charging all electrodes to a second potential and measuring an extent of charge for some of the sub-circuits, which may be the same or different from those charged to the first potential.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] 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:

[0015] **FIG. 1A** is a schematic diagram of a capacitive touchscreen of the present invention.

[0016] **FIG. 1B** shows a cross-sectional view of a capacitive touchscreen shown in **FIG. 1A** along line H1.

[0017] **FIG. 2** is a circuit layout for a controller for a capacitive sensor of the present invention.

[0018] **FIG. 3** is a circuit layout for an electronic circuit for use in a touchscreen system including a touchscreen sensor, including a configuration that allows data from either a universal serial bus connector or an RS232 serial connector to be transmitted to a microcontroller.

DETAILED DESCRIPTION OF THE INVENTION

[0019] Referring to **FIGS. 1A and 1B**, the present invention provides a capacitive touchscreen sensor **1** having a surface **2**, multiple electrodes **3**, a resistive layer **4** and a control circuit **5** which includes a circuit **13** for charging the resistive layer **4** and sensing capacitance. As shown in **FIG. 1B**, the sensor is comprised of a stack of layers, with a substrate **12** (e.g., glass) and a transparent resistive layer **4** (e.g., ITO) to which the electrodes **3** are attached at the corners **9**. A thin dielectric layer **18** is on top of the resistive layer **4**, and a touch is made to the sensor by a finger or grounded stylus **14**, forming a capacitance between the resistive layer **4** and a ground for the finger or stylus. In some embodiments, an additional conductive layer **19** is added to the bottom of the substrate as a guard electrode. The control circuit **5** comprises multiple input/output channels **6** that are connected to the screen. The electrodes are located around a periphery **7** of a sensing region **8** of the sensor and preferably the electrodes are located at corners **9** of the resistive layer. In a preferred embodiment, the resistive layer is substantially planar having four sides and four corners, and has four electrodes connected to it. Each electrode is electrically connected (e.g., with a wire **10**) to a corresponding input/output channel **6** and charging and capacitive sensing sub-circuit **11**. Preferably there are four sub-circuits. If the resistive layer is charged to a potential, and a user's finger then touches the surface of the sensor, the capacitance is changed, and the change in capacitance can be sensed by the sub-circuits. By using signals output from the sub-circuits, coordinates indicating the position of the touch can be determined.

[0020] **FIG. 2** illustrates a first set of a plurality of switching elements (**20***a,* **20***b,* **20***c,* **20***d*), each element having an open (nonconducting) state and a closed (conducting) state and including a control input; a second set of a plurality of switching elements (**22***a,* **22***b,* **22***c,* **22***d*), each element having an open (nonconducting) state and a closed (conducting) state and including a control input; a plurality of charge detectors (**24***a,* **24***b,* **24***c,* **24***d*) such as operational amplifiers; a third set of a plurality of switching elements (**26***a,* **26***b,* **26***c,* **26***d*), each element having an open (nonconducting) state and a closed (conducting) state and including a control input; a plurality of energy storage elements (**28***a,* **28***b,* **28***c,* **28***d*) which may be, for example, capacitors; an analog multiplexer **30**; a single bus buffer (3 state) **32**; a plurality of operational amplifiers (**34***a,* **34***b,* **34***c,* **34***d,* **36**); an analog to digital converter (ADC) **38**; a digital potentiometer **40**; and a plurality of series-connected Schottky diode pairs **42**, **44**, **46**, **48**, and **50**.

[0021] Referring to **FIG. 2**, the present invention provides a circuit having five input/output channels (L, X, S, H, Y). Four of the five input/output channels connect an electrode to a corresponding sub-circuit (**52***a,* **52***b,* **52***c,* **52***d*), wherein each sub-circuit includes a charging and a capacitive sensing portion. Each sub-circuit **52** comprises a first switching element **20**, a first energy storage element **28**, such as a capacitor connected to ground, a second switching element **22**, and a charge detector **24**. The outputs of each of the charge detectors **24** are connected to a multiplexer **30**, that is in turn connected to an analog to digital converter **38** which then outputs signals which are further processed to provide information back to a computer. Each switching element has two states, one open (nonconducting) and one closed (conducting), and has a control input. Examples of switching elements that can be used are transistors. In a first state, the first switching element in each sub-circuit is in a closed state and connects its associated electrode to a capacitor (which is in turn connected to ground) while the second switching element is in an open state. In a second state, the second switching element in each sub-circuit is in a closed state and connects the capacitor to a charge detector while the first switching element is in an open state. Examples of charge detectors include operational amplifiers having a reference input.

[0022] The invention includes a method in which the electrodes are charged to a specified potential (e.g., +2.5V) relative to a reference (e.g., ground or a virtual ground set to some voltage, e.g., +2.5V) using a voltage source, preferably by sending short current pulses (e.g., having duration of about 1 microsecond). Preferably all electrodes are charged simultaneously. Once an electrode has reached the specified potential, the first switching element **20***a* of the corresponding sub-circuit **52***a* is closed while at the same time the second switching element **22***a* in the same sub-circuit is opened. A touch to the sensor provides a path to ground, so that the voltage on the electrodes can partially discharge through the first energy storage element **28***a.* The degree to which the energy storage element **28***a* in each sub-circuit is discharged will depend on the location of the touch on the touch sensitive area of the sensor. The first switching element **20***a* of the sub-circuit is subsequently opened and the second switching element **22***a* is closed after a desired time (e.g., 1 microsecond). With the sub-circuit in this configuration, current is supplied back to the first energy storage element **28***a* and the current that is used to recharge the