US009543090B2

(12) **United States Patent**
Krumpelman

(10) **Patent No.: US 9,543,090 B2**
(45) **Date of Patent: Jan. 10, 2017**

(54) **KEYBOARDS WITH PLANAR TRANSLATION MECHANISM FORMED FROM LAMINATED SUBSTRATES**

(71) Applicant: **SYNAPTICS INCORPORATED**, San Jose, CA (US)

(72) Inventor: **Doug Krumpelman**, Hayden, ID (US)

(73) Assignee: **Synaptics Incorporated**, San Jose, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 117 days.

(21) Appl. No.: **14/171,106**

(22) Filed: **Feb. 3, 2014**

(65) **Prior Publication Data**

US 2014/0311881 A1 Oct. 23, 2014

Related U.S. Application Data

(60) Provisional application No. 61/813,845, filed on Apr. 19, 2013.

(51) **Int. Cl.**

H01H 9/26	(2006.01)
H01H 13/72	(2006.01)
H01H 13/76	(2006.01)
H01H 13/14	(2006.01)

(52) **U.S. Cl.**
CPC ***H01H 13/14*** (2013.01); *H01H 2215/042* (2013.01); *H01H 2221/04* (2013.01)

(58) **Field of Classification Search**
CPC H01H 13/7065; H01H 13/84; H01H 13/85; H01H 2221/04
USPC 200/344, 341–345
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,309,870	B2 *	11/2012	Peterson et al.	200/344
2009/0231792	A1 *	9/2009	Ligtenberg	G06F 1/1616 361/679.08
2013/0161172	A1 *	6/2013	Leong	H01H 13/7065 200/5 A
2014/0034469	A1 *	2/2014	Krumpelman	200/5 A
2014/0034470	A1 *	2/2014	Krumpelman et al.	200/5 A
2014/0262717	A1 *	9/2014	Krumpelman	200/5 A

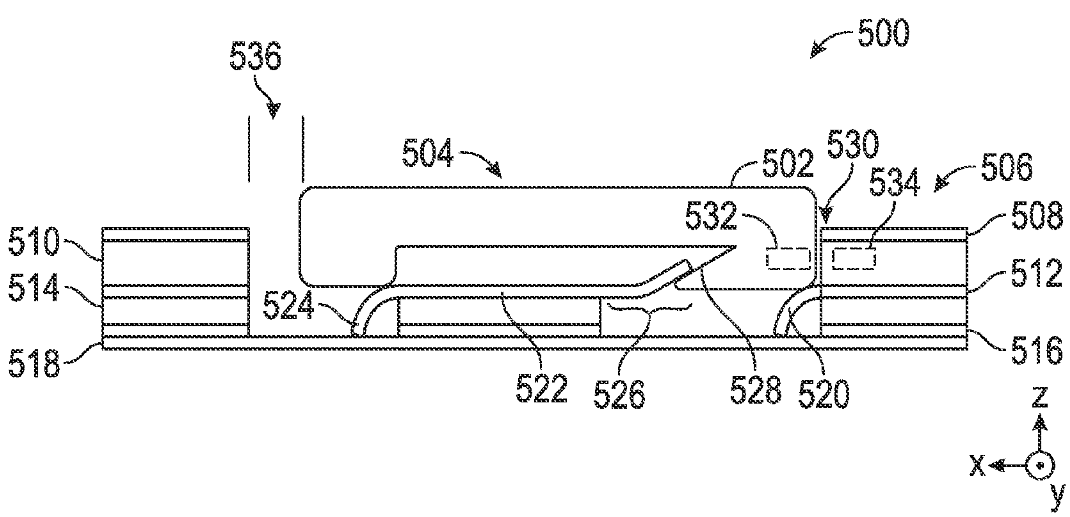
* cited by examiner

Primary Examiner — Renee S Luebke
Assistant Examiner — Lheiren Mae A Caroc
(74) *Attorney, Agent, or Firm* — Osha Liang LLP

(57) **ABSTRACT**

Keyboards with planar translation effecting mechanisms formed by laminated key guides are disclosed. A key assembly for a keyboard includes a keycap having a touch surface for receiving a press force that moves the keycap from an unpressed position toward a pressed position, the unpressed position and pressed position separated in a press direction and a second direction orthogonal to the press direction. A base is included having a laminated key guide contacting a portion of the keycap to provide a planar translation effecting mechanism to guide the keycap in the press direction and the second direction as the keycap moves from the unpressed position toward the pressed position.

