FIG. 12C is a partial cross-sectional view of a fourth mechanism for measuring the force of acceleration in a "Y" direction with a deformable ball in relaxed contact with the touch screen. This mechanism utilizes fluid to convert motion in the "Y" direction to that in the "Z" direction to enable it to be sensed.

FIGS. 13A-B provide a flow diagram of a method for detecting acceleration of the accelerometer module.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

One embodiment of the invention provides an accelerometer module for use with a touch sensitive device, such as a touch pad or touch screen, on a mobile device. The accelerometer module may be used to provide a mobile device having a touch sensitive device with the ability to sense acceleration, orientation, or both. The accelerometer module cooperates with the touch sensitive device to enable the mobile device to sense acceleration along a single axis or dual axis may be useful, for example, for producing a pedometer, automotive vibration sensor, or theft detection device. An accelerometer module that enables the device to sense acceleration along three axis may be useful, for example, for producing a handheld game controller or three-dimensional graphics instrument. A mobile device with the capabilities of an accelerometer may be adapted to many other applications.

Another embodiment of the invention provides a method of detecting acceleration of an accelerometer module in cooperation with a touch device. The accelerometer module applies a force against a deformable member to cause a change in the area of contact between the deformable member and the touch sensitive device. The contact area is a function of the amount of the force applied against the deformable member. Monitoring the touch screen to determine the extent of changes in the contact area of a deformable member enables the amount of the force to be determined. Various mechanisms may be used to deform a deformable member against the touch screen as a result of acceleration in various directions. For example, appropriate use of three independent mechanisms can enable the detection of acceleration along each of three axis. Electronic signals generated by the touch sensitive device may be used separately for various applications or combined to indicate an overall net acceleration of the module.

Yet another embodiment of the invention is a computer readable medium including a computer program product providing computer usable instructions for carrying out a method of detecting acceleration. The computer program product detects the contact area of each of one or more deformable members and uses the detected area to indicate the amount of force applied in a given direction. The amount of the force is generally proportional to the increase in contact area in accordance with a predetermined function that may be empirically determined on the basis of the composition, shape and size of the deformable member. The computer program product may determine the direction of the force in accordance with a predetermined layout of the accelerometer module. The predetermined layout may establish that a particular axial component of the overall acceleration will be indicated by a force on the touch screen in a particular region of the touch screen. Acceleration can then be determined from the force.

A touch sensitive device may be produced using various technologies including, without limitation, a touch sensitive device selected from the group consisting of resistive, surface acoustic wave (SAW), capacitive, infrared, strain gauge, optical imaging, dispersive signal technology, acoustic pulse recognition, and frustrated total internal reflection. However, an embodiment including a capacitive touch sensitive device will be described in greater detail. A capacitive touch sensitive device is known to be capable of simultaneously detecting contact at multiple points on the touch screen, whereas some touch sensitive device technologies are limited to detecting a single point of contact.

A capacitive touch sensitive device panel is coated with a material, typically indium tin oxide, that conducts a continuous electrical current across the sensor. The sensor therefore exhibits a precisely controlled field of stored electrons in both the horizontal and vertical axes and achieves capacitance. The human body is also an electrical device which has stored electrons and therefore also exhibits capacitance. When the sensor's 'normal' capacitance field (its reference state) is altered by another capacitance field, such as a finger, electronic circuits located at each corner of the panel measure the resultant 'distortion' in the sine wave characteristics of the reference field and send the information about the event to the controller for mathematical processing. Capacitive sensors can either be touched with a bare finger or other conductive device, such as the deformable member.

Furthermore, a capacitive touch sensitive device can be made to sense the area of touch as well as the location of the touch on the touch screen. Higher touch pressure causes a finger tip to flatten more and creates a larger tough area. In this manner, the touch sensitive device can determine the relative amount of pressure applied by a finger in proportion to the area touched. An embodiment of the invention includes a deformable member, such as a ball, having a conductive surface for contacting the touch sensitive device in much the same manner as a finger. The deformable member is deformed under a force directed toward the touch sensitive device by a weight that is being accelerated. The deformable member may be any three-dimensional shape that presents a surface at an angle to the touch sensitive device such that the contact area between the surface and the touch sensitive device increases with increasing force or acceleration. For example, the deformable member may have a generally rounded shape such as a sphere, spheroid, or ellipsoid; a shape having a generally rounded face directed toward the touch sensitive device; a generally pyramidal shape; a shape having one or more generally inclined surfaces facing the touch sensitive device. Furthermore, it is not necessary for the deformable member to deform against the flat touch sensitive device surface over a round area. Rather, the deformation may be substantially linear along one or two axis.

The deformable member is disposed between the touch sensitive device and a mechanism for directing a force at the deformable member in a direction toward the touch sensitive device. In one embodiment, the mechanism directs the force at a substantially perpendicular angle relative to a planar touch sensitive device. The mechanism positions a mass in a known relationship to the deformable member. Optionally, the mechanism may be selected to direct a force that represents only a single axial component of the overall acceleration.

A further embodiment includes multiple mechanisms that each direct a force representing a different axial component of an overall acceleration. For example, a set of three mechanisms may be included, where each mechanism directs a force representative of one component of a Cartesian coordinate system. The force measurements from each of the three axis can be utilized separately or in combination to determine the overall acceleration of the device.

A first type of mechanism may allow only forces directed perpendicular to the touch sensitive device (i.e., a "z direc-