US 20190223813A1

(19) United States
(12) Patent Application Publication
(10) Pub. No.: US 2019/0223813 A1
Lawrence
(43) Pub. Date: Jul. 25, 2019

(54) **CAPACITIVE ECG SENSING ELECTRONIC DISPLAYS AND RELATED METHODS**

(71) Applicant: **Intel Corporation**, Santa Clara, CA (US)

(72) Inventor: **Sean J. W. Lawrence**, Bangalore (IN)

(21) Appl. No.: **16/370,917**

(22) Filed: **Mar. 30, 2019**

Publication Classification

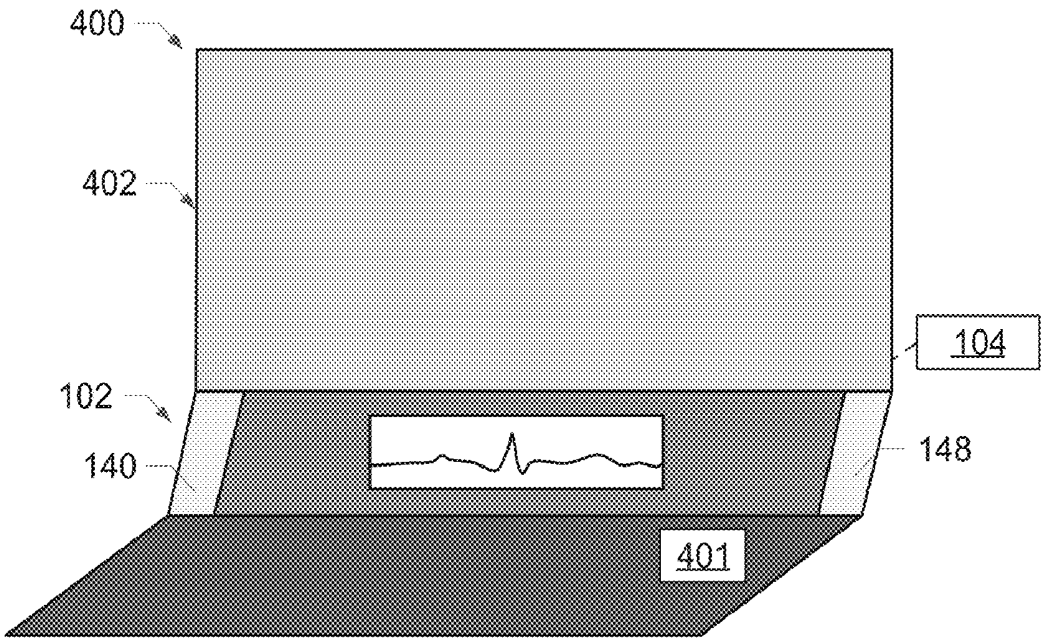
(51) **Int. Cl.**

A61B 5/00	(2006.01)
G06F 3/041	(2006.01)
G06F 3/044	(2006.01)
A61B 5/044	(2006.01)

(52) **U.S. Cl.**
CPC ***A61B 5/7475*** (2013.01); ***A61B 5/044*** (2013.01); ***G06F 3/044*** (2013.01); ***G06F 3/0416*** (2013.01)

(57) **ABSTRACT**

Capacitive ECG sensing electronic displays and related methods are disclosed herein. An example electronic device disclosed herein includes a display screen including a first electrode and a second electrode and a processor operatively coupled to the display screen. The processor is to cause the display screen to operate in a first display screen mode to detect a touch input from a user on the display screen. The processor is to cause the display screen to switch from operating in the first display screen mode to operating in a second display screen mode. The first electrode and the second electrode are to generate signal data indicative of electrocardiogram data for the user when the display screen is operating in the second display screen mode.



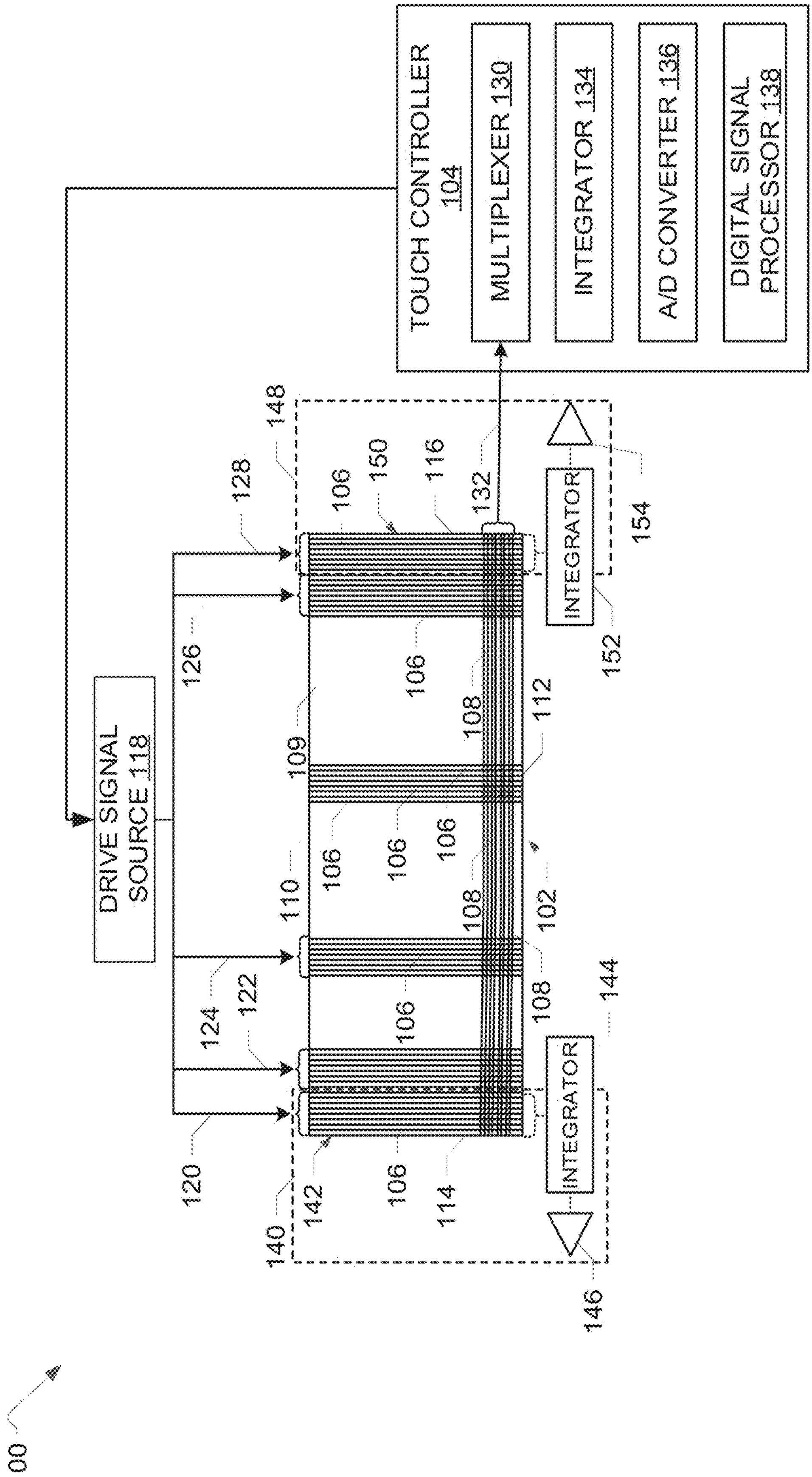

TOUCH CONTROLLER 104
MULTIPLEXER 130
INTEGRATOR 134
A/D CONVERTER 136
DIGITAL SIGNAL PROCESSOR 138
DRIVE SIGNAL SOURCE 118
INTEGRATOR
INTEGRATOR
100
102
106
108
109
110
112
114
116
120
122
124
126
128
132
140
142
144
146
148
150
152
154

FIG. 1

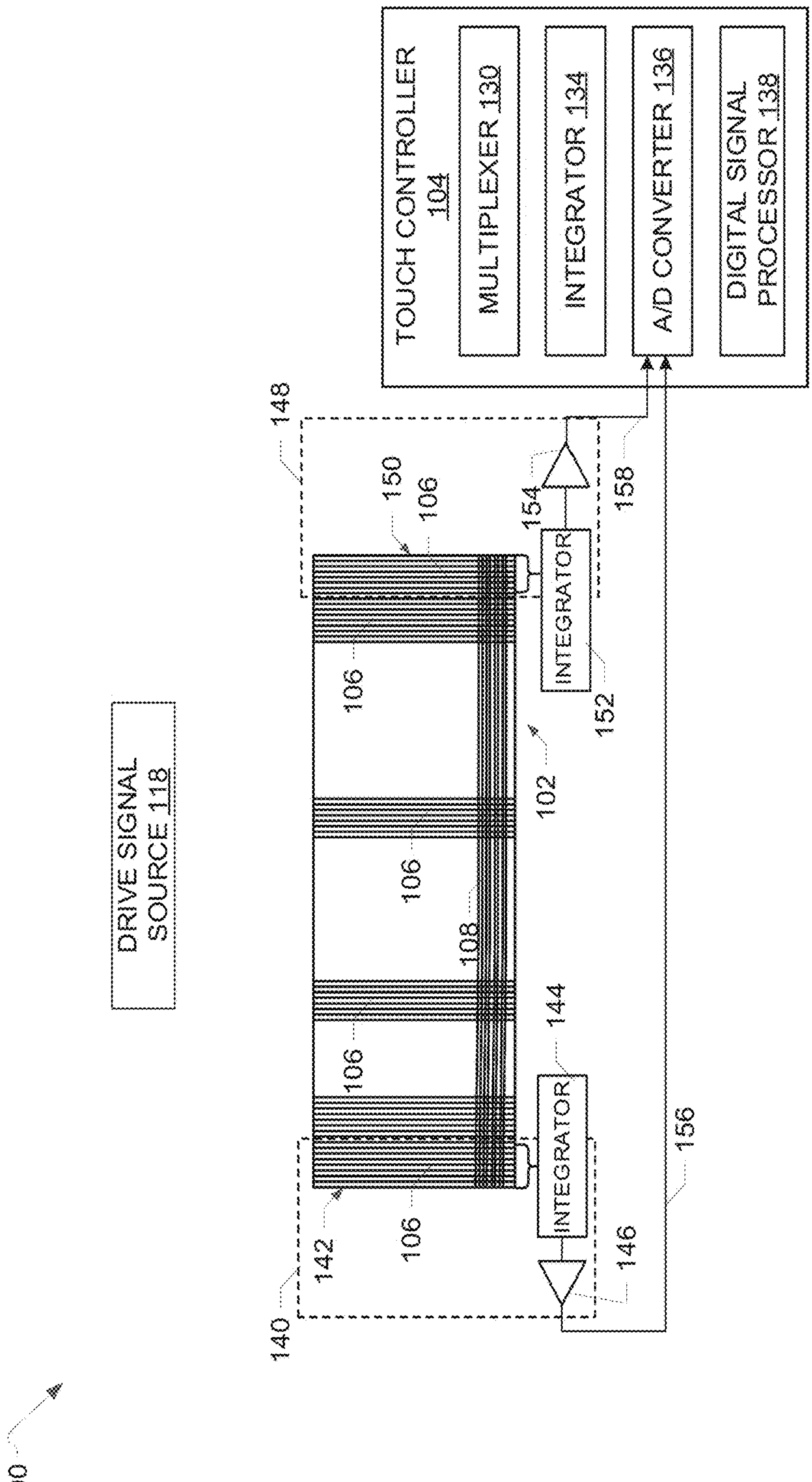

TOUCH CONTROLLER 104
MULTIPLEXER 130
INTEGRATOR 134
A/D CONVERTER 136
DIGITAL SIGNAL PROCESSOR 138
DRIVE SIGNAL SOURCE 118
INTEGRATOR
INTEGRATOR
100
102
106
108
140
142
144
146
148
150
152
154
156
158

