A method for measuring for generating a touch capacitance measurement is provided. Gain and offset control signals are generated, where the gain and offset control signals (VG, VOS) are adjusted to compensate for base capacitance of a touch sensor (202). The gain control signal (VG) is applied to a touch sensor (202) during a first phase of a clock signal (CLK1), and the offset control signal (VOS) is applied to an output circuit (209) during a second phase of the clock signal. The output circuit (209) is coupled to the touch sensor (202) during the second phase of the clock signal. The touch capacitance measurement is generated by compensating for the base capacitance with the gain and offset control signals, and a gain is applied to the touch capacitance measurement.
— before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))
TOUCH SENSING METHOD AND APPARATUS

[0001] This relates generally to a capacitive touch sensors and, more particularly, to sensing small changes in capacitive touch sensors.

BACKGROUND

[0002] Capacitive touch sensors (such as touch buttons) are increasing used in human interface devices. These touch sensors usually have a base capacitance and function based on detection of an increase in the base capacitance due to the presence of a dielectric (i.e., finger) in proximity to the sensor. With some touch sensors, this change or variation in base capacitance (which can be referred to as the touch capacitance) can be as small as 0.5%. This means that, if a 10-bit successive approximation register (SAR) analog-to-digital converter (ADC) is employed to digitize the measurement, the touch capacitance measurement may be limited to approximately the 5 least significant bits. Thus, there is a high susceptibility to error due to noise. Additionally, the base capacitance can drift over time, which can create further errors. Therefore, there is a need for an improved touch controller that can accurately measure small touch capacitances.


SUMMARY

[0004] An embodiment provides an apparatus. The apparatus comprises an interface that is configure to communicate with a touch sensor having a base capacitance; and an capacitance-to-voltage converter that receives a clock signal and that is coupled to the interface, wherein the capacitance-to-voltage converter generates gain control and offset signals, and wherein the capacitance-to-voltage converter is configured to apply the gain control signals to the touch sensor during a first phase of the clock signal, and the gain and offset control signals are adjusted
to compensate for the base capacitance, and wherein the capacitance-to-voltage converter uses the gain and offset control signals during a second phase of the clock signal to compensate for the base capacitance and provide a touch capacitance measurement.

[0005] In accordance with an embodiment, the output circuit includes a capacitor that is configured to be adjustable.

[0006] In accordance with an embodiment, the capacitance-to-voltage converter further comprises: a gain control circuit that is coupled to the interface and that receives the clock signal; an output circuit that is coupled to the gain control circuit, wherein the output circuit includes the capacitor; and an offset control circuit that is coupled to the output circuit and that receives the clock signal.

[0007] In accordance with an embodiment, the gain control circuit further comprises: a first transmission gate that is coupled between the interface and the output circuit and that is activated during the second phase of the clock signal; a second transmission gate that is coupled to the interface and that is activated during the first phase of the clock signal; and a digital-to-analog converter (DAC) that is coupled to the second transmission gate and that generates the gain control signal.

[0008] In accordance with an embodiment, the DAC further comprises a first DAC, and wherein the gain control circuit further comprises: a second DAC that generates the offset control signal; a third transmission gate that is coupled between the second DAC and the output circuit and that is activated during the second phase of the clock signal; and a fourth transmission gate that is coupled to the output circuit and that is activated during the first phase of the clock signal.

[0009] In accordance with an embodiment, the clock signal further comprises a first clock signal, and wherein the capacitor further comprises a first capacitor, and wherein the output circuit further comprises: a second capacitor that is coupled to the third and fourth transmission gates; an amplifier having a first input terminal, a second input terminal, and an output terminal, wherein the first input terminal of the amplifier is coupled to the second capacitor and the first transmission gate, and wherein the first capacitor is coupled between the first input terminal of the amplifier and the output terminal of the amplifier, and wherein the second input terminal of the amplifier receives a common mode voltage; and a fifth transmission
gate that is controlled by the second clock signal and that is coupled between the first input terminal of the amplifier and the output terminal of the amplifier.

