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(54) **Electrical key switch**

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Bouton-poussoir électrique

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Description

TECHNICAL FIELD

[0001] This invention relates to keypads, and to key switches for keypads and keyboards.

BACKGROUND

[0002] The miniaturization of electronic products is one of the primary tenets of technologic advance. Competitive advantage and the success of a product line largely hinges on the ability of a company to successfully provide products that are both increasingly functional and increasingly portable. As technology advances, it becomes increasingly possible to miniaturize electronic circuitry below human scale, with the result being that the interface alone (e.g., screens, keypads, cursor control devices) come to define the size of portable products. Therefore, the ergonomic quality and size of input devices (such as keypads) continue to have a growing significance to product acceptance and success.

[0003] One type of keypad or keyboard that provides a particularly space-efficient input means are Independent And Combination Key (IACK) keypads, having arrays of effectively lower, concave combination key regions interspersed among an array of effectively elevated, convex independent key regions. IACK keypads have both independent and combination key regions, typically arranged in alternating rows and columns. Independent key regions of my prior IACK keypads were elements of the keypad that, when pressed independent of adjacent keys, produced an associated output. By contrast, the combination key regions of my prior IACK keypads were keypad elements with adjacent independent keys (such as at diagonally-oriented corners of the combination key region) with no corresponding key switches underlying the keymat. Output corresponding to the combination key region was produced by pressing two or more adjacent elevated key regions in combination.

[0004] Other improvements leading to reliable operation of increasingly miniaturized keypads are desired, even in keypads that don't require the output of some key regions to be produced by activating combinations of switches corresponding to other key regions. For example, improvements are sought in the construction of key switches that can reliably and near-simultaneously close multiple electrical connections with a single, defined tactile feedback event. There is a class of keyboards and keypads, including IACK keypads, that require multiple key switch contacts to be made simultaneously. Snap domes (made from materials such as metal and plastic) that operate in a buckling mode provide a high quality of tactile feedback. It is extremely difficult, however, to make reliable momentary connection to more than one key switch contact at a time.

[0005] US 4,194,105 discloses an electrical switch contact member consisting of a resilient electrically con-

ductive domed diaphragm of a predetermined shape. The diaphragm includes a frustoconical region which is linked by swann-necked regions with a central domed region and a peripheral region. The frustoconical region is dimensioned to function as a Belleville spring. Each switch of a key block according to this reference is a single make contact switch in which depression of the diaphragm establishes bridging electrical connection between annular tracks on a printed circuit board.

[0006] Patent Abstracts of Japan JP 2001216866 discloses a switch with a dome-shaped contact spring, where an outer peripheral part of the contact spring is brought into contact with a contact piece of a base and the inner central part of the contact spring made as a movable contact part is brought into contact with or separated from a fixed contact part of the base for electrically switching on and off the contact.

SUMMARY

[0007] One aspect useful for understanding the invention relates to an improvement that is provided for keypads having a matrix of key regions including both an array of elevated key regions each providing a corresponding character output when actuated, and key regions interspersed between the elevated key regions and providing character output based at least in part on an operation algorithm that includes activation of at least one adjacent elevated key region. The improvement features corresponding, independently actuatable key switches disposed below the interspersed key regions, the operation algorithm also including actuation of the associated switches below the interspersed key regions.

[0008] Preferably, adjacent elevated key regions have an on-center distance of less than about half the width of the adult human finger.

[0009] In some cases, corresponding tactile feedback elements underlie each elevated key region and each interspersed key region.

[0010] In some implementations the operation algorithm, in response to sensing a combined switch actuation including any switch underlying an elevated key region and a switch underlying an interspersed key region, produces an output corresponding to the interspersed key region.

[0011] In some instances the operation algorithm, in response to sensing a combined switch actuation including a switch underlying an interspersed key region and any switch underlying an elevated key region immediately adjacent that interspersed key region, produces an output corresponding to the interspersed key region.

[0012] In some situations, each switch disposed below an interspersed key region is directly connected to a switch disposed below another interspersed key region on one side, and to a switch disposed below an elevated key region on another side.