FIG. 2

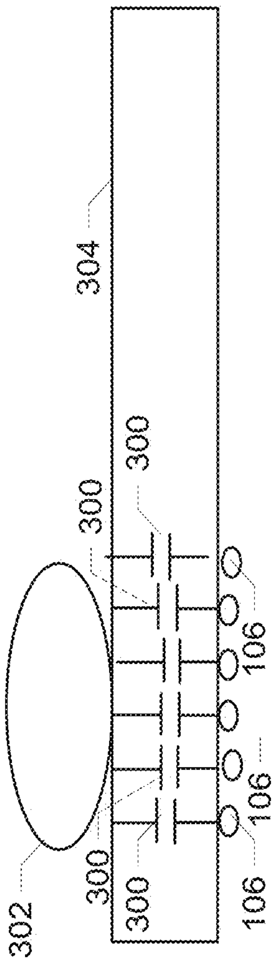


FIG. 3

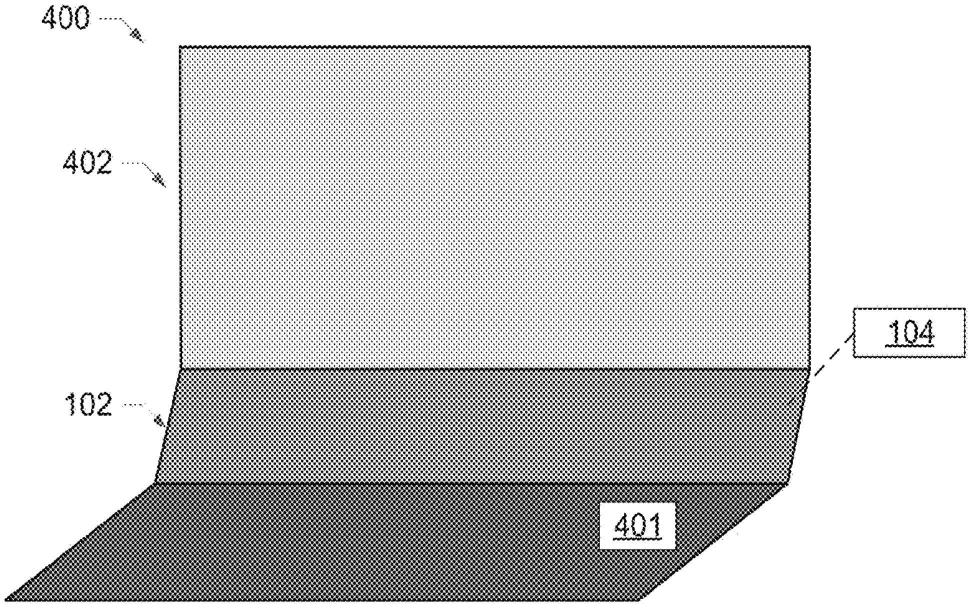


FIG. 4

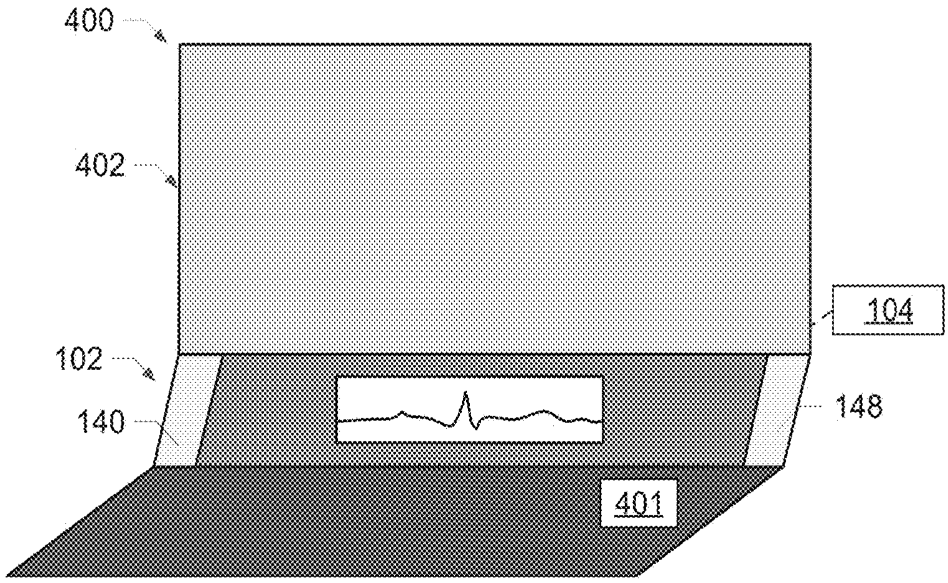


FIG. 5

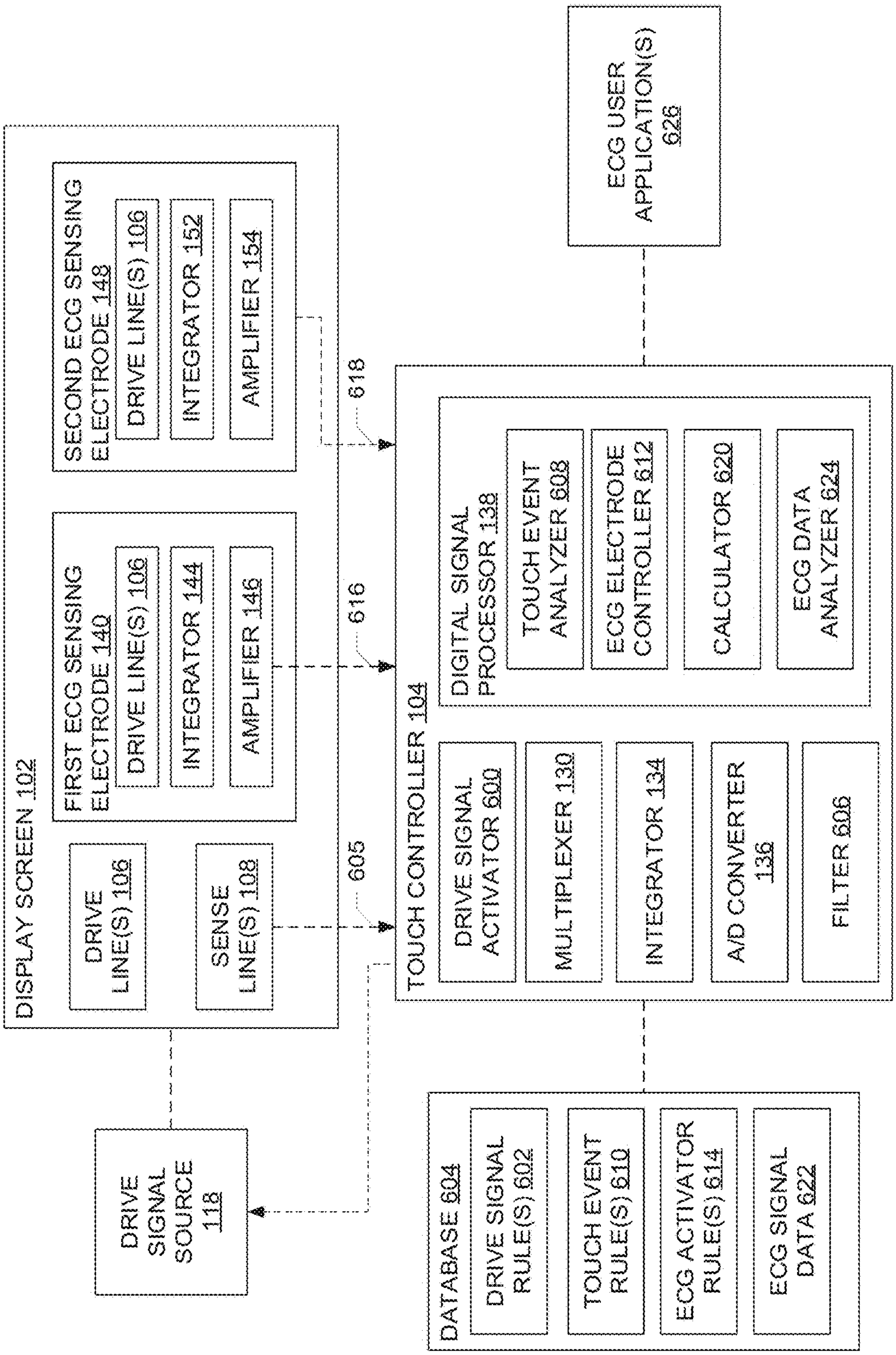

DISPLAY SCREEN 102
DRIVE LINE(S) 106
SENSE LINE(S) 108
FIRST ECG SENSING ELECTRODE 140
DRIVE LINE(S) 106
INTEGRATOR 144
AMPLIFIER 146
SECOND ECG SENSING ELECTRODE 148
DRIVE LINE(S) 106
INTEGRATOR 152
AMPLIFIER 154
605
616
618
TOUCH CONTROLLER 104
DRIVE SIGNAL ACTIVATOR 600
MULTIPLEXER 130
INTEGRATOR 134
A/D CONVERTER 136
FILTER 606
DIGITAL SIGNAL PROCESSOR 138
TOUCH EVENT ANALYZER 608
ECG ELECTRODE CONTROLLER 612
CALCULATOR 620
ECG DATA ANALYZER 624
ECG USER APPLICATION(S) 626
DRIVE SIGNAL SOURCE 118
DATABASE 604
DRIVE SIGNAL RULE(S) 602
TOUCH EVENT RULE(S) 610
ECG ACTIVATOR RULE(S) 614
ECG SIGNAL DATA 622

FIG. 6

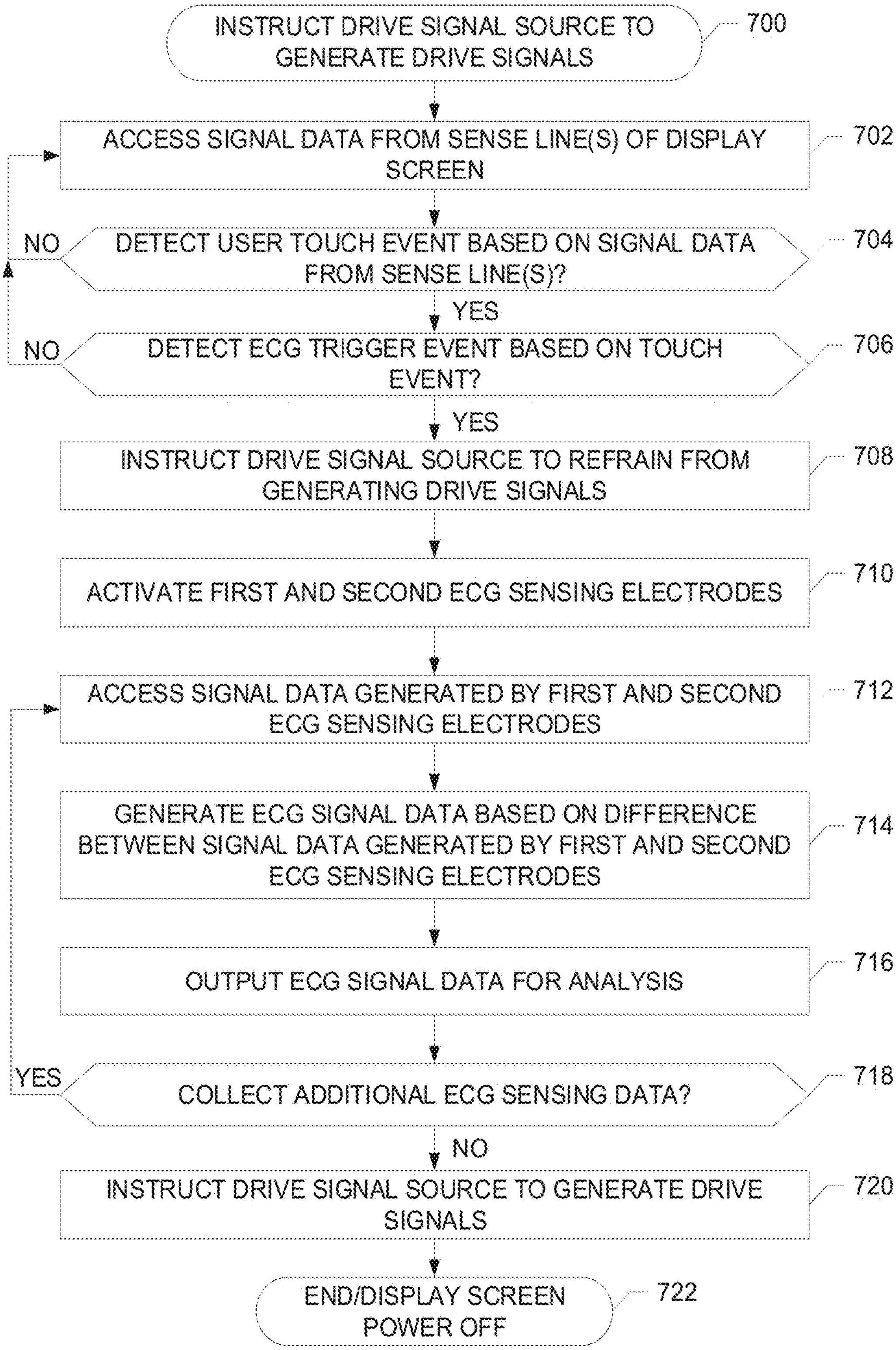

INSTRUCT DRIVE SIGNAL SOURCE TO GENERATE DRIVE SIGNALS
700
ACCESS SIGNAL DATA FROM SENSE LINE(S) OF DISPLAY SCREEN
702
DETECT USER TOUCH EVENT BASED ON SIGNAL DATA FROM SENSE LINE(S)?
704
NO
YES
DETECT ECG TRIGGER EVENT BASED ON TOUCH EVENT?
706
NO
YES
INSTRUCT DRIVE SIGNAL SOURCE TO REFRAIN FROM GENERATING DRIVE SIGNALS
708
ACTIVATE FIRST AND SECOND ECG SENSING ELECTRODES
710
ACCESS SIGNAL DATA GENERATED BY FIRST AND SECOND ECG SENSING ELECTRODES
712
GENERATE ECG SIGNAL DATA BASED ON DIFFERENCE BETWEEN SIGNAL DATA GENERATED BY FIRST AND SECOND ECG SENSING ELECTRODES
714
OUTPUT ECG SIGNAL DATA FOR ANALYSIS
716
COLLECT ADDITIONAL ECG SENSING DATA?
718
YES
NO
INSTRUCT DRIVE SIGNAL SOURCE TO GENERATE DRIVE SIGNALS
720
END/DISPLAY SCREEN POWER OFF
722

