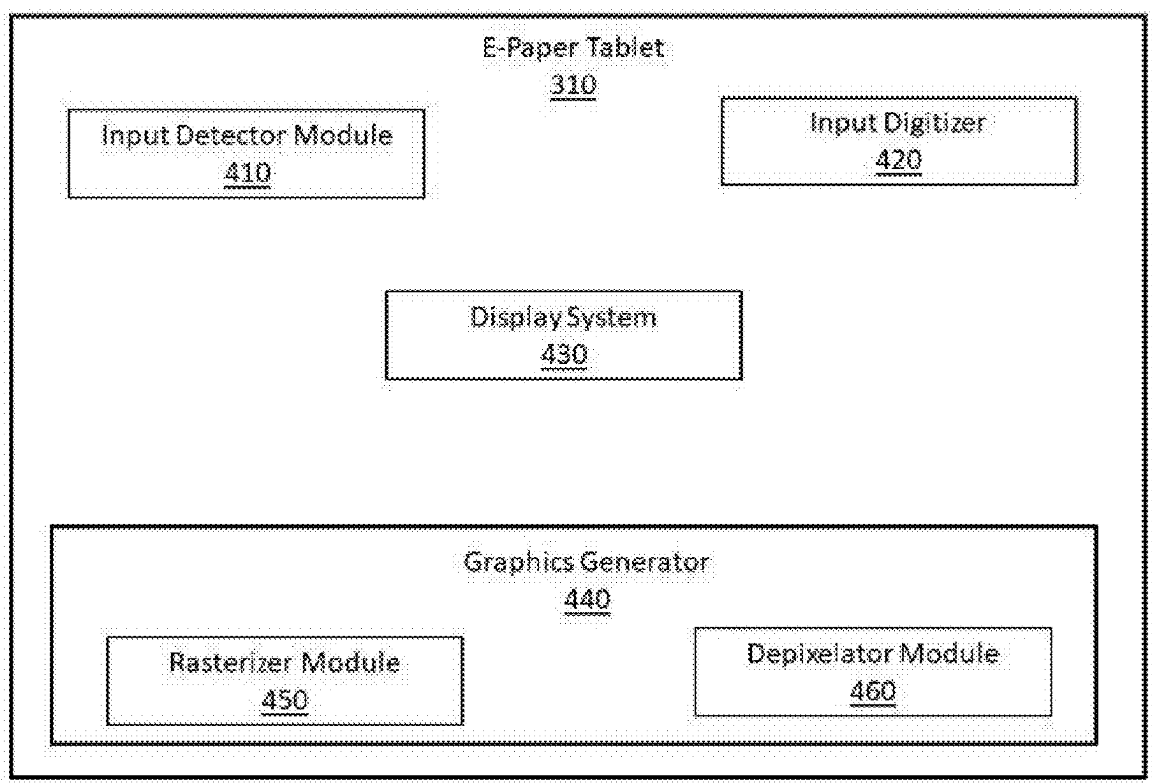

E-Paper Tablet
310
Input Detector Module
410
Input Digitizer
420
Display System
430
Graphics Generator
440
Rasterizer Module
450
Depixelator Module
460

FIG. 4

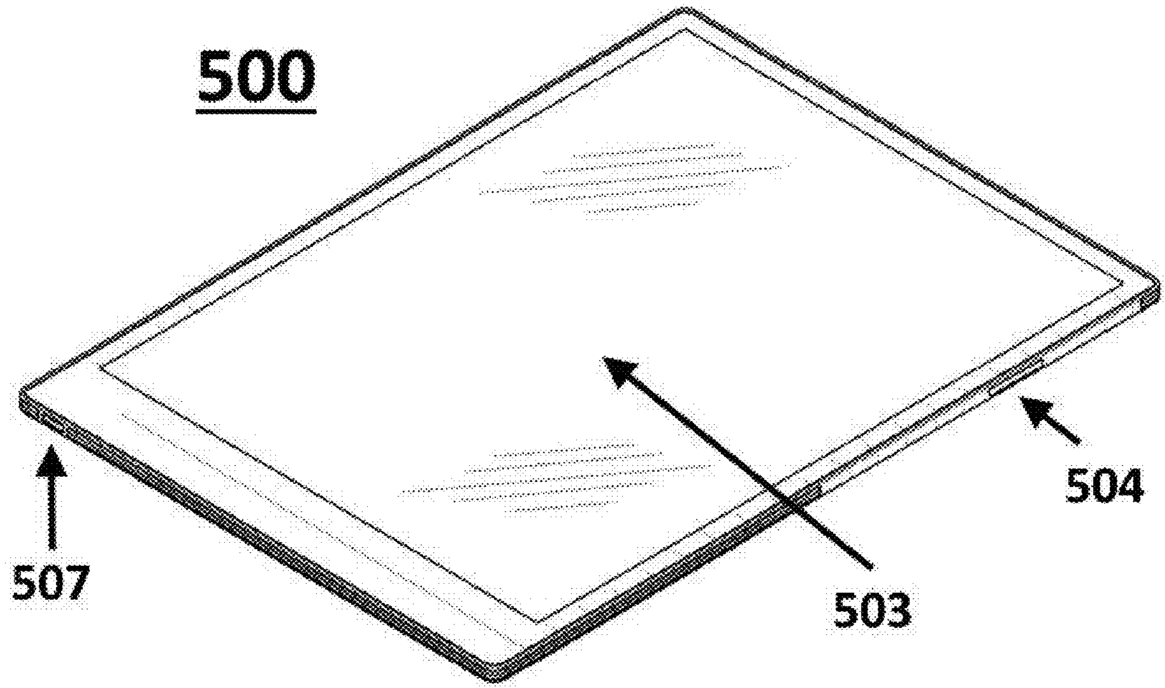

500
504
507
503

FIG. 5

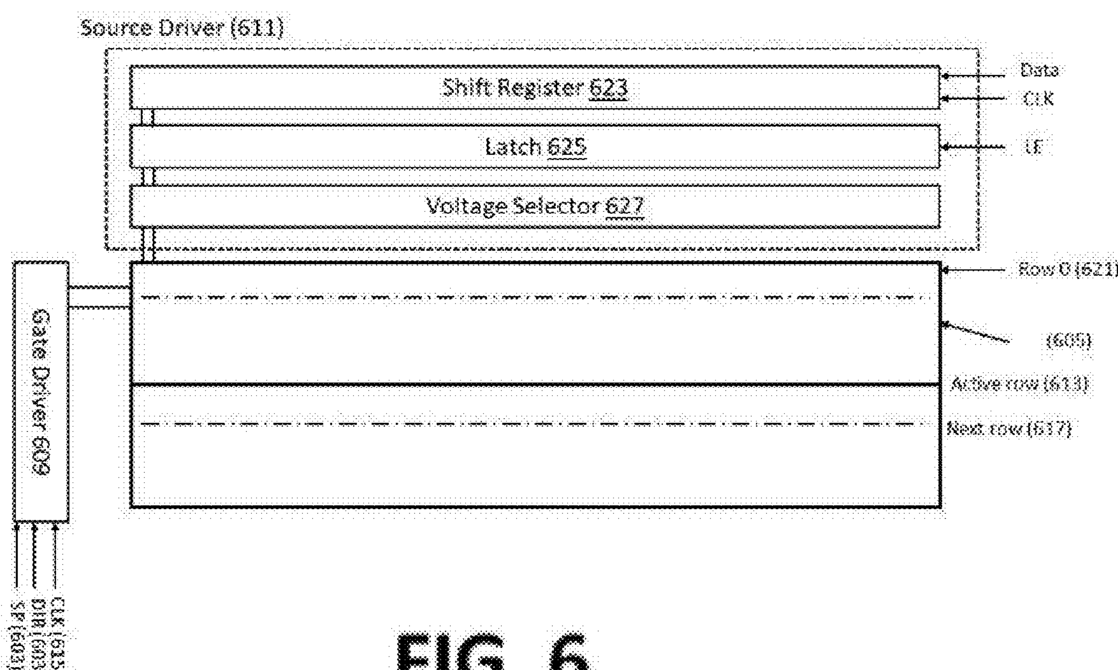

Source Driver (611)
Shift Register 623
Latch 625
Voltage Selector 627
Data
CLK
LE
Row 0 (621)
(605)
Active row (613)
Next row (617)
Gate Driver 609
CLK (615)
DIR (603)
SP (603)

FIG. 6

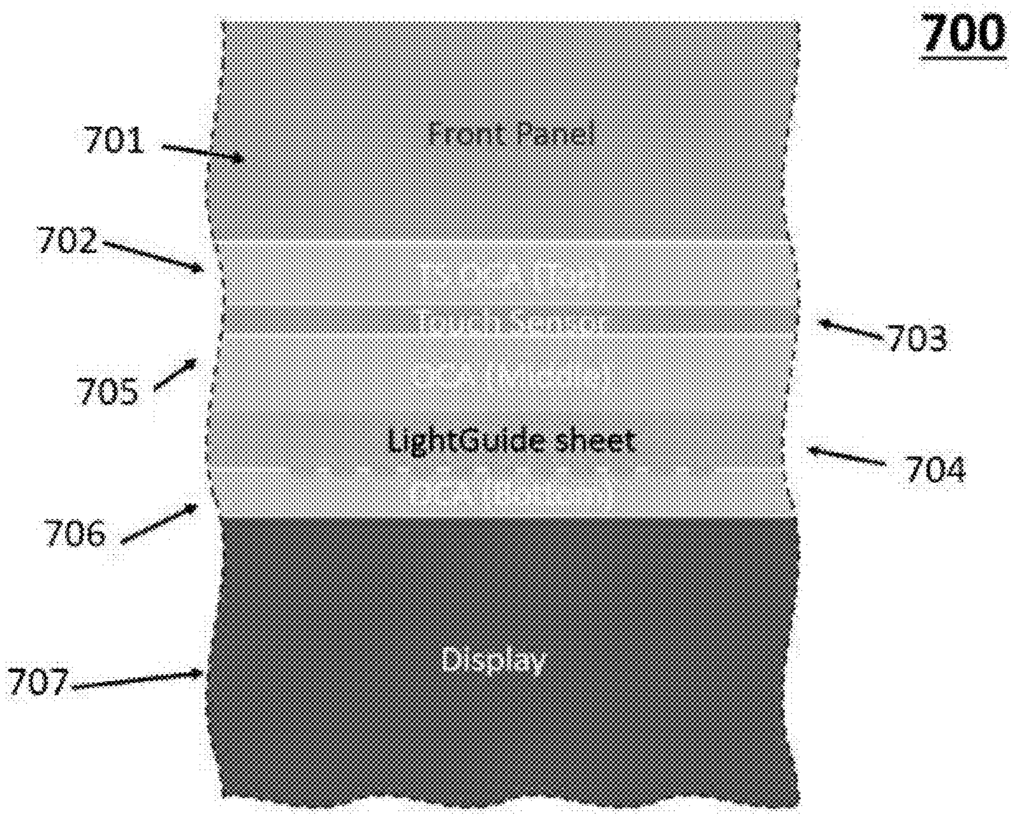

700
701
Front Panel
702
Touch Sensor
703
705
LightGuide sheet
704
706
Display
707

