Apple Inc. v. Samsung Electronics Co. Ltd. et al
Doc. 561 Att. 16

EXHIBIT 3.17

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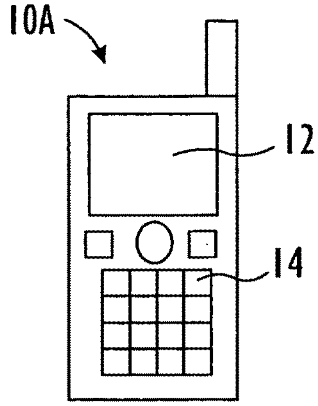

FIG. 1A
(PRIOR ART)

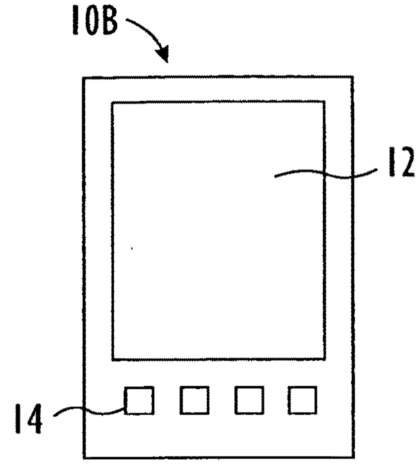

FIG. 1B
(PRIOR ART)

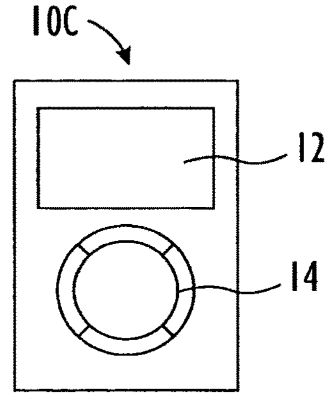

FIG. 1C
(PRIOR ART)

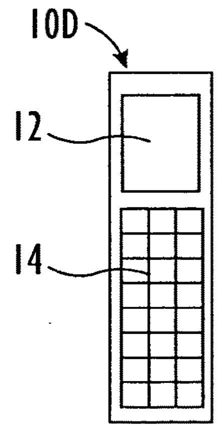

FIG. 1D
(PRIOR ART)

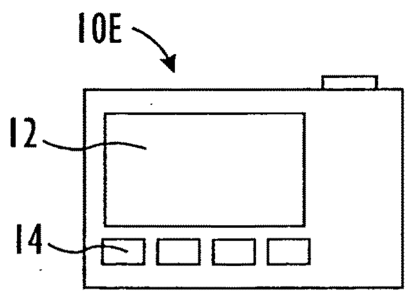

FIG. 1E
(PRIOR ART)

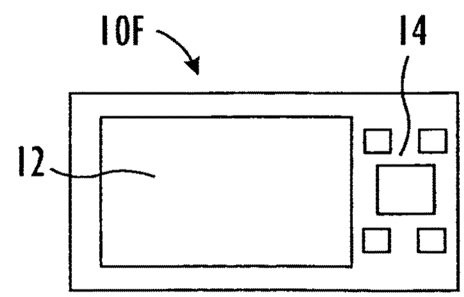

FIG. 1F
(PRIOR ART)

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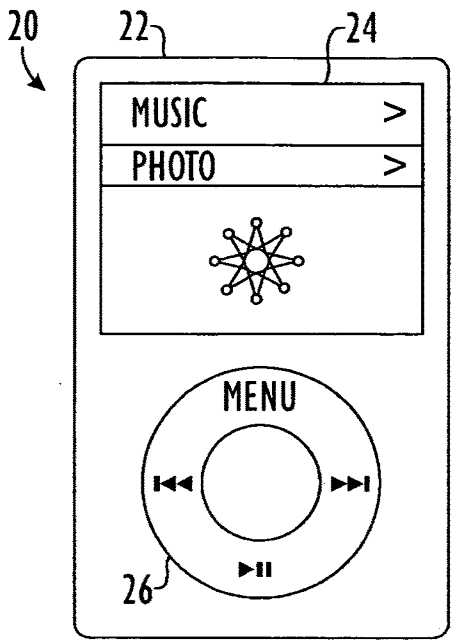

FIG. 2A
(PRIOR ART)

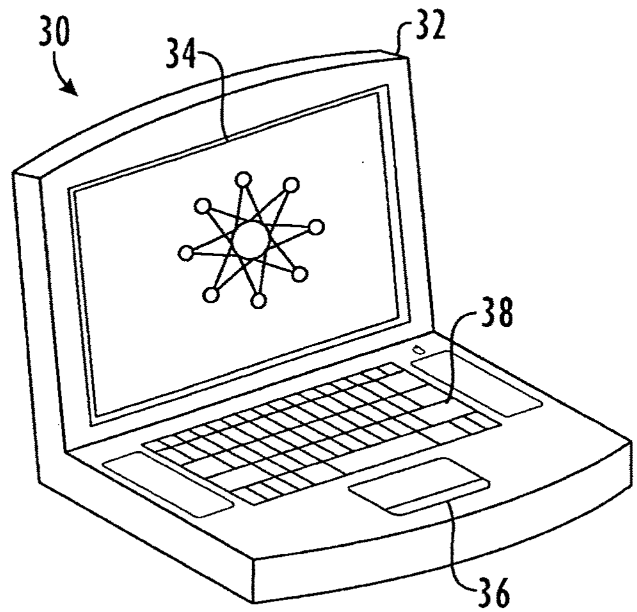

FIG. 2B
(PRIOR ART)

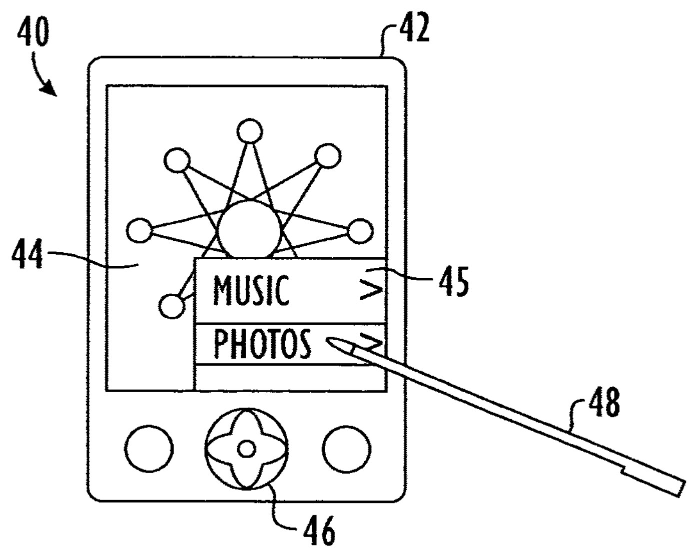

FIG. 2C
(PRIOR ART)

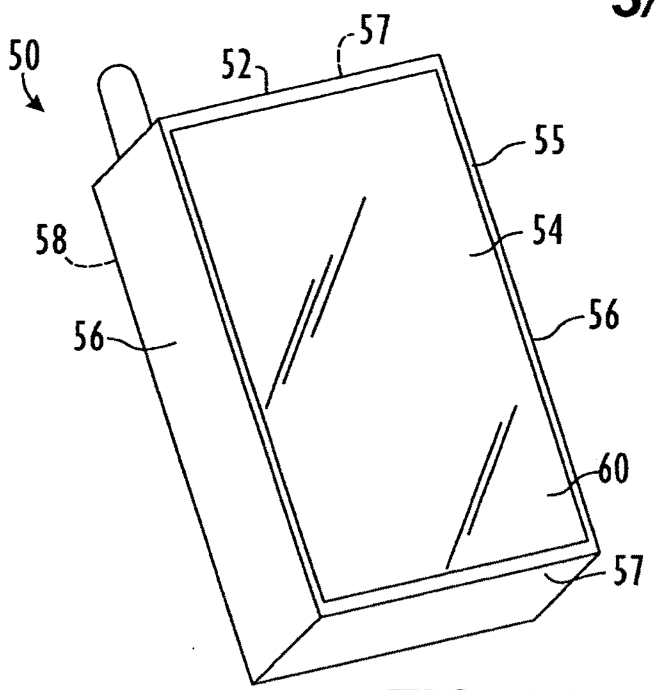

FIG. 3A

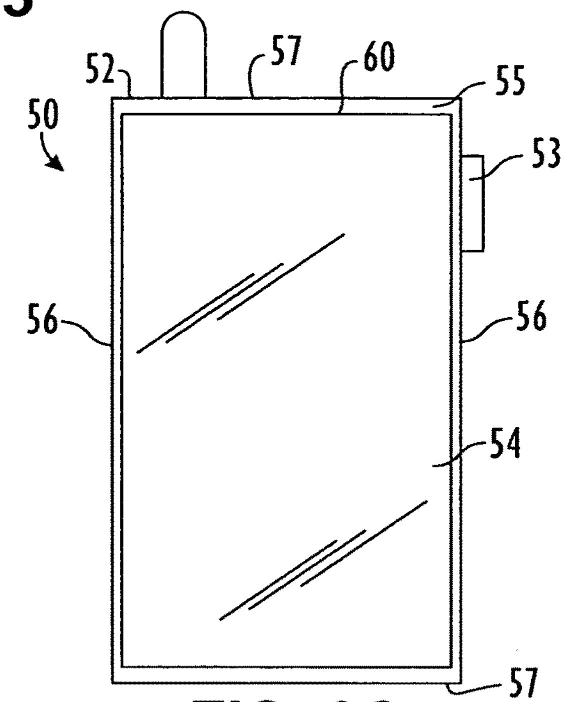

FIG. 3C

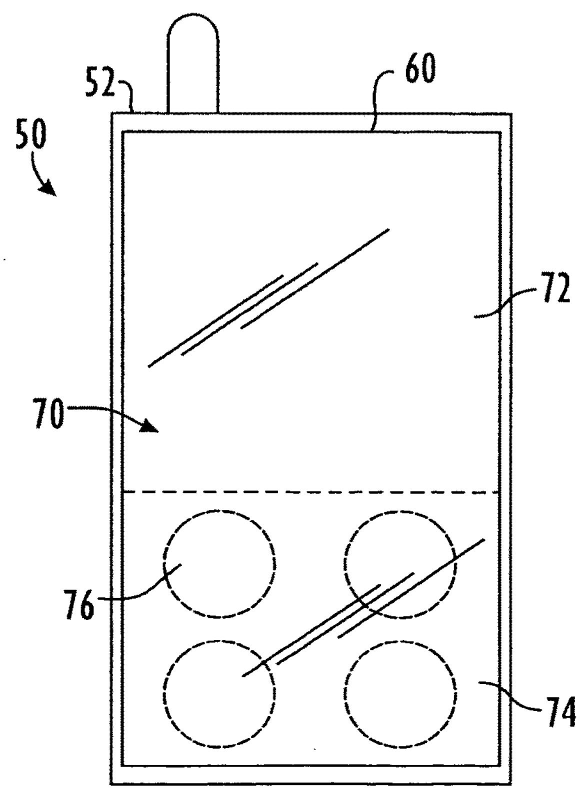

FIG. 3C

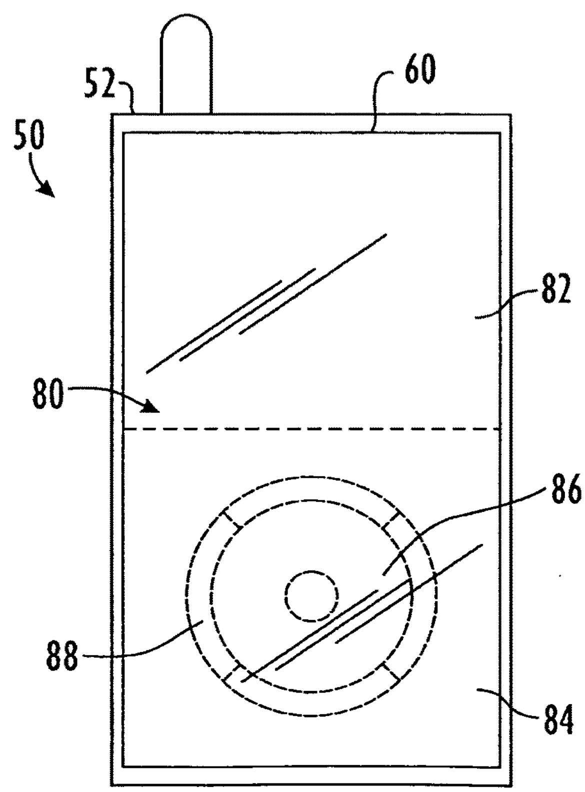

FIG. 3D

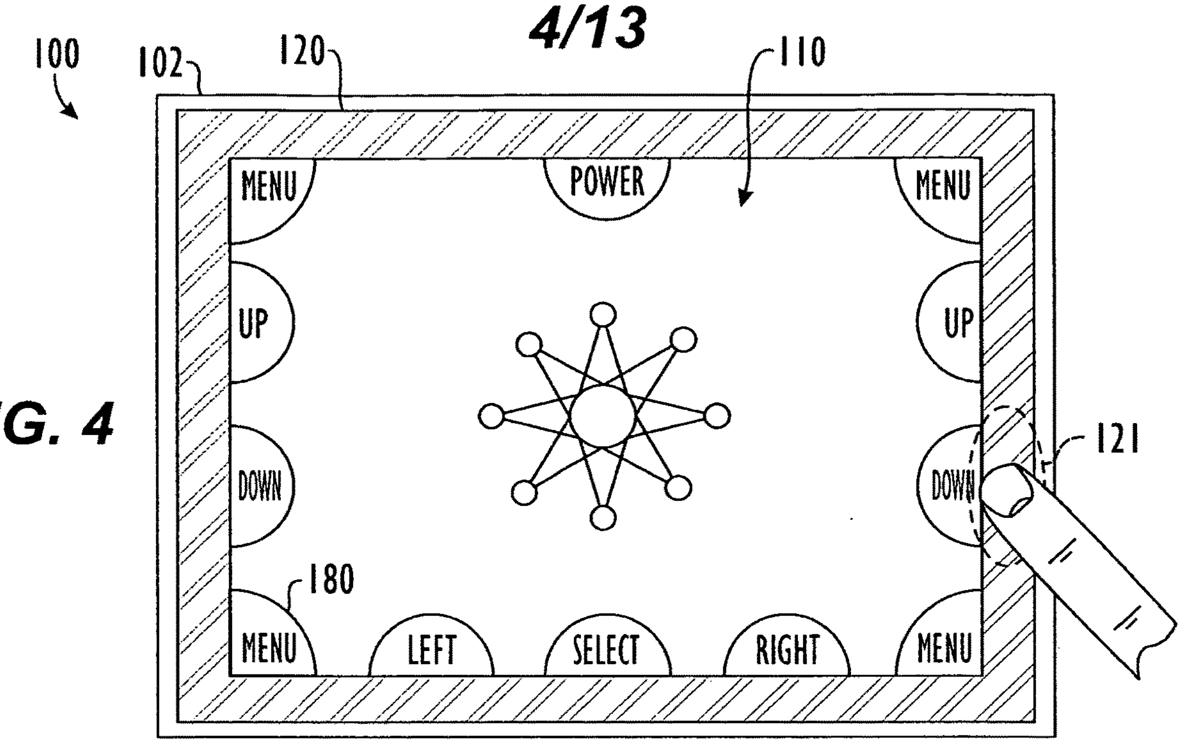
100
102
120
110
MENU
POWER
MENU
UP
UP
DOWN
DOWN
121
180
MENU
LEFT
SELECT
RIGHT
MENU

FIG. 4

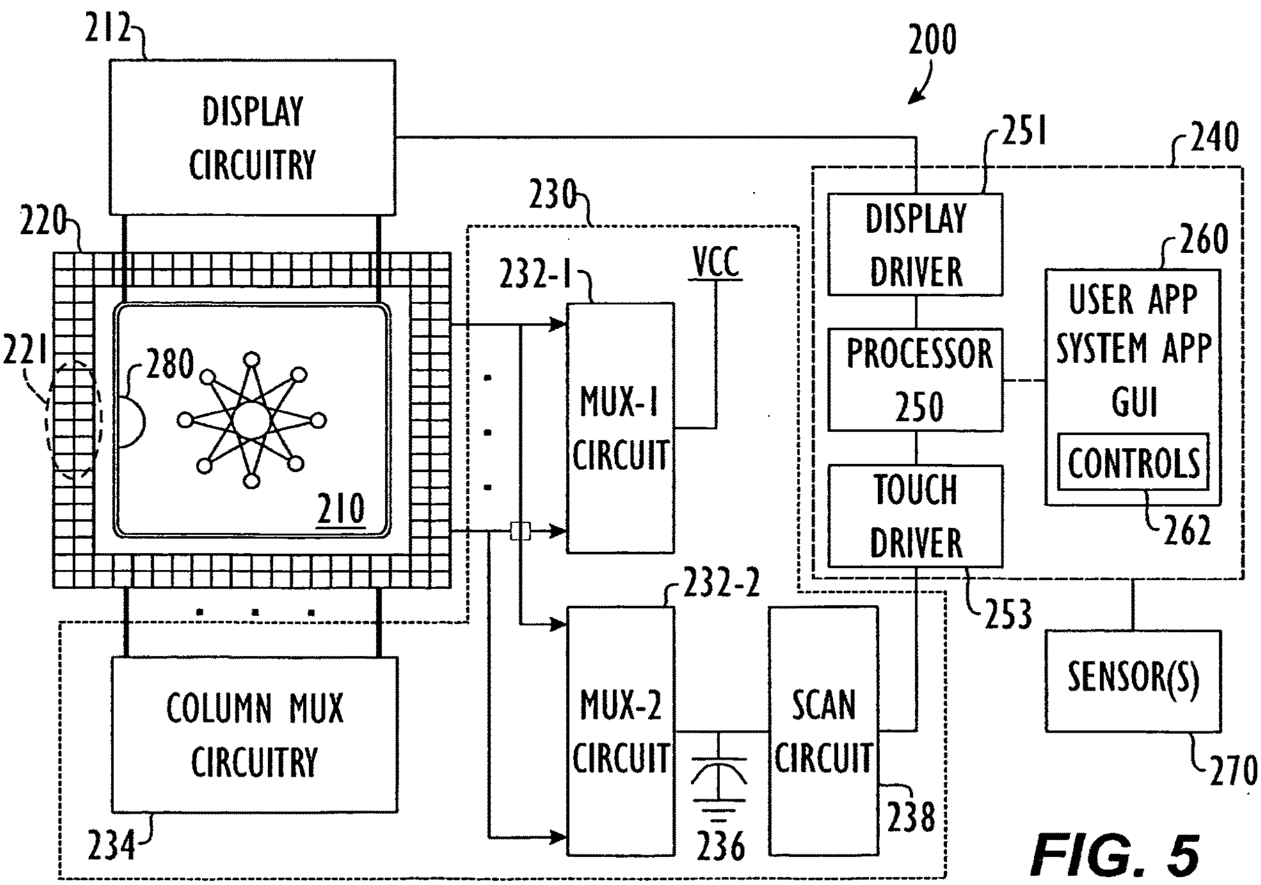
212
DISPLAY CIRCUITRY
200
251
240
220
230
DISPLAY DRIVER
232-1
VCC
260
USER APP
SYSTEM APP
GUI
221
280
MUX-1 CIRCUIT
PROCESSOR 250
CONTROLS
TOUCH DRIVER
210
262
232-2
253
SENSOR(S)
COLUMN MUX CIRCUITRY
MUX-2 CIRCUIT
SCAN CIRCUIT
270
238
234
236

FIG. 5

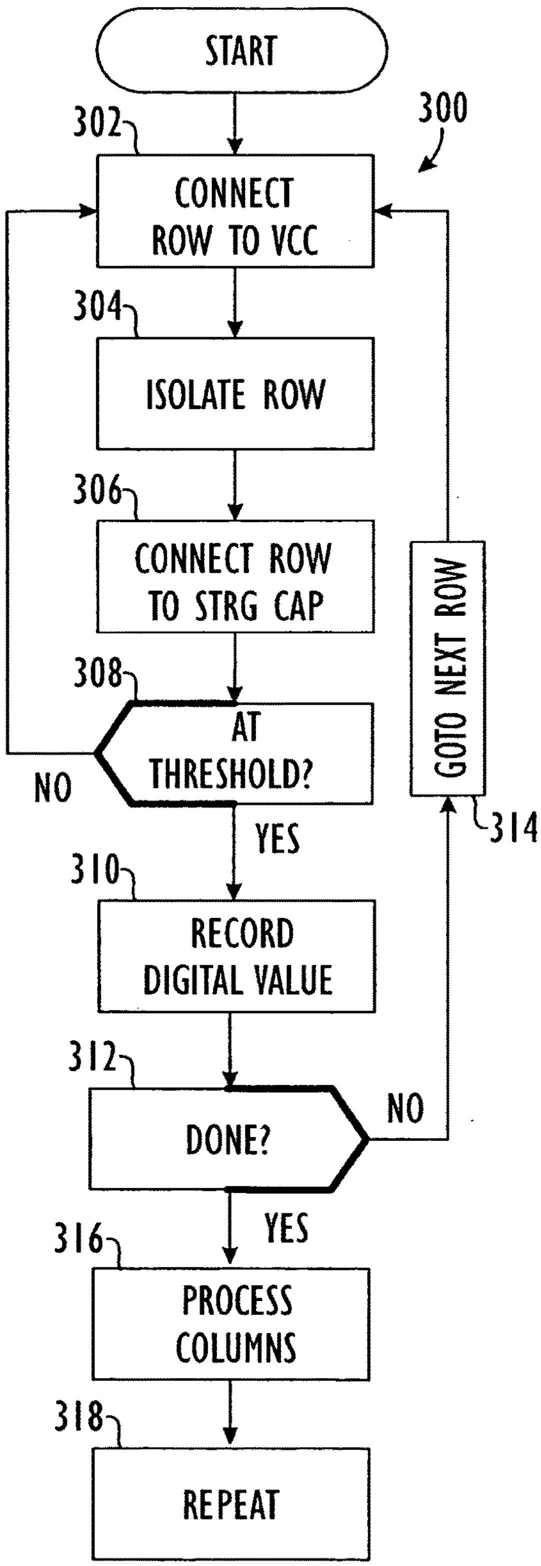
START
302
CONNECT ROW TO VCC
300
304
ISOLATE ROW
306
CONNECT ROW TO STRG CAP
308
AT THRESHOLD?
NO
YES
GOTO NEXT ROW
314
310
RECORD DIGITAL VALUE
312
DONE?
NO
YES
316
PROCESS COLUMNS
318
REPEAT