FIG. 7

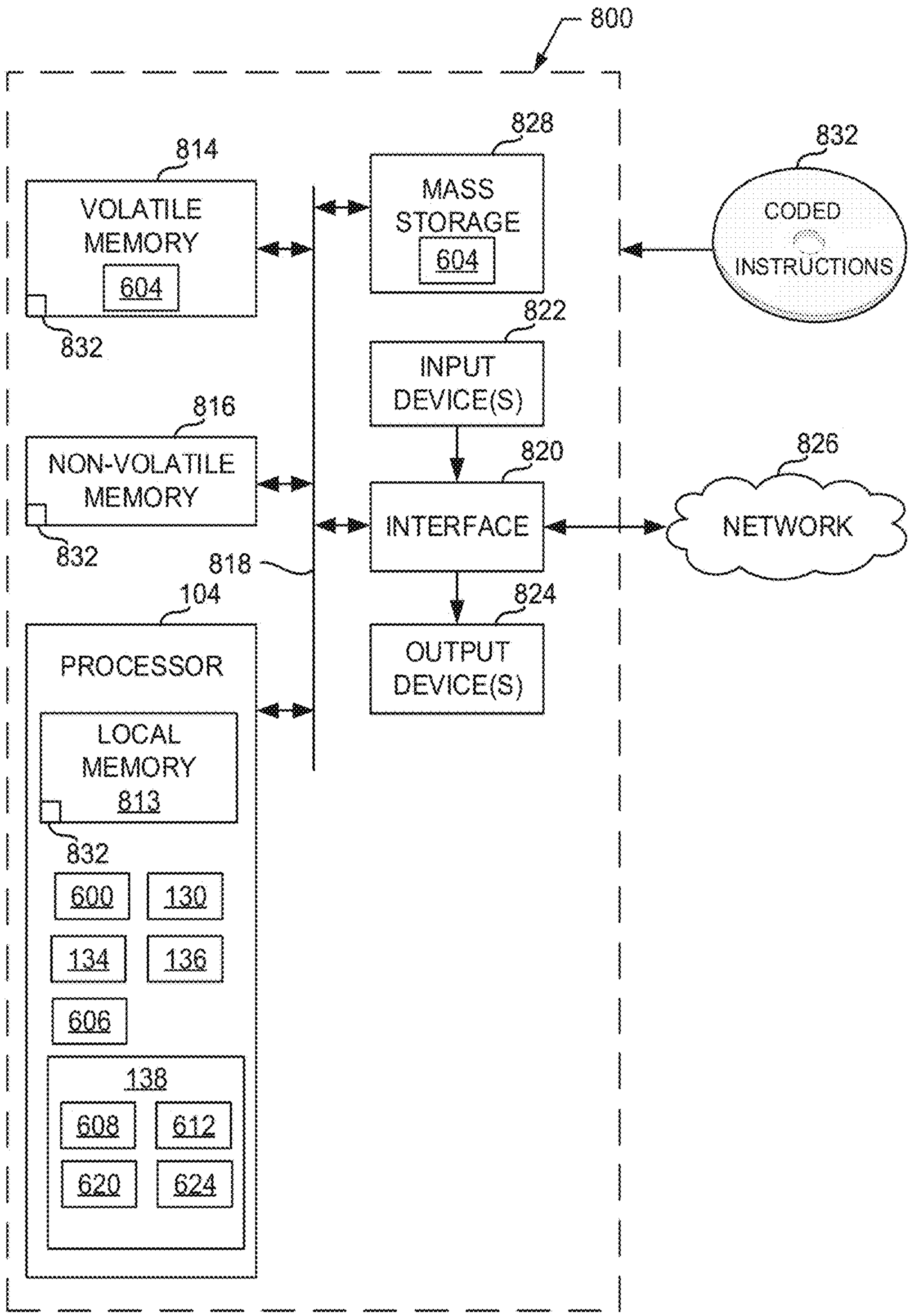

800
814
VOLATILE MEMORY
604
832
828
MASS STORAGE
604
832
CODED INSTRUCTIONS
822
INPUT DEVICE(S)
816
NON-VOLATILE MEMORY
832
820
INTERFACE
826
NETWORK
818
104
824
OUTPUT DEVICE(S)
PROCESSOR
LOCAL MEMORY
813
832
600
130
134
136
606
138
608
612
620
624

FIG. 8

CAPACITIVE ECG SENSING ELECTRONIC DISPLAYS AND RELATED METHODS

FIELD OF THE DISCLOSURE

[0001] This disclosure relates generally to electronic displays and, more particularly, to capacitive electrocardiogram (ECG) sensing electronic displays and related methods.

BACKGROUND

[0002] Electrocardiogram (ECG) sensors measure electrical activity of a heart of a subject. ECG signal data can be generated by capacitive electrodes that do not require a use of a conductive gel to reduce skin resistance. Some capacitive ECG electrodes can detect ECG signals from a subject through an object disposed between the electrode and skin of the user, such as clothing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] FIG. **1** illustrates an example system constructed in accordance with teachings of this disclosure and including an example electronic display screen and a touch controller for controlling the electronic display, where the electronic display screen is operating in a first display screen mode at a touch screen.

[0004] FIG. **2** illustrates the example display screen of FIG. **1** operating in a second display screen mode as an ECG sensor.

[0005] FIG. **3** illustrates an example capacitor of the example display screen of FIGS. **1** and **2**.

[0006] FIG. **4** illustrates an example personal computing device including the example display screen of FIGS. **1** and **2**, where the display screen is operating in the first display screen mode.

[0007] FIG. **5** illustrates an example personal computing device including the example display screen of FIGS. **1** and **2**, where the display screen is operating in the second display screen mode.

[0008] FIG. **6** is a block diagram of an example implementation of the touch controller of FIG. **1**.

[0009] FIG. **7** is a flowchart representative of example machine readable instructions which may be executed to implement the example touch controller of FIGS. **1**, **2**, and/or **6**.

[0010] FIG. **8** is a block diagram of an example processing platform structured to execute the instructions of FIG. **7** to implement the example touch controller of FIGS. **1**, **2**, and/or **6**.

[0011] The figures are not to scale. Instead, the thickness of the layers or regions may be enlarged in the drawings. In general, the same reference numbers will be used throughout the drawing(s) and accompanying written description to refer to the same or like parts. Although the figures show layers and regions with clean lines and boundaries, some or all of these lines and/or boundaries may be idealized. In reality, the boundaries and/or lines may be unobservable, blended, and/or irregular.

[0012] Descriptors "first," "second," "third," etc. are used herein when identifying multiple elements or components which may be referred to separately. Unless otherwise specified or understood based on their context of use, such descriptors are not intended to impute any meaning of priority, physical order or arrangement in a list, or ordering in time but are merely used as labels for referring to multiple elements or components separately for ease of understanding the disclosed examples. In some examples, the descriptor "first" may be used to refer to an element in the detailed description, while the same element may be referred to in a claim with a different descriptor such as "second" or "third." In such instances, it should be understood that such descriptors are used merely for ease of referencing multiple elements or components.

DETAILED DESCRIPTION

[0013] Electrocardiogram (ECG) sensors measure electrical activity of a heart of a subject. ECG signal data can be generated by capacitive electrodes that do not require a use of a conductive gel to reduce skin resistance and that are capable of detecting ECG signals from a subject through an object such as clothing. In particular, a capacitor is formed between the ECG electrode and skin of the user within a particular distance of the electrode (e.g., within 1 mm). Electrical activity generated by the user's heart and detectable via the user's skin affects the electrical charge distribution of the electrode, or self-capacitance of the electrode. Signal data indicative of changes in self-capacitance of the electrode can be used to derive the user's ECG data. For example, first signal data can be collected from a first electrode that forms a first capacitator with a first portion of the user's body (e.g., the user's right thumb) and second signal data can be collected from a second electrode that forms a second capacitator with a second portion of the user's body corresponding to the first portion of the user's body (e.g., the user's left thumb). The ECG data for the user can be calculated by taking the difference between the first signal data and the second signal data.

[0014] Some known personal computing devices include ECG sensors to obtain ECG data while the user is interacting with the device. For example, some known personal computing devices include ECG sensors located at the palm rests of, for instance a laptop keyboard. Some known personal computing device(s) include ECG sensors located on key cap(s) of a keyboard and/or at the hinge(s) of the device(s). However, such incorporation of the ECG sensors into the personal computing devices typically involves additional hardware and/or modifications to the design (e.g., form factor) of the device(s).

[0015] Disclosed herein are example display screens that include capacitive ECG electrodes to selectively generate ECG signal data for a user interacting with the display screen. Examples disclosed herein include a touch controller operatively coupled to the display screen. The touch controller causes the display screen to operate in a first mode as a touch screen that receives touch inputs from the user as the user interacts with digital content displayed via the display screen. In examples disclosed herein, the touch controller selectively instructs the display screen to operate in a second mode in which the ECG electrodes are activated to generate ECG data for the user when the user touches the portion(s) of the display screen including the ECG electrodes.

[0016] Example display screens disclosed herein includes drive lines (e.g., electrical traces, metal wires) that transmit drive signals received from a drive signal generator when the display screen is operating in the touch screen mode and sense lines (e.g., electrical traces, metal wires) to detect the signals carried by the drive lines. When the user touches the display screen, a voltage drop occurs at the location where the user touched the display screen **102** due to electrical charges transmitted by, for example, the user's fingertip. The voltage changes are detected by the sense lines and used by the touch controller to identify touch events on the display screen.

[0017] In examples disclosed herein, the ECG electrodes of the display screen include at least some of the drive lines of the display screen. To generate ECG data, the touch controller instructs the drive signal source to refrain from transmitting drive signals to the drive lines of the display screen. When the user places his or her finger(s), palm(s), etc. on the portions of the display screen including the ECG electrodes, the drive lines that form the electrodes detect changes in self-capacitance due to electrical charges on the skin of the user generated by the user's heart activity. The difference between signal data generated from two ECG electrodes of the display screen is used by the touch controller to determine the user's ECG signal data. The ECG signal data can be analyzed to, for instance, monitor the user's health.

[0018] When the ECG signal data has been collected from the user, the example touch controller instructs the driver signal source to resume transmitting drive signals to the drive lines of the display screen, thereby reactivating the touch screen functionalities of the display screen. Thus, example display screens disclosed herein incorporate ECG-sensing capabilities without significant additions and/or modifications to the hardware and/or form factor of the personal computing device that includes the display screen. Rather, examples disclosed herein provide for dual use of the drive lines of the display screen in enabling touch functionalities of the display screen and in detecting ECG signal data based on changes in capacitance.

