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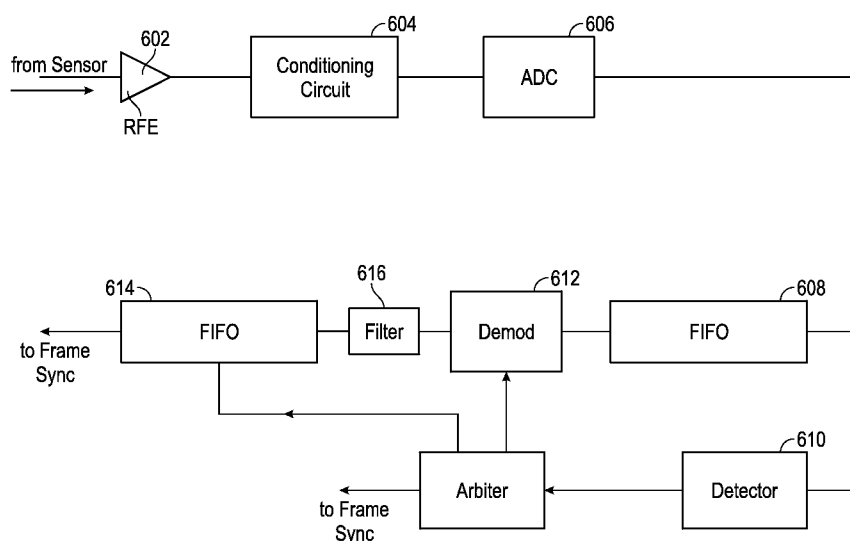


FIG. 6

(57) **Abstract:** A touch input device configured to detect stylus signals generated by an external stylus is provided. The touch input device includes a plurality of stylus signal detectors that can receive the stylus signal and estimate the start and end time of the stylus signal in order to facilitate windowed demodulation of signal. The touch input device also includes circuitry to determine which of the plurality of detectors is most likely to have received the stylus signal and based on that determination can demodulate the signal and extract data embedded within the stylus signal.

STYLUS DETECTION AND DEMODULATION

Field

[0001] This relates generally to touch sensitive devices and, more specifically, to touch sensitive devices which can also accept input from a stylus.

Background

[0002] Touch sensitive devices have become popular as input devices to computing systems due to their ease and versatility of operation as well as their declining price. A touch sensitive device can include a touch sensor panel, which can be a clear panel with a touch sensitive surface, and a display device, such as a liquid crystal display (LCD), that can be positioned partially or fully behind the panel or integrated with the panel so that the touch sensitive surface can cover at least a portion of the viewable area of the display device. The touch sensitive device can allow a user to perform various functions by touching the touch sensor panel using a finger, stylus or other object at a location often dictated by a user interface (UI) being displayed by the display device. In general, the touch sensitive device can recognize a touch event and the position of the touch event on the touch sensor panel, and the computing system can then interpret the touch event in accordance with the display appearing at the time of the touch event, and thereafter can perform one or more actions based on the touch event.

[0003] As touch sensing technology continues to improve, touch sensitive devices are increasingly being used to compose and mark-up electronic documents. In particular, styli have become popular input devices as they emulate the feel of traditional writing instruments. Most conventional styli simply include a bulky tip made of a material capable of interacting with the touch sensitive device in a manner resembling a user's finger. As a result, conventional styli lack the precision and control of traditional writing instruments. A stylus capable of receiving stimulation and force signals and generating stylus stimulation signals that can be transmitted to the touch sensitive device can improve the precision and control of the stylus. However, such a stylus can present

demodulation challenges to the touch sensitive device due to the asynchronous interaction between the stylus and the device.

Summary

[0004] A stylus signal detection and demodulation architecture that can facilitate synchronous demodulation on a touch input device is disclosed.

[0005] In one example, a plurality of stylus detectors can detect incoming stylus signals. An arbiter can determine the probable location of the stylus and can then direct the appropriate demodulation channels based on the detected position to a stylus controller that can synchronize the stylus frames as well as extract data contained within the stylus signal.

Brief Description of the Drawings

[0006] FIG. 1 illustrates an exemplary touch sensor that can be used with a touch sensitive device according to various examples.

[0007] FIG. 2 illustrates a block diagram of an exemplary stylus according to various examples.

[0008] FIG. 3 illustrates a control system for a touch sensor that can detect both a user's touch and signals from a stylus according to disclosed examples.

[0009] FIG. 4 illustrates an example stylus signal waveform according to examples of the disclosure.

[0010] FIG. 5 illustrates an example touch/stylus demodulation circuit according to examples of the disclosure.

[0011] FIG. 6 illustrates a stylus signal receiver according to examples of the disclosure.

[0012] FIG. 7 illustrates an example of a touch and stylus sensing timing arrangement according to examples of the disclosure.

[0013] FIG. 8 illustrates an exemplary stylus detection and demodulation device according to examples of the disclosure.

[0014] FIG. 9 is a block diagram of an example computing system that illustrates

one implementation of a touch sensor panel display with stylus signal noise correction according to examples of the disclosure.

[0015] FIG. 10 illustrates an exemplary system for generating or processing a stylus stimulation signal according to examples of the disclosure.

[0016] FIG. 11A-D illustrate exemplary personal devices that include a touch sensor according to various examples.

Detailed Description

[0017] In the following description of examples, reference is made to the accompanying drawings in which it is shown by way of illustration specific examples that can be practiced. It is to be understood that other examples can be used and structural changes can be made without departing from the scope of the various examples.

[0018] This relates to the processing of stylus signals by a touch sensor panel. In one example, the touch panel can process the stylus signals by first detecting the stylus signal, determining where on a touch sensor panel the stylus is located, , demodulating the stylus signal and extracting the data contained within the stylus signal.

[0019] FIG. 1 illustrates touch sensor 100 that can be used to detect touch events on a touch sensitive device, such as a mobile phone, tablet, touchpad, portable or desktop computer, portable media player, or the like. Touch sensor 100 can include an array of touch regions or nodes 105 that can be formed at the crossing points between rows of drive lines 101 (D0-D3) and columns of sense lines 103 (S0-S4), although it should be understood that the row/drive line and column/sense line associations are only exemplary. Each touch region 105 can have an associated mutual capacitance C_{sig} 111 formed between the crossing drive lines 101 and sense lines 103 when the drive lines are stimulated. The drive lines 101 can be stimulated by stimulation signals 107 provided by drive circuitry (not shown) and can include an alternating current (AC) waveform. The sense lines 103 can receive touch signals 109 indicative of a touch at the touch sensor 100 to sense circuitry (not shown), which can include a sense amplifier for each sense line, or a fewer number of sense amplifiers that can be multiplexed to connect to a larger number of sense lines.

[0020] To sense a touch at the touch sensor 100, drive lines 101 can be stimulated by

the stimulation signals 107 to capacitively couple with the crossing sense lines 103, thereby forming a capacitive path for coupling charge from the drive lines 101 to the sense lines 103. The crossing sense lines 103 can output touch signals 109, representing the coupled charge or current. When an object, such as a passive stylus, finger, etc., touches the touch sensor 100, the object can cause the capacitance C_{sig} 111 to reduce by an amount ΔC_{sig} at the touch location. This capacitance change ΔC_{sig} can be caused by charge or current from the stimulated drive line 101 being shunted through the touching object to ground rather than being coupled to the crossing sense line 103 at the touch location. The touch signals 109 representative of the capacitance change ΔC_{sig} can be received by the sense lines 103 to the sense circuitry for processing. The touch signals 109 can indicate the touch region where the touch occurred and the amount of touch that occurred at that touch region location.

[0021] While the example shown in FIG. 1 includes four drive lines 101 and five sense lines 103, it should be appreciated that touch sensor 100 can include any number of drive lines 101 and any number of sense lines 103 to form the desired number and pattern of touch regions 105. Additionally, while the drive lines 101 and sense lines 103 are shown in FIG. 1 in a crossing configuration, it should be appreciated that other configurations are also possible to form the desired touch region pattern. While FIG. 1 illustrates mutual capacitance touch sensing, other touch sensing technologies may also be used in conjunction with examples of the disclosure, such as self-capacitance touch sensing, resistive touch sensing, projection scan touch sensing, and the like. Furthermore, while various examples describe a sensed touch, it should be appreciated that the touch sensor 100 can also sense a hovering object and generate hover signals therefrom.

[0022] FIG. 2 illustrates a block diagram of an exemplary stylus 200 that can be used with a touch sensitive device, such as a mobile phone, touchpad, portable or desktop computer, or the like. Stylus 200 can generally include tip 201, ring 203, body 207, and multiple stylus stimulation signal circuitry 205 located within body 207. As will be described in greater detail below, stylus stimulation signal circuitry 205 can be used to generate a stimulation signal that can be transmitted to a touch sensitive device through tip 201. Tip 201 can include a material capable of transmitting the stylus stimulation signal from stylus stimulation signal circuitry 205 to the touch sensitive device, such as a flexible conductor, a metal, a conductor wrapped by a non-conductor, a non-conductor

coated with a metal, a transparent conducting material (e.g., indium tin oxide (ITO)) or a transparent non-conductive material (e.g., glass or plastic) coated with a transparent (e.g., ITO) (if the tip is also used for projection purposes) or opaque material, or the like. In some examples, tip 201 can have a diameter of about 1.5mm or less. Tip 201 which can be used to transmit stimulus signals from the stylus, can be implemented using a conductive ring 203. Ring 203 can include a conductive material, such as a flexible conductor, a metal, a conductor wrapped by a non-conductor, a non-conductor coated with a metal, a transparent conducting material (e.g., ITO), a transparent non-conductive material (e.g., glass) coated with a transparent material (e.g., ITO if the tip is used for projection purposes) or opaque material, or the like. Ring 203 can serve other purposes, such as providing an alternative means for transmitting the stylus stimulation signal from the stylus to the touch sensitive device. Similarly, tip 201 or ring 203 can also be used to sense the touch drive signal from the touch sensitive device. Both tip 201 and ring 203 can be segmented and each segment can be independently controlled according to the description above.