FIG. 7

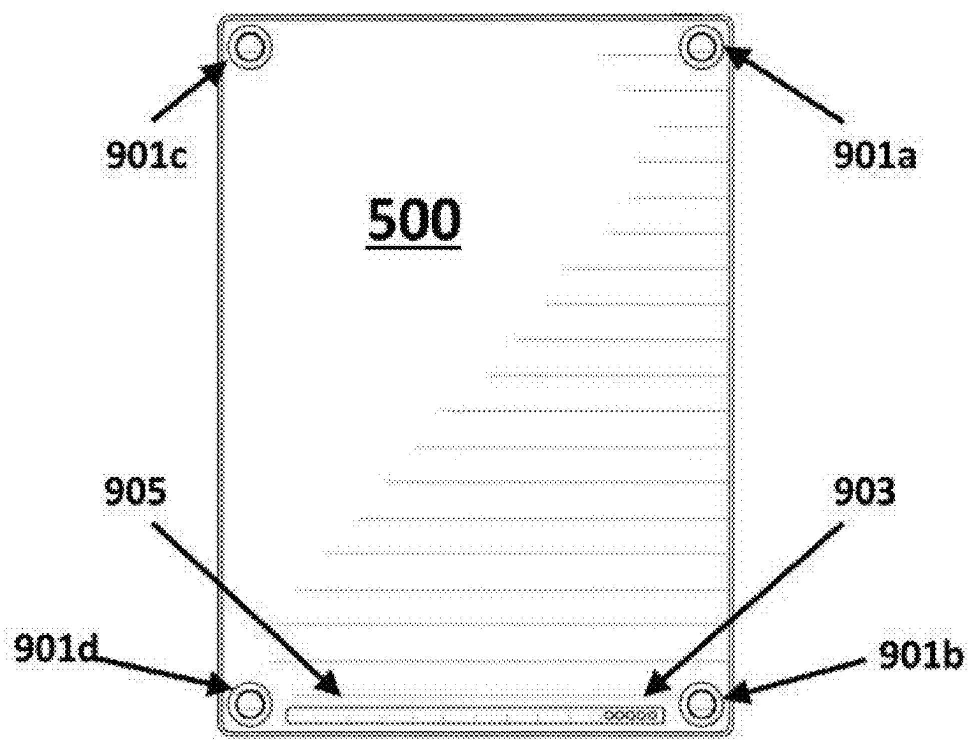

901c
901a
500
905
903
901d
901b

FIG. 9

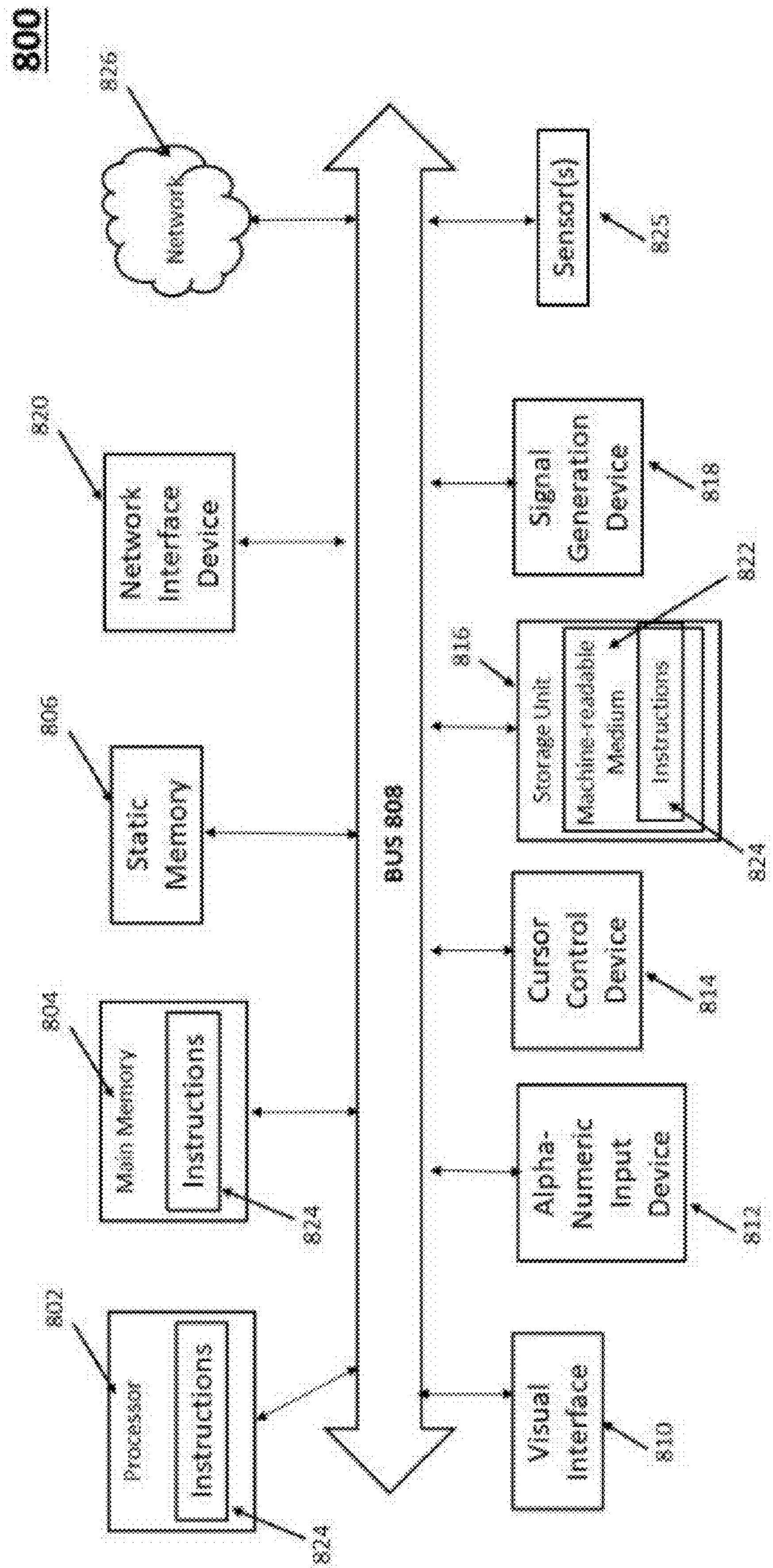

800
826
Network
Sensor(s)
825
820
Network Interface Device
Signal Generation Device
818
822
806
Static Memory
816
Storage Unit
Machine-readable Medium
Instructions
824
BUS 808
804
Main Memory
Instructions
824
Cursor Control Device
814
Alpha-Numeric Input Device
812
802
Processor
Instructions
824
Visual Interface
810

