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(54) **TOUCH SENSOR WITH IMPROVED ELECTRODE PATTERN**

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(57) **ABSTRACT**

A touch sensor includes a substrate with a touch region, and a series resistor chain for creating electrical fields across the touch region. The resistor chain comprises a plurality of conductive electrodes that to form overlap resistors therebetween. The electrodes have inner portions that are separated by junctions. The touch sensor also includes insulating regions between the touch region and the resistor chain. The insulating regions are separated by gaps to provide a plurality of conductive pathways to the touch region, thereby minimizing non-linear ripple along the sourcing sides of the substrate. Some of the gaps are junction gaps that are formed between the touch region and junctions. Electrically conductive islands are placed within the junction gaps to provide an electrical node within each junction gap, thereby preventing bunching of equipotential lines within the junction, and minimizing non-linear ripple along the non-sourcing sides of the substrate.

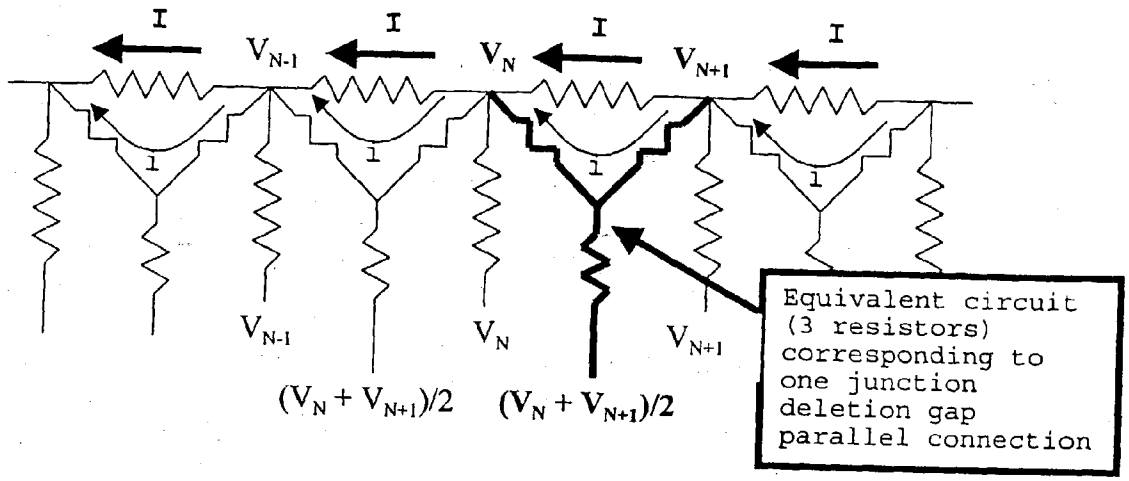
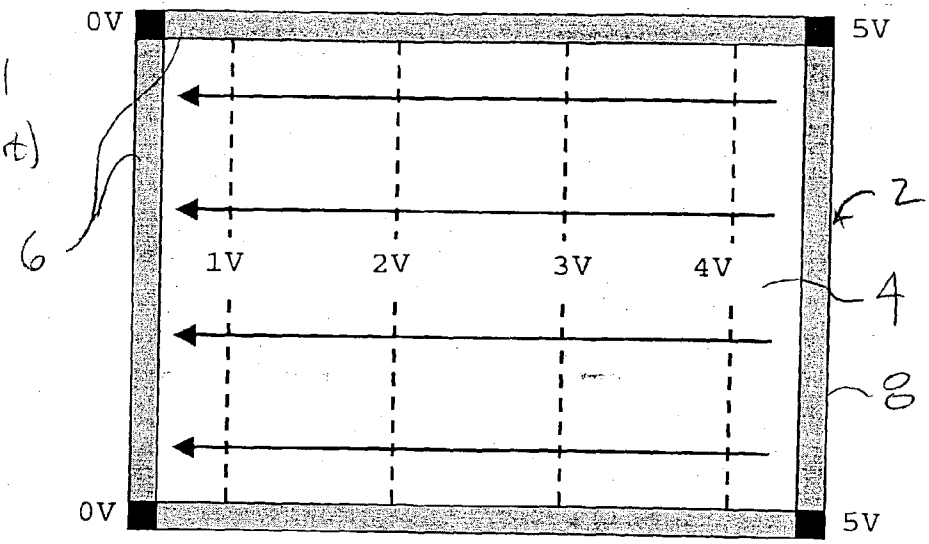
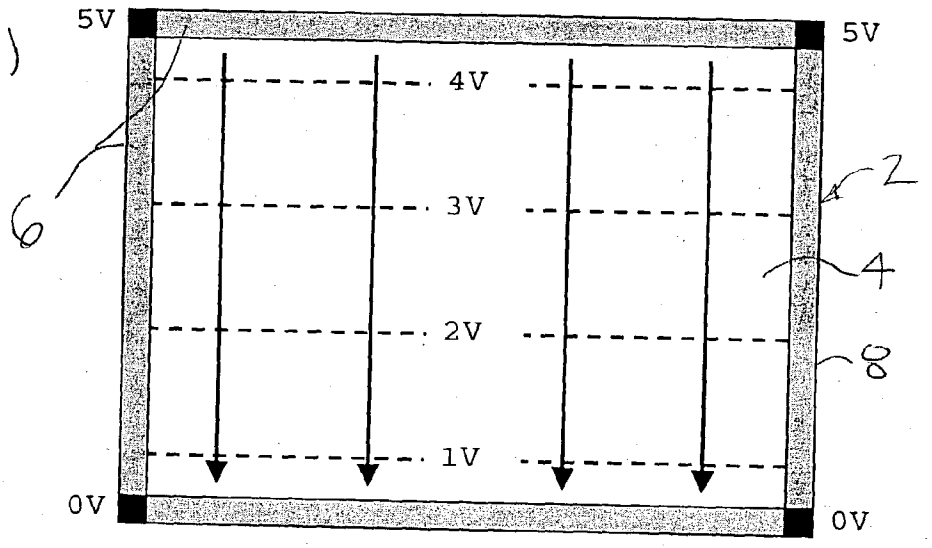


Fig. 1
(Prior Art)



X excitation:
Left & right sides "sourcing" (or sinking)
top and bottom "non-sourcing".

Fig. 2
(Prior Art)



Y excitation:
Top & bottom "sourcing" (or sinking)
Left & right "non-sourcing".

FIG. 4

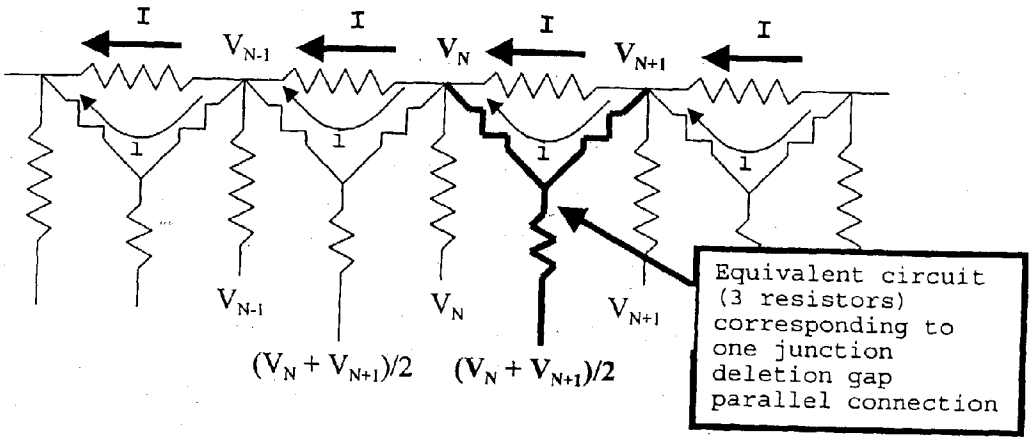
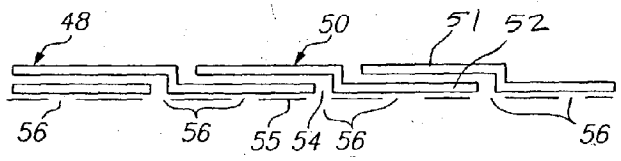

