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Olodort et al.

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(45) **Date of Patent: Sep. 28, 2004**

(54) **MOBILE COMPUTER WITH FOLDABLE KEYBOARD**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/254,721**

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Related U.S. Application Data

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(51) **Int. Cl.**[7] **G06F 1/16**

(52) **U.S. Cl.** .... **361/683**; 361/680; 455/575.1; 400/82; 400/693; 312/223.1; 345/905; 235/61 R

(58) **Field of Search** .... 361/680–686; 455/566, 575.1, 575.2, 557, 90, 546, 575; 400/82, 489, 691–693, 488; 345/168, 905, 169; 312/223.1–223.6; 235/61 R, 462.01, 375

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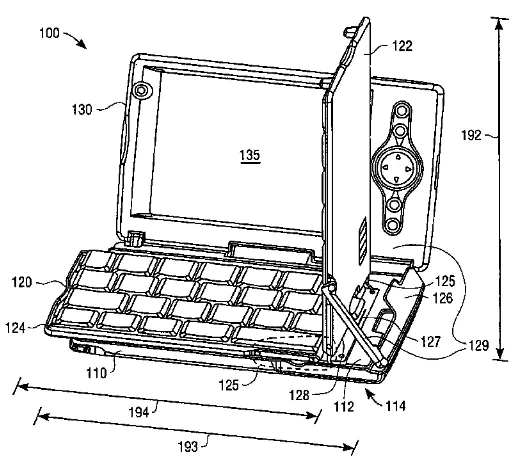
(57) **ABSTRACT**

A digital processing device including a base, a display assembly, a hinge assembly, and a foldable keyboard is described. The hinge assembly enables the back of the display assembly to be rotated between a first configuration and a second configuration. In the first configuration, the user may interact with the device in a similar manner as a PDA. In the second configuration, the hinge assembly enables the unfolding of the keyboard assembly so that it is accessible to the user to enter information by typing and the display assembly is positioned for viewing of information. The keyboard assembly unfolds to form a full-size keyboard (e.g., conformance with an ISO 9241–4:1998(E) standard) that allows a user to comfortably, quickly, and accurately "touch-type" in a manner that the user may be accustomed to. The base may be rigid to enable use of the keyboard assembly on soft or uneven surfaces.

44 Claims, 28 Drawing Sheets



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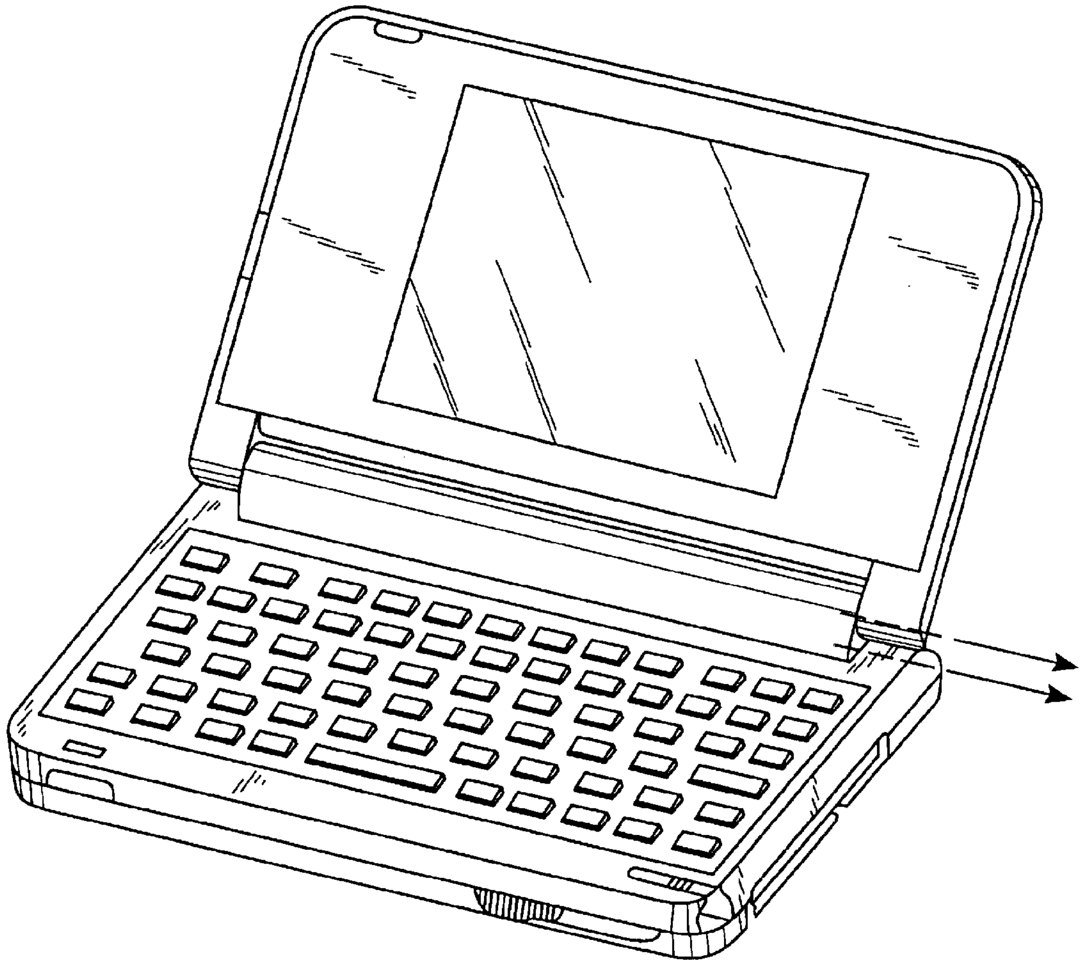

FIG. 1A

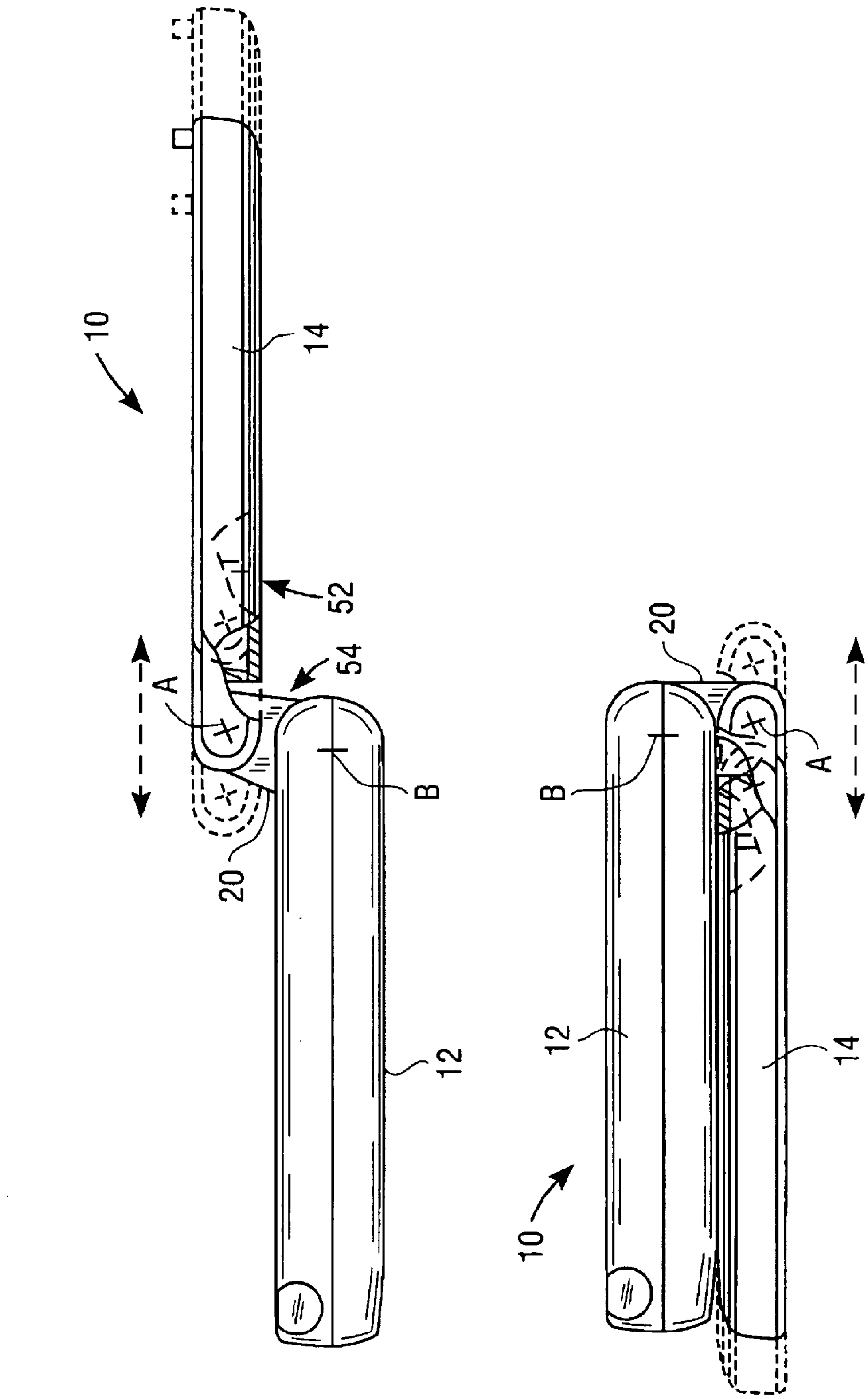

FIG. 1B

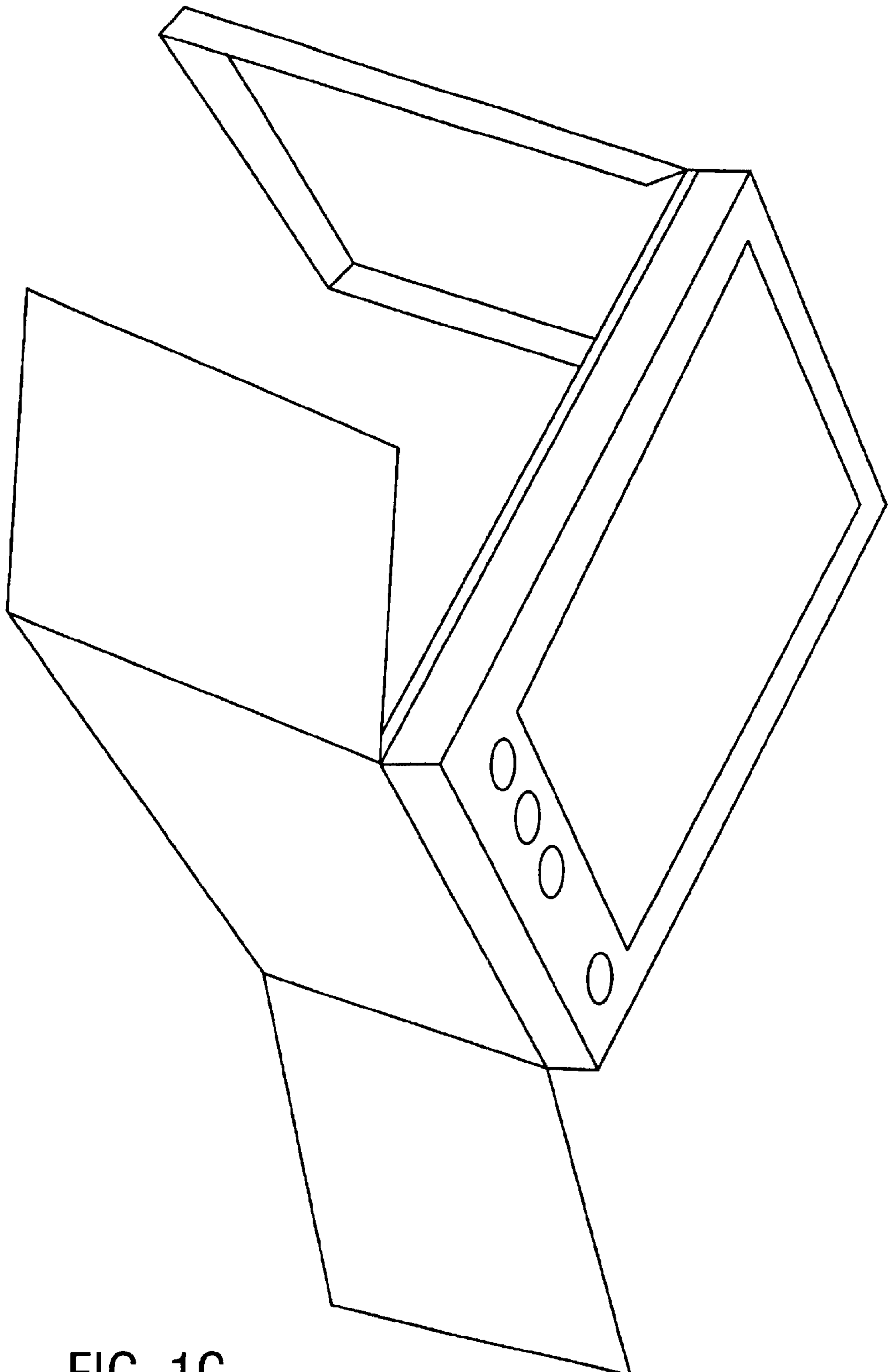

FIG. 1C

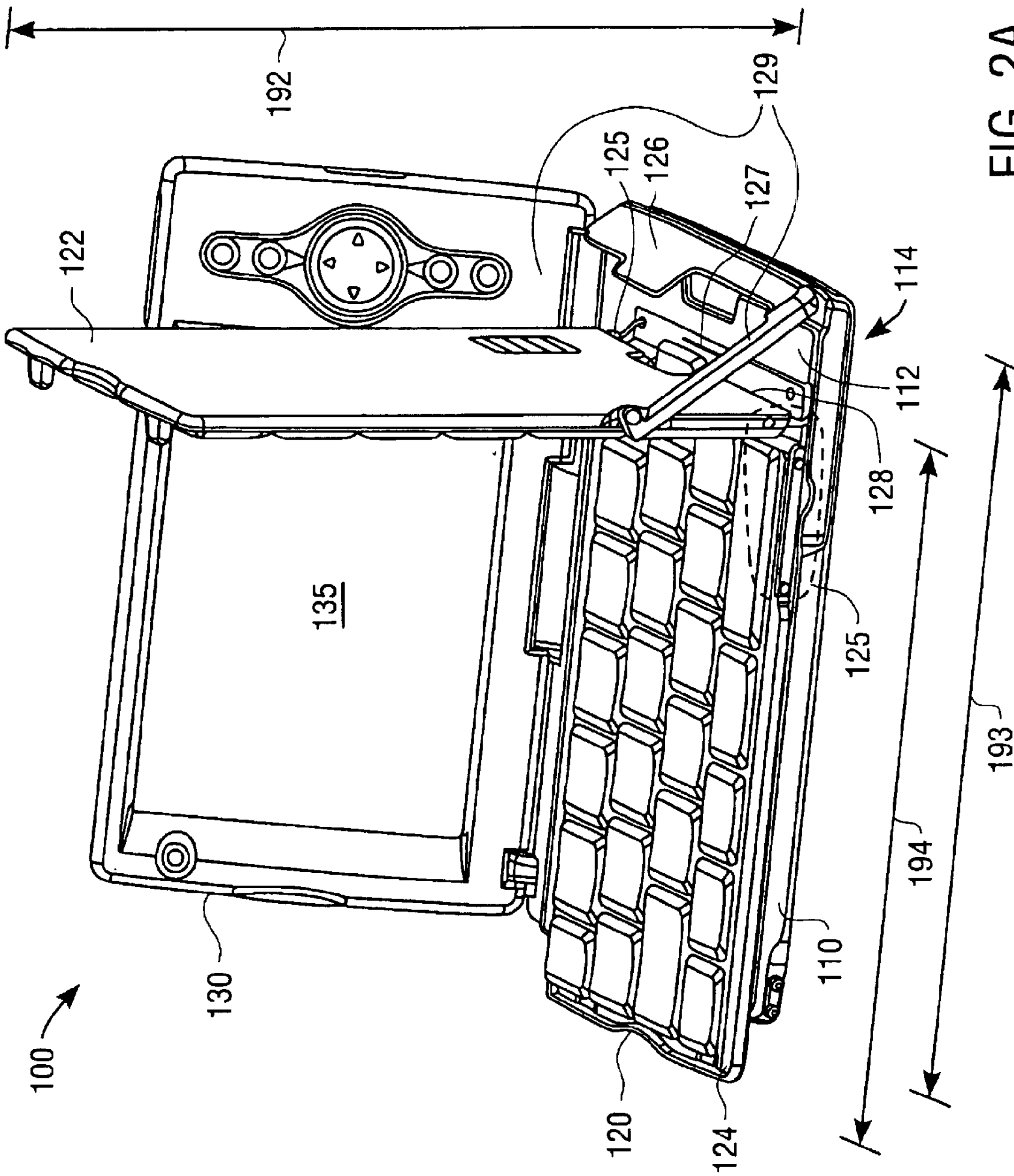
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FIG. 2A

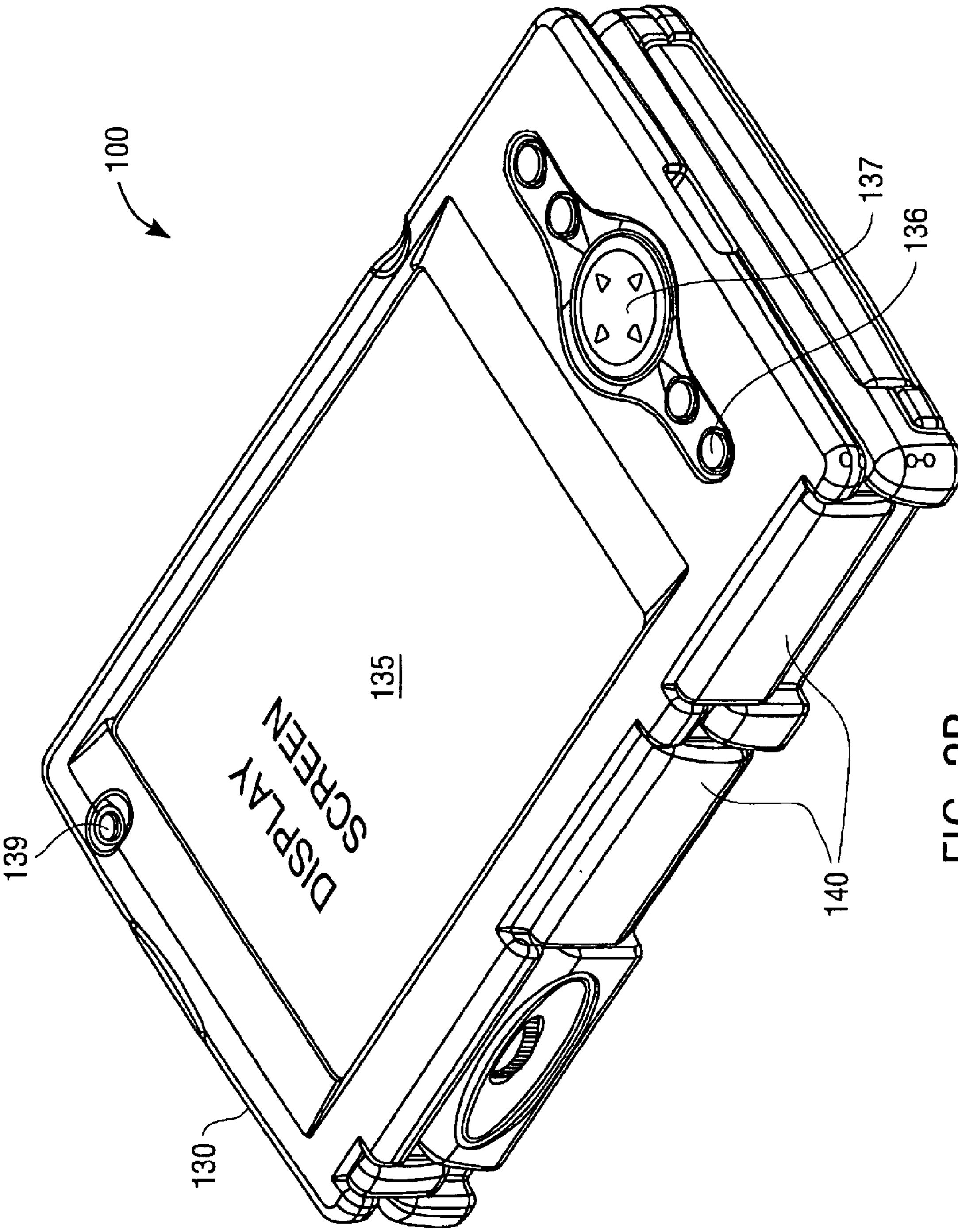
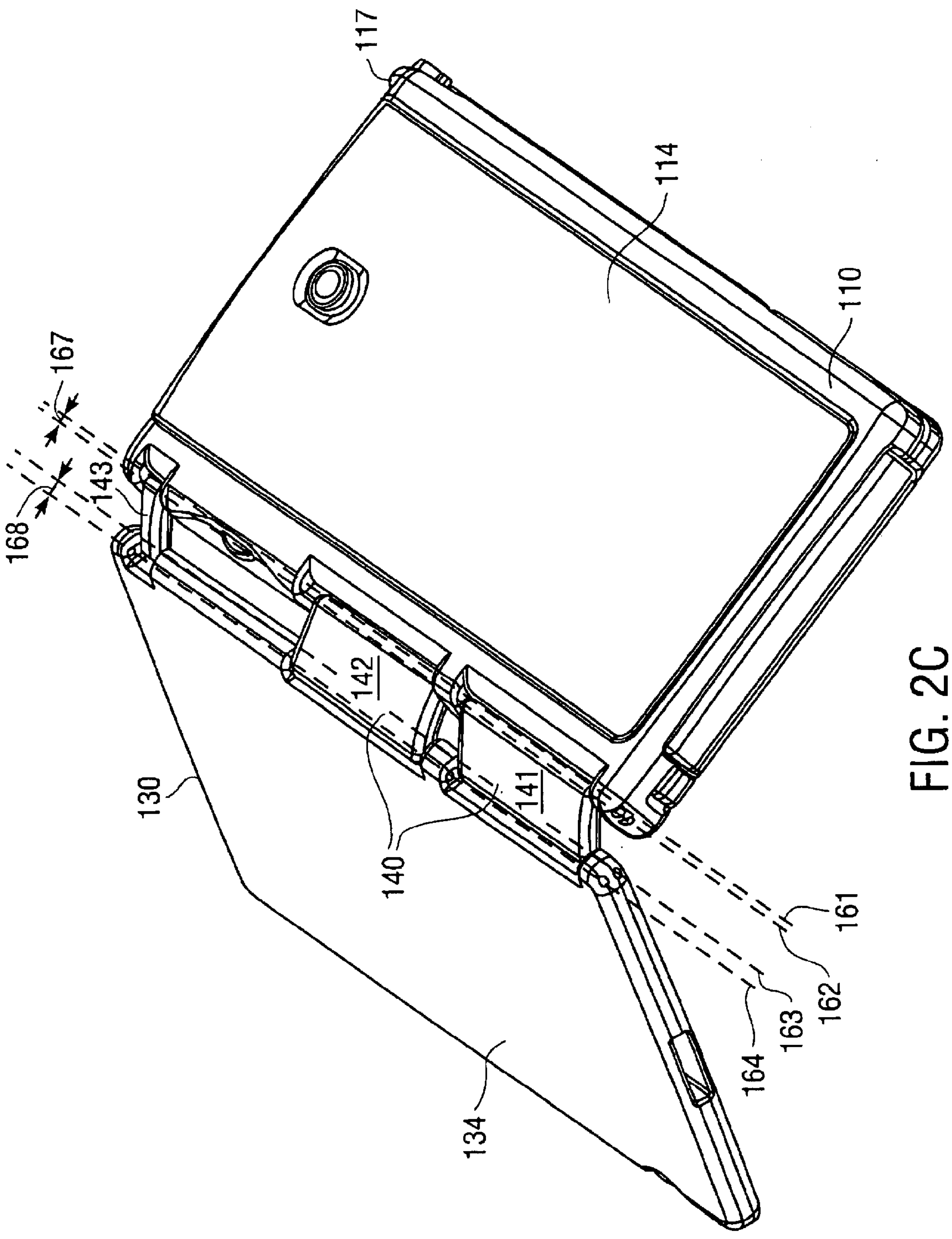


