placed thereunder. This configuration has the advantage that should support **408** flex, its curvature is very poorly transmitted to board **901**, thus preventing enclosure forces from disturbing force readings. Pivoted force bearing **121***b* is in the form of a ridge, and suffices to fix sensor sensitivity, while providing good strength against extreme overloads. Unloaded capacitance is about three picofarads, and the bottoming-out force is between four and five pounds.

[**0145**] Although the use of different materials may require other choices of dimensions, the principal element **106***b* may be made from other materials, such as plastic with a electrically conductive coating.

[**0146**] Turning to FIGS. **10**A-**10**B, a smaller sensor according to one embodiment of the invention is depicted. Principal element **106** is cut from spring steel 6 mils thick. It is 120 mils wide and 230 mils long. Alternatively, principal element **106** may be of phosphor-bronze 8 mils thick, with the same length and breadth. The capacitive gap is 1 mil, formed by spacing the gap with a temporary shim while lands **113** are reflowed with solder. Alternatively, the solder may contain particles of controlled size that act to space the principal element **106** from lands **113**.

[**0147**] Bearing dimple **121** may be created with a spring-loaded center punch while principal element **106** is pressed against an aluminum backing. The free span of principal element **106** is 150 mils, the central 86 mils of which are opposed by land **114**. Unloaded capacitance is about three picofarads, and the bottoming-out force is between three and four pounds.

[**0148**] Other details of assembly are as described for the sensors shown in **FIG. 1A**.

[**0149**] Capacitive force sensors exhibit a change in capacitive reactance as a function of a change in applied force. For the sensors of FIGS. **9**A-**9**B and **10**A-**10**B, this change is substantially linear for smaller forces, where the relative gap change is small. With larger forces, however, the center of the capacitive region closes up while the edges remain more widely spaced; this leads to a drop in reactance that becomes more rapid than linear. To increase the range of force sensing that may be accomplished with high accuracy, compensation for the response characteristic just described may be accomplished in the processing of the sensor signal; alternatively, varied embodiments of the sensor of the invention may be provided which have an inherently greater range of linear reactance change.

[**0150**] Thus in another novel aspect of the invention, a capacitive force sensor of nonuniform gap may provide improved linearity of measurement with simple processing of the signal, even where one or more capacitor plates are flexing in response to applied force.

[**0151**] For example, **FIG. 11** depicts a sensor **1100** with overall dimensions similar to those of the sensor of FIGS. **10**A-**10**B. Principal element **106**c, however, has been provided with a slight bend of controlled shape. Because this bend would otherwise be too subtle to depict with clarity, the vertical dimensions of the sensor **1100** are exaggerated tenfold in **FIG. 11** with respect to the sensor's horizontal dimensions. The bend is such that the ends of element **106***c* may attach to lands **113** with a minimal solder film, while the center provides a maximum capacitive gap (between point **1102** and the upper surface of land **114**) of about 1.5 mils.

[**0152**] There is a level of force that may be applied to coupling **121***c* which is just sufficient to first bring element **106***c* into contact with the land **114**. The tapering of the capacitive gap away from the exact center point **1102** of element **106***c* may be so shaped that this contact tends to happen simultaneously at all points where element **106***c* opposes land **114**.

[**0153**] Such a nonuniform gap design may help to provide a force sensor with optimal linearity. Call a general applied force "F", and call the minimum force to bottom out the sensor "F_max". Subject to the assumptions that the gap is thin compared to its lateral dimensions, and that Hooke's law applies, the stated condition upon the gap shape requires that the gap spacing be everywhere proportional to F_max−F. Each small region then adds to the total capacitance a contribution proportional to 1/(F max−F). This expression of the functional dependence upon applied force is not itself a function of position, and so factors out of the area integral defining the total capacitance. The overall sensor capacitance thus varies in proportion to 1/(F max−F), and its capacitive reactance at a given frequency is proportional to F_max−F. This is, of course, the expected behavior for an ideal parallel plate capacitor spaced by an ideal spring. Thus a linear measure of the perpendicular force transmitted may be obtained by differencing the reactance before and during a touch, for the full range of gap closure.

[**0154**] Principal element **106***c* is substantially rectangular and of uniform thickness, and is mounted rigidly at its ends through lands **113** to interconnect **105** or other support. Also, all deflections to be considered are small compared to the thickness of element **106***c*. Therefore, perpendicular force applied to coupling **121***c* will deflect element **106***c* in a pattern closely approximating that of a centrally loaded uniform beam with clamped end constraint. This deflection pattern may be expressed as $d\cdot(3\cdot x^2-2\cdot x^3)$, where d is the maximum deflection, and x is the fractional position along element **106***c*, measured from the last clamped point **1101**, where x=0, to the center of element **106***c* at point **1102**, where x=1. The curve from point **1102** to point **1103** then continues as the mirror image of this.

[**0155**] The desired shape for element **106***c* in its unloaded condition is, therefore, the negative of this deflection pattern, extended with flat ends for mounting. In cases where the end constraint has significant rotational flexibility, the correct shape for element **106***c* may be derived from the stated deflection pattern by associating with point **1101** a value of x that is somewhat larger than zero. In the limiting case of simply supported ends, x=0.5 may be assigned to point **1101**, while x=1 is still assigned to point **1102**.

[**0156**] For convenience of exposition, the curve for element **106***c* has been defined here over the entire span between attachments at point **1101** and point **1103**. Only the area of element **106***c* opposing the second capacitor plate (i.e., land **114**) needs to follow this curve, however, so long as other regions do not bottom out before the capacitive areas do.

[**0157**] Although providing substantial improvement, this one-dimensional analysis is not fully precise, given that coupling **121***c* approximates a point feature, rather than a linear one as does bearing **121***b* of FIGS. **9**A-**9**B. Further degrees of refinement, however, may be obtained as desired through methods of analysis well known in the art, as well