I
I
I
I
V_{N-1}
V_N
V_{N+1}
1
1
1
1
V_{N-1}
V_N
V_{N+1}
$(V_N + V_{N+1})/2$
$(V_N + V_{N+1})/2$
Equivalent circuit (3 resistors) corresponding to one junction deletion gap parallel connection

FIG. 3


48
50
51
52
56
56
55
54
56
56

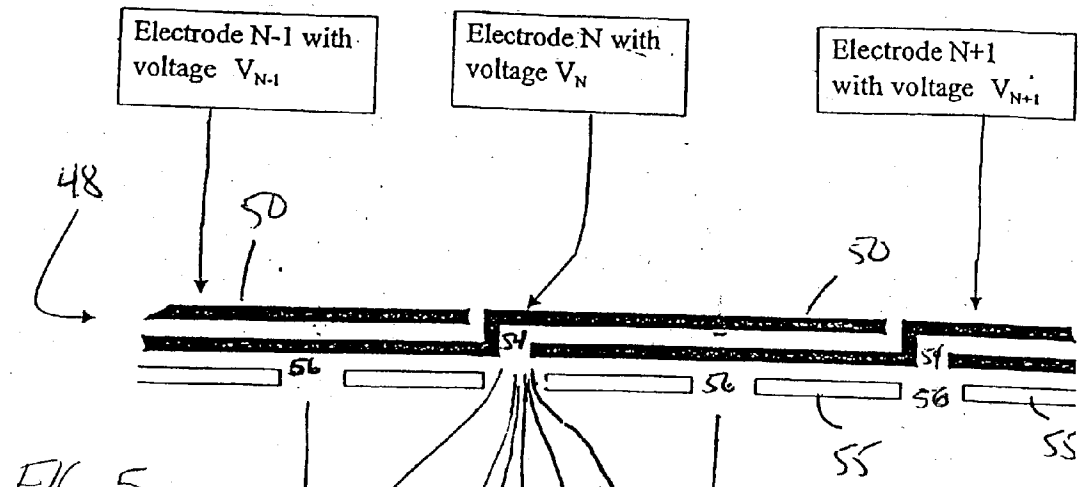

Electrode N-1 with voltage V_{N-1}
Electrode N with voltage V_N
Electrode N+1 with voltage V_{N+1}
48
50
52
54
56
55

FIG. 5

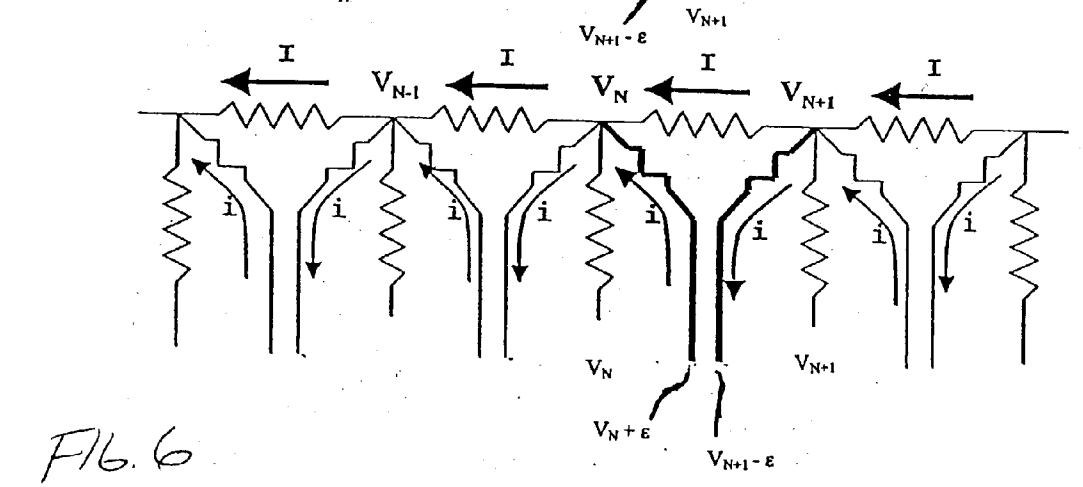

V_N
$V_N+\varepsilon$
$V_{N+1}-\varepsilon$
V_{N+1}
I
V_{N-1}
V_N
V_{N+1}
i

FIG. 6

Fig. 7

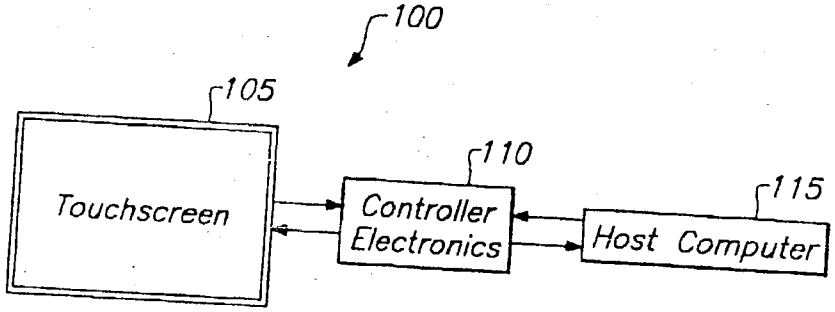
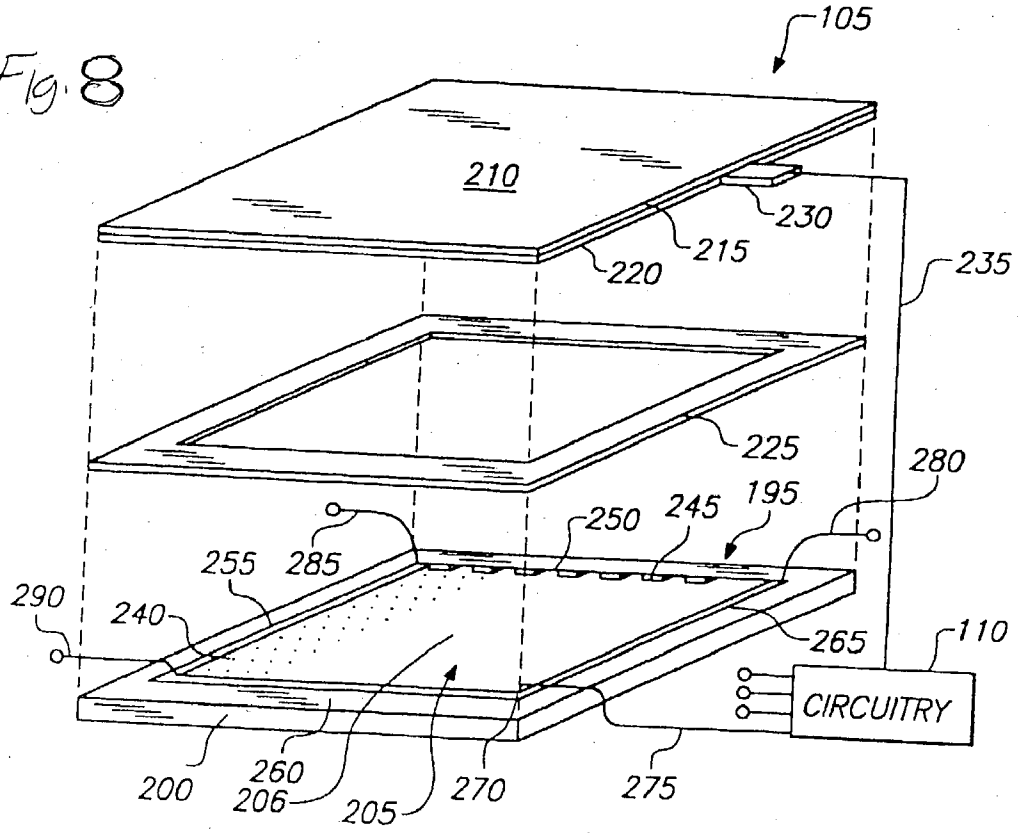