FIG. 2B



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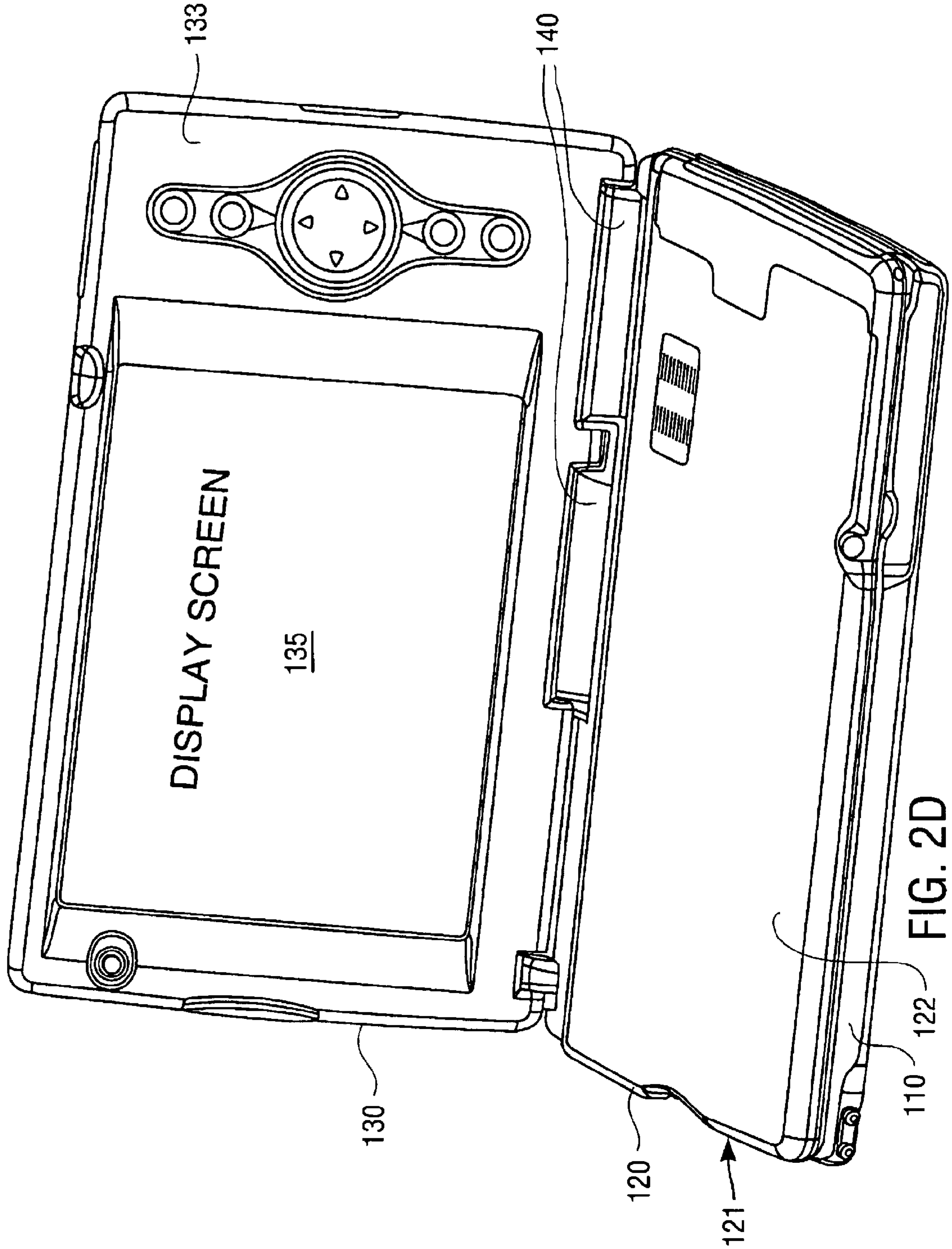

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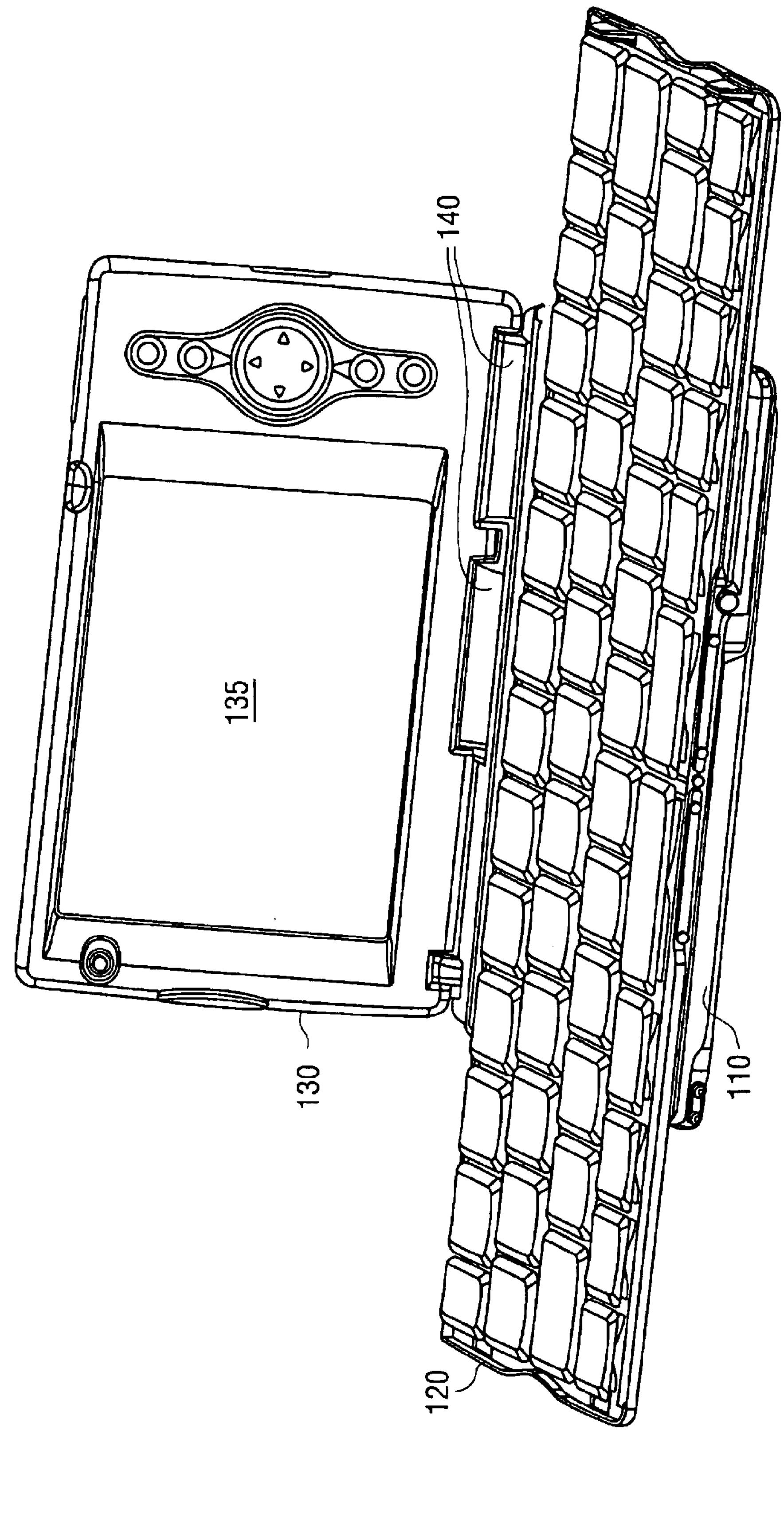
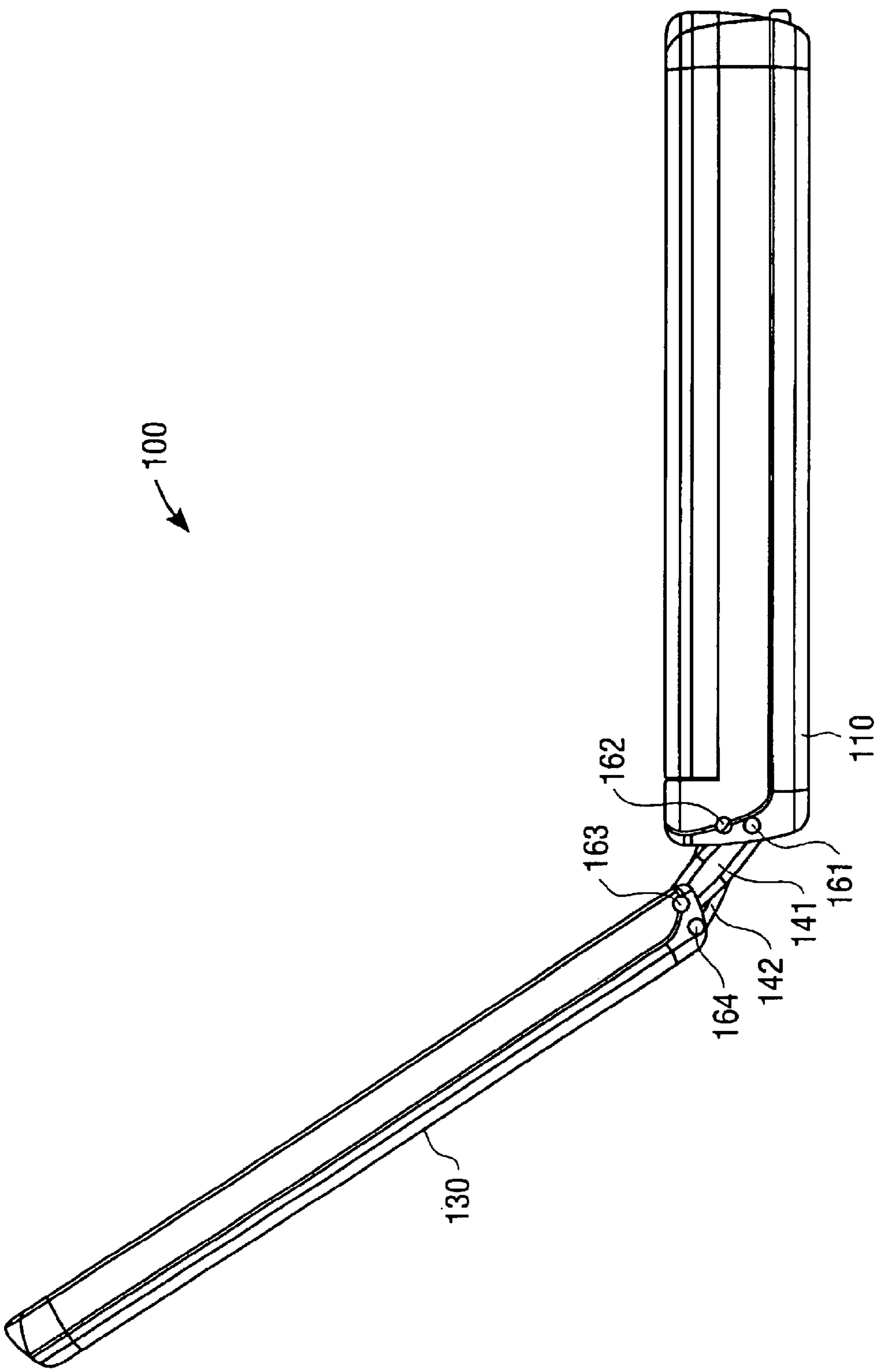


FIG. 2E



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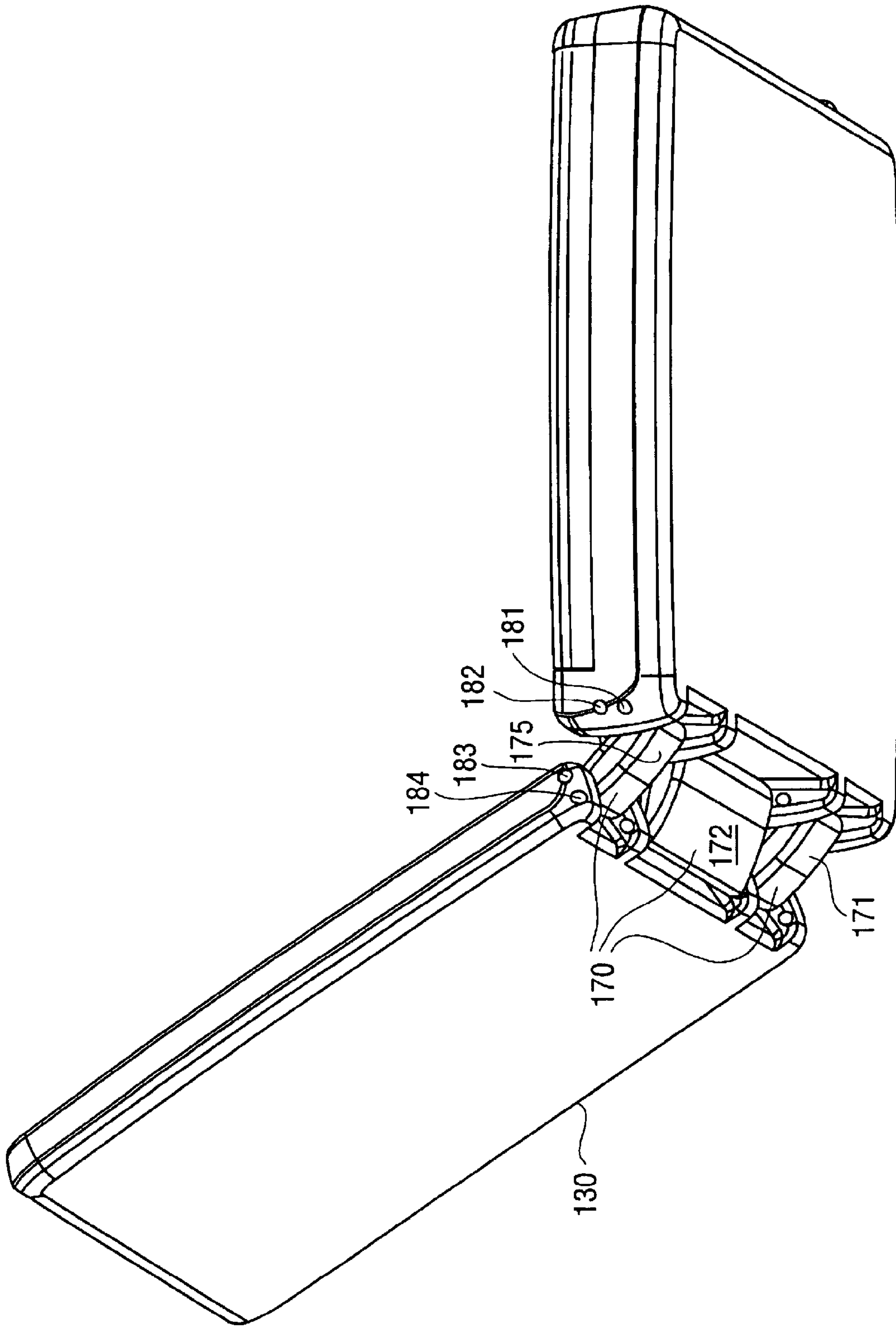