[0013] The interspersed key regions, in at least some embodiments, have exposed surfaces that are convex.

In some other cases, they are substantially flat

[0014] In some cases, the elevated key regions each include an elevated ridge defining a top surface and each interspersed key region is immediately adjacent a plurality of the elevated key regions.

[0015] In some embodiments, the keypad includes a printed circuit board with traces electrically connecting each of at least some switches underlying elevated key regions with a switch underlying a corresponding one of the interspersed key regions.

[0016] In some cases, the keypad has a printed circuit board with four electrical trace extensions extending to beneath each of the interspersed key regions, to form switch contacts. For example, two of the trace extensions under each interspersed key region may connect to a tactile dome, and the other two trace extensions connect to exposed traces that are momentarily placed into electrical contact when that interspersed key region is actuated.

[0017] In some preferred constructions, each switch disposed below an interspersed key region is actuated by electrical traces of a printed circuit board contacting a discontinuity in an inner surface of a metal snap dome. Preferably, the traces contacted by the snap dome surface discontinuity form three discrete contacts spaced about a circular contact zone beneath the snap dome. The traces may be pie-shaped beneath the snap dome, for example.

[0018] In some cases, the switches disposed below the interspersed key regions each includes a tactile feedback element and a carbon ring. In such cases, the tactile feedback elements may be electrically passive. The switches disposed below the interspersed key regions may each be connected to three signal traces, forming a single access to the switch from one side of the matrix, and two access points from another side of the matrix.

[0019] In some keypads, either the elevated or interspersed key regions are respective areas of a molded plastic keymat that flexes during key actuation. In some cases, key regions that are not respective areas of the molded plastic keymat are exposed through respective, spaced apart holes in the keymat. In some cases, snap dome actuators are molded to extend from a lower surface of the keymat. The keymat may also be molded integrally with a product housing.

[0020] In some other cases, the key regions are upper surfaces of keys secured to a sheet held in a stretched condition above an array of key switches. The stretched sheet may comprise a sheet of elastomeric resin, for example. Preferably, the elastomeric sheet is held in a stretched condition of at least 20 percent in at least one direction. In some instances, the stretched sheet comprises a plastic sheet molded to have a resiliently distendable region, such as a pleat extending out of a principal plane of the sheet.

[0021] According to another aspect useful for understanding the invention, an improvement is provided for a keypad comprising a keymat and a switch substrate un-

derlying the keymat, the keymat having an exposed upper surface forming separate elevated key regions that, when pressed independent of adjacent key regions, produces an associated output, the keymat also defining other key regions interspersed between adjacent elevated key regions and labeled to indicate other associated outputs. The improvement features that the keymat is rigidly held at its perimeter in a stretched condition across the switch substrate.

[0022] In some embodiments, the elevated key regions are upper surfaces of rigid keys secured to an elastomeric sheet.

[0023] The elastomeric sheet is preferably held in a stretched condition of at least 20 percent in a given direction, or held stretched in each of two orthogonal directions.

[0024] Some examples feature a keymat with a plastic sheet molded to have a resiliently distendable region, such as a pleat extending out of a principal plane of the sheet.

[0025] In some embodiments, the keymat defines peripheral holes that, with the keymat stretched, receive pins of a rigid keypad housing.

[0026] According to the invention, an electrical key switch includes a printed circuit board with at least two switch contacts that are normally electrically isolated from each other, and a metal snap dome disposed above the printed circuit board. The dome has an elevated central region forming a downwardly facing cavity defined at its edge by a ridge disposed above the switch contacts, such that when the snap dome is actuated the ridge about the central region engages the printed circuit board in an annular contact zone across the switch contacts, making electrical contact between the snap dome and the switch contacts. The snap dome has an outer edge disposed against and in electrical contact with a reference trace on the printed circuit board.

[0027] Preferably, the annular contact zone is about one-third of a nominal diameter of the metal dome.