FIG. 6

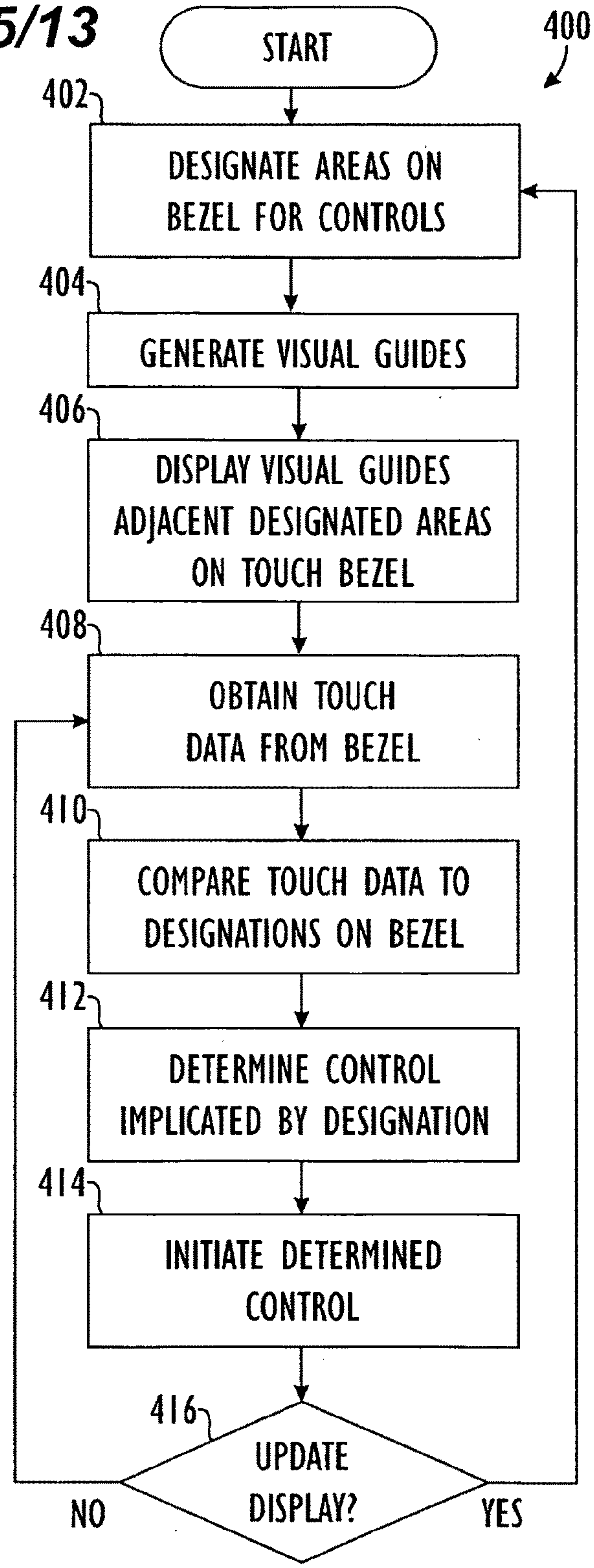
START
400
402
DESIGNATE AREAS ON BEZEL FOR CONTROLS
404
GENERATE VISUAL GUIDES
406
DISPLAY VISUAL GUIDES ADJACENT DESIGNATED AREAS ON TOUCH BEZEL
408
OBTAIN TOUCH DATA FROM BEZEL
410
COMPARE TOUCH DATA TO DESIGNATIONS ON BEZEL
412
DETERMINE CONTROL IMPLICATED BY DESIGNATION
414
INITIATE DETERMINED CONTROL
416
UPDATE DISPLAY?
NO
YES