[0023] FIG. 3 illustrates a control system for a touch sensor that can detect both a user's touch and signals from a stylus according to disclosed examples. The sensor panel 314 of the touch sensor may be configured to detect touches on the surface of the touch screen by changes in capacitance as described above in reference to FIG. 1. With reference to FIG. 3, a sensing node 344 formed by one or more electrodes (explained below) may form a first electrically conductive member and an object, such as a finger of the user, may form a second electrically conductive member. The sensor panel 314 of the touch screen may be configured in a self-capacitance arrangement or in a mutual capacitance arrangement.

[0024] In the self-capacitance arrangement, electrodes may include a single layer of a plurality of electrodes spaced in a grid or other arrangement where each electrode may form a node 344. The sensing circuit 350 can monitor changes in capacitance that may occur at each node 344. These changes typically occur at a node 344 when a user places an object (e.g., finger or tip 201 of the stylus 200) in close proximity to the electrode.

[0025] With continued reference to FIG. 3, in a mutual capacitance system, the electrodes may be separated into two layers forming drive lines 342 and sense lines 340.

The drive lines 342 may be formed on a first layer and the sense lines 340 may be formed on a second layer. The nodes 344 for the sensor panel 314 may be defined at locations where the drive lines 342 may cross over or under the sense lines 340 (although they are typically placed in different layers). The sense lines 340 may intersect the drive lines 342 in a variety of manners. For example, in one example, the sense lines 340 are perpendicular to the drive lines 342, thus forming nodes 344 with x and y coordinates. However, other coordinate systems can also be used, and the coordinates of the nodes 344 may be differently defined.

[0026] A drive controller 346 can be connected to each of the drive lines 342. The drive controller 346 can provide a stimulation signal (e.g., voltage) to the drive lines 342. The sensing circuit 350 can be connected to each of the sense lines 340, and the sensing circuit 350 can act to detect changes in capacitance at the nodes 344 in the same manner as described in FIG. 1. During operation, the stimulation signal can be applied to the drive lines 342, and due to the capacitive coupling between the drive lines 342 and sense lines 340, a current can be carried through to the sense lines 340 at each of the nodes 344. The sensing circuit 350 can then monitor changes in capacitance at each of the nodes 344. In some examples, each drive line can be switchably configured to operate as sense lines, and thus a sensing circuit and multiplexer similar to 350 and 354 can be connected to the drive lines similar to the sense lines depicted in FIG. 3.

[0027] In either the self-capacitance or mutual capacitance arrangements discussed above, the sensing circuit 350 can detect changes in capacitance at each node 344. This may allow the sensing circuit 350 to determine when and where a user has touched various surfaces of the touch screen 306 with one or more objects. The sensing circuit 350 may include one more sensors for each of the sense lines 340 and may then communicate data to a processor 348. In one example, the sensing circuit 350 may convert the analog capacitive signals to digital data and then transmit the digital data to the processor 348. In other examples, the sensing circuit 350 may transmit the analog capacitance signals to the processor 348, which may then convert the data to a digital form. Further, it should be noted that the sensing circuit 350 may include individual sensors for each sensing line 342 or a single sensor for all of the sense lines 340. The sensing circuit 350 may report a location of the node 344, as well as the intensity of the capacitance (or changed thereof) at the node 344.

[0028] In some examples, the touch screen may include one or more multiplexers. For example, during touch operation, the sensing circuit 350 may also include a multiplexer configured to perform time multiplexing for the sense lines 340. For example, the sensing circuit 350 may receive signals from each of the nodes 344 along the sense lines 340 at approximately the same time. The multiplexer can store the incoming signals and then may release the signals sequentially to the processor 348 one at a time or in subsets. As discussed above, in some examples that are not pictured, the drive lines can be configured to also act as sense lines and thus can be configured with multiplexers and sense circuitry similar to the sense lines as described above.

[0029] In addition to the multiplexers that may be used to during a touch mode to process touch signals, the touch screen may also include a drive multiplexer 352 and/or a sense multiplexer 354. These two input device multiplexers 352, 354 may be in communication with the respective set of lines 342, 344 to switch between a touch mode and a stylus or input device mode. As will be discussed in more detail below, during a stylus mode, in which the sensing circuit 350 is configured to detect input from a stylus or other input device, the touch screen may selectively scan the sense lines 340, as well as the drive lines 342, in order to receive data transmitted from the tip 202 of the stylus 200. In these examples, the drive controller 346 may further be configured to sense for signals on the drive lines 342 in order to detect a signal transmitted from the tip 202 of the stylus 200. In this manner, the drive lines 342 may be configured to act as sense lines 340 and interact with the tip 202 of the stylus 200 to receive one or more signals (e.g., voltage signals). In other words, rather than providing a stimulation signal to the drive lines 342, during a stylus scan, if the stylus is transmitting, the stylus may apply a stimulation signal to the drive lines 342 (in the form of a data transmission signal).

[0030] In some examples, the drive lines 342 may be scanned after the input device has been detected by the sense lines. These examples may reduce the scanning time required for the touch screen to detect the input device, as the drive lines 342 may only be scanned in instances where the input device is actually present. Thus, if the input device is not detected, the touch screen may more quickly return to scanning for touch inputs. That said, it should be noted that when driving, the stylus 200 may provide a stimulation signal to both the sense and drive lines simultaneously and so in some instances both lines may be scanned simultaneously. However, in some examples, the

sense lines 340 and drive lines 342 may be scanned and demodulated sequentially (when the input device is detected), as this type of scanning may allow the touch screen to re-use the same touch hardware for both scanning and drive line scanning. That is, the sense circuitry may be multiplexed to the drive lines, to reduce the separate components that may be required by the touch screen. The control system of FIG. 3 can also include a spectral analyzer for finding frequencies that have minimal noise.

[0031] Additionally, in some examples, the touch controller, such as the sense circuitry 350 and/or drive controller, may analyze the input or stimulation signal transmitted from the input device in order to detect the position of the input device, as well as to receive data communication. In other words, the input signal may be used to detect location, and the same signal may be encoded with data from the input device.

[0032] FIG. 4 illustrates an example stylus signal waveform according to examples of the disclosure. In this example, stylus signal 400 can contain multiple steps 402. Each step can be of a pre-determined time period; in the example of FIG. 4 the time period can be 150 μ s. During the step, a sinusoidal signal at a given frequency can be transmitted as the signal. During the time periods in between steps, no signal at the same frequency can be transmitted by the stylus. A grouping of steps can be called a burst. As illustrated, a group of four steps can be called a burst 404. If each step 402 can be 150 μ s and each gap between steps can be 150 μ s, then each burst can be approximately 2ms. The time between bursts can also be pre-determined. In the example of FIG. 4, the time between burst 406 can be 6ms in duration. In other words, between the last step of burst 404 and the next burst, there can be 6ms where no signal is transmitted.

[0033] FIG. 5 illustrates an example stylus receiver circuit according to examples of the disclosure. As described above, during a touch operation, the drive lines 101 can transmit a stimulation signal that can be received via the sense lines 103 due to mutual capacitance between the drive lines and sense lines. As illustrated in FIG. 5, when the device is in a stylus searching mode or stylus active mode (described in further detail below), the drive lines 101 and the sense lines 103 can be configured to receive stylus signals. Each electrode of the drive and sense electrodes 101 and 103 can be coupled to a receiver 502. As described above in a touch sensing mode, the drive lines can be coupled to signal generators that generate a stimulation signal, and the sense lines can be coupled to receivers in order to receive signals indicative of a touch occurring on the

touch sensor panel. In a stylus searching mode or a stylus active mode, both the drive lines 101 and sense lines 103 can be coupled to receivers 502 in order receive signals generated by the stylus. Thus, on a touch sensor panel that has, for example, 40 rows and 30 columns, there can be 70 total stylus receive channels. On the columns/ sense lines 103, the receive circuitry can be used for both touch and stylus. On the rows/ drive lines 101, the electrodes can be switchably configured to be coupled to drive lines during a touch sensing operation and receivers during a stylus sensing operation.

[0034] FIG. 6 illustrates a stylus signal receiver according to examples of the disclosure. A drive line 101 or sense line 103, which in a stylus detection mode become electrodes, act as inputs to a receiver front end (RFE) 602. RFE 602 can provide any analog signal processing needs, including, for example: amplification, filtering, attenuation, etc. The output of RFE 602 can be sent to conditioning circuit 604. Conditioning circuit 604 can condition the signal to be digitized by analog-to-digital converter 606 by providing filtering, buffering etc. At ADC 606, the analog signal can be converted to digital samples; the output of the ADC can then be fed into first-in-first-out buffer 608 and stylus detector 610. Stylus detector 610 can perform a single frequency windowed discrete Fourier transform of the signal, with the window sliding as a function of time, in order to detect peak energy within the window. The peak can be indicative of the end time of stylus signal. A more detailed discussion of the stylus detector can found in U.S. Patent Application No. 13/830,399 entitled “Stylus Signal Detection and Demodulation Architecture” (Attorney Docket No. 106842060400) incorporated in its entirety herein for all purposes.

[0035] The detector 610 can determine the end and beginning times of a detected stylus step. This information can be sent to an arbiter 802 (described below) and can also be sent to a burst FIFO 614 as well as a demodulator 612. Demodulator 612 can take, as its input, the output of FIFO 608. The demodulator 612 can thus receive a delayed version of the signal being output by ADC 606. When the demodulator 612 receives the start time and end time of a detected stylus signal, it can coordinate demodulation of the signal with the output of the FIFO such that demodulation occurs only during the detected beginning and end of the stylus signal. In other words, while the detector receives the stylus signal in real time, the demodulator will get a delayed version of the signal, with delay time being adequate enough to allow the detector to report to the demodulator the

beginning and end time of the stylus signal. By the time the stylus signal exits the FIFO 608, the demodulator can know when to act on the signal in order to demodulate it. The output of the demodulator 612 can then be inputted into burst FIFO 614. The arbiter 802 can relay the start time and end time of the stylus step signal to the burst FIFO 614. Burst FIFO 614 can feed the appropriate data that occurred during the time period between the estimated start and stop time of the stylus step to a frame synchronizer (discussed below).

[0036] Since the drive lines can switch their configurations depending on whether the device is detecting touch or detecting stylus signals, the operation of the device in a touch detection mode and stylus detection mode can be time multiplexed in order to allow the device to perform both touch and stylus operations. FIG. 7 illustrates an example of a touch and stylus sensing timing arrangement according to examples of the disclosure. As time progresses from left to right in the timing diagram of FIG. 7, the device can switch between touch detection mode 702 and various stylus detection modes. In this example, touch mode 702 can alternate with stylus detection mode 704. During the period of time where touch mode 702 is alternating with stylus detection mode, the touch mode can be 800 μ s in duration while stylus mode can be 250 μ s.