100
105
Touchscreen
110
Controller Electronics
115
Host Computer

Fig. 8


105
210
230
215
220
235
225
280
195
250
245
255
285
290
240
265
110
CIRCUITRY
200
260
206
205
270
275

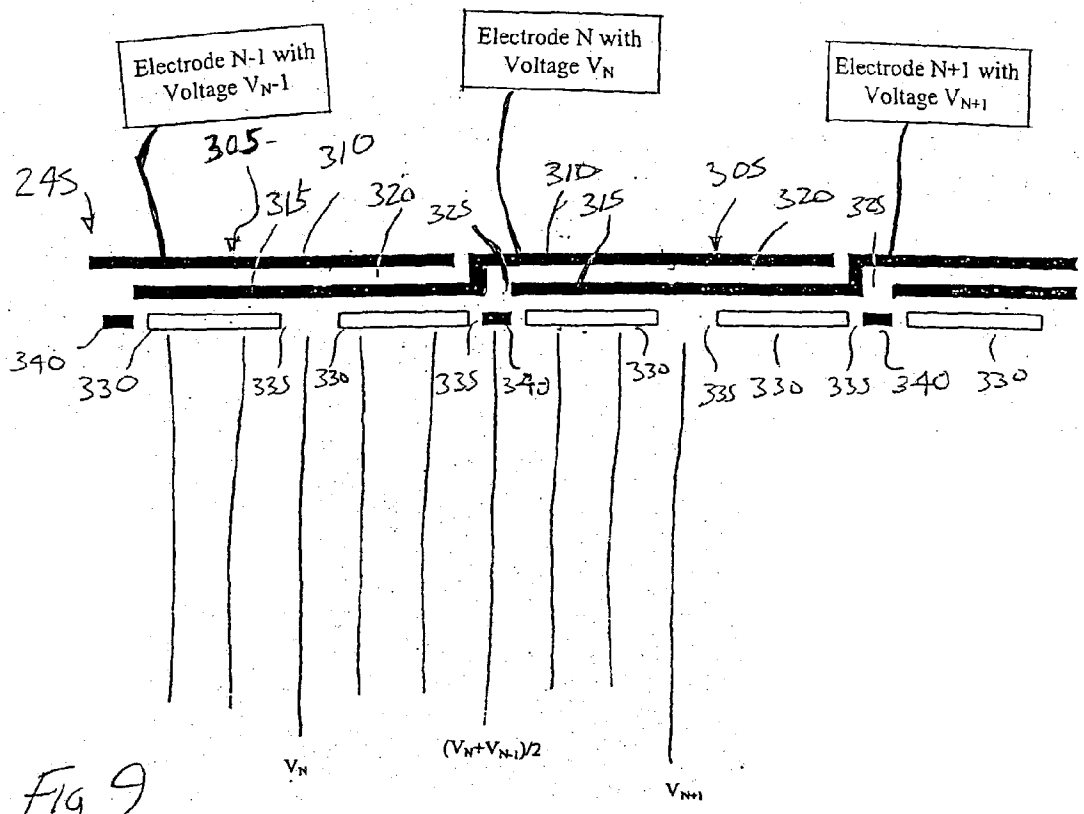

Electrode N-1 with Voltage V_{N-1}
Electrode N with Voltage V_N
Electrode N+1 with Voltage V_{N+1}
245
305
310
315
320
325
330
335
340
V_N
$(V_N+V_{N-1})/2$
V_{N+1}

Fig. 9

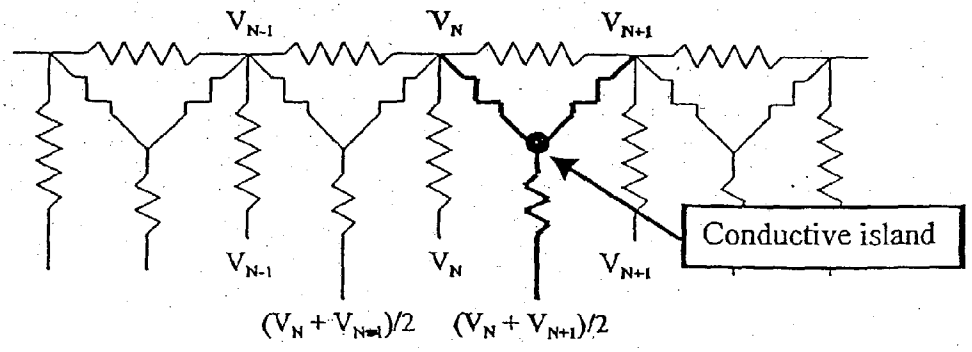
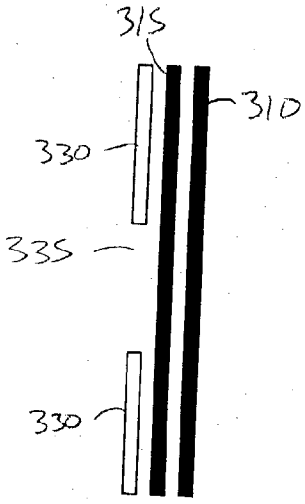