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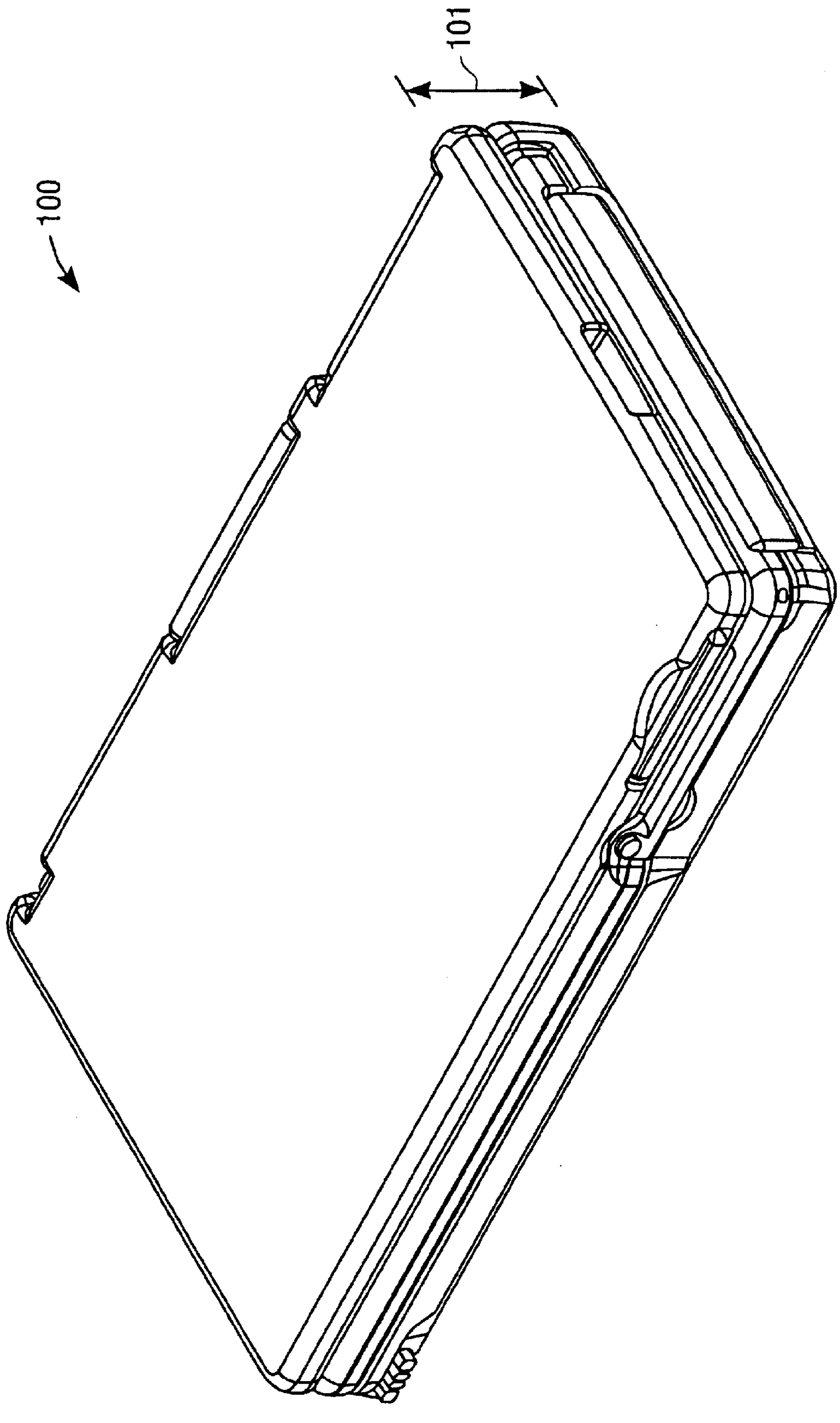
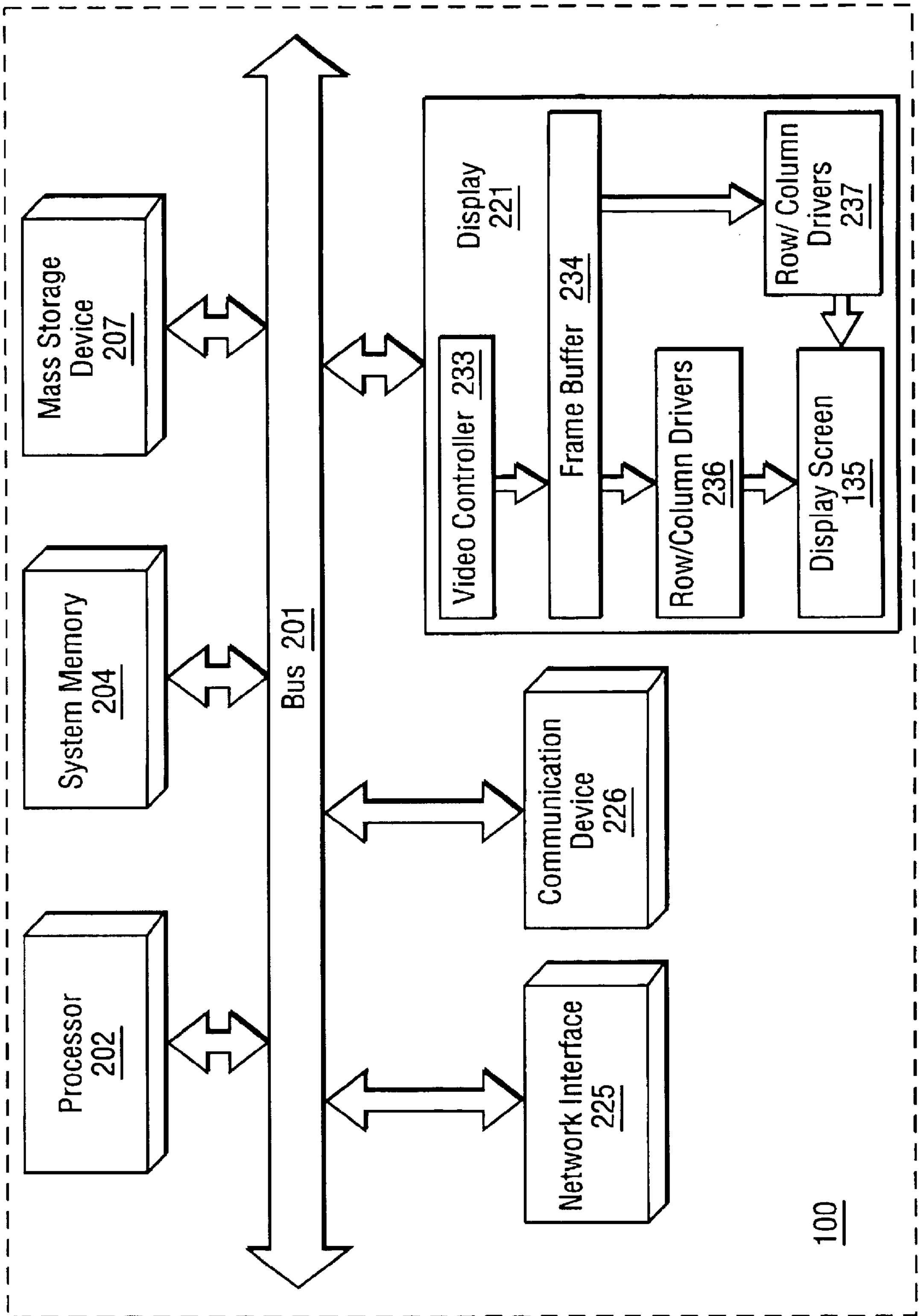


FIG. 2H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System Memory 204
Processor 202
Bus 201
Display 221
Video Controller 233
Frame Buffer 234
Row/Column Drivers 236
Row/ Column Drivers 237
Display Screen 135
Communication Device 226
Network Interface 225
100

FIG. 2I

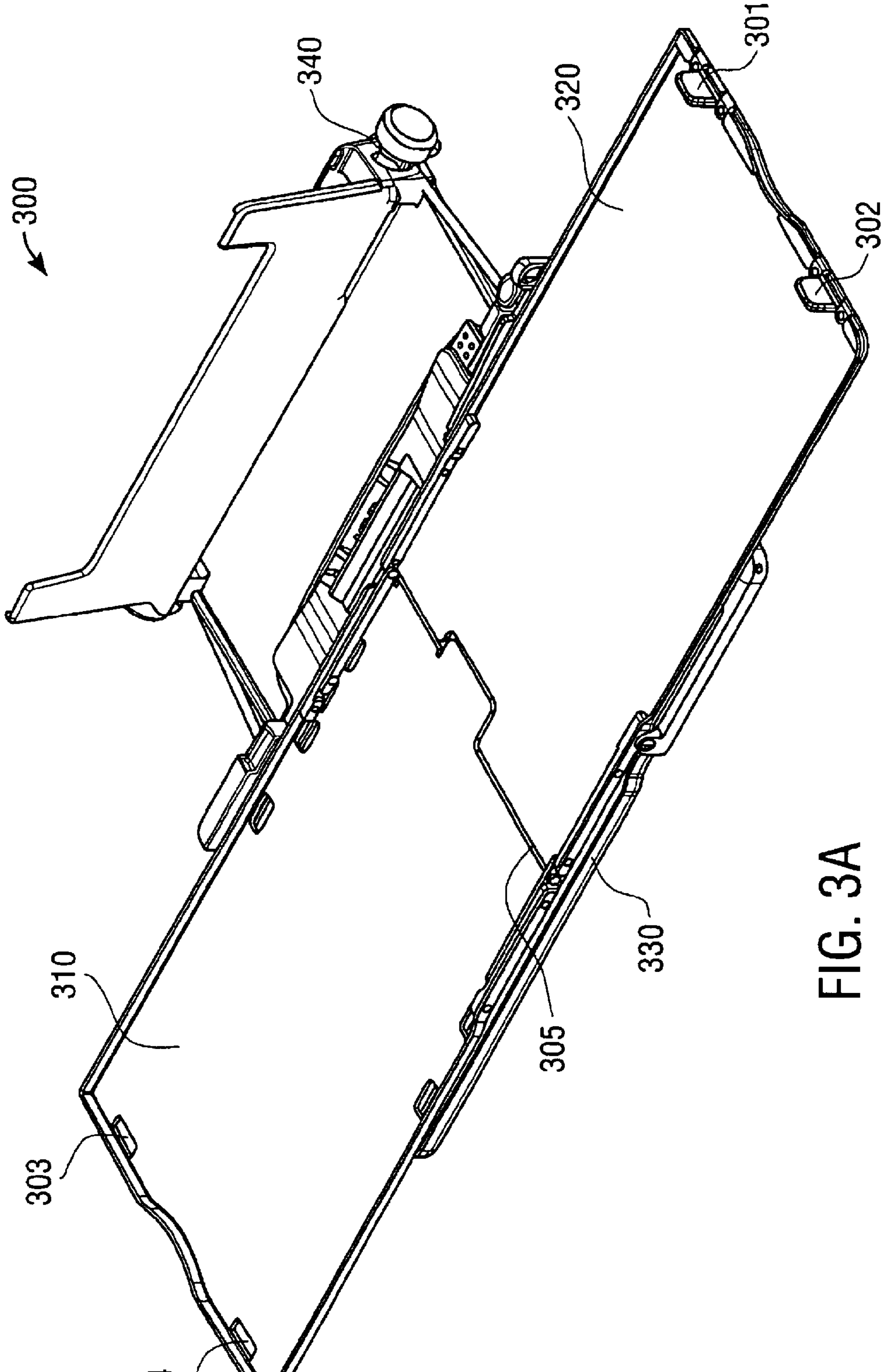

FIG. 3A

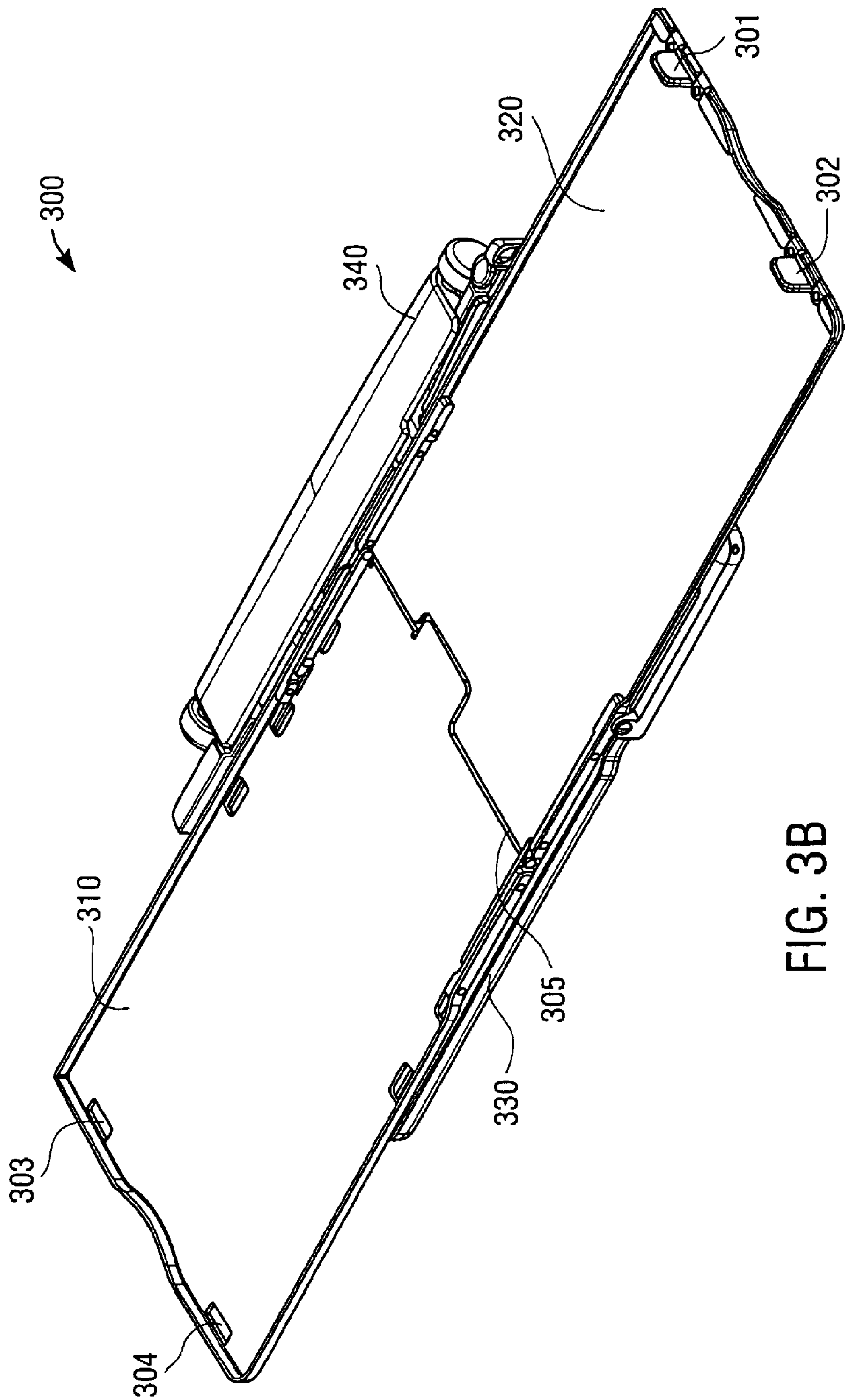

FIG. 3B

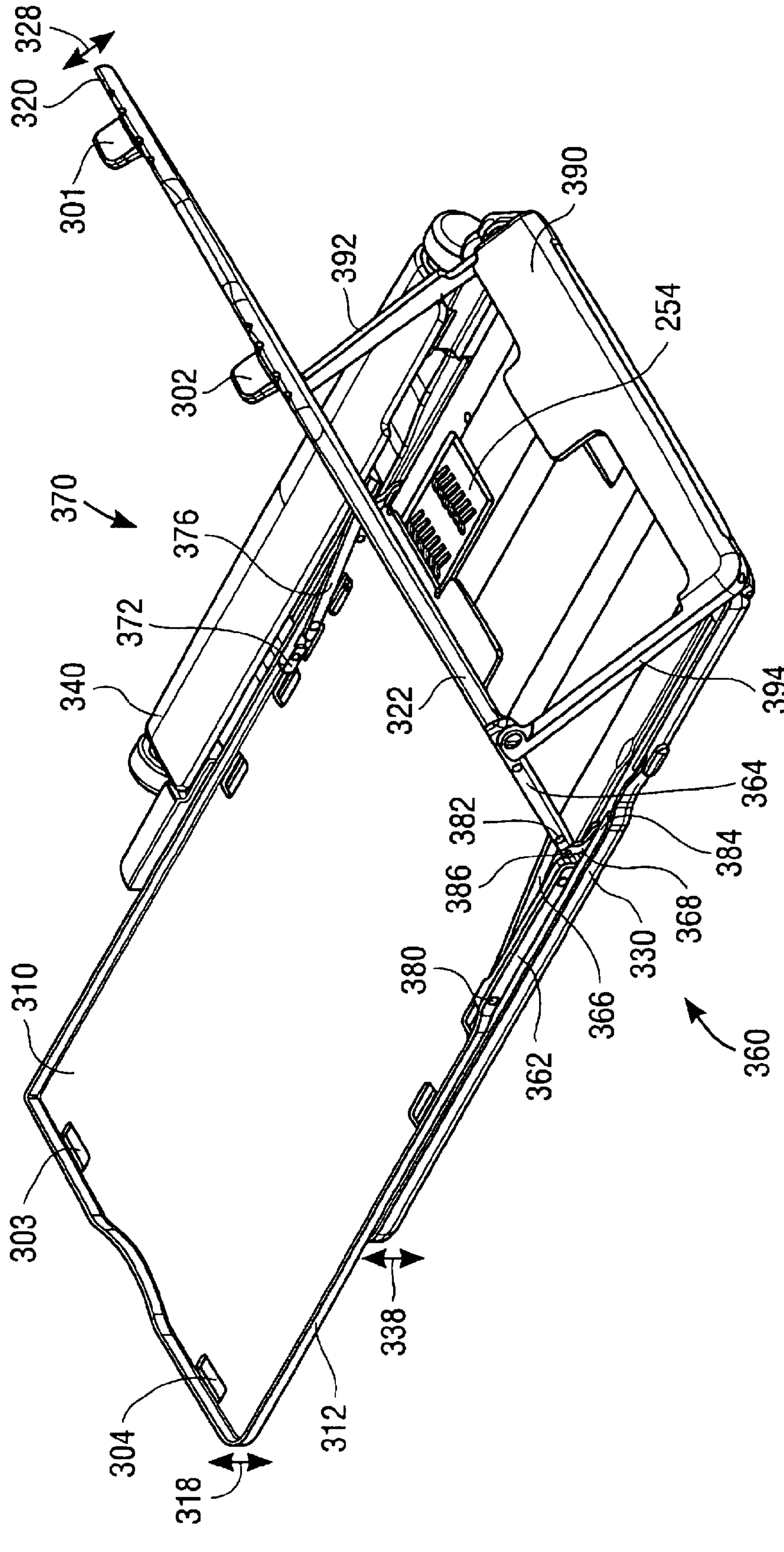
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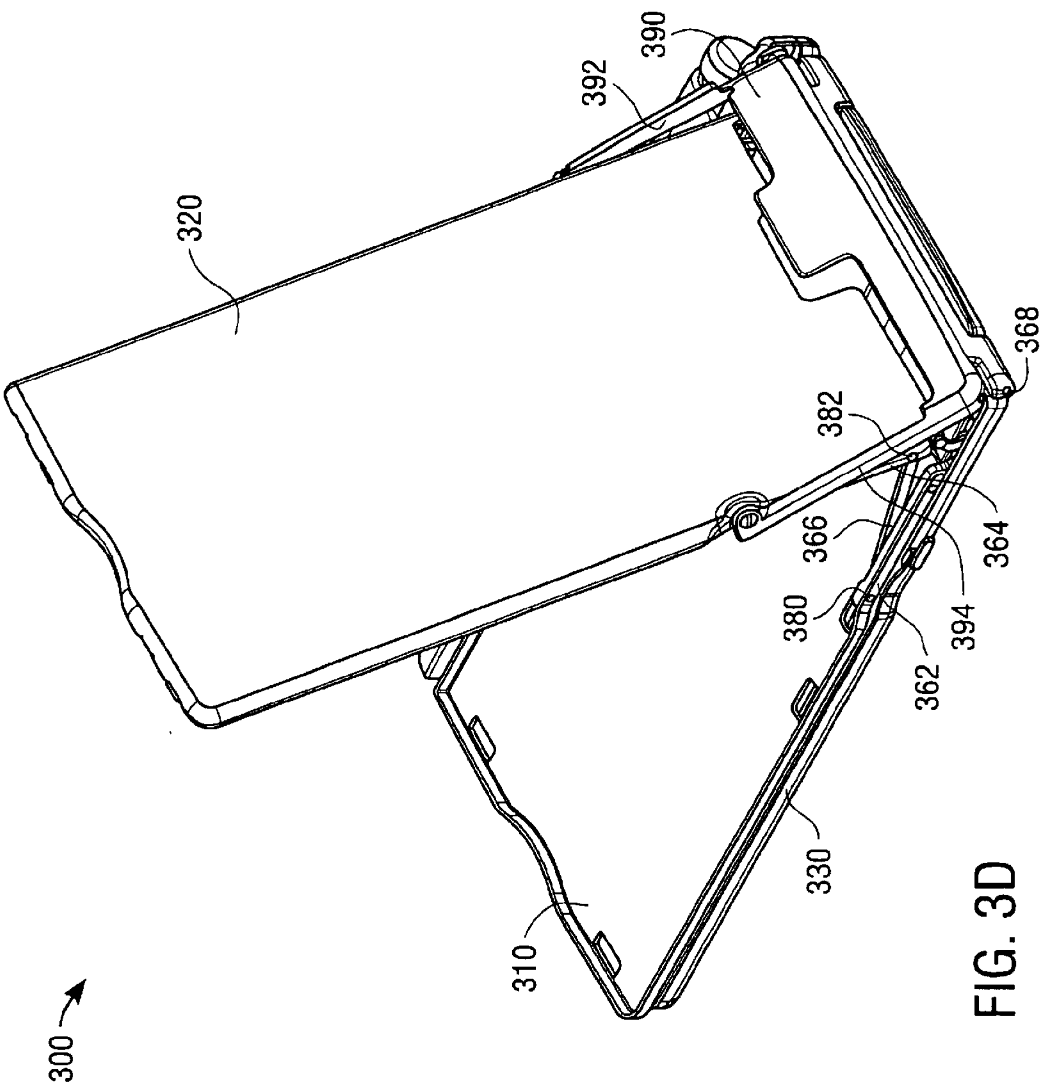
FIG. 3C