[0037] During stylus detection mode, the device can be actively searching for a stylus signal as described above, and if no stylus signal is found during the period of time allotted to stylus detection mode 704, the device can return to touch detection mode 702. However if a stylus signal is detected during stylus detection mode 704, the timing between touch detection and the stylus modes can be altered. For instance, in the example of FIG. 7, if a stylus is detected at time 706 during a stylus detection mode 704, the device can shift into a stylus active mode. During stylus active mode, the device can detect the location of stylus signals and demodulate any incoming stylus signals, the same as stylus detection mode 704; however, the timing can be synchronized with the burst/step patterns described in FIG. 4. For instance, when a stylus is first detected at time 706, the beginning of the next touch detection mode 702 can be synchronized with the time between stylus bursts 406, which in the example of FIG. 4 is 6ms. Thus, as illustrated in FIG. 7 when the stylus is detected at time 706, the next touch detection mode 702 can last for 6ms while the stylus is between bursts. The stylus detection modes that come after can be approximately 2ms, which can correspond to the time required by the stylus to transmit a burst. In this way, the touch detection mode can be timed to occur

between bursts when the stylus is not generating a signal, and the stylus active mode can correspond to a period of time when a stylus burst is expected to arrive on the device. If the device does not detect a stylus during a pre-determined number of stylus active mode time periods 708, the device can return to the timing scheme illustrated at the beginning of the timing diagram and alternate touch and stylus in 800 μ s and 250 μ s time periods, respectively.

[0038] FIG. 8 illustrates an exemplary stylus detection and demodulation device according to examples of the disclosure. As illustrated in FIG. 8, the output of each individual detector corresponding to a stylus signal channel can be inputted into arbiter 802. Each detector 804 can relay information to the arbiter 802 about the stylus signals it has detected. For instance, each detector can relay information regarding whether or not a stylus signal was detected on that detector; if a stylus signal was detected it can relay to the arbiter the estimated beginning and end times of an estimated step, and it can also relay metrics about the detected signal. Metrics can include information related to the strength of the signal detected by the detectors, for instance the magnitude of detected stylus signal, the number of zero-crossings detected, or the number of crossings of a pre-determined non-zero threshold. By relaying a metric about the detection, each detector can alert the arbiter as to the level of fidelity of the detection.

[0039] The arbiter can scan the information relayed by each detector to determine the detector most likely to have the most accurate measurement of the beginning and end time of the stylus step. When the arbiter determines the “winning” detector, it can output a signal to all stylus signal receive channels like those depicted in FIG. 6. The signal sent by the arbiter of the device can tell each receive channel the estimated start and start time of the stylus step. Referring to FIG. 6, each the arbiter signal can be received by FIFO 614. FIFO 614 can extract the data corresponding to the estimated start and stop time received from the arbiter 802 and send it to Frame Sync Module 806.

[0040] Frame Sync module 806 can receive data from each burst FIFO 614 of each stylus detection receive channel. Frame Sync module 806 can create frames of data, each frame of data corresponding to a given scan of the channels. When one frame of data is acquired, another frame can be created that corresponds to another scan of the stylus signal receive channels. The frame sync module 806 can time the beginning of the next frame of data to correspond with an individual detected burst. In this way, the data

frames are synchronized to the stylus signals being generated by the stylus after each individual burst. By synching the stylus signals being generated to the device after every burst, any clock drift associated with differing phases between the device and the stylus can be mitigated. This module could be implemented in firmware or hardware.

[0041] The frame sync module can also perform data extraction. In other words, the data that is encoded within a stylus signal can be decoded. In one example, data can be encoded into the stylus signal by modulating the phase difference between successive steps of a stylus burst. Referring to FIG. 4, step 402 can have a given phase. The next step of the burst can have another phase value. The difference in phases between the first step and the any step can be used to encode data using a standard differential phase shift keying (DPSK) technique and can be demodulated by using standard DPSK demodulation techniques. While DPSK is given as an example, the disclosure is not so limited and data can be encoded in numerous ways such as frequency shift keying (FSK), amplitude shift keying (ASK), quadrature amplitude modulating (QAM) and other various modulation and demodulation techniques known to one of skill in the art.

[0042] Once the data is decoded, the frame sync module can send the frames to firmware to determine the position of the stylus by analyzing each received frame of data and finding the channels with the highest magnitude signal in the rows (X direction) and the channels with the highest magnitude in the columns (Y-direction) and performing a centroid operation on each axis.

[0043] FIG. 9 is a block diagram of an example computing system that illustrates one implementation of a touch sensor panel display with stylus detection and demodulation according to examples of the disclosure. Computing system 900 could be included in, for example, mobile telephone 136, digital media player 140, personal computer 144, or any mobile or non-mobile computing device that includes a touch screen. Computing system 900 can include a touch sensing system including one or more touch processors 902, peripherals 904, a touch controller 906, and touch sensing circuitry. Peripherals 904 can include, but are not limited to, random access memory (RAM) or other types of memory or storage, watchdog timers and the like. Touch controller 906 can include, but is not limited to, one or more sense channels 909, channel scan logic 910 and driver logic 914. Channel scan logic 910 can access RAM 912, autonomously read data from the sense channels and provide control for the sense channels. In addition,

channel scan logic 910 can control driver logic 914 to generate stimulation signals 916 at various frequencies and phases that can be selectively applied to drive regions of the touch sensing circuitry of touch screen 920, as described in more detail below. In some examples, touch controller 906, touch processor 102 and peripherals 904 can be integrated into a single application specific integrated circuit (ASIC).

[0044] Computing system 900 can also include a host processor 929 for receiving outputs from touch processor 902 and performing actions based on the outputs. For example, host processor 929 can be connected to program storage 932 and a display controller, such as an LCD driver 934. Host processor 929 can use LCD driver 934 to generate an image on touch screen 920, such as an image of a user interface (UI), and can use touch processor 902 and touch controller 906 to detect a touch on or near touch screen 920, such a touch input to the displayed UI. The touch input can be used by computer programs stored in program storage 932 to perform actions that can include, but are not limited to, moving an object such as a cursor or pointer, scrolling or panning, adjusting control settings, opening a file or document, viewing a menu, making a selection, executing instructions, operating a peripheral device connected to the host device, answering a telephone call, placing a telephone call, terminating a telephone call, changing the volume or audio settings, storing information related to telephone communications such as addresses, frequently dialed numbers, received calls, missed calls, logging onto a computer or a computer network, permitting authorized individuals access to restricted areas of the computer or computer network, loading a user profile associated with a user's preferred arrangement of the computer desktop, permitting access to web content, launching a particular program, encrypting or decoding a message, and/or the like. Host processor 929 can also perform additional functions that may not be related to touch processing.

[0045] Integrated display and touch screen 920 can include touch sensing circuitry that can include a capacitive sensing medium having a plurality of drive lines 922 and a plurality of sense lines 923. It should be noted that the term “lines” is sometimes used herein to mean simply conductive pathways, as one skilled in the art will readily understand, and is not limited to elements that are strictly linear, but includes pathways that change direction, and includes pathways of different size, shape, materials, etc. Drive lines 922 can be driven by stimulation signals 916 from driver logic 914 through a

drive interface 924, and resulting sense signals 917 generated in sense lines 923 can be transmitted through a sense interface 925 to sense channels 909 (also referred to as an event detection and demodulation circuit) in touch controller 906. In this way, drive lines and sense lines can be part of the touch sensing circuitry that can interact to form capacitive sensing nodes, which can be thought of as touch picture elements (touch pixels), such as touch pixels 926 and 927. This way of understanding can be particularly useful when touch screen 920 is viewed as capturing an "image" of touch. In other words, after touch controller 906 has determined whether a touch has been detected at each touch pixel in the touch screen, the pattern of touch pixels in the touch screen at which a touch occurred can be thought of as an "image" of touch (e.g. a pattern of fingers touching the touch screen).

[0046] One or more of the functions relating to stylus detection and demodulation described above can be performed by a system similar or identical to system 1000 shown in FIG. 10. System 1000 can include instructions stored in a non-transitory computer readable storage medium, such as memory 1003 or storage device 1001, and executed by processor 1005. The instructions can also be stored and/or transported within any non-transitory computer readable storage medium for use by or in connection with an instruction execution system, apparatus, or device, such as a computer-based system, processor-containing system, or other system that can fetch the instructions from the instruction execution system, apparatus, or device and execute the instructions. In the context of this document, a "non-transitory computer readable storage medium" can be any medium that can contain or store the program for use by or in connection with the instruction execution system, apparatus, or device. The non-transitory computer readable storage medium can include, but is not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus or device, a portable computer diskette (magnetic), a random access memory (RAM) (magnetic), a read-only memory (ROM) (magnetic), an erasable programmable read-only memory (EPROM) (magnetic), a portable optical disc such a CD, CD-R, CD-RW, DVD, DVD-R, or DVD-RW, or flash memory such as compact flash cards, secured digital cards, USB memory devices, memory sticks, and the like.

[0047] The instructions can also be propagated within any transport medium for use by or in connection with an instruction execution system, apparatus, or device, such as a

computer-based system, processor-containing system, or other system that can fetch the instructions from the instruction execution system, apparatus, or device and execute the instructions. In the context of this document, a “transport medium” can be any medium that can communicate, propagate or transport the program for use by or in connection with the instruction execution system, apparatus, or device. The transport medium can include, but is not limited to, an electronic, magnetic, optical, electromagnetic or infrared wired or wireless propagation medium.

[0048] It is to be understood that the system is not limited to the components and configuration of FIG. 10, but can include other or additional components in multiple configurations according to various examples. Additionally, the components of system 1000 can be included within a single device, or can be distributed between multiple devices.

[0049] FIGS. 11A-11D show example systems in which touch sensor panels according to examples of the disclosure may be implemented. FIG. 11A illustrates an example mobile telephone 1136 that includes a touch sensor panel 1124. FIG. 11B illustrates an example digital media player 1140 that includes a touch sensor panel 1126. FIG. 11C illustrates an example personal computer 1144 that includes a touch sensor panel 1128. FIG. 11D illustrates an example tablet computing device 1148 that includes a touch sensor panel 1130.