V_{N-1}
V_N
V_{N+1}
Conductive island
$(V_N + V_{N-1})/2$
$(V_N + V_{N+1})/2$

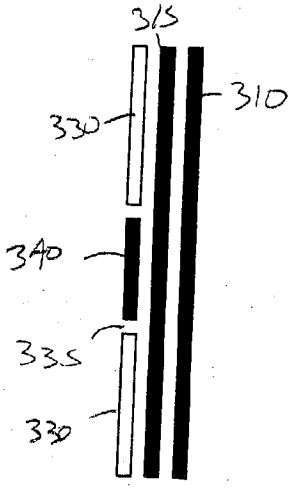
Fig. 10

Fig. 11a



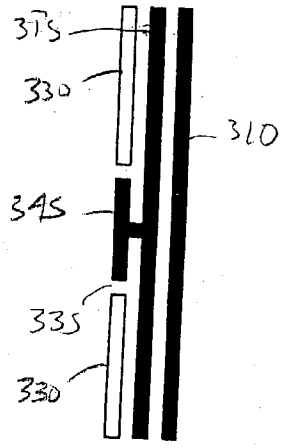
Empty gap

Fig. 11b



With conductive island

Fig. 11c



With overlap-resistor electrode extension

FIG. 12

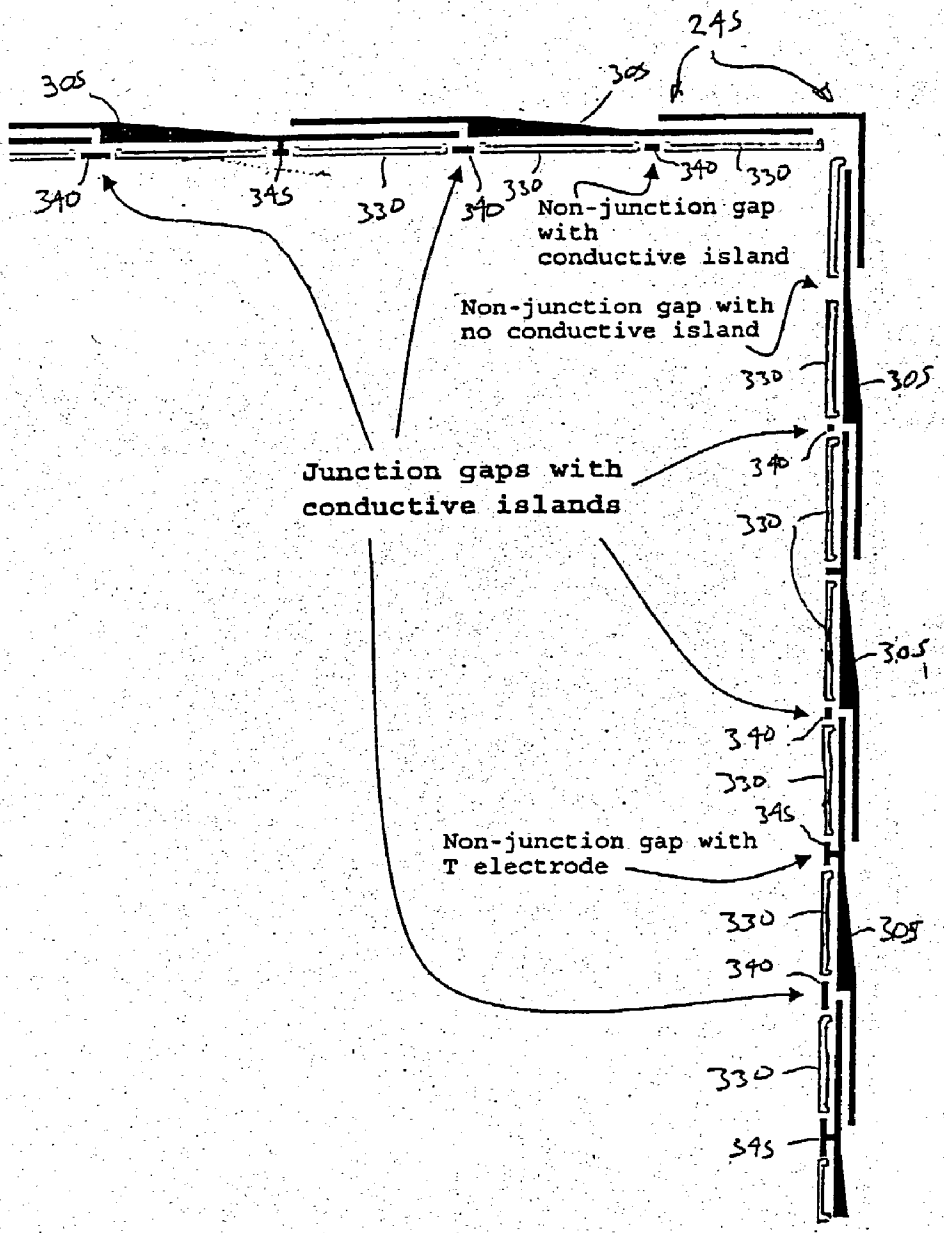
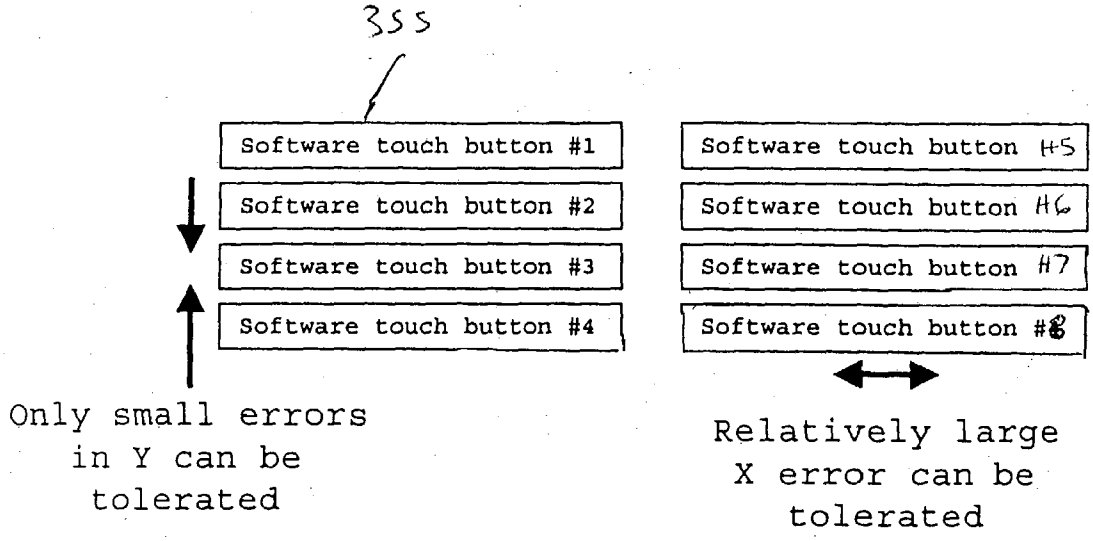

245
305
305
340
345
330
340
330
340
330
Non-junction gap with conductive island
Non-junction gap with no conductive island
330
305
Junction gaps with conductive islands
340
330
305
340
330
345
Non-junction gap with T electrode
330
305
340
330
345

FIG. 13


355
Software touch button #1
Software touch button #2
Software touch button #3
Software touch button #4
Software touch button #5
Software touch button #6
Software touch button #7
Software touch button #8
Only small errors in Y can be tolerated
Relatively large X error can be tolerated

TOUCH SENSOR WITH IMPROVED ELECTRODE PATTERN

RELATED APPLICATIONS

[0001] This application claims the benefit of the filing date of U.S. Provisional Patent Application Ser. No. 60/373,022, filed Apr. 16, 2002, and entitled "Touchscreen Having A Series Resistor Chain On The Periphery Of A Touch Area," which is expressly incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The field of the present invention relates to touch sensor technology, and more particularly to resistive and capacitive touch sensor technology.

BACKGROUND OF THE INVENTION

[0003] Touch sensors are transparent or opaque input devices for computers and other electronic systems. As the name suggests, touch sensors are activated by touch, either from a user's finger, or a stylus or some other device. Transparent touch sensors, and specifically touchscreens, are generally placed over display devices, such as cathode ray tube (CRT) monitors and liquid crystal displays, to create touch display systems. These systems are increasingly used in commercial applications such as restaurant order entry systems, industrial process control applications, interactive museum exhibits, public information kiosks, pagers, cellular phones, personal digital assistants, and video games.

[0004] The dominant touch technologies presently in use are resistive, capacitive, infrared, and acoustic technologies. Touchscreens incorporating these technologies have delivered high standards of performance at competitive prices. All are transparent devices that respond to a touch by transmitting the touch position coordinates to a host computer. An important aspect of touchscreen performance is a close correspondence between true and measured touch positions at all locations within a touch sensitive area located on the touch sensor (i.e., the touch region).