[0028] The switch contacts, in one illustrated embodiment, are wedge-shaped. Preferably each switch contact extends across about 20 degrees of the circumference of the contact zone.

[0029] The switch contacts are preferably disposed approximately equidistant from each other about the contact zone.

[0030] In some cases the ridge forms a continuous ring. In some other cases the ridge comprises a ring of spaced ridges or ridge segments.

[0031] In some applications the snap dome overlays three spaced apart switch contacts.

[0032] In some cases, the switch contacts are sufficiently thick that the deflected snap dome contacts all underlying switch contacts before contacting any other surface of the PCB, and preferably the snap dome is sufficiently thin and the switch contacts sufficiently spaced apart that, with the deflected dome in contact with all of the underlying switch contacts, the dome can deflect

further toward the PCB between adjacent switch contacts

[0033] In another improvement to a keypad comprising a keymat and a switch substrate underlying the keymat, the keymat having an exposed upper surface forming separate elevated key regions that, when pressed independent of adjacent key regions, produces an associated output, the keymat also defining other key regions interspersed between adjacent elevated key regions, the switch substrate includes both switches underlying associated and elevated key regions and switches directly underlying corresponding ones of the interspersed regions.

[0034] According to another improvement for keypads having a matrix of key regions including both an array of elevated key regions each providing a corresponding character output when actuated, and key regions interspersed between the elevated key regions and providing character output based at least in part on an operation algorithm that includes activation of at least one adjacent elevated key region, the interspersed key regions have a notably convex upper surface.

[0035] Placing multiple switches under a finger is at odds with basic tenets of sound ergonomic design: that of providing one distinct tactile feedback for each input received. Some of my early attempts to provide a high-level (metal dome) tactile feedback yielded unacceptable combination key reliability and multiple "clicks" per input. Ultimately, the solution presented by some of the embodiments disclosed herein required multiple concurrent changes, including adding an additional tactile feedback (as a means to solve the problem that there was already too much feedback), adding a submatrix within the PCB matrix (which, without some of the improvements disclosed herein) would have the undesirable effect of increasing the number of lines to a central processor, and, in some respects, abandoning the early IACK concept (of having opposing diagonals of elevated keys producing an output associated with a central combination key region) in favor of a hierarchical approach between non elevated and elevated keys, in which the non-elevated keys became dominant. Furthermore, the improved keymat structures improves the ability of a generic finger to actuate both independent and combination keys reliably.

[0036] A keypad structure is provided that employs the relative height and relative strength of a single dome structure with respect to four surrounding it, and a relatively weak deflection force within the keymat itself. This approach is particularly advantageous in combination with convex, non-elevated keys.

[0037] The reliability of making multiple switch contacts with a single metal dome is enhanced by narrowing the traces that contact the discontinuity and thickening the metal of the traces such that portions of the discontinuity locate between the three discrete contacts may materially deflect toward a printed circuit board as the discontinuity is in contact with the three discrete contacts. The reliability of making multiple contacts at once is particularly enhanced, especially if the snap dome and trac-

es only contact each other at the "triple point", or locations that divide the diameter approximately into thirds.

[0038] Material property differences between an elastomeric keypad web held in a plastic housing can result in a loss of contact with the snap domes under extreme temperature variations. In order to maintain contact between the keymat actuators and domes without needing to use an adhesive (which adds service and manufacturing concerns) it is desirable to assemble the keymat into a pre-stressed or stretched state.

[0039] Some aspects of the invention can enable a miniaturized keypad that still has a well-defined, subjectively good tactile feedback for each key entry, whether of an elevated or non-elevated key region. Other features disclosed and claimed herein can improve the durability of keymats, such as by providing a hard plastic keypad that allows the keypad to be integrated with the housing, minimizing the number of exposed edges in a keypad tiling, etc. Still other improvements increase the useful life and operability of flexible keymats. The improved dome switch construction disclosed herein can produce reliable, near-simultaneous connections across two or more contact paths with a single tactile feedback to the user.

