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(54) **STYLUS DEVICE**

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

CPC ***G06F 3/03545*** (2013.01); ***G06F 3/033*** (2013.01); ***G06F 3/041*** (2013.01); ***G06F 3/044*** (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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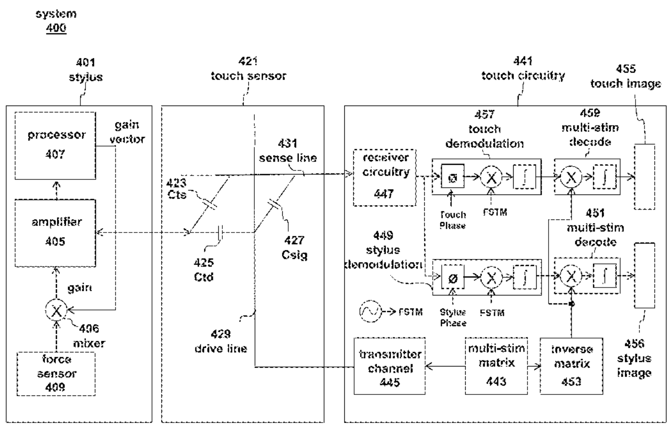
(57) **ABSTRACT**

Styluses capable of generating stylus stimulation signals and touch sensitive devices capable of receiving stylus stimulation signals are disclosed. In one example, a stylus can receive a stimulation signal from a touch sensor of a touch sensitive device and generate a stylus stimulation signal by changing an amplitude or frequency of the received stimulation signal. The stylus can transmit the stylus stimulation signal back into the touch sensor of the touch sensitive device. The touch sensor can generate a touch signal based on the device's own stimulation signals and the stylus stimulation signal. The touch sensitive device can process the touch signal to determine a location of the stylus on the touch sensor. The stylus can include a force sensor to detect an amount of force applied to a tip of the stylus. The stylus stimulation signal can be modulated based on the force detected by the force sensor.

8 Claims, 13 Drawing Sheets



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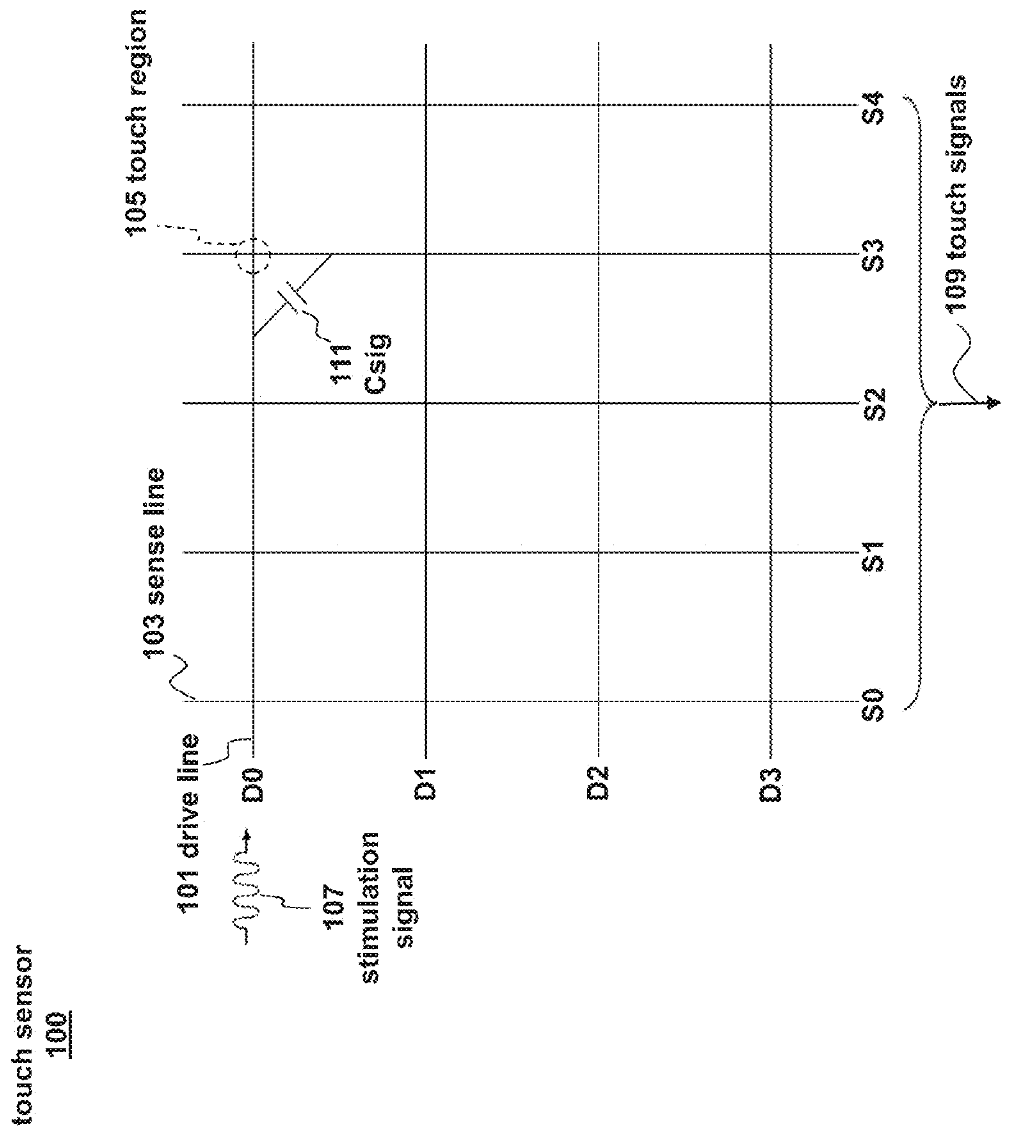

touch sensor
100
101 drive line
107
stimulation
signal
D0
D1
D2
D3
103 sense line
105 touch region
111
Csig
S0
S1
S2
S3
S4
109 touch signals