21 Claims, 5 Drawing Sheets



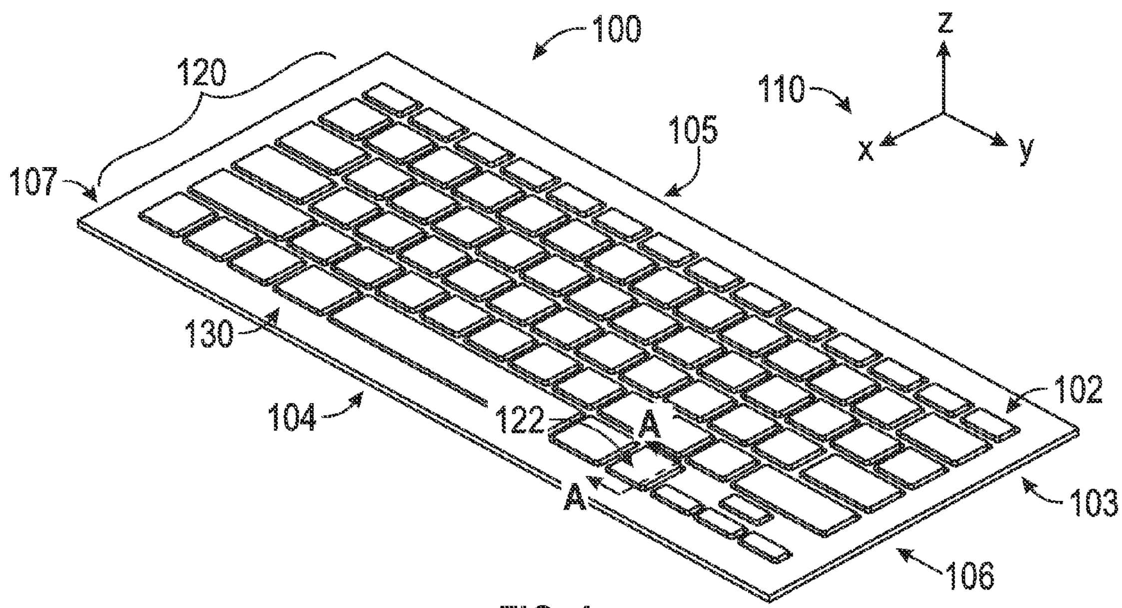

100
120
110
z
x
y
107
105
130
102
104
122
A
A
103
106

FIG. 1

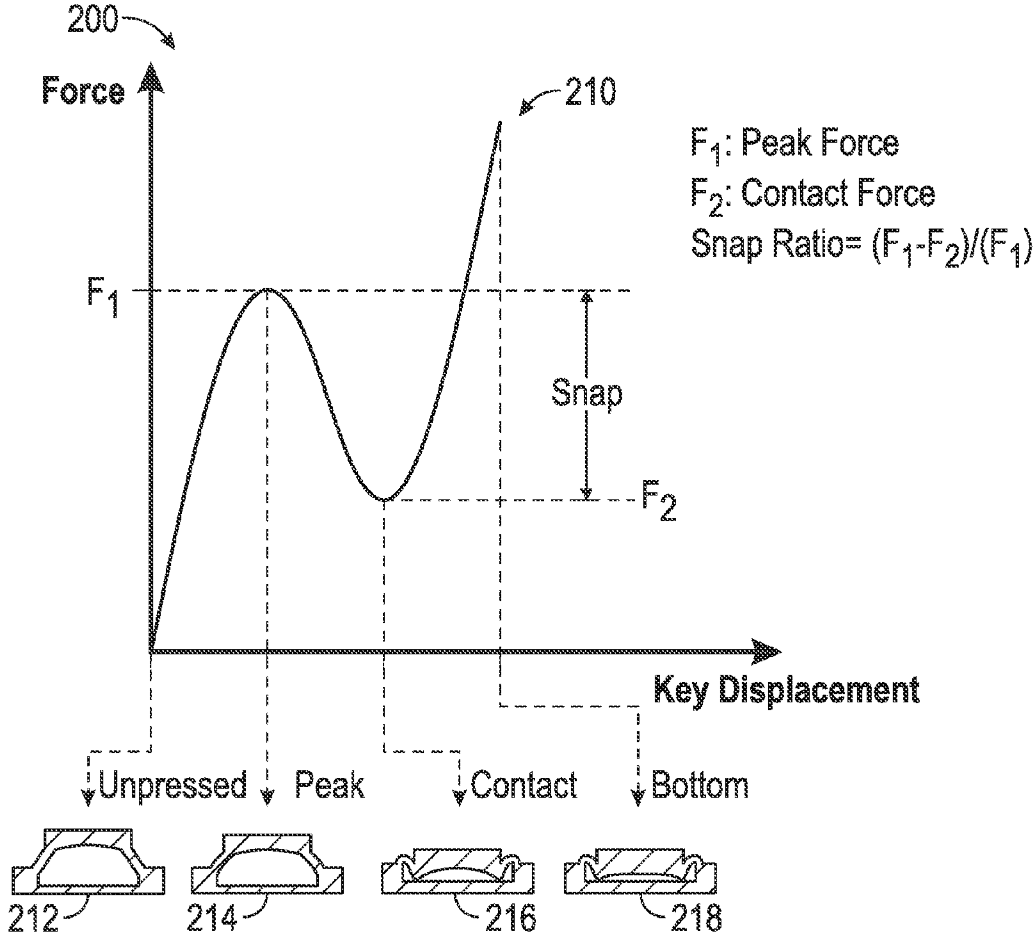

200
Force
210
F1: Peak Force
F2: Contact Force
Snap Ratio= (F1-F2)/(F1)
F1
Snap
F2
Key Displacement
Unpressed
Peak
Contact
Bottom
212
214
216
218