[0019] FIG. **1** illustrates an example system **100** constructed in accordance with teachings of this disclosure including an electronic display screen **102** and a touch controller **104** for controlling operation of the display screen **102**. In the example system **100** may be implemented in a personal computing device, such as a laptop or electronic tablet. The example display screen **102** enables a user of the personal computing device to view digital data via user interface(s) and/or to provide input(s) to interact with application(s) on the device. In particular, the example display screen **102** of FIG. **1** is a touch screen that enables the user to interact with the data presented on the display screen **102** by touching the screen with one or more fingers of a hand of the user and/or with a stylus based on changes in mutual capacitance detected by electrodes of the display screen **102** when the user and/or stylus contact the display screen **102**. As disclosed herein, the example touch controller **104** of FIG. **1** selectively controls operation of the display screen **102** between a first mode in which the display screen **102** is a touch screen that enables the user to interact with the device via touch gesture(s) on the screen and a second mode in which electrodes of the display screen **102** are activated to generate ECG signal data from the user (the terms "user" and "subject" are used interchangeably herein and both refer to a biological creature such as a human being). As discussed herein, the example touch controller **104** can be implemented by software executed on a processor of the personal computing device including the display screen **102**. In some examples, one or more components of the touch controller **104** are implemented by a cloud-based device.

[0020] The example display screen **102** of FIG. **1** is a capacitive display screen including a plurality of drive lines **106** and a plurality of sense lines **108**. The drive lines **106** and the sense lines **108** include electrical traces or wires (e.g., metal) on a conductive substrate **109** of the display screen **102**. The conductive layer including the drive lines **106** and the sense lines **108** is disposed between a glass substrate and a protective cover, which can include glass and/or a protective coating. For illustrative purposes, the glass substrate and the protective cover are not shown in FIG. **1**.

[0021] As illustrated in FIG. **1**, the drive lines **106** extend between a first edge **110** of the display screen **102** and a second edge **112** of the display screen **102** opposite the first edge **110**. The sense lines **108** extend between a third edge **114** of the display screen **102** and a fourth edge **116** of the display screen **102** opposite the third edge **114**. In the example of FIG. **1**, the sense lines **108** are perpendicular to the drive lines **106** to form a grid pattern.

[0022] The example display screen **102** can include additional or fewer drives lines **106** and/or sense lines **108** than shown in FIG. **1**. For example, although for illustrative purposes, the sense lines **108** of FIG. **1** are shown as extending across a portion of the display screen **102** (e.g., the bottom portion when the display screen **102** is oriented as in FIG. **1**), the sense lines **108** can extend across additional areas of the display screen **102** such that the grid pattern is formed between the first and second edges **110**, **112** of the display screen. Also, the spacings between the respective drive lines **106** can differ from the spacings shown in FIG. **1**. Similarly, the spacings between the respective sense lines **108** can differ from the spacings shown in FIG. **1**. Also, the display screen **102** can have a different size and/or shape than the example shown in FIG. **1**.

[0023] In the example system **100** of FIG. **1**, the touch controller **104** is communicatively coupled to a drive signal source **118** (e.g., a generator). When the display screen **102** is functioning as a user touch screen, as shown in FIG. **1**, the example touch controller **104** instructs the drive signal source **118** to emit drive signals (e.g., timed pulses) that are carried by the drive line(s) **106**, as represented by the lines **120**, **122**, **124**, **126**, **128** in FIG. **1**. The sense line(s) **108** detect the current carried by the drive line(s) **106** at the location(s) at which the respective sense line(s) **108** intersect with the drive line(s) **106**. The sense line(s) **108** generate signal data based on the detected current and transmit the signal data to a multiplexer **130** of the touch controller **104**, as represented by line **132** in FIG. **1**.

[0024] When, for example, the user's fingertip touches the display screen **102**, a voltage drop occurs at the location where the user's fingertip touches the display screen **102**. The change in voltage is detected by the sense line(s) **108**. The sense line(s) **108** of the display screen **102** transmit signal data indicating the change in voltage to the multiplexer **130** of the touch controller **104**. The multiplexer **130** forwards the signals received from the various sense lines **108** to an integrator **134** of the touch controller **104**. The integrator **134** performs an integration of the signal data to generate an output voltage indicative of the change(s) in voltage detected by the sense line(s) **108** over time. The example touch controller **104** includes an analog-to-digital (A/D) converter **136** to generate a digital signal that is transmitted to a digital signal processor **138**. The digital signal processor **138** interprets the signal data to detect touch event(s) at particular locations on the display screen **102** where the voltage change(s) were detected by the sense line(s) **108**. The touch controller **104** communicates the touch event(s) to, for example, a processor the personal computer device that executes software to interpret and output response(s) based on the touch event(s).

[0025] Thus, the example display screen **102** operates in a first mode as a touch screen that enables a user to interact with data presented via the display screen **102** by providing touch inputs on the screen. As mentioned above, in some examples, the touch controller **104** causes the display screen **102** to act in a second mode in which at least some of the drive lines **106** are converted to electrodes that measure changes in self-capacitance when the user touches the display screen **102**. The changes in self-capacitance are used by the touch controller **104** to derive ECG data for the user.

[0026] The example display screen **102** of FIG. **1** includes a first ECG sensing electrode **140**, or first means for sensing EGC data. The first ECG sensing electrode **140** includes a first drive line set **142** including one or more of the drive lines **106**, a first integrator **144**, and a first amplifier **146**. The display screen **102** includes a second ECG sensing electrode **148**, or first means for sensing EGC data. The second ECG sensing electrode **148** includes a second drive line set **150** including one or more of the drive lines **106** different from the drive line(s) **106** of the first drive line set **142**, a second integrator **152**, and a second amplifier **154**. As shown in FIG. **1**, the first ECG sensing electrode **140** is proximate to the third edge **114** of the display screen **102** and the second ECG sensing electrode **148** is proximate to the fourth edge **116** of the display screen **102**. To collect ECG data, a user places, for example, a thumb of his or her left hand on the display screen **102** proximate to the third edge **114** and, thus, the first ECG sensing electrode **140**, and a thumb of his or her right hand on the display screen **102** proximate to the fourth edge **116** and, thus, the second ECG sensing electrode **148**. The user can use other portion(s) of this body to contact the display screen **102** (e.g., palms, wrists, other fingers).

[0027] In the example of FIG. **1**, the first and second ECG sensing electrodes **140**, **148** are in an inactive state when the display screen **102** is operating in the first operational mode as a touch screen. To cause the display screen **102** to operate in the second operational mode as an ECG sensor, the touch controller **104** selectively activates the first and second ECG sensing electrodes **140**, **148** by converting the drives lines **106** in the first drive line set **142** of the first ECG sensing electrode **140** and the drive lines **106** in the second drive line set **150** of the second ECG sensing electrode **148** from drive signal transmitting lines to capacitive electrodes. The touch controller **104** activates the integrator(s) **144**, **152** and the amplifier(s) **146**, **154** (e.g., by generating instruction(s) for the integrator(s) **144**, **152** and the amplifier(s) **146**, **154** to receive data from the drive line(s) **106**). In some examples, the touch controller **104** activates the ECG sensing electrodes **140**, **148** after detecting that the user has touched one or more areas of the display screen **102** proximate to the third and fourth edges **114**, **116** (and, thus, proximate to one or more of the ECG sensing electrodes **140**, **148**) for a predetermined period of time.

[0028] When the touch controller **104** of FIG. **1** determines that first and second ECG sensing electrodes **140**, **148** should be activated, the touch controller **104** refrains from instructing the drive signal source **118** to generate and transmit drive signals to the drive lines **106** of the display screen **102**. Thus, touch screen functionality of the display screen **102** is temporarily disabled when the first and second ECG sensing electrodes **140**, **148** are activated. By instructing the drive signal source **118** to refrain from transmitting drive signals to the drive lines **106** (including the drive lines **106** of the display screen **102** that are not a part of the first drive line set **142** and the second drive line set **148**), the sensitivity of the first and second ECG sensing electrodes **140**, **148** in detecting small changes in capacitance is increased due to less noise. As a result, the ECG sensing electrodes **140**, **148** can more accurately detect ECG signals.

[0029] FIG. **2** illustrates the example system **100** including the display screen **102** and the touch controller **104**, where the display screen **102** is operating in the second display screen mode as an ECG sensor. As mentioned above, the touch controller **104** refrains from sending instructions to the drive signal source **118** when the display screen **102** is operating in the second mode. Thus, because the drive lines **106** do not transmit signals, the sense lines **108** do not transmit signal data to the multiplexer **130** measuring the current carried by the drive line(s) **106**. Therefore, the touch functionality of the display screen **102** is disabled.

[0030] To measure ECG data, the user touches the portion of the display screen **102** including the first ECG sensing electrode **140** with, for example, his or her left thumb, and the portion of the display screen **102** including the second ECG sensing electrode **148** with a corresponding body part on the right side, such as his or her right thumb. In the example of FIG. **2**, when the user touches the portion of the display screen **102** including the first ECG sensing electrode **140**, a capacitor is formed between the skin of the user and the drive lines **106** of the first drive line set **142**. Electrical activity generated by the heart of the user affects the electric charge stored by the drive line(s) **106** of the first drive line set **142** of the first ECG sensing electrode **140**. The drive lines(s) **106** of the first drive line set **142** generate signal data in response to the change in electric charge due to the user's heart activity. The signal data is transmitted to the first integrator **144** of the first ECG sensing electrode **140**. The first integrator **144** of the first ECG sensing electrode **140** integrates the signal data generated by the respective drive lines **106** of the first drive line set **142**. The signal output by the first integrator **144** is transmitted to the first amplifier **146** of the first ECG sensing electrode **140**, as represented by line **156** in FIG. **2**. The first amplifier **146** amplifies the signal and transmitted the amplified signal to the A/D converter **136** of the touch controller **104**.

[0031] Similarly, when the user touches the portion of the display screen **102** including the second ECG sensing electrode **148**, a capacitor is formed between the skin of the user and the drive lines **106** of the second drive line set **150**. Changes in capacitance due to the electrical activity of the heart of the user are detected by the drive line(s) **106** of the second drive line set **150** and the corresponding signal data is transmitted to the second integrator **152** of the second ECG sensing electrode **148**. The second integrator **152** of the second ECG sensing electrode **148** integrates the signal data generated by the respective drive lines **106** of the second drive line set **150** and outputs a signal for amplification by the second amplifier **154** of the second ECG sensing electrode **148**. The second amplifier **154** transmits the amplified signal to the A/D converter **136** of the touch controller **104**, as represented by line **158** in FIG. **2**.

[0032] The A/D converter **136** converts the analog signal data from the first ECG sensing electrode **140** and the second ECG sensing electrode **148** to digital signal data for analysis by the digital signal processor **138** of the touch controller **104**. The digital signal processor **138** generates ECG signal data by calculating the difference between the signal data from the first ECG sensing electrode **140** and the signal data from the second ECG sensing electrode **148**. In some examples, the digital signal processor **138** of FIG. **1** analyzes the ECG signal data to determine characteristics of the heart activity of the user, detect abnormalities, etc. In some examples, the digital signal processor **138** transmits the ECG signal data for analysis by other user application(s) installed on the personal computing device that includes the display screen **102** or on other user device(s) and/or cloud-based device(s).

[0033] In some examples, the touch controller **104** instructs the display screen **102** to switch from operating the second ECG-sensing mode to the first touch screen mode after a predetermined period of time and/or based on one or more trigger events. For example, the touch controller **104** can instruct the drive signal source **118** to resume generating and transmitting drive signals to the drive lines **106** when the user removes his or her finger(s) from the portion(s) of the display screen **102** including the first ECG sensing electrode **140** and/or the second ECG sensing electrode **148**. In some examples, the touch controller **104** instructs the drive signal source **118** to resume generating and transmitting drive signals to the drive lines **106** based on other trigger events corresponding to, for instance, the calculation of the ECG signal data, the presentation of the ECG signal for display via the display screen **102**, etc. When the touch controller **104** instructs the drive signal source **118** to resume transmitting the drive signals, the drive lines **106** that form the first and second drive line sets **142**, **150** of the ECG sensing electrodes **140**, **148** return to transmitting drive signals for measurement by the sense lines **108** in connection with detecting touch events on the display screen **102**. The touch controller **104** instructs the integrators **144**, **152** and the amplifiers **146**, **154** of the respective ECG sensing electrodes **140**, **148** to refrain from processing signal data associated with the drive lines **106**. Thus, the touch controller **104** of FIGS. **1** and **2** selectively controls activation of the ECG sensing electrodes **140**, **148** and, thus, operation of the display screen **102** as a touch screen or as an ECG sensor.

[0034] FIG. **3** illustrates example capacitors **300** formed between respective drive lines **106** of the example display screen **102** of FIGS. **1** and **2** and a finger **302** of a user of the display screen **102**. The drive lines **106** shown in FIG. **3** can be included in first drive line set **142** of the first ECG sensing electrode **140** or the second drive line set **150** of the second ECG sensing electrode **148** of FIGS. **1** and **2**.