FIG. 1

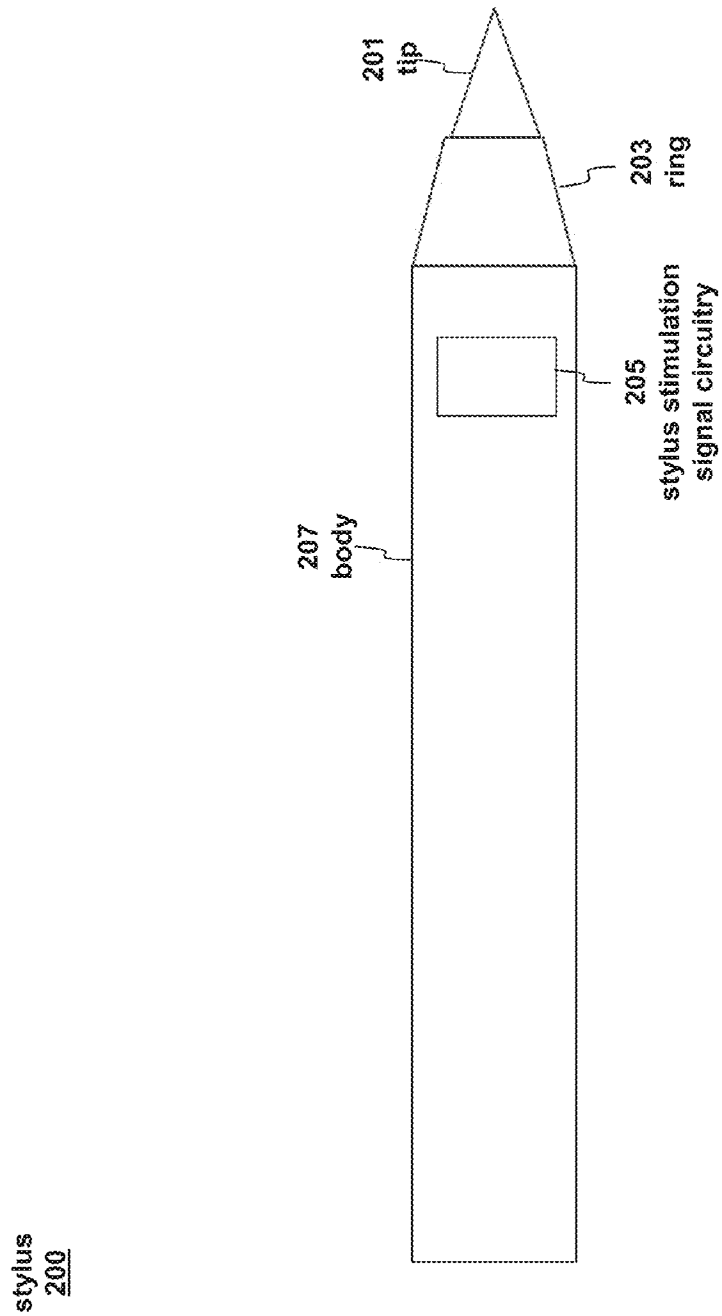

201
tip
203
ring
205
stylus stimulation
signal circuitry
207
body
stylus
200

FIG. 2

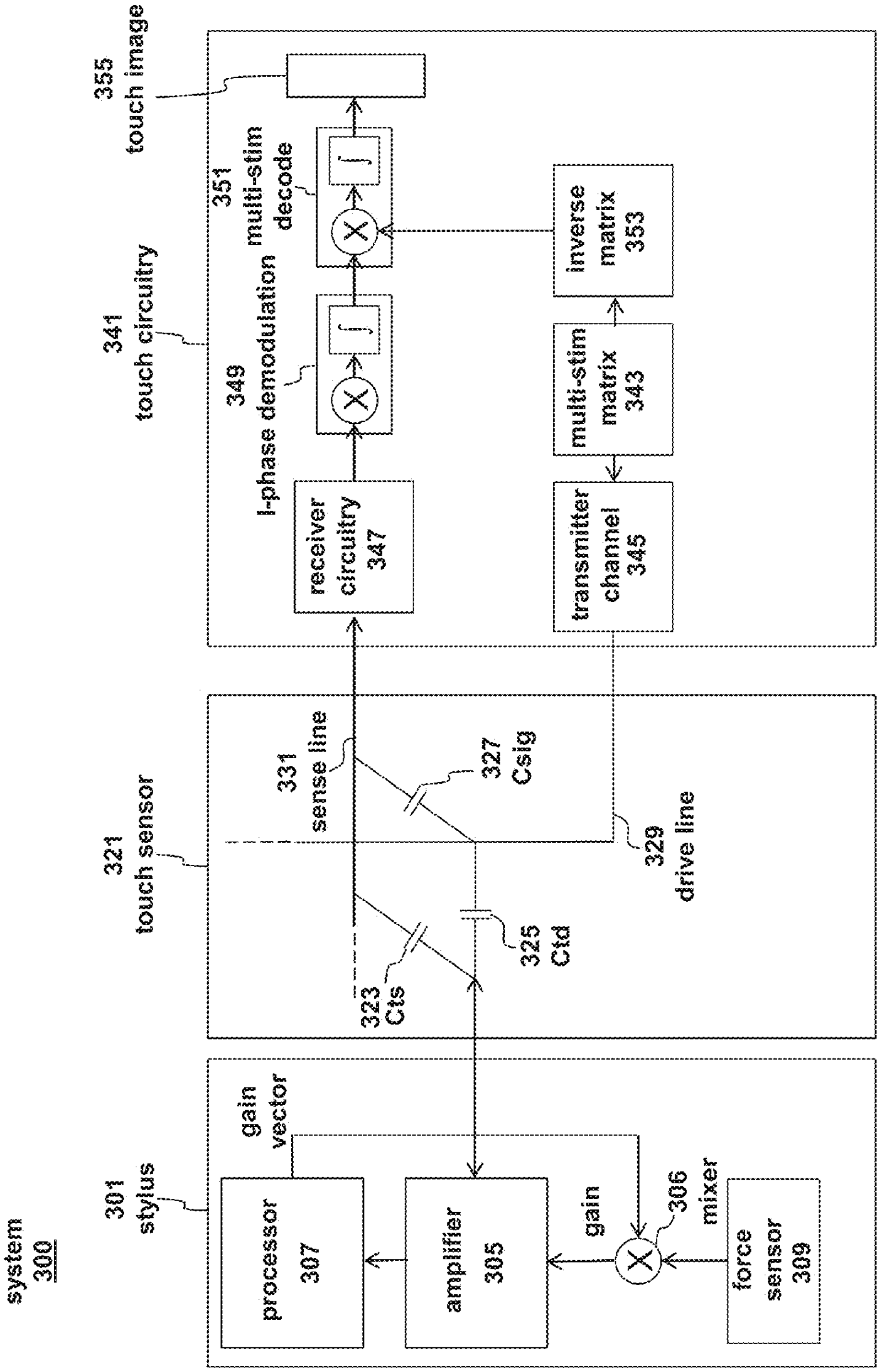

system
300
301
stylus
processor
307
gain
vector
amplifier
305
gain
306
mixer
force
sensor
309
321
touch sensor
323
Cts
325
Ctd
327
Csig
329
drive line
331
sense line
341
touch circuitry
receiver
circuitry
347
349
I-phase demodulation
351
multi-stim
decode
355
touch image
transmitter
channel
345
multi-stim
matrix
343
inverse
matrix
353

FIG. 3

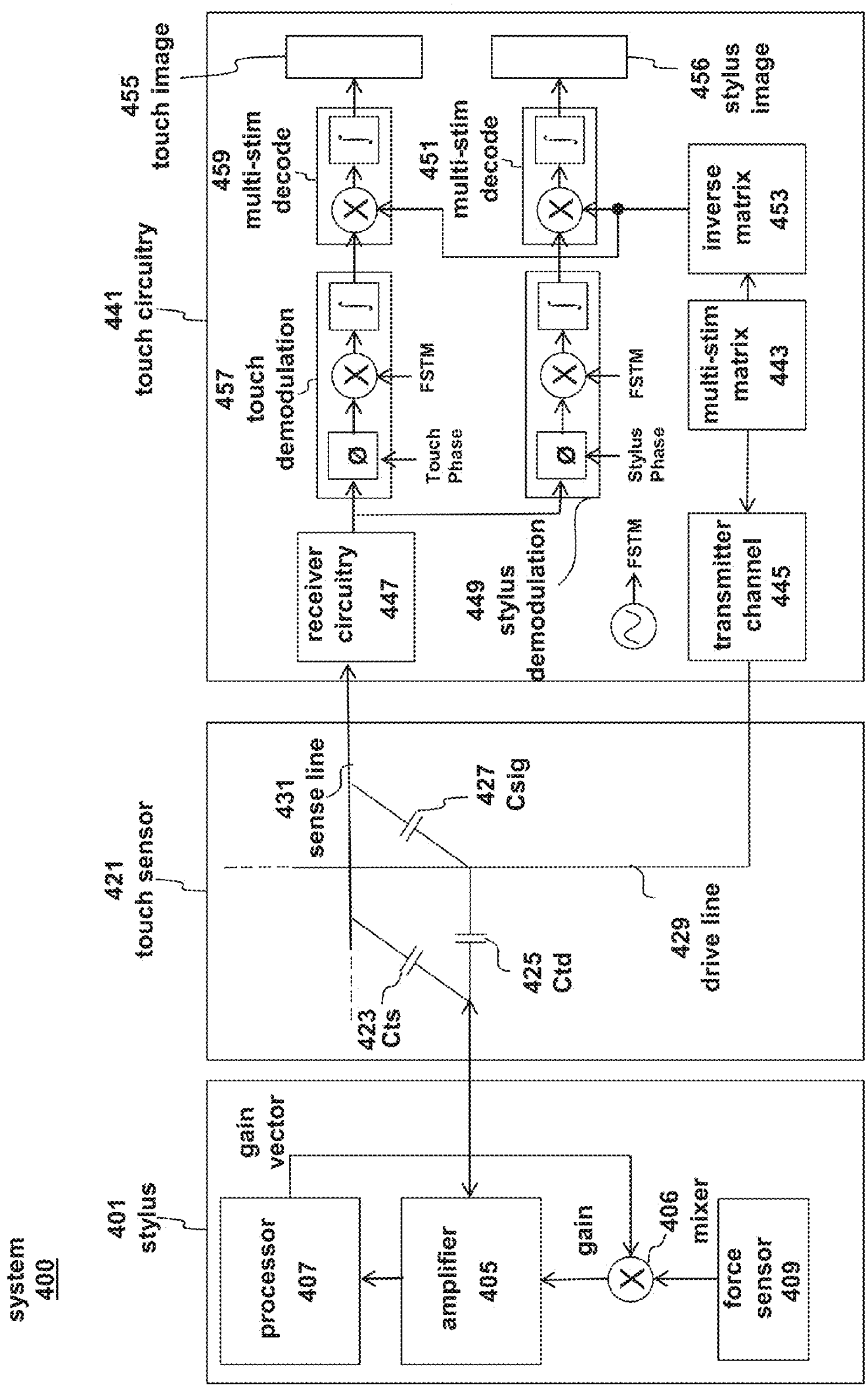

system
400
401
stylus
processor
407
amplifier
405
gain
vector
gain
406
mixer
force
sensor
409
421
touch sensor
423
Cts
425
Ctd
427
Csig
431
sense line
429
drive line
441
touch circuitry
receiver
circuitry
447
449
stylus
demodulation
FSTM
transmitter
channel
445
457
touch
demodulation
Touch
Phase
Stylus
Phase
FSTM
multi-stim
matrix
443
inverse
matrix
453
459
multi-stim
decode
451
multi-stim
decode
455
touch image
456
stylus
image