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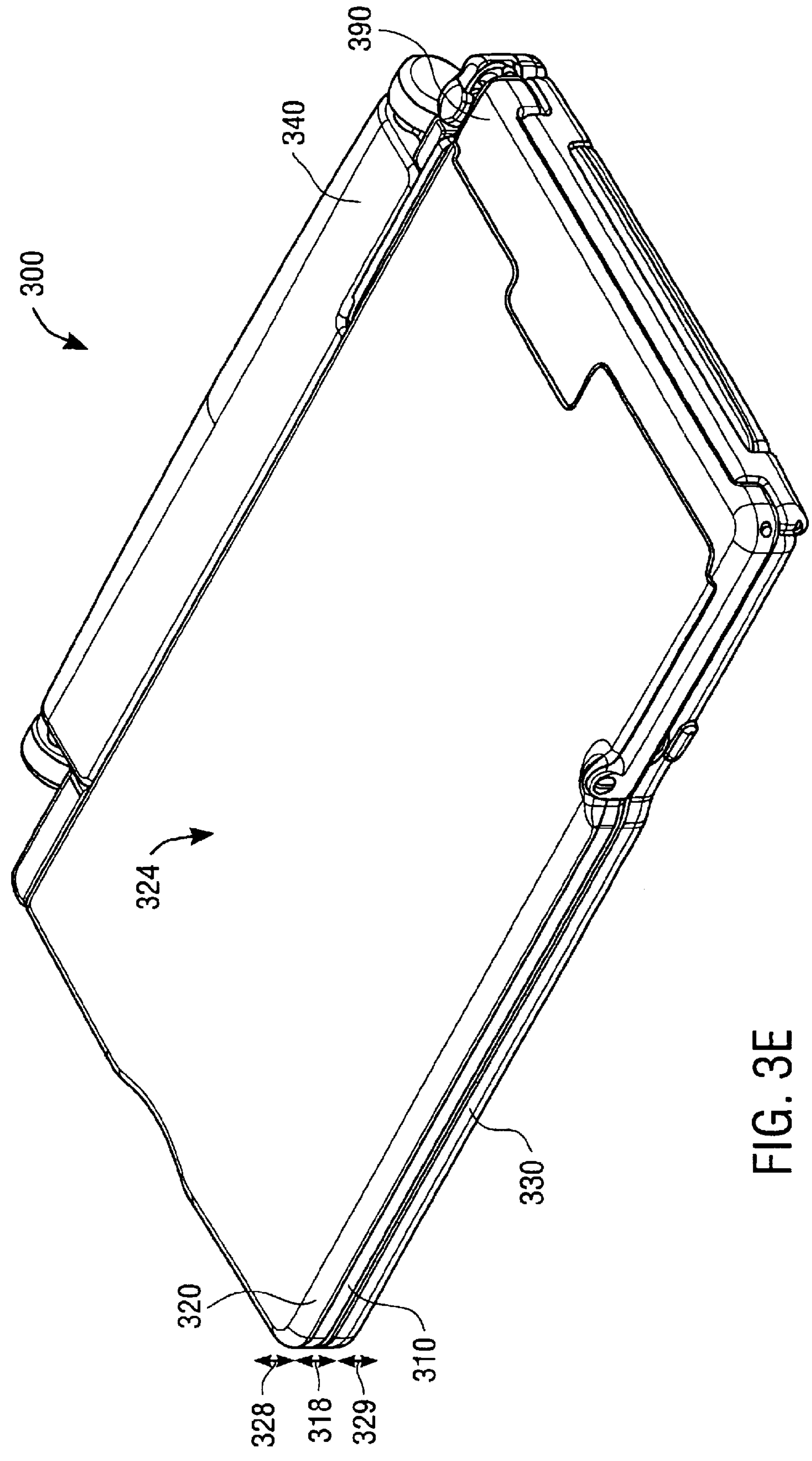

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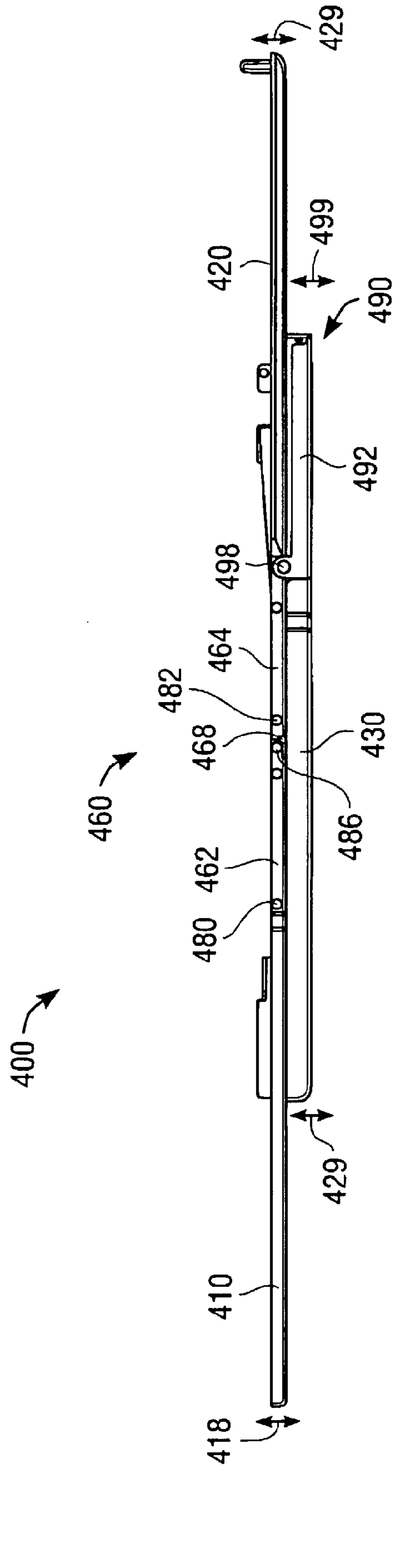
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FIG. 4A

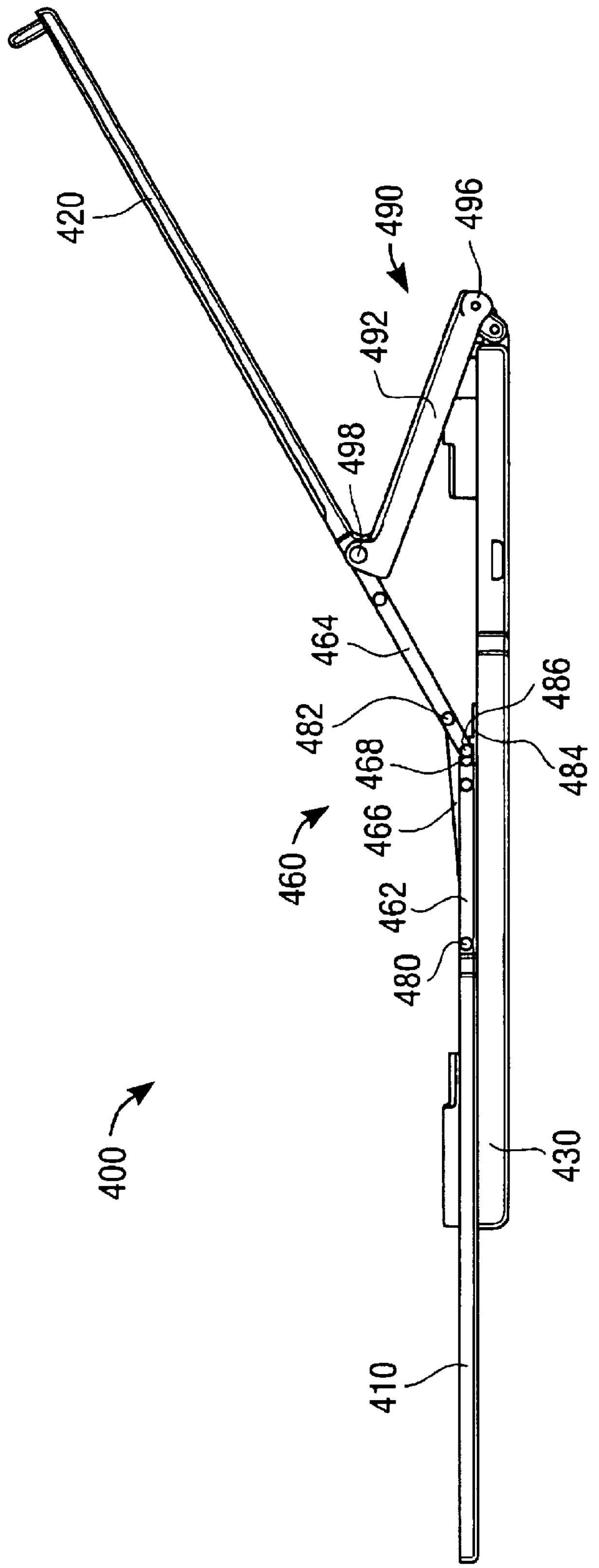
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FIG. 4B

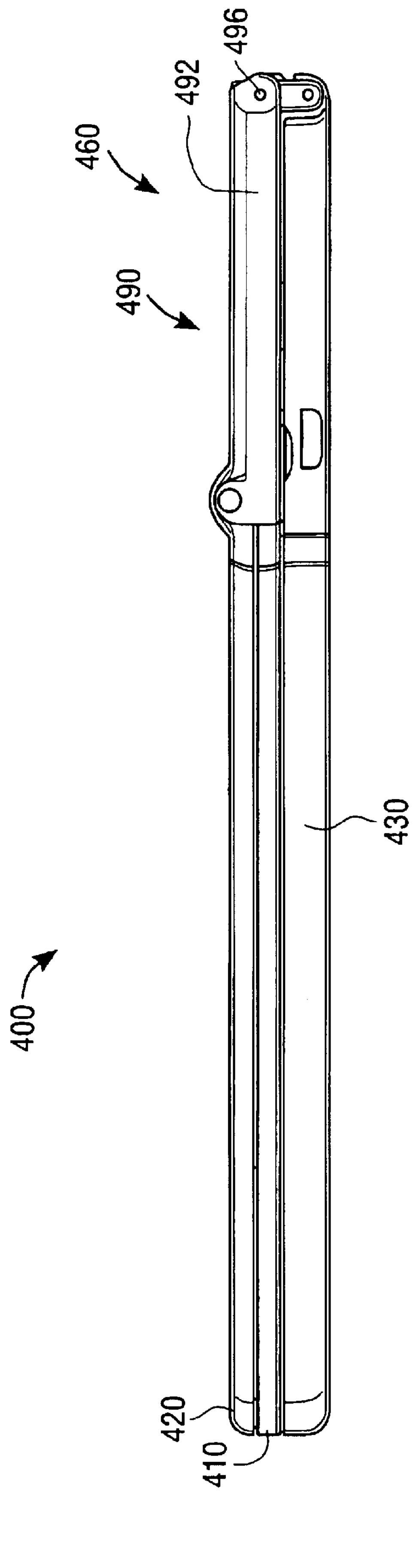

FIG. 4C

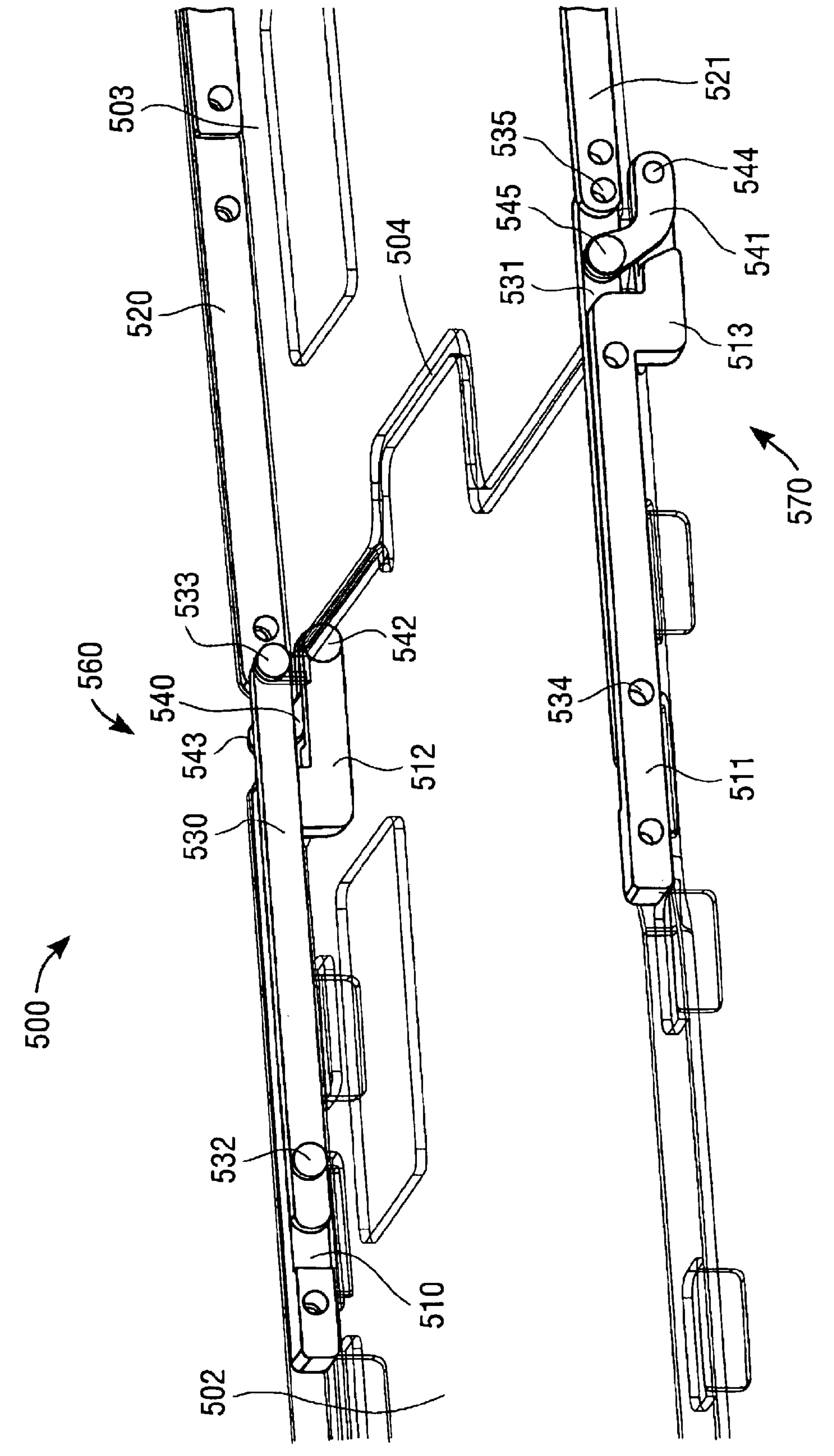
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FIG. 5A

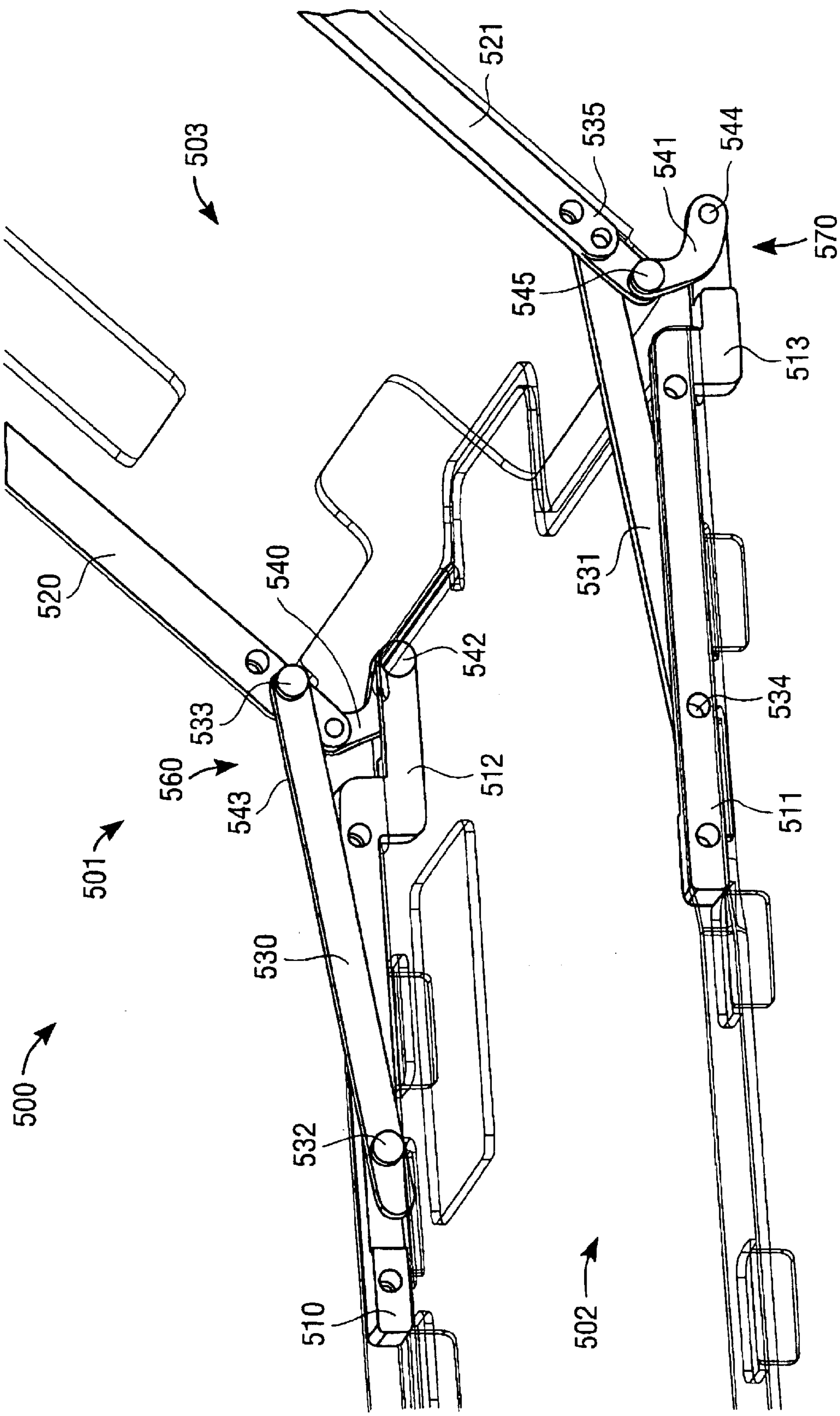

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FIG. 5B

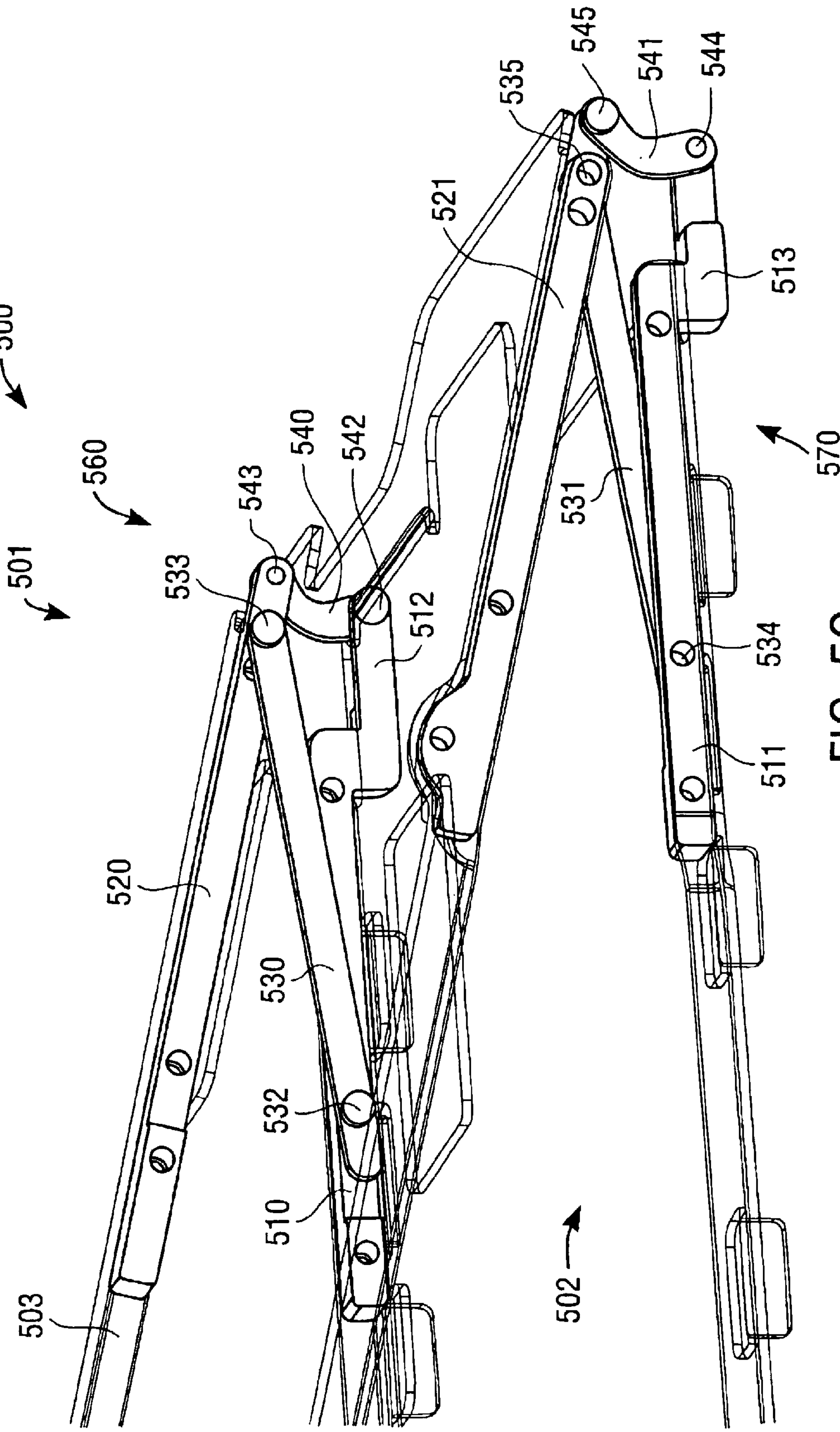
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FIG. 5C