[0035] In the example of FIG. **3**, a glass substrate **304** is disposed over the drive lines **106** to form a protective cover between the drive lines **106** and the user. The glass substrate **304** also serves as a dielectric for the capacitors **300** formed between the user's finger **302** and the respective drive lines **106** of the display screen **102**. The capacitance for one of the drive wires **106** of FIG. **3** can be calculated using the following equation:

$$C = \frac{2\pi l \epsilon_0 \epsilon_r}{\cosh^{-1}\frac{h}{r}}, \qquad \text{(Equation 1)}$$

where ε_0 is the permittivity of air (e.g., 8.854×10^{-12}F·m), ε_r is the dielectric constant of glass, r is the radius of the drive line wire, l is the length of the drive line wire, and h is the thickness of the glass **302**.

[0036] For example, for one of the drive lines **106** of FIG. **3** having a radius of 5 μm and a length of 100 mm and where the glass **302** has a thickness of 1 mm and dielectric constant from 3-10, the capacitance of the drive line **106** is approximately 10 pF. In some examples, a sensor with a capacitance of 50 pF can detect ECG signals thorough, for example, clothing. In the examples of FIGS. **1-3**, the first ECG sensing electrode **140** and the second ECG sensing electrode **148** including at least five drive lines **106** can be used to detect ECG signals from the user (e.g., 5 drive lines having a capacitance of 10 pF for a total capacitance of 50 pF).

[0037] To increase capacitance and, thus, the ECG signal detection capabilities of the ECG sensing electrodes **104**, **148**, the number of drive lines **106** that are used for ECG sensing can be increased. In some examples, a spacing between each of the drive lines **106** is minimized to increase the number of drive lines **106** in the drive line set(s) **142**, **150** and, thus, the number of capacitors **300** formed between the user's finger **302** and the drive lines **106**. In some examples, the number and/or spacing of the drive lines **106** can be based on an average size of, example, a human finger.

[0038] In some examples, conductive plates (e.g., metal plates) may be used with the ECS sensing electrode(s) **140**, **148** in addition to or instead of the drive lines **106** to increase capacitance and ECG signal fidelity. Conductive plates may be used in examples where loss of touch display screen capabilities at the portions of the display screen that include the conductive plates when the display screen **102** is operating in the touch screen mode does not substantially affect use of the display screen. For example, conductive plates can be used in display screens that are dedicated to collecting ECG data and/or larger display screens in which a portion of the display screen real estate can be designated for ECG data collection without substantially reducing an area of the display screen available for the presentation of data.

[0039] FIG. **4** illustrates an example personal computing device **400** including the example ECG-sensing display screen **102** of FIGS. **1** and **2**. In FIG. **4**, the example personal computing device **400** is a laptop including a processor **401**. In addition to the ECG-sensing display screen **102**, the example personal computing device **400** includes a second touch display screen **402** to display data and receive user touch input(s) for interacting with the data. In some examples, the second display screen **402** serves as the primary display screen for viewing and interacting with data displayed via the second display screen **402**. When operating in the first mode as a touch screen, the ECG-sensing display screen **102** can display digital data in addition to the data displayed via the second display screen **402**. The data displayed via the display screens **102**, **402** of the personal computing device **400** of FIG. **4** can be associated with software application(s) executed by the processor **401** of the personal computing device **400**. Thus, in the example of FIG. **1**, both of the display screens **102**, **402** operate as touch screens.

[0040] FIG. **5** illustrates the example personal computing device **400** of FIG. **4** including the display screen **102** of FIGS. **1** and **2** in the second operational state in which the first and second ECG sensing electrodes **140**, **148** are activated. As disclosed above, the touch controller **104**

(FIGS. **1** and **2**) selectively activates the first and second ECG sensing electrodes **140**, **148** to generate ECG data for a user touching the areas of the display screen **102** including the electrodes **140**, **148**. In the example of FIG. **5**, the second display screen **402** continues to function as a touch screen for receiving user touch input(s). As discussed above, when the ECG-sensing display screen **102** is in the ECG sensing mode, the touch screen functionality of the display screen **102** is disabled with respect to receiving user touch input(s) to interact with data displayed via the display screen **102**. Thus, in the example of FIG. **5**, the display screen **102** is acting as an ECG sensor and the second display screen **402** is acting as a touch screen.

[0041] In some examples, one or more of the display screens **102**, **402** display health data associated with the ECG signal, such as an ECG signal graph **500**, heart rate data, etc. As discussed herein, the graphical health data can be generated by one or more software applications based on the ECG data generated by the first and second ECG sensing electrodes **140**, **148**.

[0042] FIG. **6** is a block diagram of an example implementation of the example touch controller **104** of FIGS. **1** and **2**. As mentioned above, the example touch controller **104** is constructed to cause a display screen (e.g., the display screen **102** of FIGS. **1** and **2**) to operate in (1) a first mode in which the display screen functions as a touch screen to receive touch input(s) from a user to enable the user to interact with data displayed via the display screen, and (2) a second mode in which the display screen **102** acts as an ECG sensor by obtaining ECG signal data from the user via ECG sensing electrodes (e.g., the ECG sensing electrodes **140**, **148**). In the example of FIG. **6**, the touch controller **104** is implemented by one or more processors of a personal computing device that includes the display screen **102** (e.g., the processor **401** of the personal computing device **400** of FIGS. **4** and **5**). In some examples, some of the user touch event analysis and/or ECG data analysis implemented by the touch controller **104** via a cloud-computing environment and one or more other parts of the analyses is implemented by a processor of the personal computing device.

[0043] In some examples, the location(s) at which the analysis is performed by the touch controller **104** is based on the whether the analysis is to be performed in substantially real-time as the signal data is being generated or at a later time. For example, signal data generated by the sense lines **108** of the display screen **102** may be analyzed by the touch controller **104** at the processor **401** of the personal computing device **400** to detect touch event(s) on the display screen **102** in real-time. In other examples, analysis of the ECG signal data may be performed at a later time via a cloud-computing environment.

[0044] The example touch controller **104** selectively controls the operation of the display screen **102** between the first operation mode (i.e., the touch screen mode) and the second operation mode (i.e., the ECG sensing mode) by controlling transmission of the drive signals to the drive lines **106** of the display screen **102**. The example touch controller **104** includes a drive signal activator **600**. The drive signal activator **600** selectively instructs the drive signal source **118** to generate drive signals that are transmitted to the drive lines **106** of the display screen **102**. Thus, the drive signal activator **600** provides means for causing the display screen **102** to operate in the first operation mode as a touch screen based on the transmission of the drive signals to the drive lines **106**. The means for causing the display screen **102** to operate in the first operation mode as a touch screen may be implemented by a processor such as the processor of FIG. **8** executing instructions such as the instructions of FIG. **7**.

[0045] In the example of FIG. **1**, the drive signal activator **600** instructs the drive signal source **118** to generate the drive signals based on drive signal rule(s) **602** stored in a database **604**. In some examples, the touch controller **104** includes the database **604**. In other examples, the database **604** is located external to the touch controller **104** in a location accessible to the touch controller **104** as shown in FIG. **6**. The example drive signal rule(s) **602**, which can be defined by user input(s), can define, for example, the frequency at which the drive signal source **118** should emit drive signals, the number of drive signal pulses, etc.

[0046] As disclosed above, the sense line(s) **108** generate signal data **605** indicative of voltage drops with respect to the current flowing through the drive line(s) **106** when the user touches the display screen **102**. The signal data **605** from the sense line(s) **108** can be stored in the database **604**. The example touch controller **104** includes the multiplexer **130**, which receives the signal data **605** from the sense line(s) **108** and outputs the signal data via an output line to the integrator **134** of the touch controller **104**. The example touch controller **104** includes the A/D converter **136** to convert the analog signal data **605** from the sense line(s) **108** to digital data for processing by the digital signal processor **138** of the example touch controller **104**.

[0047] In some examples, the touch controller **104** of FIG. **6** includes a filter **606** (e.g., a band pass filter). The example filter **606** substantially removes noise from the signal data **605** generated by the sense line(s) **108** before the data is provided to the digital signal processor. For example, the filter **606** can filter the signal data **605** to remove data indicative of voltage changes due to the user touching the display screen **102** at, for example, locations(s) on the display screen that are not associated with receiving input(s) (e.g., a user touch on a background image displayed via the display screen).

[0048] As mentioned above, the signal data **605** generated by the sense line(s) **108** is analyzed by the digital signal processor **138** of the touch controller **104** to identify touch event(s) on the display screen **102**. The example digital signal processor **138** of FIG. **6** includes a touch event analyzer **608**, or means for detecting touch on the display screen **102**. The means for detecting touch may be implemented by a processor such as the processor of FIG. **8** executing instructions such as the instructions of FIG. **7**.

[0049] The touch event analyzer **608** analyzes the signal data **605** from the sense line(s) **108** to identify touch event(s) based on one or more touch event rule(s) **610**. The touch event rule(s) **610**, which can be defined by user input(s), define threshold value(s) or range(s) for the voltage drop(s) measured by the sense line(s) **108** that are indicative of user touch event(s). In some examples, the touch event rule(s) **610** include a mapping of the sense line(s) **108** relative to the drive lines(s) **106** of the display screen **102**. The mapping can be used by the touch event analyzer **608** to determine the location of the touch event(s) on the display screen **102**.

[0050] The example touch controller **104** of FIG. **6** includes an ECG electrode controller **612**, or means for selectively activating the first and second ECG sensing electrodes **140**, **148** of the display screen **102**. The means for selectively activating may be implemented by a processor such as the processor of FIG. **8** executing instructions such as the instructions of FIG. **7**. The example ECG electrode controller **612** determines whether the ECG sensing electrodes **140**, **148** should be activated based on one or more ECG activator rules **614**. The ECG activator rule(s) **614** can be defined by user input(s) and stored in the database **604**. The ECG activator rule(s) **614** define criteria that, when satisfied, cause the ECG electrode controller **612** to generate instructions that cause the display screen **102** to switch from operating in the first touch screen operational state to the second ECG sensing mode. In some examples, the criteria defined by the ECG activator rule(s) **614** are based on touch event(s) detected by the touch event analyzer **608**.

[0051] For example, the ECG activator rule(s) **614** include a rule that the ECG electrode controller **612** should activate the ECG sensing electrodes **140**, **148** if the touch event analyzer **608** detects that the user has touched the display screen **102** simultaneously at two different locations for a predetermined period of time (e.g., using his or her right and left fingers). ECG activator rule(s) **614** can include a rule that the ECG electrode controller **612** should activate the ECG sensing electrodes **140**, **148** when the touch event analyzer **608** determines that the user has touched the regions of the display screen **102** that include the ECG sensing electrodes **140**, **148** (e.g., proximate to the third and fourth edges **114**, **116** of the display screen of FIG. **1**) for predetermined period of time.

[0052] When the ECG electrode controller **612** determines that the criteria for activating the ECG sensing electrodes **140**, **148** as defined by the ECG activator rule(s) **614** has been satisfied, the ECG electrode controller **612** communicates with the drive signal activator **600** to cause the drive signal source **118** to refrain from transmitting the drive signals to the drive line(s) **106** of the display screen **102**. For example, based on instructions from the ECG electrode controller **612**, the drive signal activator **600** can refrain from sending instructions to the drive signal source **118** to generate the drive signals. Also, the ECG electrode controller **612** transmits instructions to activate the first and second integrators **144**, **152** and the first and second amplifiers **146**, **154** of the first and second ECG sensing electrodes **140**, **148**. Thus, the display screen **102** switches from operating in the first touch screen mode to operating in the second ECG-sensing mode.

[0053] As disclosed above, the drive line(s) **106** of the first ECG sensing electrode **140** (e.g., the drive line(s) **106** of the first drive line set **142**) generate first signal data **616** in response to changes in capacitance detected at the drive line(s) **106** due to the user's electrical heart activity. The first signal data **616** generated by the first ECG sensing electrode **140** is transmitted to the A/D converter **136** of the touch controller **104** (e.g., after integration by the first integrator **144** and amplification by the first amplifier **146** of the first ECG sensing electrode **140**). Also, the drive line(s) **106** of the second ECG sensing electrode **148** (e.g., the drive line(s) **106** of the second drive line set **150**) generate second signal data **618** in response to changes in capacitance detected at the drive line(s) **106** due to the user's electrical heart activity. The second signal data **618** generated by the second ECG sensing electrode **148** is transmitted to the A/D converter **136** of the touch controller **104** (e.g., after integration by the first integrator **152** and amplification by the first amplifier **154** of the second ECG sensing electrode **148**).