FIG. 2

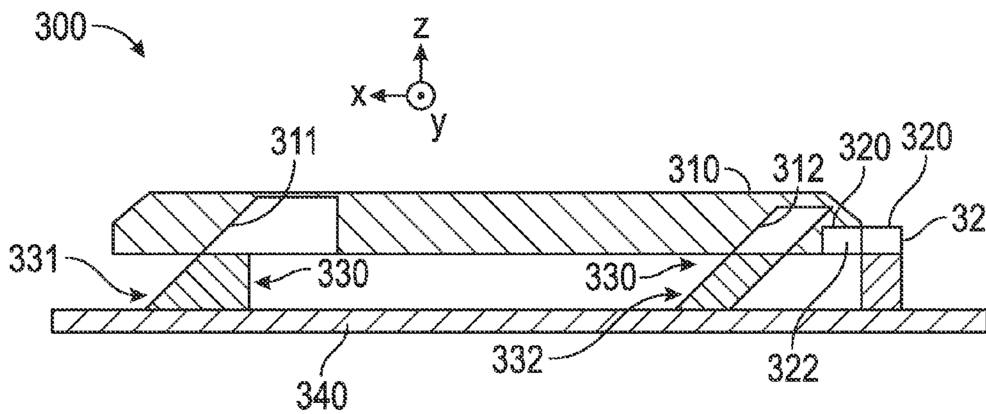

300
z
x
y
311
310
312
320
320
324
331
330
330
332
322
340

FIG. 3A

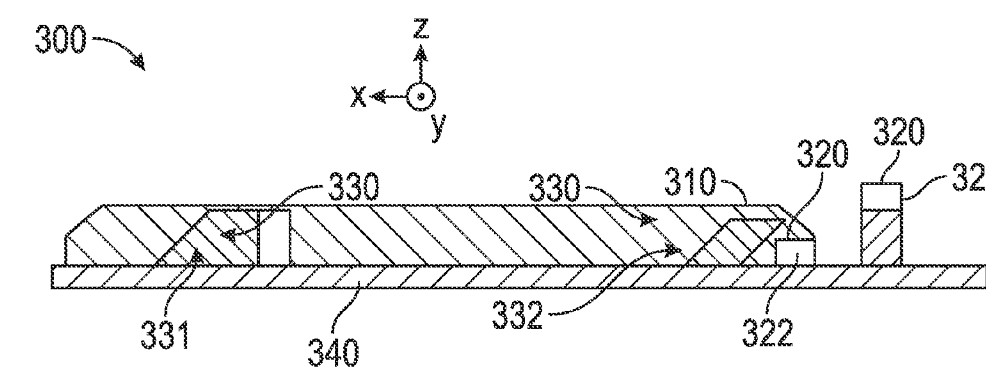

300
z
x
y
330
330
310
320
320
324
331
332
322
340

FIG. 3B

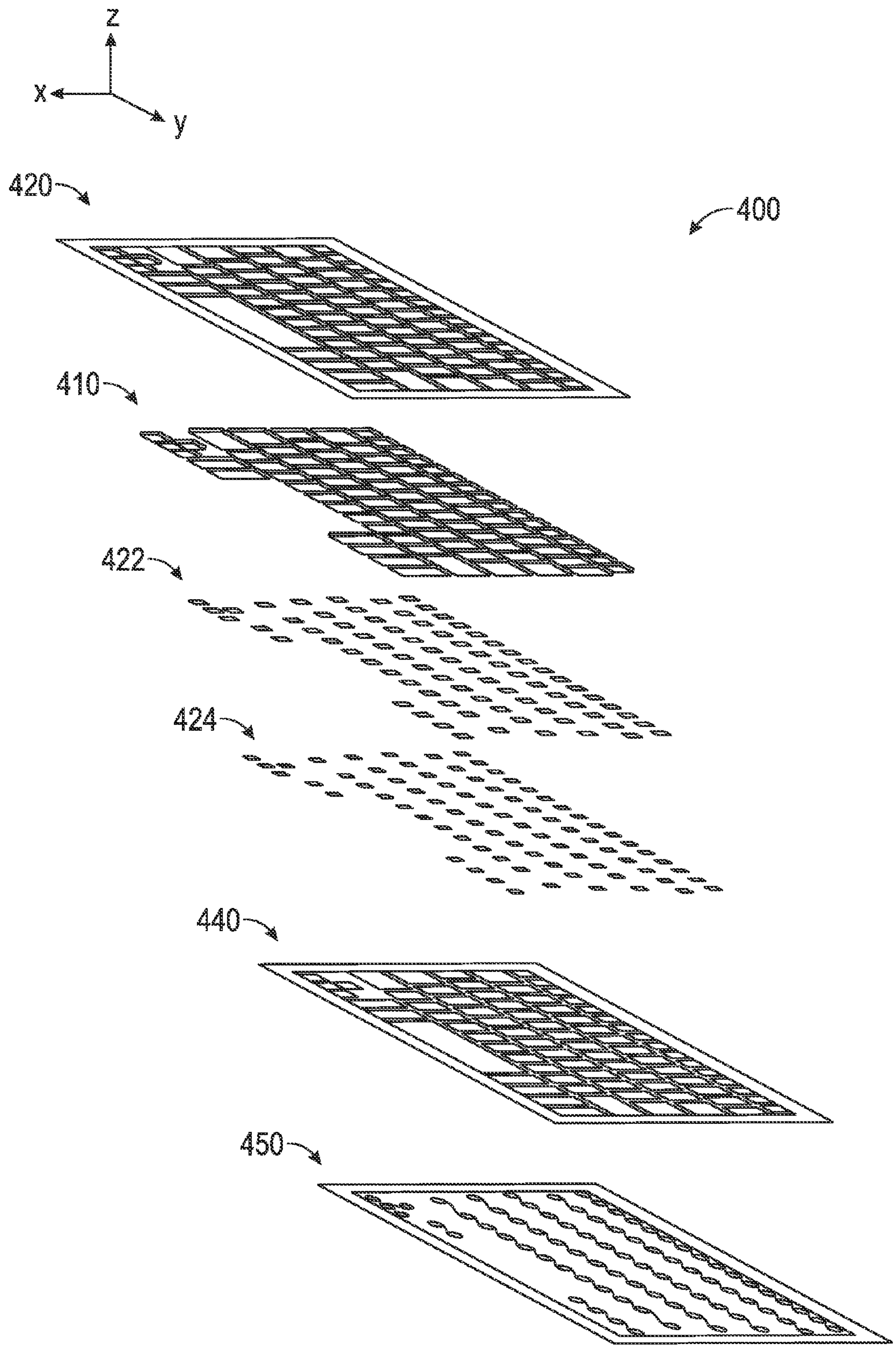


FIG. 4

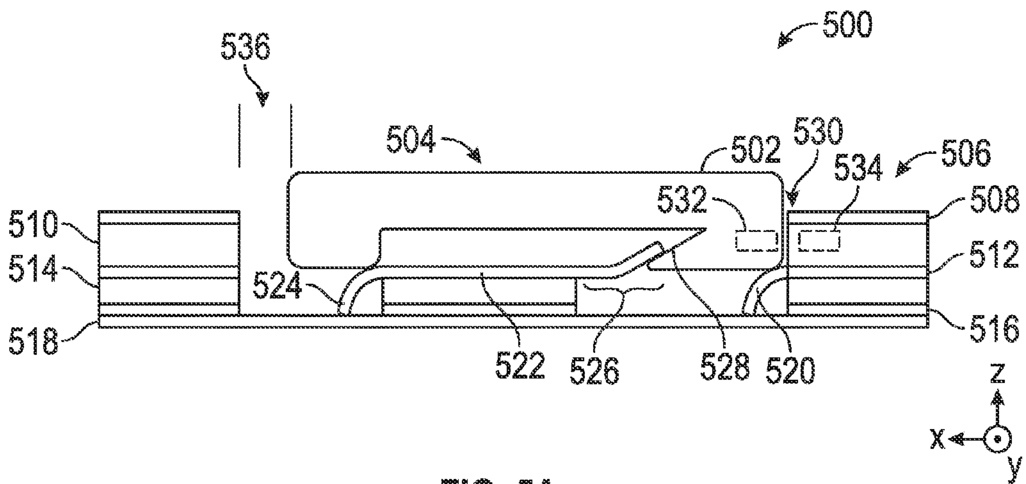


FIG. 5A

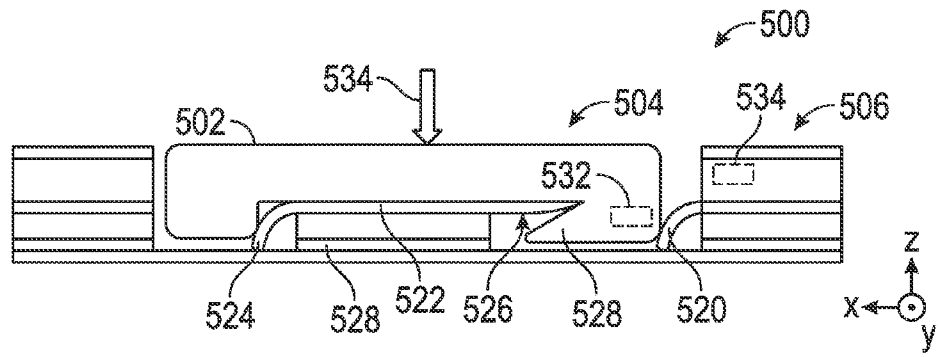


FIG. 5B

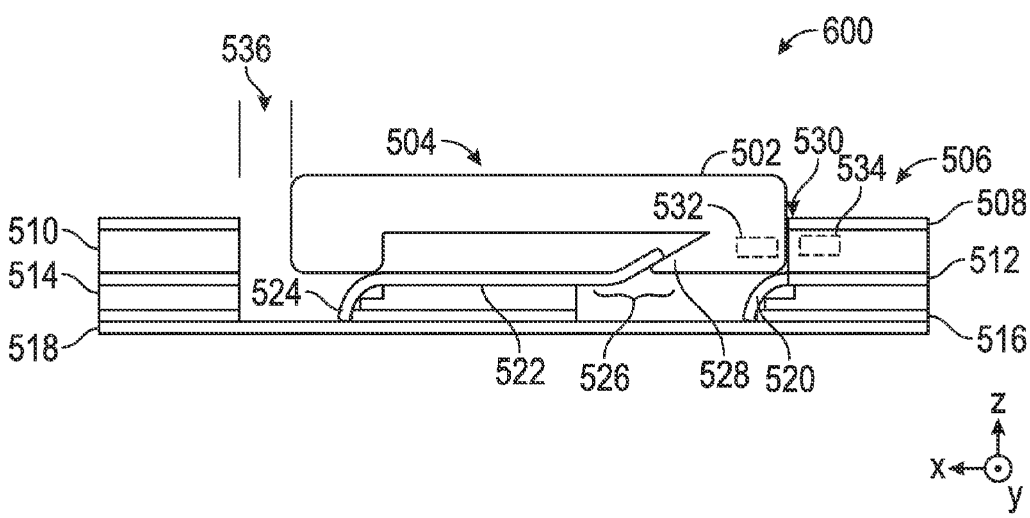


FIG. 6A

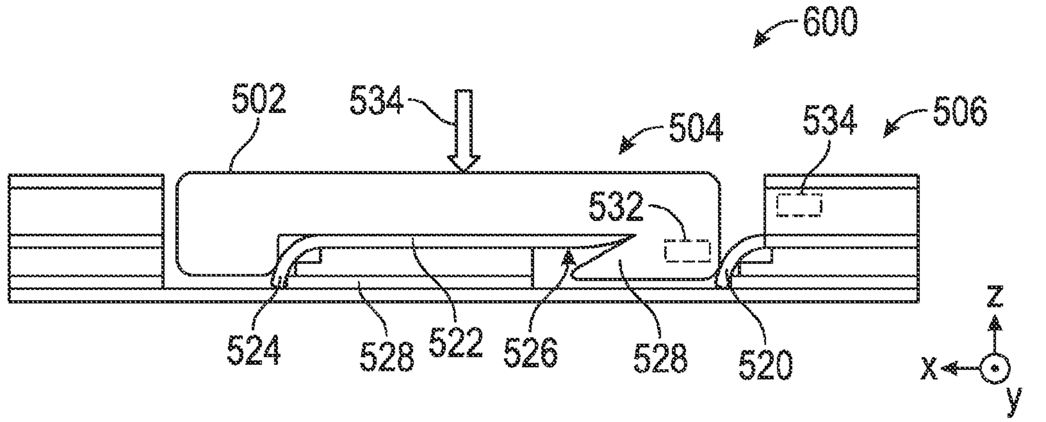


FIG. 6B

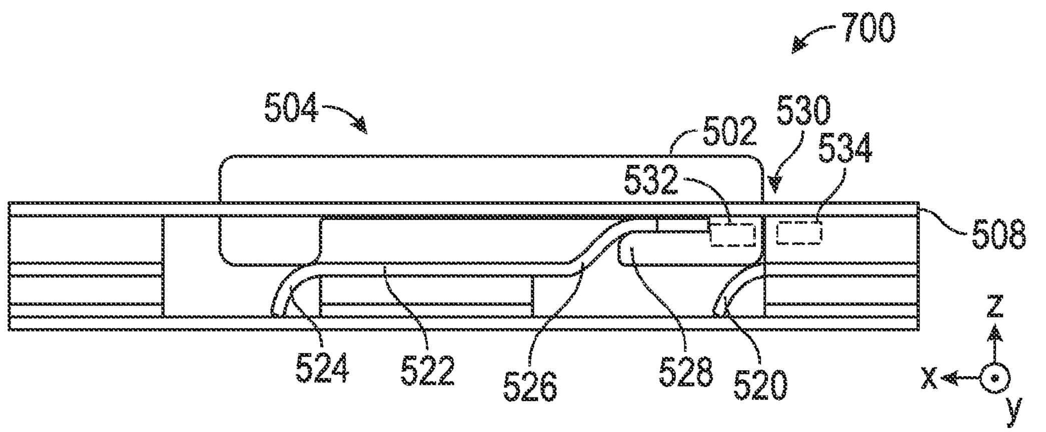


FIG. 7

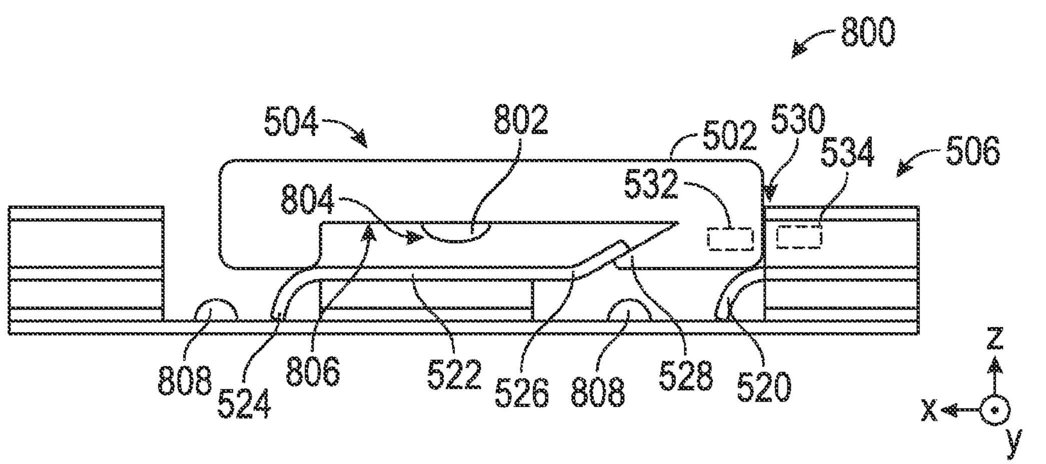


FIG. 8

KEYBOARDS WITH PLANAR TRANSLATION MECHANISM FORMED FROM LAMINATED SUBSTRATES

RELATED APPLICATION(S)