FIG. 8

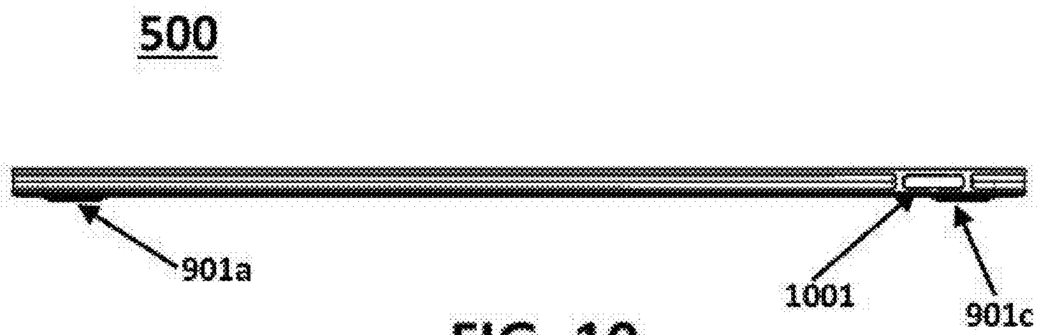


FIG. 10

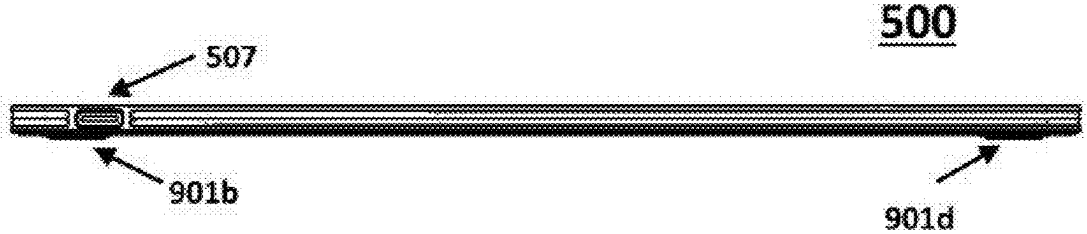


FIG. 11

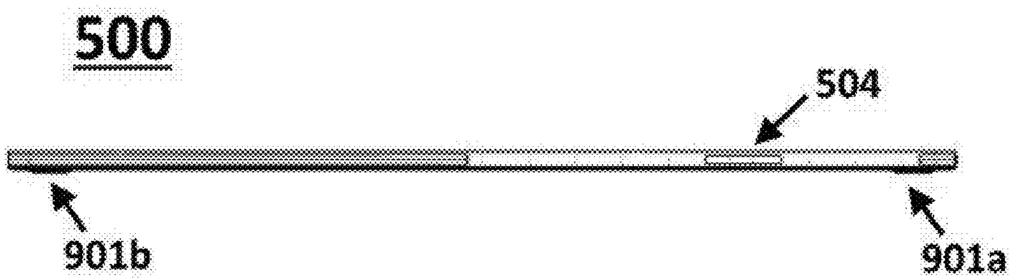


FIG. 12

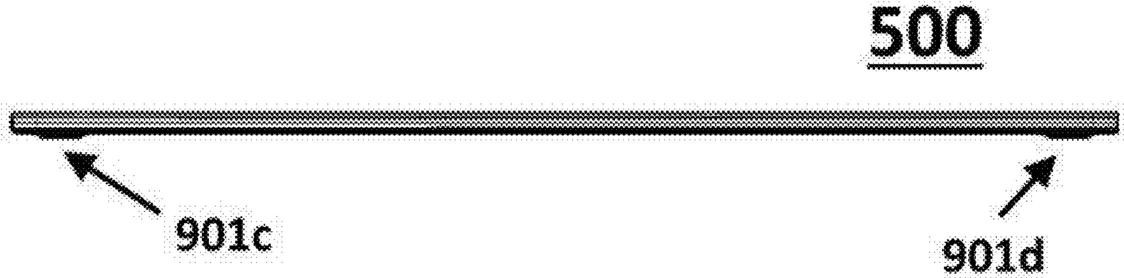


FIG. 13

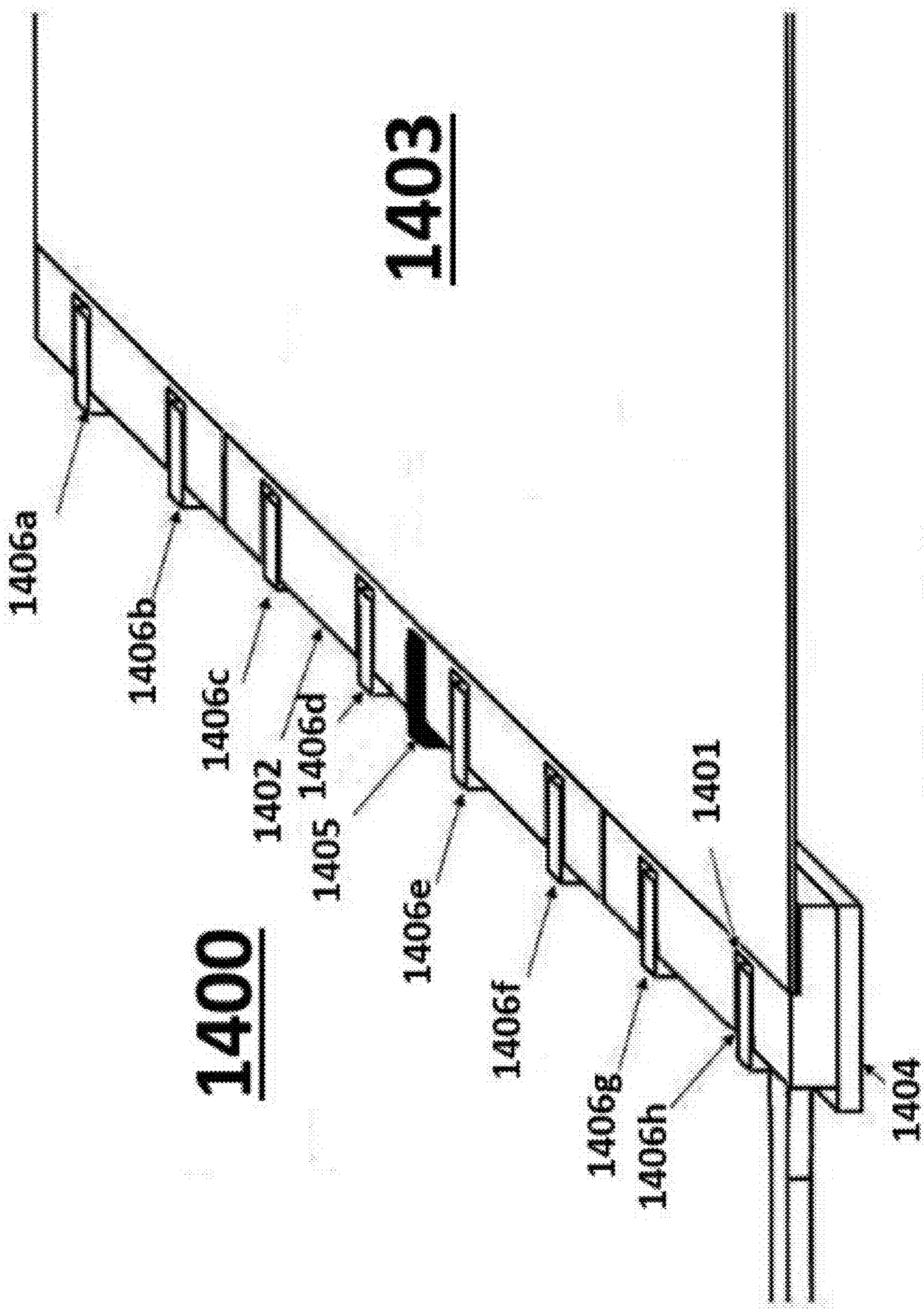

1403
1400
1406a
1406b
1406c
1402
1406d
1405
1406e
1406f
1406g
1406h
1401
1404

FIG. 14

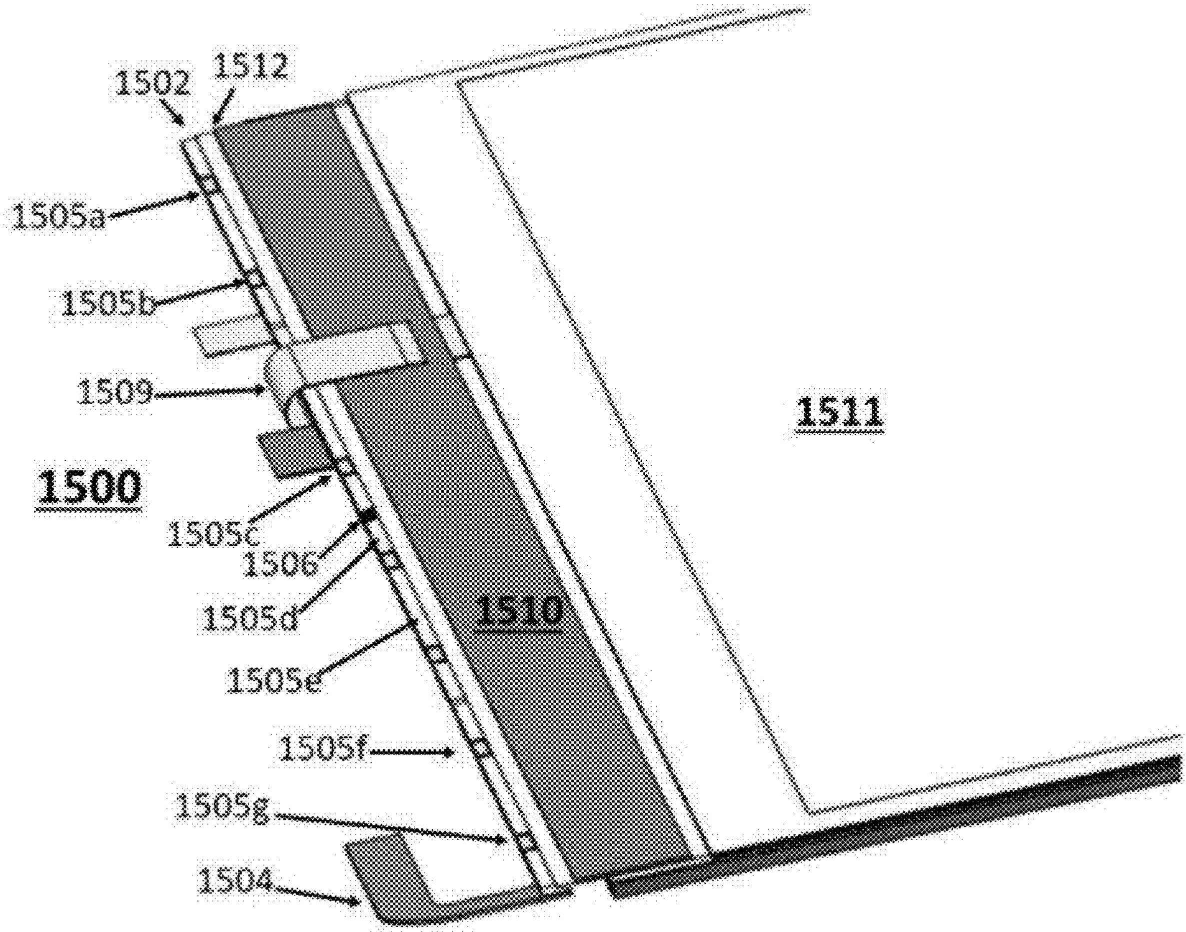

1502
1512
1505a
1505b
1509
1500
1505c
1506
1505d
1505e
1505f
1505g
1504
1510
1511