[0054] The signal data **616**, **618** generated by the ECG sensing electrodes **140**, **148** and transmitted to the touch controller **104** is stored in the database **604**. The signal data **616**, **618** from the respective ECG sensing electrodes **140**, **148** is processed by the A/D converter **136**. In some examples, the signal data **616**, **618** from the ECG sensing electrode(s) **140**, **148** is filtered by the filter **606** to remove noise from the signal data **616**, **618**. For example, the signal data **616**, **618** generated by the respective ECG sensing electrode(s) **140**, **148** can include noise in the form of motion artifacts from user movement(s). The filter **606** can filter the signal data **616**, **618** to remove the noise for improved identification of the ECG signal data.

[0055] The example digital signal processor **138** includes a calculator **620**, or means for determining ECG signal data for the user. The means for determining ECG signal data may be implemented by a processor such as the processor of FIG. **8** executing instructions such as the instructions of FIG. **7**. The example calculator **620** determines the ECG signal for the user from the first signal data **616** generated by the first ECG sensing electrode **140** and the second signal data **618** generated by the second ECG sensing electrode **148** indicative of capacitance changes at the drive line(s) **106** of the drive line set(s) **142**, **150**. In particular, the calculator **620** calculates the difference between the first signal data **616** and the second signal data **618** to generate ECG signal data **622** for the user.

[0056] The ECG signal data **622** is stored in the database **604**. In some examples, the calculator **620** outputs the ECG signal data **622** for analysis with respect to user health metrics. In some examples, at least some of the analysis of the ECG signal data **622** is performed by the digital signal processor **138**. For example, the example digital signal processor **138** of FIG. **6** includes an ECG data analyzer **624**, or means for analyzing the ECG signal data **622**. The means for analyzing may be implemented by a processor such as the processor of FIG. **8** executing instructions such as the instructions of FIG. **7**. The example ECG data analyzer **624** can calculate metrics such as, for instance, a heart rate of the user based on the ECG signal data **622**. In some examples, the ECG data analyzer **624** provides for analysis of the ECG signal data locally in examples in which at least a part of the digital signal processor **138** is implemented by an on-board processor of the personal computing device (e.g., by the on-board processor **401**).

[0057] In some examples, the calculator **620** transmits the ECG signal data **622** to one or more ECG user applications **626** implemented by one or more processors of the personal computing device **400** and/or in a cloud-computing environment (e.g., via one or more wired or wireless communication connections). For example, the ECG user application(s) **626** may generate graphs displaying the ECG signal data, track historical ECG data over time, generate audio and/or visual alert(s) to be output the subject or other individuals (e.g., a doctor) via one or more user devices (e.g., the personal computing device **400**). In some examples, the ECG data analyzer **624** transmits the ECG signal data **622** to the ECG user application(s) based on, for instance, processing resources to analyze the ECG signal data **622** with respect to particular characteristics to be analyzed. For example, the ECG data analyzer **624** may calculate the user's heart rate based on the ECG signal data **622**, which the ECG user application(s) **626** generate graph (s) and track the data over time.

[0058] In some examples, the ECG data analyzer **624** and/or the ECG user application(s) **626** generate user interface graphics that are displayed via the display screen **102** and that provide visual indications to the user of where the user should place his or her body parts (e.g., thumbs, palms) on the display screen **102** for measurement of the user's ECG data. In such examples, the ECG electrode controller **612** activates the first and second ECG sensing electrodes **140**, **148** when, for example, the touch event analyzer **608** determines that the user has touched the display screen **102** proximate to the ECG visual indicator regions and based on the ECG activator rule(s) **614** defining a length of time that the user is in contact with the display screen **102**. In some examples, the ECG activator rule(s) **614** indicate that the ECG sensing electrodes **140**, **148** should be activated when a user selects to run an ECG user application **626**. In such examples, the execution of the ECG user application(s) **626** can serve as the trigger event for the activation of the ECG sensing electrodes **140**, **148** by the ECG electrode controller **612**.

[0059] After the ECG signal data **622** has been generated, the example touch controller **104** of FIG. **1** automatically instructs the display screen **102** to resume operating as a touch screen. In particular, based on the ECG activator rule(s) **614**, the example ECG electrode controller **612** communicates with the drive signal activator **600** to cause the drive signal source **118** to resume generating drive signals that are transmitted to the drive lines **106** and measured by the sense line(s) **108** to detect user touch event(s). For example, the ECG activator rule(s) **614** can indicate that if no signal data is received by the touch controller **104** from the ECG sensing electrode(s) **140**, **148** for a predefined period of time, the user has removed one or both of his or her hands from touching the display screen **102** and, thus, the drive signal source **118** should resume generating and transmitting drive signals to the drive lines **106** of the display screen **102**. As another example, the ECG activator rule(s) **614** can indicate that the drive signal source **118** should resume generating and transmitting drive signals to the drive lines **106** after a predefined period of time, which can include a reference or threshold time for the drive lines **106** of the ECG sensing electrodes **140**, **148** to detect a change in self-capacitance. The ECG activator rule(s) **614** can indicate that the drive signal source **118** should resume generating and transmitting drive signals to the drive lines **106** based on feedback from the ECG data analyzer **624** and/or the ECG user application(s) **626** indicating that the ECG signal data **622** has been received and/or that output(s) based on the ECG signal data **622** have been generated.

[0060] While an example manner of implementing the touch controller **104** is illustrated in FIGS. **1**, **2**, and **6**, one or more of the elements, processes and/or devices illustrated in FIGS. **1**, **2**, and/or **6** may be combined, divided, re-arranged, omitted, eliminated and/or implemented in any other way. Further, the example multiplexer **130**, the example integrator **134**, the example A/D converter **136**, the example digital signal processor **138**, the example drive signal activator **600**, the example database **604**, the example filter **606**, the example touch event analyzer **608**, the example ECG electrode controller **612**, the example calculator **620**, the example ECG data analyzer **624** and/or, more generally, the example touch controller **104** of FIGS. **1**, **2**, and/or **6** may be implemented by hardware, software, firmware and/or any combination of hardware, software and/or firmware. Thus, for example, any of the example multiplexer **130**, the example integrator **134**, the example A/D converter **136**, the example digital signal processor **138**, the example drive signal activator **600**, the example database **604**, the example filter **606**, the example touch event analyzer **608**, the example ECG electrode controller **612**, the example calculator **620**, the example ECG data analyzer **624** and/or, more generally, the example touch controller **104** could be implemented by one or more analog or digital circuit(s), logic circuits, programmable processor(s), programmable controller(s), graphics processing unit(s) (GPU(s)), digital signal processor(s) (DSP(s)), application specific integrated circuit(s) (ASIC(s)), programmable logic device(s) (PLD(s)) and/or field programmable logic device(s) (FPLD(s)). When reading any of the apparatus or system claims of this patent to cover a purely software and/or firmware implementation, at least one of the example multiplexer **130**, the example integrator **134**, the example A/D converter **136**, the example digital signal processor **138**, the example drive signal activator **600**, the example database **604**, the example filter **606**, the example touch event analyzer **608**, the example ECG electrode controller **612**, the example calculator **620**, and/or the example ECG data analyzer **624** is/are hereby expressly defined to include a non-transitory computer readable storage device or storage disk such as a memory, a digital versatile disk (DVD), a compact disk (CD), a Blu-ray disk, etc. including the software and/or firmware. Further still, the example touch controller **104** of FIGS. **1**, **2**, and/or **6** may include one or more elements, processes and/or devices in addition to, or instead of, those illustrated in FIGS. **1**, **2**, and/or **6**, and/or may include more than one of any or all of the illustrated elements, processes and devices. As used herein, the phrase "in communication," including variations thereof, encompasses direct communication and/or indirect communication through one or more intermediary components, and does not require direct physical (e.g., wired) communication and/or constant communication, but rather additionally includes selective communication at periodic intervals, scheduled intervals, aperiodic intervals, and/or one-time events.

[0061] A flowchart representative of example hardware logic, machine readable instructions, hardware implemented state machines, and/or any combination thereof for implementing the touch controller **104** is shown in FIG. **7**. The machine readable instructions may be one or more executable programs or portion(s) of an executable program for execution by a computer processor such as the processor **812** shown in the example processor platform **800** discussed below in connection with FIG. **8**. The program may be embodied in software stored on a non-transitory computer readable storage medium such as a CD-ROM, a floppy disk, a hard drive, a DVD, a Blu-ray disk, or a memory associated with the processor **812**, but the entire program and/or parts thereof could alternatively be executed by a device other than the processor **812** and/or embodied in firmware or dedicated hardware. Further, although the example program is described with reference to the flowchart illustrated in FIG. **7**, many other methods of implementing the example the touch controller **104** may alternatively be used. For example, the order of execution of the blocks may be changed, and/or some of the blocks described may be changed, eliminated, or combined. Additionally or alternatively, any or all of the blocks may be implemented by one or more hardware circuits (e.g., discrete and/or integrated analog and/or digital circuitry, an FPGA, an ASIC, a comparator, an operational-amplifier (op-amp), a logic circuit, etc.) structured to perform the corresponding operation without executing software or firmware.

[0062] The machine readable instructions described herein may be stored in one or more of a compressed format, an encrypted format, a fragmented format, a packaged format, etc. Machine readable instructions as described herein may be stored as data (e.g., portions of instructions, code, representations of code, etc.) that may be utilized to create, manufacture, and/or produce machine executable instructions. For example, the machine readable instructions may be fragmented and stored on one or more storage devices and/or computing devices (e.g., servers). The machine readable instructions may require one or more of installation, modification, adaptation, updating, combining, supplementing, configuring, decryption, decompression, unpacking, distribution, reassignment, etc. in order to make them directly readable and/or executable by a computing device and/or other machine. For example, the machine readable instructions may be stored in multiple parts, which are individually compressed, encrypted, and stored on separate computing devices, wherein the parts when decrypted, decompressed, and combined form a set of executable instructions that implement a program such as that described herein. In another example, the machine readable instructions may be stored in a state in which they may be read by a computer, but require addition of a library (e.g., a dynamic link library (DLL)), a software development kit (SDK), an application programming interface (API), etc. in order to execute the instructions on a particular computing device or other device. In another example, the machine readable instructions may need to be configured (e.g., settings stored, data input, network addresses recorded, etc.) before the machine readable instructions and/or the corresponding program(s) can be executed in whole or in part. Thus, the disclosed machine readable instructions and/or corresponding program(s) are intended to encompass such machine readable instructions and/or program(s) regardless of the particular format or state of the machine readable instructions and/or program(s) when stored or otherwise at rest or in transit.

[0063] As mentioned above, the example process of FIG. **7** may be implemented using executable instructions (e.g., computer and/or machine readable instructions) stored on a non-transitory computer and/or machine readable medium such as a hard disk drive, a flash memory, a read-only memory, a compact disk, a digital versatile disk, a cache, a random-access memory and/or any other storage device or storage disk in which information is stored for any duration (e.g., for extended time periods, permanently, for brief instances, for temporarily buffering, and/or for caching of the information). As used herein, the term non-transitory computer readable medium is expressly defined to include any type of computer readable storage device and/or storage disk and to exclude propagating signals and to exclude transmission media.

[0064] FIG. **7** is a flowchart of example machine readable instructions that, when executed, implement the example touch controller **104** of FIGS. **1**, **2**, and/or **6**. In the example of FIG. **7**, the touch controller **104** selectively controls operation of the display screen **102** of FIGS. **1** and **2** to operate in a first mode as a touch screen or in a second mode as an ECG sensor. The example instructions of FIG. **7** can be executed by one or more processors of, for instance, a user device including the display screen **102** (e.g., the personal computing device **400**) and/or a cloud-based device. The instructions of FIG. **7** can be executed in substantially real-time as, for example, signal data indicative of user touch gestures on the display screen **102** is received by the controller **104**. In some examples, some of the instructions of FIG. **7** are executed some time after, for instance, signal data associated with the user's ECG data is received by the touch controller **104**.

[0065] The example drive signal activator **600** of FIG. **6** instructs the drive signal source **118** (e.g., a generator) to generate drive signals that are transmitted to the drives lines **106** of the display screen **102** (block **700**). The drive signal activator **600** instructs the drive signal source to generate the drive signals based on drive signal rule(s) **602**. The drive signal rule(s) **602** can be stored in the database **604**.