[0005] One type of resistive touchscreen, and specifically a 5-wire resistive touchscreen, e.g., the AccuTouch™ product line of Elo TouchSystems, Inc. of Fremont, Calif., has been widely accepted for many touchscreen applications. In these touchscreens, mechanical pressure from a finger or stylus causes a plastic membrane coversheet to flex and make physical contact with an underlying glass substrate. The glass substrate is coated with a resistive layer upon which voltage gradients are excited via electrode patterns that are disposed along the periphery of the substrate. Via electrical connections to the four corners of the coated glass substrate, associated electronics can sequentially excite gradients in both the X and Y directions, as described in U.S. Pat. No. 3,591,718. The underside of the coversheet has a conductive coating that provides electrical continuity between the touch location and voltage sensing electronics. Further details regarding 5-wire resistive touchscreens are found in U.S. Pat. Nos. 4,220,815, 4,661,655, 4,731,508, 4,822,957, 5,045,644, and 5,220,136.

[0006] In a typical 5-wire resistive touchscreen, an electrode pattern along each border of the substrate is operated in both a "sourcing" mode and a "non-sourcing" mode. For example, **FIGS. 1 and 2** illustrate a touch screen substrate **2** in which respective X and Y excitations are produced on a touch region **4** by applying different corner voltages (in this case, 5 volts) to an electrode pattern **6** extending along the periphery **8** of the substrate **2**. The arrows represent the direction of current flow across the touch region **4**, and the dotted lines represent equipotential lines, i.e., lines along which the voltage is constant. For ideal linear touchscreen performance, the equipotential lines are perfectly straight lines, as suggested in **FIGS. 1 and 2**. Current flows perpendicular to these equipotential lines, so lines of current flow are straight when the equipotential lines are straight.

[0007] As shown in **FIG. 1**, an X excitation is generated by passing current through the touch region **4** injected at the right side of the border electrode pattern **6** and collected at the left side. That is, the left and right sides are in "sourcing" (or sinking) mode for the X excitation. Ideally, for X excitation, no current enters or exits the touch region **4** from the top and bottom sides. That is the top and bottom sides are "non-sourcing" for the X excitation.

[0008] As shown in **FIG. 2, a** Y excitation is generated by passing current through the touch region **4** injected at the top side of the border electrode pattern **6** and collected at the bottom side. That is, the top and bottom sides are in "sourcing" (or sinking) mode for the Y excitation. Ideally, for Y excitation, no current enters or exits the touch region **4** from the left and right sides. That is, the left and right sides are "non-sourcing" for the Y excitation. Electronics can obtain touch information from a 5-wire resistive touchscreen via the voltage excitation described above, as well as current injection and capacitive architectures. A 9-wire connection scheme, which provides drive and a sense line connections between the electronics and each of the four corner connection points, is also available. These and other technologies are described in U.S. patent application Ser. No. 09/705,383, which is expressly incorporated herein by reference.

[0009] One 5-wire connection touch sensor utilizes peripheral electrode patterns with discrete overlap resistors, such as those found in Elo TouchSystems' AccuTouch™ products and disclosed in U.S. Pat. No. 5,045,644, which is expressly incorporated herein by reference. In this case, parallel resistive current paths are provided through gaps within isolation lines between peripheral electrode patterns on opposite sides of the touch region. The current paths produce an undesirable ripple non-linearity in the touch region near the peripheral electrode pattern. As a result, a finger moving across a straight line in this region will experience variations in the excitation voltage and hence variations in the measured coordinate (unless otherwise corrected for). The considerable ripple adjacent to the top and bottom resistor chains limits the accuracy of measurements in this area, and thus, the size of the effective touch region is therefore reduced.

[0010] As a result, resistor chains have been designed to reduce the ripple often found at the periphery of the touch region. U.S. patent application Ser. No. 09/705,383 discloses an approach that reduces the ripple non-linearity on the sourcing sides of the touchscreen substrate by increasing the density of discrete electrical connections between the electrode border and the touch region, i.e., the number of gaps within the isolation lines are increased.

[0011] A problem arises in that while increasing the density of discrete electrical connections between the electrode

border and the touch region improves linearity on the source sides, it provides more opportunities for parasitic sourcing and sinking of current on the non-sourcing sides. A higher density of electrical connections on the non-sourcing side tends to make matters worse. In particular, if there are more connections for the touch region than there are electrode voltages, then it is hard to avoid pairs of connections to the same electrode voltage and the consequent distortion of the desired linear voltage gradient. In practice, great linearity improvement on the sourcing sides is provided with a modest decrease in linearity on the non-sourcing sides. While this may appear to be quite a reasonable engineering trade-off, the marketplace is wary of anything that degrades any aspect of touchscreen performance.

[0012] This problem was conceptually addressed in U.S. patent application Ser. No. 09/705,383 by locating some of these gaps over the junctions between the electrodes, so that the effective voltage within these gaps is halfway between the voltages of adjacent electrodes. For example, **FIG. 3** shows a resistor chain **48** having Z-electrodes **50** with overlapping outer and inner portions **51**, **52**, the inner portions **52** of adjacent electrodes being closest at junctions **54**. An array of insulating regions **55** having two gaps **56** for each overlap resistor electrode **50** runs parallel to the inner portions **52**. Some of the gaps **56** are over the junctions **54**. As shown in the equivalent circuit of **FIG. 4**, this conceptually results in alternating connections being split between two adjacent electrodes **50**, so that the effective voltage is halfway between the voltages of the adjacent electrodes **50**, thereby decreasing the ripple on the non-sourcing sides of the touchscreen. The main current through the series resistor chain in non-sourcing mode is notated by the "I", while a secondary current "i" flows through the junction gap region, which is conceptually equivalent to a simple resistive voltage divider circuit composed of two equal resistances. Thus, as can be seen, the gap voltage sequence is V_{N-1}, $(V_{N-1}+V_N)/2$, $(V_N+V_{N+1})/2$, V_{N+1} . . .

[0013] It has been determined, however, that the effective voltage between adjacent electrodes **50** does not divide in practice. The insulating regions **55** are typically placed very close to the series resistor chain electrodes **50** in response to marketplace demand for minimal border width. The result is a gap width that is typically much bigger than the separation from the series resistor chain electrodes **50**. With such an aspect ratio, there is insufficient room for the electrode voltages V_N and V_{N+1} to mix together and present an averaged voltage $(V_N+V_{N+1})/2$ to the touchscreen. Effectively, the equipotential lines of the touch region "see" both electrode voltages. Hence, the V_N and V_{N+1} equipotential lines tend to terminate on the electrodes **50**, and all the equipotential lines in between V_N and V_{N+1} bunch up at the junction **54**, as illustrated in **FIG. 5**. As such, the resistor chain **48** of **FIG. 3** will, in practice, have the equivalent circuit illustrated in **FIG. 6**.

[0014] There thus remains a need to improve the non-sourcing side linearity of touchscreens with discrete resistor structures.

SUMMARY OF THE INVENTION

[0015] The present inventions are directed to a touch sensor that utilizes electrically conductive islands in junction gaps in order to provide a true voltage divider within the gaps, thereby providing a linearly varying voltage sequence along the resistor chain. The touch sensor can be operated as a resistive touch sensor, e.g., 5- or 9-wire, a capacitive touch sensor, or any touch sensor that requires series resistive chains.

[0016] The touch sensor comprises a substrate having a resistive surface bounded by a plurality of peripheral edges. The substrate may be transparent in the case of a touchscreen, or otherwise may be opaque. The resistive surface has a touch region that is interior to the peripheral edges. The touch sensor further comprises a series resistor chain proximate a peripheral edge for creating electric fields across the touch region. The resistor chain comprises a plurality of conductive electrodes (e.g., Z-electrodes) arranged in series with resistive regions of the surface forming overlap resistors therebetween. Each electrode has an inner portion facing the touch region, with the inner portions of adjacent electrodes being separated by junctions.