[0050] Therefore, according to the above, some examples of the disclosure are directed to a method of detecting stylus signals generated by an external stylus on a touch input device, the method comprising configuring the touch input device to receive a stylus signal, receiving the stylus signal at a plurality of stylus signal detectors, determining which of the plurality of stylus signal detectors has a greatest likelihood of having received the stylus signal, and demodulating the received stylus signal based on one or more metrics generated by the determined stylus signal detector. Additionally or alternatively to one or more of the examples disclosed above, in some examples, configuring the touch input device to receive a stylus signal includes configuring a plurality of drive lines and a plurality of sense lines configured for receiving touch inputs to additionally receive a stylus signal. Additionally or alternatively to one or more of the examples disclosed above, in some examples, configuring the plurality of sense lines to receive a stylus signal includes coupling each sense line of the plurality of sense lines to a

stylus signal detector. Additionally or alternatively to one or more of the examples disclosed above, in some examples, the one or more metrics can include an estimated start time of the detected stylus signal, an estimated end time of the stylus signal, and an estimated signal strength of the detected stylus signal. Additionally or alternatively to one or more of the examples disclosed above, in some examples, determining which of the plurality of stylus signal detectors has the greatest likelihood of having received the stylus signal includes comparing the estimated signal strengths of the plurality of detectors and determining which detector of the plurality of detectors has the greatest estimated signal strength. Additionally or alternatively to one or more of the examples disclosed above, in some examples, demodulating the received stylus signal based on the one or more metrics generated by the determined stylus detector includes using the estimated start time of the detected stylus signal and the estimated end time of the stylus signal to facilitate a windowed demodulation of the stylus signal. Additionally or alternatively to one or more of the examples disclosed above, in some examples, the method further comprises organizing the demodulated stylus signal into a frame of data, wherein the frame of data is synchronized in time to the generation of the stylus signal by an external stylus. Additionally or alternatively to one or more of the examples disclosed above, in some examples, the method further comprises extracting a plurality of data from the demodulated stylus signal.

[0051] Some examples of the disclosure are directed to an apparatus for detecting stylus signals generated by an external stylus on a touch input device, the apparatus comprising a plurality of electrodes capable of operating as touch hardware during a touch operation mode and operating as stylus detection hardware during a stylus detection mode, a plurality of stylus signal detectors coupled to the plurality of electrodes during a stylus detection mode, each stylus detector capable of receiving a stylus signal and generating one or more metrics pertaining to the detected stylus signal, an arbiter capable of determining which of the plurality of stylus signal detectors has the greatest likelihood of having received the stylus signal, and a demodulator configured to demodulate the stylus signal based on the one or more metrics generated by the stylus detector determined to have the greatest likelihood of having received the stylus signal. Additionally or alternatively to one or more of the examples disclosed above, in some examples, the apparatus further includes a processor capable of configuring the input

device to alternate between a touch detection mode and a stylus detection mode, wherein configuring the input device to operate in a stylus detection mode includes configuring a plurality of drive lines and a plurality of sense lines configured to receive a touch input to receive a stylus signal. Additionally or alternatively to one or more of the examples disclosed above, in some examples, the apparatus further comprises switching hardware configured to couple each sense line of the plurality of sense lines to a stylus signal detector. Additionally or alternatively to one or more of the examples disclosed above, in some examples, the one or more metrics generated by the plurality of stylus detectors can include an estimated start time of the detected stylus signal, an estimated end time of the stylus signal, and an estimated signal strength of the detected stylus signal. Additionally or alternatively to one or more of the examples disclosed above, in some examples, the arbiter determines which of the plurality of detectors has the greatest likelihood of having received the stylus signal by comparing the estimated signal strengths of the plurality of detectors and determining which detector of the plurality of detectors has the greatest estimated signal strength. Additionally or alternatively to one or more of the examples disclosed above, in some examples, the demodulator can use the estimated start time of the detected stylus signal and the estimated end time of the stylus signal to facilitate a windowed demodulation of the stylus signal. Additionally or alternatively to one or more of the examples disclosed above, in some examples, the apparatus further comprises a frame synchronizer configured to organize the demodulated stylus signal into a frame of data, wherein the frame of data is synchronized in time to the generation of the stylus signal by an external stylus. Additionally or alternatively to one or more of the examples disclosed above, in some examples, the apparatus further comprises a data extraction unit configured to extract a plurality of data from the demodulated stylus signal.

[0052] Some examples of the disclosure are directed to a non-transitory computer readable storage medium having stored thereon a set of instructions for detecting a demodulating a stylus signal generated by an external stylus, that when executed by a processor causes the processor to configure the touch input device to receive a stylus signal, receive the stylus signal on the touch sensor panel, determine which of the plurality of detectors has the greatest likelihood of having received the stylus signal, and demodulate the received stylus signal based on one or more metrics generated by the stylus detector determined to have the greatest likelihood of having received the stylus

signal. Additionally or alternatively to one or more of the examples disclosed above, in some examples, configuring the touch input device to receive a stylus signal includes configuring a plurality of drive lines and a plurality of sense lines configured for receiving touch inputs to additionally receive a stylus signal. Additionally or alternatively to one or more of the examples disclosed above, in some examples, configuring the plurality of sense lines to receive a stylus signal includes coupling each sense line of the plurality of sense lines to a stylus signal detector. Additionally or alternatively to one or more of the examples disclosed above, in some examples, the one or more metrics can include an estimated start time of the detected stylus signal, an estimated end time of the stylus signal, and an estimated signal strength of the detected stylus signal. Additionally or alternatively to one or more of the examples disclosed above, in some examples, determining which of the plurality of stylus signal detectors has the greatest likelihood of having received the stylus signal includes comparing the estimated signal strengths of the plurality of detectors and determining which detector of the plurality of detectors has the greatest estimated signal strength. Additionally or alternatively to one or more of the examples disclosed above, in some examples, demodulating the received stylus signal based on the one or more metrics generated by the determined stylus detector includes using the estimated start time of the detected stylus signal and the estimated end time of the stylus signal to facilitate a windowed demodulation of the stylus signal. Additionally or alternatively to one or more of the examples disclosed above, in some examples, the processor is further caused to organize the demodulated stylus signal into a frame of data, wherein the frame of data is synchronized in time to the generation of the stylus signal by an external stylus. Additionally or alternatively to one or more of the examples disclosed above, in some examples, the processor is further caused to extract a plurality of data from the demodulated signal.

[0053] Although examples have been fully described with reference to the accompanying drawings, it is to be noted that various changes and modifications will become apparent to those skilled in the art. Such changes and modifications are to be understood as being included within the scope of the various examples as defined by the appended claims.

WHAT IS CLAIMED IS:

Claim 1: A method of detecting stylus signals generated by an external stylus on a touch input device, the method comprising:

- configuring the touch input device to receive a stylus signal;
- receiving the stylus signal at a plurality of stylus signal detectors;
- determining which of the plurality of stylus signal detectors has a greatest likelihood of having received the stylus signal; and
- demodulating the received stylus signal based on one or more metrics generated by the determined stylus signal detector.

Claim 2: The method of claim 1, wherein configuring the touch input device to receive a stylus signal includes configuring a plurality of drive lines and a plurality of sense lines configured for receiving touch inputs to additionally receive a stylus signal.

Claim 3: The method of claim 2, wherein configuring the plurality of sense lines to receive a stylus signal includes coupling each sense line of the plurality of sense lines to a stylus signal detector.

Claim 4: The method of claim 1, wherein the one or more metrics can include an estimated start time of the detected stylus signal, an estimated end time of the stylus signal, and an estimated signal strength of the detected stylus signal.

Claim 5: The method of claim 4, wherein determining which of the plurality of stylus signal detectors has the greatest likelihood of having received the stylus signal includes comparing the estimated signal strengths of the plurality of detectors and determining which detector of the plurality of detectors has the greatest estimated signal strength.

Claim 6: The method of claim 4, wherein demodulating the received stylus signal based on the one or more metrics generated by the determined stylus detector includes using the estimated start time of the detected stylus signal and the

estimated end time of the stylus signal to facilitate a windowed demodulation of the stylus signal.

Claim 7: The method of claim 1, further comprising organizing the demodulated stylus signal into a frame of data, wherein the frame of data is synchronized in time to the generation of the stylus signal by an external stylus.

Claim 8: The method of claim 1, further comprising extracting a plurality of data from the demodulated stylus signal.

Claim 9: An apparatus for detecting stylus signals generated by an external stylus on a touch input device, the apparatus comprising:

- a plurality of electrodes capable of operating as touch hardware during a touch operation mode and operating as stylus detection hardware during a stylus detection mode;

- a plurality of stylus signal detectors coupled to the plurality of electrodes during a stylus detection mode, each stylus detector capable of receiving a stylus signal and generating one or more metrics pertaining to the detected stylus signal;

- an arbiter capable of determining which of the plurality of stylus signal detectors has the greatest likelihood of having received the stylus signal; and

- a demodulator configured to demodulate the stylus signal based on the one or more metrics generated by the stylus detector determined to have the greatest likelihood of having received the stylus signal.

Claim 10: The apparatus of claim 9, further including a processor capable of configuring the input device to alternate between a touch detection mode and a stylus detection mode, wherein configuring the input device to operate in a stylus detection mode includes configuring a plurality of drive lines and a plurality of sense lines configured to receive a touch input to receive a stylus signal.

Claim 11: The apparatus of claim 10, further comprising switching hardware configured to couple each sense line of the plurality of sense lines to a stylus signal detector.

Claim 12: The apparatus of claim 9, wherein the one or more metrics generated by the plurality of stylus detectors can include an estimated start time of the detected stylus signal, an estimated end time of the stylus signal, and an estimated signal strength of the detected stylus signal.

Claim 13: The apparatus of claim 12, wherein the arbiter determines which of the plurality of detectors has the greatest likelihood of having received the stylus signal by comparing the estimated signal strengths of the plurality of detectors and determining which detector of the plurality of detectors has the greatest estimated signal strength.

Claim 14: The apparatus of claim 12, wherein the demodulator can use the estimated start time of the detected stylus signal and the estimated end time of the stylus signal to facilitate a windowed demodulation of the stylus signal.