This application claims priority to Provisional Patent Application No. 61/813,845 filed Apr. 19, 2013.

FIELD OF THE INVENTION

This invention generally relates to electronic devices.

BACKGROUND OF THE INVENTION

Pressable touchsurfaces (touch surfaces which can be pressed) are widely used in a variety of input devices, including as the surfaces of keys or buttons for keypads or keyboards, and as the surfaces of touch pads or touch screens. It is desirable to improve the usability of these input systems.

FIG. **2** shows a graph **200** of an example tactile response curve associated with the "snapover" haptic response found in many keys enabled with metal snap domes or rubber domes. Specifically, graph **200** relates force applied to the user by a touchsurface of the key and the amount of key displacement (movement relative to its unpressed position). The force applied to the user may be a total force or the portion of the total force along a particular direction such as the positive or negative press direction. Similarly, the amount of key displacement may be a total amount of key travel or the portion along a particular direction such as the positive or negative press direction.

The force curve **210** shows four key press states **212**, **214**, **216**, **218** symbolized with depictions of four rubber domes at varying amounts of key displacement. The key is in the "unpressed" state **212** when no press force is applied to the key and the key is in the unpressed position (i.e., "ready" position). In response to press input, the key initially responds with some key displacement and increasing reaction force applied to the user. The reaction force increases with the amount of key displacement until it reaches a local maximum "peak force" F_1 in the "peak" state **214**. In the peak state **214**, the metal snap dome is about to snap or the rubber dome is about to collapse. The key is in the "contact" state **216** when the keycap, snap dome or rubber dome, or other key component moved with the keycap makes initial physical contact with the base of the key (or a component attached to the base) with the local minimum "contact force" F_2. The key is in the "bottom" state **218** when the key has travelled past the "contact" state and is mechanically bottoming out, such as by compressing the rubber dome in keys enabled by rubber domes.

A snapover response is defined by the shape of the reaction force curve—affected by variables such as the rate of change, where it peaks and troughs, and the associated magnitudes. The difference between the peak force F_1 and the contact force F_2 can be termed the "snap." The "snap ratio" can be determined as $(F_1-F_2)/F_1$ (or as $100*(F_1-F_2)/F_1$, if a percent-type measure is desired).

BRIEF SUMMARY OF THE INVENTION

Keyboards with planar translation effecting mechanisms formed by laminated key guides are disclosed. A key assembly for a keyboard includes a keycap having a touch surface for receiving a press force that moves the keycap from an unpressed position toward a pressed position, the unpressed position and pressed position separated in a press direction and a second direction orthogonal to the press direction. A base is included having a laminated key guide contacting a portion of the keycap to provide a planar translation effecting mechanism to guide the keycap in the press direction and the second direction as the keycap moves from the unpressed position toward the pressed position.

BRIEF DESCRIPTION OF DRAWINGS

Example embodiments of the present invention will hereinafter be described in conjunction with the appended drawings which are not to scale unless otherwise noted, where like designations denote like elements, and:

FIG. **1** shows an example keyboard that incorporates one or more implementations of key-based touchsurfaces configured in accordance with the techniques described herein;

FIG. **2** is a graph of an example tactile response that is characteristic of many keys enabled with metal snap domes or rubber domes;

FIGS. **3**A-**3**B are simplified side views of a first example touchsurface assembly configured in accordance with the techniques described herein;

FIG. **4** shows an exploded view of an example keyboard in accordance with the techniques described herein;

FIGS. **5**A-B is cross-sectional side view of a key assembly in accordance with the techniques described herein;

FIGS. **6**A-B is cross-sectional side view of a key assembly in accordance with the techniques described herein;

FIG. **7** is cross-sectional side view of a key assembly in accordance with the techniques described herein; and

FIG. **8** is cross-sectional side view of a key assembly in accordance with the techniques described herein.

DETAILED DESCRIPTION OF THE INVENTION

The following detailed description is merely exemplary in nature and is not intended to limit the invention or the application and uses of the invention.

Various embodiments of the present invention provide input devices and methods that facilitate improved usability, thinner devices, easier assembly, lower cost, more flexible industrial design, or a combination thereof. These input devices and methods involve pressable touchsurfaces that may be incorporated in any number of devices. As some examples, pressable touchsurfaces may be implemented as surfaces of touchpads, touchscreens, keys, buttons, and the surfaces of any other appropriate input device. Thus, some non-limiting examples of devices that may incorporate pressable touchsurfaces include personal computers of all sizes and shapes, such as desktop computers, laptop computers, netbooks, ultrabooks, tablets, e-book readers, personal digital assistants (PDAs), and cellular phones including smart phones. Additional example devices include data input devices (including remote controls, integrated keyboards or keypads such as those within portable computers, or peripheral keyboards or keypads such as those found in tablet covers or stand-alone keyboards, control panels, and computer mice), and data output devices (including display screens and printers). Other examples include remote terminals, kiosks, point-of-sale devices, video game machines (e.g., video game consoles, portable gaming devices, and the like) and media devices (including recorders, editors, and players such as televisions, set-top boxes, music players, digital photo frames, and digital cameras).

The discussion herein focuses largely on rectangular touchsurfaces. However, the touchsurfaces for many embodiments can comprise other shapes. Example shapes include triangles, quadrilaterals, pentagons, polygons with other numbers of sides, shapes similar to polygons with rounded corners or nonlinear sides, shapes with curves, elongated or circular ellipses circles, combinations shapes with portions of any of the above shapes, non-planar shapes with concave or convex features, and any other appropriate shape.

In addition, although the discussion herein focuses largely on the touchsurfaces as being atop rigid bodies that undergo rigid body motion, some embodiments may comprise touchsurfaces atop pliant bodies that deform. "Rigid body motion" is used herein to indicate motion dominated by translation or rotation of the entire body, where the deformation of the body is negligible. Thus, the change in distance between any two given points of the touchsurface is much smaller than an associated amount of translation or rotation of the body.

Also, in various implementations, pressable touchsurfaces may comprise opaque portions that block light passage, translucent or transparent portions that allow light passage, or both.

FIG. **1** shows an example keyboard **100** that incorporates a plurality of (two or more) pressable key-based touchsurfaces configured in accordance with the techniques described herein. The example keyboard **100** comprises rows of keys **120** of varying sizes surrounded by a keyboard bezel **130**. Keyboard **100** has a QWERTY layout, even though the keys **120** are not thus labeled in FIG. **1**. Other keyboard embodiments may comprise different physical key shapes, key sizes, key locations or orientations, or different key layouts such as DVORAK layouts or layouts designed for use with special applications or non-English languages. In some embodiments, the keys **120** comprise keycaps that are rigid bodies, such as rigid rectangular bodies having greater width and breadth than depth (depth being in the Z direction as explained below). Also, other keyboard embodiments may comprise a single pressable key-based touchsurface configured in accordance with the techniques described herein, such that the other keys of these other keyboard embodiments are configured with other techniques.

Orientation terminology is introduced here in connection with FIG. **1**, but is generally applicable to the other discussions herein and the other figures unless noted otherwise. This terminology introduction also includes directions associated with an arbitrary Cartesian coordinate system. The arrows **110** indicate the positive directions of the Cartesian coordinate system, but do not indicate an origin for the coordinate system. Definition of the origin will not be needed to appreciate the technology discussed herein.