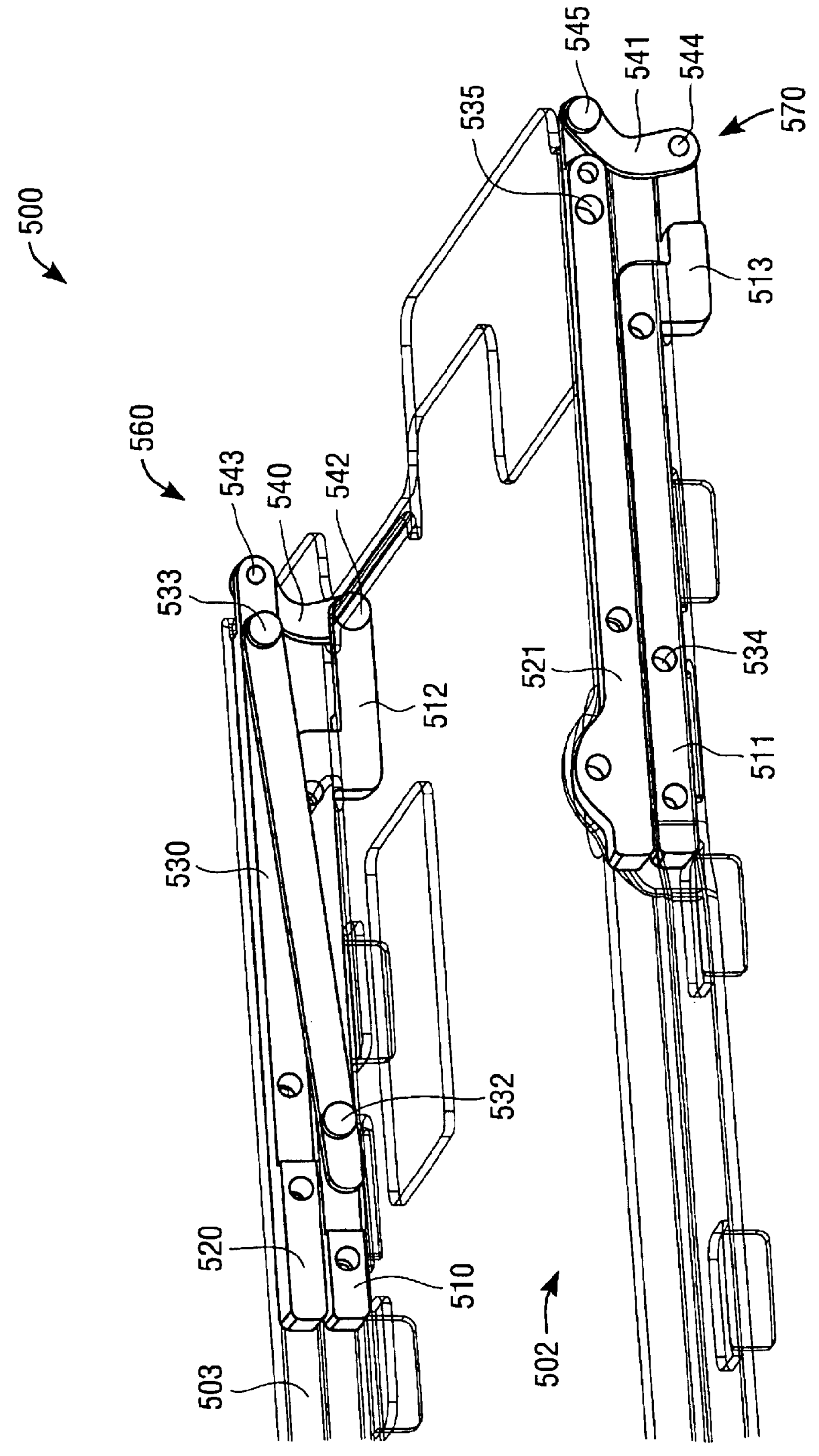
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FIG. 5D

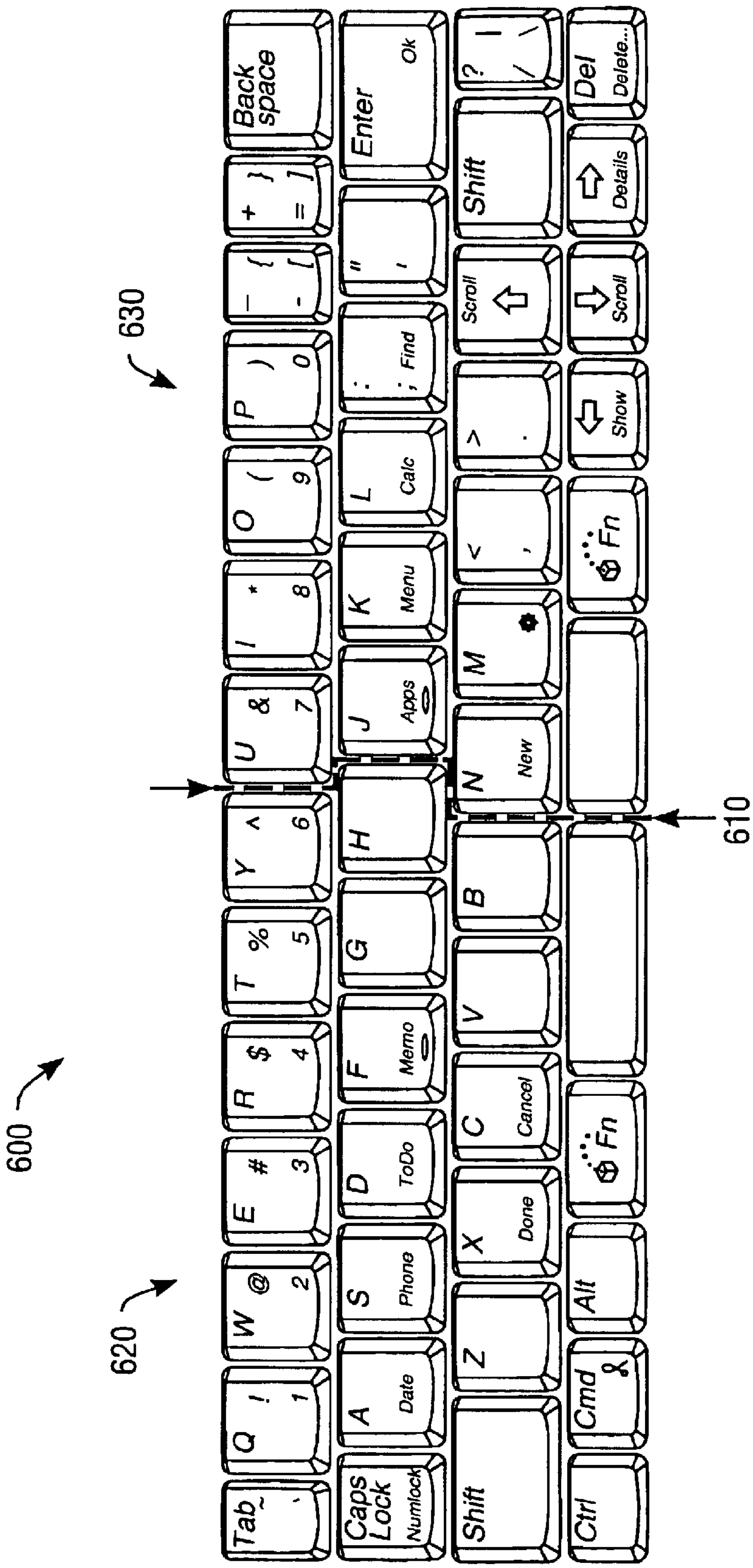
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FIG. 6

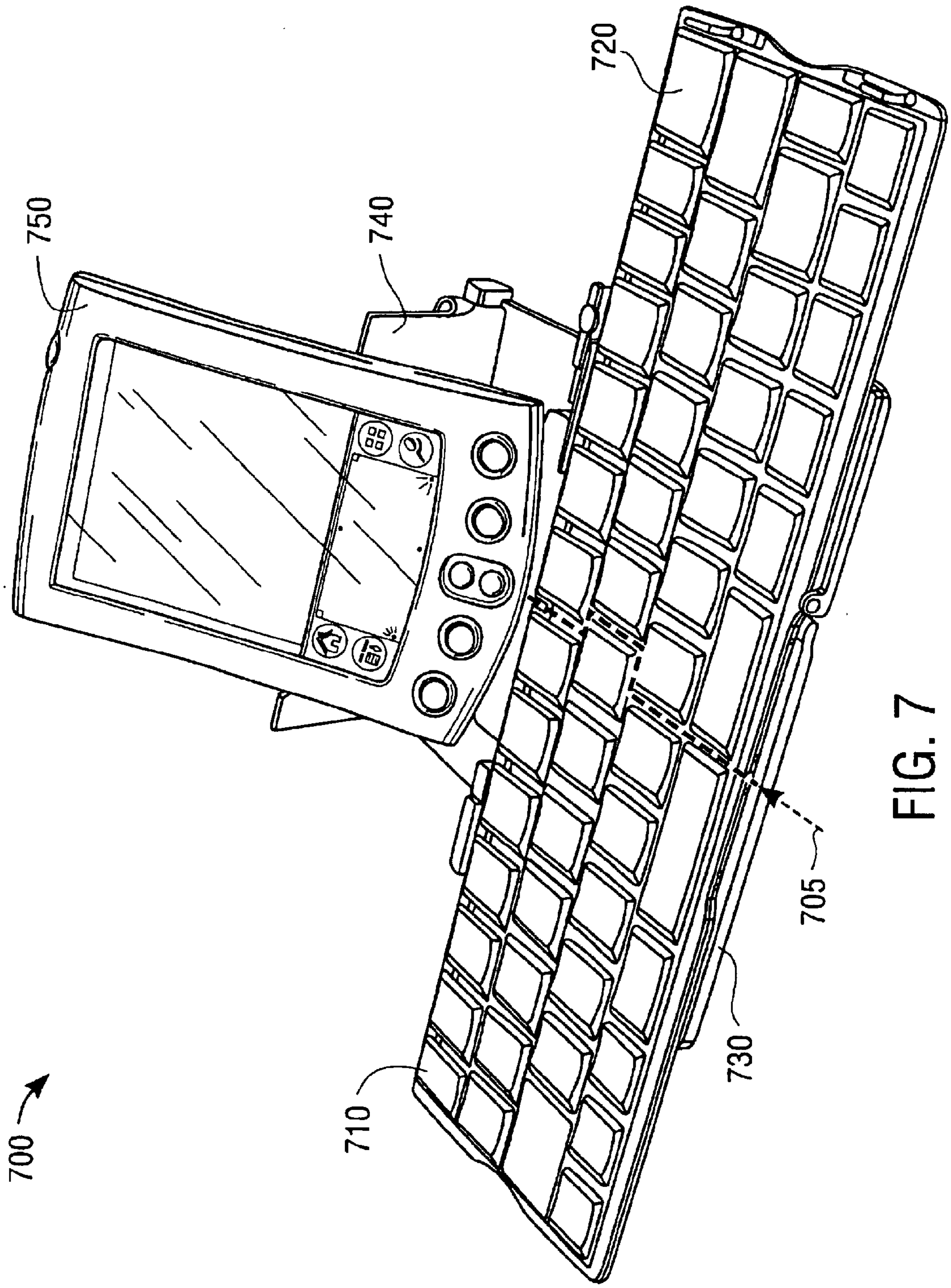

FIG. 7

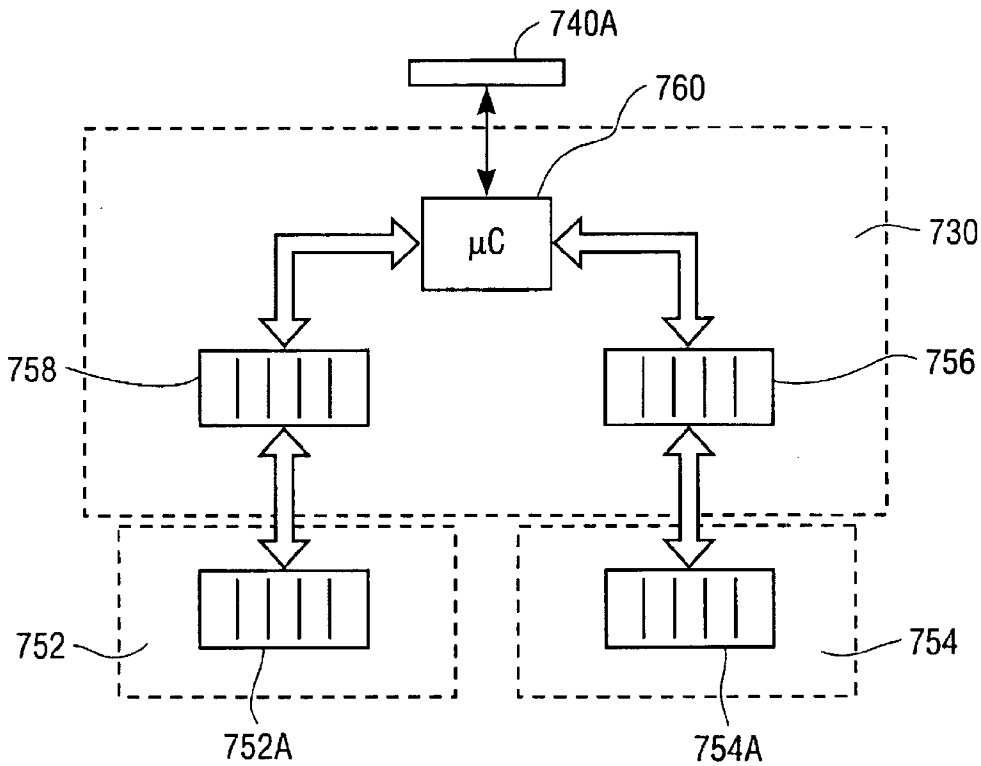

FIG. 7A

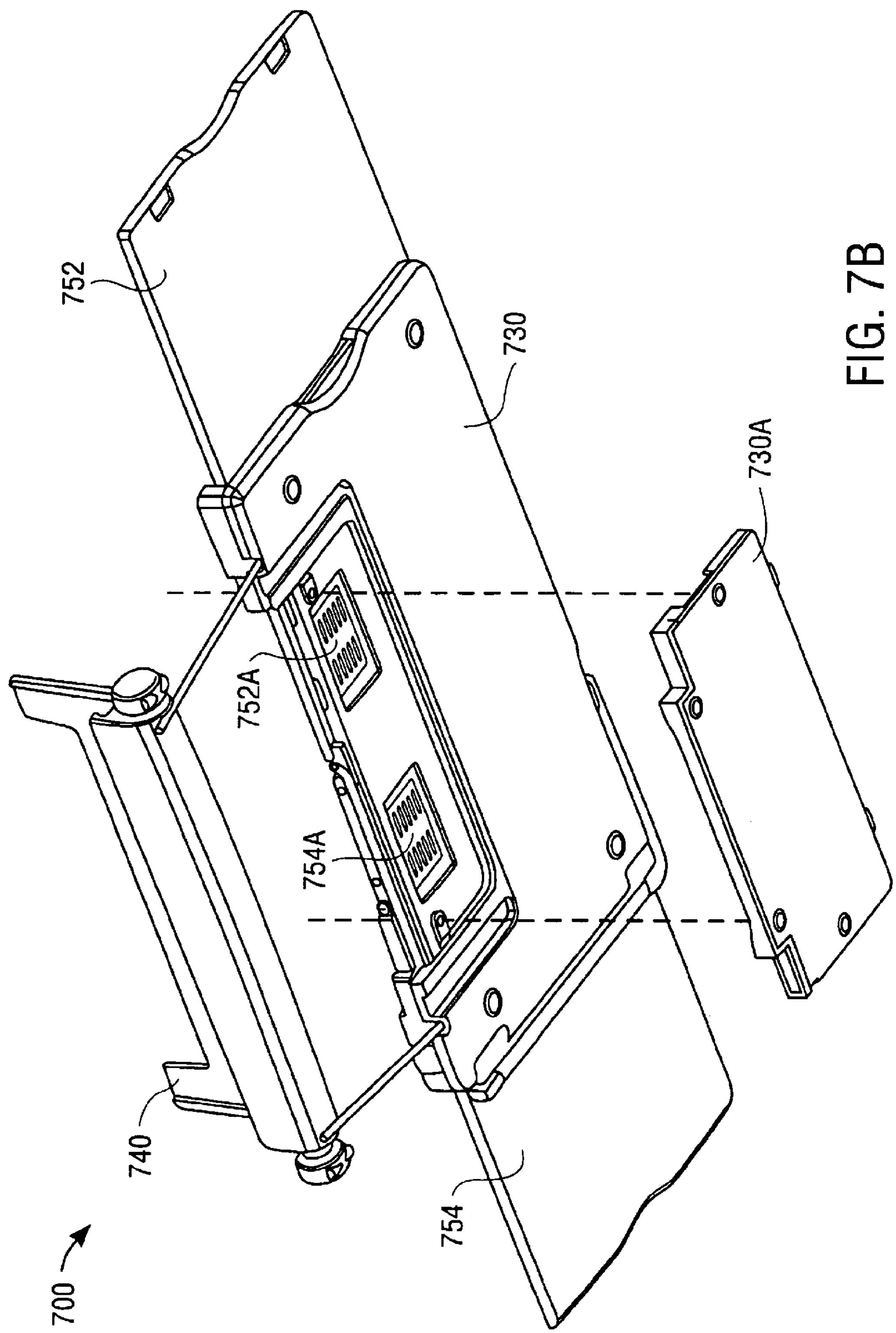

FIG. 7B

MOBILE COMPUTER WITH FOLDABLE KEYBOARD

REFERENCE TO RELATED APPLICATION

This application is related to and claims the benefit of U.S. provisional application No. 60/359,596 entitled "Mobile Computer with Foldable Keyboard," filed Feb. 25, 2002.

FIELD OF THE INVENTION

This invention relates to the field of digital processing devices and, in particular, to a compact digital processing devices having a foldable keyboard.

BACKGROUND

Personal Digital Assistants (PDAs) have succeeded as useful devices as electronic replacements of calendars and address books. Unlike notebook computers, PDAs are small enough to hold in the palm of one hand (grasped entirely within the fingers of one hand) or fit in a pocket. They power on instantly, and are easy to use. They have touch screens and styluses, which when used with appropriate handwriting recognition or onscreen "virtual" keyboards, allow for navigation, retrieving information, or entering small amounts of text. Recent advances in processing power, memory capacity, and application software, combined with the proliferation of wireless networks, have allowed PDAs to become very useful as communication devices and replacements for notebook computers. But in order to perform adequately as an e-mail machine or a notetaking device, a PDA must allow the user to quickly and comfortably enter text. Notebook computers have full size keyboards, which have been found to be the only successful solution for fast and convenient text entry. What is needed is a device that has the convenience of a PDA but has the text entry capabilities of the best notebook computers. What is also needed is a device that converts from a PDA to a notebook computer form factor.

The keyboard standard described by ISO 9241–4:1998(E) 6.2.1 calls for center-to-center key spacing of 19 mm+/−1 mm. ISO 9241–4:1998(E) 6.2.3 calls for preferred key displacement between 2.0 mm and 4.0 mm. Experience has shown that keyboards should be designed in conformance with these standards in order to allow touch-typing.

U.S. Pat. No. 5,949,408, assigned to Hewlett-Packard Company, describes a product marketed by Hewlett-Packard known as the "OmniGo 100" and is shown in FIG. **1**A. It is a PDA with a built-in keyboard. However, in order to fit the keyboard in a housing small enough for a PDA size, the keyboard is a small "chicklet" type that does not allow touch-typing. The center-to-center spacing of the keys is less than 13 mm horizontally and less than 10 mm vertically. The key "travel" or displacement is less than 0.5 mm. This is clearly outside the ISO specification quoted above.

GB 2,279,617 describes a PDA, shown in FIG. **1**C, with a built-in keyboard. However, the keyboard is a "flexible film" or membrane type keyboard. Keyboards like this have key displacements of a fraction of a millimeter and lack tactile feedback. For this reason they prevent touch-typing. Additionally, a keyboard of this design would require placement on a rigid flat surface and could not be use on one's lap without the addition of such a surface.

EP 691,603 describes a notebook computer with a built-in folding keyboard. However, this device does not convert to a hand held PDA.