[0017] The touch sensor further comprises a linear array of insulating regions in the resistive surface (areas where the resistive layer is not present) between the touch region and the resistor chain. The insulating regions are separated by gaps, e.g., areas where the resistive surface is fully left intact. At least two of the gaps are formed between the touch region and an inner portion, and one of the gaps forms a junction gap between the touch region and a junction. In the preferred embodiment, junction gaps are formed between the touch region and junctions between at least one of the inner portions.

[0018] The touch sensor further comprises a conductive island located within the junction gap. In this manner, a voltage divider is formed within the junction gap, thereby minimizing bunching of equipotential lines on the electrodes during the non-sourcing mode. In the preferred embodiment, a conductive island is located within a plurality of the junction gaps to provide maximum benefit. To provide varying resistance between different gaps, e.g., a parabolic varying resistance along the length of the resistor chain, the non-junction gaps can be variously designed. For example, to provide maximum resistance, a non-junction gap may be empty, i.e., it contains no electrically conductive material. To provide minimum resistance, the non-junction gap may contain an extension from the inner portion of the electrode. To provide a resistance somewhere in between, the non-junction gap may contain a conductive island.

[0019] The present inventions are also directed to a touch sensor that utilizes various types of gaps to control the resistance values of the gaps. The touch sensor may be similarly constructed as described above. At least two of the gaps (which can be junction and/or non-junction gaps), however, are selected from different ones of an empty gap, an island gap having an electrically conductive island, and an electrode gap having an electrically conductive extension from one of the inner portions. For example, two of the gaps can be an empty gap and an island gap, an empty gap and an electrode gap, or an island gap and an electrode gap. In the case of three gaps, a first one can be an empty gap, a second one can be an island gap, and a third one can be an electrode gap.

[0020] In this manner, the gaps can be substantially the same width, yet have substantially different resistances. For example, the gaps along one peripheral electrode can have

parabolic varying resistances. Or the gaps can have substantially different widths, yet have substantially the same resistances.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The drawings illustrate the design and utility of a preferred embodiment of the present invention, in which similar elements are referred to by common reference numerals. In order to better appreciate the advantages and objects of the present invention, reference should be made to the accompanying drawings that illustrate this preferred embodiment. However, the drawings depict only one embodiment of the invention, and should not be taken as limiting its scope. With this caveat, the invention will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

[0022] **FIG. 1** is a plan view of a prior art touchscreen being operated to provide X-excitation signals, so that the left and right sides are in the sourcing mode, and the top and bottom sides are in the non-sourcing mode;

[0023] **FIG. 2** is a plan view of a prior art touchscreen being operated to provide Y-excitation signals, so that the left and right sides are in the non-sourcing mode, and the top and bottom sides are in the sourcing mode;

[0024] **FIG. 3** is a schematic of a series resistor chain having two gaps (one junction and one non-junction) per overlap resistor electrode;

[0025] **FIG. 4** is an equivalent circuit for the resistor chain of **FIG. 3**;

[0026] **FIG. 5** is a schematic of a portion of the series resistor chain of **FIG. 3**, particularly showing equipotential lines non-linearly terminating on the resistor chain when operated in the non-sourcing mode;

[0027] **FIG. 6** is a practical equivalent circuit for the resistor chain of **FIG. 3**, particularly showing current flow and voltage potential;

[0028] **FIG. 7** is a functional diagram of a touch system constructed in accordance with a preferred embodiment of the present inventions;

[0029] **FIG. 8** is an exploded view of a touchscreen used in the touch system of **FIG. 7**;

[0030] **FIG. 9** is a schematic of a series resistor chain used in the touchscreen of **FIG. 7**;

[0031] **FIG. 10** is an equivalent circuit for resistor chain of **FIG. 9**;

[0032] **FIGS. 11***a-c* are schematics of different types of gap arrangements that can be used in the series resistor chain of **FIG. 9**;

[0033] **FIG. 12** is a plan view of the top right corner of a gradient sheet used in the touchscreen of **FIG. 7**; and

[0034] **FIG. 13** is a plan view of a display, particularly showing software touch buttons that require having asymmetric positional accuracy requirements in the X- and Y-directions.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0035] Referring to **FIG. 7, a** resistive touchscreen system **100** constructed in accordance with a preferred embodiment of the present invention is described. The touchscreen system **100** generally comprises a touchscreen **105** (i.e., a touch sensor having a transparent substrate), controller electronics **110**, and a display **120**. The touchscreen system **100** is typically coupled to a host computer **115**. Generally, the controller electronics **110** receives from the touchscreen **105** analog signals carrying touch information. The controller electronics **110** also sends to the touchscreen **105** excitation signals. Specifically, the controller electronics **110** establishes a voltage gradient across the touchscreen **105**. The voltages at the point of contact are representative of the position touched. The controller electronics **110** digitizes these voltages and transmits these digitized signals, or touch information in digital form based on these digitized signals, to the host computer **115** for processing.

[0036] Referring to **FIG. 8**, the touchscreen **105** will now be described in further detail. It will be recognized that the thickness, height, or other dimensions of some of the components in some of the drawings has been exaggerated for purposes of illustration. The touchscreen **105** comprises a gradient sheet **195** including a substrate **200** having a uniform resistive layer **205** permanently applied to one surface thereof. The resistive layer **205** further includes a touch region **206**.

[0037] The geometry of the substrate **200** may be, for example, planar (as shown in **FIG. 8**), or may be contoured to match the face of a curved object, such as a Cathode Ray Tube (CRT) face or other conventional video display screens. The substrate **200** can also have any perimeter configuration, e.g., rectangular (as shown), substantially rectangular, or circular.

[0038] To provide the necessary transparency, the substrate **200** and resistive layer **205** are preferably made of a substantially transparent material. Alternatively, if the resultant product is to be an opaque sensor, then the substrate **200** may be composed of an opaque material. Spaced a small distance above the resistive layer **205** is a cover sheet **210**, which is typically a flexible film **215** having a conductive coating **220** on the underside of the flexible film **215**. The cover sheet **210** is joined to the remainder of the touchscreen **105** with an adhesive along its associated edges, or optionally, with an insulative adhesive frame **225** or the like. Additionally, an electrode **230** connects the conductive coating **220** of the cover sheet **210** via lead **235** to appropriate external circuitry, such as the controller circuit **110**. The conductive coating **220** attached to the cover sheet **210** is separated from the resistive layer **205** by a plurality of small transparent insulator islands or dots **240**, which prevent accidental contact between the conductive coating **220** and the resistive layer **205**.

[0039] While the embodiment depicted in **FIG. 8** utilizes the cover sheet **210**, any conducting element, such as a conducting stylus (not shown), can be used as an alternative. This conducting stylus may be used when the resistive layer **205** is sufficiently durable as to withstand damage from such contact. As another alternative, a capacitive or resistive pickup system can be used along with a user's finger or with an appropriate probe.

[0040] With continuing reference to **FIG. 8, a** resistor chain **245** is spaced along each edge of the resistive layer **205** and is used for applying potentials to the resistive layer **205**, so as to create orthogonal voltage gradients therein. As to be shown in subsequent figures, the resistor chain **245** (composed of conductive regions, insulating regions, and resistive regions) includes discrete resistance units connected in series. The resistance values of the resistor chain **245** depend partly upon the resistive value of the resistive layer **205** that forms part of the resistor chain **245**. However, the resistance values of the resistor chain **245** may vary in accordance with design requirements. There are four resistor chains **245** in the embodiment of **FIG. 8**, which are more specifically labeled **250**, **255**, **260**, and **265**. The ends of each resistor chain **250**, **255**, **260** or **265** are joined at or near the corners **270** of the resistive layer **205**. Each of the corners **270** is provided with a respective one of the electrical leads **275**, **280**, **285**, **290**. In this manner, the touchscreen **105** is connected to the controller electronics **110**, which provides the voltage to the resistor chain **245** and processes information from the touchscreen **105**.