Claim 15: The apparatus of claim 9, further comprising a frame synchronizer configured to organize the demodulated stylus signal into a frame of data, wherein the frame of data is synchronized in time to the generation of the stylus signal by an external stylus.

Claim 16: The apparatus of claim 9, further comprising a data extraction unit configured to extract a plurality of data from the demodulated stylus signal.

Claim 17: A non-transitory computer readable storage medium having stored thereon a set of instructions for detecting a demodulating a stylus signal generated by an external stylus, that when executed by a processor causes the processor to:

- configure the touch input device to receive a stylus signal;
- receive the stylus signal on the touch sensor panel;

determine which of the plurality of detectors has the greatest likelihood of having received the stylus signal; and

demodulate the received stylus signal based on one or more metrics generated by the stylus detector determined to have the greatest likelihood of having received the stylus signal.

Claim 18: The non-transitory computer readable storage medium of claim 17, wherein configuring the touch input device to receive a stylus signal includes configuring a plurality of drive lines and a plurality of sense lines configured for receiving touch inputs to additionally receive a stylus signal.

Claim 19: The non-transitory computer readable storage medium of claim 18, wherein configuring the plurality of sense lines to receive a stylus signal includes coupling each sense line of the plurality of sense lines to a stylus signal detector.

Claim 20: The non-transitory computer readable storage medium of claim 17, wherein the one or more metrics can include an estimated start time of the detected stylus signal, an estimated end time of the stylus signal, and an estimated signal strength of the detected stylus signal.

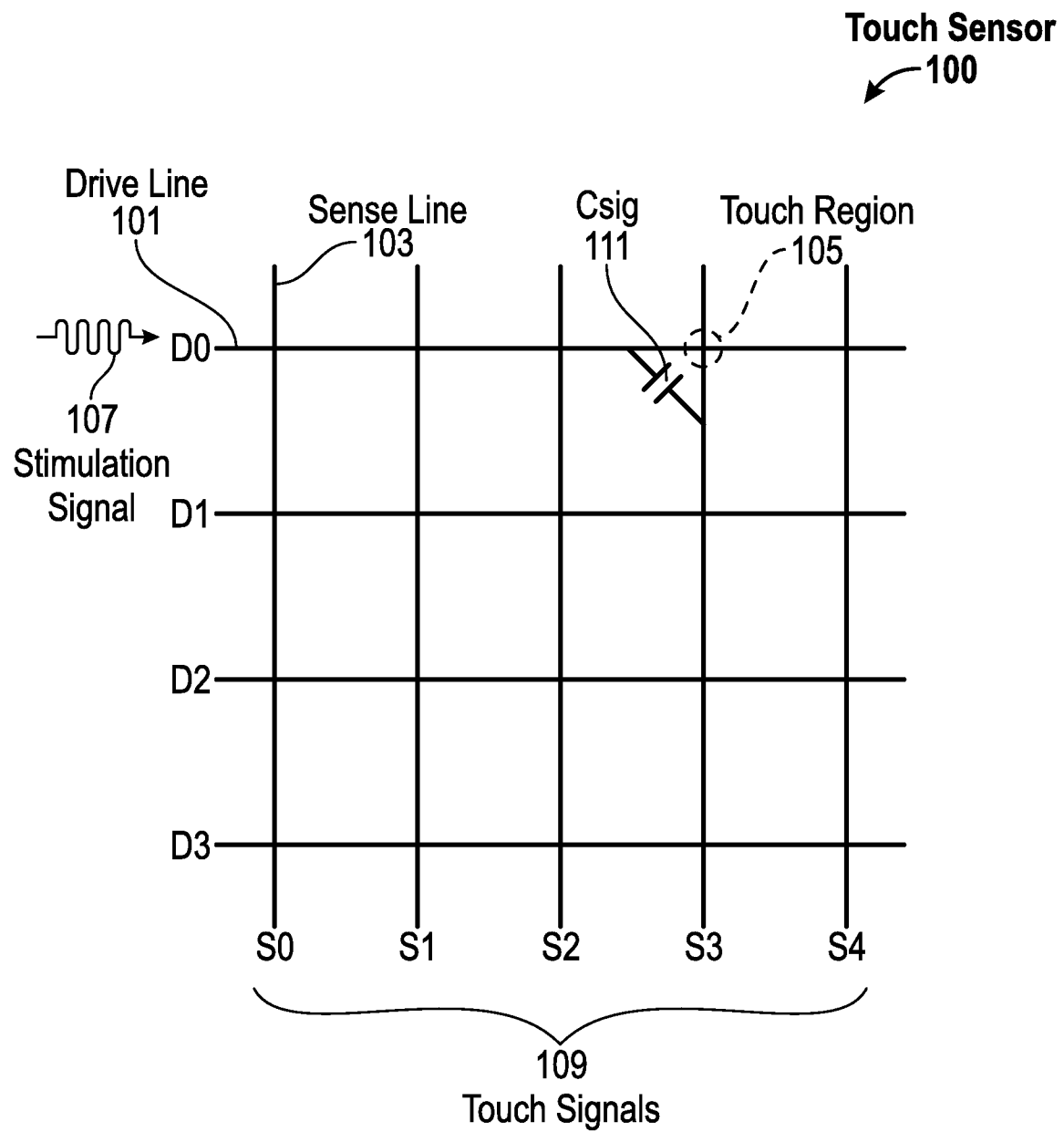
Claim 21: The non-transitory computer readable storage medium of claim 20, wherein determining which of the plurality of stylus signal detectors has the greatest likelihood of having received the stylus signal includes comparing the estimated signal strengths of the plurality of detectors and determining which detector of the plurality of detectors has the greatest estimated signal strength.

Claim 22: The non-transitory computer readable storage medium of claim 20, wherein demodulating the received stylus signal based on the one or more metrics generated by the determined stylus detector includes using the estimated start time of the detected stylus signal and the estimated end time of the stylus signal to facilitate a windowed demodulation of the stylus signal.

Claim 23: The non-transitory computer readable storage medium of claim 17, wherein the processor is further caused to organize the demodulated stylus signal into a frame of data, wherein the frame of data is synchronized in time to the generation of the stylus signal by an external stylus.

Claim 24: The non-transitory computer readable storage medium of claim 17, wherein the processor is further caused to extract a plurality of data from the demodulated signal.

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**FIG. 1**

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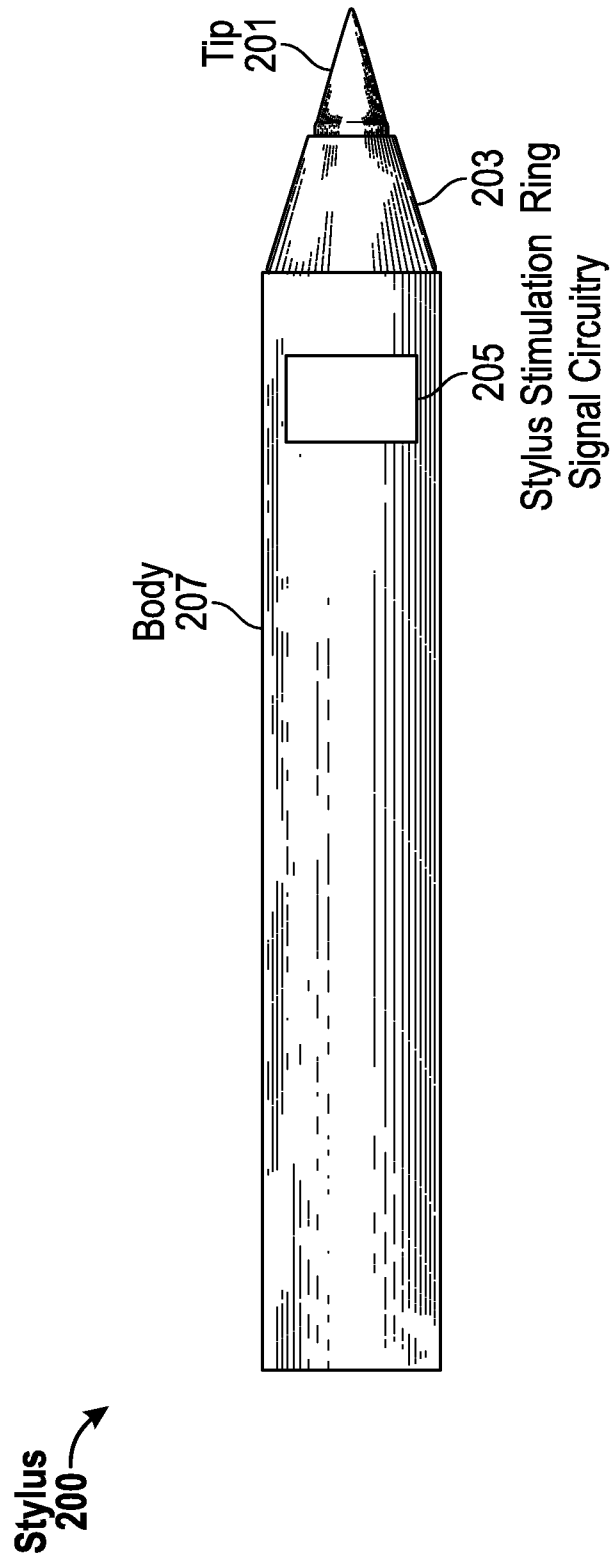