FIG. 4

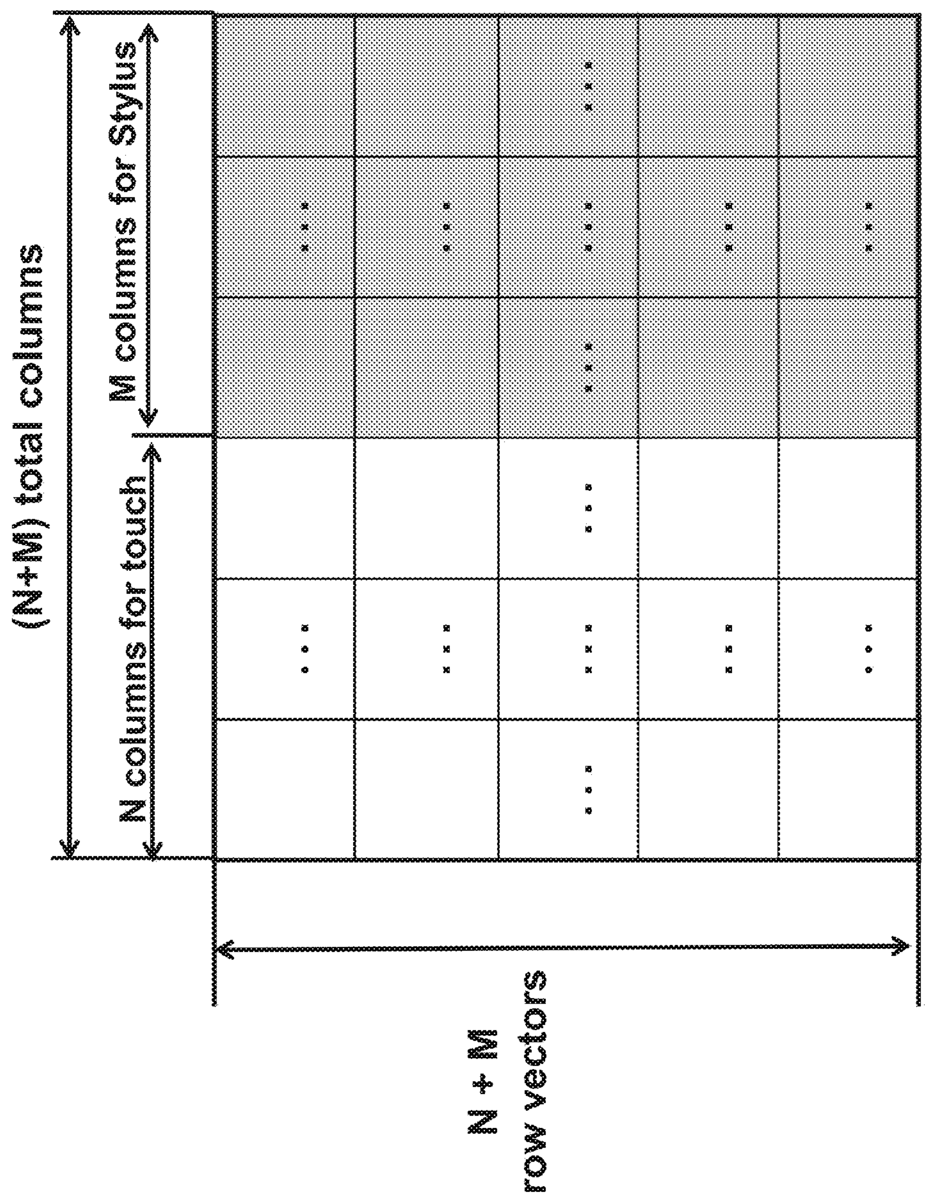

(N+M) total columns
N columns for touch
M columns for Stylus
N + M
row vectors

FIG. 5

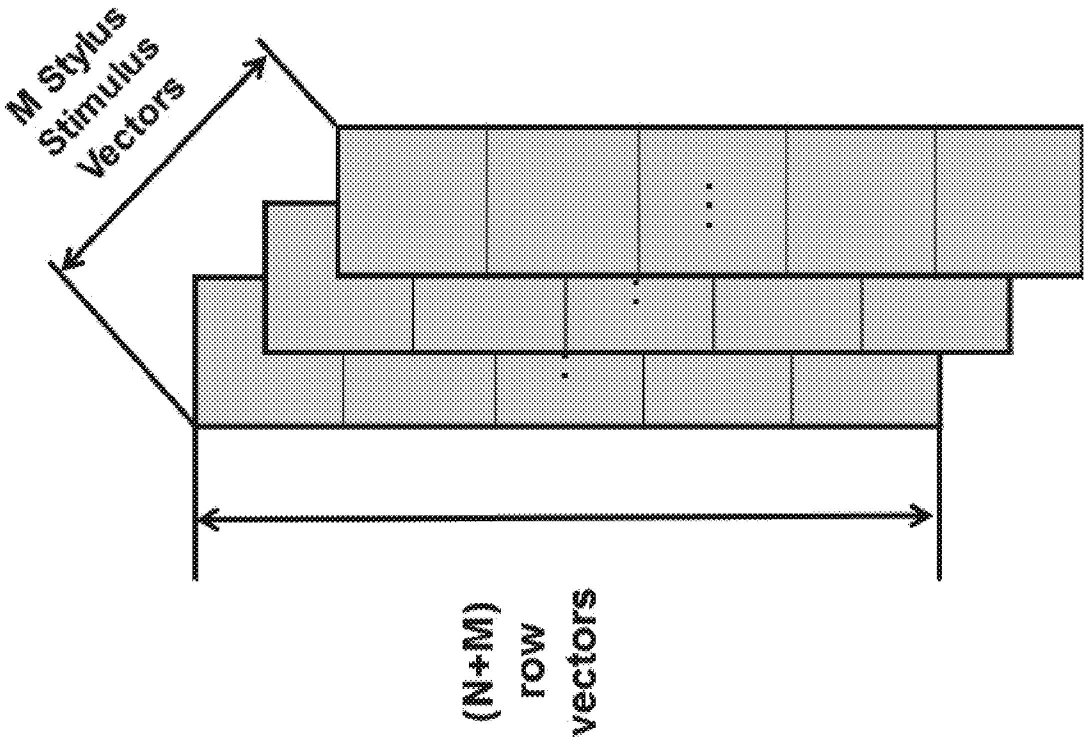


FIG. 6

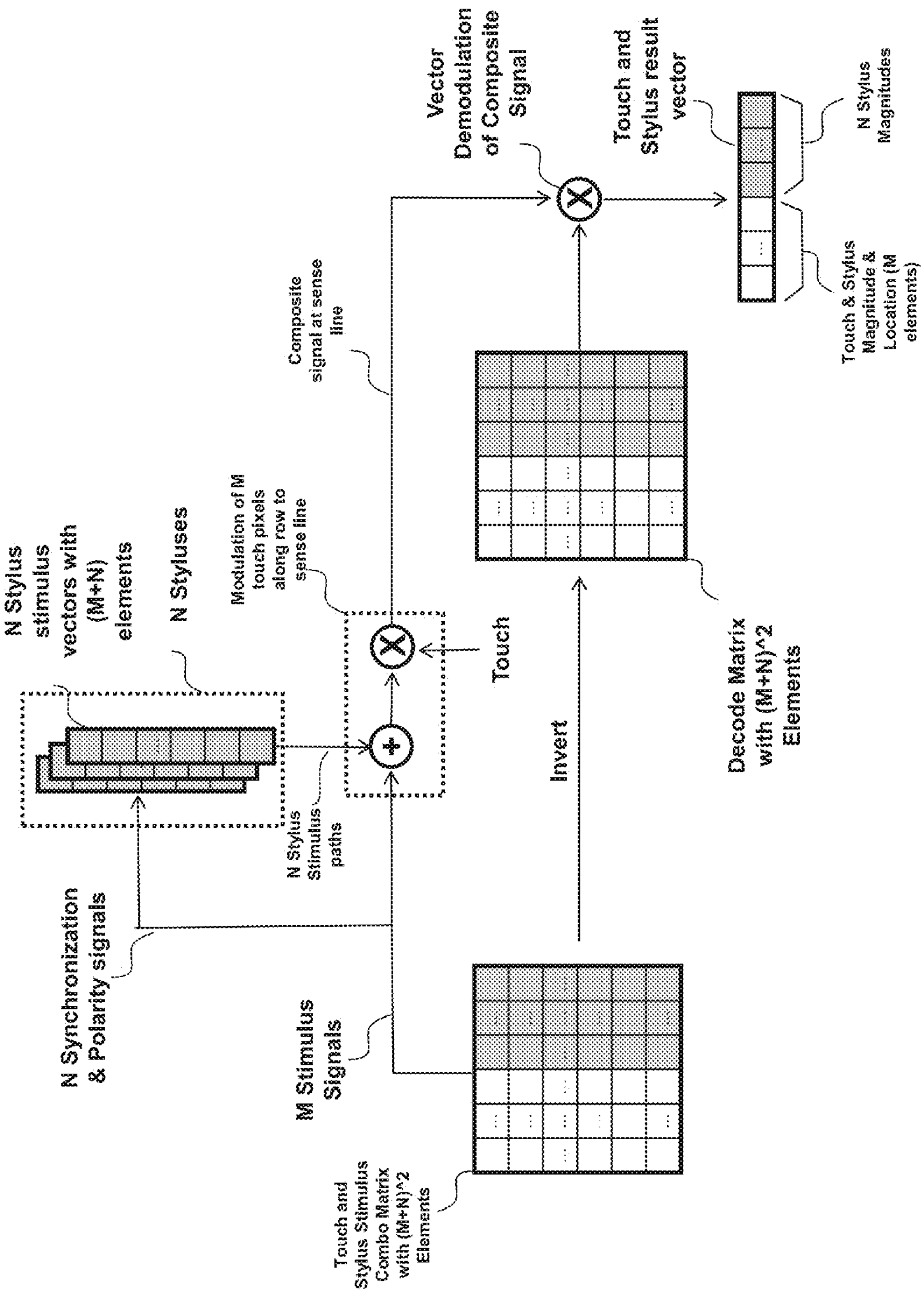

Touch and Stylus Stimulus Combo Matrix with (M+N)^2 Elements
M Stimulus Signals
N Synchronization & Polarity signals
N Stylus stimulus vectors with (M+N) elements
N Styluses
N Stylus Stimulus paths
Modulation of M touch pixels along row to sense line
Touch
Invert
Decode Matrix with (M+N)^2 Elements
Composite signal at sense line
Vector Demodulation of Composite Signal
Touch and Stylus result vector
N Stylus Magnitudes
Touch & Stylus Magnitude & Location (M elements)

FIG. 7

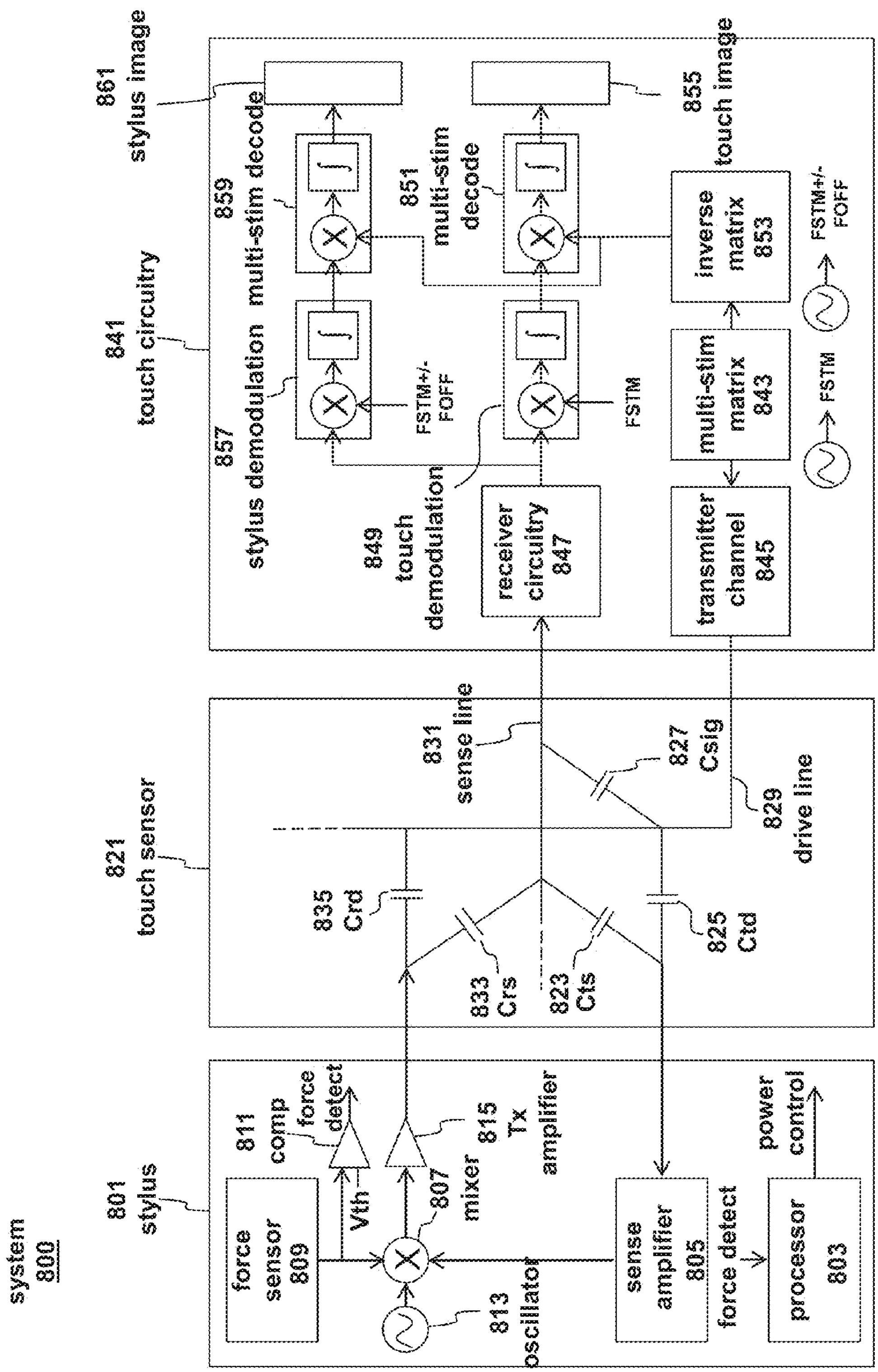

system 800
801 stylus
force sensor 809
Vth
811 comp
force detect
807 mixer
815 Tx amplifier
813 oscillator
sense amplifier 805
force detect
processor 803
power control
821 touch sensor
835 Crd
833 Crs
823 Cts
825 Ctd
831 sense line
827 Csig
829 drive line
841 touch circuitry
857 stylus demodulation
859 multi-stim decode
861 stylus image
FSTM+/- FOFF
849 touch demodulation
FSTM
851 multi-stim decode
855 touch image
receiver circuitry 847
transmitter channel 845
multi-stim matrix 843
inverse matrix 853
FSTM
FSTM+/- FOFF