FIG. 7

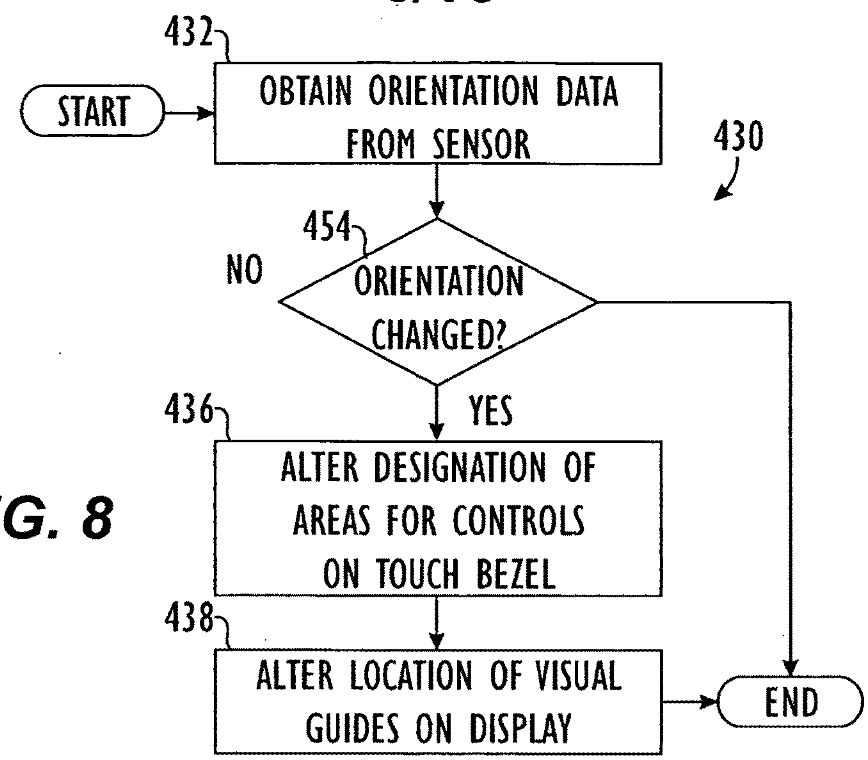

FIG. 8

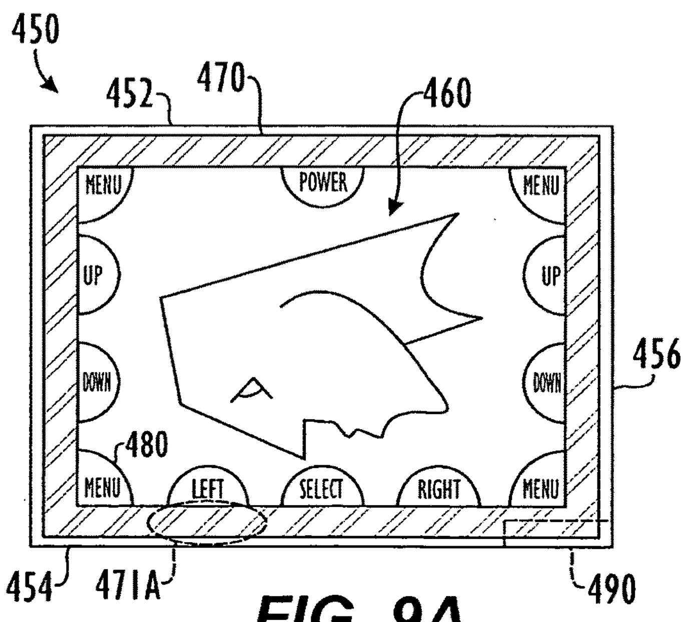

FIG. 9A

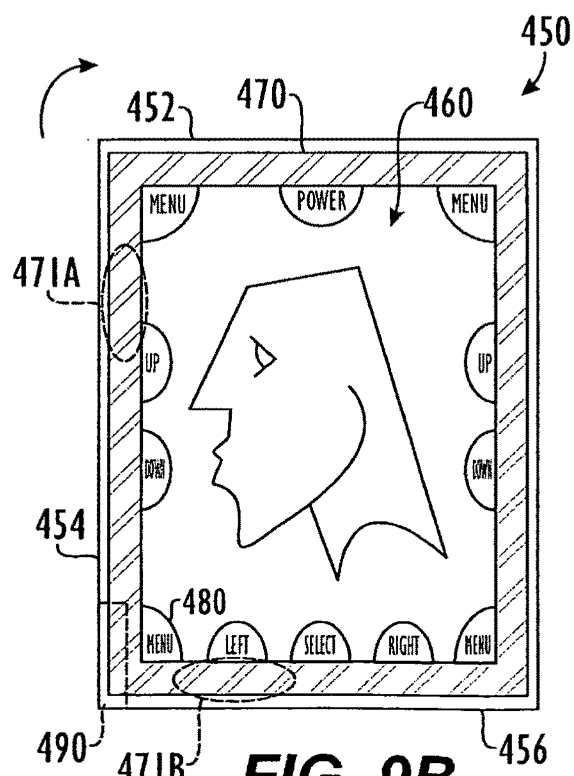

FIG. 9B

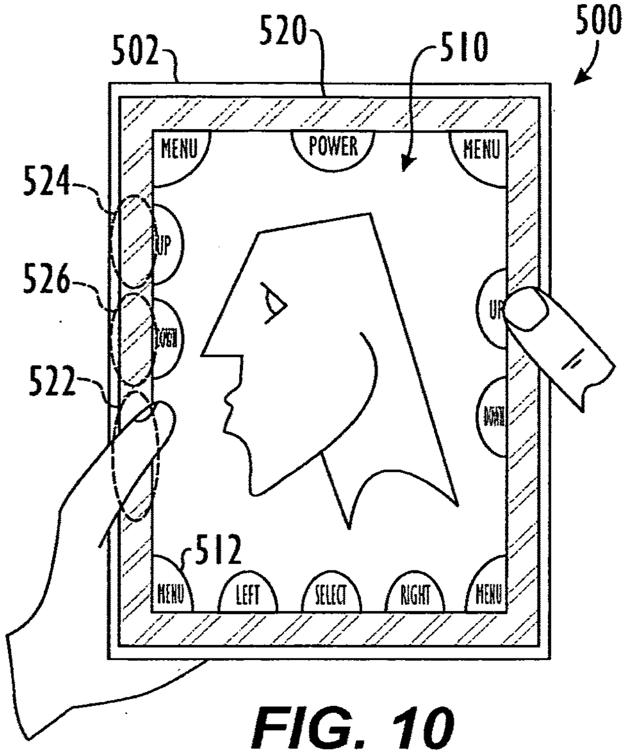

FIG. 10

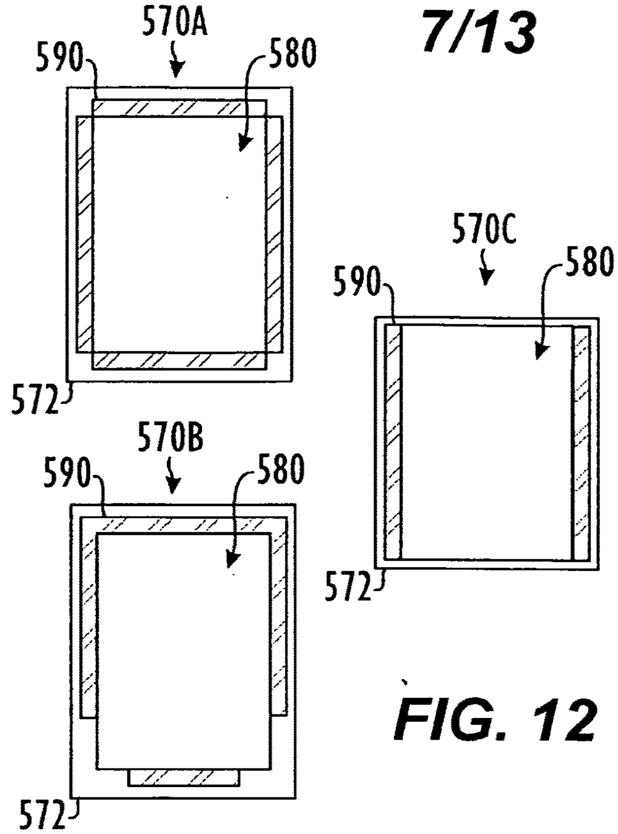

FIG. 12

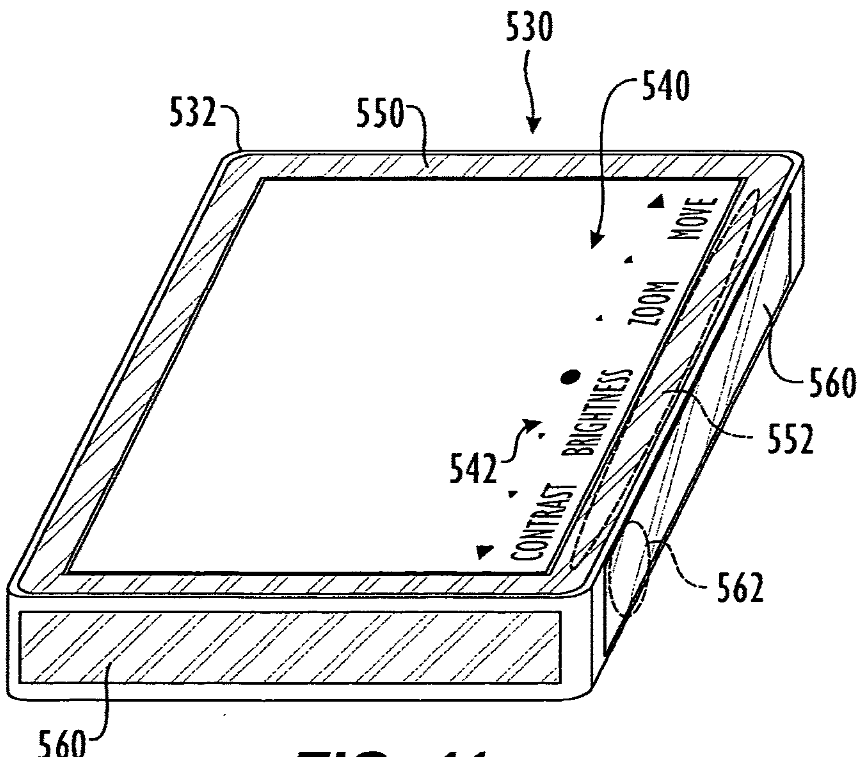

FIG. 11

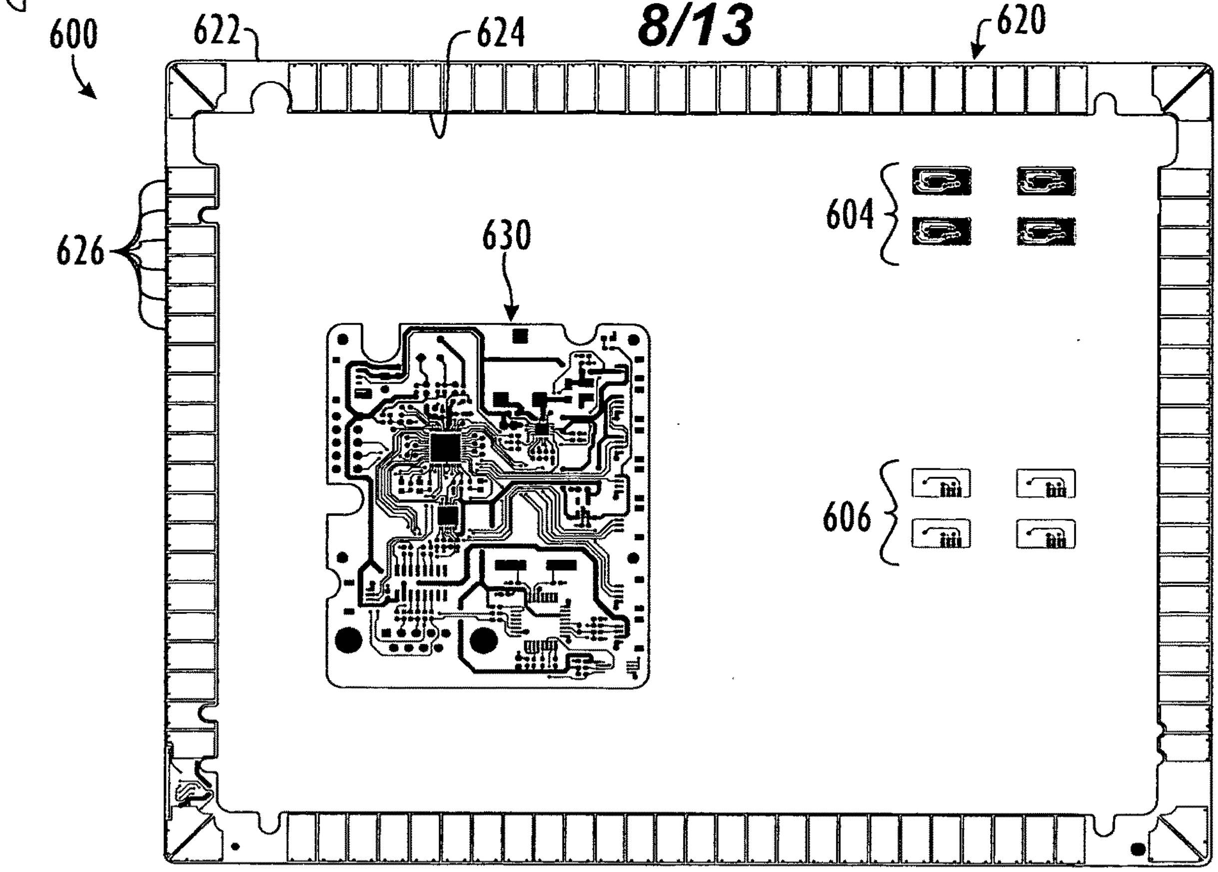

FIG. 13A

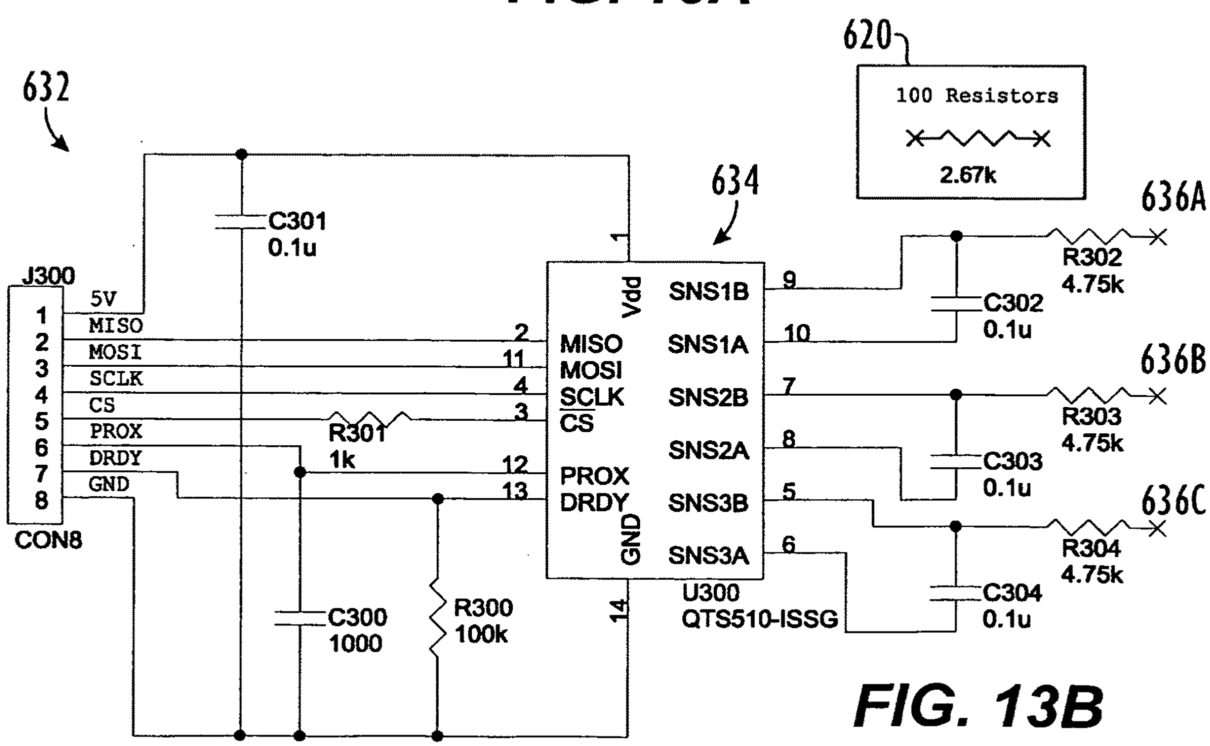

FIG. 13B

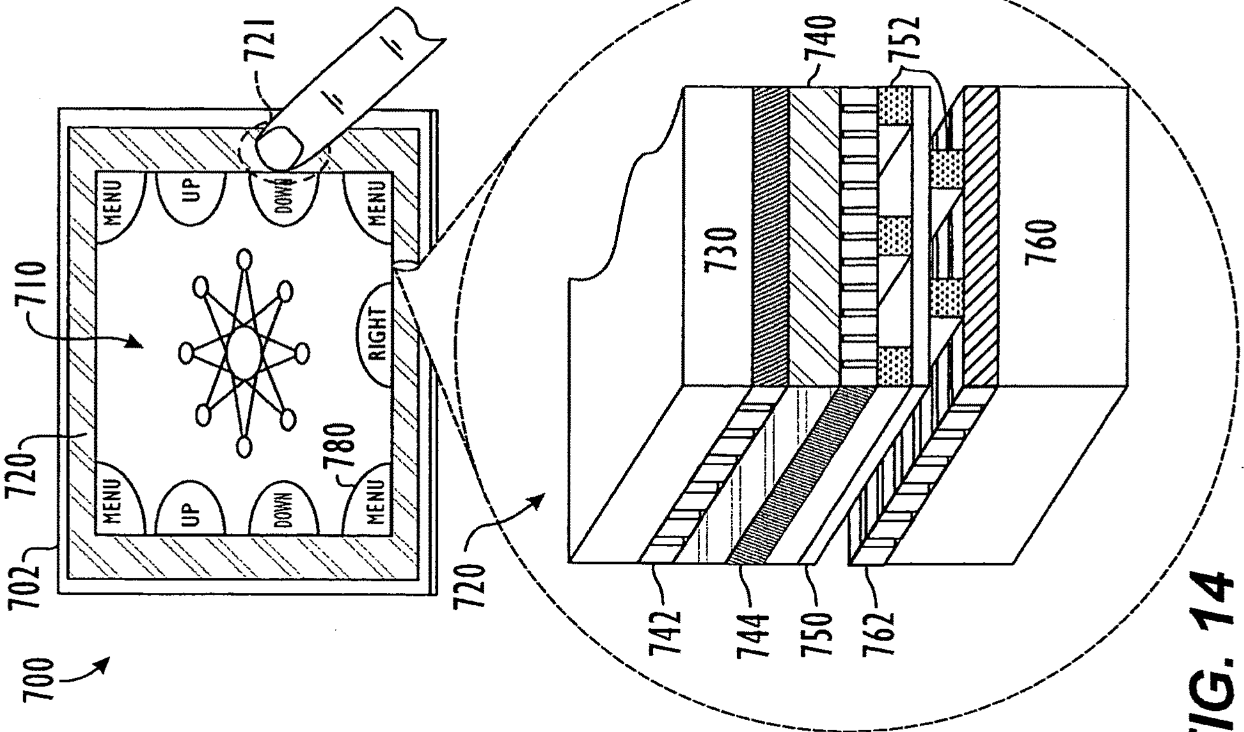

FIG. 14

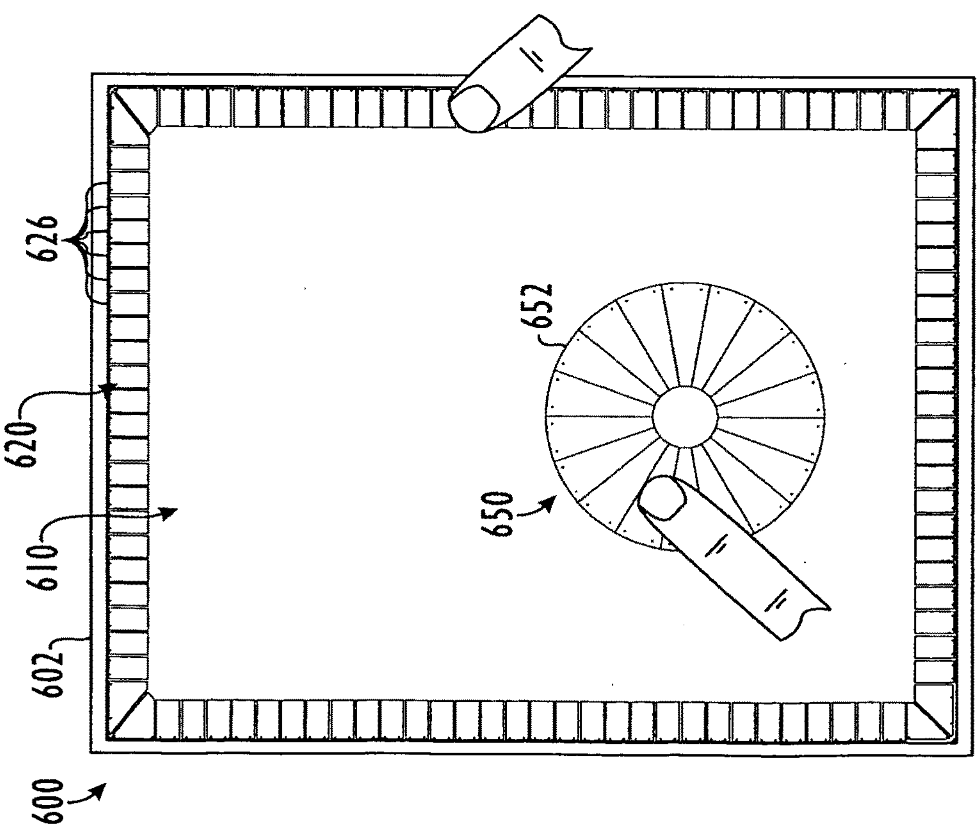

FIG. 13C

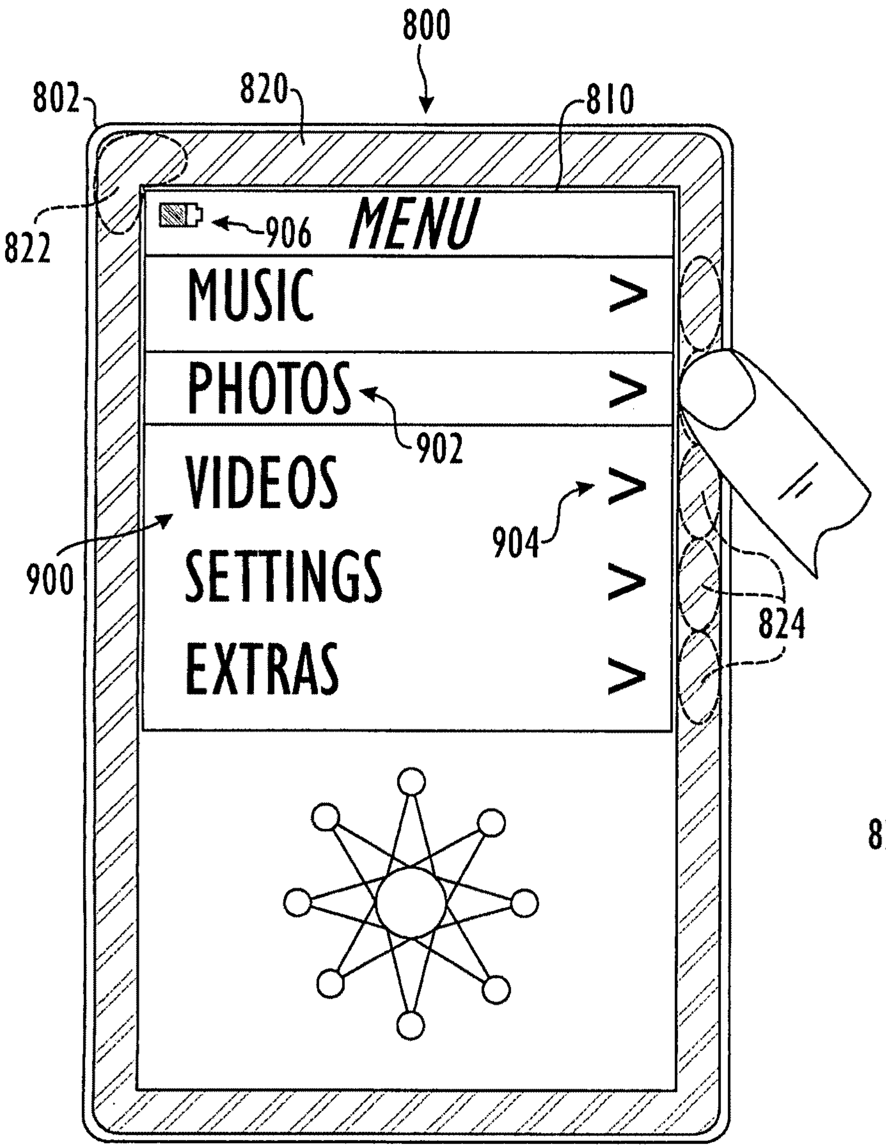
800
802
820
810
822
906
MENU
MUSIC
PHOTOS
902
VIDEOS
904
900
SETTINGS
EXTRAS
824

FIG. 15

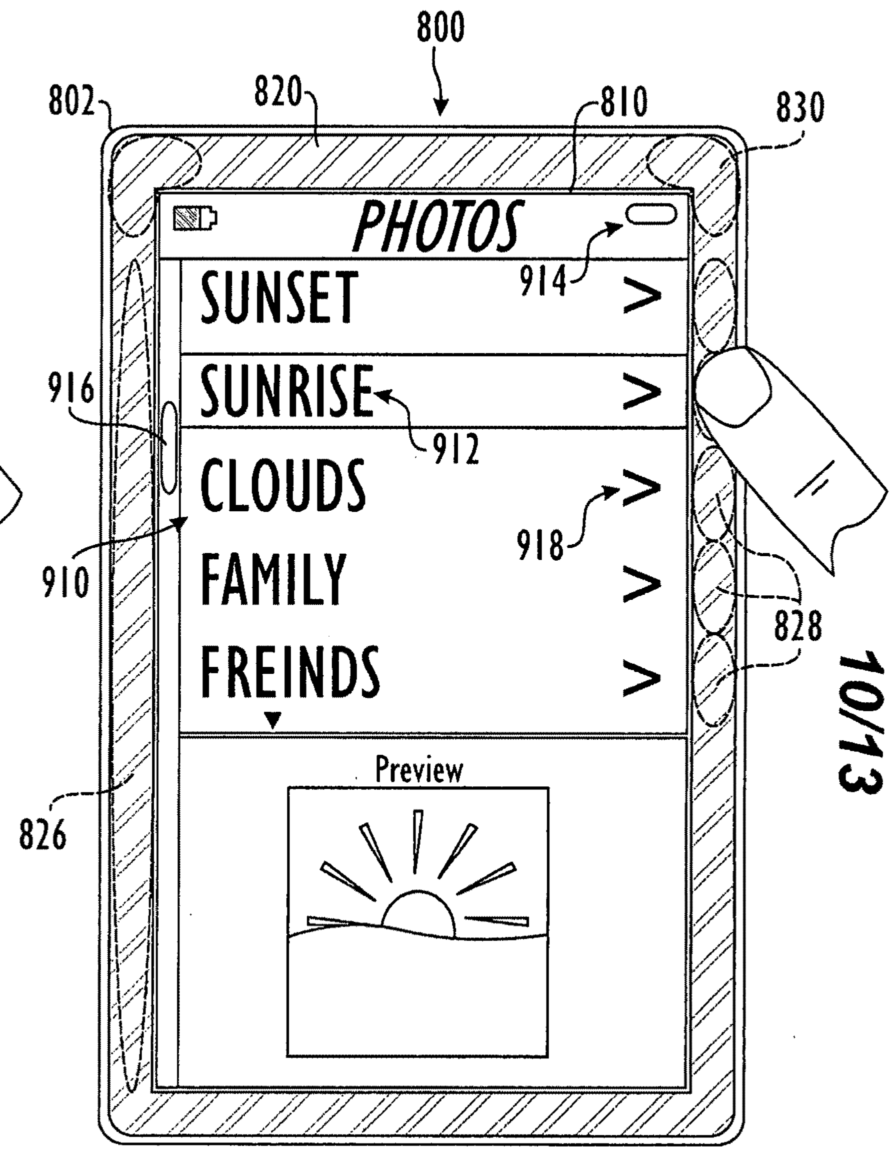
800
802
820
810
830
PHOTOS
914
SUNSET
916
SUNRISE
912
CLOUDS
918
910
FAMILY
FREINDS
828
826
Preview

FIG. 16

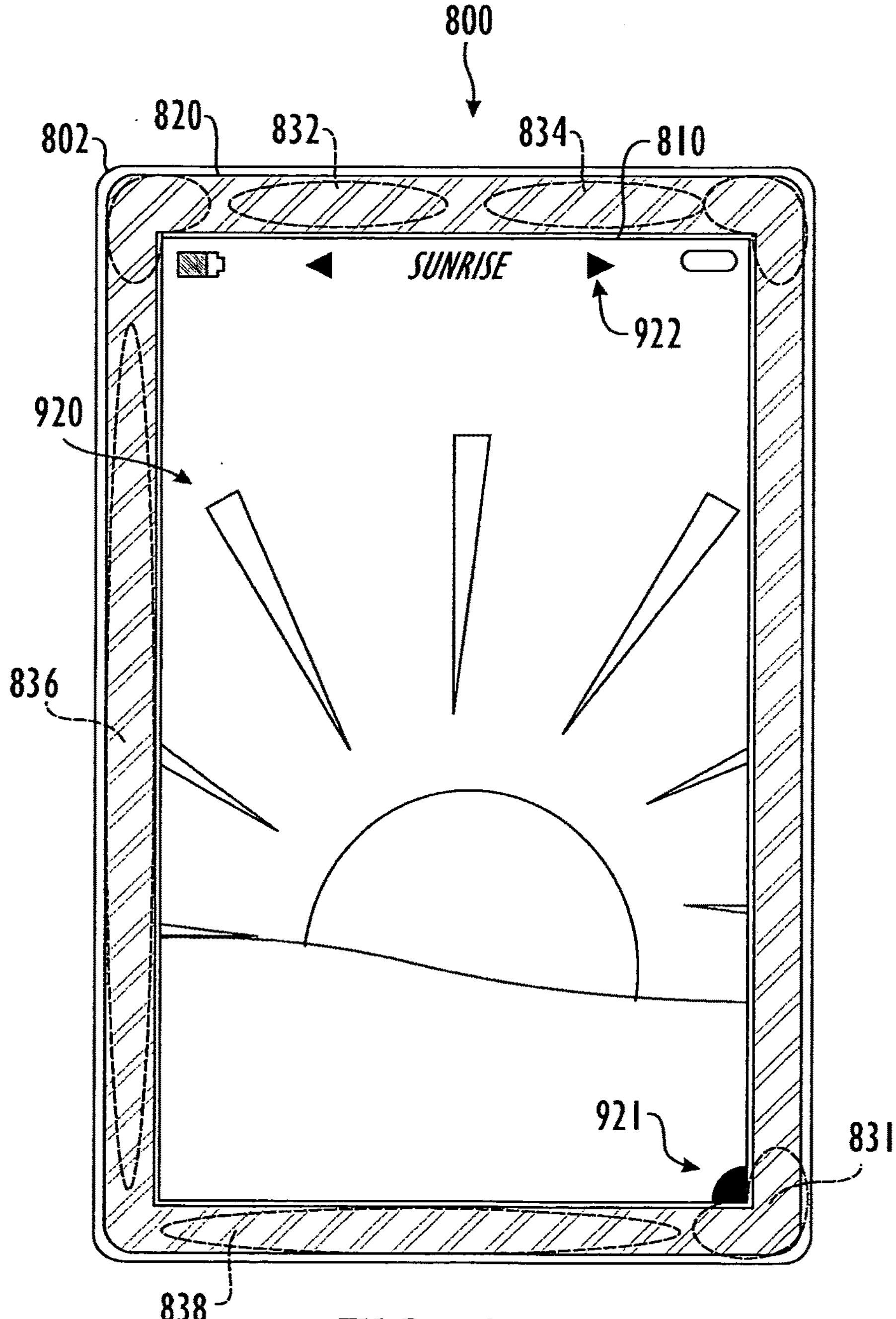

FIG. 17A

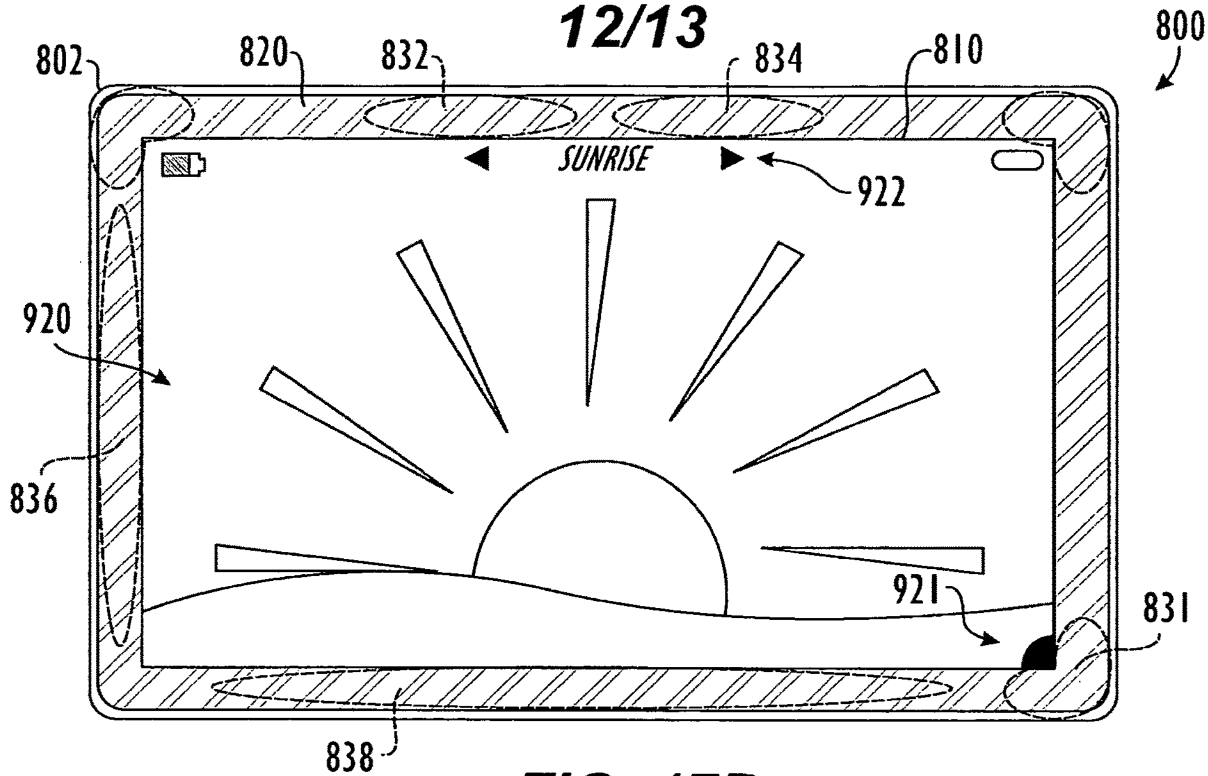

FIG. 17B

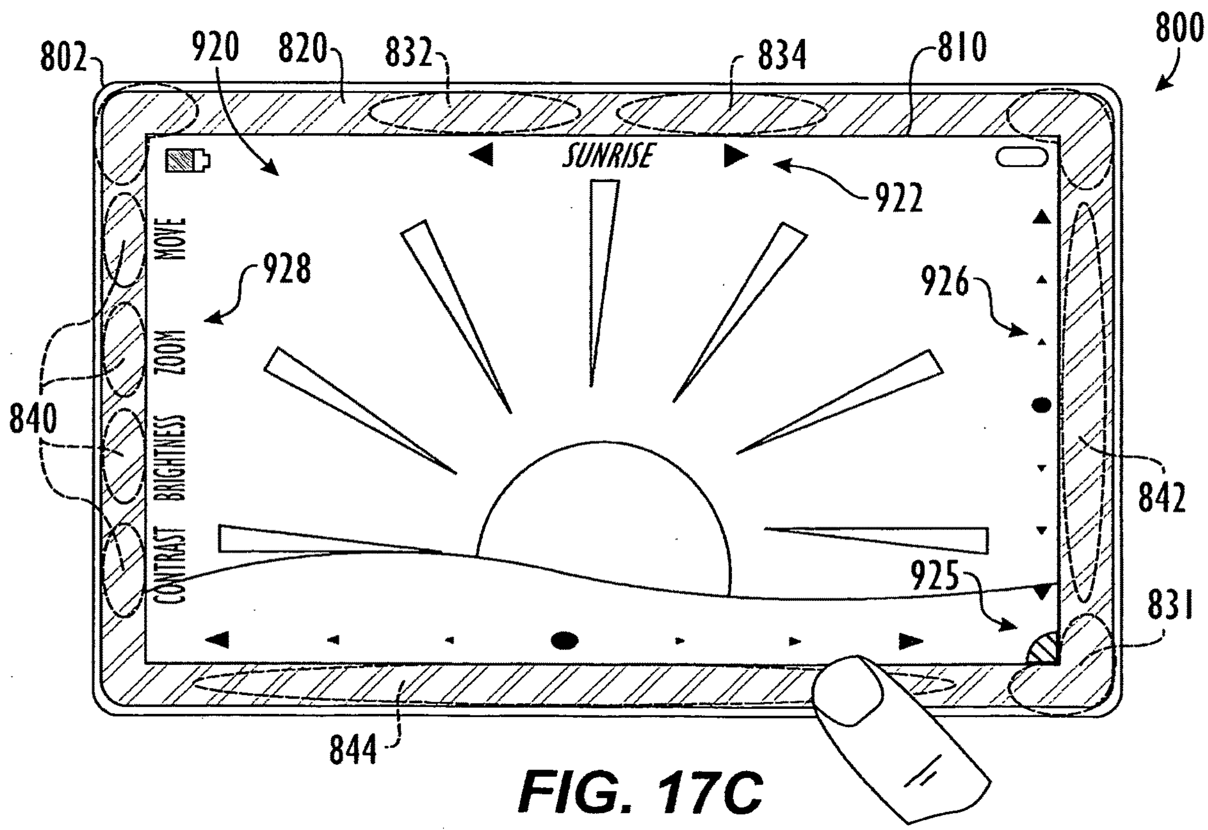

FIG. 17C

Title: Electronic Device Having Display and Surrounding Touch Sensitive Bezel for User Interface and Control
Inventors: Nick King et al.
Atty. Dkt. No.: P4194US1 / 119-0101US