FIG. 2

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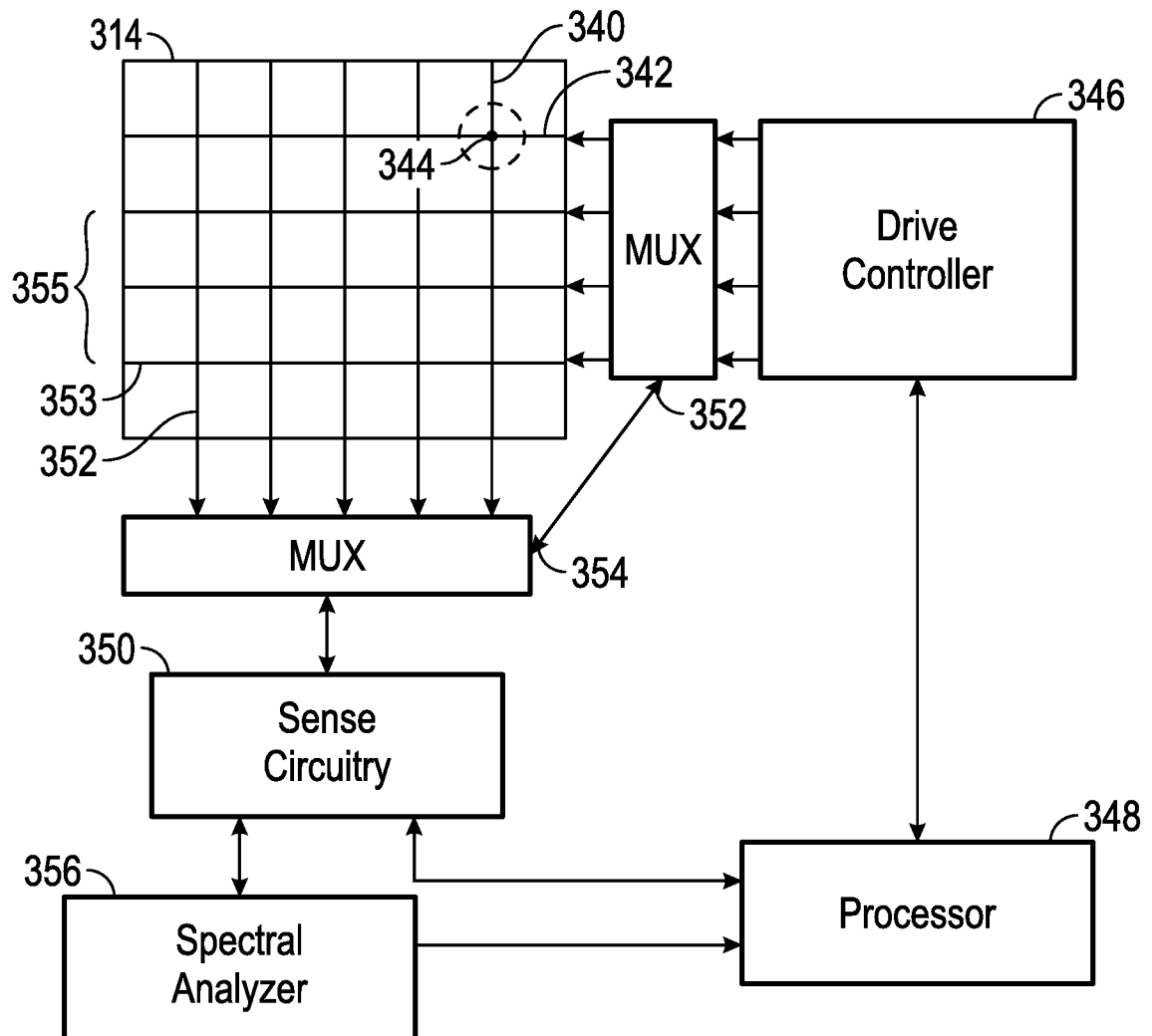