FIG. 15

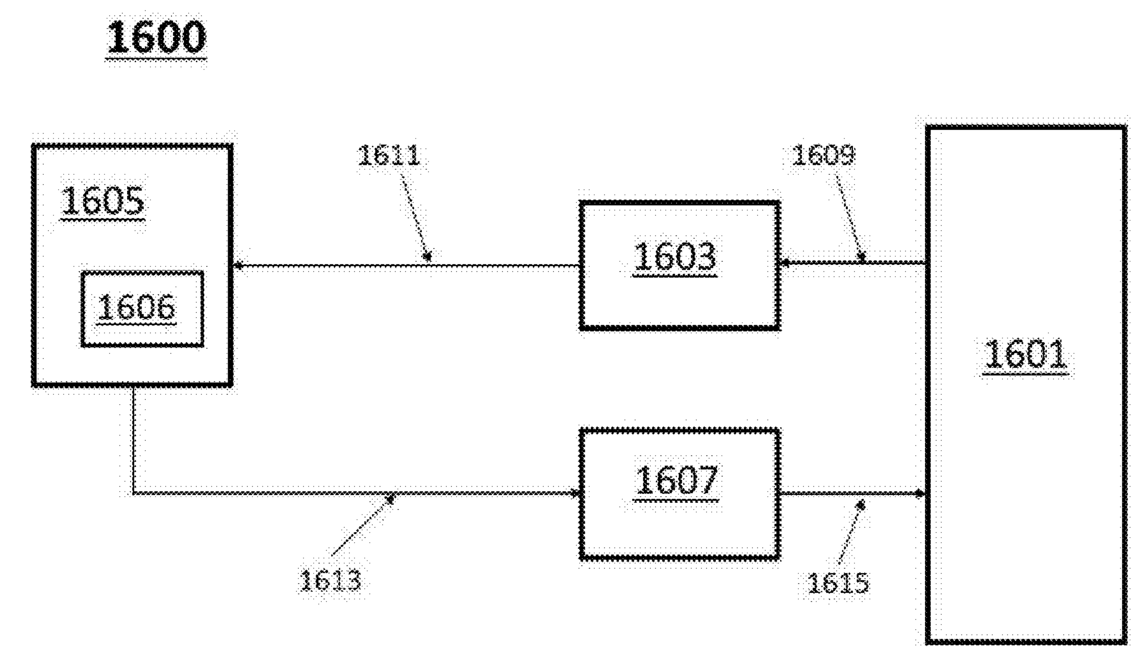

1600
1605
1606
1611
1603
1609
1601
1607
1613
1615

FIG. 16

NON-INTRUSIVE AMBIENT LIGHT SENSOR FOR FRONTLIGHT CONTROL

TECHNICAL FIELD

[0001] The disclosure relates generally to a frontlight, adapted for various display devices such as a digitizer or a tablet. In particular, embodiments of the present invention relate to an ambient light switch for engaging a frontlight in low lighting conditions.

BACKGROUND

[0002] Mobile telephones, tablet computers, PCs, car entertainment systems, white goods and many other devices are commonly equipped with interactive displays. These interactive displays combine a display screen, such as an LCD, oLED, plasma or electrophoretic display (EPD), with an input system, such as a touch- or pen-stylus-input system. The input system recognizes the presence of an input object such as a pen-stylus touching or in close proximity to the display screen.

[0003] The displays screens, such as EPDs, included in these devices are typically passive in that they modulate light but do not produce light in the manner of other types of displays. As a consequence, when passive displays like EPD displays are placed in darkened environments, users may have difficulty seeing the display. In a completely darkened room, the user might not be able to see the display at all.

[0004] As a consequence, passive display devices may be equipped with various lighting means, such as a frontlight that adds light to the display enabling users to see the display in low ambient light conditions. FIG. **1** illustrates a prior art frontlight having a lightguide **103**, a thin filament of a transparent material, such as glass or plastic, which is capable of transmitting light signals through successive internal reflections. The lightguide **103** receives its light from a plurality of light sources (e.g., LEDs **105***a*-**105***h*) mounted on an LED circuit board **109** and then reflects the image from the underlying display (e.g., EPD not shown in FIG. **1** but located beneath the lightguide **103**) so as to make the underlying image visible in low light levels. The light sources **105***a*-**105***h* are located at various positions along the edge of the lightguide **103**.

[0005] FIG. **2** illustrates a conventional prior art design in a passive display device **200** for an ambient light sensor **201** that automatically engages a frontlight (like the frontlight shown in FIG. **1**) in an interactive display **202** when a low light level is detected. An input for the ambient light sensor **201** is conventionally located on the surface of the interactive display device **200** having the interactive display **202**. Thus, a conventional solution for engaging the frontlight automatically calls for the ambient light sensor **201** to comprise a hole inserted somewhere on the surface of the display device **200** so that ambient light may pass through the hole where it is detected by an ambient light sensor portion of the ambient light sensor **201**. Having detected the ambient light, the sensor **201** controls the level of frontlight employed and/or may turn off the frontlight when high levels of ambient light are detected to enable savings of battery power. The conventional input holes for ambient light sensors impact device design, and some users may find such holes unaesthetically pleasing. Moreover, such holes provide a possible entry point for dirt, dust, and/or water that could eventually impair or damage the ambient light sensor **201** and possibly the display device **200** as well. While great strides have been made in recent years in improving frontlights on passive display devices, further improvements are still warranted.

SUMMARY OF THE INVENTION

[0006] Embodiments of the invention provide an ambient light sensor system that comprises a lightguide, an ambient light sensor that receives ambient light from the lightguide, a processor the receives an ambient light signal from the ambient light sensor, and a frontlight that can be controlled by the processor. When the processor determines that the received ambient light level detected by the ambient light sensor has fallen below a first threshold (e.g., the tablet display associated with the frontlight is too dim for users given the ambient light), then the processor turns the frontlight on. Conversely, when the processor determines that the ambient light level detected by the ambient light sensor has risen above a second threshold (e.g., ambient lighting conditions do not require the frontlight for reading the tablet display associated with the frontlight), then the processor turns the frontlight off.

[0007] In some embodiments of the invention, the ambient light sensor comprises an LED and the frontlight comprises a plurality of LEDs. The LED of the ambient light sensor may be positioned in the same layer as the LEDs of the frontlight. The LED employed for ambient light sensing sends an ambient light signal to the processor.

BRIEF DESCRIPTION OF DRAWINGS

[0008] The disclosed embodiments have other advantages and features which will be more readily apparent from the detailed description, the appended claims, and the accompanying figures (or drawings). A brief introduction of the figures is below.

[0009] FIG. **1** illustrates a prior art frontlight having a lightguide **103** that is directly coupled to an array of light sources (e.g., LEDs **105***a*-**105***h*).

[0010] FIG. **2** illustrates a prior art ambient light sensor **201** in a display device **200**.

[0011] FIG. **3** illustrates a system architecture for an e-paper tablet device **310** that receives inputs from the input mechanism such as a pen-stylus, according to one example embodiment.

[0012] FIG. **4** is a block diagram of the system architecture of an e-paper tablet device **310**, according to one example embodiment.

[0013] FIG. **5** illustrates a front and right perspective view of an e-paper tablet **500** having the functionality described for the e-paper tablet device **310** in FIGS. **3**-**4**.

[0014] FIG. **6** illustrates hardware components of an example Electrophoretic Display (EPD) operating in an e-paper tablet device **310**, according to one example embodiment.

[0015] FIG. **7** illustrates a representative display stack **700** comprised of various display component layers.

[0016] FIG. **8** is a block diagram illustrating components of an example machine able to read instructions from a machine-readable medium and execute them in a processor (or controller), according to one example embodiment.

[0017] FIG. **9** illustrates a rear view of the e-paper tablet **500** showing volcano fee **901***a*-**901***d*, a pogo pad **903**, and an antenna region **905**, according to an embodiment of the invention.

[0018] FIG. **10** illustrates a top view of the e-paper tablet device **500** showing volcano feet **901***a*, **901***d*, and a power button **1001**, according to an embodiment of the invention.

[0019] FIG. **11** illustrates a bottom view of the e-paper tablet device **500** showing volcano feet **901***b*, **901***d* and the USB-c connector **507**, according to an embodiment of the invention.

[0020] FIG. **12** illustrates a right view of the e-paper tablet device **500** showing volcano feet **901***b*, **901***a*, and the charging area **504** for recharging the input device **320**, when the input device is an active pen-stylus, according to an embodiment of the invention.

[0021] FIG. **13** illustrates a left view of the e-paper tablet device **500** showing volcano feet **901***c*, **901***d*, according to an embodiment of the invention.

[0022] FIG. **14** illustrates an ambient light sensor **1405** in a frontlight **1400** having a lightguide **1403** positioned at the top of a structure into which the light source (e.g., LEDs **1406***a*-**1406***h*) provides light when the ambient light sensor **1405** indicates a low light level condition.

[0023] FIG. **15** illustrates a frontlight **1500** having an ambient light sensor **1506** along with other components in a display stack, such as the display stack **700** shown in FIG. **7**.

[0024] FIG. **16** illustrates a block diagram for an ambient light control system **1600** in a tablet device (e.g., the e-paper tablet device **310** shown in FIG. **4**).

[0025] The figures depict various embodiments of the presented invention for purposes of illustration only. One skilled in the art will readily recognize from the following discussion that alternative embodiments of the structures and methods illustrated herein may be employed without departing from the principles described herein.

DETAILED DESCRIPTION

[0026] The Figures (FIGS.) and the following description relate to preferred embodiments by way of illustration only. It should be noted that from the following discussion, alternative embodiments of the structures and methods disclosed herein will be readily recognized as viable alternatives that may be employed without departing from the principles of what is claimed.

[0027] Reference will now be made in detail to several embodiments, examples of which are illustrated in the accompanying figures. It is noted that wherever practicable similar or like reference numbers may be used in the figures and may indicate similar or like functionality. The figures depict embodiments of the disclosed system (or method) for purposes of illustration only. An ordinarily skilled artisan will readily recognize from the following description that alternative embodiments of the structures and methods illustrated herein may be employed without departing from the principles described herein.

Overview

[0028] Disclosed is a system for an ambient light sensor for a frontlight that provides a solution for automatic control over the brightness of the frontlight for the user while also balancing battery lifetime. A description of a specific embodiment of the invention begins at FIG. **14**. Before describing the invention in greater detail, a description will be provided of the e-paper tablet into which embodiments of the invention may be applied. As discussed, for paper tablets and other devices having a frontlight, users would like to have control of the brightness of the display while also balancing battery lifetime with the need for light based on ambient light conditions. Paper tablets may include soft switches (and/or hard switches) that allow users to actuate the frontlight themselves. However, attaining a good user experience may also call for the automatic control of the frontlight.