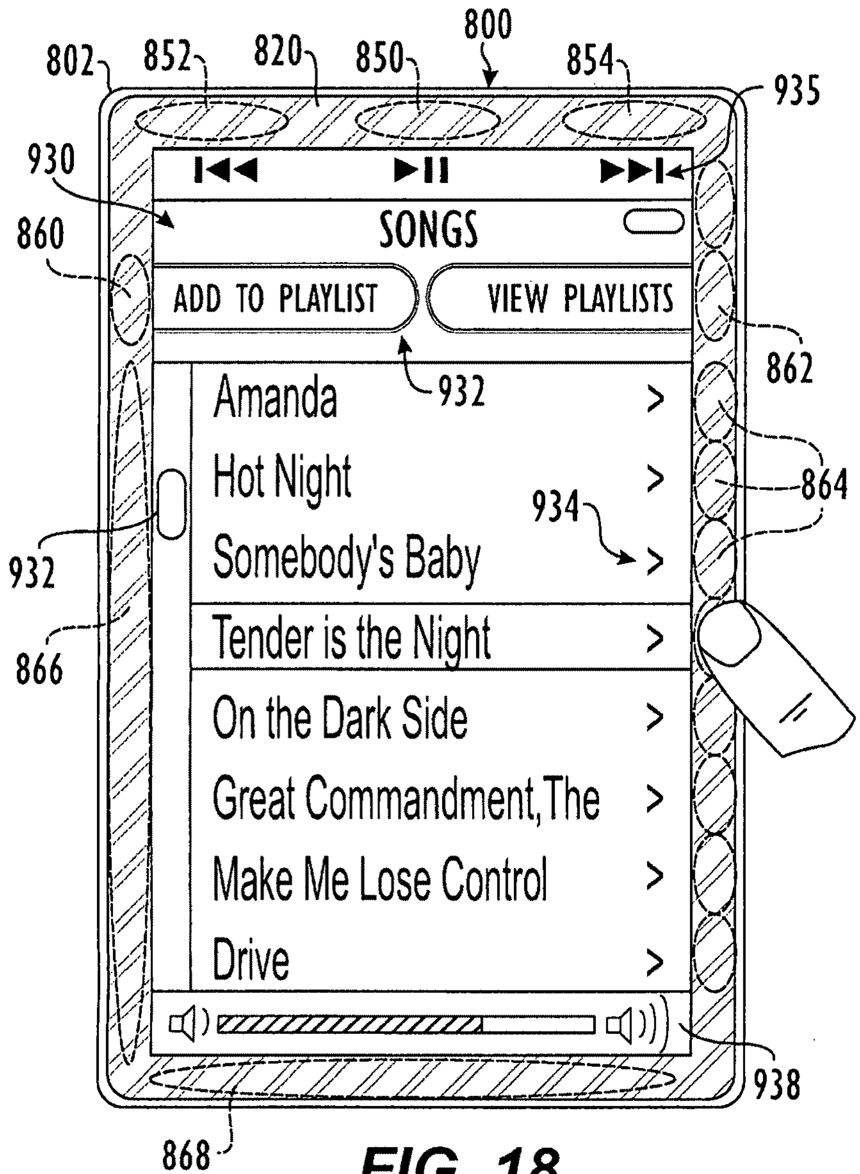

FIG. 18

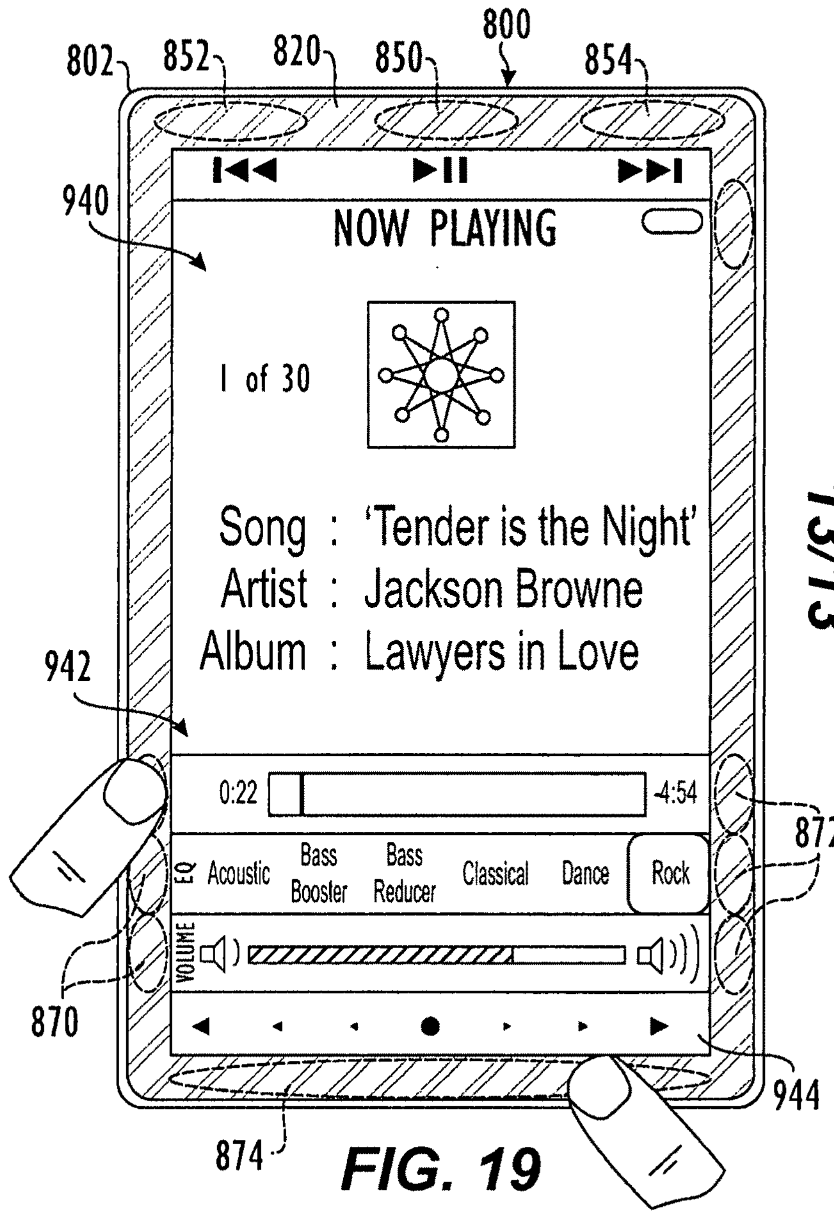

FIG. 19

MULTIPOINT TOUCH SURFACE CONTROLLER

Background

[0001] There exist today many styles of input devices for performing operations in a computer system. The operations generally correspond to moving a cursor and/or making selections on a display screen. By way of example, the input devices may include buttons or keys, mice, trackballs, touch pads, joy sticks, touch screens and the like. Touch pads and touch screens (collectively "touch surfaces") are becoming increasingly popular because of their ease and versatility of operation as well as to their declining price. Touch surfaces allow a user to make selections and move a cursor by simply touching the surface, which may be a pad or the display screen, with a finger, stylus, or the like. In general, the touch surface recognizes the touch and position of the touch and the computer system interprets the touch and thereafter performs an action based on the touch.

[0002] Of particular interest are touch screens. Various types of touch screens are described in applicant's co-pending patent application serial no. 10/840,862, entitled "Multipoint Touchscreen," filed May 6, 2004, which is hereby incorporated by reference in its entirety. As noted therein, touch screens typically include a touch panel, a controller and a software driver. The touch panel is generally a clear panel with a touch sensitive surface. The touch panel is positioned in front of a display screen so that the touch sensitive surface covers the viewable area of the display screen. The touch panel registers touch events and sends these signals to the controller. The controller processes these signals and sends the data to the computer system. The software driver translates the touch events into computer events.

[0003] There are several types of touch screen technologies including resistive, capacitive, infrared, surface acoustic wave, electromagnetic, near field imaging, etc. Each of these devices has advantages and disadvantages that are taken into account when designing or configuring a touch screen. One problem found in these prior art technologies is that they are only capable of reporting a single point even when multiple

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objects are placed on the sensing surface. That is, they lack the ability to track multiple points of contact simultaneously. In resistive and traditional capacitive technologies, an average of all simultaneously occurring touch points are determined and a single point which falls somewhere between the touch points is reported. In surface wave and infrared technologies, it is impossible to discern the exact position of multiple touch points that fall on the same horizontal or vertical lines due to masking. In either case, faulty results are generated.

[0004] These problems are particularly problematic in handheld devices, such as tablet PCs, where one hand is used to hold the tablet and the other is used to generate touch events. For example, as shown in Figs. 1A and 1B, holding a tablet 2 causes the thumb 3 to overlap the edge of the touch sensitive surface 4 of the touch screen 5. As shown in Fig. 1A, if the touch technology uses averaging, the technique used by resistive and capacitive panels, then a single point that falls somewhere between the thumb 3 of the left hand and the index finger 6 of the right hand would be reported. As shown in Fig. 1B, if the technology uses projection scanning, the technique used by infrared and surface acoustic wave panels, it is hard to discern the exact vertical position of the index finger 6 due to the large vertical component of the thumb 3. The tablet 2 can only resolve the patches shown in gray. In essence, the thumb 3 masks out the vertical position of the index finger 6.

[0005] While virtually all commercially available touch screen based systems available today provide single point detection only and have limited resolution and speed, other products available today are able to detect multiple touch points. Unfortunately, these products only work on opaque surfaces because of the circuitry that must be placed behind the electrode structure. Examples of such products include the Fingerworks series of touch pad products. Historically, the number of points detectable with such technology has been limited by the size of the detection circuitry.

[0006] Therefore, what is needed in the art is a multi-touch capable touch screen controller that facilitates the use of transparent touch sensors and provides for a conveniently integrated package.

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Summary

[0007] A controller for multi-touch touch surfaces is disclosed herein. One aspect of the multi-touch touch surface controller relates to the integration of drive electronics for stimulating the multi-touch sensor and sensing circuits for reading the multi-touch sensor into a single integrated package.

[0008] Another aspect of the controller relates to a technique for suppressing noise in the sensor by providing a plurality of stimulus waveforms to the sensor wherein the waveforms have different frequencies. This permits at least one noise-free detection cycle in cases where noise appears at a particular frequency.

[0009] Another aspect of the controller relates to a charge amplifier that includes programmable components, namely, programmable resistors and capacitors to allow the circuit to be easily reconfigured to provide optimum sensing configurations for a variety of sensor conditions.

[0010] Another aspect of the controller relates to an offset compensation circuit that expands the dynamic range of the controller by eliminating a static portion of the multi-touch surface sensor output allowing the full dynamic range of the sensing circuitry to be allocated to the changing portions of the output signal.

[0011] Another aspect of the controller relates to a demodulation circuit that enhances the noise immunity of the sensor arrangement by application of particular demodulation waveforms known to have particular frequency characteristics.

[0012] Another aspect of the controller relates to the application of various algorithms to the sensor outputs obtained from the multiple stimulus frequencies described above to further increase noise immunity of the system.

[0013] These and other aspects will be more readily understood by reference to the following detailed description and figures.

Brief Description of the Drawings

[0014] Figures 1A and 1B illustrates certain problems with prior art touch screen technologies.

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[0015] Figure 2 illustrates a perspective view of a computing device incorporating a multi-touch touch screen and multi-touch touch screen controller according to certain teachings of the present disclosure.

[0016] Figure 3 is a block diagram of a computing device incorporating a multi-touch touch screen and multi-touch touch screen controller according to certain teachings of the present disclosure.

[0017] Figures 4A and 4B illustrate two possible arrangement of drive and sense electrodes in a multi-touch touch surface.

[0018] Figure 5 is a layer diagram illustrating communication between the multi-touch surface and the host computer device by way of a multi-touch controller incorporating various teachings of the present disclosure.

[0019] Figure 6 is an equivalent circuit showing the output circuitry of the controller, a cell of the multi-touch sensor, and the input circuitry of a multi-touch controller incorporating various teachings of the present disclosure.

[0020] Figure 7 is a circuit schematic of a charge amplifier incorporated in certain embodiments of a multi-touch controller incorporating various teachings of the present disclosure.

[0021] Figure 8 is a block diagram of the multi-touch surface and multi-touch controller system in accordance with various teachings of the present disclosure.

[0022] Figure 9 illustrates the sequence in which drive waveforms of varying frequencies are applied to the multi-touch sensor in accordance with certain teachings of the present disclosure.

[0023] Figure 10 is a block diagram illustrating the input circuitry of a multi-touch controller incorporating certain teachings of the present disclosure.

[0024] Figures 11A and 11B illustrate various demodulation waveforms together with frequency spectra of their passbands.

[0025] Figure 12 illustrates a sequence of stimulus waveforms, together with a particular demodulation waveform, and the resulting output.

[0026] Figure 13 illustrates the noise rejection technique employed by the majority rules algorithm.

Detailed Description

[0027] A multipoint touch screen controller (MTC) is described herein. The following embodiments of the invention, described in terms of devices and applications compatible with computer systems manufactured by Apple Computer, Inc. of Cupertino, California, are illustrative only and should not be considered limiting in any respect.

[0028] Fig. 2 is a perspective view of a touch screen display arrangement 30. Display arrangement 30 includes a display 34 and a transparent touch screen 36 positioned in front of display 34. Display 34 may be configured to display a graphical user interface (GUI) including perhaps a pointer or cursor as well as other information to the user. Transparent touch screen 36 is an input device that is sensitive to a user's touch, allowing a user to interact with the graphical user interface on display 34. In general, touch screen 36 recognizes touch events on surface 38 of touch screen 36 and thereafter outputs this information to a host device. The host device may, for example, correspond to a computer such as a desktop, laptop, handheld or tablet computer. The host device interprets the touch event and thereafter performs an action based on the touch event.

[0029] In contrast to prior art touch screens, touch screen 36 shown herein is configured to recognize multiple touch events that occur simultaneously at different locations on touch sensitive surface 38. That is, touch screen 36 allows for multiple contact points T1–T4 to be tracked simultaneously. Touch screen 36 generates separate tracking signals S1–S4 for each touch point T1–T4 that occurs on the surface of touch screen 36 at the same time. In one embodiment, the number of recognizable touches may be about 15 which allows for a user's 10 fingers and two palms to be tracked along with 3 other contacts. The multiple touch events can be used separately or together to perform singular or multiple actions in the host device. Numerous examples of multiple touch events used to control a host device are disclosed in U.S. Patents 6,323,846; 6,888,536; 6,677,932; 6,570,557, and co-pending U.S. patent applications 11/015,434; 10/903,964; 11/048,264; 11/038,590; 11/228,758;

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11/228,700; 11/228,737; 11/367,749, each of which is hereby incorporated by reference in its entirely.

[0030] Fig. 3 is a block diagram of a computer system 50, employing a multi-touch touch screen. Computer system 50 may be, for example, a personal computer system such as a desktop, laptop, tablet, or handheld computer. The computer system could also be a public computer system such as an information kiosk, automated teller machine (ATM), point of sale machine (POS), industrial machine, gaming machine, arcade machine, vending machine, airline e-ticket terminal, restaurant reservation terminal, customer service station, library terminal, learning device, etc.

[0031] Computer system 50 includes a processor 56 configured to execute instructions and to carry out operations associated with the computer system 50. Computer code and data required by processor 56 are generally stored in storage block 58, which is operatively coupled to processor 56. Storage block 58 may include read-only memory (ROM) 60, random access memory (RAM) 62, hard disk drive 64, and/or removable storage media such as CD-ROM, PC-card, floppy disks, and magnetic tapes. Any of these storage devices may also be accessed over a network. Computer system 50 also includes a display device 68 that is operatively coupled to the processor 56. Display device 68 may be any of a variety of display types including liquid crystal displays (e.g., active matrix, passive matrix, etc.), cathode ray tubes (CRT), plasma displays, etc.

[0032] Computer system 50 also includes touch screen 70, which is operatively coupled to the processor 56 by I/O controller 66 and touch screen controller 76. (The I/O controller 66 may be integrated with the processor 56, or it may be a separate component.) In any case, touch screen 70 is a transparent panel that is positioned in front of the display device 68, and may be integrated with the display device 68 or it may be a separate component. Touch screen 70 is configured to receive input from a user's touch and to send this information to the processor 56. In most cases, touch screen 70 recognizes touches and the position and magnitude of touches on its surface.

[0033] Better understanding of the interface between the touch sensor and the host computer system may be had with reference to Fig. 5, which is a layer diagram of

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the system illustrated in Fig. 3. The touch sensor 301 resides at the lowermost layer. In a preferred embodiment, the sensor interfaces with an ASIC (application specific integrated circuit) 305 that stimulates the sensor and reads the raw sensor output as described in more detail below. ASIC 305 interfaces via signaling 306 with a DSP (digital signal processor) and/or microcontroller 307, which generates the capacitance images. Together ASIC 305 and DSP/microcontroller 307 form the multipoint touch screen controller.

[0034] DSP/Microcontroller 307 includes an interface 308 for accepting the signaling 306 from ASIC 305, and these signals are then passed to a data capture and error rejection layer 309. Data from this layer may be accessed both for calibration, baseline and standby processing by module 310, as well as feature (*i.e.*, touch point) extraction and compression module 311. Once the features are extracted they are passed as high-level information to the host computer 302 via interface 303. Interface 303 may be, for example, a USB (universal serial bus) interface. Alternatively, other forms of interface, such as IEEE 1394 ("Firewire"), RS-232 serial interface, SCSI (small computer systems interface), etc. could be used.

[0035] The exact physical construction of the sensing device is not necessary for a complete understanding touch screen controller disclosed herein. Nonetheless, details of the construction may be understood by reference to the patents and patent applications incorporated by reference above. For purposes of the present description, the sensor may be assumed to be a mutual capacitance device constructed as described below with reference to Figs. 4A and 4B.

[0036] The sensor panel is comprised of a two-layered electrode structure, with driving lines on one layer and sensing lines on the other. In either case, the layers are separated by a dielectric material. In the Cartesian arrangement of Fig. 4A, one layer is comprised of N horizontal, preferably equally spaced row electrodes 81, while the other layer is comprised of M vertical, preferably equally spaced column electrodes 82. In a polar arrangement, illustrated in Fig. 4B, the sensing lines may be concentric circles and the driving lines may be radially extending lines (or vice versa). As will be appreciated by those skilled in the art, other configurations based on an infinite variety of coordinate systems are also possible.

[0037] Each intersection 83 represents a pixel and has a characteristic mutual capacitance, C_{SIG}. A grounded object (such as a finger) that approaches a pixel 83 from a finite distance shunts the electric field between the row and column intersection, causing a decrease in the mutual capacitance C_{SIG} at that location. In the case of a typical sensor panel, the typical signal capacitance C_{SIG} is about 0.75pF and the change induced by a finger touching a pixel, is about 0.25pF.

[0038] The electrode material may vary depending on the application. In touch screen applications, the electrode material may be ITO (Indium Tin Oxide) on a glass substrate. In a touch tablet, which need not be transparent, copper on an FR4 substrate may be used. The number of sensing points 83 may also be widely varied. In touch screen applications, the number of sensing points 83 generally depends on the desired sensitivity as well as the desired transparency of the touch screen 70. More nodes or sensing points generally increases sensitivity, but reduces transparency (and vice versa).

[0039] During operation, each row (or column) is sequentially charged by driving it with a predetermined voltage waveform 85 (discussed in greater detail below). The charge capacitively couples to the columns (or rows) at the intersection. The capacitance of each intersection 83 is measured to determine the positions of multiple objects when they touch the touch surface. Sensing circuitry monitors the charge transferred and time required to detect changes in capacitance that occur at each node. The positions where changes occur and the magnitude of those changes are used to identify and quantify the multiple touch events. Driving each row and column and sensing the charge transfer is the function of a multipoint touch screen controller.

[0040] Fig. 6 is a simplified diagram of the equivalent mutual capacitance circuit 220 for each coupling node. Mutual capacitance circuit 220 includes a driving line 222 and a sensing line 224 that are spatially separated thereby forming a capacitive coupling node 226. When no object is present, the capacitive coupling at node 226 stays fairly constant. When an object, such as a finger, is placed proximate the node

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226, the capacitive coupling through node 226 changes. The object effectively shunts the electric field so that the charge transferred across node 226 is less.

[0041] With reference to Figs. 5 and 8, ASIC 305 generates all the drive waveforms necessary to scan the sensor panel. Specifically, the microprocessor sends a clock signal 321 to set the timing of the ASIC, which in turn generates the appropriate timing waveforms 322 to create the row stimuli to the sensor 301. Decoder 311 decodes the timing signals to drive each row of sensor 301 in sequence. Level shifter 310 converts timing signals 322 from the signaling level (*e.g.*, 3.3V) to the level used to drive the sensor (*e.g.*, 18V).

[0042] Each row of the sensor panel is driven determined by microprocessor 307. For noise rejection purposes it is desirable to drive the panel at multiple different frequencies for noise rejection purposes. Noise that exists at a particular drive frequency may not, and likely will not exist at the other frequencies. In a preferred embodiment, each sensor panel row is stimulated with three bursts of twelve square wave cycles (50% duty-cycle, 18V amplitude), while the remaining rows are kept at ground. For better noise rejection, described in greater detail below the frequency of each burst is different, exemplary burst frequencies are 140kHz, 200kHz, and 260Khz.

[0043] During each burst of pulses ASIC 305 takes a measurement of the column electrodes. This process is repeated for all remaining rows in the sensor panel. The results are three images, each image taken at a different stimulus frequency.

[0044] Additionally, it is preferable to minimize the amount of stimulus frequency change required for each subsequent burst. Therefore a frequency hopping pattern that minimizes the changes is desirable. Figure 29 shows one possible frequency hopping pattern. In this arrangement, a first row is driven with a 140 kHz burst, then a 200 kHz, and finally a 260 kHz burst. Then a next row is driven with three bursts at 260 kHz, 200 kHz, and 140 kHz, respectively. This particular frequency pattern was chosen to keep changes between frequencies small and allow the frequency transitions have to be smooth and glitch free. However, other frequency hopping arrangements are also possible, including scanning more than three frequencies, scanning the frequencies in a quasi-random sequence rather than the ordered pattern described, and adaptive

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frequency hopping, in which the scan frequencies are selected based on the noise environment.