[0010] In accordance with an embodiment, an apparatus is provided. The apparatus comprises a touch panel having a plurality of touch sensors, wherein each touch sensor has a base capacitance; a touch panel controller having: an interface that is coupled to each touch sensor; a capacitance-to-voltage converter having: a gain control circuit that is coupled to the interface and that receives a clock signal, wherein the gain control circuit generates a gain control signal, and wherein the gain control circuit is configured to apply the gain control signal to a selected touch sensor from the plurality of touch sensors during a first phase of the clock signal; an output circuit that is coupled to the gain control circuit, wherein the output circuit is configured to be coupled to the touch sensor during a second phase of the clock signal; and an offset control circuit that is coupled to the output circuit and that receives the clock signal, wherein the offset control circuit generates an offset control signal, and wherein the offset control circuit applies the offset control signal to the output circuit during the second phase of the clock signal, and wherein the gain and offset control signals are adjusted to compensate for the base capacitance of the selected touch sensor.

[0011] In accordance with an embodiment, the capacitor further comprises a first capacitor, and wherein the output circuit further comprises: a second capacitor that is coupled to the offset control circuit; and an amplifier having a first input terminal, a second input terminal, and a output terminal, wherein the first input terminal of the amplifier is coupled to the second capacitor and the gain control circuit, and wherein the first capacitor is coupled between the first input terminal of the amplifier and the output terminal of the amplifier, and wherein the second input terminal of the amplifier receives a common mode voltage.

[0012] In accordance with an embodiment, the clock signal further comprises a first clock signal, and wherein the output circuit further comprises a first transmission gate that is controlled by the second clock signal and that is coupled between the first input terminal of the amplifier and the output terminal of the amplifier.

[0013] In accordance with an embodiment, the gain control circuit further comprises: a DAC that generates the offset control signal; a second transmission gate that is coupled between the DAC and the second capacitor and that is activated during the second phase of the clock
signal; and a third transmission gate that is coupled to the second capacitor and that is activated during the first phase of the clock signal.

[0014] In accordance with an embodiment, the DAC further comprises a first DAC, and wherein the gain control circuit further comprises: a fourth transmission gate that is coupled between the interface and the first input terminal of the amplifier and that is activated during the second phase of the clock signal; a fifth transmission gate that is coupled to the interface and that is activated during the first phase of the clock signal; and a second DAC that is coupled to the second transmission gate and that generates the gain control signal.

[0015] In accordance with an embodiment, the touch panel controller further comprises: an analog-to-digital converter (ADC) that is coupled to the output terminal of the amplifier; a digital front end (DFE) that is coupled to the ADC; and control logic that is coupled to the DFE, the first and second DACs, and the first, second, third, fourth, and fifth transmission gates.

[0016] In accordance with an embodiment, the ADC is a successive approximation register (SAR) ADC.

[0017] In accordance with an embodiment, the DFE provides noise cancellation using correlated double sampling (CDS).

[0018] In accordance with an embodiment, a method is provided. The method comprises generating gain and offset control signals, wherein the gain and offset control signals are adjusted to compensate for base capacitance of a touch sensor; applying the gain control signal to a touch sensor during a first phase of a clock signal; applying the offset control signal to an output circuit during a second phase of the clock signal; coupling the output circuit to the touch sensor during the second phase of the clock signal; compensating for the base capacitance with the gain and offset control signals to generate a touch capacitance measurement; and applying a gain to the touch capacitance measurement.

[0019] In accordance with an embodiment, the step of applying the gain control signal further comprises coupling a DAC to the touch sensor during the first phase of the clock signal.

[0020] In accordance with an embodiment, the method further comprises converting the touch measurement with the applied gain to a digital signal.