FIG. 8

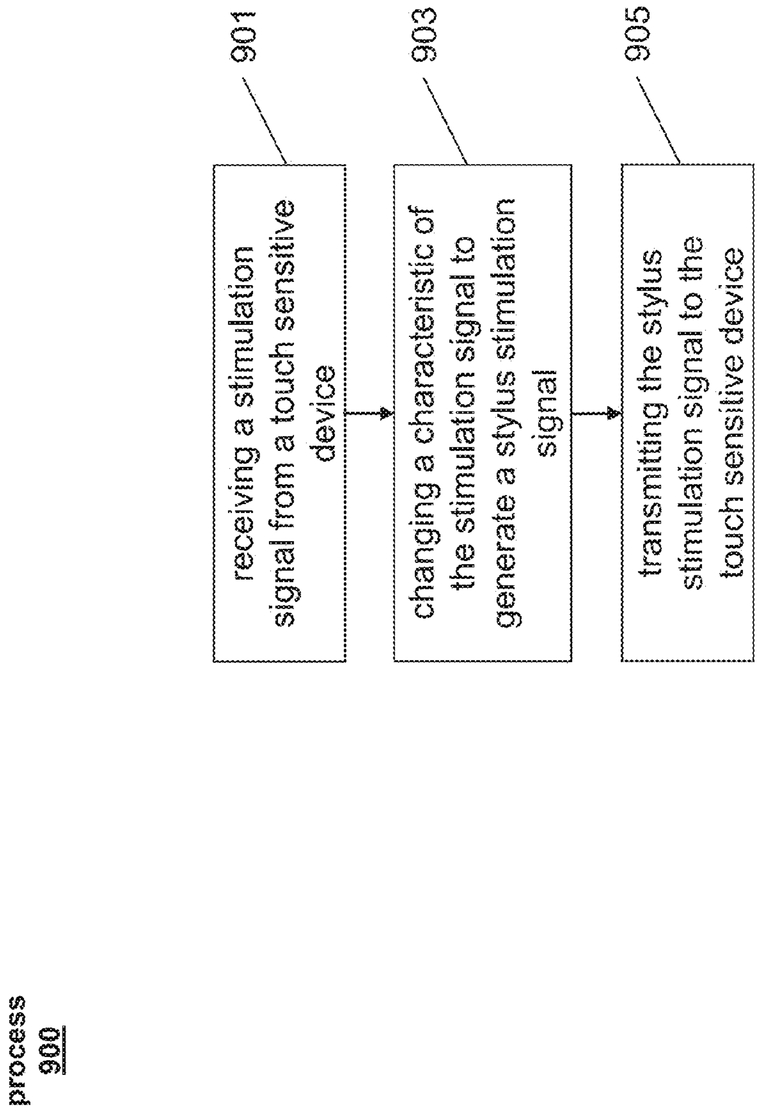

process
900
receiving a stimulation signal from a touch sensitive device
901
changing a characteristic of the stimulation signal to generate a stylus stimulation signal
903
transmitting the stylus stimulation signal to the touch sensitive device
905

FIG. 9

process
1000

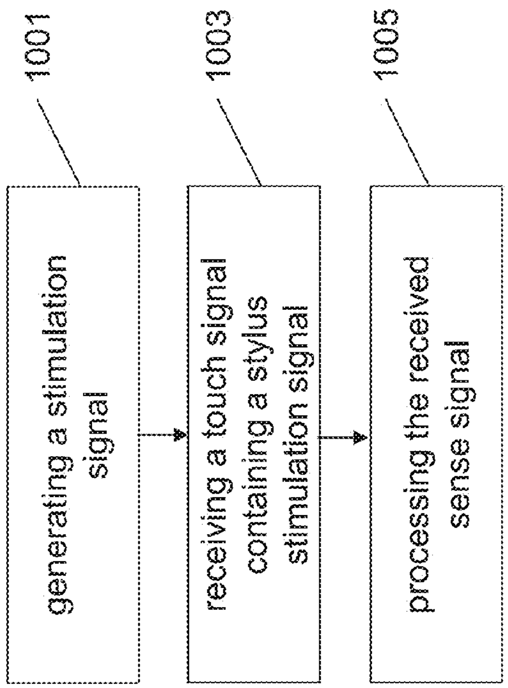


FIG. 10

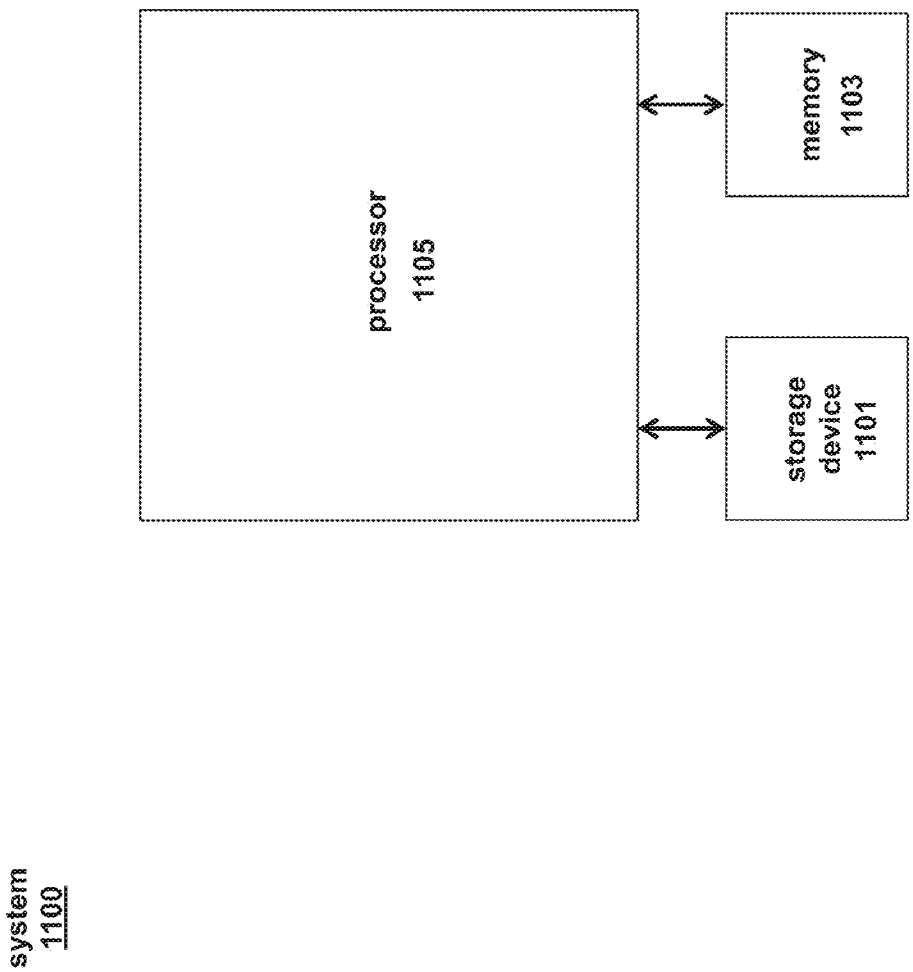
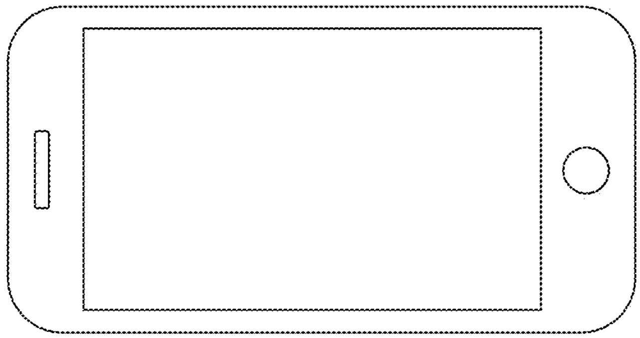
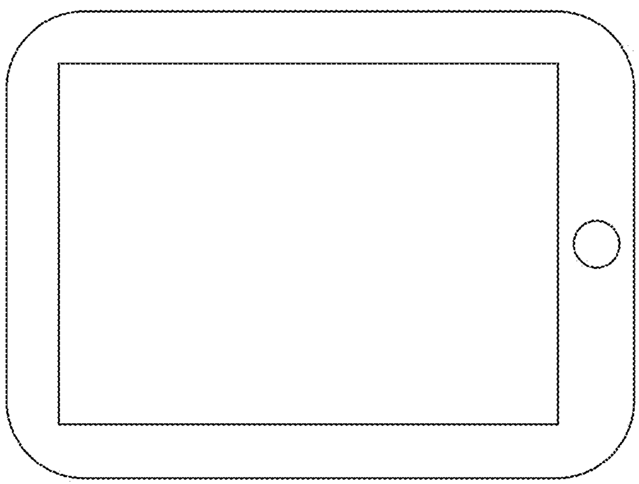

processor
1105
memory
1103
storage
device
1101
system
1100

FIG. 11



personal device 1300

FIG. 13



personal device 1200

FIG. 12

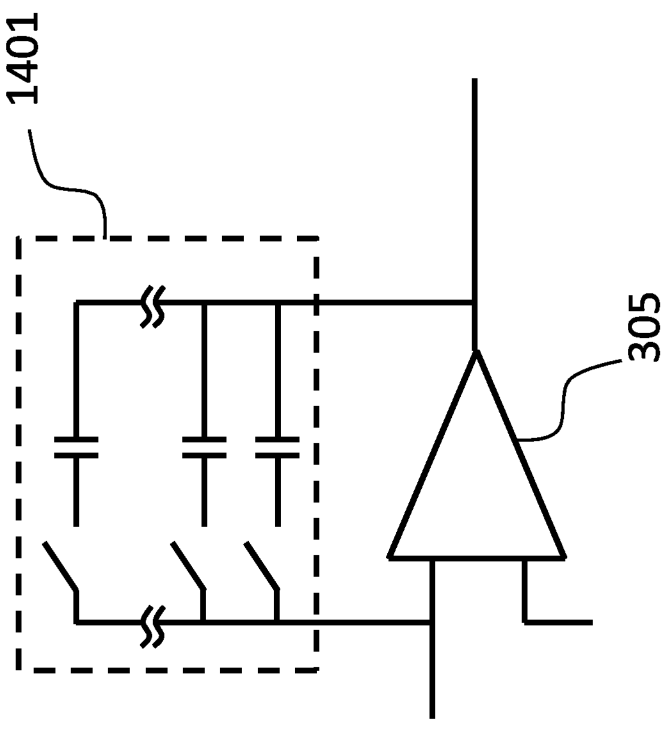


FIG. 14

STYLUS DEVICE

FIELD

This relates generally to touch sensitive devices and, more specifically, to styluses for use with touch sensitive devices.

BACKGROUND

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.

As touch sensing technology continues to improve, touch sensitive devices are increasingly being used to compose and mark-up electronic documents. In particular, styluses have become popular input devices as they emulate the feel of traditional writing instruments. However, while touch sensing technology has greatly improved over the past few years, little has been done to improve the stylus itself. Most conventional styluses simply include a bulky tip made of a material capable of interacting with the touch sensitive device. As a result, conventional styluses lack the precision and control of traditional writing instruments.

SUMMARY

Styluses capable of receiving stimulation and force signals and generating stylus stimulation signals, and touch sensitive devices capable of receiving stylus stimulation signals are disclosed. In one example, a stylus can receive a stimulation signal from a touch sensor of a touch sensitive device and generate a stylus stimulation signal by changing an amplitude or frequency of the received stimulation signal. The stylus can transmit the stylus stimulation signal back into the touch sensor of the touch sensitive device. The touch sensor can generate a touch signal based on the device's own stimulation signals and the stylus stimulation signal. The touch sensitive device can process the touch signal to determine a location of the stylus on the touch sensor. The stylus can include a force sensor to detect an amount of force applied to a tip of the stylus. The stylus stimulation signal can be modulated based on the force detected by the force sensor.