The face of keyboard **100** including the exposed touchsurfaces configured to be pressed by users is referred to as the "top" **102** of the keyboard **100** herein. Using the Cartesian coordinate directions indicated by the arrows **110**, the top **102** of the keyboard **100** is in the positive-Z direction relative to the bottom **103** of the keyboard **100**. The part of the keyboard **100** that is typically closer to the body of a user when the keyboard **100** is in use atop a table top is referred to as the "front" **104** of the keyboard **100**. In a QWERTY layout, the front **104** of the keyboard **100** is closer to the space bar and further from the alphanumeric keys. Using the Cartesian coordinate directions indicated by the arrows **110**, the front **104** of the keyboard **100** is in the positive-X direction relative to the back **105** of the keyboard **100**. In a typical use orientation where the top **102** of the keyboard **100** is facing upwards and the front **104** of the keyboard **100** is facing towards the user, the "right side" **106** of the keyboard **100** is to the right of a user. Using the Cartesian coordinate directions indicated by the arrows **110**, the right side **106** of the keyboard **100** is in the positive-Y direction relative to the "left side" **107** of the keyboard **100**. With the top **102**, front **104**, and right side **106** thus defined, the "bottom" **103**, "back" **105**, and "left side" **107** of the keyboard **100** are also defined.

Using this terminology, the press direction for the keyboard **100** is in the negative-Z direction, or vertically downwards toward the bottom of the keyboard **100**. The X and Y directions are orthogonal to each other and to the press direction. Combinations of the X and Y directions can define an infinite number of additional lateral directions orthogonal to the press direction. Thus, example lateral directions include the X direction (positive and negative), the Y direction (positive and negative), and combination lateral directions with components in both the X and Y directions but not the Z direction. Motion components in any of these lateral directions is sometimes referred herein as "planar," since such lateral motion components can be considered to be in a plane orthogonal to the press direction.

Some or all of the keys of the keyboard **100** are configured to move between respective unpressed and pressed positions that are spaced in the press direction and in a lateral direction orthogonal to the press direction. That is, the touchsurfaces of these keys exhibit motion having components in the negative Z-direction and in a lateral direction. In the examples described herein, the lateral component is usually in the positive X-direction or in the negative X-direction for ease of understanding. However, in various embodiments, and with reorientation of select key elements as appropriate, the lateral separation between the unpressed and the pressed positions may be solely in the positive or negative X-direction, solely in the positive or negative Y-direction, or in a combination with components in both the X and Y directions.

Thus, these keys of the keyboard **100** can be described as exhibiting "diagonal" motion from the unpressed to the pressed position. This diagonal motion is a motion including both a "Z" (or vertical) translation component and a lateral (or planar) translation component. Since this planar translation occurs with the vertical travel of the touchsurface, it may be called "planar translational responsiveness to vertical travel" of the touchsurface, or "vertical-lateral travel."

Some embodiments of the keyboard **100** comprise keyboards with leveled keys that remain, when pressed during normal use, substantially level in orientation through their respective vertical-lateral travels. That is, the keycaps of these leveled keys (and thus the touchsurfaces of these keys) exhibit little or no rotation along any axes in response to presses that occur during normal use. Thus, there is little or no roll, pitch, and yaw of the keycap and the associated touchsurfaces remain relatively level and substantially in the same orientation during their motion from the unpressed position to the pressed position.

In various embodiments, the lateral motion associated with the vertical-lateral travel can improve the tactile feel of the key by increasing the total key travel for a given amount of vertical travel in the press direction. In various embodiments, the vertical-lateral travel also enhances tactile feel by imparting to users the perception that the touchsurface has travelled a larger vertical distance than actually travelled. For example, the lateral component of vertical-lateral travel may apply tangential friction forces to the skin of a finger pad in contact with the touchsurface, and cause deformation of the skin and finger pad that the user perceives as additional vertical travel. This then creates a tactile illusion of greater vertical travel. In some embodiments, returning the key from the pressed to the unpressed position on the return stroke also involves simulating greater vertical travel using lateral motion.

To enable the keys **120** of the keyboard **100** with vertical-lateral travel, the keys **120** are parts of key assemblies each comprising mechanisms for effecting planar translation, readying the key **120** by holding the associated keycap in the unpressed position, and returning the key **120** to the unpressed position. Some embodiments further comprise mechanisms for leveling keycaps. Some embodiments achieve these functions with a separate mechanism for each function, while some embodiments achieve two or more of these functions using a same mechanism. For example, a "biasing" mechanism may provide the readying function, the returning function, or both the readying and returning functions. Mechanisms which provide both readying and returning functions are referred to herein as "ready/return" mechanisms. As another example, a leveling/planar-translation-effecting mechanisms may level and effect planar translation. As further examples, other combinations of functions may be provided by a same mechanism.

The keyboard **100** may use any appropriate technology for detecting presses of the keys of the keyboard **100**. For example, the keyboard **100** may employ a key switch matrix based on conventional resistive membrane switch technology. The key switch matrix may be located under the keys **120** and configured to generate a signal to indicate a key press when a key **120** is pressed. Alternatively, the example keyboard **100** may employ other key press detection technology to detect any changes associated with the fine or gross change in position or motion of a key **120**. Example key press detection technologies include various capacitive, resistive, inductive, magnetic, force or pressure, linear or angular strain or displacement, temperature, aural, ultrasonic, optical, and other suitable techniques. With many of these technologies, one or more preset or variable thresholds may be defined for identifying presses and releases.

As a specific example, capacitive sensor electrodes may be disposed under the touchsurfaces, and detect changes in capacitance resulting from changes in press states of touchsurfaces. The capacitive sensor electrodes may utilize "self capacitance" (or "absolute capacitance") sensing methods based on changes in the capacitive coupling between the sensor electrodes and the touchsurface. In some embodiments, the touchsurface is conductive in part or in whole, or a conductive element is attached to the touchsurface, and held at a constant voltage such as system ground. A change in location of the touchsurface alters the electric field near the sensor electrodes below the touchsurface, thus changing the measured capacitive coupling. In one implementation, an absolute capacitance sensing method operates with a capacitive sensor electrode underlying a component having the touchsurface, modulates that sensor electrodes with respect to a reference voltage (e.g., system ground), and detects the capacitive coupling between that sensor electrode and the component having the touchsurface for gauging the press state of the touchsurface.

Some capacitive implementations utilize "mutual capacitance" (or "transcapacitance") sensing methods based on changes in the capacitive coupling between sensor electrodes. In various embodiments, the proximity of a touchsurface near the sensor electrodes alters the electric field between the sensor electrodes, thus changing the measured capacitive coupling. The touchsurface may be a conductive or non-conductive, electrically driven or floating, as long as its motion causes measurable change in the capacitive coupling between sensor electrodes. In some implementations, a transcapacitive sensing method operates by detecting the capacitive coupling between one or more transmitter sensor electrodes (also "transmitters") and one or more receiver sensor electrodes (also "receivers"). Transmitter sensor electrodes may be modulated relative to a reference voltage (e.g., system ground) to transmit transmitter signals. Receiver sensor electrodes may be held substantially constant relative to the reference voltage to facilitate receipt of resulting signals. A resulting signal may comprise effect(s) corresponding to one or more transmitter signals, and/or to one or more sources of environmental interference (e.g., other electromagnetic signals). Sensor electrodes may be dedicated transmitters or receivers, or may be configured to both transmit and receive.

In one implementation, a trans-capacitance sensing method operates with two capacitive sensor electrodes underlying a touchsurface, one transmitter and one receiver. The resulting signal received by the receiver is affected by the transmitter signal and the location of the touchsurface.

In some embodiments, the sensor system used to detect touchsurface presses may also detect pre-presses. For example, a capacitive sensor system may also be able to detect a user lightly touching a touchsurface, and distinguish that from the press of the touchsurface. Such a system can support multi-stage touchsurface input, which can respond differently to light touch and press.

Some embodiments are configured to gauge the amount of force being applied on the touchsurface from the effect that the force has on the sensor signals. That is, the amount of depression of the touchsurface is correlated with one or more particular sensor readings, such that the amount of press force can be determined from the sensor reading(s).