[0021] In accordance with an embodiment, the method further comprises performing a CDS operation on the digital signal to compensate for noise.
BRIEF DESCRIPTION OF THE DRAWINGS

[0022] FIG. 1 is a diagram of an example of a system in accordance with an embodiment;

[0023] FIG. 2 is a diagram of a detailed example of a portion of the analog front end (AFE) and a touch sensor for the system of FIG. 1; and

[0024] FIG. 3 is a diagram of an example of the operation of the AFE and touch sensor of FIG. 2.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

[0025] FIG. 1 illustrates a system 100 in accordance with an example embodiment. As shown, the system 100 generally comprises a touch panel 102 and a touch panel controller 104. The touch panel 102 generally comprises one or more touch sensors (such as touch buttons) arranged in a variety of ways (i.e., an array or line), and the touch panel controller 104 generally comprises an interface or I/F 106, an AFE 108, a digital front end (DFE) 110, host controller 112, and control logic 114.

[0026] In operation, the touch panel controller 114 is able to detect touch events on the touch panel 106. To accomplish this, the touch panel controller 104 is able to "scan through" or select various touch sensors on the touch panel 102. The scanning or selection is normally accomplished with the interface 106 (which may include a multiplexer) so as to allow an appropriate or selected touch sensor to be coupled to the AFE 108. Once coupled to the selected touch sensor through the interface 106, the AFE 108 determines whether a touch event with the selected touch sensor has occurred with the use of control signals (i.e., clock signal) provided by the control logic 114. The AFE 108 is able to digitize a measurement for the touch event (which should be a measurement of the touch capacitance) for the DFE 110. The DFE 110 (which also can receive control signals from the control logic 114) can then perform error correction on the digitized measurement as well as other operations for the host controller 112.

[0027] Performing the measurement of the touch capacitance, however, can be difficult, but the AFE 108 (which is shown in greater detail in FIG. 2) is able to perform this measurement with relative ease. As shown in the example in FIG. 2, one of the touch sensors 202 from the touch panel 102 is coupled to the capacitance-to-voltage converter 203 of AFE 108 through interface 106, and this touch sensor 202 is shown to formed of two capacitors $C_B$ and $AC_B$ (which represent the base capacitance and touch capacitance, respectively). The AFE 108 is generally comprised of a gain control circuit 205, offset control circuit 207, and output circuit
209. The gain and offset control circuits 205 and 207 generally receive a clock signal \( \overline{CLK1} \) and inverse clock signal \( CLK1 \) from control logic 114, while output circuit 209 receives a clock signal \( CLK2 \) and inverse clock signal \( \overline{CLK2} \) from control logic 114. These signals \( CLK1, \overline{CLK1},CLK2, \) and \( \overline{CLK2} \) are used by the transmission gates 206-1 to 206-5 such that transmission gates 206-2 and 206-4 are open when clock signal \( CLK1 \) is logic high (i.e., one phase of clock signal \( CLK1 \)), transmission gates 206-1 and 206-3 are open when clock signal \( CLK1 \) is logic low (i.e., another phase of clock signal \( CLK1 \)), and transmission gate 206-5 is open when clock signal \( CLK2 \) is logic high. With this configuration, digital-to-analog converter (DAC) 204-2 (which is controlled by the control logic 114) is able to provide a gain control signal \( V_G \) to the touch sensor 202 during one phase of clock signal \( CLK1 \) (i.e., when \( CLK1 \) is logic high), while reference voltage \( REF \) is applied to the capacitor \( Cos \) during this same phase. This allows the capacitors \( C_B, AC_B, \) and \( Cos \) to be charged. Then, during another phase of clock signal \( CLK1 \) (i.e., when clock signal \( CLK1 \) is logic low), the capacitors \( C_B \) and \( AC_B \) are coupled to the amplifier 208 (preferably at its inverting terminal), and the offset control signal \( Vos \) is applied to capacitor \( Cos \) from DAC 204-1. Additionally, the amplifier 208 receives a common mode voltage \( V_{CM} \) (preferably at its non-inverting terminal). Amplifier 208, with the use of capacitor \( C_F \) (which is adjustable) and transmission gate 206-5, apply a gain and generate an output signal \( VOUT \) (which corresponds to an amplified measurement of the touch capacitance or the capacitance for capacitor \( AC_B \)) for ADC 210 (which can, for example, be a 10-bit SAR ADC).