In one example, a touch sensor of a touch sensitive device can generate a touch signal based on the device's own stimulation signals and the stylus stimulation signal. The touch sensitive device can process the touch signal to determine that a stylus has been detected, a location of the stylus on the touch sensor, and an amount of pressure applied by the stylus to the touch sensitive device. The determinations can be made based on properties of the touch signal caused by the stylus stimulation signal.

Processes for generating and processing stylus stimulation signals are also disclosed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an exemplary touch sensor that can be used with a touch sensitive device according to various embodiments.

FIG. **2** illustrates a block diagram of an exemplary stylus according to various embodiments.

FIG. **3** illustrates a system block diagram showing the interaction between a touch sensitive device and an exemplary stylus according to various embodiments.

FIG. **4** illustrates a system block diagram showing the interaction between another touch sensitive device and an exemplary stylus according to various embodiments.

FIG. **5** illustrates an exemplary touch and stylus combo matrix according to various embodiments.

FIG. **6** illustrates exemplary stylus stimulus vectors according to various embodiments.

FIG. **7** illustrates an exemplary touch/stylus combo system according to various embodiments.

FIG. **8** illustrates a system block diagram showing the interaction between a touch sensitive device and another exemplary stylus according to various embodiments.

FIG. **9** illustrates an exemplary process for generating a stylus stimulation signal according to various embodiments.

FIG. **10** illustrates an exemplary process for processing a stylus stimulation signal according to various embodiments.

FIG. **11** illustrates an exemplary system for generating or processing a stylus stimulation signal according to various embodiments.

FIG. **12** illustrates an exemplary personal device that includes a touch sensor according to various embodiments.

FIG. **13** illustrates another exemplary personal device that includes a touch sensor according to various embodiments.

FIG. **14** illustrates a symbolic illustration of one or more capacitive elements coupled between the input and output of an amplifier according to various embodiments.

DETAILED DESCRIPTION

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

This relates to styluses capable of receiving stimulation and force signals and generating stylus stimulation signals and touch sensitive devices capable of receiving stylus stimulation signals. In one example, a stylus can receive a stimulation signal from a touch sensor of a touch sensitive device and generate a stylus stimulation signal by changing an amplitude or frequency of the received stimulation signal. The stylus can transmit the stylus stimulation signal back into the touch sensor of the touch sensitive device. The touch sensor can generate a touch signal based on the device's own stimulation signals and the stylus stimulation signal. The touch sensitive device can process the touch signal to determine a location of the stylus on the touch sensor. The stylus can include a force sensor to detect an amount of force applied to a tip of the stylus. The stylus stimulation signal can be modulated based on the force detected by the force sensor. A touch sensor of a touch sensitive device can generate a touch signal based on the device's own stimulation signals and the stylus stimulation signal. The touch sensitive device can process the touch signal to determine that a stylus has been detected, a location of the stylus on the touch sensor, and an amount of pressure applied by the stylus to the touch sensitive device. The determinations can be made based on properties of the touch signal caused by the stylus stimulation signal. Processes for generating and processing stylus stimulation signals are also disclosed.

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 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** (D**0**-D**3**) and columns of sense lines **103** (S**0**-S**4**). Each touch region **105** can have an associated mutual capacitance Csig **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 transmit 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.

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 stylus, finger, etc., touches the touch sensor **100**, the object can cause the capacitance Csig **111** to reduce by an amount ΔCsig at the touch location. This capacitance change ΔCsig 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 ΔCsig can be transmitted 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.

While the embodiment 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 embodiments of the disclosure, such as self-capacitance touch sensing, resistive touch sensing, projection scan touch sensing, and the like. Furthermore, while various embodiments describe a sensed touch, it should be appreciated that the touch sensor **100** can also sense a hovering object and generate hover signals therefrom.

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 computer, or the like. Stylus **200** can generally include tip **201**, ring **203**, body **207**, and 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) 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 1 mm or less. Tip **201** can be coupled to body **207** by 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) or a transparent non-conductive material (e.g., glass) coated with a transparent (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 by serving as an antenna for a wireless module (e.g., RFID, Bluetooth, WI-FI, or the like). Similarly, tip **201** can also be used to sense the touch 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.

In some examples, stylus **200** can be a modular stylus, such as that described in U.S. patent application Ser. No. 13/560,960, entitled "Modular Stylus Device".

FIG. **3** illustrates a functional block diagram of an exemplary system **300** showing the interaction between stylus **301**, touch sensor **321**, and touch circuitry **341**. In this embodiment, a stimulation signal from touch sensor **321** can be detected at a location where the tip of stylus **301** contacts or is near touch sensor **321** (e.g., where the tip contacts or hovers above a screen of a touch sensitive device). A modified stimulation signal can then be transmitted back into touch sensor **321** at the same frequency in phase or at an arbitrary phase (including quadrature) at the same location. The modified stimulation signal can be transmitted back into touch sensor **321** through the tip and/or ring of stylus **301**. It should be appreciated that FIG. **3** is a functional block diagram and that the actual components used to implement the various portions of system **300** can vary and one of ordinary skill, given the functional diagram, can select known circuit elements to implement the system.

Stylus **301** is one example of stylus **200** that can be used as an input device to a touch sensitive device having a touch sensor similar or identical to touch sensor **100**. Stylus **301** can be configured to generate a stylus stimulation signal having a greater magnitude than that generated by the touch sensitive device. Thus, when stylus **301** is used with a touch sensitive device, stylus **301** can cause the touch sensitive device to measure a "negative" touch. In other words, the charge detected at the stylus' touch location can be greater than the amount of charge detected when no touch is present. This is different than non-stylus touch events, which typically cause the charge detected at the touch location to decrease.

Stylus **301** can include amplifier **305** coupled to receive a stimulation signal (e.g., a stimulation signal similar or identical to stimulation signal **107**) generated by an associated touch sensitive device and transmit a stylus stimulation signal to the associated touch sensitive device. The associated touch sensitive device can include a touch sensitive device in contact with, or in close proximity to, the tip of stylus **301**. Stylus **301** can receive the stimulation signal through the touch sensor (e.g., touch sensor **321**) of the touch sensitive device. Amplifier **305** can be configured to receive and amplify the stimulation signal by an amount based at least in part on a force detected by force sensor **309** and a gain vector generated by processor **307**. In some examples, amplifier **305** can be configured to amplify the received stimulation signal by an amount representing an increase of capacitance by 0.1 pF or more, depending on the particular configuration. However, it should be appreciated that other amplifications can be used depending on the system design.

Stylus **301** can further include force sensor **309** to detect an amount of force applied to the tip of stylus **301**. Force sensor **309** can include any type of force sensor, such as a capacitive pressure sensor, semiconductor strain gauge, or the like. The amount of force detected by force sensor **309** can be used by amplifier **305** to determine the amount of amplification to be applied to the stimulation signal received from the associated touch sensitive device. In this way, the magnitude of the amplified stimulation signal generated by amplifier **305** can be adjusted based on how hard the stylus tip is applied to the surface of the associated touch sensitive device. This allows stylus **301** to convey information associated with the location of its tip on the surface of the touch sensitive device as well as the amount of force being applied to the surface of the touch sensitive device. In response, the touch sensitive device can interpret the location and force information as two different inputs. For example, in a drawing application, a brush stroke can be displayed on the screen of the touch sensitive device corresponding to a location of the tip of stylus **301** and with a width corresponding to the amount of force being applied to the touch sensitive device by the tip of stylus **301**.

Stylus **301** can further include processor **307** coupled to receive an amplified stimulation signal from amplifier **305**. Processor **307** can be configured to generate a signal representative of a gain vector that can be used to modulate the amplified output of amplifier **305**. The processor can monitor the stimulation signal received from the touch sensor **321** in order to synchronize the gain vector with the received stimulation sequence. The gain vector signal can be transmitted to mixer **306** where it, along with the output of force sensor **309**, can be used to control the amount of amplification applied to the stimulation signal from touch sensor **321**. The amplified and modulated stimulation signal can be transmitted back into touch sensor **321** as the stylus stimulation signal.

It should be appreciated that amplifier **305** can be configured to amplify the received stimulation signal based on the amount of force detected by force sensor **309** and the gain vector of processor **307** in many ways. In one example, amplifier **305** can include a regenerative amplifier operable to amplify the received stimulation signal using a feedback loop between the amplifier output and the amplifier input. FIG. **14** illustrates a symbolic illustration of one or more capacitive elements **1401** coupled between the input and output of an amplifier **305**. The received stimulation signal can be added at the amplifier input in phase. The amplified stimulation signal can be transmitted to touch sensor **321**, thereby increasing the signal charge locally between drive and sense (negative pixel) as opposed to reducing it in the presence of a touch. In this example, force sensor **309** can control one or more capacitive elements **1401** coupled between the input and output of amplifier **305**. Switches can also be coupled to the capacitive elements to selectively couple the capacitive elements between the input and output of amplifier **305**. The one or more capacitive elements **1401** can be configured such that the capacitance of each of the one or more capacitive elements is inversely related to the amount of force applied to the tip of stylus **301**. Thus, as the force against the tip of stylus **300** increases, the capacitance of the one or more capacitive elements **1401** of force sensor **309** decreases, thereby increasing the overall gain of amplifier **305**. Conversely, as the force against the tip of stylus **300** decreases, the capacitance of the one or more capacitive elements **1401** of force sensor **309** increases, thereby decreasing the overall gain of amplifier **305**. In this example, processor **307** can be configured to cause amplifier **305** to modulate the stimulation signal using a gain vector by selectively coupling one of the one or more capacitive elements **1401** (each having a different capacitance value) between the input and output of amplifier **305** based on the gain vector. Processor **307** can accomplish this by selectively opening and closing the switches coupled to each capacitive element. In this way, the gain caused by each of the capacitive elements **1401** can be changed by adjusting the pressure applied to the tip of stylus **301** while processor **307** can modulate the amplified signal by selecting between each of the capacitive elements having different capacitance values.

In some examples, amplifier **305** can be configured to yield a loop gain of less than one to prevent oscillation. In other alternative examples, amplifier **305** can include a super regenerative amplifier, comprised of an amplifier with a loop gain of greater than 1 and a quench signal generator having a quench rate based on the received stimulation signal from touch sensor **321**. In these examples, the quench signal generator can apply a quench signal that can cause the gain of the regenerative amplifier to drop substantially below the gain needed for the regenerative amplifier to sustain oscillation, causing the regenerative amplifier to repeatedly go into oscillation at the beginning of each scan step. In yet other examples, amplifier **305** can add the received stimulation signal at the amplifier input in a different phase (including quadrature).

System **300** can further include touch sensor **321** of a touch sensitive device. Touch sensor **321** can include a touch sensor similar or identical to touch sensor **100**, described above. As shown in FIG. **3**, touch sensor **321** can include a drive line **329** coupled to receive a stimulation signal similar or identical to stimulation signal **107** from touch circuitry **341** and a sense line **331** capacitively coupled to drive line **329** and coupled to transmit a touch signal similar or identical to touch signal **109** to touch circuitry **341**. It should be appreciated that touch sensor **321** is shown with only one drive line and one sense line for illustrative purposes only and that touch sensor **321** can actually include any number of drive lines and any number of sense lines.