[0045] Turning back to Fig. 6, sensing line 224 is electrically coupled to a capacitive sensing circuit 230. Capacitive sensing circuit 230 detects and quantifies the current change and the position of the node 226 where the current change occurred and reports this information to a host computer. The signal of interest is the capacitance C_{SIG}, which couples charge from RC network A to RC network B. The output from RC network B connects directly to the analog input terminals of ASIC 305. ASIC 305 also uses the clock signal 321 (Fig. 8) from microprocessor 307 (Fig. 8) to time the detection and quantification of the capacitance signals.

[0046] Figure 10 is a block diagram illustrating the input stage of ASIC 305. The input signal is first received by a charge amplifier 401. The charge amplifier performs the following tasks: (1) charge to voltage conversion, (2) charge amplification, (3) rejection or stray capacitance present at the column electrode, and (4) anti aliasing, and (5) gain equalization at different frequencies. Figure 7 is a diagram of one possible charge amplifier 401.

[0047] Charge to voltage conversion is performed by a capacitor C_{FB} in the feedback path of an operational amplifier 450. In one embodiment, the feedback capacitor can be programmed with values ranging from 2 to 32 pF, which allows the output voltage level to be adjusted to obtain the best dynamic range for a range of C_{SIG} values. The feedback resistor R_{FB} is also preferably programmable to control the amplifier gain.

[0048] Because C_{SIG} will vary across a touch surface because of a variety of manufacturing tolerance related factors, it is useful to adjust the charge amplifier feedback capacitance C_{FB} on a per-pixel basis. This allows gain compensation to be performed to optimize the performance of each pixel. In one embodiment, quasi-per pixel adjustment is performed as follows: The feedback capacitor C_{FB} has its value set by a register known as CFB_REG. The value of CFB_REG is set according to the following equation:

CFB_REG[Y]=CFB_UNIV+CFB[Y]

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where Y is an individual pixel within a row, CFB_UNIV is adjusted on a row by row basis, and CFB[Y] is a lookup table loaded at system startup. In alternative arrangements, CFB_UNIV may be constant for all rows, or the CFB[Y] lookup table may be switched out on a row by row basis. Also, although discussed in terms of rows and columns, the adjustment arrangement is equally applicable to non-Cartesian coordinate systems.

[0049] Obviously it is desirable to measure C_{SIG} while rejecting as much as possible the effects of any parasitic resistance and capacitance in the physical sensor. Rejection of parasitic resistance and capacitance in the sensor may be accomplished by holding the non-inverting input 451 of amplifier 45D at a constant value, *e.g.*, ground. The inverting input 452 is coupled to the node being measured. As will be appreciated by those skilled in the art, inverting input 452 (connected to the column electrode being measured) is thus held at virtual ground. Therefore any parasitic capacitance present at the column electrode, *e.g.*, PCB stray capacitance or dynamic stray capacitance caused by the user touching the column electrode, is rejected because the net charge of the stray capacitor does not change (*i.e.*, the voltage across the stray capacitance is held at virtual ground). Therefore the charge amplifier output voltage 453 is only a function of the stimulus voltage, C_{SIG}, and C_{FB}. Because the stimulus voltage and C_{FB} are determined by the controller, C_{SIG} may be readily inferred.

[0050] A series resistor 454 between the ASIC input pin 455 and the inverting input 452 of the charge amplifier forms an anti-aliasing filter in combination with the feedback network of R_{FB} and C_{FB}.

[0051] The high pass roll off of the charge amplifier is set by the parallel combination of the feedback resistor R_{FB} and the feedback capacitor C_{FB}.

[0052] Again with reference to Fig. 10, the output of charge amplifier 401 passes to demodulator 403. Demodulator 403 is a 5-bit quantized continuous time analog (four-quadrant) multiplier. The purpose of demodulator 403 is to reject out of band noise sources (from cell phones, microwave ovens, etc.) that are present on the signal entering ASIC 305. The output 402 of the charge amplifier (V_{SIG}) is mixed with a 5-bit quantized waveform that is stored in a lookup table 404. The shape, amplitude, and frequency of the demodulation waveform is determined by programming suitable coefficients into lookup table 404. The demodulation waveform determines pass band, stop band, stop band ripple and other characteristics of the mixer. In a preferred embodiment, Gaussian shaped sine wave is used as the demodulation waveform. A Gaussian sine wave provides a sharp pass band with reduced stop band ripple.

[0053] Another aspect of demodulator 403 relates to demodulator phase delay adjustment. As can be seen with reference to Fig. 10, the touch surface electrodes can be represented by a RC networks (RC Network A and RC Network B) that have a mutual capacitance (C_{SIG}) at the point they intersect. Each RC network constitutes a low pass filter, while C_{SIG} introduces a high pass filter response. Therefore the touch panel looks like a bandpass filter, only allowing signals with a certain frequency ranges to pass the panel. This frequency range, *i.e.*, those frequencies that are below the cutoff of C_{SIG} but above the cutoff of RC Networks A and B, determines the stimulus frequencies that may be used to drive the touch panel.

[0054] The panel will therefore impose a phase delay on the stimulus waveform passing through it. This phase delay is negligible for traditional opaque touch panels, wherein the electrode structure is typically formed by PCB traces, which have negligible resistance to their characteristic impedance. However, for transparent panels, typically constructed using Indium Tin Oxide (ITO) conductive traces, the resistive component may be quite large. This introduces a significant time (phase) delay in the propagation of the stimulus voltage through the panel. This phase delay causes the demodulation waveform to be delayed with respect to the signal entering the pre-amplifier, thereby reducing the dynamic range of the signal coming out of the ADC.

[0055] To compensate for this phase delay, a delay clock register ("DCL", not shown) may be provided, which can be used to delay the demodulation waveform relative to the signal entering the preamplifier therefore compensating for the external panel delay and maximizing the dynamic range. This register is input into the demodulator 403 and simply delays the demodulation waveform by a predetermined amount. The amount may be determined either on startup of the panel by measurement, or may be estimated for the panel as a whole based on known

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manufacturing characteristics. Each pixel of the touch surface may have its own uniquely determined delay parameter to fully optimize the reading circuitry, or the delay parameter may be determined on a row by row basis. Adjustment would be generally similar to the techniques discussed above for adjustment of the charge amplifier feedback capacitor and the offset compensation voltage.

[0056] The demodulated signal is then passed to offset compensation circuitry. The offset compensation circuitry comprises mixer 402 and programmable offset DAC 405. Mixer 402 takes the output voltage 453 of the demodulator and subtracts an offset voltage (discussed below) to increase the dynamic range of the system.

[0057] Offset compensation is necessary because the pixel capacitance C_{SIG} is comprised of a static part and a dynamic part. The static part is a function of sensor construction. The dynamic part is a function of the change of C_{SIG} when the finger approaches the pixel, and is thus the signal of interest. The purpose of the offset compensator is to eliminate or minimize the static component thereby extending the dynamic range of the system.

[0058] As noted above, the offset compensation circuitry is comprised of two parts, a programmable offset DAC 405 and a mixer 402. Offset DAC 405 generates a programmable offset voltage from the digital static offset value VOFF_REG. This digital value is converted into a static analog voltage (or current, if operating in the current domain) by the DAC and then mixed (by mixer 403b) with a voltage (or current) set by the absolute value (determined by block 404b) of the demodulation waveform. The result is a rectified version of the demodulation waveform, the amplitude of which is set by the static value of VOFF_REG and the absolute portion of the demodulation waveform currently retrieved from the DMOD lookup table 404. This allows for the right amount of offset compensation for a given portion of the demodulation waveform. Therefore the offset compensation waveform effectively tracks the demodulation waveform.

[0059] As with the charge amplifier feedback capacitor, it is useful to adjust the offset compensation circuitry to account for variations in the individual pixel capacitance due to manufacturing tolerances, etc. The adjustment may be substantially similar to

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that discussed above with respect to the charge amplifier feedback capacitor. Specifically, the offset voltage value stored in VOFF_REG may be calculated as follows:

VOFF_REG[Y]=VOFF_UNIV+VOFF[Y]

where Y is the individual column within a row, VOFF_UNIV is an offset voltage set on a row by row basis, and VOFF[Y] is a lookup table. Again, the adjustment could be performed on a true pixel by pixel basis or VOFF_UNIV could be a single constant value, depending on a particular implementation. Also, although discussed in terms of rows and columns, the adjustment arrangement is equally applicable to non-Cartesian coordinate systems.

[0060] As an alternative to the arrangement described above with respect to Fig. 10, the offset compensation could take place prior to demodulation. In this case, the shape of the offset compensation waveform has to match the waveform coming out of the preamplifier rather than the waveform coming out of the demodulator, *i.e.*, it has to be a square wave, assuming negligible attenuation in the panel, such that the shape of the drive waveform is preserved. Also, if offset compensation is performed first, the offset waveform is an AC waveform with respect to the reference voltage, *i.e.*, the maxima are positive in respect to V_{REF} and the minima are negative in respect to V_{REF}. The amplitude of the offset waveform is equivalent to the amount of offset compensation. Conversely, if demodulation is performed first, the offset waveform is a DC waveform, i.e. it is either positive in respect to Vref or negative (since the demodulated waveform is also DC in respect to Vref). Again, the amplitude in this case is equivalent to the amount of offset compensation for every part of the demodulated waveform. In essence, the offset compensation circuit needs to correlate the amount of offset compensation needed dependent on the shape of the waveform.

[0061] The demodulated, offset compensated signal is then processed by programmable gain ADC 406. In one embodiment, ADC 406 may be a sigma-delta, although similar type ADCs (such as a voltage to frequency converter with a subsequent counter stage) could be used. The ADC performs two functions: (1) it converts the offset compensated waveform out of the mixer arrangement (offset and signal mixer) to a digital value; and (2) it performs low pass filtering functions, *i.e.*, it averages the

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rectified signal coming out of the mixer arrangement. The offset compensated, demodulated signal looks like a rectified Gaussian shaped sine wave, whose amplitude is a function of C_{FB} and C_{SIG}. The ADC result returned to the host computer is actually the average of that signal.

[0062] One advantage of using a sigma delta ADC is that such ADCs are much more efficient for performing averaging in the digital domain. Additionally, digital gates are a lot smaller than analog low pass filters and sample and hold elements, thus reducing the size of the total ASIC. One skilled in the art will further appreciated other advantages, particularly with regard to power consumption and clock speed.

[0063] Alternatively, one could use an ADC separate from the controller ASIC. This would require a multiplexor to share the ADC between multiple channels and a sample and hold circuit for each channel to average and hold the average of the demodulation waveform. This would likely consume so much die area as to be impractical for controllers intended for use with touch surfaces having a large number of pixels. Additionally, to achieve acceptable operation, the external ADC would need to operate very fast, as a large number of pixels must be processed very quickly to provide timely and smooth results in response to a user's input.

[0064] As noted above, the sensor is driven at three different frequencies, resulting in three capacitance images, which are used for noise rejection as described below. The three frequencies are chosen such that the pass band at one particular frequency does not overlap with the pass bands at the other frequencies. As noted above, a preferred embodiment uses frequencies of 140 kHz, 200 kHz, and 240 kHz. The demodulation waveform is chosen such that the side bands are suppressed.

[0065] As noted above, a Gaussian enveloped sine wave, illustrated in Fig. 11A together with its passband frequency spectrum, is one preferred demodulation waveform. The Gaussian shaped sine wave provides a well-defined pass band with minimum stop band ripple. Alternatively, other waveforms having well defined pass bands with minimum stop band ripple could also be used. For example, a ramp-enveloped sine wave, illustrated in Fig. 11B together with its passband frequency spectrum, also has a well defined pass band, although the stop band ripple is slightly greater than that for a Gaussian enveloped sine wave. As will be appreciated by those skilled in the art, other waveforms could also be used.

[0066] Turning now to Fig. 12, nine waveforms are illustrated that explain the noise suppression features of the system. Voltage waveform 501 is a square wave demonstrating the stimulus waveform applied to the sensor. Waveform 504 is the Gaussian enveloped sine wave signal used as a demodulation waveform. Waveform 507 is the output of the demodulator, *i.e.*, the product of the waveforms 501 and 504. Note that it provides a well defined pulse at the fundamental frequency of the applied square wave voltage.

[0067] The center column illustrates an exemplary noise waveform 502. Demodulation waveform 505 is the same as demodulation waveform 504. Note that the demodulated noise signal 508 does not produce a significant spike, because the fundamental frequency of the noise signal is outside the passband of the demodulation signal.

[0068] The composite of the excitation waveform and noise signal is illustrated in 503. Again, demodulation waveform 506 is the same as demodulation waveforms 505 and 504. The demodulated composite does still show the noise waveform, although various signal processing algorithms may be applied to extract this relatively isolated spike.

[0069] Additionally, noise rejection may accomplished by providing multiple stimulus voltage at different frequencies and applying a majority rules algorithm to the result. In a majority rules algorithm, for each capacitance node, the two frequency channels that provide the best amplitude match are averaged and the remaining channel is disposed of. For example, in Fig. 13 vertical line 600 represents the measured capacitance, with the markings 601, 602, and 603 representing the three values measured at three stimulus frequencies. Values 602 and 603 provide the best match, possibly suggesting that value 601 is corrupted. Thus value 601 is discarded and values 602 and 603 are averaged to form the output.

[0070] Alternatively, a median filter could be applied, in which case value 602, *i.e.*, the median value would be selected as an output. As yet another alternative, the three results could simply be averaged, in which case a value somewhere between value 601 and 602 would result. A variety of other noise rejection techniques for multiple sample values will be obvious to those skilled in the art, any of which may suitably be used with the controller described herein.

[0071] Operation of the circuit may be further understood with respect to Fig. 14, which is a flowchart depicting operation of the controller. One skilled in the art will appreciate that various timing and memory storage issues are omitted from this flowchart for the sake of clarity.

[0072] Image acquisition begins at block 701. The system then sets the clock so as to acquire samples at the middle clock frequency (*e.g.*, 200kHz) as discussed above with respect to Fig. 9 (block 702). The various programmable registers, which control such parameters as voltage offset, amplifier gain, delay clocks, etc., are then updated (block 703). All columns are read, with the result stored as a Mid Vector (block 704) The high clock frequency is then set (block 705), and the steps of updating registers (block 706) and reading all columns and storing the result (step 707) are repeated for the high sample frequency. The clock is then set to the low frequency (step 708) and the register update (block 709) and column reading (block 710) are repeated for the low sample frequency.

[0073] The three vectors are then offset compensated, according to the algorithm described above (block 711). The offset compensated vectors are then subjected to a median filter as described above. Alternatively, the offset compensated vectors could be filtered by the majority rules algorithm described with respect to Fig. 13 or any other suitable filtering technique. In any case, the result is stored. If more rows remain, the process returns to the mid frequency sampling at block 702). If all rows are completed (block 713), the entire image is output to the host device (block 714), and a subsequent new image is acquired (block 701).

[0074] While this invention has been described in terms of several preferred embodiments, there are alterations, permutations, and equivalents, which fall within the scope of this invention. For example, the term "computer" does not necessarily mean any particular kind of device, combination of hardware and/or software, nor should it be considered restricted to either a multi purpose or single purpose device. Additionally, although the embodiments herein have been described in relation to touch screens, the teachings of the present invention are equally applicable to touch pads or any other touch surface type of sensor. Furthermore, although the disclosure is primarily directed at capacitive sensing, it should be noted that some or all of the features described herein may be applied to other sensing methodologies. It should also be noted that there are many alternative ways of implementing the methods and apparatuses of the present invention. It is therefore intended that the following appended claims be interpreted as including all such alterations, permutations, and equivalents as fall within the true spirit and scope of the present invention.

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What is claimed is:

1. A controller for a multi-touch surface, the multi-touch surface having at least one drive electrode, at least one sense electrode, and at least one node disposed at an intersection of the at least one drive electrode and the at least one sense electrode, the controller comprising:

   output circuitry operatively connected to the at least one drive electrode, the output circuitry being configured to generate timing signals that may be used to generate drive waveforms for the multi-touch surface; and

   input circuitry operatively connected to the at least one sense electrode, the input circuitry being configured to determine proximity of an object at each node by measuring capacitive coupling of the drive waveforms from the drive electrode to the sense electrode;

   wherein the output circuitry and input circuitry are part of a single application specific integrated circuit.

2. The controller of claim 1 further comprising decoding and level shifting circuitry connected between the output circuitry and the drive electrode, the decoding and level shifting circuitry being configured to receive the timing signals and generate drive waveforms for the multi-touch surface.

3. The controller of claim 1 wherein the decoding and level shifting circuitry are part of the single application specific integrated circuit.

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4. The controller of claim 1 wherein the drive waveforms comprise:
   a first periodic waveform having a first predetermined frequency; and
   at least one additional periodic waveform having an additional predetermined frequency different from the first predetermined frequency;
   wherein the first periodic waveform and at least one additional periodic waveforms are applied sequentially to the drive electrode.

5. The controller of claim 4 wherein the at least one additional periodic waveforms comprise a second periodic waveform having a second predetermined frequency and a third periodic waveform having a third predetermined frequency, each of the second predetermined frequency and the third predetermined frequency being different from the first predetermined frequency and different from each other.

6. The controller of claim 1 wherein the input circuitry comprises a charge amplifier, the charge amplifier further comprising:
   an operational amplifier having an inverting input terminal, a non-inverting input terminal, and an output terminal, wherein the non-inverting input terminal is operatively connected to the at least one sense electrode;
   a feedback capacitor connected between the output terminal and the inverting input terminal, wherein the feedback capacitor is programmable to take on a range of values; and
   a feedback resistor connected between the output terminal and the inverting input terminal, wherein the feedback resistor is programmable to take on a range of values.

7. The controller of claim 6 wherein the charge amplifier further comprises a resistor coupled between the non-inverting input terminal and the at least one sense electrode to form an anti-aliasing filter in combination with the feedback resistor and feedback capacitor.

8. The controller of claim 6 wherein the non-inverting input of the amplifier is coupled to ground.

9. The controller of claim 1 wherein the input circuitry comprises an offset compensator, the offset compensator comprising:

a programmable offset digital to analog converter adapted to generate an offset signal corresponding to a static component of the capacitive coupling between the drive electrode and the sense electrode; and

a subtractor circuit configured to subtract the offset signal from a measured signal indicative of the capacitive coupling between the at least one drive electrode and the at least one sense electrode.

10. The controller of claim 6 wherein the input circuitry further comprises an offset compensator, the offset compensator comprising:

a programmable offset digital to analog converter adapted to generate an offset signal corresponding to a static component of the capacitive coupling between the drive electrode and the sense electrode; and

a subtractor circuit configured to subtract the offset signal from an output signal of the charge amplifier, the output signal being indicative of the capacitive coupling between the at least one drive electrode and the at least one sense electrode.

11. The controller of claim 1 wherein the input circuitry comprises a demodulator, the demodulator comprising a multiplier configured to mix a signal indicative of a capacitive coupling between the at least one drive electrode and the at least one sense electrode with a demodulation waveform.

12. The controller of claim 6 wherein the input circuitry further comprises a demodulator, the demodulator comprising a multiplier configured to mix an output signal of the operational amplifier, said output signal being indicative of a capacitive coupling between the at least one drive electrode and the at least one sense electrode, with a demodulation waveform.

13. The controller of claim 12 wherein the input circuitry further comprises an offset compensator, the offset compensator comprising:

a programmable offset digital to analog converter adapted to generate an offset signal corresponding to a static component of the capacitive coupling between the drive electrode and the sense electrode; and

a subtractor circuit configured to subtract the offset signal from the output signal of the demodulator, said output signal being indicative of the capacitive coupling between the at least one drive electrode and the at least one sense electrode.

14. The controller of claim 9 wherein the input circuitry further comprises a demodulator, the demodulator comprising a multiplier configured to mix an output signal of the offset compensator, said output signal being indicative of a capacitive coupling between the at least one drive electrode and the at least one sense electrode, with a demodulation waveform.

15. The controller of claim 11, 12, 13, or 14 wherein the demodulation waveform is determined with reference to a lookup table.

16. The controller of claim 15 wherein the demodulation waveform is a Gaussian-enveloped sine wave.

17. The controller of claim 1, 6, 9, 10, 11, 12, 13, or 14, wherein the input circuitry further comprises an analog to digital converter configured to produce a digital output from the measured capacitive coupling of the drive waveforms from the drive electrode to the sense electrode.

18. The controller of claim 17 wherein the analog to digital converter is a sigma-delta converter.

19. A method of operating a multi-touch surface, the multi-touch surface comprising at least one drive electrode, at least one sense electrode, and at least one node disposed at an intersection of the at least one drive electrode and the at least one sense electrode, the method comprising:

stimulating the at least one drive electrode with a first periodic waveform having a first predetermined frequency;

reading the at least one sense electrode to determine a capacitance of the node disposed at the intersection of the at least one drive electrode and the at least one sense electrode;

stimulating the at least one drive electrode with at least one additional periodic waveform having an additional predetermined frequency different from the first predetermined frequency;

reading the at least one drive electrode to determine a capacitance of the node disposed at the intersection of the at least one drive electrode and the at least one sense electrode; and

comparing the capacitance determined by the first stimulus with the capacitance determined by the at least one additional stimulus to determine the true capacitance of the node.

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20. The method of claim 19 wherein stimulating the at least one drive electrode with at least one additional periodic waveform having an additional predetermined frequency different from the first predetermined frequency comprises:

 stimulating the at least one drive electrode with a second periodic waveform having a second predetermined frequency; and

 stimulating the at least one drive electrode with a third periodic waveform having a third predetermined frequency;

 wherein the second and third predetermined frequencies are different from the first predetermined frequency and different from each other.