Typically, as shown in FIG. 3, the gain and offset control signals \( V_G \) and \( Vos \) are modulated signals that are adjusted to compensate for the base capacitance. Typically, these signals \( V_G \) and \( Vos \) can be represented as:

1. \( V_G = A \cdot V_G + V_{CM} \); and
2. \( V_{OS} = A \cdot V_{OS} + V_{CM} \).

As shown in the pre-calibration phase (i.e., prior to the adjustment of the gain and offset control signals \( V_G \) and \( Vos \)), the offset control signal \( Vos \) is set to the common mode voltage \( V_{CM} \), which results in the output signal \( VOUT \) being:

3. \( V_{OUT} = \frac{\Delta V_G}{C_F} \cdot C_B + V_{CM} \).
Additionally, when the offset voltage $V_{os}$ is applied in the post-calibration phase, the output signal $V_{out}$ is:

$$V_{OUT} = \frac{\Delta V_G}{C_F} C_B - \frac{\Delta V_{os}}{C_F} C_{os} + V_{CM}.$$  

Since, the output voltage $V_{OUT}$ for the pre-calibration phase (as shown in equation (3)) is a function of the capacitance of capacitor $C_B$. System 100 (i.e., host controller 112 or control logic 114) can adjust the offset control signal $V_{os}$ such that:

$$\frac{\Delta V_G}{C_B} C_B = \frac{\Delta V_{os}}{C_F} C_{os} \Rightarrow \Delta V_{os} = \frac{C_B}{C_{os}} \Delta V_G.$$  

This results in the output signal $V_{OUT}$ being approximately equal to the common mode voltage $V_{CM}$ when the capacitance of capacitor $ACB$ is approximately zero so as to, effectively, "cancel out" the capacitance of capacitor $C_B$. When the capacitance of capacitor $ACB$ is non-zero (i.e., when a touch event occurs), the output signal $V_{OUT}$ is:

$$V_{OUT} = \frac{\Delta V_G}{C_F} (C_B + \Delta C_B) - \frac{\Delta V_{os}}{C_F} C_{os} + V_{CM}$$

$$= \left[ \frac{\Delta V_G}{C_F} C_B - \frac{\Delta V_{os}}{C_F} C_{os} \right] + \frac{\Delta V_G}{C_F} \Delta C_B + V_{CM} = \frac{\Delta V_G}{C_F} \Delta C_B + V_{CM},$$

which is a function of the capacitance of capacitor $ACB$. Thus, once calibrated, capacitance-to-voltage converter 203 is able to accurately measure the touch capacitance or capacitance of capacitor $ACB$. Additionally, as indicated by equation (6), the capacitor $C_F$ can operate as a gain control element to boost sensitivity.

With an accurate measurement of the touch capacitance, DFE 110 can perform a correlated double sampling (CDS) operation in the post-calibration phase to compensate for other noise (i.e., 60-cycle noise) in the system 100. During the CDS period indicated in FIG. 3, a CDS output during a touch event in the presence of touch conduction noise coupling can be expressed as:

$$V_0 UF(T_1) = \frac{\Delta V_G}{C_F} \frac{V_{uf}(T_1)}{\Delta C_B} + V_{CM};$$
\[ V_{OUT}(T_2) = -\frac{\Delta V_G + V_n(T_2)}{C_F} \Delta C_B + V_{CM}; \]

such that

\[ \Delta V_{OUT,CDS} = V_{OUT}(T_1) - V_{OUT}(T_2) \]

\[ = 2\frac{\Delta V_G}{C_F} \Delta C_B + \frac{\Delta C_B}{C_F} (V_n(T_1) - V_n(T_2)). \]

As can be seen from equation (9), the noise component is \( V_n(T_1) - V_n(T_2) \), so, by increasing the sampling period (i.e., \( T_s = T_1 - T_2 \)), the noise can be made very small.