[0066] The multiplexer **130** of FIGS. **1**, **2**, and **6** accesses signal data generated by the sense line(s) **108** of the display screen **102** (block **702**). As discussed above, the sense line(s) **108** detect voltage drops with respect to the current flowing through the drive line(s) **106** when a user touches the display screen **102** due to changes in mutual capacitance. The multiplexer **130** receives signal data **605** from the sense line(s) **108** indicative of the voltage changes and provides the data to the integrator **134** of the touch controller **104**. The integrator **134** performs an integration on the signal data **605** from the sense line(s) **108** and transmits the signal data the A/D converter **136** of the touch controller **104** for digital processing.

[0067] The example touch event analyzer **608** of the digital signal processor of FIG. **6** analyzes the signal data **605** from the sense line(s) **108** to determine if the signal data **605** indicates a user touch gesture on the display screen **102** (block **704**). For example, the touch event analyzer **608** identifies touch events based on the touch event rule(s) **610** that define, for instance, threshold voltage drop values corresponding to user touch event(s) and location(s) of the touch event(s).

[0068] In the example of FIG. **7**, if the touch event analyzer **608** identifies a user touch event, the ECG electrode controller **612** of FIG. **6** determines if the touch event represents a trigger event to activate the ECG sensing electrodes **140**, **148** (block **706**). For example, based on the ECG activator rule(s) **614** and the data received from the touch event analyzer **608**, the ECG electrode controller **612** determines if the user has touched the display screen **102** proximate to the areas of the display screen **102** including the ECG sensing electrodes **140**, **148** (e.g., proximate to the third and fourth edges **114**, **116** of the display screen **102**). In some examples, the ECG electrode controller **612** determines if the user has touched the display screen **102** proximate to the areas of the display screen **102** including the ECG sensing electrodes **140**, **148** for a predetermined period of time based on the ECG activator rule(s) **614** and data received from the touch event analyzer **608**.

[0069] In the example of FIG. **7**, if the touch event analyzer **608** does not detect a touch event based on the signal data from the sense line(s) **108** or if the touch event analyzer detects a touch event, but does not detect an ECG trigger event based on the touch event, then the touch controller **104** continues to access signal data from the sense line(s) **108** of the display screen **102** (block **702**) and the touch event analyzer **608** continues to analyze the signal data to detect touch event(s) (blocks **704**, **706**).

[0070] If the ECG electrode controller **612** determines that an ECG trigger event has occurred, the ECG electrode controller **612** communicates with the drive signal activator **600** to instruct the drive signal source **118** to refrain from generating the drive signals (block **708**). The ECG electrode controller **612** also activates the first and second ECG sensing electrodes **140**, **148** (block **710**). For example, the ECG electrode controller **612** generates instructions for data from the drive line(s) **106** to be transmitted to the integrators **144**, **152** and the amplifiers **146**, **154** of the respective ECG sensing electrodes **140**, **148**. As discussed above, when the first and second ECG sensing electrodes **140**, **148** are activated, the touch functionality of the display screen **102** is disabled due to the lack of drive signals from the drive signal source **118**.

[0071] When the display screen **102** is operating in the ECG-sensing mode, the A/D converter **136** of the touch controller **104** accesses first signal data **616** generated by the first ECG sensing electrode **140** in response to changes in self-capacitance detected by the drive line(s) **106** of the first drive line set **142** of the first ECG sensing electrode **140** (block **712**). The A/D converter **136** accesses second signal data **618** generated by the second ECG sensing electrode **148** in response to changes in self-capacitance detected by the drive line(s) **106** of the second drive line set **150** of the second ECG sensing electrode **148** (block **712**). The A/D converter **136** converts the signal data **616**, **618** to digital data for processing by the digital signal processor **138**. In some examples, the filter **606** filters the signal date for noise related to, for instance, user movements.

[0072] The calculator **620** of FIG. **6** generates ECG signal data **622** by calculating the difference between the first signal data **616** from the first ECG sensing electrode **140** and the second signal data **618** from the second ECG sensing electrode **148** (block **714**). The ECG signal data **622** can be stored in the database **604**.

[0073] The calculator **620** of FIG. **6** outputs the ECG signal data for analysis with respect to, for example, health metrics of the user (block **716**). In some examples, the ECG data analyzer **624** of the digital signal processor **138** performs at least some analysis of the ECG signal data. For instance, the ECG data analyzer **624** can calculate the user's heart rate based on the ECG signal data **622**. In some examples, the calculator **620** transmits the ECG signal data **622** to one or more ECG user applications **626** implemented by processor(s) of the personal computing device including the display screen **102** and/or by cloud-based device(s).

[0074] In FIG. **7**, the ECG electrode controller **612** determines if additional ECG data should be collected from the user and, thus, the ECG sensing electrodes **140**, **148** should remain active, or if the display screen **102** should return to operating as a touch screen (block **718**). If additional ECG signal data is to be collected, then the example of FIG. **7** continues to access signal data generated by the first and second ECG sensing electrodes **140**, **148** (block **712**). However, if no additional ECG signal data is to be collected, then the example of FIG. **7** determines that the display screen **102** should return to operating as a touch screen. For example, if the A/D converter **136** does not receive signal data **616**, **618** from the ECG sensing electrode(s) **140**, **148** for a predefined period of time, the ECG electrode controller **612** determines that the user removed his or her hand(s) from the display screen. In such examples, the ECG electrode controller **612** generates instructions for the integrators **144**, **152** and the amplifiers **146**, **154** of the respective ECG sensing electrodes **140**, **148** to become inactive.

[0075] When no additional ECG data is to be collected, the ECG electrode controller **612** communicates with the drive signal activator **600** to instruct the drive signal source **118** to resume generation and transmission of drive signals to the drive line(s) **106** of the display screen **102**, thereby reactivating the touch functionality of the display screen **102** (block **720**). The example instructions of FIG. **7** end when the display screen **102** is powered off (block **722**).

[0076] FIG. **8** is a block diagram of an example processor platform **800** structured to execute the instructions of FIG. **7** to implement the example touch controller **104** of FIGS. **1**, **2**, and/or **6**. The processor platform **800** can be, for example, a server, a personal computer, a workstation, a self-learning machine (e.g., a neural network), a mobile device (e.g., a cell phone, a smart phone, a tablet such as an iPad™), a personal digital assistant (PDA), an Internet appliance, a headset or other wearable device, or any other type of computing device.

[0077] The processor platform **800** of the illustrated example includes a processor **104**. The processor **104** of the illustrated example is hardware. For example, the processor **104** can be implemented by one or more integrated circuits, logic circuits, microprocessors, GPUs, DSPs, or controllers from any desired family or manufacturer. The hardware processor may be a semiconductor based (e.g., silicon based) device. In this example, the processor executes the instructions represented by FIG. **7** to implement the example multiplexer **130**, the example integrator **134**, the example A/D converter **136**, the example digital signal processor **138**, the example drive signal activator **600**, the example database **604**, the example filter **606**, the example touch event analyzer **608**, the example ECG electrode controller **612**, the example calculator **620**, and/or the example ECG data analyzer **624**.

[0078] The processor **104** of the illustrated example includes a local memory **813** (e.g., a cache). The processor **812** of the illustrated example is in communication with a main memory including a volatile memory **814** and a non-volatile memory **816** via a bus **818**. The volatile memory **814** may be implemented by Synchronous Dynamic Random Access Memory (SDRAM), Dynamic Random Access Memory (DRAM), RAMBUS® Dynamic Random Access Memory (RDRAM®) and/or any other type of random access memory device. The non-volatile memory **816** may be implemented by flash memory and/or any other desired type of memory device. Access to the main memory **814**, **816** is controlled by a memory controller.

[0079] The processor platform **800** of the illustrated example also includes an interface circuit **820**. The interface circuit **820** may be implemented by any type of interface standard, such as an Ethernet interface, a universal serial bus (USB), a Bluetooth® interface, a near field communication (NFC) interface, and/or a PCI express interface.

[0080] In the illustrated example, one or more input devices **822** are connected to the interface circuit **820**. The input device(s) **822** permit(s) a user to enter data and/or commands into the processor **812**. The input device(s) can be implemented by, for example, an audio sensor, a microphone, a camera (still or video), a keyboard, a button, a mouse, a touchscreen, a track-pad, a trackball, isopoint and/or a voice recognition system.

[0081] One or more output devices **824** are also connected to the interface circuit **820** of the illustrated example. The output devices **824** can be implemented, for example, by display devices (e.g., a light emitting diode (LED), an organic light emitting diode (OLED), a liquid crystal display (LCD), a cathode ray tube display (CRT), an in-place switching (IPS) display, a touchscreen, etc.), a tactile output device, a printer and/or speaker. The interface circuit **820** of the illustrated example, thus, typically includes a graphics driver card, a graphics driver chip and/or a graphics driver processor.

[0082] The interface circuit **820** of the illustrated example also includes a communication device such as a transmitter, a receiver, a transceiver, a modem, a residential gateway, a wireless access point, and/or a network interface to facilitate exchange of data with external machines (e.g., computing devices of any kind) via a network **826**. The communication can be via, for example, an Ethernet connection, a digital subscriber line (DSL) connection, a telephone line connection, a coaxial cable system, a satellite system, a line-of-site wireless system, a cellular telephone system, etc.

[0083] The processor platform **800** of the illustrated example also includes one or more mass storage devices **828** for storing software and/or data. Examples of such mass storage devices **828** include floppy disk drives, hard drive disks, compact disk drives, Blu-ray disk drives, redundant array of independent disks (RAID) systems, and digital versatile disk (DVD) drives.

[0084] The machine executable instructions **832** of FIG. **7** may be stored in the mass storage device **828**, in the volatile memory **814**, in the non-volatile memory **816**, and/or on a removable non-transitory computer readable storage medium such as a CD or DVD.

[0085] From the foregoing, it will be appreciated that example apparatus. methods, and articles of manufacture have been disclosed that provide for sensing of ECG data from a user via an electronic touch display screen of a personal computing device. Examples disclosed herein provide for selective operation of the display screen in a first mode as a touch screen to receive user touch inputs to enable the user to interact with digital content presented via the display screen or in a second mode in which the display screen as an ECG sensor. In examples disclosed herein, drive lines of the display screen can detect changes in self-capacitance when the user touches the display screen and, thus, act as capacitive ECG electrodes. Accordingly, example display screens disclosed herein utilize existing components of the display screen to sense user ECG data that can provide indications of the user's health.

[0086] Example 1 includes an electronic user device including a display screen including a first electrode and a second electrode and a processor operatively coupled to the display screen. The processor is to cause the display screen to operate in a first display screen mode to detect a touch input from a user on the display screen. The processor is to cause the display screen to switch from operating in the first display screen mode to operating in a second display screen mode. The first electrode and the second electrode are to generate signal data indicative of electrocardiogram data for the user when the display screen is operating in the second display screen mode.

[0087] Example 2 includes the electronic user device as defined in example 1, wherein the processor is to cause the display screen to operate in the second display screen mode based on the touch input from the user.

[0088] Example 3 includes the electronic user device as defined in example 1, wherein the display screen includes a plurality of drive lines and the first electrode includes at least one of the plurality of drive lines.

[0089] Example 4 includes the electronic user device as defined in example 3, wherein the first electrode further includes an amplifier in communication with the at least one of the plurality of drive lines.

[0090] Example 5 includes the electronic user device as defined in example 3, wherein the at least one of the plurality of drive lines is to transmit a drive signal when the display screen is operating in the first display screen mode and generate signal indicative of a change in capacitance when the display screen is operating in the second display screen mode.

[0091] Example 6 includes the electronic user device as defined in examples 1 or 2, wherein the first electrode is to generate first signal data in response to a first touch of the user on the display screen proximate to the first electrode and the second electrode is to generate second signal data in response to a second touch of the user on the display screen proximate to the second electrode when the display screen is operating in the second display screen mode and the processor is to calculate a difference between the first signal data and the second signal data and output electrocardiogram signal data for the user based on the difference.

[0092] Example 7 includes the electronic user device as defined in example 1, wherein the first electrode is disposed proximate to a first edge of the display screen and the second electrode is disposed proximate to a second edge of the display screen opposite the first edge.

[0093] Example 8 includes the electronic user device as defined in example 7, wherein the processor is to detect a first touch input by the user proximate to the first edge of the display screen, detect a second touch input by the user proximate to the second edge of the display screen, and cause the display screen to switch from operating in the first display screen mode to operating in the second display screen mode based on the first touch input and the second touch input.

