tion have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit the invention to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the scope of the invention as defined by the appended claims.

## DETAILED DESCRIPTION

**[0038]** In the following description of the illustrated embodiments, references are made to the accompanying drawings which form a part hereof, and various embodiments by which the invention may be practiced are shown by way of illustration. It is to be understood that other embodiments may be utilized, and structural and functional changes may be made without departing from the scope of the present invention.

**[0039]** As stated above, and for other reasons stated below which will become apparent upon reading the present specification, there is a need for a method and a system for accurately determining the location of a finger touch or an instrument touch on a touch surface. There exists a further need for such a method and system that calculates touch location with improved signal-to-noise ratio of the touch signal, and increases the accuracy of the touch location determination.

**[0040]** The present invention is applicable to touch sensing techniques and is believed to be particularly useful when features of the present invention are combined with a data processing system operating a display device enhanced by a transparent touch screen. For example, a touch screen of the present invention may be used in a desktop, handheld or laptop computer system, a point-of-sale terminal, personal data assistant (PDA), or a cell phone. Although described in combination with a microprocessor-based system, a touch screen device of the present invention may be combined with any logic-based system, if desired.

**[0041]** The present invention provides for the accurate determination of a touch location on a touch screen. A touch may be sensed by a number of touch sensors and represented by one or more touch signals. Accurate touch location determination involves measuring the magnitudes of one or more touch signals at a preferred time during a touch on a touch screen. The preferred time for making the touch location measurement may be ascertained by detecting a feature of a touch signal shape. The touch location measurement may be made at the preferred time in response to detection of the feature of the touch signal shape.

**[0042]** Conventional methods use a magnitude-based technique to measure the touch signal at the time the touch signal surpasses a fixed threshold magnitude. The threshold magnitude used in conventional methods is chosen to provide an acceptable signal-to-noise ratio, without regard to the level of touch-induced error present in the signal as it crosses at the particular threshold chosen. In contrast, a system and method of the present invention perform a touch location measurement at a particular time within the touch signal profile associated with lower touch signal error. Measurement of the touch signal at the particular time may result in higher signal to noise ratio due in large part to a decrease in touch signal error. The present system correlates the point of reduced touch signal error to a feature of the touch signal shape. Thus, the present system uses a shape-based approach for detecting the preferred time to make the touch location measurement. A touch signal shape may be characterized by as few as two points of the touch signal or by the entire set of points representing a touch signal. In one example, the slope of a touch signal is a touch signal shape that may be characterized by two points of the touch signal.

**[0043]** Touch signals representing the force of a touch acting on the touch screen are produced by one or more touch sensors coupled to a touch surface of the touch screen. A touch signal may be derived from a single sensor, or by combining sensor signals from two or more touch sensors. Determination of a touch location involves analyzing the sensor signals produced by the touch sensors. A tap touch in a single location characteristically produces a touch signal that increases in magnitude as the touch is applied and then decreases in magnitude as the touch is removed. A touch may be a continuing touch wherein the touch remains on the touch surface for a period of time. For example, the touch may be present in a single location for a period of time. Further, the touch may be a "streaming touch," wherein the touch is applied at one location, moved across the surface of the touch screen, and removed at another location, causing the generation of a continuously changing signal at each sensor.

**[0044]** A generalized diagram of a touch screen is illustrated in **FIG. 1**. A touch surface **100** is coupled to one or more touch sensors **110**, **120**, **130**, **140**. In the embodiment shown, the touch sensors **110**, **120**, **130**, **140** are arranged at four corners of a rectangular touch surface. Although the touch screen illustrated in **FIG. 1** is rectangular with sensors located at the corners, various configurations using three or more touch sensors with differing touch surface shapes may also be used.

**[0045]** The sensors **110**, **120**, **130**, **140**, may be, for example, small capacitive force sensors constructed of two capacitor plates separated by a gap. A capacitive force sensor may be arranged so that when a touch force of sufficient magnitude and direction is applied to the touch surface, one capacitor plate deflects towards the second plate. The deflection alters the distance between the capacitor plates, changing the capacitance of the sensor. The touch force may be measured by control system circuitry as a change in an alternating electrical signal applied to the touch sensor. One embodiment of a capacitive force sensor appropriate for use in touch screen applications is described in U.S. patent application, U.S. Ser. No. 09/835,040, filed Apr. 13, 2001, entitled "Method and Apparatus for Force-Based Touch Input," which is incorporated herein by reference. The force sensor is appropriate for use with a liquid crystal display (LCD), cathode ray tube (CRT) or other transparent display, and is schematically illustrated in **FIG. 2**. In this particular embodiment, the sensor measures the applied force based on the change of capacitance of a capacitive element.

**[0046]** A touch surface **210**, or overlay, is located within a structure or housing **215**. The touch surface **210** is typically transparent to allow viewing of a display or other object through the touch surface. In other applications, the touch surface **210** can be opaque.

**[0047]** The structure or housing **215** may be provided with a large central aperture through which the display may be viewed. If desired, the undersurface of the housing **215** may