U.S. Pat. No. 5,666,694 describes a double hinge arrangement for a "clam-shell" like device shown in FIG. **1**B. It uses a friction clutch and spring mechanism to sequence the rotation of the two panels. However, this mechanism is complicated, consumes much space, and the relative positions of the two panels are not necessarily kept constant.

Some prior art PDAs employ screen rotation techniques to rotate the configuration of the screen from portrait to landscape mode when the PDA is switched from a PDA data entry mode to a keyboard data entry mode. Various methods have been used to perform such screen rotation. For examples, using software pixel manipulation (e.g., as used in the HandEra, and Jimmy Software for the Compaq iPAQ) and by hardware assisted pixel manipulation (e.g., as performed by the MediaQ chip in Sony's Clie).

Another screen rotation method used in Hewlett Packard's OmniGo employs a customized LCD panel where the rotation is performed in the LCD panel, itself, in order to provide minimum impact on the software. One disadvantage of the screen rotation techniques employed in the Hewlett Packard OmniGo is that the LCD panel must be symmetrical (e.g., 240 v 240), thereby limiting the size of the display screen that may be used in PDAs. Another disadvantage of the screen rotation techniques employed in the Hewlett Packard OmniGo is that such techniques may only be used with monochrome displays that contain only a single cell for each pixel. For a color screen, each of the pixels, for example, may contain three colors—red, green, and blue—(RGB) cells lined in one direction, which require realignment to prevent color split. Such realignment may not be possible with the screen rotation techniques employed in the Hewlett Packard OmniGo. Another disadvantage of the Hewlett Packard OmniGo is that the device may not be practical for rotation beyond 90 degrees (e.g., 270 degrees of rotation), thereby limiting its range of use.

SUMMARY OF THE INVENTION

The present invention pertains to a digital processing device having a foldable keyboard. In one embodiment, the digital process device includes a rigid base, a display assembly with a display screen, a foldable keyboard assembly coupled with the base, and a hinge assembly that couples the display assembly to the base. The hinge assembly allows the display assembly to rotate between a first configuration and a second configuration.

Additional features and advantages of the present invention will be apparent from the accompanying drawings, and from the detailed description that follows below.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example and not intended to be limited by the figures of the accompanying drawings.

FIG. **1**A illustrates a prior art PDA.

FIG. **1**B illustrates a prior art hinge assembly on a PDA.

FIG. **1**C illustrates a prior art device with a foldable keyboard.

FIG. **2**A illustrates one embodiment of a digital processing device having a foldable keyboard.

FIG. **2**B illustrates one embodiment of the digital processing device in a first configuration.

FIG. **2**C illustrates one embodiment of a hinge assembly of the digital processing device.

FIG. **2**D illustrates one embodiment of the digital processing device with a keyboard assembly folded in one configuration.

FIG. **2**E illustrates one embodiment of the digital processing device with a keyboard assembly unfolded in another configuration.

FIG. 2F is a side view illustrating one embodiment of the hinge assembly of the digital processing device.

FIG. 2G illustrates an alternative embodiment of the hinge assembly of the digital processing device.

FIG. 2H illustrates one embodiment of the digital processing device in a folded configuration.

FIG. 2I illustrates one embodiment of the components of digital processing device.

FIG. 3A illustrates one embodiment of a foldable keyboard assembly that may be used with the digital processing devices of FIGS. 2A–2I.

FIG. 3B illustrates one embodiment of a foldable keyboard in another unfolded configuration.

FIG. 3C illustrates one embodiment of a foldable keyboard in a partially unfolded configuration.

FIG. 3D illustrates one embodiment of a foldable keyboard in another partially unfolded configuration.

FIG. 3E illustrates one embodiment of a foldable keyboard in a folded configuration.

FIG. 4A illustrates in a side view one embodiment of a foldable keyboard in an unfolded configuration.

FIG. 4B illustrates in a side view one embodiment of a foldable keyboard in a partially unfolded configuration.

FIG. 4C illustrates in a side view one embodiment of a foldable keyboard in a folded configuration.

FIG. 5A illustrates one embodiment of a linkage assembly in an unfolded configuration.

FIG. 5B illustrates one embodiment of a linkage assembly in a partially unfolded configuration.

FIG. 5C illustrates one embodiment of a linkage assembly in another partially unfolded configuration.

FIG. 5D illustrates one embodiment of a linkage assembly in a folded configuration.

FIG. 6 illustrates a standard QWERTY keyboard layout.

FIG. 7 illustrates one embodiment of an unfolded keyboard assembly digital processing device

FIG. 7A illustrates one embodiment of a conductive strip arrangement on a foldable keyboard.

FIG. 7B illustrates another embodiment of a conductive strip arrangement on a foldable keyboard.

DETAILED DESCRIPTION

In the following description, numerous specific details are set forth such as examples of specific, components, circuits, processes, etc. in order to provide a thorough understanding of the present invention. It will be apparent, however, to one skilled in the art that these specific details need not be employed to practice the present invention. In other instances, well known components or methods have not been described in detail in order to avoid unnecessarily obscuring the present invention. The term "coupled" as used herein means connected directly to or indirectly connected through one or more intervening components or circuits.

A digital processing device having a foldable keyboard is described. In one embodiment, the digital processing device includes a rigid base, a display assembly, and a foldable keyboard assembly coupled to the rigid base. The digital processing device also includes a hinge assembly to rotatably couple the display assembly to the base. The hinge assembly enables the back of the display assembly to be rotated between a first configuration and a second configuration. In the first configuration, the digital processing device is small enough to be held in the palm of the hand. The user may interact with the device in a similar manner as a personal digital assistant (PDA), handheld organizer, or other type of hand-held computing device with the keyboard assembly capable of folding to facilitate the holding of the device and to prevent unintentional interaction through the keyboard. In the second configuration, the digital processing device may be used in a similar manner as a portable computing device such as a laptop or notebook computer. In other words, the keyboard assembly is unfolded and is accessible to the user to enter information by typing and the display assembly is positioned for viewing of information (e.g., information that is entered by a user, information retrieved from a remote system on a network, etc.). The keyboard assembly unfolds to form a full-size keyboard (e.g., in conformance with ISO 9241–4:1998(E) 6.2.1/6.2.3 standards for keyboards) that allows a user to comfortably, quickly, and accurately "touch-type" in a manner that the user may be accustomed to. For example, the keyboard standard described by ISO 9241–4:1998(E) 6.2.1 calls for center-to-center key spacing of 19 mm+/−1 mm and the keyboard standard described by ISO 9241–4:1998(E) 6.2.3 calls for preferred key displacement between 2.0 mm and 4.0 mm. A copy of ISO 9241–4:1998(E) is attached as Appendix A hereto.

The device can quickly and easily transform to various useful positions. In its closed position, it has a protective housing so requires no case, and is small enough to be carried in a pocket or purse. In its PDA position, it operates just like a normal PDA. In one embodiment, the device has a touch screen and stylus and can be held in one hand with the thumb and fingers grasping either side of a portrait mode display. In its notebook position, its mechanical configuration is like a notebook computer—the unit can be placed on a surface or one's lap, with the display is in landscape mode and a full size keyboard beneath and in front of the display. In a desktop/docking like position, it can rest on a desktop without the need of an accessory stand, while providing a landscape mode display.

In order to facilitate the transformation of the various positions, in one embodiment, an X-shaped linkage can be used between the main body of the device and its display panel. This linkage may provide up to 360 degrees rotation of the display panel through a prescribed path, thus ensuring that the center of gravity of the device is controlled, so that the display and keyboard portions are always stable with respect to each other. The X-shaped linkage also consumes minimal space, provides constant friction in all positions, and allows routing of circuitry or an antenna though the hinge.

FIG. 2A illustrates one embodiment of a digital processing device having a foldable keyboard. In one embodiment, digital processing device **100** includes a rigid base **110**, a foldable keyboard assembly **120**, and a display assembly **130**. The base **110** has a front **112** and a back **114**. The front **112** of the base **110** is coupled to the keyboard assembly **120**. A hinge assembly **140** rotatably couples the display assembly **130** to the base **110** and allows for the device **100** to be used in various configurations.

FIG. 2B illustrates the device in a first configuration where the back **134** (as shown in FIG. 2C) of the display assembly **130** is rotated to be in contact **114** with the back **114** of the base **110**. In the first configuration, the digital processing device **100** is small enough to be held in the palm of a user's hand. The user may interact with the device **100** in a similar manner to a personal digital assistant (PDA), handheld organizer, or other type of hand-held computing device, where information is displayed to the user in a portrait mode that has text and/or graphics that are oriented perpendicular to the longest side of display assembly **130**.

The display assembly **130** includes a display screen **135** and one or more manual interface controls (e.g., button **136**, push pad **137**, dials, switches, etc.). The user may interact with digital processing device **100**, for example, by touching (e.g., with finger, stylus **117**, etc.) a touch sensitive display screen **135** or buttons on the display assembly **130**, thereby entering data and/or commands into the device **100**. In one embodiment, digital processing device **100** may also hardware and/or software to enable user interaction through other means, for example, voice recognition. Digital processing device **100** includes hardware and software to enable such operation as discussed below. In one embodiment, display screen **135** is a liquid crystal display. Alternatively, other types of display screens may be used, for example, electroluminescent displays. Display screens and manual interface controls are known in the art; accordingly, a detailed discussion is not provided.

With the digital processing device **100** in this first configuration, it may be necessary to prevent a user from mistakenly entering data and/or commands using the keyboard assembly **120**. As such, the keyboard assembly **120** may be folded in the first configuration **121**, illustrated in FIG. **2**D, to prevent unintentional interaction through the keyboard, as discussed below. In one embodiment, a power button **139** may be located external to the keyboard assembly **120** (e.g., on the display assembly **130**) to enable the digital processing device **100** to be turned on or off when the keyboard assembly **120** is in the folded position.

The hinge assembly **140** enables the display assembly **130** to be rotated to a second configuration with an angle up to 180 degrees between the front **133** of the display assembly **130** and the keyboard assembly **120**. For example, the display assembly **130** may be rotated such that it forms approximately a 90 degree angle with the base **110**, as illustrated in FIG. **2**E. In this second configuration (e.g., with the keyboard assembly fully unfolded), the digital processing device **100** may be used in a similar manner to a portable computing device such as a laptop or notebook computer. In the second configuration, information is displayed to the user in a landscape mode that is oriented 90 degrees relative to the portrait mode. In other words, the keyboard assembly **120** is accessible to the user to enter information by typing and the display assembly **130** is positioned for viewing of information (e.g., information that is entered by a user, information retrieved from a remote system on a network, etc.) oriented parallel with a longest side of display assembly **130**. It should be noted that the hinge assembly enables the display assembly **130** to be rotated approximately 360 degrees relative to keyboard assembly **120**.

Referring to FIG. **2**C, in one embodiment, hinge assembly **140** includes two hinges **141** and **142**. Each of hinges **141** and **142** operate as a linkage in the hinge assembly **140**. One end of hinge **141** is coupled to base **110** at pivot axis **161**. The other end of hinge **141** is coupled to display assembly **130** at pivot axis **163**. One end of hinge **142** is coupled to base **110** at pivot axis **162** and the other end of hinge **142** is coupled to display assembly **130** at pivot axis **164**. The hinges **141** and **142** are coupled to base **110** at different pivot axes **161** and **162**, respectively, that are offset from each other. In one exemplary embodiment, for a display panel having a thickness of 6 mm, the offset may be 2 mm. The hinges **141** and **142** are coupled to display assembly **130** at different pivot axes **163** and **164**, respectively, that are offset from each other.

In this manner, hinges **141** and **142** are cross-connected between base **110** and display assembly **130** relative to their connection points on base **110** and display assembly **130**, as illustrated in FIG. **2**F. The cross-connection results in a total of four pivot axes **161–164** that allows for rotation of the base **110** and display assembly **130** without any substantial translation of them with respect to each other, as occurs with some prior art two pivot axes hinge assemblies. The cross-connection of hinge assembly **140** generates a common axis of rotation between the base **110** and the display assembly **130**. In one embodiment, the distance **167** between the base pivot axes **161** and **162** is the same as the distance **168** between the display assembly pivot axes **163** and **164**. Device **100** may also include additional one or more additional hinges (e.g., hinge **143**) coupled between base **110** and display assembly **130**.

In one embodiment, each of hinges **141** and **142** has pins on their end sections for coupling with corresponding pin holes on base **110** and display assembly **130** to receive the pins. This allows for pivoting of the hinges **141** and **142** about the particular axis **161–164** through use of the pin/pin hole connection. In one embodiment, one or both of hinges **141** and **142** contains a cavity that may contain a flex circuit for carrying electrical signals between components in base **110** and display assembly **130**. In alternative embodiments, the hinge assembly of digital processing device **100** may have other cross-connection configurations, for example, hinge assembly **170** as discussed below in relation to FIG. **2**F.

FIG. **2**G illustrates an alternative embodiment of hinge assembly on a digital processing device. In one embodiment, digital processing device **100** includes a hinge assembly **170** having inner hinge **172** and outer hinges **171** and **173**. One end of inner hinge **172** may be coupled to base **110** at pivot axis **182** and the other end of inner hinge **172** may be coupled to display assembly **130** at pivot axis **184**. The ends of outer hinges **171** and **173** that are coupled to base **110** may be coupled to pivot axis **181** and the other ends of outer hinges **171** and **173** that are coupled to display screen **130** may be coupled to pivot axis **183**. In this manner, outer hinges **171** and **173** are cross-connected with respect to inner hinge **172** between base **110** and display assembly **130** relative to their respectively connection points on base **110** and display assembly **130**. In other embodiments, other configurations for a cross-connected hinge assembly may be used. As yet another example, the hinge assembly may include two outer hinges coupled to base **110** and display assembly **130** in a cross-connected manner without an inner hinge. It should be noted that yet other types of hinge assemblies known in the art may be used, such as hinge assemblies without cross-connected hinges.

Referring again to FIG. **2**A, in one embodiment, the foldable keyboard assembly **120** includes two keyboard panels **122** and **124** that are adjustably coupled to base **110**. The keyboard assembly **120** also includes a linkage mechanism **125** that operates to slide the bottom panel **124** in response to rotation of the top panel **122** in order to reconfigure the device **100** from a working position illustrated in FIG. **2**E to a closed position illustrate in FIG. **2**D. The linkage mechanism **125** also operates to center the adjoining edges **126** and **128** of the panels **122** and **124**, respectively, over the base **110** when the keyboard assembly **120** is completely unfolded. The keyboard assembly **120** includes another linkage mechanism **129** to fold a cover **126** over a section of the bottom panel **124** exposed by the top panel **122** when the top panel **122** is in a folded position over the bottom panel **124**. Details of the linkage mechanisms are discussed in more detail below with respect to FIG. **3**A.

In one embodiment, each of the keyboard panels **122** and **124** has an area smaller than the area of the base **110**. For example, each of the keyboard panels **122** and **124** has a length **192** and **194**, respectively, that is no greater than the length **193** of the base **110** to allow for the keyboard assembly **120** to be folded to a length that fits within the length **193** of the base **110**.

Moreover, in the embodiment where base **110** is rigid, the device **100** does not need to be placed on a hard surface for use of the keyboard as is required with prior art devices that utilize a flexible folding keyboard. In one embodiment, for example, the base **110** may be constructed from a plastic material of sufficient thickness to provide rigidity. Alternatively, other materials (e.g., metal) of sufficient thickness may be used for base **110**. In alternative embodiment, base **110** may be a non-rigid base.

Because consumer acceptance of devices may be based on their ease and familiarity of use, the foldable keyboard assembly **120** is designed to be larger, when unfolded, than keyboards on prior hand-held computing devices. Moreover, the mechanical action of the keyboard mechanism of the keyboard assembly **120** is designed to feel similar to a desktop keyboard so that the user can touch-type quickly, comfortably, and accurately in an accustomed manner with no leaning required. The keys of, for example, an 84-key keyboard are arranged in the standard "QWERTY" layout. In one embodiment, the keyboard assembly **120** unfolds to conform with an ISO 9241–4:1998(E) 6.2.1/6.2.3 standard for keyboards. This may allow a user to comfortably, quickly, and accurately "touch-type" in a manner that the user may be accustomed to. The keys may have full-sized tops whose center-to-center spacing (referred to as pitch) is at least 18 mm horizontally and 18 mm vertically. In one particular embodiment, both the horizontal and vertical center-to-center spacing is approximately 18 mm.

In one embodiment, the length (panel length **194** plus panel length **192**) of the keyboard assembly **120** (i.e., the distance from the left edge of the left-most key to the right edge of the right-most key) is approximately 11 inches. Any reduction in this spacing as is found on prior devices may slow down and frustrate the touch-typist. Additionally, the keys of keyboard assembly **120** have sufficient "travel" (i.e., the vertical displacement of the key when it is pressed) tactile feedback, and an over-center buckling action that signals the user that the key has been pressed sufficiently. For example, in one embodiment, the keys of keyboard assembly **120** have a travel of approximately 1.5 mm to 6 mm and the maximum force to depress a key is approximately in the range of 0.25 N to 1.5 N. In one particular embodiment, the key travel is approximately 3 mm. When a key is pressed there is also an over-center "buckling" of an elastomeric spring to create tactile feedback similar to the feedback provided by high-quality keyboards.

As previously noted, the keyboard assembly **120** is capable of collapsing into its own protective housing formed by the base **110** and the back of top keyboard panel **122**. When the housing is closed (configuration **121** of FIG. 2D), it forms a dust-proof enclosure surrounding the keyboard assembly's mechanism. When the keyboard assembly **120** is in its collapsed position or state, the length is approximately 138 mm, the width is approximately 74 mm, and the height or thickness of the keyboard assembly is approximately 6 mm. In one embodiment, the thinness of the keyboard assembly **120**, in a collapsed state, enables the total thickness **101** of the digital process device **100** to be less than 20 mm, as illustrated in FIG. 2H. This allows for the device to be more easily carried in a purse or pocket.

Expanding the keyboard assembly **120** from a collapsed state to a keyboard having conventionally spaced keys is done in a single step in one embodiment of the invention. The user simply pulls the keyboard assembly's top panel **122** apart from the bottom panel **124**.

FIG. **7** illustrates a top perspective view of an embodiment of an unfolded keyboard assembly configured with a personal digital processing device. The keyboard assembly includes first keyboard assembly **710**, second keyboard assembly **720**, support plate **730**, and connector **740**. In one embodiment, the parts of the keyboard assembly are in continuous contact with each other. Division line **705** shows where first keyboard section **710** and second keyboard section **720** divide when the keyboard assembly folds.

In one embodiment, keyboard sections unfold to a full-size, standard "QWERTY" layout. "QWERTY" is indicative of the keyboard layout in that the first six letters of the top row, in a direction from left to right, are Q-W-E-R-T-Y. The key tops of a keyswitch assembly comply with full size standards (e.g., about 18–19 mm center to center horizontal pitch, about 18–21 mm center to center vertical pitch, and a minimum horizontal strike surface width of about 12 mm). FIG. **6** illustrates one embodiment of standard QWERTY layout with a complete set of keys. The overall arrangement of the keys results in a rectangular layout. The keys corresponding to letters are about substantially the same size, while function keys (e.g., "Shift" and "Enter") may be of varying sizes. Line **610** shows the jagged division separating first keyboard section **620** from second keyboard section **630**. The division exists between the letters "Y" and "U," "H" and "J," "B" and "N", and between the space bar.

Full-size keyboards allow the user to comfortably, privately, and quickly "touch-type." They have a number of desirable features. Importantly, the keyswitches may be designed to provide sufficient "travel" (i.e., the distance the key moves when it is pressed), and tactile feedback (i.e., an over-center buckling action), that signals to the user that the key has been pressed sufficiently.

When users type quickly with all fingers, they often strike the keys off center. To prevent the keys from binding, high quality keyswitches use mechanisms that keep the key caps parallel to the base as they are pressed. This allows the keys to be struck on any portion of their surface and at non-perpendicular angles to the direction of depression. Co-pending U.S. patent application Ser. No. 09/738,000, filed Dec. 14, 2000, entitled "Keyswitch," describes an example of a keyswitch assembly for use in keyboards. Co-pending U.S. patent application Ser. No. 09/737,015, filed Dec. 14, 2000, entitled "Spring," describes an example of a spring for use in keyswitch assemblies. Both applications are hereby incorporated herein by reference. U.S. provisional application No. 60/359,596 entitled "Mobile Computer with Foldable Keyboard," filed Feb. 25, 2002, is also incorporated herein by reference.

Referring again to FIG. **7**, in a QWERTY layout, keyboard sections **710**, **720** may not be divided evenly down the exact center of the unfolded keyboard. Nevertheless, first keyboard section **710** and second keyboard section **720** have substantially similar sizes, with substantially equal width, length, and thickness. Also, the support plate **730** has substantially the same width and length.