In some embodiments, substrates used for sensing are also used to provide backlighting associated with the touchsurfaces. As a specific example, in some embodiments utilizing capacitive sensors underlying the touchsurface, the capacitive sensor electrodes are disposed on a transparent or translucent circuit substrate such as polyethylene terephthalate (PET), another polymer, or glass. Some of those embodiments use the circuit substrate as part of a light guide system for backlighting symbols viewable through the touchsurfaces.

FIG. **1** also shows a section line A-A' relative to the key **122** of the keyboard **100**, which will be discussed below.

The keyboard **100** may be integrated into or coupled to computer such as a laptop computer comprising one or more processing systems. The processing system(s) each comprise one or more ICs (integrated circuits) having appropriate processor-executable instructions for responding to key presses. These instructions direct the appropriate IC(s) to operate keyboard sensors to determine if a key has been pressed (or the extent of the press), and provide an indication of press status to a main CPU of the laptop or a response to the press status to a user of the laptop.

While the orientation terminology, vertical-lateral travel, sensing technology, and implementation options discussed here focuses on the keyboard **100**, these discussions are readily analogized to other touchsurfaces and devices described herein.

Various embodiments in accordance with the techniques described herein, including embodiments without metal snap domes or rubber domes, provide force response curves similar to the curve **210** of FIG. **2**. Many tactile keyboard keys utilize snap ratios no less than 0.4 and no more than 0.6.

Other tactile keyboard keys may use snap ratios outside of these ranges, such as no less than 0.3 and no more than 0.5, and no less than 0.5 and no more than 0.7.

Other embodiments provide other response curves having other shapes, including those with force and key travel relationships that are linear or nonlinear. Example nonlinear relationships include those which are piecewise linear, which contain linear and nonlinear sections, or which have constantly varying slopes. The force response curves may also be non-monotonic, monotonic, or strictly monotonic.

For example, the keys **120** made in accordance with the techniques described herein may be configured to provide the response shown by curve **210**, or any appropriate response curve. The reaction force applied to a user may increase linearly or nonlinearly relative to an amount of total key travel, an amount of key travel the press direction, or an amount of key travel in a lateral direction. As a specific example, the force applied may increase with a constant slope relative to the amount of key travel for up to a first amount of force or key movement relative to its unpressed position, and then plateau (with constant force) or decrease for up to a second amount of force or key movement.

FIGS. **3**A-**3**B are simplified cross-sectional views of a first example touchsurface assembly. The key assembly **300** may be used to implement various keys, including the key **122** of the keyboard **100**. In the embodiment where FIGS. **3**A-**3**B depict the key **122**, these figures illustrate A-A' sectional views of the key **122**. FIG. **3**A shows the example key assembly **300** in an unpressed position and FIG. **3**B shows the same key assembly **300** in a pressed position. The key assembly **300** may also be used in other devices utilizing keys, including keyboards other than the keyboard **100** and any other appropriate key-using device. Further, assemblies analogous to the key assembly **300** may be used to enable non-key touchsurface assemblies such as buttons, opaque touchpads, touchscreens, or any of the touchsurface assemblies described herein.

The key assembly **300** includes a keycap **310** that is visible to users and configured to be pressed by users, a ready/return mechanism **320**, and a base **340**. The unpressed and pressed positions of the keycap **310** are spaced in a press direction and in a first lateral direction orthogonal to the press direction. The press direction is analogous to the key motion found in conventional keyboards lacking lateral key motion, is in the negative-Z direction, and is the primary direction of press and key motion. In many keyboards the press direction is orthogonal to the touchsurface of the keycap or the base of the key, such that users would consider the press direction to be downwards toward the base.

The components of the key assembly **300** may be made from any appropriate material, including plastics such as polycarbonate (PC), acrylonitrile butadiene styrene (ABS), nylon, and acetal, metals such as steel and aluminum, elastomers such as rubber, and various other materials. In various embodiments, the keycap **310** is configured to be substantially rigid, such that the touchsurface of the keycap **310** appears to unaided human senses to move with rigid body motion between its unpressed and pressed positions during normal operation.

The ready/return mechanism **320** is a type of "biasing mechanism" that provides both readying and returning functions. The ready/return mechanism **320** physically biases the keycap **310** during at least part of the key press operation. It should be noted that a mechanism which only provides readying or returning function may also be termed a "biasing mechanism," if it biases the keycap **310** during at least part of the key press operation. The ready/return mechanism **320** is configured to hold the keycap **310** in its unpressed position so that the keycap **310** is ready to be pressed by a user. In addition, the ready/return mechanism **320** is also configured to return the keycap **310** partially or entirely to the unpressed position in response to a release of the press force to keycap **310**. The release of the press force may be a removal of the press force, or a sufficient reduction of press force such that the key assembly is able to return the keycap **310** to the unpressed position as a matter of normal operation. In the example embodiment of FIG. **3**, the key assembly **300** utilizes magnetically coupled components **322**, **324** to form the ready/return mechanism **320**. Magnetically coupled components **322**, **324** may both comprise magnets, or one may comprise a magnet while the other comprise a magnetically coupled material such as a ferrous material. Although magnetically coupled components **322**, **324** are each shown as a single rectangular shape, either or both magnetically coupled components **322**, **324** may comprise non-rectangular cross-section(s) or comprise a plurality of magnetically coupled subcomponents having the same or different cross sections. For example, magnetically coupled component **322** or **324** may comprise a magnetic, box-shaped subcomponent disposed against a central portion of a ferrous, U-shaped subcomponent.

In some implementations, the magnetically coupled component **322** is physically attached to a bezel or base proximate to the keycap **310**. The magnetically coupled component **324** is physically attached to the keycap and magnetically interacts with the magnetically coupled component **322**. The physical attachment of the magnetically coupled components **322**, **324** may be direct or indirect (indirectly being through one or more intermediate components), and may be accomplished by press fits, adhesives, or any other technique or combination of techniques. The amount of press force needed on the keycap to overcome the magnetic coupling (e.g., overpower the magnetic attraction or repulsion) can be customized based upon the size, type, shape, and positions of the magnetically coupling components **322**, **324** involved.

The key assembly **300** comprises a planar-translation-effecting (PTE) mechanism **330** configured to impart planar translation to the keycap **310** when it moves between the unpressed and pressed positions, such that a nonzero component of lateral motion occurs. The PTE mechanism **330** is formed from parts of the keycap **310** and the base **340**, and comprises four ramps (two ramps **331**, **332** are visible in FIGS. **3**A-B) disposed on the base **340**. These four ramps are located such that they are proximate to the corners of the keycap **310** when the key assembly **300** is assembled. In the embodiment shown in FIGS. **3**A-B, these four ramps (including ramps **331**, **332**) are simple, sloped planar ramps located at an angle to the base **340**. These four ramps (including ramps **331**, **332**) are configured to physically contact corresponding ramp contacting features (two ramp contacting features **311**, **312** are visible in FIGS. **3**A-B) disposed on the underside of the keycap **310**. The ramp contacting features of the keycap **310** may be any appropriate shape, including ramps matched to those of the ramps on the base **340**.

In response to a press force applied to the touchsurface of the keycap **310** downwards along the press direction, the ramps on the base **340** (including ramps **331**, **332**) provide reaction forces. These reaction forces are normal to the ramps and include lateral components that cause the keycap **310** to exhibit lateral motion. The ramps and some retention or alignment features that mate with other features in the bezel or other appropriate component (not shown) help retain and level the keycap **310**. That is, they keep the keycap **310** from separating from the ramps and in substantially the same orientation when travelling from the unpressed to the pressed position.

As shown by FIGS. **3**A-B, the keycap **310** moves in the press direction (negative Z-direction) in response to a sufficiently large press force applied to the top of the keycap **310**. As a result, the keycap **310** moves in a lateral direction (in the positive X-direction) and in the press direction (in the negative Z-direction) due to the reaction forces associated with the ramps. The ramp contacting features (e.g., **311**, **312**) of the keycap **310** ride on the ramps of the base **340** (e.g., **331**, **332**) as the keycap **310** moves from the unpressed to the pressed position. This motion of the keycap **310** moves the magnetically coupled components **322**, **324** relative to each other, and changes their magnetic interactions.

FIG. **3**B shows the keycap **310** in the pressed position. For the key assembly **300**, the keycap **310** has moved to the pressed position when it directly or indirectly contacts the base **340** or has moved far enough to be sensed as a key press. FIG. **3**A-B do not illustrate the sensor(s) used to detect the press state of the keycap **310**, and such sensor(s) may be based on any appropriate technology, as discussed above.

