[0083] The focus of these inventive embodiments is primarily on tactile feedback implementations, not kinesthetic force feedback embodiments. As described herein, there are two basic classes of tactile feedback as applied to the present invention: inertial haptic feedback and moving contact haptic feedback. Inertial feedback is generated using inertially coupled vibrations and is based on moving an inertial mass that is coupled to the housing/user through a compliant flexure, where the mass motions cause inertial vibrations in a surface contacted by the user. Moving contact feedback relates to directly moving a surface or member, with respect to an earth ground, against the user and usually is generated by creating small displacements of the user's skin.

[0084] The distinction between inertial and moving contact feedback can be made in terms of the actual mechanism used to provide information to the user. Both inertial and tactile stimulation cause displacement of the hand or finger tissue; the inertial feedback is coupled through some enclosure by the transmissibility of that enclosure and the compliance of whatever holds the enclosure (e.g., a mouse pad plus the user's hand for an inertial feedback mouse). Moving contact feedback refers to a mechanism that is more direct in how it stimulates the user's tissue. Examples would be tactile dots or surfaces that shear the skin of the finger to cause sensation by locally deforming the finger or palm tissue. This distinction is made for the purposes of classifying two types of embodiments described below: inertial and surface translation.

[0085] A novel actuator, referred to as Flat-E herein, is described below and can be used in all of the embodiments herein and represents a class of very low profile, power efficient, high performance, planar actuators. A Flat-E actuator can achieve acceptable performance levels and approach the limited volume and form factor required for laptop and other device applications.

Inertial Embodiments

[0086] These embodiments move an inertial mass to cause inertial haptic feedback to the user, which is typically transmitted through an enclosure or mechanism such as a housing or other surface. In many cases, inertial mass does not impact any surfaces in its travel, although such impacts can alternatively be used to provide additional haptic effects.

[0087] **FIG. 5** is a perspective view of one embodiment **150** of an actuator assembly that can be used to provide inertial haptic sensations for touchpads and housings of devices of the present invention. Embodiments of an actuator assembly (or "inertial harmonic drive") are described in copending application Ser. No. 09/585,741, incorporated herein by reference in its entirety. Actuator assembly **150** includes a grounded flexure **160** and an actuator **155**. The flexure **160** can be a single, unitary piece made of a material such as polypropylene plastic ("living hinge" material) or other flexible material. Flexure **160** can be grounded to the housing of the device **12**, for example, at portion **161**.

[0088] Actuator **155** is coupled to the flexure **160**. The housing of the actuator is coupled to a receptacle portion **162** of the flexure **160** which houses the actuator **155** as shown. A rotating shaft **164** of the actuator is coupled to the flexure **160** in a bore **165** of the flexure **160** and is rigidly coupled to a central rotating member **170**. The rotating shaft **164** of the actuator is rotated about an axis A which also rotates member **170** about axis A. Rotating member **170** is coupled to a first portion **172*a*** of an angled member **171** by a flex joint **174**. The flex joint **174** preferably is made very thin in the dimension it is to flex so that the flex joint **174** will bend when the rotating portion **170** moves the first portion **172*a*** approximately linearly. The first portion **172**a is coupled to the grounded portion **180** of the flexure by a flex joint **178** and the first portion **172*a*** is coupled to a second portion **172*b*** of the angled member by flex joint **182**. The second portion **172*b*,** in turn, is coupled at its other end to the receptacle portion **162** of the flexure by a flex joint **184**.

[0089] The angled member **171** that includes first portion **172*a*** and second portion **172*b*** moves linearly along the x-axis as shown by arrow **176**. In actuality, the portions **172*a*** and **172*b*** move only approximately linearly. When the flexure is in its origin position (rest position), the portions **172*a*** and **172*b*** are preferably angled as shown with respect to their lengthwise axes. This allows the rotating member **170** to push or pull the angled member **171** along either direction as shown by arrow **176**.

[0090] The actuator **155** is operated in only a fraction of its rotational range when driving the rotating member **170** in two directions, allowing high bandwidth operation and high frequencies of pulses or vibrations to be output. A flex joint **192** is provided in the flexure portion between the receptacle portion **162** and the grounded portion **180**. The flex joint **192** allows the receptacle portion **162** (as well as the actuator **155**, rotating member **170**, and second portion **172*b***) to move approximately linearly in the z-axis in response to motion of the portions **172*a*** and **172*b*.** A flex joint **190** is provided in the first portion **172*a*** of the angled member **171** to allow the flexing about flex joint **192** in the z-direction to more easily occur.

[0091] By quickly changing the rotation direction of the actuator shaft **164**, the actuator/receptacle can be made to oscillate along the z-axis and create a vibration on the housing with the actuator **155** acting as an inertial mass. Preferably, enough space is provided above and below the actuator to allow its range of motion without impacting any surfaces or portions of the housing. In addition, the flex joints included in flexure **160**, such as flex joint **192**, act as spring members to provide a restoring force toward the origin position (rest position) of the actuator **155** and receptacle portion **172**. In some embodiments, the stops can be included in the flexure **160** to limit the motion of the receptacle portion **122** and actuator **110**.

[0092] Other embodiments can provide other types of actuator assemblies to provide inertial sensations, such as a flexure that moves a separate inertial mass instead of the actuator itself. Or, an eccentric mass coupled to a rotating shaft of an actuator can be oscillated to provide rotational inertial tactile sensations to the housing. The eccentric mass can be unidirectionally driven or bidirectionally driven. Other types of actuator assemblies may also be used, as disclosed in U.S. Pat. No. 6,184,868, such as a linear voice coil actuator, solenoid, moving magnet actuator, etc.

[0093] In one embodiment, an actuator assembly such as described above may be coupled to any of various locations of a laptop housing or other device housing and used to vibrate parts of the housing, relying on the transmission of vibrations through the product housing by the remotely mounted actuator module. The actuator assembly can be