A mutual capacitance Csig **327** can be formed between the crossing drive line **329** and sense line **331** when the drive line is stimulated. Similarly, a mutual capacitance Cts **323** and Ctd **325** can be formed between the tip of stylus **301** and sense line **331** and drive line **329**, respectively, when the stylus stimulation signal is generated. As mentioned above, if the tip of stylus **301** is placed near or at the crossing point between drive line **329** and sense line **331**, stylus **301** can receive the stimulation signal transmitted on drive line **329** via the capacitive path formed between the stylus tip and drive line **329**, amplify the received stimulation signal using amplifier **305**, force sensor **309**, and processor **307**, and transmit an amplified stimulation signal in the form of a stylus stimulation signal back into touch sensor **321** via the capacitive path formed between the stylus tip and sense line **331**. Thus, the touch signal generated by sense line **331** can include charges coupled from both drive line **329** and stylus **301**. As a result, the amount of charge detected by sense line **331** can increase when the tip of stylus **301** is placed on or above the crossing point between drive line **329** and sense line **331**. This increase in charge can be used by the touch sensitive device to distinguish a stylus touch event from a non-stylus touch event because, as mentioned above, non-stylus touch events typically cause capacitance Csig **327** to decrease due to charge or current from the stimulated drive line **329** being shunted through the non-stylus object to ground rather than being coupled to the crossing sense line **331** at the touch location. Moreover, the touch sensitive device can determine the location of the stylus touch event because the same stimulation signal being driven on drive line **329** is being amplified and transmitted back into the touch sensor at the crossing point between drive line **329** and sense line **331**.

System **300** can further include touch circuitry **341** included in or associated with the touch sensitive device. Touch circuitry **341** can include multi-stim matrix **343** stored in a computer-readable storage medium. Multi-stim matrix **343** can include a matrix containing stimulation phase information for stimulation signals that can be simultaneously applied to the drive lines of touch sensor **321**, such as that described in U.S. patent Ser. No. 12/208,329, entitled "Multiple Stimulation Phase Determination." Specifically, each row of the matrix can represent a single step among multiple steps needed to compute values for generating an image of touch, each column of the matrix can represent a drive line of touch sensor panel **321** to be stimulated, and each cell of the matrix can represent the phase of a stimulation signal to be applied to a particular drive line in a particular step. In one example, multi-stim matrix **343** can include an additional row and column to support the stylus stimulation signal from stylus **301**. Specifically, the additional column can represent a drive line that is not driven, or a drive line that does not actually exist on touch sensor panel **321**. The purpose of the additional column is to detect the stylus stimulation signal. Touch circuitry **341** can further include inverse multi-stim matrix **353** stored in a computer-readable storage medium. Inverse multi-stim matrix **353** can include a matrix representing an inverse of multi-stim matrix **343** for decoding a touch signal received from a sense line of touch sensor **321** to generate a touch image representing a touch detected by touch sensor **321**. These matrices will be described in greater detail below with respect to FIGS. **4-7**.

Referring back to FIG. **3**, touch circuitry **341** can further include transmitter channel **345** coupled to transmit a stimulation signal to drive line **329** of touch sensor **321**. Transmitter channel **345** can be configured to generate a stimulation signal similar or identical to stimulation signal **107** to be applied to drive line **329** based on the phase information contained in multi-stim matrix **343**. In some examples, the stimulation signal can have a frequency between 80-120 KHz (e.g., 90, 100, or 110 KHz) and an amplitude between 3-5V (e.g., 4V). In other examples, the stimulation signal can have a frequency between 100 KHz to 1 MHz or higher (e.g., between 100-300 KHz or 100-500 KHz). Although not shown, touch circuitry **341** can include one transmitter channel for each drive line of touch sensor **321**.

Touch circuitry **341** can further include receiver circuitry **347** coupled to receive a touch signal from sense line **331** of touch sensor **321**. Receiver circuitry **347** can include amplifiers, filters, and/or analog to digital converters that one of ordinary skill in the art can select to appropriately process the touch signal received from sense line **331**. Although not shown, touch circuitry **341** can include additional receiver circuitry for each sense line of touch sensor **321**.

Touch circuitry **341** can further include in-phase (I-phase) demodulation circuitry **349** configured to demodulate the touch signal received from receiver circuitry **347**. I-phase demodulation circuitry **347** can include a demodulation mixer and a demodulation integrator to extract the I-phase component of the touch signal output by sense line **331**. Although not shown, touch circuitry **341** can include additional I-phase demodulation circuitry for each sense line of touch sensor **321**. In some examples, transmitter channel **345**, receiver circuitry **347**, and I-phase demodulation circuitry **349** can include circuitry similar or identical to that described in U.S. patent application Ser. No. 11/818,345, which is incorporated by reference herein in its entirety as if put forth in full below.

Touch circuitry **341** can further include multi-stim decode circuitry **351** configured to decode the I-phase component of the touch signal received from I-phase demodulation circuitry **341**. Multi-stim decode circuitry **351** can include a mixer coupled to multiply the I-phase component of the touch signal received from I-phase demodulation circuitry **341** with inverse multi-stim matrix **353**. Multi-stim decode circuitry **351** can further include an integrator coupled to receive the output of the mixer and to output touch image **355** representing a touch detected by sense line **331** of touch sensor **321**. Although not shown, touch circuitry **341** can include additional multi-stim decode circuitry for each sense line of touch sensor **3211**.

FIG. **4** illustrates a functional block diagram of another exemplary system **400** showing the interaction between stylus **401**, touch sensor **421**, and touch circuitry **441**. In this embodiment, similar to that shown in FIG. **3**, stylus **401** can receive a stimulation signal from touch sensor **421** at a location where the tip of stylus **401** contacts or is near touch sensor **421** (e.g., where the tip contacts or hovers above a screen of a touch sensitive device). A modified stimulation signal can then be transmitted back into touch sensor **421** at the same frequency in phase or at an arbitrary phase (including quadrature) at the same location. The modified stimulation signal can be transmitted back into touch sensor **421** through the tip and/or ring of stylus **401**. It should be appreciated that FIG. **4** is a functional block diagram and that the actual components used to implement the various portions of system **400** can vary and one of ordinary skill, given the functional diagram, can select known circuit elements to implement the system.

System **400** can include stylus **401**, amplifier **405**, processor **407**, mixer **406**, force sensor **409**, touch sensor **421**, Cts **423**, Ctd **425**, Csig **427**, drive line **429**, sense line **431**, multi-stim matrix **443**, transmitter channel **445**, receiver circuitry **447**, and inverse matrix **453** similar or identical to stylus **301**, amplifier **305**, processor **307**, mixer **306**, force sensor **309**, touch sensor **321**, Cts **323**, Ctd **325**, Csig **327**, drive line **329**, sense line **331**, multi-stim matrix **343**, transmitter channel **345**, receiver circuitry **347**, and inverse matrix **353**, respectively. However, touch circuitry **441** can include two demodulation paths. The first demodulation path can include stylus demodulation circuitry **449** and multi-stim decode circuitry **451** for demodulating the touch signal received from receiver circuitry **447** at a first touch phase to generate stylus image **456**. The second demodulation path can include touch demodulation circuitry **457** and multi-stim decode circuitry **459** for demodulating the touch signal received from receiver circuitry **447** at a second stylus phase to generate touch image **455**, Including a phase shift between the touch and stylus signals further helps to distinguish the touch and stylus signals in addition to the latter having a positive phase. In some examples, the difference between the first and second phases can be 90 degrees. In other examples, the phase difference between the first and second phases can have a different value.

FIG. **5** illustrates an exemplary touch and stylus stimulus combo matrix that can be used in systems **300** or **400**. In this embodiment, a touch stimulus matrix may be extended by M columns and M rows to form the modified touch and stylus stimulus combo matrix. The first N columns may be used for touch stimulus and the M columns may be used for stylus magnitude. Each column vector can correspond to a different channel. In order for the stimulus matrix to be invertible, the matrix should be a square matrix and therefore can be extended by M rows. FIG. **6** illustrates M exemplary stylus stimulus vectors. Each stylus stimulus vector represents a copy of one of the M column vectors from the touch and stylus stimulus combo matrix shown in FIG. **5**. Using the touch and stylus stimulus combo matrix, the system can support a total of N styluses.

FIG. **7** illustrates a simplified view of a touch/stylus combo system that utilizes separate channels to encode stylus magnitude. The touch and stylus stimulus combo matrix is extended by N columns and N rows, where N is the number of stylus or devices for which to encode magnitude information. In this example, the touch controller can drive the M drive lines for which touch and stylus location need to be resolved. M touch pixels can be modulated along the M touch pixels along a sense line by touch and up to N stylus devices. The N stylus devices may potentially modulate different touch pixels along a sense line. Each stylus device can have its own stylus stimulus vector, which represents a copy of one of the M column vectors from the touch and stylus stimulus combo matrix. The stylus can modulate the gain of the amplifier (e.g., amplifier **305** or **405**) as a function of the stylus stimulus vector or can add its own stimulus signal directly to a given touch pixel (e.g., through the stylus ring). The stimuli from the N styluses can be synchronized in the stylus device by the respective stylus device monitoring the stimulus signal at a given touch panel location and then synchronizing its own stimulus with the received stimulus signal at that touch panel location. For example, synchronization can occur at the first scan step, representing the first row vector in the touch and stylus stimulus combo matrix. In some embodiments, all elements in the first row vector may be 1 (i.e., all M stimulus signals can be driven in positive phase), if the touch and stylus stimulus combo matrix is a hadamard matrix. The stylus device can use this first step to synchronize its own stimulus. The composite signal at the sense line can be vector demodulated with a decode matrix, which represents the inverse of the touch and stylus stimulus combo matrix. The touch and stylus locations can be stored in the touch and stylus result vector, which is comprised of M entries containing M elements indicating the location/magnitude of touch and styluses and N dedicated stylus magnitudes.

In some examples, some or all of the functional blocks of touch circuitry **341** or **441** can be implemented by ASIC processor, ARM processor, other electrical components, or combinations thereof.

FIG. **8** illustrates a functional block diagram of another exemplary system **800** showing the interaction between stylus **801**, touch sensor **821**, and touch circuitry **841**. It should be appreciated that FIG. **8** is a functional diagram and that the actual components used to implement the various portions of system **800** can vary and one of ordinary skill, given the functional diagram, can select known circuit elements to implement the system

Stylus **801** is one example of stylus **200** that can be used as an input device to a touch sensitive device having a touch sensor similar or identical to touch sensor **100**. Stylus **801** can be configured to generate a stylus stimulation signal having a frequency that is different than a frequency of a stimulation signal generated by the touch sensitive device. In some examples, the stylus stimulation frequency can be between 40-60 KHz (e.g., about 50 Khz) greater than or less than the frequency of a stimulation signal from a touch sensor. Thus, when stylus **801** is used with a touch sensitive device, stylus **801** can cause the touch sensitive device to generate a touch signal containing signals having two or more different frequencies.