[0041] When the touchscreen **105** is pressed, the conductive coating **220** of the cover sheet **210** makes direct electrical contact with the resistive layer **205** on the substrate **200**. For a quasi-DC resistive touchscreen, commonly referred to as a "resistive touchscreen," the cover sheet **210** can function as either a voltage sensing probe for sensing the voltage at the contacted area, or as a current injection source. As another option, the coversheet **210** may be replaced with a thin dielectric coating applied directly to resistive layer **205**, in which case, the controller electronics **110** may support AC operation.

[0042] Further details on the general construction of touch screen system **100** is disclosed in U.S. Pat. No. 6,163,313, which is expressly incorporated herein by reference.

[0043] Referring now to **FIG. 9, a** portion of the resistor chain **245** will now be described in further detail. The resistor chain **245** has Z-shaped electrodes **305**, each having an outer portion **310** and an inner portion **315**. The inner portion **315** of a first electrode **305** overlaps the outer portion **310** of a second, adjacent electrode **305**. As a result, the resistive layer **205** (shown in **FIG. 8**) between these inner and outer portions forms a resistive connection **320**. The inner portions **315** of adjacent electrodes **305** are separated from each other by junctions **325**. A plurality of insulating regions **330** are formed in the gradient sheet **195** (shown in **FIG. 8**), for example, by removing the resistive layer **205** at selected places. Thereafter, areas of resistive coating **205** remain between adjacent insulating regions **330**, referred to herein as "gaps"**335**. Some of the gaps **335** are positioned between the inner portions **315** of the electrodes **305** and the touch region **206** (referred to as "non-junction gaps") and some of the gaps **335** are positioned between the junctions **325** and the touch region **206** (referred to as "junction gaps").

[0044] The insulating regions **330** and gaps **335** may also be formed by removing a line of the resistive layer **205** (an insulation line) and thereafter placing resistive material, such as ITO, on the sheet at selected places along the insulation line. In the illustrated embodiment, the insulating regions **330** and gaps **335** are formed in a line parallel to the inner portions **315** of the electrodes **305**. As a result, a plurality of parallel current paths across the touch region **206** are established. The insulating regions **330** may be readily formed by laser ablation of the resistive layer **205**. Insulating subsections extending between the electrodes **305** may also be formed. Laser adjustment of these subsections effectively trims the resistors between the electrodes **305**.

[0045] In order to achieve the object of a true voltage divider at the junction **325** between adjacent electrodes **305**, a conductive region or "island"**340** is positioned within the junction gaps **335**. The conductive material may be, e.g., a conductive frit. As a result, the V_N equipotential line in the touch region **206** no longer "sees" the electrode with voltage V_N through the junction gap **335**, because the conductive island **340** cleanly provides the electronic node for the desired equivalent circuit, as illustrated in **FIG. 10**.

[0046] Simulations and prototype touchscreens have shown that the use of conductive islands **340** within the junction gaps **335** not only avoids increased ripple nonlinearity on the non-sourcing side, but in fact, compared to existing commercial products with one electrical connection per overlap-resistor electrode, linearity on the non-sourcing side is improved. The reason for this improvement can be appreciated in **FIG. 9**, which illustrates equipotential lines of the touch region **206** as they approach the electrode border. Because a conducting region is at a constant voltage, at most one equipotential line can terminate on a conductive electrode **305** or conducting island **340**. In contrast, many equipotential lines may terminate on a insulating region **330**. Loosely speaking, conducting regions connected to the touch region through the gaps **335**"repel" equipotential lines. The wider the gap is, the larger the distortion of the equipotential lines, and hence the greater is the ripple nonlinearity. Replacing a large gap with a conductive island surrounded by two smaller gaps can provide a significant net gain in non-sourcing ripple non-linearity.

[0047] Thus, minimizing gap widths minimizes the amount of non-sourcing ripple non-linearity. It should be noted, however, that wider gaps are preferred for minimizing sourcing ripple non-linearity. As a result, it is best to avoid too much variation in gap widths. This desire to avoid unnecessary variation in gap widths, however, competes with another design requirement. As is well known in the prior art, a linear touchscreen design requires a parabolic variation in resistance of the connections between the touch region and the resistor chain series. As such, it is preferred that the gap widths, at least in the prior art, vary.

[0048] Given this, the resistor chain **245** preferably employs a variety of gap designs. Specifically, the resistor chain **245** comprises three different types of gap designs: an empty gap; a gap with a conductive island **340**; and a gap with an electrode extension of an overlap-resistor electrode **305** (e.g., a "T"). These three types are illustrated in **FIGS. 1***a-c*. Even if the gaps are all the same width, as illustrated in **FIGS. 11***a-c*, the three different gap designs provide different resistances between the resistor chain **245** and the touch region **206**. The empty gap illustrated in **FIG. 11***a* has the higher resistance, and a "T" shaped electrode extension **345** illustrated in **FIG. 11***c* provides the lowest resistance. Alternatively, for the same resistance to the touch region **206**, the empty gap will be wider and the "T" shaped electrode extension **345** will be narrower. Using this design degree of freedom to provide, in part, the desired parabolic

resistance variations, has the beneficial result of reducing the needed variation in gap widths to some extent, thereby improving linearity. This flexibility also helps avoid tolerance issues involving the screen-printing of extremely small conductive islands **340** and gaps **335**.

[**0049**] As illustrated in **FIG. 12**, the resistor chain **245**, in addition to using conductive islands **340** within the junction gaps **335**, also uses the different types of gap designs illustrated in **FIGS. 11***a-c* within the non-junction gaps **335** to provide the necessary parabolic resistance variation. Although it is generally desirable to use conductive islands **340** within the junction gaps **335** in order to improve ripple linearity along the non-sourcing side as previously discussed, it is sometimes desirable to use empty gap designs (**FIG. 11***a*) for the junction gaps **335**. For example, in cases where a high resistance is desired, such as at the gaps **335** adjacent the corners, it may be advantageous to use the empty gap design in combination with a relatively narrow gap through which there is less of a problem of the touch region **206**"seeing" the unmixed voltages of the pair of electrodes **305** through the junction gap **335**.

[**0050**] It should be noted that in some applications, it may be desirable to fully optimize the linearity of one coordinate at the expense of increased border ripple nonlinearity in the other coordinate, e.g., when there exists an application that has unequal demands for X and Y linearity. For example, consider **FIG. 13**, which illustrates an exemplary display of software touch buttons **355** that one may see when viewing the display of the touchscreen system **100**. As can be seen, the touch buttons **355** are much wider than they are tall. Thus, for the user to correctly activate the intended touch button **355**, the touchscreen system **100** must correctly determine the Y-coordinate with small errors, but only roughly determine the X-coordinate.

[**0051**] As previously discussed, for Y-coordinate measurement, the left and right sides of the electrode border are non-sourcing and the top and bottom sides are sourcing. For such an application, it may be advantageous to use gaps **335** with conductive islands **340** on the left and right sides of the electrode border, and then to use more than two gaps per electrode on the top and bottom sides of the electrode border. Such a design leads to increased ripple non-linearity along the top and bottom for the X-coordinate measurement, but this is of secondary importance for applications, such as that illustrated in **FIG. 13**.