[0030] Those skilled in the art will appreciate that modifications may be made to the described example embodiments, and also that many other embodiments are possible, within the scope of the claimed invention.
1. An apparatus comprising:

   an interface that is configured to communicate with a touch sensor having a base capacitance; and

   a capacitance-to-voltage converter that receives a clock signal and that is coupled to the interface;

   wherein the capacitance-to-voltage converter generates gain control and offset signals;

   wherein the capacitance-to-voltage converter is configured to apply the gain control signals to the touch sensor during a first phase of the clock signal, and the gain and offset control signals are adjusted to compensate for the base capacitance; and wherein the capacitance-to-voltage converter uses the gain and offset control signals during a second phase of the clock signal to compensate for the base capacitance and provide a touch capacitance measurement.

2. The apparatus of Claim 1, wherein the output circuit includes a capacitor that is configured to be adjustable.

3. The apparatus of Claim 2, wherein the capacitance-to-voltage converter further comprises:

   a gain control circuit that is coupled to the interface and that receives the clock signal;

   an output circuit that is coupled to the gain control circuit, wherein the output circuit includes the capacitor; and

   an offset control circuit that is coupled to the output circuit and that receives the clock signal.

4. The apparatus of Claim 3, wherein the gain control circuit further comprises:

   a first transmission gate that is coupled between the interface and the output circuit and that is activated during the second phase of the clock signal;

   a second transmission gate that is coupled to the interface and that is activated during the first phase of the clock signal; and
a digital-to-analog converter (DAC) that is coupled to the second transmission gate and that generates the gain control signal.

5. The apparatus of Claim 4, wherein the DAC further comprises a first DAC, and wherein the gain control circuit further comprises:

- a second DAC that generates the offset control signal;
- a third transmission gate that is coupled between the second DAC and the output circuit and that is activated during the second phase of the clock signal; and
- a fourth transmission gate that is coupled to the output circuit and that is activated during the first phase of the clock signal.

6. The apparatus of Claim 5, wherein the clock signal further comprises a first clock signal, and wherein the capacitor further comprises a first capacitor, and wherein the output circuit further comprises:

- a second capacitor that is coupled to the third and fourth transmission gates;
- an amplifier having a first input terminal, a second input terminal, and an output terminal, wherein the first input terminal of the amplifier is coupled to the second capacitor and the first transmission gate, and wherein the first capacitor is coupled between the first input terminal of the amplifier and the output terminal of the amplifier, and wherein the second input terminal of the amplifier receives a common mode voltage; and
- a fifth transmission gate that is controlled by the second clock signal and that is coupled between the first input terminal of the amplifier and the output terminal of the amplifier.

7. An apparatus comprising:

- a touch panel having a plurality of touch sensors, wherein each touch sensor has a base capacitance;
- a touch panel controller having:
  - an interface that is coupled to each touch sensor;
- a capacitance-to-voltage converter having:
  - a gain control circuit that is coupled to the interface and that receives a clock signal, wherein the gain control circuit generates a gain control signal, and wherein the gain control
circuit is configured to apply the gain control signal to a selected touch sensor from the plurality of touch sensors during a first phase of the clock signal;

an output circuit that is coupled to the gain control circuit, wherein the output circuit is configured to be coupled to the touch sensor during a second phase of the clock signal; and

an offset control circuit that is coupled to the output circuit and that receives the clock signal, wherein the offset control circuit generates an offset control signal, and wherein the offset control circuit applies the offset control signal to the output circuit during the second phase of the clock signal, and wherein the gain and offset control signals are adjusted to compensate for the base capacitance of the selected touch sensor.