Stylus **801** can optionally include sense amplifier **805** coupled to receive a stimulation signal (e.g., a stimulation signal similar or identical to stimulation signal **107**) generated by an associated touch sensitive device and transmit a stylus stimulation signal to the associated touch sensitive device. The associated touch sensitive device can include a touch sensitive device in contact with, or in close proximity to, the tip of stylus **801**. Sense amplifier **805** can be used to amplify the received stimulation signal to a level sufficient to be used by stylus **801** to generate a stylus stimulation signal, which is described in greater detail below. However, if the strength of the received stimulation signal is sufficiently high, sense amplifier **805** can be omitted from stylus **801**.

Stylus **801** can further include force sensor **809** for detecting the amount of force applied to the tip of stylus **801**. Force sensor **809** can be similar or identical to force sensor **309**, described above. For example, force sensor **809** can include any type of force sensor, such as a capacitive pressure sensor, semiconductor strain gauge, or the like, operable to detect the amount of force applied to the tip of stylus **801**. The amount of force detected by force sensor **809** can be used to modulate an oscillating signal generated by oscillator **813**. In this way, the magnitude of the oscillating signal generated by oscillator **813** can be adjusted based on how hard the stylus tip is applied to the surface of the associated touch sensitive device. As described above, this allows stylus **801** to convey information associated with the location of its tip on the surface of the touch sensitive device as well as the amount of force being applied to the surface of the touch sensitive device.

Stylus **801** can further include comparator **811** coupled to receive the output of force sensor **809** and a threshold voltage Vth. Comparator **811** can be configured to compare the output of force sensor **809** to the threshold voltage Vth and output a force detection signal based on the comparison. For example, the force detection signal can be driven high (or low, depending on the circuit design) when the output of force sensor **809** is greater than threshold voltage Vth and can be drive low (or high, depending on the circuit design) when the output of force sensor **809** is less than threshold voltage Vth.

Stylus **801** can further include processor **803** coupled to receive the force detection signal output by comparator **811**. Processor **803** can be configured to generate a power control signal based on the received force detection signal. For example, if the force detection signal is at a level indicating that the force detected by force sensor **809** is greater than a threshold amount (represented by threshold voltage Vth), processor **803** can drive the power control signal to a high level (or low, depending on the circuit design) to cause oscillator **813** to generate a signal. The force detection signal and the power control signal can be used to control the power state of some or all components within stylus **801** to improve battery life. For example, if the force is below the set force threshold, the device can be in an idle state and the device can remain in a low power state, thereby conserving battery power. When the force is above the force detection threshold, the device can transitions into an active mode. This way battery power can be conserved when the stylus is not actively being used.

Stylus **801** can further include oscillator **813** configured to generate an oscillating signal having frequency F_{off}. Oscillator **813** can include any type of oscillator, such as a tuned LC oscillator (e.g, a colpitts-oscillator), crystal oscillator, MEMS based oscillator, voltage controlled oscillator, RC oscillator, ring oscillator, or the like. In one example, oscillator **813** can be configured to generate a sinusoidal signal having an amplitude between 8-12V (e.g., 9, 10, or 11V) and a frequency F_{off} between 80-120 KHz (e.g., 90, 100, or 110 KHz). In other examples, the stimulation signal can have a frequency between 100 KHz to 1 MHz or higher (e.g., between 100-300 KHz or 100-500 KHz). The signal generated by oscillator **813** can have the same phase as the stimulation signal received from touch sensor **821**.

Stylus **801** can further include mixer **807** coupled to receive the output of force sensor **809**, the signal having frequency F_{off} output by oscillator **813**, and the amplified stimulation signal from sense amplifier **805**. Mixer **807** can be configured to modulate the amplitude of the signal having frequency F_{off} output by oscillator **813** by an amount corresponding to the force detected by force sensor **809** to generate a modulated oscillating signal. Mixer **807** can be further configured to mix the modulated oscillating signal with the amplified signal received from sense amplifier **805** to generate a stylus stimulation signal. The resultant composite stimulation signal can have a frequency equal to the frequency of the stimulation signal received from touch sensor **821** plus or minus the offset frequency F_{off} amplitude modulated by the force signal.

Stylus **801** can further include transmission amplifier **815** coupled to receive the stylus stimulation signal output by mixer **807**. Amplifier **815** can be configured to amplify the composite stimulation signal by an amount sufficient to be received by touch sensor **821**.

System **800** can further include touch sensor **821** of a touch sensitive device. Touch sensor **821** can include a touch sensor similar or identical to touch sensor **100**, described above. As shown in FIG. **8**, touch sensor **821** can include a drive line **829** coupled to receive a stimulation signal similar or identical to stimulation signal **107** from touch circuitry **841** and a sense line **831** capacitively coupled to drive line **829** and coupled to transmit a touch signal similar or identical to touch signal **109** to touch circuitry **841**. It should be appreciated that touch sensor **821** is shown with only one drive line and one sense line for illustrative purposes only and that touch sensor **821** can actually include any number of drive lines and any number of sense lines.

A mutual capacitance Csig **827** can be formed between the crossing drive line **829** and sense line **831** when the drive line is stimulated. Similarly, a mutual capacitance Cts **823** and Ctd **825** can be formed between the tip of stylus **801** and sense line **831** and drive line **829**, respectively, when the stylus stimulation signal is generated. A mutual capacitance Crs **833** and Crd **835** can also be formed between the ring of stylus **801** and sense line **831** and drive line **829**, respectively, when the composite stylus stimulation signal is generated. As mentioned above, if the tip of stylus **801** is placed at the crossing point between drive line **829** and sense line **831**, stylus **801** can receive the stimulation signal transmitted on drive line **829** via the capacitive path formed between the stylus tip and drive line **829**, amplify the received stimulation signal using sense amplifier **805**, mix the amplified stimulation signal with a modulated oscillating signal generated by modulating a signal having frequency F_{off} by an amount corresponding to a force detected by force sensor **809**, and transmit the stylus stimulation signal back into touch sensor **821** via the capacitive path formed between the stylus ring and sense line **831**. Thus, the touch signal generated by sense line **831** can include charge coupled from both drive line **829** and stylus **801**.

System **800** can further include touch circuitry **841** included in or associated with the touch sensitive device. Touch circuitry **841** can be similar to touch circuitry **341**, described above, except that touch demodulation circuitry **849** and multi-stim decode circuitry **851** can be configured to demodulate the touch component of the signal output by receiver circuitry **847** and post the result in a touch image memory **855**. Touch circuitry **841** can further include stylus demodulation circuitry **857** and multi-stim decode circuitry **859** to demodulate the stylus component of the signal output by receiver circuitry **847** and post the result to stylus image memory **861**. In the illustrated example, stylus demodulation can occur at FSTM+/−FOFF, since the received signal on the stylus device can be FSTM and modulated with FOFF to generate the stylus signal. The touch demodulation can be performed at FSTM. Multi-stim matrix **843**, transmitter channel **845**, receiver circuitry **847**, and inverse matrix **853** can be similar or identical to multi-stim matrix **343**, transmitter channel **345**, receiver circuitry **347**, and inverse matrix **353** of touch circuitry **341**, respectively. However, multi-stim matrix **843** and inverse matrix **853** may not include an extra row and step like that contained in multi-stim matrix **343** and inverse matrix **353**. The differences between touch circuitry **341** and touch circuitry **841** will now be described in more detail.

Touch circuitry **841** can include separate demodulation and decode circuitry for handling stylus touch events and non-stylus touch events. Specifically, touch circuitry **841** can include touch demodulation circuitry **849** and multi-stim decode circuitry **851** to process non-stylus touch events and can include stylus demodulation circuitry **857** and multi-stim decode circuitry **859** to process stylus touch events.

Touch demodulation circuitry **849** can be configured to demodulate the portion of the touch signal received from receiver circuitry **847** having a frequency corresponding to the frequency of the stimulation signal generated by transmitter channel **845**. Touch demodulation circuitry **849** can include a demodulation mixer and a demodulation integrator to extract the touch component of the signal output by sense line **831** having the frequency corresponding to the frequency of the stimulation signal generated by transmitter channel **845**.

Multi-stim decode circuitry **851** can be configured to decode the touch component of the signal received from touch demodulation circuitry **849**. Multi-stim decode circuitry **851** can include a mixer coupled to multiply the touch component of the signal received from touch demodulation circuitry **849** with inverse multi-stim matrix **853**. Multi-stim decode circuitry **851** can further include an integrator coupled to receive the output of the mixer and to post the result in a touch image memory **855**, representing a non-stylus touch detected by sense line **831** of touch sensor **821**.

Stylus demodulation circuitry **857** can be configured to demodulate the portion of the touch signal received from receiver circuitry **847** having a frequency corresponding to the frequency of the stimulation signal generated by transmitter channel **845** plus or minus the offset frequency F_{off}. Stylus demodulation circuitry **857** can include a demodulation mixer and a demodulation integrator to extract the stylus component of the signal output by sense line **831** having the frequency corresponding to the frequency of the stimulation signal generated by transmitter channel **845** plus or minus the offset frequency F_{off}.

Multi-stim decode circuitry **859** can be configured to decode the stylus component of the signal received from stylus demodulation circuitry **857**. Multi-stim decode circuitry **859** can include a mixer coupled to multiply the stylus component of the touch signal received from stylus demodulation circuitry **857** with inverse multi-stim matrix **853**. Multi-stim decode circuitry **859** can further include an integrator coupled to receive the output of the mixer and to post the result in a touch image memory **861**, representing a stylus touch detected by sense line **831** of touch sensor **821**.

In some examples, the functional blocks of touch circuitry **841** can be implemented by ASIC processor, ARM processor, other electrical components, or combinations thereof.

While system **800** is shown and described above as using one signal having an offset frequency F_{off}, it should be appreciated that any number of these signals can be used. For example, stylus **801** can include any number of additional oscillators to generate additional signals to be modulated by an amount corresponding to the force detected by force sensor **809**. These additional signals can have varying frequencies and can each be mixed with the amplified stimulation signal received from sense amplifier **805** (or non-amplified stimulation signal received from touch sensor **821** if no sense amplifier **805** is used) to generate the stylus stimulation signal. In this example, touch circuitry **841** can also include additional circuitry to process the additional signals generated by stylus **801**. For example, touch circuitry can include additional I-phase demodulations circuits and multi-stim decoder circuits for each additional signal to be demodulated.

FIG. **9** illustrates an exemplary process **900** for generating and transmitting a stylus stimulation signal. At block **901**, a stimulation signal can be received by a stylus from a touch sensitive device. The stimulation signal can be received by capacitively coupling a portion of the stylus to the touch sensitive device. In one example, a stimulation signal similar or identical to stimulation signal **107** can be generated by a touch sensitive device similar or identical to those shown in FIGS. **3**, **4**, and **8**. The stimulation signal can be generated by a transmitter channel similar or identical to transmitter channels **345**, **445**, or **845** using a multi-stim matrix similar or identical to multi-stim matrix **343**, **443**, or **843**. The stimulation signal can be sent through a drive line similar or identical to drive lines **329**, **429**, or **829** of a touch sensor similar or identical to touch sensors **321**, **421**, or **821**. A stylus similar or identical to stylus **200**, **301**, **401**, or **801** having a tip similar or identical to tip **201** can receive the stimulation signal via a capacitive path formed between the drive line and the tip of the stylus when the stylus tip is placed on or near the touch sensitive surface of the touch sensitive device.