21. The method of claim 20 wherein comparing the capacitance determined by the first stimulus with the capacitance determined by the at least one additional stimulus to determine the true capacitance of the node comprises taking an average of the capacitances determined by the first, second, and third stimuli.

22. The method of claim 20 wherein comparing the capacitance determined by the first stimulus with the capacitance determined by the at least one additional stimulus to determine the true capacitance of the node comprises applying a majority rules algorithm to the capacitances determined by the first, second, and third stimuli.

23. The method of claim 20 wherein comparing the capacitance determined by the first stimulus with the capacitance determined by the at least one additional stimulus to determine the true capacitance of the node comprises taking the median of the capacitances determined by the first, second, and third stimuli.

24. A charge amplifier comprising:
    an operational amplifier having an inverting input terminal, a non-inverting input terminal, and an output terminal;
    a feedback capacitor connected between the output terminal and the inverting input terminal, wherein the feedback capacitor is programmable to take on a range of values; and
    a feedback resistor connected between the output terminal and the inverting input terminal, wherein the feedback resistor is programmable to take on a range of values.

25. The charge amplifier of claim 24 wherein the charge amplifier further comprises a resistor coupled between the non-inverting input terminal and an input to form an anti-aliasing filter in combination with the feedback resistor and capacitor.

26. The charge amplifier of claim 24 wherein the non-inverting input of the amplifier is coupled to ground.

27. A method of operating a multi-touch surface, the multi-touch surface comprising at least one drive electrode, at least one sense electrode, and at least one node disposed at an intersection of the at least one drive electrode and the at least one sense electrode, the method comprising:
    detecting a waveform on the at least one sense electrode caused by capacitive coupling of a drive waveform at the at least one node, said drive waveform having been applied to the at least one drive electrode;
    amplifying the detected waveform; and
    demodulating the amplified waveform to detect an object located proximate the at least one node.

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28. The method of claim 27 further comprising subtracting an offset from the amplified waveform, the offset being determined as a function of the static capacitance of the at least one node, wherein the step of demodulating the amplified waveform takes place subsequent to subtracting the offset.

29. The method of claim 27 wherein:

detecting a waveform on the at least one sense electrode comprises:

detecting a first waveform on the at least one sense electrode caused by capacitive coupling of a first drive waveform at the at least one node, the first drive waveform having been applied to the at least one drive electrode and having a first predetermined frequency; and

detecting at least one additional waveform on the at least one sense electrode caused by capacitive coupling of at least one additional drive waveform at the at least one node, the at least one additional drive waveform having been applied to the at least one drive electrode and having an additional predetermined frequency; and

demodulating the amplified waveform comprises:

demodulating each of the first waveform and the at least one additional waveform and comparing the demodulated waveforms to determine a capacitance of the node.

30. The method of claim 29 wherein comparing the demodulated waveforms comprises taking an average.

31. The method of claim 29 wherein comparing the demodulated waveforms comprises selecting a median.

32. The method of claim 29 wherein comparing the demodulated waveforms comprises applying a majority rules algorithm.

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33. The method of claim 27 wherein demodulating the amplified waveform comprises mixing the amplified waveform with a Gaussian enveloped sine wave.

34. An offset compensation circuit for use in conjunction with a capacitive touch sensor, wherein the capacitive touch sensor is operated by measuring capacitive coupling of a drive waveform from a drive electrode to a sense electrode, the offset compensation circuit comprising:

a programmable offset digital to analog converter adapted to generate an offset signal corresponding to a static component of the capacitive coupling between the drive electrode and the sense electrode; and

a subtractor circuit configured to subtract the offset signal from a measured signal indicative of the capacitive coupling between the at least one drive electrode and the at least one sense electrode.

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MULTIPOINT TOUCH SUFRACE CONTROLLER

Abstract

[0075] A multipoint touch surface controller is disclosed herein. The controller includes an integrated circuit including output circuitry for driving a capacitive multi-touch sensor and input circuitry for reading the sensor. Also disclosed herein are various noise rejection and dynamic range enhancement techniques that permit the controller to be used with various sensors in various conditions without reconfiguring hardware.

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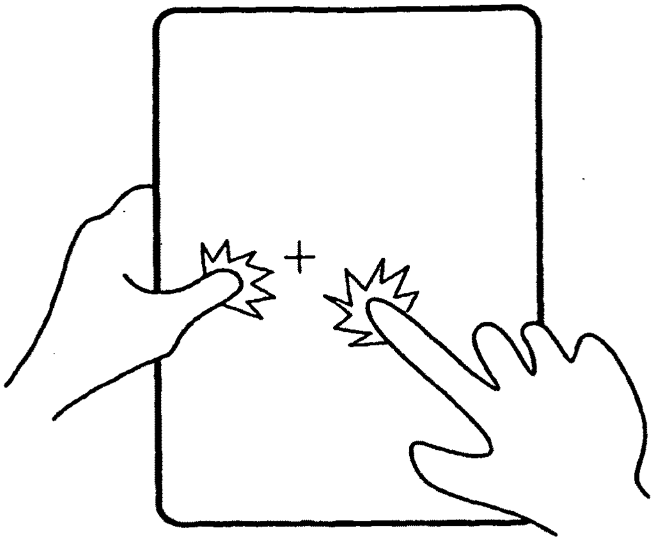


FIG. 1A

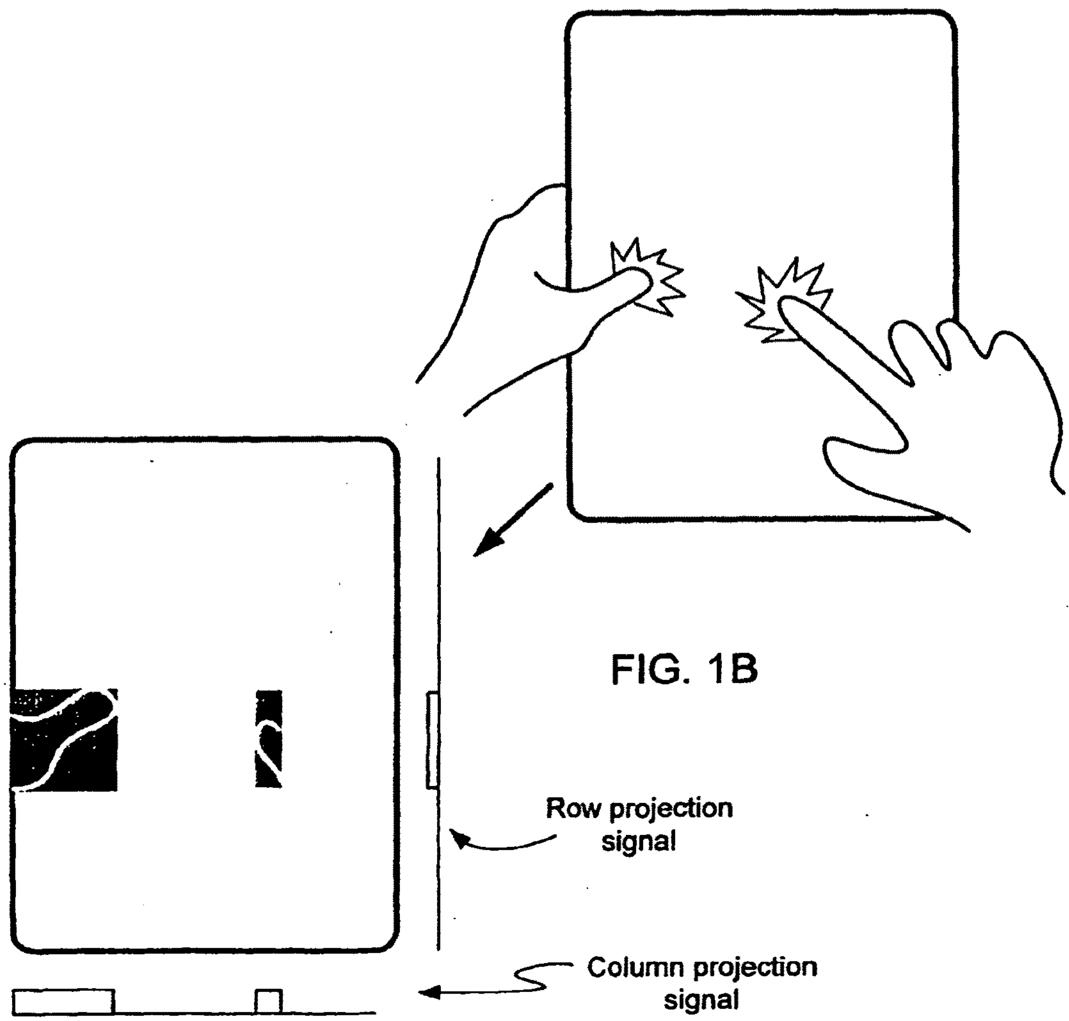


FIG. 1B

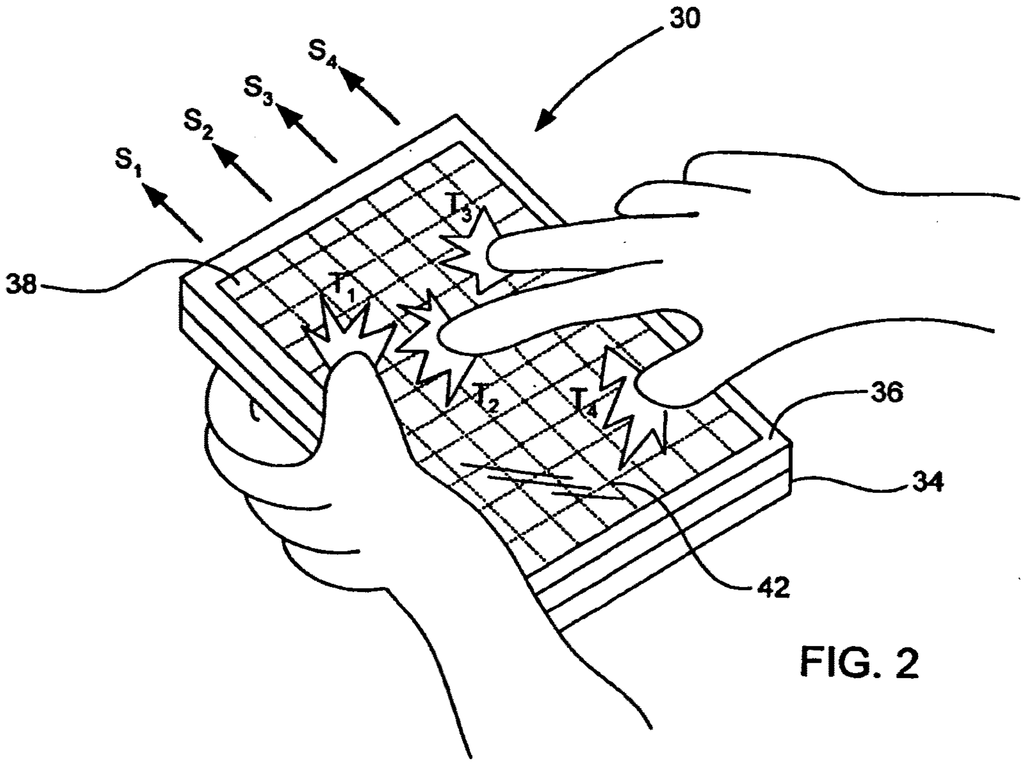


FIG. 2

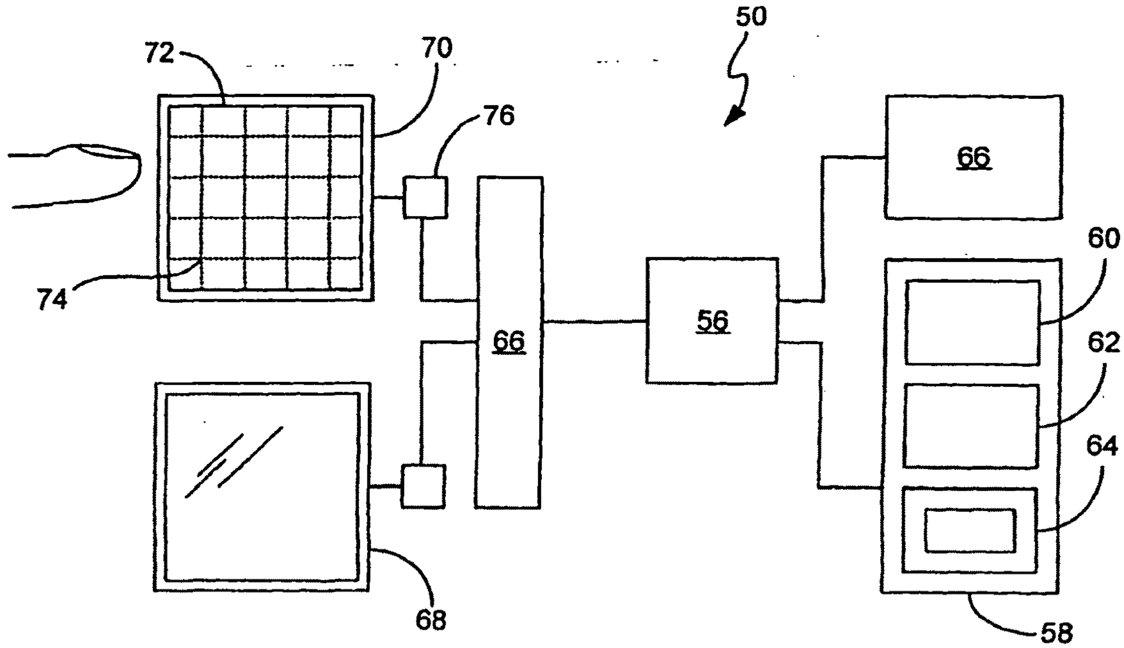


FIG. 3

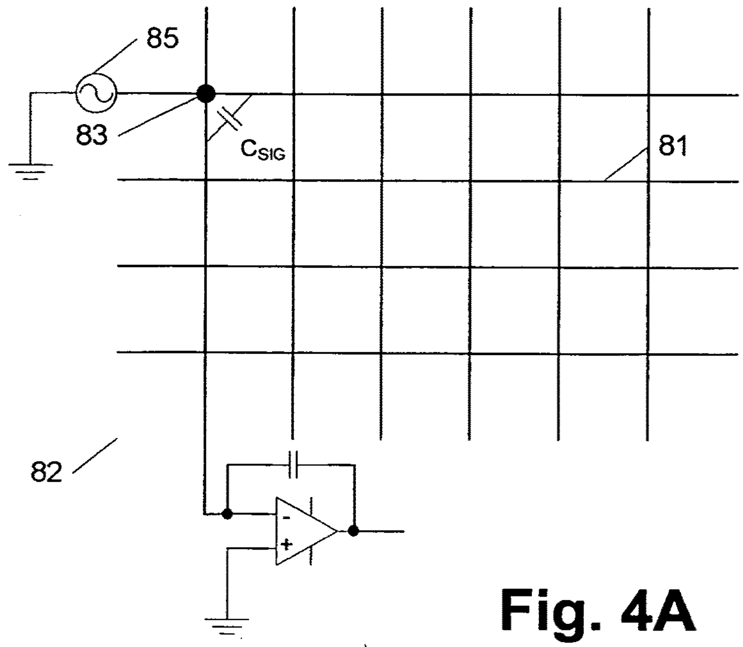


Fig. 4A

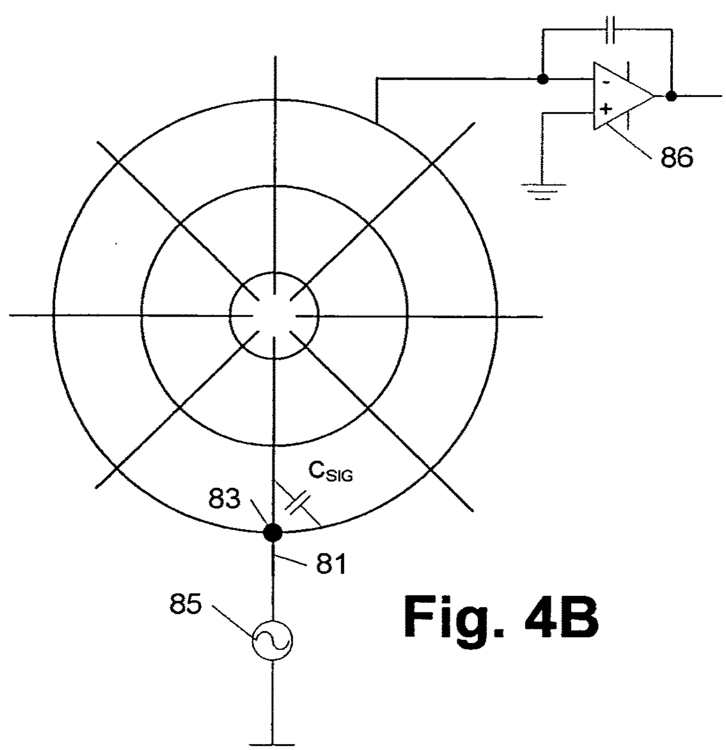


Fig. 4B

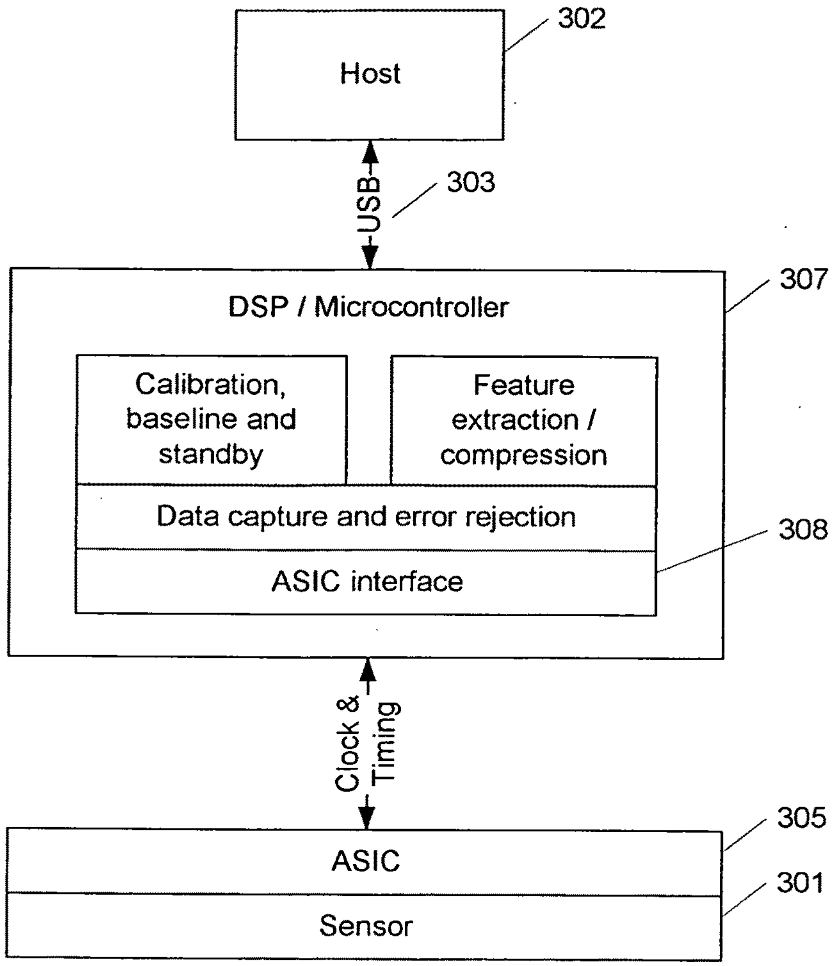

Host
302
USB
303
DSP / Microcontroller
307
Calibration, baseline and standby
Feature extraction / compression
Data capture and error rejection
308
ASIC interface
Clock & Timing
305
ASIC
301
Sensor