In one embodiment, support plate **730** may overlap first keyboard section **710** and second keyboard section **720** in the unfolded configuration. Support plate **730** may also be substantially the same size as the two keyboard sections **710**, **720**, with substantially equal width, length and thickness. In one embodiment the thickness of the two keyboard sections **710**, **720** and the support plate **730** may be in the range of about 2 mm to about 6 mm, although the support plate may be thicker than the two keyboard sections, such as is shown in the exemplary embodiment of FIG. **4**B, and the keyboard sections may be thinner than about 2 mm. The lengths of the two keyboard sections **710**, **720** and the support plate **730**, in certain embodiments, may be in the range of about 6 cm to about 15 cm. As shown in the exemplary embodiment of FIG. **4**C, the lengths of these three components may be virtually the same or substantially the same. The widths of the two keyboard sections and the support plate, in certain embodiments, may be in the range of about 4 cm to about 12 cm.

In a particular embodiment, the support plate or base plate **730** (which may house the CPU, battery, and other electrical components) has a thickness up to about 8 mm. Without the CPU, battery and other electrical components, the thickness may be up to about 5 mm. The keyboard sections **710**, **720** (each section, when the keyboard is in a collapsed position) have a thickness of about 3 mm. Support plate or base plate **710** has a width of about 74 mm and a length of about 138 mm, and each keyboard section **710**, **720** has a width of about 74 mm, and a length of about 138 mm. Support plate **730** does not extend across the entire length of the unfolded keyboard, but overlaps a portion of each keyboard section **710**, **720**. In one embodiment, support plate overlaps **730** each keyboard section substantially equally. This configuration may provide the optimal configuration for a user to use all the keys of the unfolded keyboard comfortably. Support plate **730** aligns along a length of keyboard sections **710**,**720** in the unfolded configuration. Support plate **730** is coupled to keyboard sections **710**, **720** along the length of keyboard sections such that from a top view, support plate **730** is not visible.

In one embodiment, the keyboard assembly folds and unfolds in the following manner. In the unfolded, fully extended configuration (e.g., the configuration shown in FIGS. **7**, **3**A or **4**A), support plate **730** overlaps equally first keyboard section **710** and second keyboard section **720**, such that portions of first keyboard section **710** and second keyboard section **720** extend past the length of support plate **730**. First keyboard section **710**, second keyboard section **720** and support plate **730** may be in continuous contact with each other and are substantially similar in size. In addition, first keyboard section may be coupled to support plate **730** by sliding rails along at least a portion of the length of first keyboard section **710**.

From the unfolded configuration, second keyboard section **720** folds or rotates toward first keyboard section **710**. The folding region between first keyboard section **710** and second keyboard section **720** may be jagged division **705**. During this motion, first keyboard section slides along support plate **730** towards an end of support plate **730** (e.g., towards the right side of support plate **730**), such that first keyboard section **710** aligns over support plate **730** without any portion of first keyboard section extending past a length of support plate **730**. Second keyboard section **720** aligns over first keyboard section **710** without any portion of second keyboard section **720** extending past a length of first keyboard section **710**. As such, because first keyboard section **710**, second keyboard section **720**, and support plate **730** are of substantially equal size and shape, when folded, all three parts align over each other.

The mechanics of folding second keyboard section **720** and sliding first keyboard section **710** are, in one embodiment, tied together such that any distance second keyboard section **720** folds or rotates, first keyboard section **710** slides by a corresponding distance. This way, completely unfolding second keyboard section results in first keyboard section sliding along support plate **730** such that support plate **730** extends over first keyboard section **710** and second keyboard section **720** equally. Completely folding second keyboard section **720** over first keyboard section **710** results in first keyboard section **710**, second keyboard section **720**, and support plate **730** aligning over each other to give the appearance of a unitary body. Second keyboard section **720** may rotate up to 180 degrees with respect to first keyboard section **710** to change between a folded and unfolded keyboard configuration.

Thus, keyboard assembly **700** may be defined as having two main keyboard configurations. One main configuration is an unfolded, or open configuration in which the two keyboard sections are fully exposed, co-planar and coupled to each other to form a full-size QWERTY layout keyboard having full size key tops. Support plate **730** overlaps each keyboard section substantially evenly underneath the keyboard sections to provide a rigid base for keyboard use.

The other main keyboard configuration is the folded or closed configuration, in which one keyboard section folds with respect to each the other such that the keys (and hence the key tops of the keys) from each keyboard section oppose each other. First keyboard section **710**, second keyboard section **720**, and support plate **730** align on top of each other to form a unitary body. To make the folded keyboard sections as thin as possible, the keys may be fully depressed in the folded configuration (such that the keyswitches of each key are electrically shorted). In the folded configuration, a bottom surface of support plate **730** and a bottom surface of second keyboard section **720** form the exterior of a self-contained housing for the keyboard assembly. In the folded configuration, because none of the keys are exposed, the self-contained housing protects the keys of the keyboard sections. In addition, the footprint of the folded keyboard, in one embodiment, may be small enough to fit comfortably in a shirt pocket or in the palm of the user's hand for carrying from one location to another.

In one embodiment, connector **740** may be coupled to the keyboard assembly. Connector **740** provides for electrical connection between the keyboard and the personal processing device, such as a personal digital assistant (PDA). Electrical signals, such as key codes that identify keystrokes, may be sent from the keyboard to the personal processing device. Support plate **730** is coupled to connector **740**. A personal processing device may be electrically and mechanically coupled to connector **740** in the unfolded configuration.

Two groups (first and second groups) of conductive strips may be fixed on the inner surface of support plate **730** (which faces the bottom sides of the keyboard sections in the unfolded configuration) and a first and a second corresponding group of conductive strips may be attached to the bottom side of the first and second keyboard sections respectively. An example of this arrangement is shown in FIG. **7**A. In the unfolded configuration, the first corresponding group of conductive strips on the first keyboard section (e.g., strips **752**A in FIG. **7**A) electrically contacts the first group of conductive strips (e.g., strips **758**) on the inner surface of support plate **730**, thereby allowing for electrical connection of signals between the first keyboard section (e.g., section **752** of FIG. **7**A) and a keyboard controller which scans the electrical matrix of keyswitches in each section, such as keyboard controller **760** shown in FIG. **7**A.

Similarly, the second corresponding group of conductive strips (e.g., strips **754**A of FIG. **7**A) on the second keyboard section (e.g., section **754**) electrically contacts the second group of conductive strips (e.g., strips **756**) on the inner surface of support plate **730**, thereby allowing for electrical connection of signals between the second keyboard section and the keyboard controller (e.g., controller **760** of FIG. 7A).

When the two keyboard sections are moved from the unfolded to the folded configuration these electrical connections are, in this embodiment, disconnected. The sets of conductive strips allow for the folding and unfolding without requiring a flexible electrical cable; however, in one alternative embodiment, a flexible electrical cable (which allows for the folding and unfolding) may connect each keyboard section to the keyboard controller (e.g., controller **760**) which may be disposed on the support plate **730**. The controller **760** is electrically coupled to electrical contractor **740**A which is part of connector **740** and provides keystroke signals, identifying individual keys which have been depressed as a user types, to the connector **740** which in turn provides these signals to the PDA connected to the connector **740**. It will be appreciated that the controller **760** may scan a conventional electrical matrix of keyswitches in the two keyboard sections in a conventional manner. It will also be appreciated that, in an alternative embodiment, the keyboard controller may be disposed in the PDA and may scan the electrical matrix of keyswitches through electrical contractor **740**A.

FIG. **7**B illustrates one embodiment of an arrangement of conductive strips in the unfolded configuration, viewed from the bottom side of keyboard assembly **700**. First keyboard section **752** has conductive strips **752**A disposed above and within an area of support plate **730**. Second keyboard section **754** also has corresponding conductive strips **754**A disposed above and within an area of support plate **730**. Connector **740** is shown coupled to support plate **730**, and in an extended position to support a PDA or similar device.

Support plate segment **730**A is shown in an exploded view with respect to support plate **730**. When part of support plate **730**, support plate segment **730**A overlaps conductive strips **752**A of first keyboard section **752** and conductive strips **754**A of second keyboard section **754**. Conductive strips **756**, **758**, as well as keyboard controller **760** and connector **740**A described with respect FIG. 7A, may be disposed on an inner surface (not shown) of support plate segment **730**A. Conductive strips **756, 758** would align with conductive strips **754**A, **752**A, respectively, allowing for electrical connection of signals of first keyboard section **752** and second keyboard section **754** with keyboard controller **760**. As described above, keyboard controller **760** is electrically coupled to electrical contractor **740**A, which is part of connector **740**, and provides keystroke signals, identifying individual keys that have been depressed as a user types, to the connector **740**. Connector **740** in turn provides these signals to the PDA connected to the connector **740**.

FIG. **3**A illustrates one embodiment of a keyboard assembly in the unfolded configuration with a personal processing device connector in an extended configuration. In the unfolded configuration, keyboard assembly **300** has first keyboard section **310**, second keyboard section **320**, support plate **330** and connector **340**. For clarity of description, keyboard sections **310, 320** are shown without the keys. It will be appreciated that these keys are supported on the surfaces of these two sections. First keyboard section **310** and second keyboard section **320** arm divided along line **305**. The division between the keyboard sections is not straight because a standard keyboard layout in QWERTY format has rows of keys staggered from one row to the next. Inserts **301, 302** may be disposed near an end of second keyboard section **320**. Slots **303, 304** may be displaced on first keyboard section **310** that aligns with inserts **301, 302**, in the folded configuration, such that the keyboard sections may be securely coupled together.

In one embodiment, first keyboard section **310**, second keyboard section **320**, and support plate **330** are substantially equal in size. Support plate **330** overlaps first keyboard section **310** and second keyboard section **320** equally. Because support plate **330** overlaps first and second keyboard sections substantially equally, the unfolded keyboard is supported firmly for comfortable use under a variety of surfaces. Support plate stabilizes the keyboard sections and allows a user to apply an amount of force consistent with the use of any standard-type keyboard. As such, the keyboard assembly provides the advantages of operating comparably to a full-size, unitary keyboard and the portability to use the keyboard under a variety of environments and circumstances.

Connector **340** allows the keyboard assembly to attach to a personal digital processor to register keystrokes. Connector **340** is coupled centrally to support plate **330** along a length of support plate **330** on the back side of plate **330** as shown in FIG. **3**A. Connector **340** may have an extended configuration to secure a personal digital processor, and a closed configuration, as illustrated in FIG. **3**B.

FIG. **3**C illustrates a perspective view of foldable keyboard assembly **300** in an intermediate configuration that is neither completely folded nor unfolded. In this configuration, foldable keyboard sections **310**, **320** are coupled to each other by linkage assembly **360**. Linkage assembly **360** serves as the folding mechanism that allows keyboard sections **310**, **320** to alternate from a folded configuration to an unfolded configuration. Linkage assembly includes first bar **362**, second bar **364**, third bar **366**, and fourth bar **368**. In an alternative embodiment, keyboard assembly **300** may also include second linkage assembly **370** disposed on a side opposite linkage assembly **360**. Second linkage assembly **370** may also have first bar **372**, second bar **374** (not shown), third bar **376**, and fourth bar **378** (not shown). Second linkage assembly **370** may provide additional support and stability to the keyboard assembly, as well as facilitating the folding of the keyboard sections **310**, **320**. It may be appreciated that second linkage assembly **370** may not be required for keyboard sections **310, 320** to fold and unfold.

First keyboard section **310** has a thickness **318**, second keyboard section **320** has a thickness **328**, and support plate **330** has a thickness **338**. In one embodiment, the thickness of all three parts are substantially equal. A layout of keys (not shown) on first keyboard section **310** and second keyboard section **320** may be compressed (i.e., travel) such that the overall thickness of the keyboard sections with the keys may be substantially the thickness of the keyboard sections.

First bar **362** of linkage assembly **360** is coupled to edge **312** of first keyboard section **310**. First bar **362** is coupled along edge **312** near a point where first keyboard section **310** meets second keyboard section **320**. For example, in FIG. **3**A, division **305** between first keyboard section **310** and second keyboard section **320** is denoted being uneven (e.g., **305**). Similarly, second bar **364** is coupled to edge **322** of second keyboard section **320**. Third bar **366** is coupled to first bar **362** at first pivot **380**, and to second bar **364** at second pivot **382**. Fourth bar **368** also couples first bar **362** and second bar **364**. One end of fourth bar **368** forms a third pivot with first bar **362** and the other end of fourth bar **368** forms a fourth pivot with second bar **364**.

The mechanics of the folding and unfolding of keyboard assembly **300** was described generally above. As will be described in greater detail below, first pivot **380** and second pivot **382** allow keyboard sections **310**, **320** to fold and unfold with respect to each other. Third pivot **384** and fourth pivot **386** allow first keyboard section **310** to slide along support plate **330** when keyboard assembly **300** changes from an unfolded configuration to a folded configuration. Thus, the four pivots **380**, **382**, **384**, **386** operate cooperatively to allow the simultaneous folding and unfolding of second keyboard section **320**, and sliding of first keyboard section **310**.

Optionally, keyboard assembly **300** may include brace **390** to support second keyboard section **320**. Arms **392**, **394** coupled to edges **322**, **324** (note: **324** not shown) of second keyboard section **320** provide rigid support as second keyboard section rotates from a folded to an unfolded configuration. However, it may be appreciated that brace **390** is not essential to allow the folding or sliding of keyboard assembly **300**.

Keyboard assembly **300** illustrated in FIG. **3**C also shows conductive strip **256** disposed on support plate **330**. As described with respect to FIGS. 2A, 2B, conductive strip **256** makes contact with a corresponding conductive strip (e.g., conductive strip **254**A) disposed on second keyboard section **320**. The connection between the two conductive strips allows for electrical connection of signals between second keyboard section **320** and a keyboard controller (e.g., controller **260** from FIGS. 2A, 2B).

FIGS. **3**B–**3**E illustrate one embodiment showing the range of motion of a keyboard assembly changing from a fully extended, unfolded configuration to a completely folded configuration. Turning now to FIG. **3**B, keyboard assembly **300** is illustrated in a fully unfolded configuration with first keyboard section **310** and second keyboard section **320** co-planar with respect to each other, and support plate **330** disposed underneath the keyboard sections and overlapping the keyboard sections **310**, **320** equally. First keyboard section **310** and second keyboard section **320** each has top surface **314**, **324** respectively for a distribution of keys. The keyboard sections also have a bottom section (not shown) that is generally smooth and rigid. The bottom surface of first keyboard section **310** allows it to slide along support plate **330** and the bottom surface of second keyboard section **320** becomes one side of a self-contained housing when keyboard assembly **300** is in the folded configuration.

In this configuration, linkage assembly **360** has first bar **362**, second bar **364**, and third bar **366** substantially parallel with each other and substantially parallel to the plane of the keyboard sections. Fourth bar **368** (not shown) maintains a low position such that it stays within a height of first bar **362** and second bar **364**. As such, pivots **380**, **382**, **384**, and **386** (not viewable) are substantially parallel to each other. Optionally, linkage assembly **300** may have second linkage assembly **370** described above. With respect to key assemblies (not shown) on the keyboard sections, linkage assembly **360** may be at a height lower than the height of the keycaps, such that none of the linkage assembly bars, including the pivots, interfere with the pressing of keys, when in the unfolded configuration.

FIG. **3**C illustrates keyboard assembly **300** in a partially folded configuration. Here, rotating second keyboard section **320** on pivots **384**, **386** of fourth bar **368** pulls first keyboard section **310** towards second keyboard section **320** by rotating pivot **382** of third bar **366** coupled to second bar **364**. Because third bar **366** is also coupled to first bar **362**, first keyboard section **310** slides along support plate **330**. In this configuration, pivot **382** moves such that it is raised above first arm **360** and pivot **380**.

Thus, a rotational force applied to second keyboard section **320** to fold over first keyboard section **310** corresponds to a horizontal force on first keyboard section **310**. First keyboard section **310** slides along rails (not shown) on support plate **330**. In this configuration, because second keyboard section **320** is only approximately 25% folded, first keyboard section **310** still extends past support plate **330**. Alternatively, this keyboard configuration may be one in which the keyboard is approximately 75% unfolded. In addition, applying a horizontal force on first keyboard section **310** towards second keyboard section **320** may cause second keyboard section **320** to fold toward first keyboard section **310**. Thus, the motions of folding and unfolding of keyboard assembly **300** are inter-related.

FIG. **3**D illustrates keyboard assembly **300** in another intermediate folded configuration. Depending on one's perspective, keyboard assembly **300** maybe seen as either partially open or nearly folded. In this configuration, first keyboard section **310** extends marginally past support plate **330** because keyboard assembly **300** is closer to the folded configuration than the fully extended, unfolded configuration. As mentioned above, first keyboard section **310** is able to slide along support plate **330** because first keyboard **310** engages rails (not shown) on support plate **330**. It should be noted that the movement of first keyboard section **310** may be accomplished by means other than engaging rails on support plate **330**.

The movement of first keyboard section **310** along support plate **330** as illustrated from FIG. **3**C to FIG. **3**D shows that first keyboard section **310** has a width that is approximately the same width as support plate **330**. Second keyboard section **320** also has approximately the same width as first keyboard section **310** and support plate **330**. One end of second keyboard section **320** has an indented configuration corresponding to the uneven division between first keyboard section **310** and second keyboard section **320**. The layout of keys in a standard QWERTY layout does not make for a division of the keyboard down the middle. Tab portion **396** of brace **390** integrates with indented portion **321** of second keyboard section **320**. This way, when second keyboard section **320** lies flat over first keyboard section **310**, the exposed surface of second keyboard section **320** appears smooth and seamless with brace **390**.

FIG. **3**E illustrates keyboard assembly **300** in a completely folded configuration. In this perspective view, top side **324** of second keyboard section **320** is seen with first keyboard section **310** disposed between second keyboard section **320** and support plate **330**. Brace **390** integrates with second keyboard section **320** such that top surface **324** appears to mate seamlessly with second keyboard section **320**. This folded keyboard configuration may be one embodiment of a compact form keyboard assembly **300** may take.

In the completely folded configuration, keys (not shown) of first keyboard section **310** and second keyboard section **320** may face each other and be fully compressed, thereby minimizing the thickness of each keyboard section **310**, **320**. When the keys are fully depressed, the overall thickness of each keyboard section **310**, **320** may be approximately the thickness **318**, **328** of each keyboard section only. By having the keys compress as much as possible, the overall size of keyboard assembly **300** in the folded configuration may be minimized. In an alternative embodiment, the thickness of keyboard sections **310**, **320** may be approximately half the thickness **329** of support plate **330**. As such, in the folded configuration, the combined thickness of the keyboard sections **318**, **328** is substantially the same as thickness **329** of support plate **330**.

FIGS. **4**A–**4**C illustrate a side view of keyboard assembly **400** changing from an unfolded configuration to a folded configuration. FIG. **4**A shows keyboard assembly **400** in an unfolded configuration. First keyboard section **410** and second keyboard section **420** are generally co-planar with respect to each other and appear to integrate continuously with each other to form a full-size keyboard. In one embodiment, the full-size keyboard conforms to a QWERTY layout. Linkage **460** couples first keyboard section **410** and second keyboard section **420** to each other, as well as acting as the pivot region for second keyboard section **420** to fold with respect to the first keyboard section **410**. Bar **468** of linkage assembly **460** shows the general location of the pivot region. In this unfolded configuration, pivots **480**, **482**, and **486** are visible. Pivot **484** is obstructed from view by support plate **430**. First keyboard section **410** and second keyboard section **420** are generally similar in length and thickness.

Both keyboard sections **410**, **420** are coupled to support plate **430**. Support plate **430** is generally flat and rigid, and has a thickness **429** that is generally similar to the keyboard sections. In addition, support plate **430** has a length that is generally similar to each keyboard section **410**, **420**. As shown, support plate **430** couples to the keyboard sections **410**, **420** simultaneously, and is disposed near a substantially center portion of the overall length of the first and second keyboard sections **410**, **420**. Because first keyboard section **410** and second keyboard section **420** are similar in length, it is not possible for support plate to extend across the entire length of both keyboard sections. As such, support plate **430** overlaps each keyboard section **410**, **420** equally to provide a rigid and balanced support to keyboard assembly **400**.

First arm **492** of brace **490** couples to support plate **430** along a horizontal edge of support plate **430**. First arm **492** has thickness **499** substantially equal to the thickness **429** of support plate **430** so as not to add any additional thickness to support plate **430**. First arm **492** of brace **490** extends from an end of support plate **430** to pivot **498**.

FIG. **4**B shows keyboard assembly **400** in an intermediate configuration in which keyboard assembly **400** is partially folded. As second keyboard section **420** is raised above support plate **430**, brace **490** pivots at pivot ends **496**, **498**. First arm **492** pivots upwards from pivot end **496** of support plate **430** and at pivot end **498** where brace **490** is coupled to second keyboard section **420**. Linkage assembly **460** with pivots **480**, **482**, **484**, **486** that couple first keyboard section **410** and second keyboard section **420** has shifted horizontally along a length of support plate **430** towards pivot end **496**. A portion of first keyboard section **410** still extends past support plate **430** at an end opposite pivot end **496**.