8. The apparatus of Claim 7, wherein the output circuit includes a capacitor that is configured to be adjustable.

9. The apparatus of Claim 5, wherein the capacitor further comprises a first capacitor, and wherein the output circuit further comprises:

a second capacitor that is coupled to the offset control circuit; and

an amplifier having a first input terminal, a second input terminal, and a output terminal, wherein the first input terminal of the amplifier is coupled to the second capacitor and the gain control circuit, and wherein the first capacitor is coupled between the first input terminal of the amplifier and the output terminal of the amplifier, and wherein the second input terminal of the amplifier receives a common mode voltage.

10. The apparatus of Claim 5, wherein the clock signal further comprises a first clock signal, and wherein the output circuit further comprises a first transmission gate that is controlled by the second clock signal and that is coupled between the first input terminal of the amplifier and the output terminal of the amplifier.

11. The apparatus of Claim 10, wherein the gain control circuit further comprises:

a DAC that generates the offset control signal;

a second transmission gate that is coupled between the DAC and the second capacitor and that is activated during the second phase of the clock signal; and
a third transmission gate that is coupled to the second capacitor and that is activated during the first phase of the clock signal.

12. The apparatus of Claim 11, wherein the DAC further comprises a first DAC, and wherein the gain control circuit further comprises:

   a fourth transmission gate that is coupled between the interface and the first input terminal of the amplifier and that is activated during the second phase of the clock signal;

   a fifth transmission gate that is coupled to the interface and that is activated during the first phase of the clock signal; and

   a second DAC that is coupled to the second transmission gate and that generates the gain control signal.

13. The apparatus of Claim 12, wherein the touch panel controller further comprises:

   an analog-to-digital converter (ADC) that is coupled to the output terminal of the amplifier;

   a digital front end (DFE) that is coupled to the ADC; and

   control logic that is coupled to the DFE, the first and second DACs, and the first, second, third, fourth, and fifth transmission gates.

14. The apparatus of Claim 13, wherein the ADC is a successive approximation register (SAR) ADC.

15. The apparatus of Claim 14, wherein the DFE provides noise cancellation using correlated double sampling (CDS).

16. A method comprising:

   generating gain and offset control signals, wherein the gain and offset control signals are adjusted to compensate for base capacitance of a touch sensor;

   applying the gain control signal to a touch sensor during a first phase of a clock signal;

   applying the offset control signal to an output circuit during a second phase of the clock signal;
coupling the output circuit to the touch sensor during the second phase of the clock signal;
compensating for the base capacitance with the gain and offset control signals to generate a touch capacitance measurement; and
applying a gain to the touch capacitance measurement.

17. The method of Claim 16, wherein the step of applying the gain control signal further comprises coupling a DAC to the touch sensor during the first phase of the clock signal.

18. The method of Claim 17, wherein the method further comprises converting the touch measurement with the applied gain to a digital signal.

19. The method of claim 18, wherein the method further comprises performing a CDS operation on the digital signal to compensate for noise.
A. CLASSIFICATION OF SUBJECT MATTER

G06F 3/044(2006.01)i, G09G 3/20(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G06F 3/044; G06F 3/045; G06F 3/041

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic database consulted during the international search (name of database and, where practicable, search terms used)
ekOMPASS(KIPO internal) & Keywords: touch, capacitance, gain, offset, compensate, clock signal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>US 2009-0231286 AL (KUO CHUN-TING) 17 September 2009</td>
<td>1-3, 7, 8, 16</td>
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<td>A</td>
<td>See paragraphs [0010]-[0013] ; claim 1; and figure 2.</td>
<td>4-6, 9-15, 17-19</td>
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☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
  "A" document defining the general state of the art which is not considered to be of particular relevance
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Date of the actual completion of the international search


Date of mailing of the international search report


Name and mailing address of the ISA/KR

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Facsimile No. 82-42-472-7140

Authorized officer

LEE, Jung Suk

Telephone No. 82-42-481-5585

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