When the press force is released, the ready/return mechanism **320** returns the keycap **310** to its unpressed position. The attractive forces between the magnetically coupled components **322**, **324** pull the keycap **310** back up the ramps (including the ramps **331**, **322**), toward the unpressed position.

Many embodiments using magnetic forces utilize permanent magnets. Example permanent magnets include, in order of strongest magnetic strength to the weakest: neodymium iron boron, samarium cobalt, alnico, and ceramic. Neodymium-based magnets are rare earth magnets, and are very strong magnets made from alloys of rare earth elements. Alternative implementations include other rare earth magnets, non-rare earth permanent magnets, and electromagnets.

Although the key assembly **300** utilizes magnetically coupled components to form its ready/return mechanism **320**, various other techniques can be used instead or in addition to such magnetic techniques in other embodiments. In addition, separate mechanisms may be used to accomplish the readying and returning functions separately. For example, one or more mechanisms may retain the keycap in its ready position and one or more other mechanisms may return the keycap to its ready position. Examples of other readying, returning, or ready/return mechanisms include buckling elastomeric structures, snapping metallic domes, deflecting plastic or metal springs, stretching elastic bands, bending cantilever beams, and the like. In addition, in some embodiments, the ready/return mechanism push (instead of pull) the keycap **310** to resist keycap motion to the pressed position or to return it to the unpressed position. Such embodiments may use magnetic repulsion or any other appropriate technique imparting push forces.

Many variations of or additions to the components of the key assembly **300** are possible. For example, other embodiments may include fewer or more components. As a specific example, another key assembly may incorporate any number of additional aesthetic or functional components. Some embodiments include bezels that provide functions such as hiding some of the key assembly from view, protecting the other components of the key assembly, helping to retain or guide the touchsurface of the key assembly, or some other function.

As another example, other embodiments may comprise different keycaps, readying mechanisms, returning mechanisms, PTE mechanisms, leveling mechanisms, or bases. As a specific example, the keycap **310**, the base **340**, or another component that is not shown may comprise protrusions, depressions, or other features that help guide or retain the keycap **310**. As another specific example, some embodiments use non-ramp techniques in place or (or in addition to) ramps to effect planar translation. Examples other PTE mechanisms include various linkage systems, cams, pegs and slots, bearing surfaces, and other motion alignment features.

As yet another example, although the PTE mechanism **330** is shown in FIGS. **3**A-B as having ramps disposed on the base **340** and ramp contacting features disposed on the keycap **310**, other embodiments may have one or more ramps disposed on the keycap **310** and ramp contacting features disposed on the base **340**. Also, the PTE mechanism **330** is shown in FIGS. **3**A-B as having ramps **331**, **332** with simple, sloped plane ramp profiles. However, in various embodiments, the PTE mechanism **330** may utilize other profiles, including those with linear, piecewise linear, or nonlinear sections, those having simple or complex curves or surfaces, or those including various convex and concave features. Similarly, the ramp contacting features on the keycap **310** may be simple or complex, and may comprise linear, piecewise linear, or nonlinear sections. As some specific examples, the ramp contacting features may comprise simple ramps, parts of spheres, sections of cylinders, and the like. Further, the ramp contacting features on the keycap **310** may make point, line, or surface contact the ramps on the base **340** (including ramps **331**, **332**). "Ramp profile" is used herein to indicate the contour of the surfaces of any ramps used for the PTE mechanisms. In some embodiments, a single keyboard may employ a plurality of different ramp profiles in order to provide different tactile responses for different keys.

As a further example, embodiments which level their touchsurfaces may use various leveling techniques which use none, part, or all of the associate PTE mechanism.

FIG. **4** shows an exploded view of an example keyboard construction **400** in accordance with the techniques described herein. A construction like the keyboard construction **400** may be used to implement any number of different keyboards, including keyboard **100**. Proceeding from the top to the bottom of the keyboard, the bezel **420** comprises a plurality of apertures through which keycaps **410** of various sizes are accessible in the final assembly. Magnetically coupled components **422**, **424** are attached to the keycaps **410** or the base **440**, respectively. The base **440** comprises a plurality of PTE mechanisms (illustrated as simple rectangles on the base **440**) configured to guide the motion of the keycaps **410**. Underneath the base **440** is a key sensor **450**, which comprises one or more layers of circuitry disposed on one or more substrates.

Various details have been simplified for ease of understanding. For example, one or more of the substrates may be laminated or otherwise bonded together. In FIG. **4**, adhesives that may be used to bond components together are not shown. Additionally, on some of the substrates may be a combination of layers (for example three layers) laminated or bonded together. Also, various embodiments may have more or fewer components than shown in keyboard construction **400**, or the components may be in a different order. For example, the base and the key sensor **450** may be combined into one component, or swapped in the stack-up order.

FIGS. **5**A-B are cross-sectional side views of a key assembly **500** in accordance with an embodiment. FIG. **5**A illustrated the key assembly **500** in an unpressed (or ready) position and FIG. **5**B shows the key assembly in the pressed position. As can be seen, in the pressed position, the keycap **502** of the key assembly **500** has moved in a press direction (Z direction) and also translated in a second direction (X direction) orthogonal to the press direction via a planar translation effecting mechanism that includes laminated key guides as will be explained below.

The key assembly **500** comprises a keycap **502** having a touch surface **504** that may receive a press force from a user. A base **506** interacts with the keycap **502** to form the planar translation effecting (PTE) mechanism, which is comprised of several layers of the substrate stack-up. The top layer (in the Z direction) is a bezel or cover layer **508**. Under the bezel **508** is a spacer layer **510**, a key guide layer **512**, a second spacer **514**, a sensor layer **516** and a bottom plate or cover **518**. According to fundamental embodiments, some or all of these layers are laminated together to form the PTE mechanism. In some embodiments, the key guide layer **512** includes a flexible portion **526** that flexes during movement of the keycap **502** toward the pressed position.

In the embodiment shown in FIGS. **5**A-B, a portion of the laminated key guide layer **512** is cantilevered from the laminated substrate stack-up into a space formed for the keycap when moving from the unpressed to the pressed position and forms a key guide surface **520**, which is part of the PTE mechanism. The key guide surface **520** may be in the shape of an arc or ramp or other configuration as desired for any particular implementation. The key guide surface **520** may be formed through a variety of conventional processes, including, without limitation, thermoforming, bending, embossing, cutting, punching, machining, and the like. Another portion of the key guide layer **512** provide an intermediate laminated key guide **522** having a key guide surface **524** that operates in the same manner as key guide surface **520**. A portion **526** of the intermediate laminated key guide **522** is flexible and engages the keycap **502** along a surface **528** and operates to bias the keycap **502** toward the key guide surface **520** in the event the keycap is pressed off-center. Thus, the flexible portion **526** provides a reverse ramp function for the PTE mechanism.

The key assembly **500** also includes a ready-return mechanism **530**, which comprises a first magnetic component **532** and a second magnetic component **534**. In some embodiments, both the first magnetic component **532** and the second magnetic component **534** are magnets. Non-limiting examples of magnets include neodymium iron boron, samarium cobalt, alnico and ceramic magnets. In some embodiments, one of the first magnetic component **532** or the second magnetic component **534** consists of a non-magnetic ferrous material, while the other magnetic component is a magnet. Non-limiting examples of non-magnetic ferrous material includes steel (including some stainless steels), iron and nickel. In the unpressed position, the magnetic attraction between the first magnetic component **532** and the second magnetic component **534** maintains the keycap **502** in the ready position (i.e., ready to be pressed).

Upon the application of a press force sufficient to overcome the magnetic attraction of the ready-return mechanism **530**, the keycap **502** moves in the press direction toward the pressed position as shown in FIG. **5**B. As the keycap moves along the key guide surfaces **520** and **524**, the keycap **502** also translates in a second direction orthogonal to the press direction (the X direction) and moves into a space **536** as the keycap **502** moves toward the pressed position. As the keycap **502** nears the pressed position, the sensor layer **516** can produce a signal indicating that the keycap **502** of the key assembly **500** has been pressed.