The configuration of keyboard assembly **400** in FIG. **4**B also shows the movement of four-bar linkage assembly **460**. First bar **462** is coupled to an edge of first keyboard section **410** and second bar **464** is coupled to an edge of second keyboard section **420**. Third bar **466** is coupled to first bar **462** at pivot **480** and to second bar **464** at pivot **482**. Fourth bar **468** is also coupled to first bar **462** at pivot **484** (not visible) and to second bar **464** at pivot **486**. The four pivots formed by linkage assembly **460** allow first keyboard section **410** to slide along support plate **430** while second keyboard section **420** folds over first keyboard section **410**.

As second keyboard section **420** is raised above support plate **430**, third bar **466** is raised such that pivot **482** is at a height above first keyboard section **410**. Pivot **482** behaves as a moving pivot that arcs toward first bar **462**. In the unfolded configuration as illustrated in FIG. **4**A, pivot **482** is substantially co-planar with first bar **462** and pivot **480**.

FIG. **4**C illustrates keyboard assembly **400** in the folded configuration. Second keyboard assembly **420** rests on top of first keyboard assembly **410**, keyboard sections **410**, **420** together rest on support plate **430**. In the folded configuration, the key cap surface (not shown) of keyboard sections **410**, **420** oppose each other. Bottom surface **424** of second keyboard section **420** and bottom surface **434** of support plate **430** form the exterior surfaces of folded keyboard assembly **400**. Bottom surfaces **424**, **434** may be made of a hard, plastic or metallic material. As such, keyboard assembly **400** in the folded configuration forms a self-contained housing for keyboard sections **410**, **420**. The keys remain protected allowing keyboard assembly **400** to be truly portable without the potential of the keys becoming damaged.

The keyboard assembly in the folded configuration also maintains a very low profile. First keyboard section **410** and second keyboard section **420** have a combined thickness that is substantially equal to the thickness of support plate **430**. In addition, keyboard sections **410**, **420** and support plate **430** have substantially equal lengths, giving the folded keyboard the appearance of a rectangular unitary body.

Linkage assembly **460** region connecting first keyboard section **410** and second keyboard **420** has shifted near pivot end **496**. In the folded configuration, linkage assembly **460** is not visible, having been disposed behind arm **492** of brace **490**.

FIGS. **5**A–**5**D illustrate perspective views of one embodiment of a linkage assemblies **560**, **570** that enable keyboard assembly **501** to change from an unfolded configuration to a folded configuration. For clarity of description and understanding, linkage assemblies **560**, **570** are illustrated without the corresponding keyboard sections. However, description of linkage assemblies **560**, **570** may be considered with respect to the description above relating to the folding and unfolding of the keyboard sections, in particular, with respect to FIGS. **3**A–**3**E and FIGS. **4**A–**4**C.

The illustration in FIG. **5**A shows the configuration of linkage assemblies **560**, **570** corresponding to an unfolded keyboard configuration. Linkage assembly **560**, coupled near one side of a keyboard assembly, is a four-bar linkage having first bar **510**, second bar **520**, third bar **530**, and fourth bar **540**. Alternatively, second four-bar linkage **570** may be disposed near the opposite side of linkage assembly **560**. Second four-bar linkage **570** includes first bar **511**, second bar **521**, third bar **531**, and fourth bar **541**.

First bar **510** is coupled to first keyboard section **502** along a horizontal edge of first keyboard section **502**. First bar **510** has arm portion **512** that extends towards second keyboard section **503** at a height below the longer elongated portion of first bar **510**. As will be described in greater detail below, first bar **510** is configured with arm portion **512** to enable fourth bar **540** to pivot such that in the folded configuration, second keyboard section **503** may rest evenly on first keyboard section **502**.

Second bar **520** is coupled to the second keyboard section **503** along a horizontal edge of second keyboard section **503**. In the unfolded keyboard configuration, first bar **510** and second bar **520** are substantially co-planar. First bar **510** and second bar **520** have a length that may be shorter than the length of each keyboard section **502**, **503**, and as such, do not extend along the entire length of both keyboard sections **502**, **503**. First bar **510** and second bar **520** are disposed near division **504** between first keyboard section **502** and second keyboard section **503**.

First bar **510** and second bar **520** may not be directly coupled together; alternatively, they may be coupled together through third bar **530**. Third bar **530** is coupled to first bar **530** at pivot **532** and to second bar **520** at pivot **533**. First bar **510** and second bar **520** is also coupled through fourth bar **540**. Fourth bar **540** is coupled to arm portion **512** of first bar **510** at pivot **542**, and to second bar at pivot **543**. Fourth bar **540** is a short segment that is slightly bent from pivot **542** to pivot **543**.

As noted above, keyboard assembly **501** may also have a second linkage assembly **570**. Although not necessary to enable keyboard assembly **501** from folding and unfolding, second linkage assembly **570** provides added support and stability. Second linkage assembly **570** has corresponding four-bar linkage **511**, **521**, **531**, **541** with corresponding pivots **534**, **535**, **544**, **545** as described for linkage **560**.

Linkage assemblies **560**, **570** illustrated in FIG. **5**B correspond to keyboard assembly **501** in a partially folded configuration. The change in configurations of the four-bar linkage assemblies **560**, **570** and corresponding pivots **532**, **533**, **542**, **543**, **534**, **535**, **545**, **544** may be compared to linkage assemblies **560**, **570** in the unfolded configuration of FIG. **5**A, to show the mechanics of linkage assemblies **560**, **570**. As second keyboard section **503** is raised and rotated towards first keyboard section **502**, pivot **533** rotates with respect to pivot **532** from its relatively co-planar configuration with second bar **520** and first bar **510**. Pivot **543** rotates with respect to pivot **542**. Thus, pivots **533** and **543** act as moving pivots while pivots **532** and **542** remain stationary. The linkage assemblies **560**, **570** operate such that when keyboard assembly **501** changes from an unfolded configuration to a folded configuration, moving pivots **533** and **543** rotate in opposite directions. Pivot **533** moves towards first bar **510** while pivot **543** moves away from first bar **510**.

FIG. **5**C shows linkage assemblies **560**, **570** in a position with first keyboard section **502** and second keyboard section **503** in a nearly closed configuration. Second bar **520** has rotated nearly **180** degrees towards first bar **510**.

FIG. **5**D shows linkage assemblies **560**, **570** in a configuration that corresponds to a completely folded keyboard assembly with second keyboard section **503** rotated over first keyboard section **502**. Second bar **520** rests on first bar substantially parallel to each other. Second bar **520**, pivot **533**, and pivot **543** are generally along the same plane. Third bar **530** spans diagonally across both first bar **510** and second bar **520** from pivot **532** to pivot **533**.

Linkage assemblies **560**, **570** illustrated in FIG. **5**D correspond to a folded keyboard configuration. Linkage assembly **560** has four bars **510**, **520**, **530**, **540**. In one embodiment, second linkage assembly **570** may be disposed on an opposite side of linkage assembly **560**. Second linkage assembly **570** has four bars **512**, **522**, **532**, **540** and pivots **534**, **535**, **544**, **545**.

Digital processing device **100** also includes hardware and software components to enable it to operate as a digital processing device. FIG. **21** illustrates one embodiment of the hardware components of digital processing device **100**. In one embodiment, digital processing device **100** includes a bus or other communication means **201** for communicating information, and a processing means such as processor **202** coupled with bus **201** for processing information. Bus **201** may include address, data, and/or control lines to provide communication among the various components of device **100**. Processor **202** may represent one or more processors such as an Intel Strongarm, an Intel Xscale, or an Intel Pentium processor, etc. In one embodiment, digital processing device **100** is configured to operate with a POCKET PC operating system stored on data storage device **207**. In alternative embodiments, another operating system may be used, for examples, PALM, LINUX, Windows CE, or Windows.

Digital processing device **100** further includes device memory **204** that may include a random access memory (RAM), or other dynamic storage device, coupled to bus **201** for storing information and instructions to be executed by processor **202**. Device memory **204** also may be used for storing temporary variables or other intermediate information during execution of instructions by processor **202**. Device memory **204** may also include a read only memory (ROM) and/or other static storage device coupled to bus **201** for storing static information and instructions for processor **202**.

A data storage device **207** such as a magnetic disk drive (e.g., a micro-drive) may also be coupled to digital processing device **100** for storing information and instructions. The data storage device **207** may be used to store data and software for performing various digital processing functions.

The various components illustrated in FIG. **2**I may be disposed within either of base plate **110** or display assembly **130**. In one embodiment, components disposed within base plate **110** may be coupled to other components in display assembly **130** (e.g., bus **201**) using a flex circuit that runs through embodiments of the hinge assembly. In addition, the keyboard assembly **120** may be coupled to bus **201** using a flex circuit running through hinge assembly.

It will be appreciated that the components shown in FIG. **2**I represents only one example of digital processing device **100**, which may have many different configurations and architectures, and which may be employed with the present invention. For example, device **100** may include multiple buses, such as a peripheral bus, a dedicated cache bus, a local bus, etc. to connect certain components. Moreover, digital processing device **100** may include additional components. For example, in one embodiment, digital processing device **100** may include one or more of hardware and software components found in commercially available notebook computers or PDA's such as the COMPAQ IPAQ, the Hewlett Packard Jornada or Palm Connected Organizers, for example, an MP3 player, a digital recorder, image viewer, auxiliary device interfaces (e.g., PCMCIA, Compact Flash, SIMD), auxiliary device cards (e.g., PCMCIA card, Compact Flash card, SIMD card), wireless modem, battery pack, etc. Such components may be detachably coupled with the digital processing device **100** or, alternatively, integrated into the device in either the base **110** or the display assembly **130**.

In one embodiment, for example, the digital processing device **100** may include a wireless communication device (e.g., a modem) integrated into the base **110**. An antenna may be adjustably coupled to the base **110** to allow for repositioning of the antenna so as not to interfere with typing on the keyboard assembly **120** or operation of the various hinge assemblies during reconfiguration of the device **100**.

As previously discussed, device **100** is designed to enable rotation of the image rendered on display screen **135**.

Display 221 receives signals from processor 202 to enable the generation of a frame image on display screen 135. In one embodiment, processor 202 transmits information to video controller 233 to display images in a particular orientation on display screen 135. A change in orientation may be initiated, for example, based on a hardware switch connected to display assembly 130. Display screen 135 may be, for example, a liquid crystal display (LCD) screen. Display screen 135 may include an array of picture elements ("pixels") cells (not shown) that form corresponding pixels of the frame image. A pixel is the basic unit of programming in an image or frame. A pixel is the smallest area of a display's screen that can be turned on or off to help create the image with the physical size of a pixel depending on the resolution of the display. Pixel cells may be formed into rows and columns of a display in order to render a frame image.

In one embodiment, display screen 135 may be a color display screen capable of rendering color images. If the frame buffer 234 contains a color image, each pixel may be turned on with a particular color in order to render the color image. The specific color that a pixel describes is some blend of components of the color spectrum such as red, green, and blue. To accomplish this, each pixel cell may receive an electrical voltage that controls the optical properties of the pixel cell and, thereby, the intensity of the corresponding pixel cell. The electrical voltages for particular pixel cells are transmitted by corresponding row/column drivers 236 and 237.

Digital processing device 100 may also have additional related components, for example, analog-to-digital converters, timing generators, voltage sources, logic circuits, etc. (not shown) in order to generate an image on display screen 135. Image rendering and related components are known in the art; accordingly, a detailed discussion is not provided. In one embodiment, video controller 233 is a MediaQ video controller. Alternatively, the operation of video controller 233 may be performed by processor 202 to control the generation of images on display screen 135. In another embodiment, display screen 135 may be a monochrome display screen.

As previously mentioned, the image rendered on display screen 135 may be rotated from a portrait mode to a landscape mode when the digital processing device is reconfigured from a PDA configuration (e.g., as illustrated in FIG. 2B) to a keyboard typing configuration (e.g., as illustrated in FIG. 2E), respectively. The portrait mode has text and/or graphics that are oriented perpendicular to the longest side of the display assembly. In one embodiment, when processor 202 detects a toggle of the hardware switch, the processor 202 executes an instruction to video controller 233 to initiate screen image rotation. Video controller 233 loads data (e.g., received from processor 202 or stored in memory 204) representative of the desired image orientation in frame buffer 234 to control row/column drivers 236 and 237 to render a set of RGB values for each pixel cell in display screen 135.

In one embodiment, screen image rotation may be performed using screen buffer transforms which are known in the art that are not dependent on the LCD's physical or electrical design. The screen rotation is achieved during the frame buffer 234 reading instead of inside the physical display itself. By logically changing frame buffer 234 reading scan start point and the address counter increase or decrease directions, it should be noted that any degree of image rotation on display screen 135 (e.g., 90 degrees, 180 degrees, 270 degrees) may be performed. For a specific screen rotation, the parameters that control the frame buffer memory address can be written into the graphics chip in advance, or be changed dynamically.

As another example, for more complicated color depths (e.g., those that lie on non-byte boundaries), the pixels may be moved by copying the number of bits that make a pixel from the horizontal (e.g., row) to a pixel-aligned position in the vertical (e.g., column). For 12-bit color, for example, the copying may be performed 12-bits at a time.

In the forgoing specification, the invention has been described with reference to specific exemplary embodiments thereof. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader spirit and scope of the invention as set forth in the appended claims. The specification and drawings are, accordingly, to be regarded in an illustrative sense rather than a restrictive sense.

What is claimed is:

1. A digital processing device, comprising:

a rigid base;

a display assembly comprising a display screen;

a foldable keyboard assembly coupled with the base, said foldable keyboard assembly having keyboard sections substantially equal in size; and

a hinge assembly rotatably coupling the display assembly to the base, the hinge assembly enabling the display assembly to be rotated between a first configuration and a second configuration.

2. The digital processing device of claim **1**, wherein the base has a front and a back and the display assembly has a side, a back and a front, and wherein the first configuration configures the display assembly to be in contact with the back of the base and wherein the second configuration configures the display assembly to form an angle of at least 180 degrees between the front of the display assembly and the keyboard assembly.

3. The digital processing device of claim **1**, wherein the hinge assembly is configured to rotate through substantially 360 degrees.

4. The digital processing device of claim **1**, wherein the hinge assembly comprises:

first and second hinge linkages cross-connected between the base and the display assembly relative to each other.

5. The digital processing device of claim **4**, wherein the cross-connected linkages enables rotation of the base and display assembly without any substantial translation with respect to each other.

6. The digital processing device of claim **4**, wherein at least one of the first and second hinge linkages contains a flex circuit disposed within a cavity.

7. The digital processing device of claim **1**, wherein the hinge assembly rotatably couples the display assembly to the base at four pivot axes.

8. The digital processing device of claim **1**, wherein the hinge assembly comprises:

a first hinge coupled to the base at a first base pivot axis and coupled to the display assembly a first display assembly pivot axis; and

a second hinge coupled to the base a second base pivot axis different than the first base pivot axis, the second hinge coupled to the display assembly at a second display assembly pivot axis different from the first display assembly pivot axis.

9. The digital processing device of claim **8**, wherein a first distance between the first display assembly pivot axis and the second display assembly pivot axis is the same as a distance between a second distance between the first base pivot axis and the second base pivot axis.

10. The digital processing device of claim **9**, the first and second hinges form a common axis of rotation between the base and the display assembly.

11. The digital processing device of claim **1**, the hinge assembly forms a common axis of rotation between the base and the display assembly.

12. The digital processing device of claim **1**, wherein the hinge assembly rotatably couples the keyboard assembly along a longest side of the display assembly.

13. The digital processing device of claim **1**, wherein the first configuration enables information entry into the digital processing device through the display screen and wherein the second configuration enables information entry into the digital processing device using the keyboard assembly.

14. The digital processing device of claim **13**, wherein the display screen is configured to display an image in first and second orientations corresponding to the first and second configurations, respectively.

15. The digital processing device of claim **14**, wherein the first and second orientations are disposed 90 degrees relative to each other.

16. The digital processing device of claim **14**, wherein the image on the display screen automatically orientates from the first and second orientations corresponding to the first and second configurations, respectively.

17. The digital processing device of claim **16**, wherein the image on the display screen automatically orientates using a screen buffer transforms.

18. The digital processing device of claim **1**, wherein the keyboard assembly unfolds to a plurality of keys having a kev displacement of about 2 mm to about 4 mm.

19. The digital processing device of claim **1**, wherein the keyboard assembly comprises keys and wherein the keys are not exposed when in first configuration.

20. The digital processing device of claim **1**, wherein at least one set of keys of the keyboard assembly slides from a second position in the second configuration to a first position for storage in the first configuration.

21. The digital processing device of claim **1**, wherein the keyboard assembly comprises first and second key panels and wherein each of the first and second key panels has a length that is no greater than approximately the length of the base.

22. The digital processing device of claim **21**, wherein the keyboard assembly comprises a linkage mechanism to substantially center adjoining edges of the first and second panels over the base when the keyboard assembly is completely unfolded.

23. The digital processing device of claim **21**, wherein a linkage mechanism operates to slide the first panel in response to rotation of the second panel.

24. The digital processing device of claim **21**, wherein a linkage mechanism comprises a moving pivot point of the second panel.

25. The digital processing device of claim **21**, further comprising a third panel disposed over a section of the first panel exposed by the second panel when folded over the first panel.

26. The digital processing device of claim **1**, wherein the keyboard assembly comprises keys having centers and wherein at least two keys have a distance between the centers of at least approximately 18 mm.

27. The digital processing device of claim **1**, wherein the keyboard assembly comprises:

a first keyboard section and a second keyboard section; and

at least one linkage assembly coupled to the first keyboard section and the second keyboard section, the at least one linkage assembly to enable the keyboard sections to alternate between a folded configuration and an unfolded configuration, the at least one linkage assembly comprising:

a first bar coupled to the first keyboard section along a length of the first keyboard section near a region where the first keyboard section meets the second keyboard section in the unfolded configuration;

a second bar coupled to the second keyboard section along a length of the second keyboard section near a region where the second keyboard section meets the first keyboard section in the unfolded configuration;

a third bar coupled to the first bar and the second bar; the third bar having a first pivot coupled to the first bar and a second pivot coupled to the second bar, the second pivot to move along a rotating arc of the first pivot; and

a fourth bar coupled to the first bar and the second bar, the fourth bar having a third pivot coupled to the first bar and a fourth pivot coupled to the second bar.

28. The digital processing device of claim **1**, wherein the foldable keyboard assembly comprises two keyboard sections.

29. A digital processing device, comprising:

a keyboard assembly having a collapsed form relative to an open form, the open form exposing a plurality of keys having a center-to-center spacing of about 19 mm; and

a display assembly coupled with the keyboard, the display assembly configured to display data in a landscape mode when the keyboard assembly is in the open form and to display data in a portrait mode when the keyboard assembly is in the collapsed form.

30. The digital processing device of claim **29**, wherein the keyboard assembly comprises:

a first keyboard section having first keys of said plurality of keys; and

a second keyboard section having second keys of said plurality of keys, wherein the first keys face the second keys and are compressed when the keyboard assembly is in the collapsed form.

31. The digital processing device of claim **30**, wherein the keyboard assembly is foldable and said digital processing device is a mobile computer.

32. The digital processing device of claim **31**, wherein the display assembly is rotatably coupled to the keyboard assembly.

33. The digital processing device of claim **29**, wherein said plurality of keys have a key displacement between about 2 mm to about 4 mm and a force near the character generation point between about 0.25 N to about 1.5 N.

34. The digital processing device of claim **29**, wherein said keyboard assembly further comprises at least one key which does not substantially comply with said key sizes.

35. The digital processing device of claim **29**, further comprising:

a cellular communication transceiver for voice communications and for network data communications, said cellular communication transceiver coupled to a keyboard controller which is coupled to said keyboard assembly.

36. A digital processing device, comprising:

a rigid base;

a display assembly comprising a display screen;

a foldable keyboard assembly coupled with the base, said foldable keyboard assembly having keyboard sections substantially equal in size; and

means for rotatably coupling the display assembly to the base enabling the display assembly to be rotated between a first configuration and a second configuration.

37. The digital processing device of claim **36**, further comprising means for rotating the base and display assembly without any substantial translation with respect to each other.

38. The digital processing device of claim **36**, further comprising means for entering information into the digital processing device through the display assembly in the first configuration and means for entering information using the foldable keyboard assembly in the second configuration.

39. The digital processing device of claim **36**, further comprising means for automatically orientating an image on the display assembly from a first and a second orientation corresponding to the first and second configurations, respectively.

40. The digital processing device of claim **36**, wherein the foldable keyboard assembly comprises two keyboard sections.

41. A digital processing device, comprising:

means for collapsing a keyboard assembly having a collapsed form relative to an open form, the open form exposing a plurality of keys having a center-to-center spacing of about 19 mm; and

means for coupling a display assembly with the keyboard, the display assembly configured to display data in a landscape mode when the keyboard assembly is in the open form and to display data in a portrait mode when the keyboard assembly is in the collapsed form.

42. The digital processing device of claim **41**, further comprising means for folding the keyboard from the collapsed form to the open form.

43. The digital processing device of claim **41**, further comprising means for entering information into the digital processing device through the display screen in a first configuration and means for entering information using the keyboard assembly in a second configuration.

44. The digital processing device of claim **41**, further comprising means for automatically orientating data on the display assembly from the portrait mode and the landscape mode.

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