[0032] **FIG. 3** is a cross sectional view of a second embodiment, in a typical application installation.

[0033] **FIG. 4** is a partially schematic cross-sectional view of a general touch-locating system, illustrating reduction of tangential force errors according to one embodiment of the invention.

[0034] **FIGS. 5A through 5C** provide partial cross sectional views illustrating the use of a flat suspension film or beam used as a lateral stiffening means.

[0035] **FIG. 6** is a partial cross sectional view of a lateral stiffening and/or lateral restraint means with extended range of vertical motion, and directionally selective lateral stiffening.

[0036] **FIGS. 7A through 7C** are partial cross sectional views of further variations on the lateral stiffening means.

[0037] **FIG. 8** is a partial cross sectional view of a touch system with a field-replaceable touch surface protector and liquid/dust seal.

[0038] **FIG. 9A** is a cross sectional view of a larger sensor of a type built in accordance with the invention.

[0039] **FIG. 9B** is an exploded perspective view of the sensor assembly of **FIG. 9A**.

[0040] **FIG. 10A** is a cross sectional view of a smaller sensor of a type built in accordance with the invention.

[0041] **FIG. 10B** is an exploded perspective view of the sensor assembly of **FIG. 10A**.

[0042] **FIG. 11** is a vertically exaggerated cross section of a sensor variation employing a nonuniform gap, built in accordance with one embodiment of the present invention.

[0043] **FIGS. 12A through 12D** are plan views depicting possible variations in the outline and mounting arrangement of principal elements of sensors according to embodiments of the invention.

[0044] **FIGS. 13A and 13B** are vertically exaggerated cross sections depicting possible variations in the thickness distribution of principal elements of sensors according to embodiments of the invention.

[0045] **FIG. 14A** is a plan view of a sensor variation employing a principal element with simply supported ends, according to embodiments of the invention.

[0046] **FIG. 14B** is a side view of the plastic spacer used in the sensor variation of **FIG. 14A**.

[0047] **FIG. 14C** is a partial cross-sectional view of a touch location device employing variations of aspects of the invention, including the sensor variation of **FIG. 14A**.

[0048] **FIGS. 15A and 15B** are exploded and cross-sectional views, respectively, of a sensor variation incorporating nonmetallic elastic portions, according to embodiments of the invention.

[0049] **FIG. 15C** is a cross-sectional view of a related sensor variation incorporating nonmetallic elastic portions, according to one embodiment of the invention.

DETAILED DESCRIPTION

[0050] In one of its aspects, the invention provides a novel capacitive force sensor. As described in more detail below, the sensor may be implemented with a small number of mechanical parts and a very small capacitive gap, making the sensor easy and inexpensive to manufacture and making the sensor widely applicable, but particularly so for use in mobile and handheld devices. The sensor comprises a principal element, and an essentially planar support. The principal element combines the functions of elastic energy storage and one capacitor plate, and may be as simple as a plane rectangle of thin spring metal. The principal element is held in close parallel alignment with the essentially planar support by mechanical contacts at one or more bearing points or areas. These may be under the two ends of the rectangular principal element, though many other arrangements, such as cantilever, cross, disk, etc., will readily occur to one of ordinary skill in the art, and are within the scope of the invention. The support also bears a thin conductive region opposed to a portion of the principal element away from the contacts, which functions as a second capacitor plate, or counter electrode. The mechanical contacts may provide either simple, or clamped support to the principal element, viewed as a load bearing beam. The contacts however, should be designed to minimize dissipative or frictional effects. The principal element receives forces through an upper loading contact, at a point or area opposite the counter electrode. Components of force perpendicular to the support surface deflect the principal element so as to change the distance separating it from the counter electrode, thus altering the capacitance therebetween. If the mechanical contacts provide clamped end constraint, it is desirable that this be stiff; that is, most of the distance change occasioned by a force should be due to flexure of the principal element, rather than twisting of the mechanical contact areas. Although cleanly elastic clamped end constraints may be tolerable, where they engender only a systematic change in sensitivity, better reproducibility and freedom from hysteresis usually may be obtained if the end constraints are stiff clamped end constraints, or fully flexible simple supports, such as pivots.

[0051] The essentially planar support surface may be part of an interconnect system, such as a printed wiring board or flexible circuit with appropriate stiffeners. The counter electrode may comprise a land, or foil, within the context of such an interconnect. The mechanical contacts may also constitute electrical contacts, and may be accomplished by soldering the ends of the principal element to other lands in the support plane.

[0052] Force may be measured as the ratio of an exciting AC voltage to the current it forces through the sensor. As a matter of practice, a constant current may be applied by a feedback circuit, and the exciting voltage measured (as in Roberts, U.S. Pat. No. 5,376,948); or a constant exciting voltage may be applied, and the reciprocal of the resulting current computed. The latter method may enable use of a somewhat simpler interconnect, and provides a somewhat more convenient opportunity for subtracting off estimates of fixed strays which might otherwise degrade linearity of response. The force-responsive signals derived from the force sensors may be processed to yield touch location information in accordance with principles known in the art.

[0053] The curvature resulting from flexure of the principal element is not ideal, but by confining the counter electrode to an area near the center of the principal element, potential nonlinearities of response may be reduced to a