Fig. 5

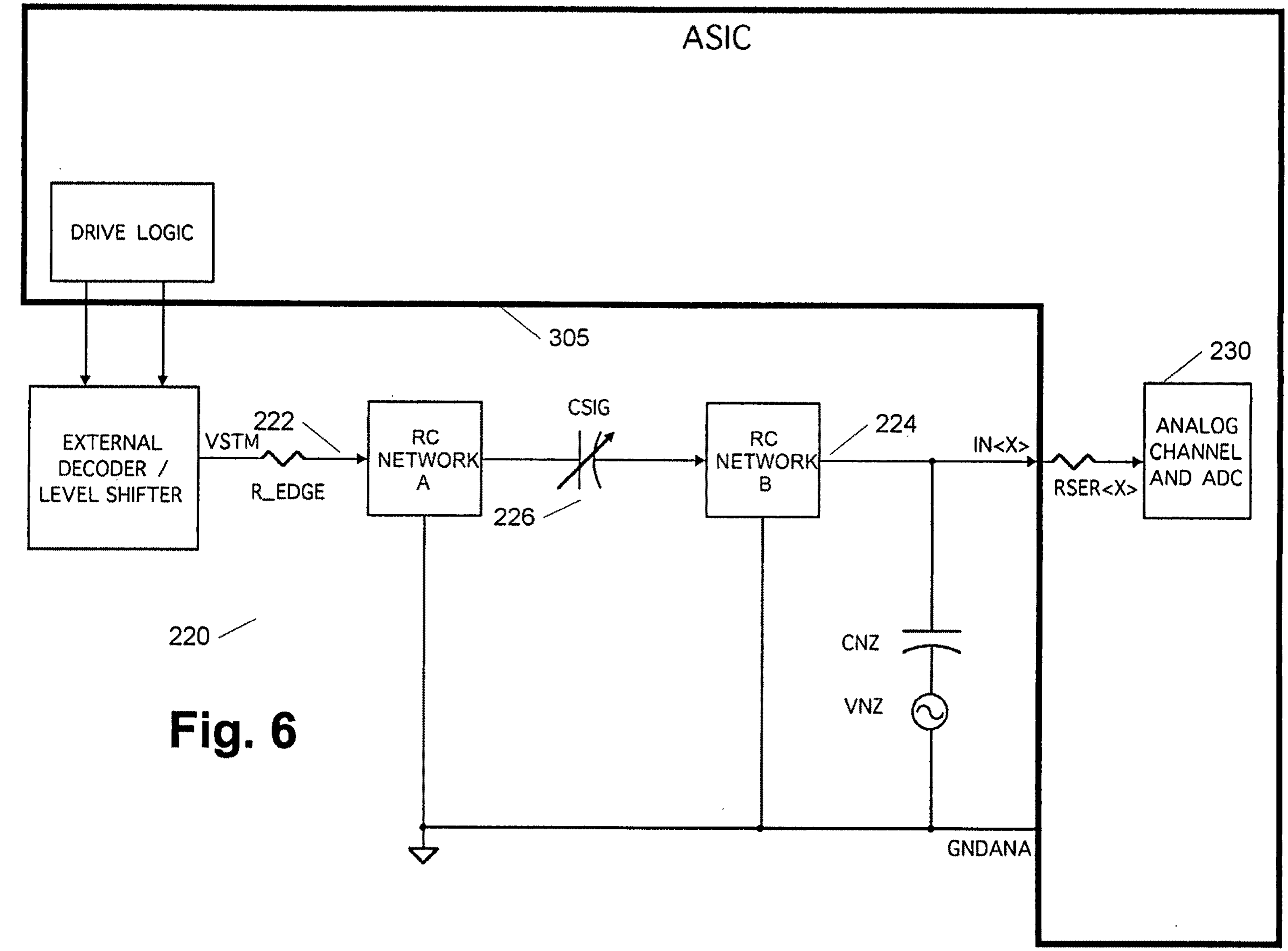

ASIC
DRIVE LOGIC
305
230
EXTERNAL DECODER / LEVEL SHIFTER
VSTM
222
R_EDGE
RC NETWORK A
CSIG
226
RC NETWORK B
224
IN<X>
RSER<X>
ANALOG CHANNEL AND ADC
220
CNZ
VNZ
GNDANA

Fig. 6

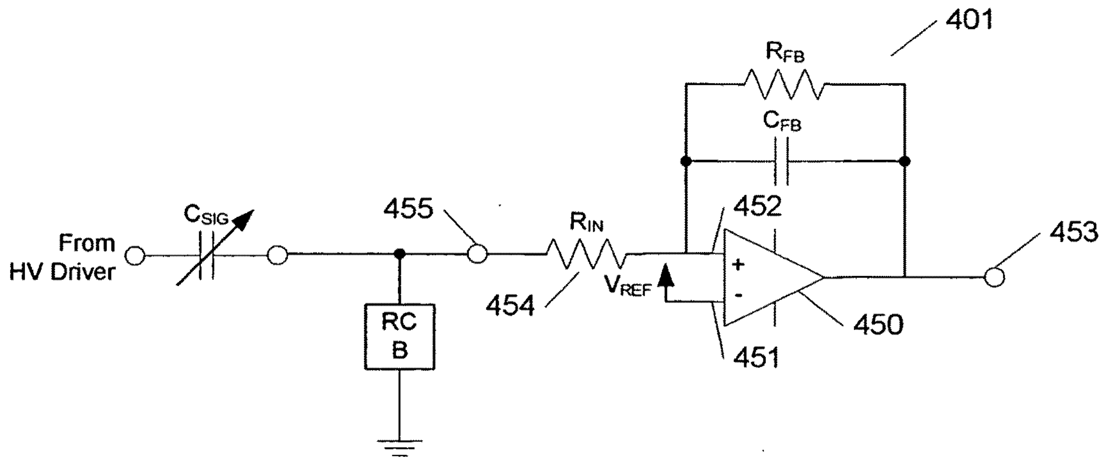

401
R_{FB}
C_{FB}
452
455
C_{SIG}
From
HV Driver
R_{IN}
453
+
-
454
V_{REF}
RC
B
450
451

Fig. 7

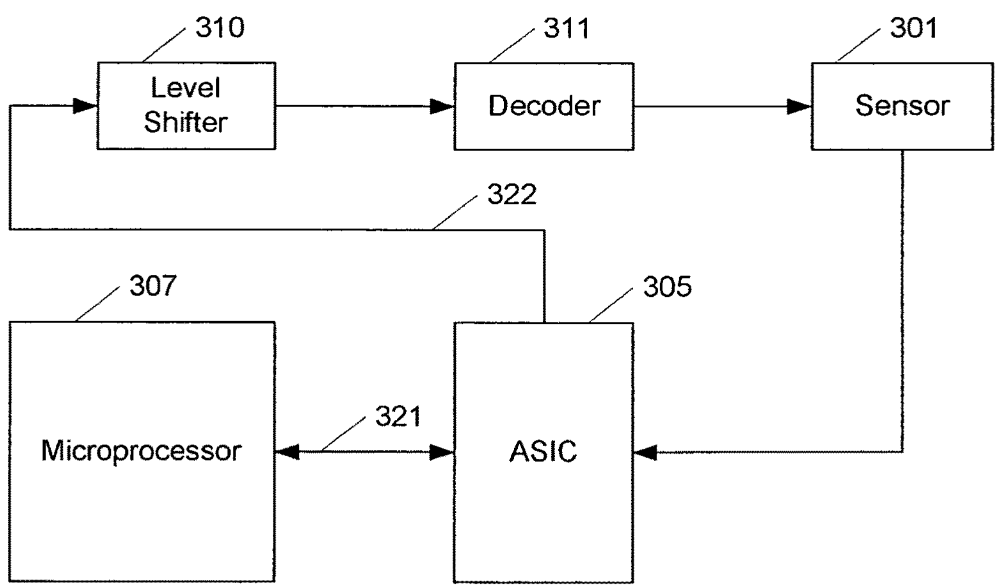

310
311
301
Level
Shifter
Decoder
Sensor
322
307
305
321
Microprocessor
ASIC

Fig. 8

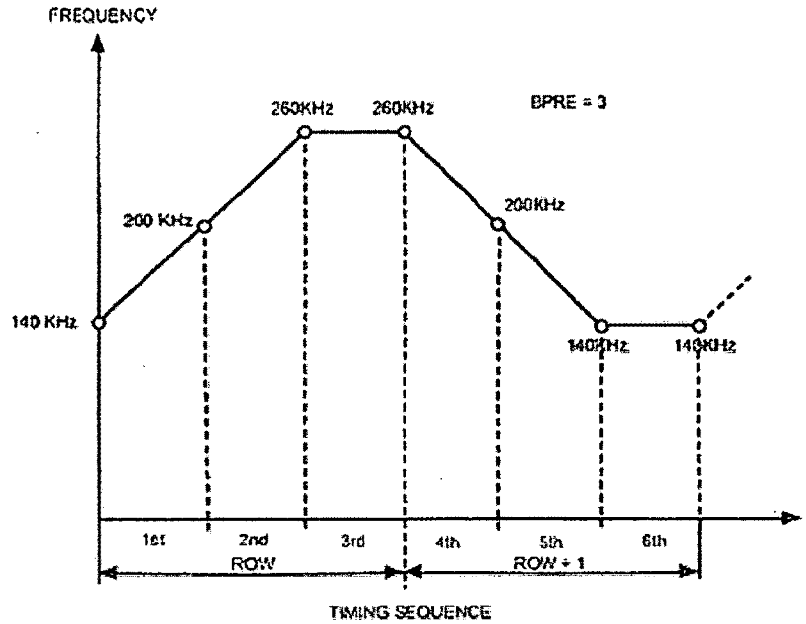

FREQUENCY
BPRE = 3
140 KHz
200 KHz
260KHz
260KHz
200KHz
140KHz
140KHz
1st
2nd
3rd
4th
5th
6th
ROW
ROW + 1
TIMING SEQUENCE

Fig. 9

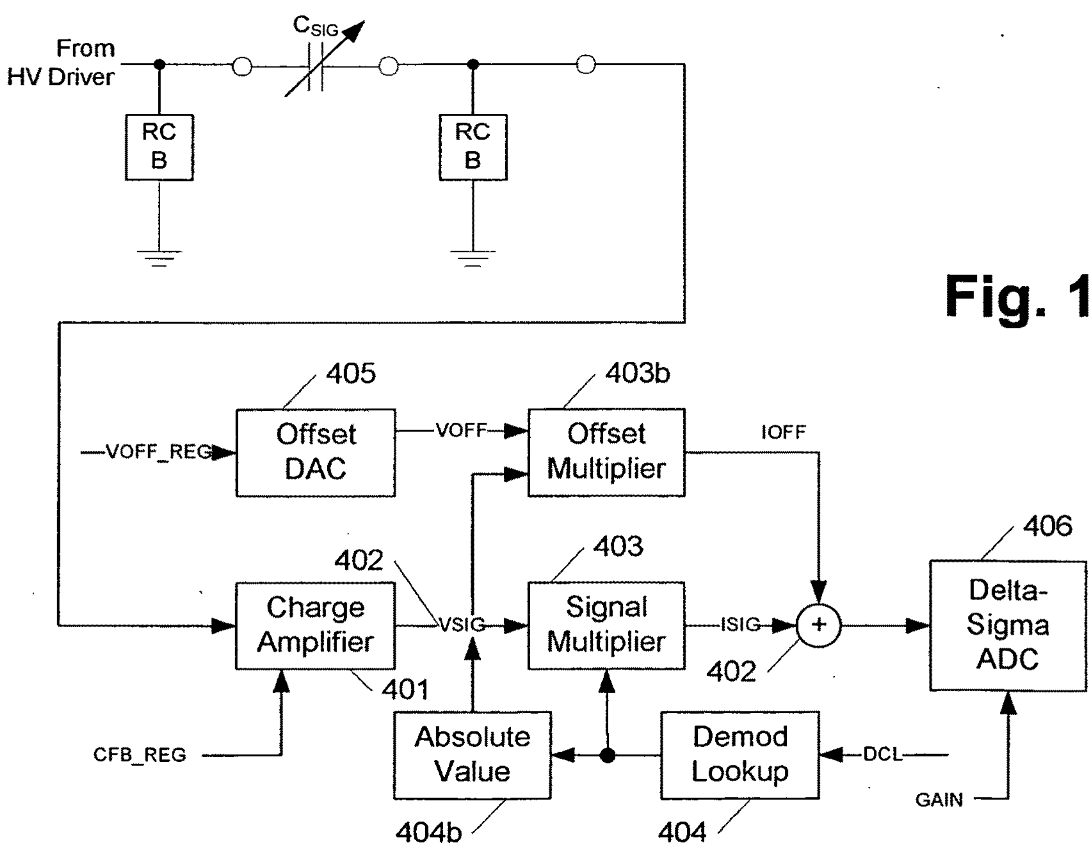
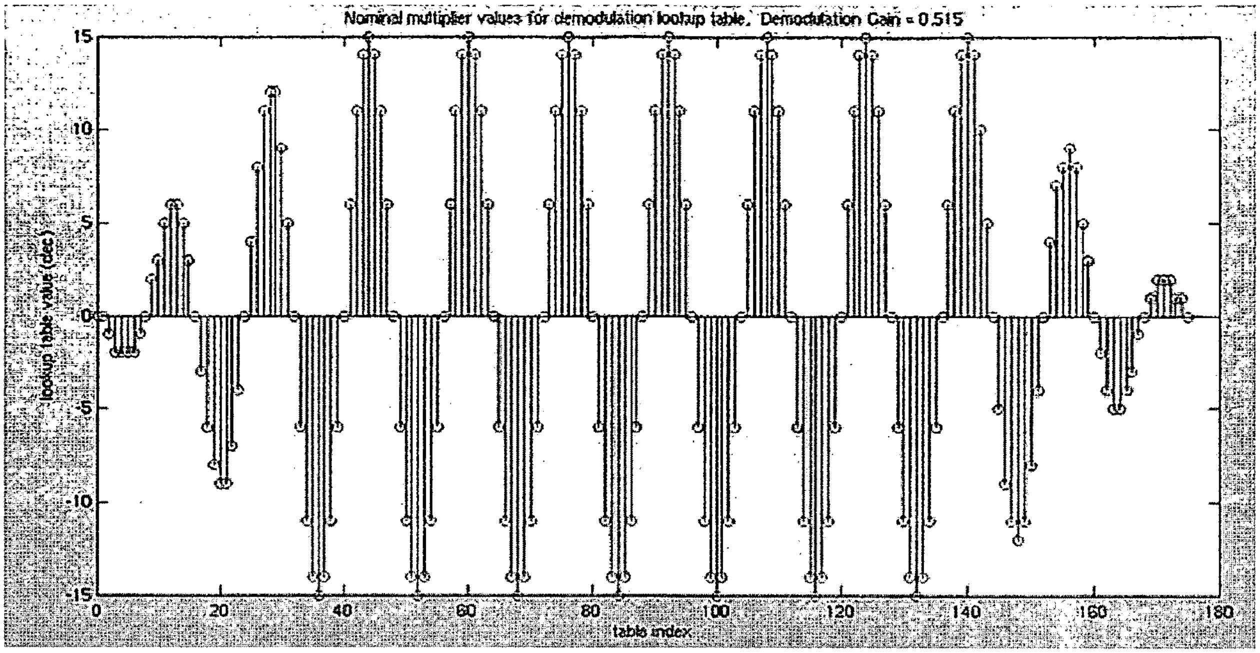

From
HV Driver
CSIG
RC
B
RC
B
405
Offset
DAC
VOFF_REG
VOFF
403b
Offset
Multiplier
IOFF
402
Charge
Amplifier
VSIG
401
403
Signal
Multiplier
ISIG
+
402
406
Delta-
Sigma
ADC
CFB_REG
Absolute
Value
404b
Demod
Lookup
DCL
404
GAIN

Fig. 10



Demodulated Signal vs. Noise Frequency, No Frequency Modulation

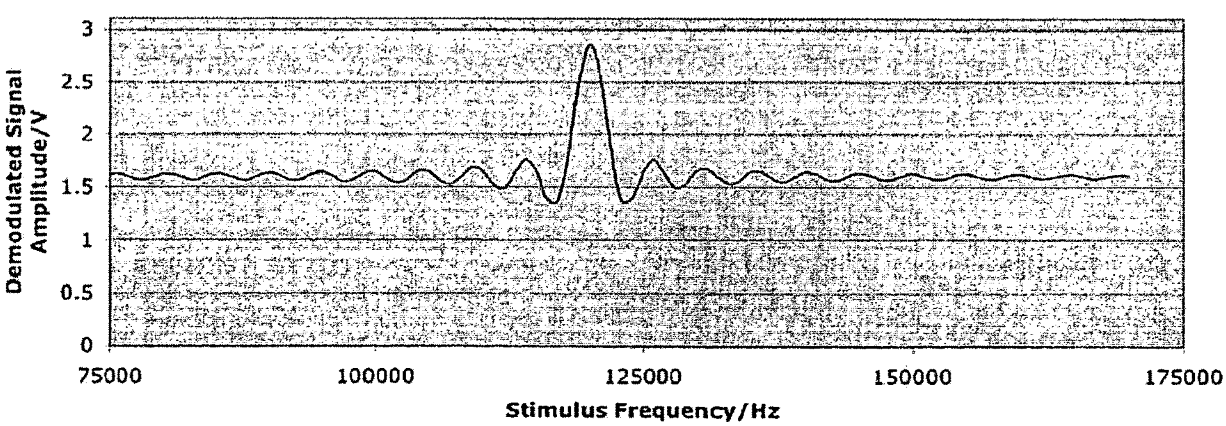
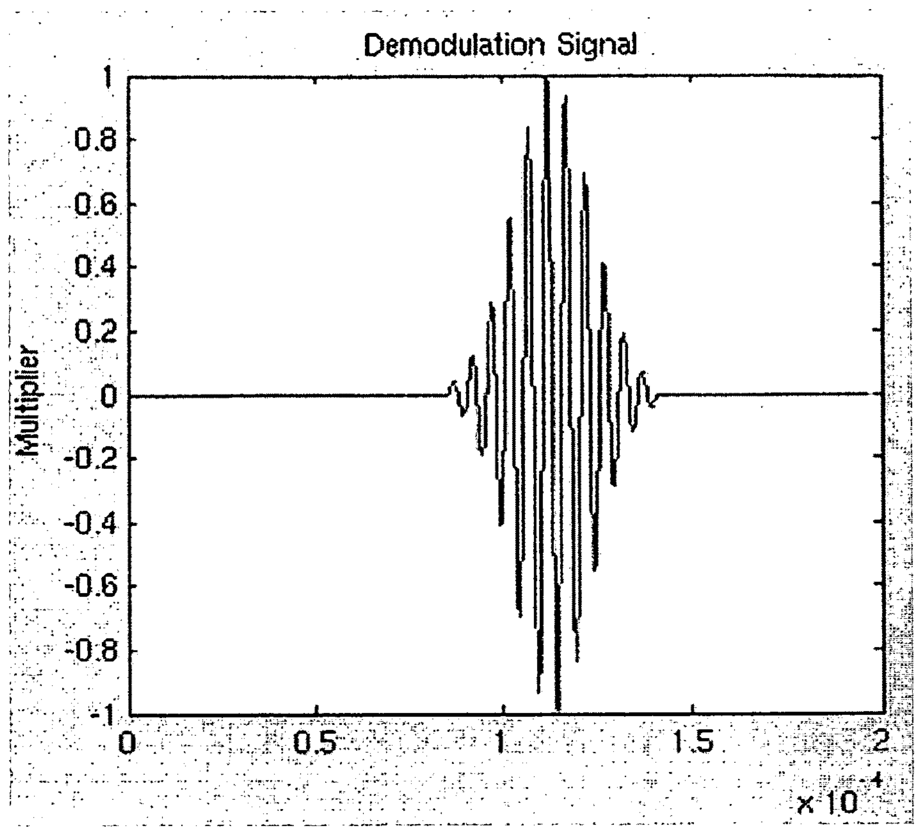


Fig. 11A


Demodulation Signal
Multiplier
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
0.5
1
1.5
2
x 10

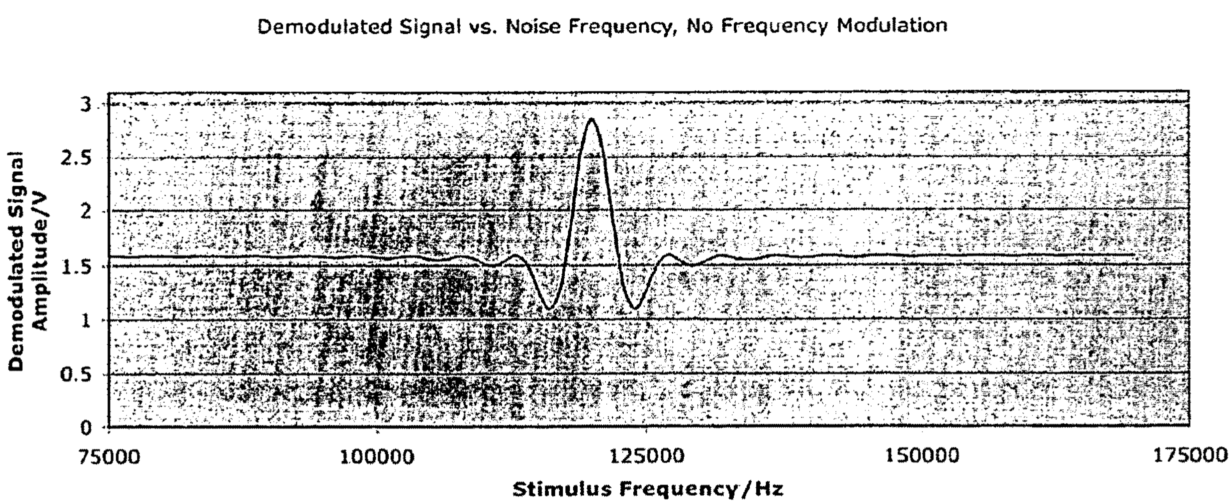

Demodulated Signal vs. Noise Frequency, No Frequency Modulation
Demodulated Signal Amplitude/V
3
2.5
2
1.5
1
0.5
0
75000
100000
125000
150000
175000
Stimulus Frequency/Hz