FIG. 3

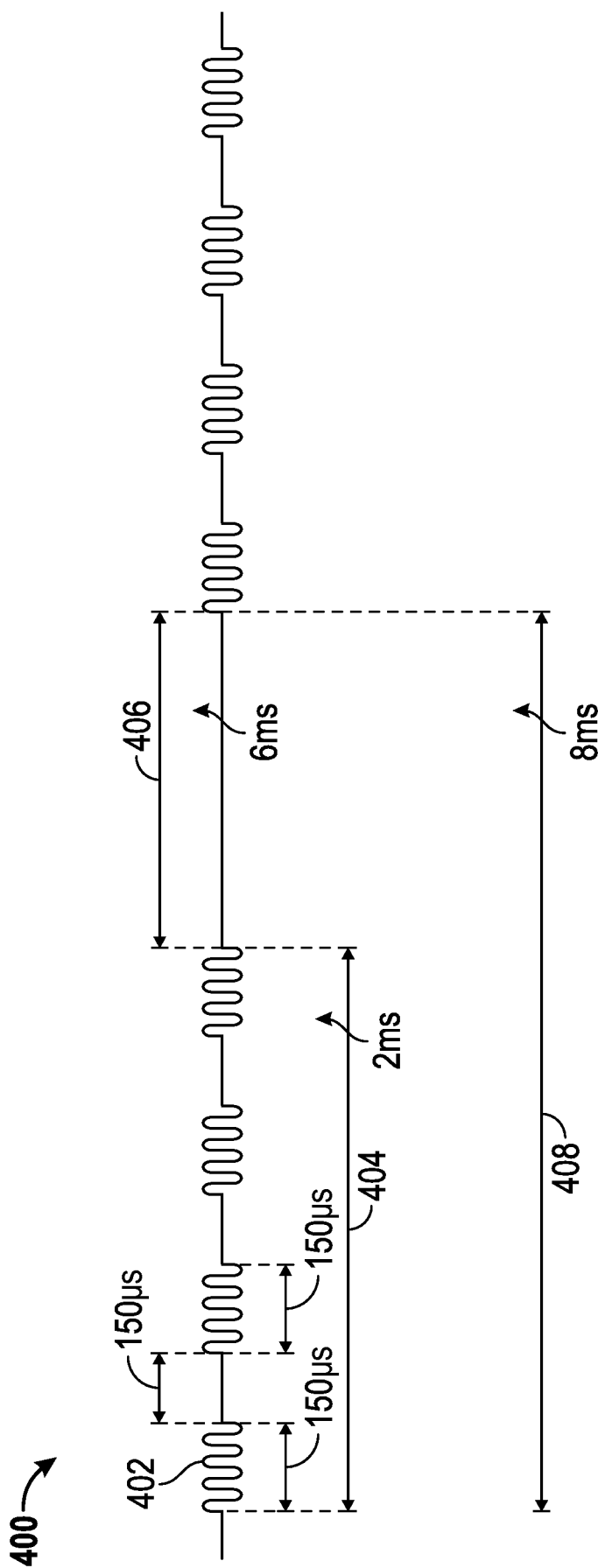


FIG. 4

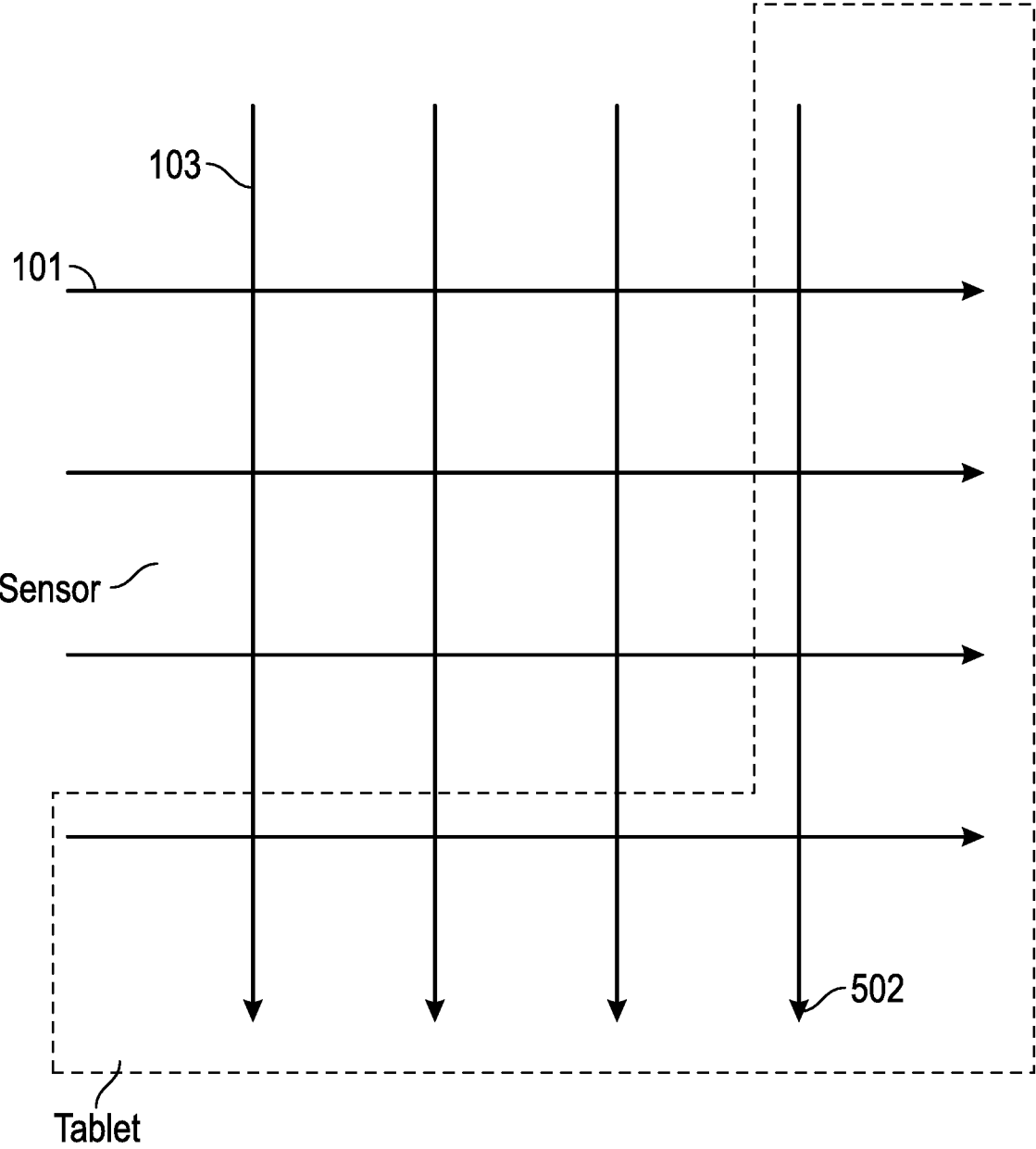


FIG. 5

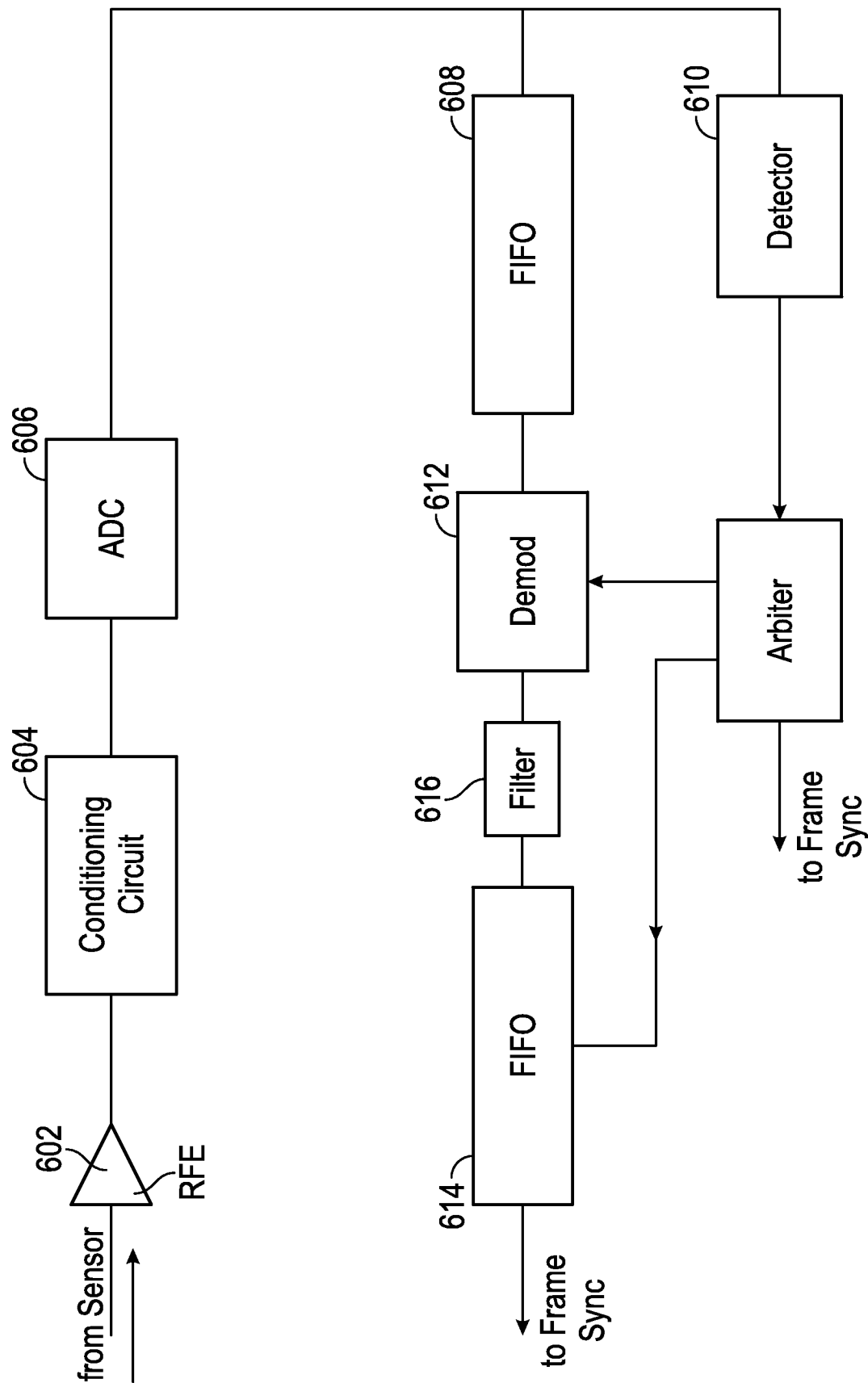


FIG. 6

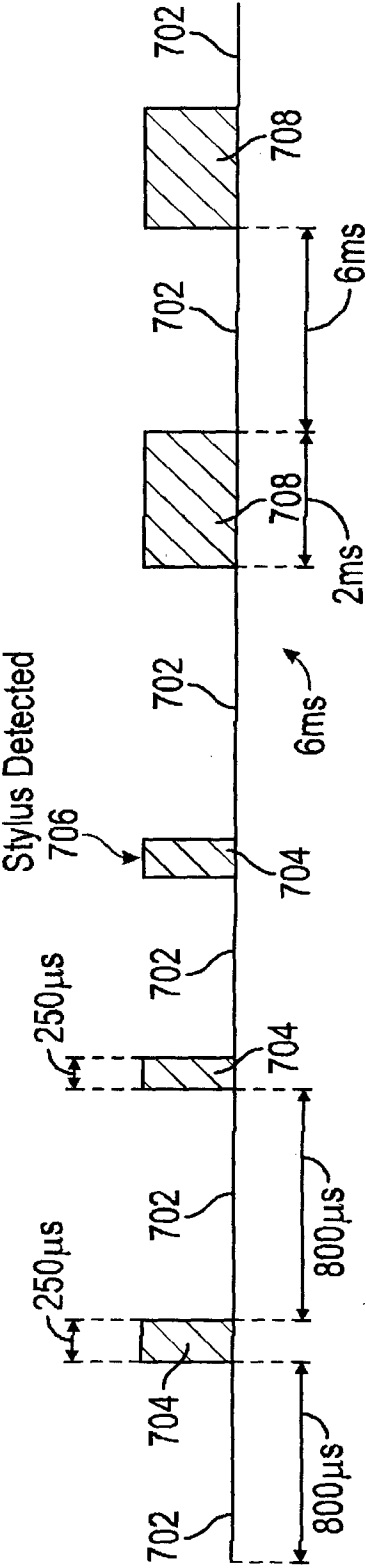


FIG. 7

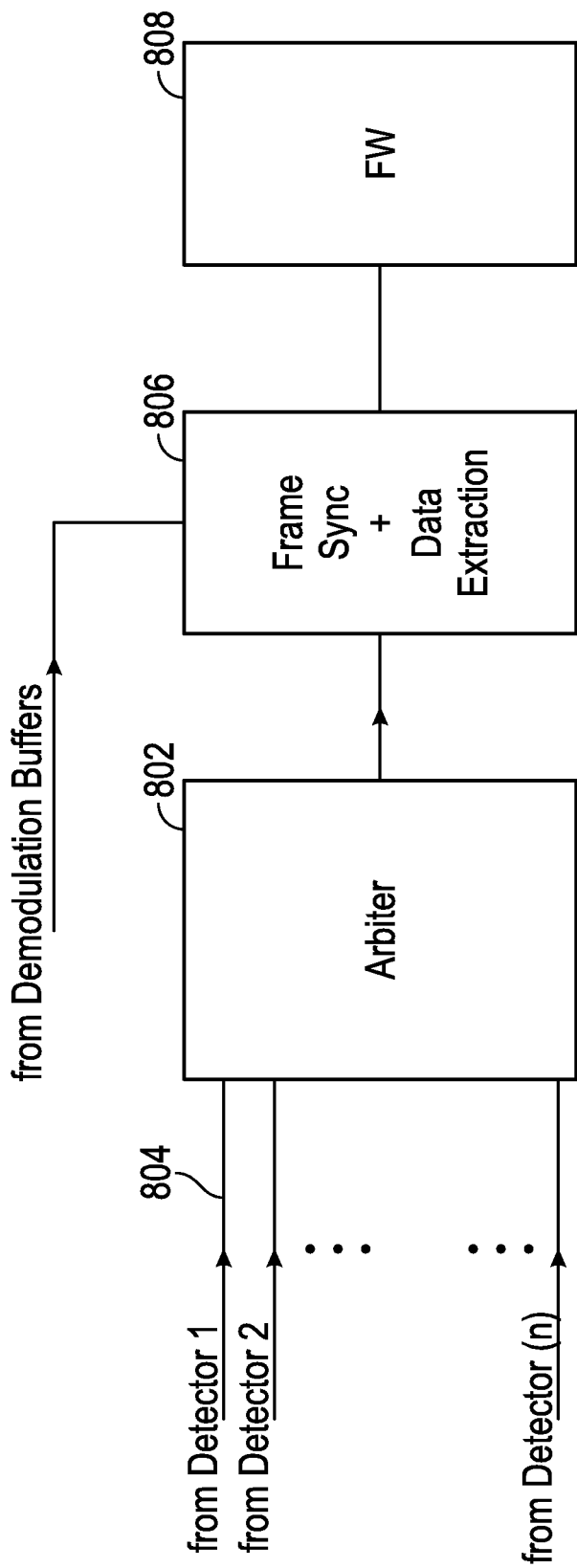
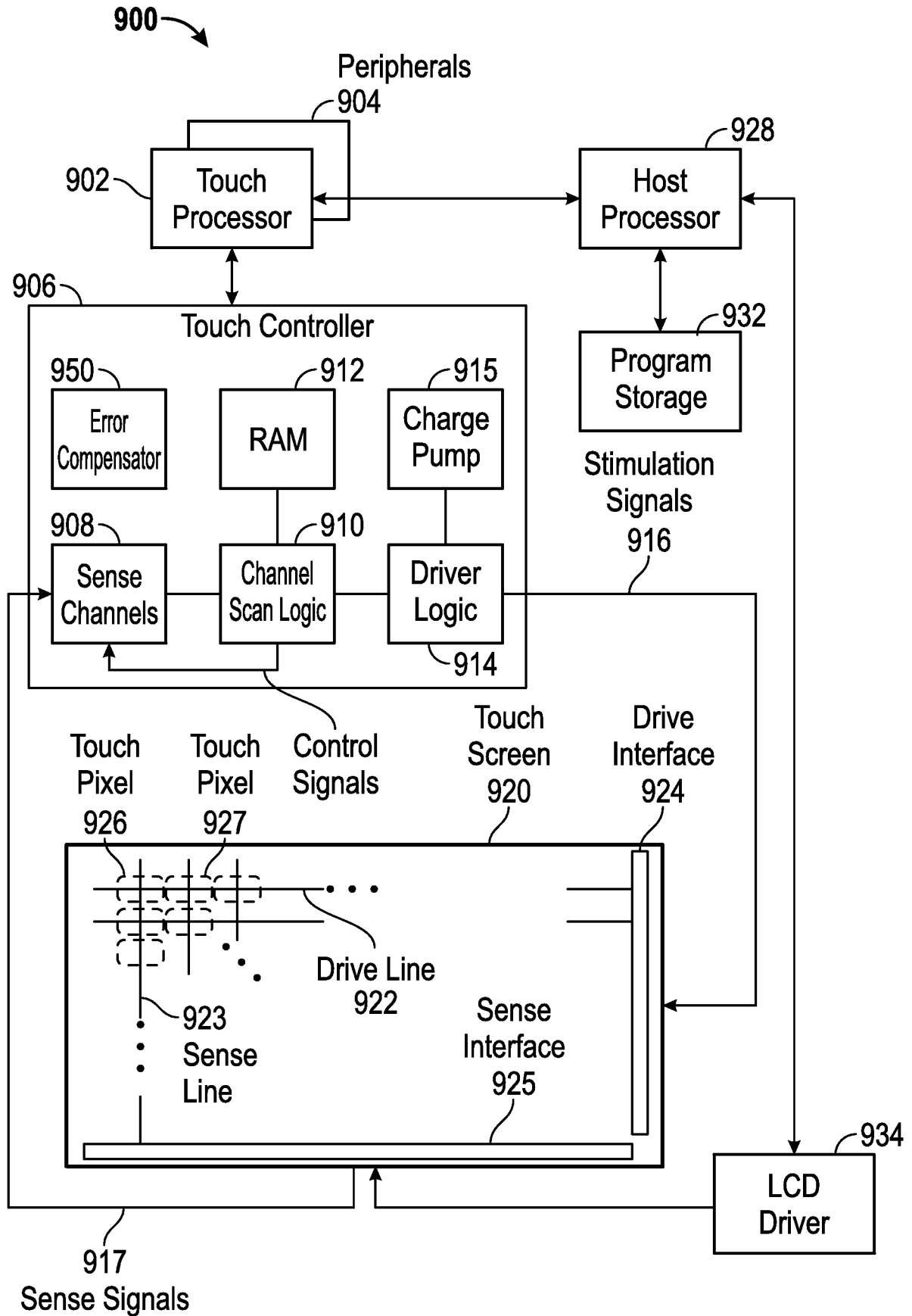
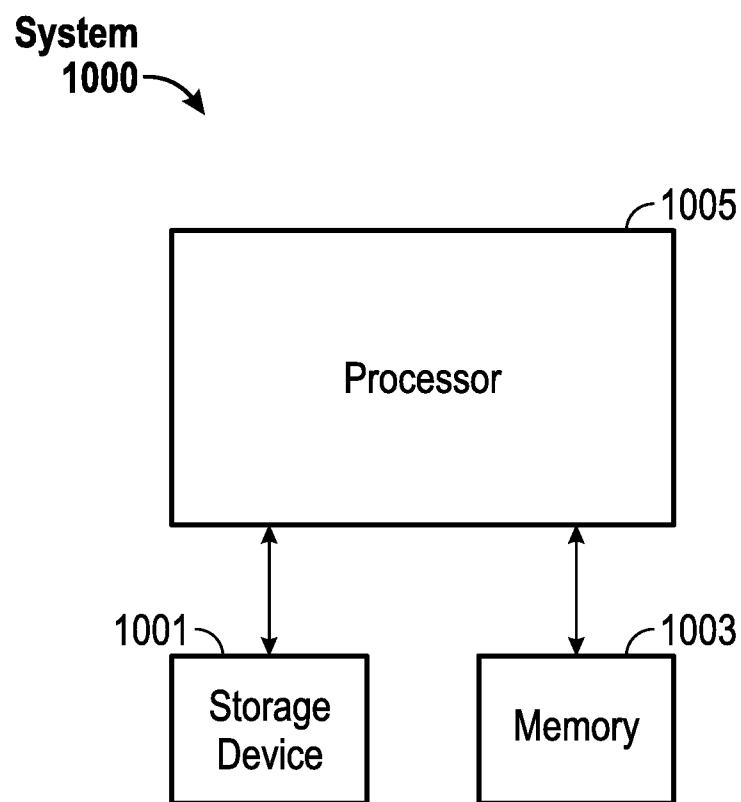