[**0052**] Although the above discussion has been set forth in the context of a resistive touchscreen system **100**, it applies to the more general setting of a touch-sensitive system. This includes other types of touch sensors (e.g., opaque touch pads or touch sensitive robot shells). A variety of sensors with sensitive surfaces can be imagined. Indeed, the resistive touchscreen system **100** is really just a specific type of a touch sensitive system, where the gradient sheet **195** and cover sheet **210** are specifically designed to operate in the touchscreen **105**. Thus, the present discussion, in its broadest aspects, should be thought of as applying in that more general setting.

[**0053**] Although particular embodiments of the present invention have been shown and described, it should be understood that the above discussion is not intended to limit the present invention to these embodiments. Those of ordinary skill in the art will appreciate that various changes and modifications may be made without departing from the spirit and scope of the present invention. Thus, the present invention is intended to cover alternatives, modifications, and equivalents that may fall within the spirit and scope of the present invention as defined by the claims.

What is claimed is:

1. A touch sensor, comprising:

a substrate having a resistive surface bounded by a plurality of peripheral edges, said resistive surface having a touch region interior to said edges;

a series resistor chain proximate a peripheral edge for creating electric fields across said touch region, said resistor chain comprising a plurality of conductive electrodes arranged in series with resistive regions of said surface to form overlap resistors therebetween, each electrode having an inner portion facing said touch region, said inner portions of adjacent electrodes being separated by junctions;

a linear array of insulating regions in said resistive surface between said touch region and said resistor chain, said insulating regions being separated by gaps, at least one of said gaps formed between said touch region and at least one junction; and

an electrically conductive island located within said at least one junction gap.

2. The touch sensor of claim 1, wherein two gaps are formed between said touch region and two adjacent inner portions, and said at least one junction gap is between said two gaps.

3. The touch sensor of claim 1, wherein said substrate is substantially transparent.

4. The touch sensor of claim 1, wherein non-junction gaps are formed between said touch region and at least a majority of said inner portions.

5. The touch sensor of claim 1, wherein junction gaps are formed between said touch region and at least a majority of said junctions.

6. The touch sensor of claim 1, further comprising an electrically conductive island located within at least a plurality of said junction gaps.

7. The touch sensor of claim 1, wherein said resistive surface is fully intact within said gaps.

8. The touch sensor of claim 1, wherein said insulating regions run parallel to said resistor chain.

9. The touch sensor of claim 1, wherein said array of insulating regions is a line where said resistive surface has been removed, said line being parallel to said resistor chain.

10. The touch sensor of claim 1, wherein the electric fields are non-linear.

11. The touch sensor of claim 1, further comprising a dielectric coating disposed over said touch region.

12. A touch sensor, comprising:

a substrate having a resistive surface at least partially bounded by a pair of opposing peripheral edges, said resistive surface having a touch region interior to said edges;

a series resistor chain proximate each peripheral edge for creating electric fields across said touch region, each resistor chain comprising a plurality of conductive electrodes arranged in series with resistive regions of said surface to form overlap resistors therebetween,

each electrode having an inner portion facing said touch region, said inner portions of adjacent electrodes being separated by junctions;

a linear array of insulating regions in said resistive surface adjacent each resistor chain between said touch region and said respective resistor chain, said insulating regions being separated by gaps, said gaps including junction gaps between said touch region and said junctions; and

an electrically conductive island located within at least one of said junction gaps.

13. The touch sensor of claim 12, wherein at least two gaps are formed between said touch region and at least two adjacent inner portions, and said at least one junction gap is between said at least two gaps.

14. The touch sensor of claim 12, further comprising an electrically conductive island located within at least a plurality of said junction gaps.

15. The touch sensor of claim 12, wherein said resistive surface is fully intact within said gaps.

16. The touch sensor of claim 12, wherein said arrays of insulating regions are lines where said resistive surface has been removed, said lines being parallel to said respective resistor chains.

17. The touch sensor of claim 12, wherein a plurality of conductive paths per overlap resistor is formed between said touch region and said respective resistor chain.

18. The touch sensor of claim 12, wherein the electric fields are non-linear.

19. The touch sensor of claim 12, further comprising a dielectric coating disposed over said touch region.

20. The touch sensor of claim 12, wherein at least one non-junction gap has no electrically conductive element, at least one non-junction gap has an electrically conductive island, and at least one non-junction gap has an electrode extending from an inner portion of an adjacent electrode.

21. The touch sensor of claim 12, wherein said resistive surface is bounded by another pair of opposing peripheral edges, said touch region interior to said other pair of opposing peripheral edges, the touch sensor comprising:

another series resistor chain proximate each of said other pair of peripheral edges for creating electric fields across said touch region, each other resistor chain comprising another plurality of conductive electrodes arranged in series with resistive regions of said surface to form overlap resistors therebetween, each other electrode having another inner portion facing said touch region, said other inner portions of adjacent electrodes being separated by junctions;

another linear array of insulating regions in said resistive surface adjacent each other resistor chain between said touch region and said respective resistor chain, said other insulating regions being separated by gaps, the number of said gaps equaling at least twice the number of overlap resistors in the other resistor chains.

22. The touch sensor of claim 21, wherein said peripheral edges terminate at four corners.

23. The touch sensor of claim 21, wherein the linear array of insulating regions has approximately two gaps per overlap resistor, and the other linear array of insulating regions has approximately three or more gaps per overlap resistor.

24. A touch sensor, comprising:

a substrate having a resistive surface bounded by a plurality of peripheral edges, said resistive surface having a touch region interior to said edges;

a series resistor chain proximate a peripheral edge for creating electric fields across said touch region, said resistor chain comprising a plurality of conductive electrodes arranged in series with resistive regions of said surface to form overlap resistors therebetween, each electrode having an inner portion facing said touch region, said inner portions of adjacent electrodes being separated by junctions;

a linear array of insulating regions in said resistive surface between said touch region and said resistor chain, said insulating regions being separated by gaps, wherein at least two of said gaps are selected from different ones of an empty gap, an island gap having an electrically conductive island, and an electrode gap having an electrically conductive extension from one of said inner portions.

25. The touch sensor of claim 24, wherein said at least two of said gaps are respectively said empty gap and said island gap.

26. The touch sensor of claim 24, wherein said at least two of said gaps are respectively said empty gap and said electrode gap.

27. The touch sensor of claim 24, wherein said at least two of said gaps are respectively said island gap and said electrode gap.

28. The touch sensor of claim 24, wherein said at least two of said gaps comprises three gaps, a first of which is said empty gap, a second of which is said island gap, and a third of which is said electrode gap.

29. The touch sensor of claim 24, wherein said at least two gaps are adjacent to each other.

30. The touch sensor of claim 24, wherein said at least two gaps form junction gaps between said touch region and respective junctions.

31. The touch sensor of claim 24, wherein said at least two gaps form non-junction gaps between said touch region and respective inner portions.

32. The touch sensor of claim 24, wherein said at least two gaps have substantially the same width and substantially different resistances.

33. The touch sensor of claim 24, wherein said at least two gaps have substantially different widths and substantially the same resistances.

34. The touch sensor of claim 24, wherein said gaps have parabolic varying resistances.

35. The touch sensor of claim 24, wherein said resistive surface is fully intact within said gaps.

36. The touch sensor of claim 24, wherein said insulating regions run parallel to said resistor chain.

37. The touch sensor of claim 24, wherein said array of insulating regions is a line where said resistive surface has been removed, said line being parallel to said resistor chain.

38. The touch sensor of claim 24, wherein each of said electrodes is a Z-shaped electrode.

39. The touch sensor of claim 24, wherein the electric fields are non-linear.

40. The touch sensor of claim 24, further comprising a cover sheet having an electrically conductive coating to provide electrical coupling to said touch region.

41. The touch sensor of claim 24, further comprising a dielectric coating disposed over said touch region.

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