Fig. 11B

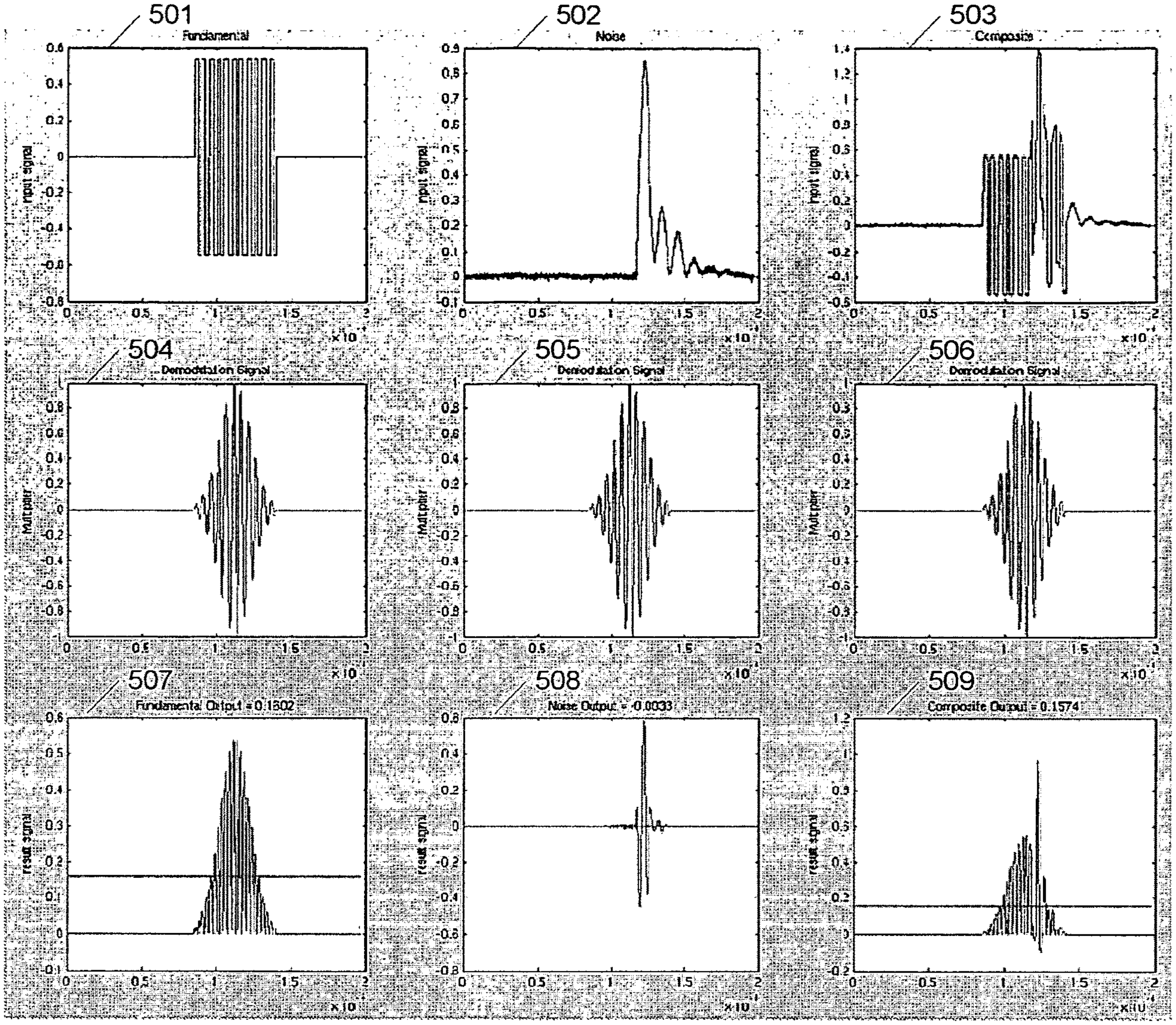

501
Fundamental
502
Noise
503
Composite
504
Demodulation Signal
505
Demodulation Signal
506
Demodulation Signal
507
Fundamental Output = 0.1602
508
Noise Output = -0.0033
509
Composite Output = 0.1574

Fig. 12

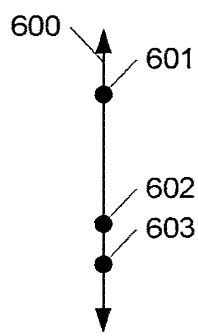

600
601
602
603

Fig. 13

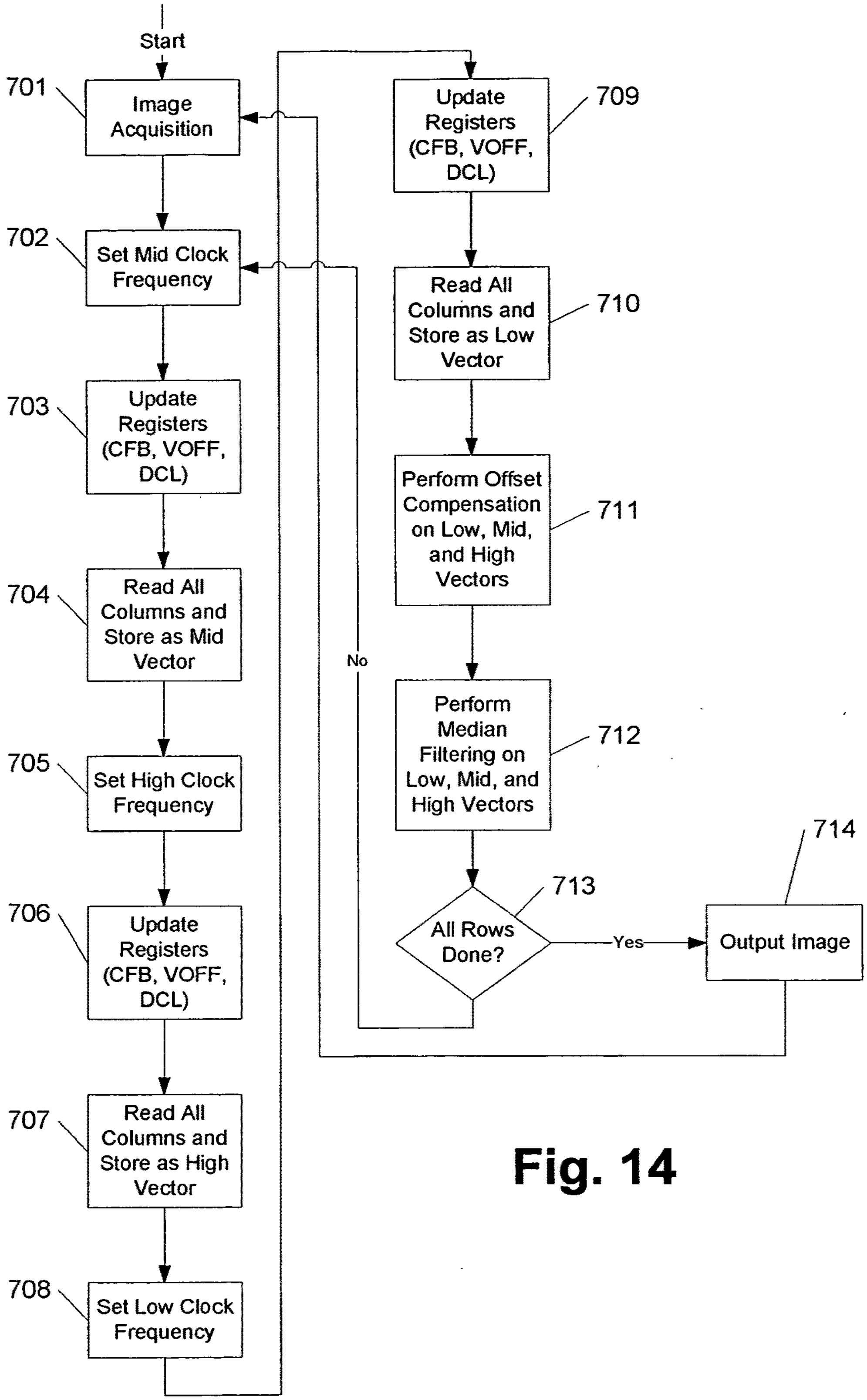

Start
701
Image Acquisition
702
Set Mid Clock Frequency
703
Update Registers (CFB, VOFF, DCL)
704
Read All Columns and Store as Mid Vector
705
Set High Clock Frequency
706
Update Registers (CFB, VOFF, DCL)
707
Read All Columns and Store as High Vector
708
Set Low Clock Frequency
709
Update Registers (CFB, VOFF, DCL)
710
Read All Columns and Store as Low Vector
711
Perform Offset Compensation on Low, Mid, and High Vectors
712
Perform Median Filtering on Low, Mid, and High Vectors
713
All Rows Done?
Yes
No
714
Output Image

Fig. 14

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CALIFORNIA 90013-1024

TELEPHONE: 213.892.5200
FACSIMILE: 213.892.5454

WWW.MOFO.COM

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WALNUT CREEK, CENTURY CITY
TOKYO, LONDON, BEIJING,
SHANGHAI, HONG KONG,
SINGAPORE, BRUSSELS

2007 OCT 26 PM 4:23

To:

NAME:	**FACSIMILE:**	**TELEPHONE:**
US PATENT AND TRADMARK OFFICE	**(571) 273-8300**	(571)

FROM: Beverly S. Carter **DATE:** October 26, 2007

Number of pages with cover page:	**3**	RE: U.S. Patent Application No. 10/840,862 Our Ref.: 10684-20090.00

Preparer of this slip has confirmed that facsimile number given is correct: **9098/BSC4**

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Comments:

Please see the attached Power of Attorney and Statement under 37 CFR 3.73(b)

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LA-815688

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STATEMENT UNDER 37 CFR 3.73(b)

Applicant/Patent Owner: APPLE INC.

Application No./Patent No.: 10/840,862 Filed/Issue Date: May 6, 2004

Entitled: MULTIPOINT TOUCHSCREEN

Apple Inc. , a corporation
(Name of Assignee) (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that it is:

1. ☒ the assignee of the entire right, title, and interest; or

2. ☐ an assignee of less than the entire right, title and interest.
The extent (by percentage) of its ownership interest is ________ %

in the patent application/patent identified above by virtue of either:

A. ☐ An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel ________ , Frame ________ , or for which a copy thereof is attached.

OR

B. ☒ A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as shown below:

1. From: Steve Hotelling; Joshua A. Strickon; Brian Q. Huppi To: Apple Computer, Inc.
The document was recorded in the United States Patent and Trademark Office at Reel 015311 , Frame 0760 , or for which a copy thereof is attached.

2. From: Apple Computer, Inc. To: Apple Inc.
The document was recorded in the United States Patent and Trademark Office at Reel 019265 , Frame 0961 , or for which a copy thereof is attached.

3. From: ________ To: ________
The document was recorded in the United States Patent and Trademark Office at Reel ________ , Frame ________ , or for which a copy thereof is attached.

☐ Additional documents in the chain of title are listed on a supplemental sheet.

☐ Copies of assignments or other documents in the chain of title are attached.
[NOTE: A separate copy (*i.e.*, a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, if the assignment is to be recorded in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

Signature: [signature] Date: October 26, 2007

Hristo Vachovsky (Reg. No. 55,694) (213) 892-5790
Printed or Typed Name Telephone Number

Attorney for Applicants
Title

106842009000
P3266US1

LA-933350

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PTO/SB/80 (01-06)
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POWER OF ATTORNEY TO PROSECUTE APPLICATIONS BEFORE THE USPTO

I hereby revoke all previous powers of attorney given in the application identified in the attached statement under 37 CFR 3.73(b).

I hereby appoint:

[X] Practitioners associated with the Customer Number: 69753

OR

[ ] Practitioner(s) named below (if more than ten patent practitioners are to be named, then a customer number must be used):

Name	Registration Number	Name	Registration Number

as attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with any and all patent applications assigned only to the undersigned according to the USPTO assignment records or assignment documents attached to this form in accordance with 37 CFR 3.73(b).

Please change the correspondence address for the application identified in the attached statement under 37 CFR 3.73(b) to:

[X] The address associated with Customer Number: 69753

OR

[ ] Firm or Individual Name

Address					
City		State		Zip	
Country		Telephone		Email	

Assignee Name and Address:

APPLE INC.
1 Infinite Loop
Cupertino, CA 95014

A copy of this form, together with a statement under 37 CFR 3.73(b) (Form PTO/SB/96 or equivalent) is required to be filed in each application in which this form is used. The statement under 37 CFR 3.73(b) may be completed by one of the practitioners appointed in this form if the appointed practitioner is authorized to act on behalf of the assignee, and must identify the application in which this Power of Attorney is to be filed.

SIGNATURE of Assignee of Record

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee

Signature		Date	10/16/2007
Name	Richard J. Lutton	Telephone	(408) 974-9453
Title	Assistant Secretary and Chief Patent Counsel		

106842009000
P3266US1

LA-939738

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UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
10/840,862	05/06/2004	Steve Hotelling	119-0093US

CONFIRMATION NO. 8470

POA ACCEPTANCE LETTER

OC000000026569715

69753
APPLE C/O MORRISON AND FOERSTER ,LLP
LOS ANGELES
555 WEST FIFTH STREET SUITE 3500
LOS ANGELES, CA 90013-1024

Date Mailed: 11/09/2007

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 10/26/2007.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

/hchristian/

Office of Initial Patent Examination (571) 272-4000 or 1-800-PTO-9199

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
10/840,862	05/06/2004	Steve Hotelling	119-0093US

CONFIRMATION NO. 8470

POWER OF ATTORNEY NOTICE

OC000000026569666

29855
WONG, CABELLO, LUTSCH, RUTHERFORD & BRUCCULERI,
L.L.P.
20333 SH 249
SUITE 600
HOUSTON, TX 77070

Date Mailed: 11/09/2007

NOTICE REGARDING CHANGE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 10/26/2007.

- The Power of Attorney to you in this application has been revoked by the assignee who has intervened as provided by 37 CFR 3.71. Future correspondence will be mailed to the new address of record(37 CFR 1.33).

/hchristian/

Office of Initial Patent Examination (571) 272-4000 or 1-800-PTO-9199

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/840,862	05/06/2004	Steve Hotelling	119-0093US	8470

69753 7590 12/27/2007
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LOS ANGELES
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LOS ANGELES, CA 90013-1024

EXAMINER	
NGUYEN, KIMNHUNG T	

ART UNIT	PAPER NUMBER
2629	

MAIL DATE	DELIVERY MODE
12/27/2007	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No.	Applicant(s)
	10/840,862	HOTELLING ET AL.
	Examiner	Art Unit
	Kimnhung Nguyen	2629

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *06 May 2004*.

2a)☐ This action is **FINAL**. 2b)☐ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) 1-31 is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☐ Claim(s) _____ is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☒ Claim(s) *1-31* are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☐ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☐ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____.
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

Election/Restriction

Restriction to one of the following inventions is required under 35 U.S.C. 121:

I. Claims 1-26 and 29 drawn to touch panel display with multiple touch, classified in class 345, subclass 173.

II. Claims 27-28, drawn to a computer readable medium including at least computer code executable by a computer, classified in class 345, sùbclass 169.

III. Claims 30-31, drawn to a digital signal processing method, comprising filter the raw data and gradient data, classified in class 345, subclass 207.

The inventions are distinct, each from the other because of the following reasons:

1. Inventions I, II and III are related as subcombinations disclosed as usable together in a single combination. In the instant case, invention I has separate utility such as touch panel display with multiple touch and doe not require a computer readable medium including at least computer code executable by a computer of invention II, and a digital signal processing method, comprising filter the raw data and gradient data of invention III See MPEP § 806.05(d).

2. Because these inventions are independent or distinct for the reasons given above and there would be a serious burden on the examiner if restriction is not required because the inventions require a different field of search (see MPEP § 808.02), restriction for examination purposes as indicated is proper.

3. A telephone call was made to Mr. Peter David on 12/22/07 to request an oral election to the above restriction requirement, but did not result in an election being made.

Applicant is advised that the reply to this requirement to be complete must include (i) an election of a species or invention to be examined even though the requirement be traversed (37 CFR 1.143) and (ii) identification of the claims encompassing the elected invention.

Correspondence

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Kimnhung Nguyen whose telephone number is (571) 272-7698. The examiner can normally be reached on MON-FRI, FROM 8:30 AM-5:30 PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Richard Hjerpe can be reached on (571) 272-7691. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

Kimnhung Nguyen
December 25, 2007

VIA EFS
Docket No.: 106842009000
Client ref: P3266US1
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Steve Porter HOTELLING et al.

Confirmation No.: 8470

Application No.: 10/840,862

Examiner: Kimnhung T. Nguyen

Filed: May 6, 2004

Art Unit: 2629

For: MULTIPOINT TOUCHSCREEN

RESPONSE TO RESTRICTION REQUIREMENT

MS Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

INTRODUCTORY COMMENTS

This is in response to the Restriction Requirement set forth in the Office Action dated December 27, 2007, for which a response is due on January 28, 2008 (the first business day following January 27, 2008).

Remarks/Arguments begin on page 2 of this paper.

REMARKS

Claims 1-31 were pending in the application. Restriction was required between Group I (claims 1-26 and 29), Group II (claims 27 and 28), and Group III (claims30 and 31).

Applicants hereby elect without traverse Group I (claims 1-26 and 29). The non-elected claims are hereby withdrawn. Applicants expressly reserve their right under 35 U.S.C. §121 to file divisional applications directed to the nonelected subject matter during the pendency of this application, or an application claiming priority from this application.

Applicants request examination of the elected subject matter on the merits.

In view of the above, each of the presently pending claims in this application is believed to be in immediate condition for allowance. Accordingly, the Examiner is respectfully requested to pass this application to issue.

If, for any reason, the Examiner finds the application other than in condition for allowance, Applicants request that the Examiner contact the undersigned attorney at the Los Angeles telephone number (213) 892-5752 to discuss any steps necessary to place the application in condition for allowance.

In the unlikely event that the transmittal letter is separated from this document and the Patent Office determines that an extension and/or other relief is required, Applicants petition for any required relief including extensions of time and authorizes the Commissioner to charge the cost of such petitions and/or other fees due in connection with the filing of this document to **Deposit Account No. 03-1952** referencing Docket No. 106842009000.

Dated: January 25, 2008

Respectfully submitted,

By

Glenn M. Kubota
Registration No.: 44,197
MORRISON & FOERSTER LLP
555 West Fifth Street, Suite 3500
Los Angeles, California 90013
(213) 892-5200

Electronic Acknowledgement Receipt

EFS ID:	2766233
Application Number:	10840862
International Application Number:	
Confirmation Number:	8470
Title of Invention:	Multipoint touchscreen
First Named Inventor/Applicant Name:	Steve Hotelling
Customer Number:	69753
Filer:	Glen Masashi Kubota/Cheryl Price
Filer Authorized By:	Glen Masashi Kubota
Attorney Docket Number:	106842009000
Receipt Date:	25-JAN-2008
Filing Date:	06-MAY-2004
Time Stamp:	11:50:53
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes) /Message Digest	Multi Part /.zip	Pages (if appl.)
1	Response to Election / Restriction Filed	responserestreq20090.pdf	72883 b5762ab13cbd753f3e81bf504554e9de112f2016	no	3

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New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Index of Claims	Application/Control No. 10840862	Applicant(s)/Patent Under Reexamination HOTELLING ET AL.
	Examiner KIMNHUNG NGUYEN	Art Unit 2629

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE							
Final	Original	05/11/2008							
	1	v							
	2	v							
	3	o							
	4	o							
	5	o							
	6	o							
	7	o							
	8	o							
	9	o							
	10	o							
	11	o							
	12	o							
	13	v							
	14	o							
	15	o							
	16	o							
	17	O							
	18	o							
	19	o							
	20	o							
	21	o							
	22	o							
	23	o							
	24	o							
	25	o							
	26	O							
	27	-							
	28	-							
	29	v							

Application Number	Application/Control No.	Applicant(s)/Patent under Reexamination	
	10/840,862	HOTELLING ET AL.	
	Examiner	**Art Unit**	
	KIMNHUNG NGUYEN	2629	

Search Notes	Application/Control No. 10840862	Applicant(s)/Patent Under Reexamination HOTELLING ET AL.
	Examiner KIMNHUNG NGUYEN	Art Unit 2629

SEARCHED

Class	Subclass	Date	Examiner
345	173-179	5/10/08	KN
178	18.01-18.04	5/10/08	KN

SEARCH NOTES

Search Notes	Date	Examiner
East search	5/10/08	KN
Inventor name	5/10/08	KN

INTERFERENCE SEARCH

Class	Subclass	Date	Examiner

OIPE JC131
AUG 25 2005
PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: Hotelling et al. | Attorney Docket No.: APL1P305/P3266

Application No.: 10/840,862 | Examiner: Unassigned

Filed: May 6, 2004 | Group: 2673

Title: MULTIPOINT TOUCHSCREEN

CERTIFICATE OF MAILING
I hereby certify that this correspondence is being deposited with the U.S. Postal Service with sufficient postage as first-class mail on August 23, 2005 in an envelope addressed to the Commissioner for Patents, P.O. Box 1450 Alexandria, VA 22313-1450.

Signed: Linda L. Pollock
Linda L. Pollock

INFORMATION DISCLOSURE STATEMENT
37 CFR §§1.56 AND 1.97(b)

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

The references listed in the attached PTO Form 1449, copies of non-U.S. references are attached, may be material to examination of the above-identified patent application. Applicants submit these references in compliance with their duty of disclosure pursuant to 37 CFR §§1.56 and 1.97. The Examiner is requested to make these references of official record in this application.

This Information Disclosure Statement is not to be construed as a representation that a search has been made, that additional information material to the examination of this application does not exist, or that these references indeed constitute prior art.

This Information Disclosure Statement is: (i) filed within three (3) months of the filing date of the above-referenced application, (ii) believed to be filed before the mailing date of a first Office Action on the merits, or (iii) believed to be filed before the mailing of a first Office Action after the filing of a Request for Continued Examination under §1.114. Accordingly, it is believed that no fees are due in connection with the filing of this Information Disclosure Statement. However, if it is determined that any fees are due, the Commissioner is hereby authorized to charge such fees to Deposit Account 500388 (Order No. APL1P305).

Respectfully submitted,
BEYER WEAVER & THOMAS, LLP

Hoellwarth

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Oakland, CA 94612-0250

AUG 2 5 2005 OIPE JC131 PATENT & TRADEMARK OFFICE

Form 1449 (Modified) Information Disclosure Statement By Applicant (Use Several Sheets if Necessary)	Atty Docket No. APL1P305/P3266	Application No.: 10/840,862
	Applicant: Hotelling et al.	
	Filing Date May 6, 2004	Group 2673

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Examiner Initial	No.	Patent No.	Date	Patentee	Class	Sub-class	Filing Date
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/K.N./	A12	6,888,536 B2	05-03-05	Westerman et al.			07-31-01

Foreign Patent or Published Foreign Patent Application

Examiner Initial	No.	Document No.	Publication Date	Country or Patent Office	Class	Sub-class	Translation Yes	Translation No
/K.N./	A13							
/K.N./	A14							
/K.N./	A15							
/K.N./	A16							
/K.N./	A17							

Other Documents

Examiner Initial	No.	Author, Title, Date, Place (e.g. Journal) of Publication
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Examiner	/Kimnhung Nguyen/	Date Considered	05/11/2008

Examiner: Initial citation considered. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.