[0029] To control the light automatically the ambient light must be measured. Ambient light is conventionally measured using a dedicated ambient light sensor (ALS). As shown in FIG. **2**, the ALS typically needs a physical opening into the device, through which light can be sensed. These light openings are typically not desired from a product design and robustness perspective, and are also vulnerable to being covered, for example, by the user's hand during operation.

[0030] An ambient light sensor is typically needed for implementing basic automated control of the light generated by a frontlight. From a battery lifetime perspective, the ability of the device to turn off the frontlight if there is enough ambient light offers a sizeable advantage. In addition, there are likely many user scenarios where the user forgets to turn off the frontlight. Thus, users will know that the device will automatically turn off its frontlight when the light is no longer needed.

[0031] To provide a context for the implementation of an improved ambient light sensor in devices having frontlights, the initial portion of the following disclosure describes a tablet device into which the frontlight and an improved ambient light sensor configuration could be applied. An ordinary artisan will recognize and appreciate that the frontlight disclosed is amenable to incorporation in a number of different devices and not just the tablet computing device described.

Example Tablet System and Configuration

[0032] As shown in FIG. **3**, an e-paper tablet device **310** receives inputs from the input mechanism **320**, for example, when the input mechanism **320** makes physical contact with a contact-sensitive surface (e.g., the touch-sensitive screen) on the e-paper tablet device **310** as the user makes a gesture of some sort with the input mechanism **320**. The input mechanism **320** may be a finger, pen-stylus or marker. The tablet device **310** here is referred to as an "e-paper tablet," a device that mimics the feeling of writing with ordinary pen and paper for users of the device. Such devices are also known as "electronic paper" and "electronic ink". Based on the nature of the contact, the e-paper tablet device **310** generates and executes instructions for updating content displayed on the contact-sensitive screen to reflect the gesture inputs. For example, in response to a gesture transcribing a verbal message (e.g., a written text or a drawing), the e-paper tablet device **310** updates the contact-sensitive screen to display the transcribed message. As another example, in response to a gesture selecting a navigation option, the e-paper tablet device **310** updates the screen to display a new page associated with the navigation option. While embodiments of the invention have been designed for e-paper systems, embodiments of the invention may also be suitable for other forms of computing devices capable of receiving and processing inputs from pen-stylus devices.

[0033] The input mechanism **320** may refer to any device or object that is compatible with the contact-sensitive screen of the e-paper tablet device **310**, in particular a pen-stylus device, such as a so-called active pen device having its own power source or a static pen that receives its power from engagement with the contact-sensitive screen on the e-paper tablet device **310**. In one embodiment, the input mechanism **320** may work with an electronic ink (e.g., E-ink) contact-sensitive screen. For example, the input mechanism **320** may refer to any device or object that can interface with a screen and, from which, the screen can detect a touch or contact of said input mechanism **320**. Once the touch or contact is detected, electronics associated with the screen generate a signal which the e-paper tablet device **310** can process as a gesture that may be provided for display on the screen. Upon detecting a gesture by the input mechanism **320**, electronics within the contact-sensitive screen generate a signal that encodes instructions for displaying content or updating content previously displayed on the screen of the e-paper tablet device **310** based on the movement of the detected gesture across the screen. For example, when processed by the e-paper tablet device **310**, the encoded signal may cause a representation of the detected gesture to be displayed on the screen of the e-paper tablet device **310**, such as a scribble. As mentioned, the input mechanism **320** may be a pen-stylus or another type of pointing device, including a part of a user's body, such as a finger.

[0034] In one embodiment, the input mechanism **320** is an encased magnetic coil. When in proximity to the screen of the e-paper tablet device **310**, the magnetic coil helps generate a magnetic field that encodes a signal that communicates instructions, which are processed by the e-paper tablet device **310** to provide a representation of the gesture for display on the screen, e.g., as a marking. The input mechanism **320** may be pressure and tilt-sensitive such that the system can make natural, visual response to both the pressure and tilt applied by the user. In turn, the interaction between the input mechanism and the contact-sensitive screen of the e-paper tablet device **310** may generate a different encoded signal for processing, for example, to provide for display a representation of the gesture on the screen that has different characteristics, e.g., thicker line marking. In alternate embodiments, the input mechanism **320** includes a power source (e.g., a battery) which can generate an electric field with a contact-sensitive surface. It is noted that the encoded signal is a signal that is generated and may be communicated. The encoded signal may have a signal pattern that may be used for further analog or digital analysis (or interpretation).

[0035] In one embodiment, the contact-sensitive screen is a capacitive touchscreen. The screen may be designed using a glass or polymer material coated with a conductive material. Electrodes, or an alternate current carrying electric component, are arranged along the coating of the screen (e.g., in a diamond-shaped cross hatch) to maintain a constant level of current running throughout the screen. A second set of electrodes are arranged horizontally. The matrix of vertical active electrodes and horizontal inactive electrodes generates an electrostatic field at each point on the screen. When an input mechanism **320** with conductive properties, for example the encased magnetic coil, a human finger, or something else that triggers the capacitive effect, is brought into contact with an area of the screen of the e-paper tablet device **310**, current flows through the horizontally arranged electrodes, disrupting the electrostatic field at the contacted point on the screen. The disruption in the electrostatic field at each point that a gesture covers may be measured, for example as a change in capacitance, and encoded into an analog or digital signal.

[0036] In an alternate embodiment, the contact-sensitive screen is a resistive touchscreen. The resistive touch screen comprises two metallic layers: a first metallic layer in which striped electrodes are positioned on a substrate, such as a glass or plastic and a second metallic layer in which transparent electrodes are positioned. When contact from an input mechanism, for example a pen-stylus, finger, or palm, is made on the surface of the touchscreen, the two layers are pressed together. Upon contact, a voltage gradient is applied to the first layer and measured as a distance by the second layer to determine a horizontal coordinate of the contact on the screen. The voltage gradient is subsequently applied to the second layer to determine a vertical coordinate of the contact on the screen. The combination of the horizontal coordinate and the vertical coordinate register an exact location of the contact on the contact-sensitive screen. Unlike capacitive touchscreens which rely on conductive input mechanisms, a resistive touchscreen is configured to sense contact from nearly any input mechanism. Although some embodiments of the e-paper tablet device **310** are described herein with reference to a capacitive touchscreen, one skilled in the art would recognize that a resistive touchscreen could also be implemented.

[0037] In an alternate embodiment, the contact-sensitive screen is an inductive touchscreen. An inductive touchscreen comprises a metal front layer that is configured to detect deflections when contact is made on the screen by an input mechanism. Accordingly, an inductive touchscreen is configured to sense contact from nearly any input mechanism. Although some embodiments of the e-paper tablet device **310** are described herein with reference to a capacitive touchscreen, an ordinarily skilled artisan would recognize that alternative touchscreen technology may be implemented, for example, an inductive touchscreen could also be implemented.

[0038] The cloud server **330** is configured to receive information from the e-paper tablet device **310** and/or communicate instructions to the e-paper tablet device **310**, according to some embodiments of the invention. As illustrated in FIG. **3**, the cloud server **330** may comprise a cloud data processor **350** and a data store **360**. Data recorded and stored by the e-paper tablet device **310** may be communicated via the network **340** to the cloud server **330** for storage in the data store **360**. For example, the data store **360** may store documents, images, or other types of content generated or recorded by a user through the e-paper tablet device **310**. In some embodiments, the cloud data processor **350** monitors the activity and usage of the e-paper tablet device **310** and communicates processing instructions to the e-paper tablet device **310**. For example, the cloud data processor **350** may regulate synchronization protocols for data stored in the data store **360** with the e-paper tablet device **310**.

[0039] Interactions between the e-paper tablet device **310** and the cloud server **330** are typically performed via the network **340**, which enables communication between the e-paper tablet device **310** and the cloud server **330**. In one embodiment, the network **340** uses standard communication technologies and/or protocols including, but not limited to, links using technologies such as Ethernet, 802.11, worldwide interoperability for microwave access (WiMAX), 3G, 4G, LTE, digital subscriber line (DSL), asynchronous transfer mode (ATM), InfiniBand, and PCI Express Advanced Switching. The network **340** may also utilize dedicated, custom, or private communication links. The network **340** may comprise any combination of local area and/or wide area networks, using both wired and wireless communication systems. The cloud server **330** may be alternatively implemented, and in some embodiments may be replaced by hardware and software that provide similar functionality while possibly not being considered a conventional cloud server.

[0040] FIG. **4** is a block diagram of the system architecture of an e-paper tablet device **310**, according to one example embodiment. In the embodiment illustrated in FIG. **4**, the e-paper tablet device **310** comprises an input detector module **410**, an input digitizer **420**, a display system **430**, and a graphics generator **440**.

[0041] The input detector module **410** recognizes that a gesture has been or is being made on the screen of the e-paper tablet device **310**. The input detector module **410** refers to electronics integrated into the screen of the e-paper tablet device **310** that are configured to interpret an encoded signal generated by contact between the input mechanism **320** and the screen into a recognizable gesture. To do so, the input detector module **410** may evaluate properties of the encoded signal to determine whether the signal represents a gesture made intentionally by a user or a gesture made unintentionally by a user.

[0042] The input digitizer **420** may be configured to convert the analog signal encoded by the contact between the input mechanism **320** and the screen into a digital set of instructions. The converted digital set of instructions may be processed by the e-paper tablet device **310** to generate or update a user interface displayed on the screen to reflect an intentional gesture.

[0043] The display system **430** may include the physical and firmware (or software) components to provide for display (e.g., render) on a screen a user interface. The user interface may correspond to any type of visual representation that may be presented to or viewed by a user of the e-paper tablet device **310**.

[0044] Based on the digital signal generated by the input digitizer **420**, the graphics generator **440** may be configured to generate or update graphics of a user interface to be displayed on the screen of the e-paper tablet device **310**. The display system **430** may be configured to present those graphics of the user interface for display to a user using electronics integrated into the screen.