The sensor layer **516** may use any appropriate technology, including any of the ones described herein. In some embodiments, the sensor layer **516** detects changes in capacitance, the keycap **502** comprises primarily dielectric material, and the change in the position of the dielectric material of the keycap **502** causes the primary changes in capacitance detected by the sensor layer **516**. In some embodiments, the sensor layer **516** detect changes in capacitance, conductive material is disposed in or on the keycap **502**, and the change in position of the conductive material of the keycap **502** causes the primary changes in capacitance detected by the sensor layer **516**. In some embodiments, the senor layer **516** is configured to actively detect unpressed and pressed positions of the keycap **502**. In some embodiments, the sensor layer **516** is configured to actively detect only the pressed state of the keycap **502**, and it is assumed that no detection of the pressed state means the keycap **502** is unpressed, or vice versa. A processing system (not shown) communicatively coupled to the sensor layer **516** operates the sensor layer **516** to produce signals indicative of the pressed state of the key assembly, and determines a press state of the keycap **502** based on these signals. Upon removal of the press force **534**, the magnetic attraction of the ready-return mechanism **530** draws the keycap back toward the unpressed (ready) position.

FIG. **6**A-B are cross-sectional side views of a key assembly **600** in accordance with an embodiment. In this embodiment, a portion of the spacer layer **514** and the sensor layer **516** have been extended to contact and support the key guide layer **512**. It will be appreciated at more or fewer of the laminated substrate stack-up can be used to support the key guide layer **512** depending upon the actual implementation realized.

FIG. **7** are cross-sectional side views of a key assembly **700** in accordance with an embodiment. In this embodiment, the flexible portion **526** of the intermediate key guide **522** and the contact surface **528** of the keycap **502** have been configured to provide an up-stop feature. The up-stop feature cushions the keycap **502** in the unpressed position and dampens the impact of the keycap **502** against the bezel **508** when returning to the unpressed position. The flexible portion **526** of the intermediate key guide **522** is compressed by the contact surface **528** of the keycap **502** when the keycap **502** is in, or returns to, the unpressed position.

FIG. **8** illustrate additional features that provide various advantages to the key assembly **800**. In some embodiments, the keycap **502** is provided with a protrusion **802** which may be formed of conductive material to facilitate the sensor layer **516** detecting the keycap **502** approaching the pressed position. In some embodiments, the protrusion **802** which may be formed of elastomeric material to provide an end-stop feature to cushions the keycap **502** as it reaches the pressed position. In other embodiments, the protrusion **802** which may be formed of elastomeric material to provide an end-stop feature, but have a conductive layer applied to a surface **804** to facilitate the sensor layer **516** detecting the keycap **502** approaching the pressed position. In some embodiments, a conductive layer may be applied to a bottom surface **806** of the keycap **502**. For example, the conductive layer may be conductive tape, a conductive inlay or conductive material sprayed or plated on the bottom surface **806**. In still other embodiments, an elastomeric material **808** on the base **506** can provide the end-stop feature to cushions the keycap **502** as it reaches the pressed position. As will be appreciated, some or all of the features may be combined in any way desired for any particular implementation.

Thus, the techniques described herein can be used to implement any number of devices utilizing different touch-surface assemblies, including a variety of keyboards each comprising one or more key assemblies in accordance with the techniques described herein. Some components may be shared when multiple touchsurfaces are placed in the same device. For example, the base may be shared by two or more touchsurfaces. As another example, the sensor layer may be shared by a plurality of key assemblies formed into a keypad or keyboard.

The implementations described herein are meant as examples, and many variations are possible. As one example, any appropriate feature described with one implementation may be incorporated with another. As a first specific example, any of the implementations described herein may or may not utilize a finishing tactile, aesthetic, or protective layer. As a second specific example, ferrous material may be used to replace magnets in various magnetically coupled component arrangements.

In addition, the structure providing any function may comprise any number of appropriate components. For example, a same component may provide leveling, planar translation effecting, readying, and returning functions for a key press. As another example, different components may be provide these functions, such that a first component levels, a second component effects planar translation, a third component readies, and a fourth component returns. As yet another example, two or more components may provide a same function. For example, in some embodiments, magnets and springs together provide the return function, or the ready and return functions. Thus, the techniques described in the various implementations herein may be used in conjunction with each other, even where the function may seem redundant. For example, some embodiments use springs to back-up or augment magnetically-based ready/return mechanisms.

What is claimed is:

1. A key assembly, comprising:

a keycap having a touch surface for receiving a press force that moves the keycap from an unpressed position toward a pressed position, the unpressed position and pressed position separated in a press direction and a second direction orthogonal to the press direction; and

a base having a laminated key guide contacting a portion of the keycap to provide a planar translation effecting mechanism to guide the keycap in the press direction and the second direction as the keycap moves from the unpressed position toward the pressed position, the laminated key guide comprising a flexible portion, the flexible portion engaging an interior surface of the keycap.

2. The key assembly of claim **1**, wherein:

the keycap includes a first magnetic component;

the base includes a second magnetic component;

the first and second magnetic components form a ready-return mechanism that biases the keycap toward the unpressed position.

3. The key assembly of claim **2**, wherein at least one of the first and second magnetic components comprises a non-magnetized ferrous material.

4. The key assembly of claim **1**, wherein the laminated key guide comprises laminated substrates from the group of substrates; spacer layers; sensor layers, backlight layer and key guide layer.

5. The key assembly of claim **4**, wherein at least some of the substrates are rigid.

6. The key assembly of claim **5**, wherein at least a portion of the key guide layer is the flexible portion.

7. The key assembly of claim **5**, wherein one or more of the substrates contact the key guide layer to support the key guide layer.

8. The key assembly of claim **4**, wherein the flexible portion is configured to provide an up-stop feature to dampen the keycap when returning to the unpressed position.

9. The key assembly of claim **1**, wherein the base includes a protrusion to provide an end-stop feature to dampen the keycap when reaching the pressed position.

10. The key assembly of claim **1**, wherein the keycap includes a protrusion to provide an end-stop feature to dampen the keycap when reaching the pressed position.

11. The key assembly of claim **1**, further comprising a capacitive sensor for sensing when the keycap is in the pressed position.

12. The key assembly of claim **11**, wherein the keycap includes a conductive protrusion to provide a change in capacitance detectable by the capacitive sensor.

13. The key assembly of claim **11**, wherein the keycap includes a protrusion having a conductive coating to provide a change in capacitance detectable by the capacitive sensor.

14. A keyboard comprising:

a plurality of keycaps, each keycap of the plurality of keycaps having a touch surface for receiving a press force that moves the keycap from an unpressed position toward a pressed position, the unpressed position and pressed position separated in a press direction and a second direction orthogonal to the press direction; and

a base having a laminated key guide contacting a portion of the plurality of keycaps to provide a planar translation effecting mechanism for the keycaps, wherein when the press force being applied to a respective keycap of the plurality of keycaps the laminated key guide guides the respective keycap in the press direction and the second direction as the respective keycap moves toward the pressed position, the laminated key guide comprising a flexible portion, the flexible portion engaging an interior surface of the keycap.

15. The keyboard of claim **14**, wherein, for each keycap of the plurality of the keycaps:

the keycap includes a first magnetic component;

the base includes a second magnetic component; and

the first and second magnetic components form a ready-return mechanism that biases the keycap towards the unpressed position.

16. The keyboard of claim **14**, wherein the laminated key guide comprises laminated substrates from the group of substrates; spacer layers; sensor layer, backlight layer and key guide layer.

17. The keyboard of claim **14**, wherein a portion of the laminated key guide is configured to provide an up-stop feature to dampen the respective keycap when returning to the unpressed position.

18. The keyboard of claim **14**, further comprising capacitive sensor electrodes for sensing when the respective keycap of the plurality of keycaps is in the pressed position.

19. The keyboard of claim **18**, wherein each keycap of the plurality of keycaps includes a conductive protrusion to provide a change in capacitance detectable by the capacitive sensor electrodes.

20. A method of effecting motion of a keycap of a key assembly, wherein the keycap is supported in an unpressed position by a laminated key guide of a base of the key assembly, the keycap configured to move between the unpressed position and a pressed position relative to a base, the laminated key guide comprising a flexible portion, the flexible portion engaging an interior surface of the keycap, wherein the unpressed and pressed positions are separated in a press direction and in a second direction orthogonal to the press direction, the method comprising:

in response to a press input to the keycap, guiding the keycap in the press direction and the second direction as the keycap moves toward the pressed position.

21. The method of claim **20**, further comprising:

in response to a release of the press input, guiding the keycap toward the unpressed position via magnetic forces of a ready-return mechanism.

* * * * *