[0094] Example 9 includes the electronic user device as defined in examples 1 or 2, wherein the display screen is a first display screen and further including a second display screen, the second display screen to operate in the first display screen mode when the first display screen is operating in the second display screen mode.

[0095] Example 10 includes an apparatus including a display screen including drive lines to transmit drive signals, sense lines, a first electrode including a first portion of the drive lines, and a touch controller operatively coupled to the display screen. The touch controller to cause the drive lines to transmit drive signals, the sense lines to detect the drive signals, detect a touch event by a user on the display screen based on signal data received from the sense lines, and activate the first electrode based on the touch event, the first portion of the drive lines to generate first signal data indicative of electrocardiogram data for the user when the first electrode is activated.

[0096] Example 11 includes the apparatus of example 10, wherein the display screen includes a second electrode including a second portion of the drive lines, the touch controller to further activate the second electrode based on the touch event, the second portion of the drive lines to generate second signal data indicative of the electrocardiogram data for the user when the second electrode is activated.

[0097] Example 12 includes the apparatus of example 11, wherein the touch controller is to generate electrocardiogram data for the user based the first signal data and the second signal data.

[0098] Example 13 includes the apparatus of example 12, wherein the touch controller is to cause the first portion of the drives lines to switch from generating the first signal data to transmitting the drive signals based on the generation of the electrocardiogram data.

[0099] Example 14 includes the apparatus of example 11, wherein the first electrode is disposed at a first region of the display screen and the second electrode is disposed at a second region of the display screen and the touch event includes a first touch input received at the first region and a second touch input received at the second region.

[0100] Example 15 includes the apparatus of example 11, wherein the first electrode is disposed at a first region of the display screen and the second electrode is disposed at a second region of the display screen and the touch event includes a first touch input received at the first region and a second touch input received at the second region.

[0101] Example 16 includes the apparatus of example 10, wherein the first electrode further includes an integrator and an amplifier.

[0102] Example 17 include at least one non-transitory computer readable storage medium comprising instructions that, when executed, cause a machine to cause a display screen of an electronic user device to operate in a first mode, the display screen including drives lines to transmit drive signals and sense lines to generate signal data indicative of a touch of a user on the display screen based on the drive signals when the display screen is operating the first mode and cause the display screen to switch from operating in the first mode to operating in a second mode, the display screen including an electrode to generate signal data indicative of electrocardiogram data for the user when the display screen is operating in the second mode.

[0103] Example 18 includes the at least one non-transitory computer readable storage medium as defined in example 17, wherein the instructions, when executed, further cause the machine to selectively instruct a drive signal generator to generate the drive signals based on the operation of the display screen in the first mode or the second mode.

[0104] Example 19 includes the at least one non-transitory computer readable storage medium as defined in example 17, wherein the electrode includes a first electrode and a second electrode, the signal data includes first signal data generated by the first electrode and second signal data generated by the second electrode, and the instructions, when executed, further cause the machine to calculate electrocardiogram signal data for the user based on the first signal data and the second signal data.

[0105] Example 20 includes the at least one non-transitory computer readable storage medium as defined in example 19, wherein the instructions, when executed, further cause the machine to determine a health metric for the user based on the electrocardiogram signal data.

[0106] Example 21 includes the at least one non-transitory computer readable storage medium as defined in example 17, wherein the instructions, when executed, further cause the machine to cause the display screen to operate in the second mode based on the signal data from the sense lines.

[0107] Example 22 includes the at least one non-transitory computer readable storage medium as defined in example 17, wherein the instructions further cause the machine to filter the signal data generated by the electrode.

[0108] Example 23 includes an apparatus comprising a display screen including first means for sensing electrocardiogram data from a subject, second means for sensing electrocardiogram data from a subject, means for causing the display screen to operate in a first mode as a touch screen, and means for selectively activating the first means for sensing and the second means for sensing to cause the display screen to operate in a second mode as an electrocardiogram sensor.

[0109] Example 24 includes the apparatus of example 23, wherein the means for causing the display screen to operate in a first mode is to cause a drive signal generator to transmit drive signals to drive lines of the display screen.

[0110] Example 25 includes the apparatus of example 23, wherein the means for selectively activating is to activate the first means for sensing and the second means for sensing based on a touch input on the display screen.

[0111] Example 26 includes the apparatus of example 23, further including means for determining electrocardiogram signal data for the subject based on first signal data from the first means for sensing and second signal data from the second means for sensing.

[0112] Example 27 includes the apparatus of example 26, further including means for analyzing the electrocardiogram signal data to determine a health metric for the subject.

[0113] "Including" and "comprising" (and all forms and tenses thereof) are used herein to be open ended terms. Thus, whenever a claim employs any form of "include" or "comprise" (e.g., comprises, includes, comprising, including, having, etc.) as a preamble or within a claim recitation of any kind, it is to be understood that additional elements, terms, etc. may be present without falling outside the scope of the corresponding claim or recitation. As used herein, when the phrase "at least" is used as the transition term in, for example, a preamble of a claim, it is open-ended in the same manner as the term "comprising" and "including" are open ended. The term "and/or" when used, for example, in a form such as A, B, and/or C refers to any combination or subset of A, B, C such as (1) A alone, (2) B alone, (3) C alone, (4) A with B, (5) A with C, (6) B with C, and (7) A with B and with C. As used herein in the context of describing structures, components, items, objects and/or things, the phrase "at least one of A and B" is intended to refer to implementations including any of (1) at least one A, (2) at least one B, and (3) at least one A and at least one B. Similarly, as used herein in the context of describing structures, components, items, objects and/or things, the phrase "at least one of A or B" is intended to refer to implementations including any of (1) at least one A, (2) at least one B, and (3) at least one A and at least one B. As used herein in the context of describing the performance or execution of processes, instructions, actions, activities and/or steps, the phrase "at least one of A and B" is intended to refer to implementations including any of (1) at least one A, (2) at least one B, and (3) at least one A and at least one B.

Similarly, as used herein in the context of describing the performance or execution of processes, instructions, actions, activities and/or steps, the phrase "at least one of A or B" is intended to refer to implementations including any of (1) at least one A, (2) at least one B, and (3) at least one A and at least one B.

[0114] Although certain example methods, apparatus and articles of manufacture have been disclosed herein, the scope of coverage of this patent is not limited thereto. On the contrary, this patent covers all methods, apparatus and articles of manufacture fairly falling within the scope of the claims of this patent.

1. An electronic user device comprising:

a display screen including a first electrode and a second electrode; and

a processor operatively coupled to the display screen, the processor to:

cause the display screen to operate in a first display screen mode to detect a touch input from a user on the display screen; and

cause the display screen to switch from operating in the first display screen mode to operating in a second display screen mode, the first electrode and the second electrode to generate signal data indicative of electrocardiogram data for the user when the display screen is operating in the second display screen mode.

2. The electronic user device as defined in claim **1**, wherein the processor is to cause the display screen to operate in the second display screen mode based on the touch input from the user.

3. The electronic user device as defined in claim **1**, wherein the display screen includes a plurality of drive lines and the first electrode includes at least one of the plurality of drive lines.

4. The electronic user device as defined in claim **3**, wherein the first electrode further includes an amplifier in communication with the at least one of the plurality of drive lines.

5. The electronic user device as defined in claim **3**, wherein the at least one of the plurality of drive lines is to:

transmit a drive signal when the display screen is operating in the first display screen mode; and

generate signal indicative of a change in capacitance when the display screen is operating in the second display screen mode.

6. The electronic user device as defined in claim **1**, wherein the first electrode is to generate first signal data in response to a first touch of the user on the display screen proximate to the first electrode and the second electrode is to generate second signal data in response to a second touch of the user on the display screen proximate to the second electrode when the display screen is operating in the second display screen mode, the processor to:

calculate a difference between the first signal data and the second signal data; and

output electrocardiogram signal data for the user based on the difference.

7. The electronic user device as defined in claim **1**, wherein the first electrode is disposed proximate to a first edge of the display screen and the second electrode is disposed proximate to a second edge of the display screen opposite the first edge.

8. The electronic user device as defined in claim **7**, wherein the processor is to:

detect a first touch input by the user proximate to the first edge of the display screen;

detect a second touch input by the user proximate to the second edge of the display screen; and

cause the display screen to switch from operating in the first display screen mode to operating in the second display screen mode based on the first touch input and the second touch input.

9. The electronic user device as defined in claim **1**, wherein the display screen is a first display screen and further including a second display screen, the second display screen to operate in the first display screen mode when the first display screen is operating in the second display screen mode.

10. An apparatus comprising:

a display screen including:

drive lines to transmit drive signals;

sense lines;

a first electrode including a first portion of the drive lines; and

a touch controller operatively coupled to the display screen, the touch controller to:

cause the drive lines to transmit drive signals, the sense lines to detect the drive signals;

detect a touch event by a user on the display screen based on signal data received from the sense lines; and

activate the first electrode based on the touch event, the first portion of the drive lines to generate first signal data indicative of electrocardiogram data for the user when the first electrode is activated.

11. The apparatus of claim **10**, wherein the display screen includes a second electrode including a second portion of the drive lines, the touch controller to further activate the second electrode based on the touch event, the second portion of the drive lines to generate second signal data indicative of the electrocardiogram data for the user when the second electrode is activated.

12. The apparatus of claim **11**, wherein the touch controller is to generate electrocardiogram data for the user based the first signal data and the second signal data.

13. The apparatus of claim **12**, wherein the touch controller is to cause the first portion of the drives lines to switch from generating the first signal data to transmitting the drive signals based on the generation of the electrocardiogram data.

14. The apparatus of claim **11**, wherein the first electrode is disposed at a first region of the display screen and the second electrode is disposed at a second region of the display screen and the touch event includes a first touch input received at the first region and a second touch input received at the second region.

15. The apparatus of claim **10**, further including a drive signal generator in communication with the touch controller, the touch controller to selectively cause the drive signal generator to generate the drive signals based on the signal data from the sense lines.

16. The apparatus of claim **10**, wherein the first electrode further includes an integrator and an amplifier.

17. At least one non-transitory computer readable storage medium comprising instructions that, when executed, cause a machine to:

cause a display screen of an electronic user device to operate in a first mode, the display screen including drives lines to transmit drive signals and sense lines to generate signal data indicative of a touch of a user on the display screen based on the drive signals when the display screen is operating the first mode; and

cause the display screen to switch from operating in the first mode to operating in a second mode, the display screen including an electrode to generate signal data indicative of electrocardiogram data for the user when the display screen is operating in the second mode.

18. The at least one non-transitory computer readable storage medium as defined in claim **17**, wherein the instructions, when executed, further cause the machine to selectively instruct a drive signal generator to generate the drive signals based on the operation of the display screen in the first mode or the second mode.

19. The at least one non-transitory computer readable storage medium as defined in claim **17**, wherein the electrode includes a first electrode and a second electrode, the signal data includes first signal data generated by the first electrode and second signal data generated by the second electrode, and the instructions, when executed, further cause the machine to calculate electrocardiogram signal data for the user based on the first signal data and the second signal data.

20. (canceled)

21. The at least one non-transitory computer readable storage medium as defined in claim **17**, wherein the instructions, when executed, further cause the machine to cause the display screen to operate in the second mode based on the signal data from the sense lines.

22.-**27**. (canceled)

* * * * *

专利名称(译)	电容式ECG感应电子显示器及相关方法		
公开(公告)号	US20190223813A1	公开(公告)日	2019-07-25
申请号	US16/370917	申请日	2019-03-30
[标]申请(专利权)人(译)	英特尔公司		
申请(专利权)人(译)	英特尔公司		
当前申请(专利权)人(译)	英特尔公司		
[标]发明人	LAWRENCE SEAN J W		
发明人	LAWRENCE, SEAN J. W.		
IPC分类号	A61B5/00 G06F3/041 G06F3/044 A61B5/044		
CPC分类号	A61B5/7475 G06F3/0416 G06F3/044 A61B5/044 A61B5/0404 A61B5/04085 A61B5/04284 G06F3/041662 G06F3/04182		
外部链接	Espacenet USPTO		

摘要(译)

本文公开了电容式ECG感测电子显示器和相关方法。这里公开的示例电子设备包括：显示屏，包括第一电极和第二电极;以及处理器，可操作地耦合到显示屏。处理器使显示屏幕以第一显示屏幕模式操作，以检测来自用户在显示屏幕上的触摸输入。处理器将使显示屏从在第一显示屏模式下操作切换到在第二显示屏模式下操作。当显示屏在第二显示屏模式下操作时，第一电极和第二电极产生指示用户的心电图数据的信号数据。