[0045] When an input mechanism **320** makes contact with a contact-sensitive screen of an e-paper tablet device **310**, the input detector module **410** recognizes a gesture has been made through the screen. The gesture may be recognized as a part of an encoded signal generated by a pressure or force sensor in the input mechanism **320** and/or corresponding electronics of the screen of the display system **430**. The encoded signal is transmitted to the input detector module **410**, which evaluates properties of the encoded signal in view of at least one gesture rule to determine whether the gesture was made intentionally by a user. If the input detector module **410** determines that the gesture was made intentionally, the input detector module **410** communicates the encoded signal to the digitizer output. The encoded signal is an analog representation of the gesture received by a matrix of sensors embedded in the screen of the device **310**.

[0046] In one example embodiment, the input digitizer **420** translates the physical points on the screen that the input mechanism **320** made contact with into a set of instructions for updating what is provided for display on the screen. For example, if the input detector module **410** detects an intentional gesture that swipes from a first page to a second page, the input digitizer **420** receives the analog signal generated by the input mechanism **320** as it performs the swiping gesture. The input digitizer **420** generates a digital signal for the swiping gesture that provides instructions for the display system **430** of the e-paper tablet device **310** to update the user interface of the screen to transition from, for example, a current (or first page) to a next (or second page, which may be before or after the first page).

[0047] In one example embodiment, the graphics generator **440** receives the digital instructional signal, such as a swipe gesture indicating page transition (e.g., flipping or turning) generated by the input digitizer **420**. The graphics generator **440** generates graphics or an update to the previously displayed user interface graphics based on the received signal. The generated or updated graphics of the user interface are provided for display on the screen of the e-paper tablet device **310** by the display system **430**, e.g., displaying a transition from a current page to a next page to a user. In the displayed embodiment of the FIG. **4**, the graphics generator **440** comprises a rasterizer module **450** and a depixelator module **460**. Input gestures drawn by a user on a contact-sensitive surface are received as vector graphics and are input to the rasterizer module **450**. The rasterizer module **450** converts the input vector graphics to raster graphics, which can be displayed (or provided for display) on the contact-sensitive surface. The depixelator module **460** may apply image processing techniques to convert the displayed raster graphics back into vector graphics, for example to improve processing power of the e-paper tablet device **310** and to conserve memory of the e-paper tablet device **310**. In at least one implementation, the depixelator module **460** may convert a displayed raster graphic back to a vector graphic when exporting content displayed on the screen into a different format or to a different system.

[0048] Further details about structures and functions of e-paper tablets and their graphical displays can be found in U.S. Pat. No. 11,158,097 to Martin Sandsmark and Gunnar Sletta entitled "Generating vector graphics by processing raster graphics" and in U.S. Pat. No. 10,824,274 to Sondre Hoff Dyvik, Martin Sandsmark, and Magnus Haug Wanberg, entitled "Interactive displays," both of which are incorporated by reference herein.

[0049] FIG. **5** illustrates a front and right perspective view of an e-paper tablet **500** having the functionality described for the e-paper tablet device **310** in FIGS. **3-4**. Among other things, the e-paper table **500** includes a touch-sensitive display **503**. The display **503** has been treated to provide a paper-feeling for users of the device when they engage with it using an input device **320**. FIG. **5** also shows a charging area **504** for recharging the input device **320**, when the input device is an active pen-stylus, according to an embodiment of the invention. Inside the e-paper tablet **500** near where the charging area **504** is located may be a set of magnets to hold the input device **320** in place while it is re-charging. FIG. **5**

also shows a USB-c connector **507** that may be used to provide electrical power to the e-paper tablet **500**, as well as transmitting various types of data into or out of the e-paper tablet **500**. The e-paper tablet **500** also includes several actuators and other features that will be shown below in FIGS. **5-13**.

[0050] FIG. **6** illustrates hardware components of an example Electrophoretic Display (EPD) in accordance with a disclosed embodiment. As discussed, a variety of display technologies may be employed, including EPDs, LCDs, and reflective LCDs (rLCDs). The specific display device deployed may be part of the display system **430** of the e-paper tablet device **310** shown in FIG. **4** and produce the images shown on the display **503** of the e-paper tablet **500** shown in FIG. **5**. The EPD includes a gate driver **609**, a source driver **611**, a shift register **623** with data and clock signal line, a latch **625**, a voltage selector **627**, and rows making up a display **605**. The EPD industry borrowed certain components and concepts from the LCD industry; however, these two devices have some fundamental differences as well. Of particular relevance here is the persistence of pixels in EPD displays. Unlike LCD displays, EPD displays do not require the frequent refreshing required in an LCD display. In an EPD display, once a neutral voltage is set for a pixel, the pixel will not change, for example, and will persist for a long period of time, especially relative to an LCD display.

[0051] As mentioned, Electrophoretic displays (EPDs) **605** have utilized many aspects of LCD production infrastructure and driving mechanisms. The driving electronics typically consist of a gate driver (GD) **609** and a source driver (SD) **611**. The display **605** has multiple rows of pixels. Pixel values within a row may be changed, e.g., logic high voltage may be a "black" pixel and a logic low voltage or "ground" may be a no color pixel. The pixels in the EPD **605** function similarly to small capacitors that persist over long time intervals. An EPD pixel contains a large number of charged particles that are suspended in a liquid. If a charge is applied, the particles will move to a surface where they become visible. White and black particles have opposite charges such that a pixel's display may change from white to black by applying an opposite charge to the pixel. Thus, the waveforms applied to an EPD comprise long trains of voltages to change from black to white or vice versa. The EPD arts are also known to have the ability to apply variable voltage levels that mix the white and black particles to produce various shades of gray. Voltage levels in a pixel also may be tiered between to provide shades between no color and black (e.g., levels of grey). Groups of pixels around each other may form a region that provides some visible characteristic to a user, e.g., an image on a screen, e.g., of the display system **430** of the e-paper tablet device **310**.

[0052] To change pixel values in a region, a scan of a display **605** will conventionally start at a top row, e.g., row **0 421**, and apply voltages to update pixels within a particular row where pixels need to be changed to correspond with the image that is displayed. In this example, a start pulse (GDSP) **603** can be used to reset the driver **611** to row **0 621**. A row-by-row selection is made by driving the driver gate **609** to select a row, e.g., active row **613**. All pixels in one row are addressed concurrently using data transferred to the display. Latch **625** receives from the shift register **623** the next set of voltages to be applied to a row of pixels. When the scan of the active row is completed and, if necessary, pixels changed or updated, a clock pulse (GDCLK) **315** is issued to the driver gate **609** to change to the next row **617** for a scan.

[0053] As mentioned above, an ordinary artisan will recognize that a similar function can be accomplished also with a standard LCD, OLED, MicroLED or other type of display, and the description of EPD technology is provided here merely for illustration of one embodiment of the invention.

[0054] The source driver **611** is used to set the target voltage for each of the pixels/columns for the selected row. It consists of a shift register **623** for holding the voltage data, a latch circuit **625** for enabling pixel data transfer while the previous row is being exposed, and a voltage selector (multiplexer) **627** for converting the latched voltage selection into an actual voltage. For all rows to be updated all the voltage values have to be shifted into the register **623** and latched for the voltages to be available.

[0055] FIG. **7** illustrates a representative display stack **700** comprised of various display component layers. From the bottom layer to a top layer, these layers comprise an EPD display **707**, an optical clear adhesive layer **706**, a lightguide sheet **704**, an optical clear adhesive layer **705**, a touch sensor **703**, an optical clear adhesive layer **702**, and a front panel **701**. The EPD display **707** may comprise components similar to those described in FIG. **4**. If writing technology is present (not shown in FIG. **7**, but if present, then it is likely below the EPD display **707**), the writing technology may comprise similar elements to the graphics generator **340** disclosed in FIG. **4**. The optical clear adhesive layers **706**, **704**, **702** are employed to attach components from other portions in the stack **700** together but to do so in a manner that does not alter or impede the light transiting through the stack **700** to the user. The touch sensor **703** operates as a portion of the touchscreen that has been described above. The stack **700** is conventionally capped by a front panel **701** that the user may touch during device operation. The front panel **701** is conventionally comprised of glass but could be comprised of other materials. For example, U.S. Provisional Application No. 63/314,500, filed on 28 Feb. 2022, entitled "Cover Lens for Consumer Electronics Device," incorporated by reference, describes one such front panel suitable for implementation in the stack **700**.

[0056] The lightguide sheet **704** could comprise several different types of lightguides, including ultra-thin lightguide sheet (e.g., 50 um). However, conventional lightguides could just as easily be employed. As discussed above, consumer demands have compelled display stacks like the display stack **700** to become increasingly thinner so that the overall device (e.g., the e-paper tablet device **410**) can itself become thinner and so that the parallax effect due to the separation between the EPD and the writing surface can be reduced.

[0057] FIG. **8** is a block diagram illustrating components of an example machine able to read instructions from a machine-readable medium and execute them in a processor (or controller), according to one embodiment. In this example, FIG. **8** shows a diagrammatic representation of a machine in the example form of a computer system **800** (e.g., the computing portions of the e-paper tablet **311** shown in FIG. **3**) within which program code (e.g., software) for causing the machine to perform any one or more of the methodologies discussed herein may be executed. The e-paper tablet device **310** may include some or all of the components of the computer system **800**. The program code may be comprised of instructions **824** executable by one or more processors **802**. In the e-paper tablet system **310**, the instructions may correspond to the functional components described in FIGS. **3**, **4**, and **6**, for example. FIG. **8** is an example of a processing system, of which a some of the described components or all of the described components may be leveraged by the modules described herein for execution.

[0058] While the embodiments described herein are in the context of the e-paper tablet system **310**, it is noted that the principles may apply to other touch sensitive devices. In those contexts, the machine of FIG. **8** may be a server computer, a client computer, a personal computer (PC), a tablet PC, a set-top box (STB), a personal digital assistant (PDA), a cellular telephone, a smartphone, a web appliance, a network router, an internet of things (IoT) device, a switch or bridge, or any machine capable of executing instructions **824** (sequential or otherwise) that specify actions to be taken by that machine. Further, while only a single machine is illustrated, the term "machine" shall also be taken to include any collection of machines that individually or jointly execute instructions **824** to perform any one or more of the methodologies discussed herein.