FIG. 8

**Computing
System****9/12****FIG. 9**

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**FIG. 10**

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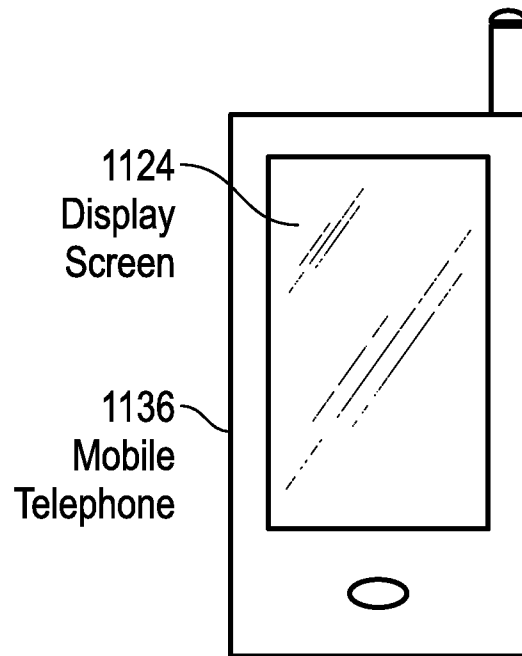


FIG. 11A

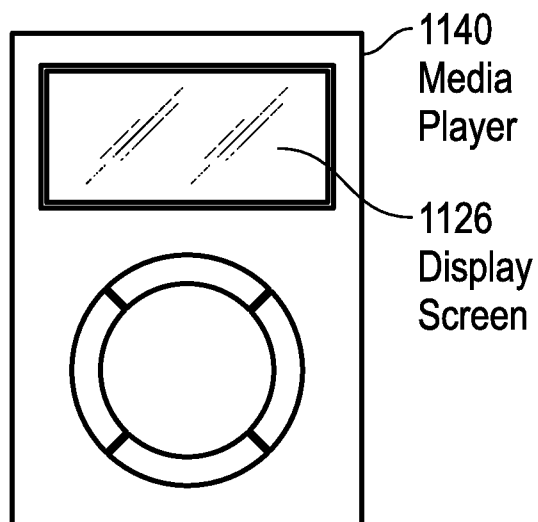


FIG. 11B

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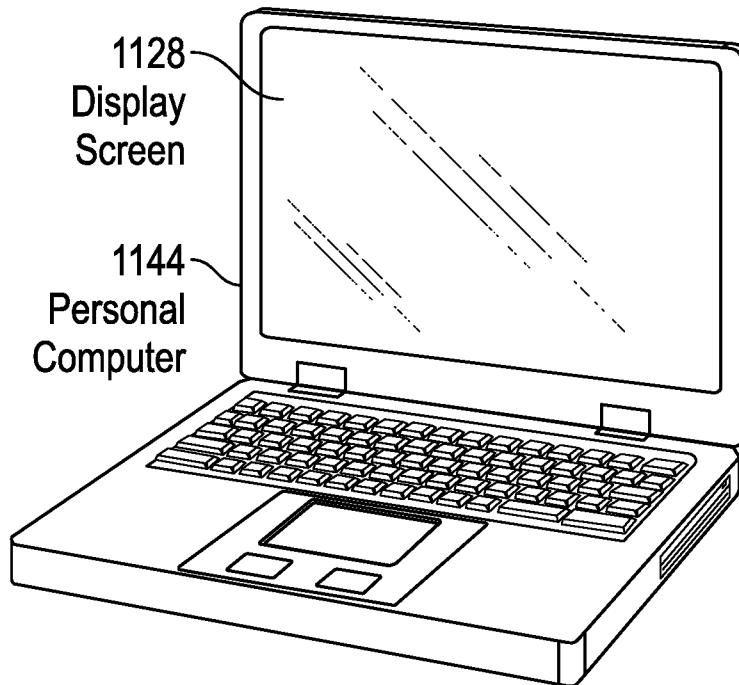


FIG. 11C

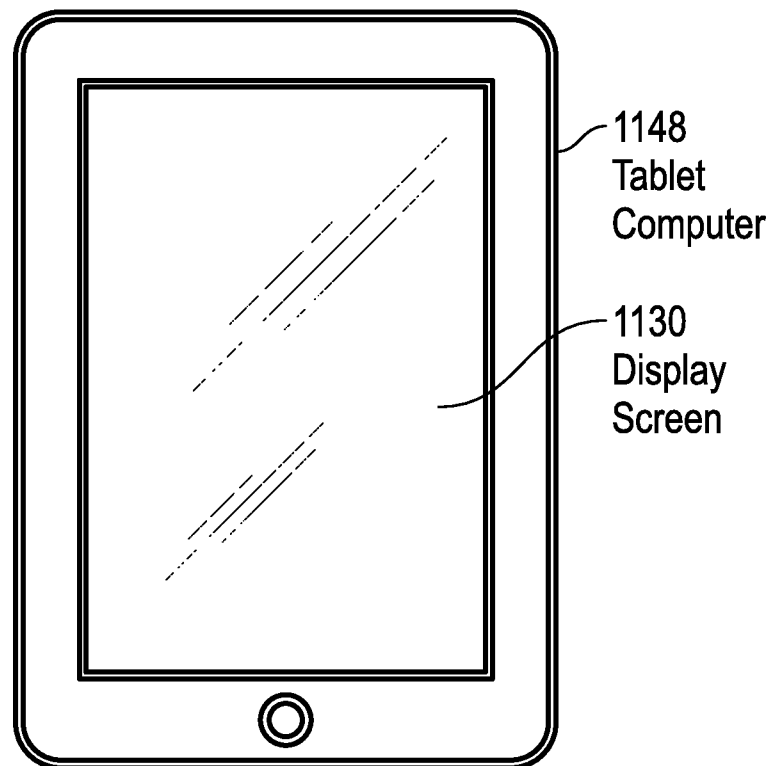


FIG. 11D

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/013927

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06F3/041 G06F3/044
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010/155153 A1 (ZACHUT RAFI [IL]) 24 June 2010 (2010-06-24) paragraph [0009] - paragraph [0020] paragraph [0064] paragraph [0071] paragraph [0081] - paragraph [0082] paragraph [0106] paragraph [0123] - paragraph [0129]; claims; figures -----	1-24
X	US 2012/068964 A1 (WRIGHT DAVID G [US] ET AL) 22 March 2012 (2012-03-22) paragraph [0033] paragraph [0049] paragraph [0057] - paragraph [0058] paragraph [0061] - paragraph [0065] paragraph [0083]; claims; figures ----- -/-	1-24



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

9 April 2014

Date of mailing of the international search report

23/04/2014

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Authorized officer

Durand, Jacques

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/013927

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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International application No

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