[0040] The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Some of these embodiments are described with respect to improvements to IACK keypads, or to keypads having key regions whose output is determined only by the combined states of switches associated with adjacent, elevated key regions. However, it will be understood that several aspects of the invention are not limited to such types of keypads, and that others distinguish such operational algorithms. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

[0041]

Fig. 1 shows a first printed circuit board (PCB) for a keypad, with some switches including both exposed carbon and metal dome switch plates.

Fig. 2 shows a cross section of a keypad with elevated and interspersed key regions.

Figs. 3 and 4 illustrate the actuation of a combination key region and an independent key region, respectively, of a thermoformed IACK keymat.

Fig. 5 shows narrow actuation posts molded in to a back-filled elastomer.

Figs. 6 and 7 show operational algorithms for a keypad.

Figs. 8 and 9 show circuit board layouts useful with the algorithms of Figs. 6 and 7.

Fig. 10 shows a finger pressing on an elevated key region.

Fig. 11 shows a finger pressing on a convex, non-

elevated key region.

Fig. 12 shows a finger pressing on a flat, non-elevated key region.

Fig. 13 shows a finger pressing on an elevated key region with a raised edge.

Fig. 14 shows an elastic keymat disassembled from its housing.

Fig. 15 shows the keypad of Fig. 14 as assembled

Fig. 16 shows a keypad with a keymat molded with a flexure points.

Fig. 17 shows a keymat with independent key regions defined on a rigid structure.

Fig. 18 is a cross-sectional view, taken along line 18-18 of Fig. 17.

Fig. 19 shows a keymat with combination key regions defined on a rigid structure.

Fig. 20 is a cross-sectional view, taken along line 20-20 of Fig. 19.

Fig. 21 is a cross-sectional view taken through a metal dome designed to contact multiple switch elements at once.

Fig. 22 shows the PCB traces underlying the dome of Fig. 21.

Fig. 23 shows a discontinuous ring element on the underside of a metal dome.

[0042] Like reference symbols in the various drawings indicate like elements.

DETAILED DESCRIPTION

[0043] Fig. 1 shows switches 21 to accommodate traditional snap domes 12 (Fig. 3) made of metal or plastic providing a momentary connection between two lines located at one of the intersections of drive lines 24 (shown vertical) and sense lines 26 (shown horizontal), under the independent keys 11 of an IACK keypad having an array of independent key regions 11 interspersed between combination key regions 22 (see also Figs. 3,10). The base of snap dome 12 (preferably made of metal) rests on a printed conductive base 29 in electrical contact with the drive lines 24 above it, and the center of switch 21 is in electrical continuity with the sense line 26 to its right. The result is that actuation of associated snap dome 12 is the electrical equivalent of actuating the switch under the independent key 11 located upwards and to the right of the intended combination key 22. Also shown is one auxiliary contact 20 in electrical continuity with the drive line 24 below it, and one auxiliary contact 20 in electrical continuity with the sense line 26 to its left. A tape layer covers the snap domes 12, preventing contact to auxiliary conductor 18 (Fig. 3), and also has cut outs corresponding with auxiliary contacts 20 that allow contact between the auxiliary conductors and the PCB. The result is that actuation of associated snap dome 12 is the electrical equivalent of actuating the switch under the independent key 11 located downwards and to the left of the intended combination key 22. The simultaneous ac-

tuation of these two independent keys 11 (located diagonally opposite from each other across a combination key 22) acts as an indication to the controller that the intent is to actuate the central combination key.

[0044] Fig. 2 shows drive lines 24 electrically isolated from sense lines 26, although electrical connectivity between them can be made at each independent intersection 14, corresponding to the location of an independent key region 11. As in some earlier IACK keypads, the software of the system registers a combination key input as a result of activation of at least two diagonally adjacent (i.e. opposite adjacent) independent key regions 11. For example, activating both "E" and "L", or "F" and "K", is registered by the system as an intention to enter the number "3". In this matrix, however, trace extensions 50 extend from each of the four trace segments that bound each combination key region 22, to almost contact each other at each combination intersection 15. Trace extensions 50 extend in each combination key region 22 to within a contact region 141. Extensions 50 may be made of as conductive ink which may be selectively doped or otherwise varied to provide a unique resistance at each intersection during contact, such that the identity of the intersection under contact can be verified by sensing trace resistances.