[0059] The example computer system **800** includes one or more processors **802** (e.g., a central processing unit (CPU), one or more graphics processing units (GPU), one or more digital signal processors (DSP), one or more application specific integrated circuits (ASICs), one or more radio-frequency integrated circuits (RFICs), or any combination of these), a main memory **804**, and a static memory **806**, which are configured to communicate with each other via a bus **808**. The computer system **800** may further include visual display interface **810**. The visual interface may include a software driver that enables displaying user interfaces on a screen (or display). The visual interface may display user interfaces directly (e.g., on the screen) or indirectly on a surface, window, or the like (e.g., via a visual projection unit). For ease of discussion the visual interface may be described as a screen or display screen. The visual interface **810** may include or may interface with a touch enabled screen, e.g., of the e-paper tablet system **310** and may be associated with the display system **430**. The computer system **800** may also include an input device **812** (e.g., a pen-stylus, a keyboard, or touch screen keyboard), a cursor control device **814** (e.g., a mouse, a trackball, a joystick, a motion sensor, or other pointing instrument), a storage unit **816**, a signal generation device **818** (e.g., a speaker), and a network interface device **820**, which also are configured to communicate via the bus **808**.

[0060] The storage unit **816** includes a machine-readable medium **822** on which is stored (or encoded) instructions **824** (e.g., software) embodying any one or more of the methodologies or functions described herein. The instructions **824** (e.g., software) may also reside, completely or at least partially, within the main memory **804** or within the processor **802** (e.g., within a processor's cache memory) during execution thereof by the computer system **800**, the main memory **804** and the processor **802** also constituting machine-readable media. The instructions **824** (e.g., software) may be transmitted or received over a network **826** via the network interface device **820**.

[0061] While machine-readable medium **822** is shown in an example embodiment to be a single medium, the term "machine-readable medium" should be taken to include a single medium or multiple media (e.g., a centralized or distributed database, or associated caches and servers) able to store instructions (e.g., instructions **824**). The term "machine-readable medium" shall also be taken to include any medium that is capable of storing instructions (e.g., instructions **824**) for execution by the machine and that cause the machine to perform any one or more of the methodologies disclosed herein. The term "machine-readable medium" includes, but not be limited to, data repositories in the form of solid-state memories, optical media, and magnetic media.

[0062] The computer system **800** also may include the one or more sensors **825**. Also note that a computing device may include only a subset of the components illustrated and described with FIG. **8**. For example, an IoT device may only include a processor **802**, a small storage unit **816**, a main memory **804**, a visual interface **810**, a network interface device **820**, and a sensor **825**.

Representative E-Paper Tablet

[0063] FIG. **5** provided a representative view of an e-paper tablet **500**, resembling the e-paper **310** shown in FIGS. **3-4**. FIG. **9** illustrates a rear view of the e-paper tablet **500** showing volcano fee **901***a*-**901***d*, a pogo pad **903**, and an antenna region **905**, according to an embodiment of the invention. The antenna region **905** resides outside and above the location for a main antenna for the e-paper tablet **500**, allowing the e-paper tablet device **500** to connect to the Internet, for example. The pogo pad **903** allows the e-paper tablet device **500** to connect to other devices, such as a folio device having a keyboard, for example.

[0064] FIG. **10** illustrates a top view of the e-paper tablet device **500** showing volcano feet **901***a*, **901***d*, and a power button **1001**, according to an embodiment of the invention.

[0065] FIG. **11** illustrates a bottom view of the e-paper tablet device **500** showing volcano feet **901***b*, **901***d* and the USB-c connector **507**, according to an embodiment of the invention.

[0066] FIG. **12** illustrates a right view of the e-paper tablet device **500** showing volcano feet **901***b*, **901***a*, and the charging area **504** for recharging the input device **320**, when the input device is an active pen-stylus, according to an embodiment of the invention. Inside the e-paper tablet **500** near where the charging area **504** is located may be a set of magnets to hold the input device **320** in place while it is re-charging.

[0067] FIG. **13** illustrates a left view of the e-paper tablet device **500** showing volcano feet **901***c*, **901***d*, according to an embodiment of the invention.

Example of a Frontlight Having an Ambient Light Sensor

[0068] FIGS. **14-16** describe embodiments of a frontlight having an ambient light sensor that aids in efficiently turning on and off the light being emitted by the frontlight in response to changing ambient lighting conditions. Embodiments of the invention offer a solution to the problem of automatically turning on and off a frontlight in response to changes in ambient light conditions without having to change or disfigure an outer surface of the device (e.g., the e-paper tablet device **210** shown in FIG. **2**), which would be the case with a conventional ambient light sensor (e.g., the ambient light sensor **201** located on the surface of the interactive display device **200** shown in FIG. **2**.)

[0069] Embodiments of the invention attempt to solve to the problem of ambient light detection in devices using EPD displays by incorporating the ambient light sensor onto the same light distribution layer as the LEDs that provide light into the lightguide for the frontlight. The resulting frontlight with ambient light sensor is suitable for implementation in a display stack, such as the display stack **700** shown in FIG. **7** and ultimately suitable for integration into devices, such as the e-paper tablet device **410** shown in FIG. **4**.

[0070] FIG. **14** illustrates an ambient light sensor **1405** in a frontlight **1400** having a lightguide **1403** positioned in a structure into which the light source (e.g., LEDs **1406***a*-**1406***h*) provides light when the ambient light sensor **1405** indicates a low light level condition (e.g., a predetermined level that may correspond to a light level at which a typical user has difficulty reading the tablet's display). This structure, optical coupling element **1402**, is placed adjacent to the lightguide **1403**. The light sources may be placed adjacent to the optical coupling element **1402**, or in a recess **1401** in the optical coupling element as shown on FIG. **14**. Thus, the optical coupling element **1402** resides between the lightguide **1403** and the light source (e.g., LEDs **1406***a*-**1406***h*).

[0071] Because the lightguide **1403** acts as a light distribution layer, the lightguide **1403** may function as a two-way component. While the lightguide **1403** spreads light from the LEDs **1406***a*-**1406***h* across the display, the lightguide **1403** may also collect ambient light and direct it towards the edge where the ambient light sensor **1405** and LEDs **1406***a*-**1406***h* are placed.

[0072] Thus, the ambient light sensor **1405** may be placed in a similar location to the location of the LEDs **1406***a*-**1406***h*. The ambient light sensor **1405** detects the ambient light collected by the lightguide **1403**, effectively serving as a light level sensor that is useful for turning on/off the frontlight and/or adjusting the light levels provided by the frontlight. For example, the frontlight **1400** may switch on when an ambient light level drops below a level at which users have difficulty reading the tablet's display and may switch off when an ambient light level exceeds a level at which users may read the tablet's display without the need for the frontlight **1400**.

[0073] The lightguide **1403** presents a large light collection surface. Because this surface is large, the prior art issue involving the sensor input hole being covered by a hand or by dirt is largely (if not entirely) eliminated. In addition, the frontlight's LED strip where the ambient light sensor **1405** is located is covered by a front panel (such as the front panel **701** shown in FIG. **7**) and not visible to the end user. Thus, the impact of requiring a separate opening for a light sensor in the device design is also mitigated. Put another way, the tablet's design and aesthetics are not disrupted by an opening hole for the light sensor.

[0074] As shown in FIG. **14**, the ambient light sensor **1405** shares the lightguide **1403** with the front light LEDs (**1406***a*-**1406***h*). The actual ambient light must be calculated as a function of the known emitted light and the ambient light, as discussed in connection with the ambient light control system **1600** disclosed in FIG. **16**. The relevant calculation can be computed in the microcontroller in the system (e.g., the processor **1605** shown in FIG. **16**). The algorithm implemented in the microcontroller is a fairly conventional algorithm that should be known to ordinarily skilled artisans in the relevant field.

[0075] In terms of its construction, the ambient light sensor **1405** may comprise a dedicated light sensor component. As an alternative, a conventional LED may be employed as the ambient light sensor because a conventional LED generates current relative to the incoming ambient light. So, for example, the ambient light sensor **1405** may be an LED. Detecting light with an LED is a skill known by ordinarily artisans and can be performed in different ways. Ordinary artisans may want to determine for a given implementation where they obtain a desired balance between speed of detection and accuracy. The LED acting as the ambient light sensor **1405** would generate a small current from ambient light received from the lightguide **1403** and at certain levels of detected ambient light can be used to turn on or turn off the frontlight (e.g., the LEDs **1406***a*-**1406***h*). The ambient light sensor **1405** (whether an LED or another sensor type) could also be configured to adjust the light from the frontlight to provide more light settings than just on/off but could provide a number of ranges that would accordingly impact the light level coming from the frontlight. More than one ambient light sensor **1405** may be employed in some embodiments of the invention.

[0076] Using an LED as the ambient light sensor **1405** may present variations in accuracy. The tablet device (e.g., the e-paper tablet device **310** shown in FIG. **4**) may have a moveable cover (e.g., a folio) over its display when not in use. If the tablet device has a mechanism to detect that the cover is closed (e.g., a magnet and Hall Effect sensor), a control system for the ambient light sensor can perform a calibration of the ambient light sensor LEDs when the cover is known to be closed. Among other things, this would provide an indication regarding how much light was still being received when the device cover was closed and the user was presumably not using the device (e.g., a condition where the frontlight should presumably be turned off so as to save battery power.)

[0077] The recess (e.g., the recess **1401**) for the LEDs **1406***a*-**1406***h* and the ambient light sensor **1405** may include small gaps at either side. These gaps are not necessary for the optical functioning of the frontlight **1400** but may be included to allow for manufacturing tolerances. The optical coupling element **1402** typically has a height that is greater than or equal to the height of the light source (e.g., LEDs **1406***a*-**1406***h*).

[0078] The optical coupling element **1402** is typically comprised of the same material (e.g., a polycarbonate) as the lightguide **1403**. The optical coupling element **1402** has the same refractive index as the lightguide **1403**. The optical coupling element **1402** does not have to be perfectly index matched to the lightguide **1403**; preferably, the optical coupling element **1402** is index matched to the lightguide **1403**, otherwise the efficiency is likely reduced. In the frontlight **1400**, the light source (e.g., LEDs **1406***a*-**1406***h*) rests on a circuit board **1404** (e.g., a flex PCB) which also supports the optical coupling element **1402**. The lightguide **1403** is supported by other layers of the display stack above or below it which are not shown in FIG. **14**.