At block **903**, a stylus stimulation signal can be generated by changing a characteristic of the received stimulation signal. For example, one or more of a frequency or amplitude of the received stimulation signal can be changed to generate the stylus stimulation signal.

In one example, an amplifier similar or identical to amplifier **305** or **405** including a regenerative amplifier can be used to amplify the received stimulation signal. The amplification can be based on an amount of force detected by a force sensor similar or identical to force sensor **309** or **409** and a gain vector generated by processor similar or identical to processor **307** or **407**. The force sensor can detect the amount of force being applied to the tip of the stylus. In this way, the magnitude of the stylus stimulation signal can be varied by adjusting the amount of force being applied between the stylus tip and the surface of the touch sensitive device.

In another example, an oscillator and mixer similar or identical to oscillator **813** and mixer **807** can be used to change a frequency of the received stimulation signal. In this example, the oscillator can be configured to generate an oscillating signal (e.g., a sinusoidal signal) having a frequency that is different from that of the received stimulation signal. In some examples, the oscillator can be configured to turn on in response to a sufficient force being applied to the tip of the stylus as detected by a force sensor similar or identical to force sensor **809**. The stylus signal generated by the oscillator can modulated at a mixer similar or identical to mixer **807** by an output of the force sensor such that the amplitude of the amplitude modulated stylus stimulation signal corresponds to an amount of force detected by the force sensor. The amplitude modulated oscillating signal can be mixed with the received stimulation signal by a mixer similar or identical to mixer **807** to generate a stylus stimulation signal. In some examples, prior to mixing with the amplitude modulated stylus stimulation signal, the received stimulation signal can be amplified using an amplifier to increase the signal strength to a desirable amount. For example, an amplifier similar or identical to sense amplifier **805** can be used to amplify the received stimulation signal.

At block **905**, the stylus stimulation signal can be transmitted to the touch sensitive device. For example, the stylus stimulation signal generated at block **903** can be transmitted to the touch sensitive device via a capacitive path formed between the stylus device and the touch sensor of the device.

In one example, an amplitude-modulated stylus stimulation signal generated by a stylus similar or identical to stylus **301** or **401** can be transmitted to a touch sensor similar or identical to touch sensor **321** or **421** of a touch sensitive device via a capacitive path formed between the stylus device and the touch sensor of the device.

In another example, a frequency-shifted composite stylus stimulation signal generated by a stylus similar or identical to stylus **801** can be transmitted to a touch sensor similar or identical to touch sensor **821** of a touch sensitive device via a capacitive path formed between the stylus device and the touch sensor of the device. The frequency-shifted composite stylus stimulation signal can be amplified prior to transmission using a transmission amplifier similar or identical to transmission amplifier **815**.

FIG. **10** illustrates an exemplary process **1000** for receiving and processing a touch signal having a stylus stimulation signal. At block **1001**, a stimulation signal can be generated by a touch sensitive device. The stimulation signal can be transmitted to drive lines of a touch sensor. In one example, a stimulation signal similar or identical to stimulation signal **107** can be generated by a touch sensitive device similar or identical to those shown in FIGS. **3**, **4**, and **8**. The stimulation signal can be generated by a transmitter channel similar or identical to transmitter channels **345**, **445**, or **845** using a multi-stim matrix similar or identical to multi-stim matrices **343**, **443**, or **843**. The stimulation signal can be sent through a drive line similar or identical to drive lines **329**, **429**, or **829** of a touch sensor similar or identical to touch sensors **321**, **421**, or **821**.

At block **1003**, a touch signal having a stylus stimulation signal can be received by the touch sensitive device. The touch signal can represent a detected touch event on a touch sensitive surface of the touch sensitive device. In one example, a touch signal similar or identical to touch signal **109** can be received from a sense line similar or identical to sense line **331**, **431**, or **831** of a touch sensor similar or identical to touch sensor **321**, **421**, or **821**. The touch signal can contain a stylus stimulation signal generated by a stylus similar or identical to stylus **301**, **401**, or **801**. The stylus stimulation signal can be an amplitude-modulated and/or frequency-shifted version of the stimulation signal.

At block **1005**, the received sense signal can be processed. For example, the received sense signal can be filtered, converted from an analog to a digital signal, amplified, or combinations thereof. The signal can further be demodulated and decoded to generate a touch image representing a touch event detected by the touch sensor. In one example, a receiver circuitry similar or identical to receiver circuitry **347**, **447**, or

847 can be used to filter, convert the signal from an analog to a digital signal, amplify, or combinations thereof, the received sense signal.

In one example, the signal output by the receiver circuitry, such as receiver circuitry **347**, can be sent through demodulation circuitry similar or identical to demodulation circuitry **349** to extract the I-phase component of the touch signal. The demodulated signal can be transmitted to decode circuitry similar or identical to multi-stim decode circuitry **351** to generate a touch image similar or identical to touch image **355**. In another example, the signal output by the receiver circuitry, such as receiver circuitry **447**, can be sent through demodulation circuitry similar or identical to touch demodulation circuitry **457** and stylus demodulation circuitry **449** to extract the touch and stylus components of the touch signal. The demodulated signals can be transmitted to decode circuitry similar or identical to multi-stim decode circuitry **451** and **459** to generate a stylus image similar or identical to stylus image **456** and a touch image similar or identical to touch image **455**.

In another example, the signal output by receiver circuitry, such as receiver circuitry **847**, can be sent through two or more sets of demodulation circuitry similar or identical to touch and stylus demodulation circuitry **849** and **857** to extract the touch and stylus components of the touch signal. The touch demodulation circuitry **849** can be configured to demodulate the signal output by the receiver circuitry at a frequency corresponding to the frequency of the signal transmitted at block **1001**. The stylus demodulation circuitry **857** can be configured to demodulate the signal output by the receiver circuitry at the frequency corresponding to the frequency of the signal transmitted at block **1001** plus or minus an offset frequency corresponding to a frequency of an oscillating signal generated by the stylus device. If the stylus is configured to generate more than one oscillating signal, additional demodulation circuits can be used to demodulate the signal output by the receiver circuitry at frequencies corresponding to the frequency of the signal transmitted at block **1001** plus or minus offset frequencies corresponding to frequencies of the additional oscillating signals. The demodulated signal can be transmitted to decode circuitry similar or identical to multi-stim decode circuitry **851** or **859**. Additional decode circuitry can be included if additional demodulation circuits are used. The multi-stim decode circuitry can be used to generate touch images similar or identical to touch and stylus images **855** and **861**.

Using styluses **301**, **401**, and **801** or processes **900** or **1000**, a stylus device can be used to input both positional data and pressure into a touch sensitive device. These inputs can be used to improve a user experience in various applications. For example, in a drawing application, a user can use the stylus as a paintbrush, with the stylus' motion and pressure being detected by the touch sensitive device. As the user increases the pressure of the stylus against the touch sensitive device, the thickness of the brushstrokes can be increased. As the user reduces the pressure of the stylus against the touch sensitive device, the thickness of the brushstrokes can similarly decrease. In another example, when drawing with a line rather than a brush, the line thickness can change as a function of pressure. Similarly, when using the stylus as an eraser, the eraser width can vary as a function of pressure.

One or more of the functions relating to the generation or processing of a stylus stimulation signal described above can be performed by a system similar or identical to system **1100** shown in FIG. **11**. System **1100** can include instructions stored in a non-transitory computer readable storage medium, such as memory **1103** or storage device **1101**, and executed by processor **1105**. 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.

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.

The system **1100** shown in FIG. **11** can be used in either the stylus to generate a stylus stimulation signal as described above with respect to FIGS. **3**, **4**, **8**, and **9**, or the touch sensitive device to receive and process a touch signal as described above with respect to FIGS. **3**, **4**, **8**, and **10**.

It is to be understood that the system is not limited to the components and configuration of FIG. **11**, but can include other or additional components in multiple configurations according to various embodiments. Additionally, the components of system **1100** can be included within a single device, or can be distributed between multiple devices.

FIG. **12** illustrates an exemplary personal device **1200**, such as a tablet, that can be used with a stylus according to various embodiments.

FIG. **13** illustrates another exemplary personal device **1300**, such as a mobile phone, that can be used with a stylus according to various embodiments.

Although embodiments 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 embodiments as defined by the appended claims.

What is claimed is:

1. A stylus comprising:

a stylus tip capable of receiving a stimulation signal from a touch sensitive device and further capable of transmitting a stylus stimulation signal to the touch sensitive device;

a force sensor circuit capable of detecting a force applied to the stylus tip;

an amplification circuit coupled to receive the stimulation signal from the stylus tip, the amplification circuit comprising a processor and an amplifier, the processor coupled to receive an output signal from the amplifier and capable of generating a gain signal, wherein the amplification circuit is capable of modulating the received stimulation signal to generate the stylus stimulation signal based on the gain signal and the force detected by the force sensor circuit; and

a mixer circuit coupled to receive the gain signal and an output from the force sensor circuit and capable of controlling the amount of amplification applied to the received stimulation signal based on the output from the force sensor circuit and the gain signal.

2. The stylus of claim **1**, wherein a phase and a frequency of the stylus stimulation signal are at least substantially equal to a phase and a frequency of the stimulation signal from the touch sensitive device.

3. The stylus of claim **1**, wherein the amplification circuit comprises a regenerative or super regenerative amplifier, and wherein a quench rate of the super regenerative amplifier is synchronous to at least a portion of the received stimulation signal and a gain of the super regenerative amplifier is based on the received stimulation signal.

4. The stylus of claim **1**, wherein the amplification circuit further comprises a plurality of capacitive elements switchably coupled between an input and an output of the amplifier and the gain signal selectively couples one or more of the plurality of capacitive elements to modulate an amplitude of the received stimulation signal.

5. The stylus of claim **1**, wherein the amplification circuit further comprises a plurality of capacitive elements switchably coupled between an input and an output of the amplifier and the force sensor circuit is capable of adjusting the capacitance of one or more of the plurality of capacitive elements based on the amount of force applied to the stylus tip.

6. A method comprising:

receiving a stimulation signal from a touch-sensitive device;

generating a stylus stimulation signal based on the received stimulation signal and a force detected by a force sensor, wherein generating the stylus stimulation signal comprises

generating a gain vector using a processor receiving an amplified version of the received stimulation signal,

modulating an amplitude of the received stimulation signal based at least in part on the output of a mixer circuit, wherein the mixer is coupled to receive the gain vector and an output from the force sensor; and

transmitting the generated stylus stimulation signal to the touch-sensitive device.

7. The method of claim **6**, wherein generating the stylus stimulation signal further comprises selectively coupling one or more capacitive elements between the input and output of an amplifier based on the gain vector to modulate the amplitude of the received stimulation signal.

8. The method of claim **6**, wherein generating the stylus stimulation signal comprises modulating the amplitude of the received stimulation signal using a regenerative amplifier.

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