[0079] In some embodiments of the invention, a wire coming from the ambient light sensor **1405** may be bundled (e.g., in a flex cable) with the wires attached to LEDs **1406***a*-**1406***h*. However, as previously noted, the wires attached to the LEDs **1406***a*-**1406***h* ultimately attach to a battery that provides power for lighting the LEDs **1406***a*-**1406***h* when the frontlight is engaged. In contrast, the wire coming from the ambient light sensor **1405** passes an electrical signal corresponding to detected ambient light from the lightguide **1403** into the device for further processing, such as described in connection with the ambient light control system **1600** disclosed in FIG. **16**.

[0080] The optical coupling element **1402** that houses the ambient light sensor **1405** may have a number of overall shapes. FIG. **14** illustrates an essentially rectangular optical coupling element **1402**, but the shape of the optical coupling element **1402** could take other forms. The rectangular shape shown in FIG. **14** is possibly easier to manufacture by some processes (e.g., molding) than if the optical coupling element **1402** had another shape. Thus, if a different manufacturing process was more optimal for some particular material, then it may be possible to adjust the shape of the optical coupling element **1402** without a significant degradation of performance.

[0081] The performance of the frontlight **1400** may depend on the specific materials selected for the lightguide **1403** and the optical coupling element **1402**. For the lightguide, materials having a higher refractive index have a larger acceptance angle and so will be able to couple more light through the structure of the frontlight **1400**. So, for example, polycarbonate lightguides have a larger acceptance angle than those made of Polymethyl methacrylate (PMMA). The optical absorption properties are also important—for example, Polyethylene terephthalate (PET) may be employed but is more highly absorbing of blue light and can cause a yellowing color shift which may be undesirable for some applications, such as when a "cooler" color tone is desired. The materials employed for the optical coupling element **1402** are essentially materials conventionally employed in lightguides, and a unique material does not appear to be necessary for the optical coupling element **1402**.

[0082] FIG. **15** illustrates an ambient light sensor **1506** in a frontlight **1500** along with other components in a display stack, such as the display stack **700** shown in FIG. **7**. The frontlight **1500** comprises a lightguide **1512**, an optical coupling element **1502** and a plurality of light sources (LEDs **1505*a*-1505*g***) disposed on a circuit board **1504**. FIG. **15** also illustrates other components in a display stack, such as a front panel **1511** and a light blocking film **1510** which is attached to a portion of the lightguide **1512**. The display stack may include a touchscreen cable **1509**. FIG. **15** otherwise resembles the embodiment of the invention shown in FIG. **14**.

[0083] FIG. **16** illustrates a block diagram for an ambient light control system **1600** in a tablet device (e.g., the e-paper tablet device **310** shown in FIG. **4**). The ambient light control system **1600** comprises a lightguide **1601**, an ambient light sensor **1603**, a processor **1605**, and a frontlight **1607**. The lightguide **1601** provides ambient light **1609** to the ambient light sensor **1603**. As discussed above, the ambient light sensor **1603** may comprise an LED. The ambient light sensor **1603** turns received ambient light from the lightguide **1601** into an electric signal **1611** that is provided to a processor **1605** (e.g., the computer system **800** shown in FIG. **8**) that performs signal processing on the signal **1611** received from the ambient light sensor **1603**. The signal processing may, for example, convert an analog signal to a digital signal and then perform a comparison between the detected ambient light level and certain device conditions (e.g., an ambient light level low enough for the processor **1605** to engage a command for turning on the frontlight **1607**, or an ambient light level high enough for the processor **1605** to engage a command for turning off the frontlight **1607**, or an ambient light condition that causes the processor **1605** to engage a command for an intermediate adjustment of the light coming from the frontlight **1607**).

[0084] The processor **1605** may include a memory **1606** that includes a soft signal processor that may be engaged to perform the signal processing. The memory **1606** may also include predetermined light levels for engaging (e.g., switching on) and/or disengaging (e.g., switching off) the frontlight **1607** based on ambient light conditions, e.g., the display becomes difficult to read due to a low detected light level or the display becomes easy to read due to a high detected light level. A dedicated signal processor may be employed in some embodiments of the invention.

[0085] When the processor **1605** detects that an ambient light condition has changed, then the processor sends a signal **1613** to the frontlight **1607** instructing the frontlight **1607** to change its level of output light **1615** into the lightguide **1601**.

[0086] Also, as mentioned above, if the device (e.g., the e-paper tablet device **310** shown in FIG. **4**) has detected that a folio cover has been closed and provided an input (not shown) to the processor **1605**, then the signal **1611** from the ambient light sensor **1603** may be used in a test function to calibrate the level of ambient light received when the device display has been covered. This information may be helpful in adjusting the predetermined lighting thresholds stored in the memory **1606**.

Additional Considerations

[0087] This disclosed configuration provides additional precision and options for users as they go about erasing portions of drawings on an e-paper tablet. This should improve the efficiency of users interacting with e-paper tablets while also enabling them with more precise functional capabilities.

[0088] It is to be understood that the figures and descriptions of the present disclosure have been simplified to illustrate elements that are relevant for a clear understanding of the present disclosure, while eliminating, for the purpose of clarity, many other elements found in a typical system. Those of ordinary skill in the art may recognize that other elements and/or steps are desirable and/or required in implementing the present disclosure. However, because such elements and steps are well known in the art, and because they do not facilitate a better understanding of the present disclosure, a discussion of such elements and steps is not provided herein. The disclosure herein is directed to all such variations and modifications to such elements and methods known to those skilled in the art.

[0089] Some portions of above description describe the embodiments in terms of algorithms and symbolic representations of operations on information. These algorithmic descriptions and representations are commonly used by those skilled in the data processing arts to convey the substance of their work effectively to others skilled in the art. These operations, while described functionally, computationally, or logically, are understood to be implemented by computer programs or equivalent electrical circuits, microcode, or the like. Furthermore, it has also proven convenient at times, to refer to these arrangements of operations as engines, without loss of generality. The described operations and their associated engines may be embodied in software, firmware, hardware, or any combinations thereof.

[0090] As used herein any reference to "one embodiment" or "an embodiment" means that a particular element, feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. The appearances of the phrase "in one embodiment" in various places in the specification are not necessarily all referring to the same embodiment.

[0091] As used herein, the terms "comprises," "comprising," "includes," "including," "has," "having" or any other variation thereof, are intended to cover a non-exclusive inclusion. For example, a process, method, article, or apparatus that comprises a list of elements is not necessarily limited to only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus. Further, unless expressly stated to the contrary, "or" refers to an inclusive or and not to an exclusive or. For example, a condition A or B is satisfied by any one of the following: A is true (or present) and B is false (or not present), A is false (or not present) and B is true (or present), and both A and B are true (or present).

[0092] In addition, use of the "a" or "an" are employed to describe elements and components of the embodiments herein. This is done merely for convenience and to give a general sense of the invention. This description should be read to include one or at least one and the singular also includes the plural unless it is obvious that it is meant otherwise.

[0093] While particular embodiments and applications have been illustrated and described, it is to be understood that the disclosed embodiments are not limited to the precise construction and components disclosed herein. Various modifications, changes, and variations, which will be apparent to those skilled in the art, may be made in the arrangement, operation and details of the method and apparatus disclosed herein without departing from the spirit and scope defined in the appended claims.

1. An ambient light sensor system, comprising:
- a lightguide;
- an ambient light sensor that receives ambient light from the lightguide;
- a processor the receives an ambient light signal from the ambient light sensor; and
- a frontlight controlled by the processor.

2. The ambient light sensor system of claim **1** wherein the processor determines that the ambient light signal has dropped below a first predetermined threshold and wherein the processor sends a signal to the frontlight that causes the frontlight to turn on.

3. The ambient light sensor system of claim **2** wherein the first predetermined threshold comprises a display light level below a user's ability to read a display on a tablet device that includes the frontlight.

4. The ambient light sensor system of claim **1** wherein the processor determines that the ambient light signal has risen above a second predetermined threshold and wherein the processor sends a signal to the frontlight that causes the frontlight to turn off.

5. The ambient light sensor system of claim **4** wherein the second predetermined threshold comprises a display light level above a user's ability to read a display on a tablet device that includes the frontlight.

6. The ambient light sensor system of claim **1** wherein the ambient light sensor comprises an LED.

7. The ambient light sensor system of claim **6** wherein the frontlight comprises a plurality of LEDs located in a common layer, and wherein the ambient light sensor resides in the common layer.

8. The ambient light sensor system of claim **7**, wherein the common layer comprises an optical coupling element that resides between the lightguide and the LEDs and has a matching refractive index to the lightguide.

9. The ambient light sensor system of claim **8** wherein the optical coupling element has a height at least equal to a height of the plurality of LEDs.

10. The ambient light sensor system of claim **9** wherein the optical coupling element and the plurality of LEDs reside on a circuit board.

11. The ambient light sensor system of claim **8**, wherein the optical coupling element comprises a same material as the lightguide.

12. The ambient light sensor system of claim **11** wherein the same material is a polycarbonate.

13. The ambient light sensor system of claim **1**, further comprising:
- a moveable cover that blocks the lightguide when moved to a closed position,
- wherein the processor determines a closed position light level using an ambient light signal received from the ambient light sensor when the moveable cover is in the closed position, and
- wherein the processor updates a first predetermined threshold corresponding to a low ambient light level using the closed position light level.

14. The ambient light sensor system of claim **1** wherein the lightguide resides in a display stack of a display system in a tablet device, wherein elements of the display stack support the lightguide.

15. The ambient light sensor system of claim **14** wherein the display stack includes an electrophoretic display (EPD).

16. The ambient light sensor system of claim **1**, further comprising a plurality of ambient light sensors that receive ambient light from the lightguide, wherein the processor receives ambient light signals from the plurality of ambient light sensors.

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