[0045] Actuation of a combination key 22 directly above a combination intersection 15 closes contact between the four adjacent ends of the trace extensions 50 at that intersection 15, thereby connecting the adjacent pairs of drive lines 24 and sense lines 26 and creating the electrical equivalent of actuating all four surrounding independent intersections 14. Examples of switch constructions for connecting all four trace extensions 50 of a given combination intersection 15 are shown in Figs. 1 and 21-23.

[0046] Figs. 3-4 illustrate the operation of an IACK keymat 30a having a thin sheet 70 formed into the undulating surface contour of the exposed key regions, including elements for independent keys 11 and combination keys 22. The sheet 70 may be made of relatively hard and stiff material, such as polycarbonate or polyester, and formed with a process such as thermoforming. A sheet thickness of 0.002 to 0.005 inch is preferred, for example. Below each independent key region 11 is an actuator 36 of another material, formed in place such as by injection molding. Actuators 36 are disposed directly above respective, high-feedback n, such as metal or polyester domes. Likewise, there is an actuator 36 and high-feedback snap dome 12 below each combination key region 22.

[0047] As shown, there is a difference in the spacing between the lower surfaces of actuators 36 and their associated snap domes 12. The area of contact between sheet 70 and the actuators 36 of the independent keys 11 is limited to the portion of the independent key 11 that will not deform during use, predominantly the flat area at the top that is contacted by a finger 55 during activation of the independent key 11. The object is to transmit force to the tactile feedback element 12 while minimizing the

rigidity of the sloped sides of the independent keys 11. The structure or structures that transmit force between sheet 70 and tactile feedback elements (snap domes) 12 need not be attached to sheet 70. At rest the actuators 36 located below independent key regions 11 are separated from their associated tactile elements by a distance "d" at least slightly greater than the stroke length of the tactile elements. In this illustrated embodiment, the heights and stroke lengths of all snap domes 12 are the same. Tactile feedback (specifically one distinct sensory feedback for one input sensed) is an extremely important aspect of any keypad, and in opposition to the inherent nature of a technology that places a plurality of tactile elements directly beneath a user's finger, such as IACK. This structure provides a single, well-defined tactile feedback in an IACK keypad when either a combination key 22 or an independent key 11 is pressed.

[0048] As shown, independent key actuators 36 underlie only the uppermost plateau regions of the independent key regions 11, across which the majority of finger actuation force is applied. This leaves the slanted sides of the raised independent key regions 11 free to bend during key actuation, as not constrained by actuators 36.

[0049] As a user's finger 55 presses to input the character printed on combination key 22 (Fig. 3), some deformation occurs within sheet 70, but the primary result is downward deflection of the adjacent independent key regions 11 as the intended combination key region 22 deflects downward. Notably, however, the snap dome 12 directly below the combination key region 22 is tripped at a lower deflection distance than those of the adjacent independent key regions 11, as shown in Fig 3. This provides a single and highly-defined tactile feedback (such as from a metal or poly dome) in response to actuating a combination key 22.

[0050] Conversely, as a user's finger 55 presses to actuate an independent key region 11 (Fig. 4), the snap dome 12 directly below that independent key is tripped before any of the surrounding tactile elements is tripped. As long as the force required to deflect sheet 70 about the actuated independent key region 11 is less than the combined trip force of the snap domes 12 located below the adjacent combination key regions 22, the selected independent key 11 will continue to advance to trip only its associated snap dome 12.

[0051] Fig. 5 shows keymat 30b, a variation of the embodiment of Fig. 3, in which actuators 36 are formed of a rigid, optically transmissive material, and/or are cone-shaped for improved light transmission while minimizing material compression. These may be formed with a two shot in-mold process, in which the elastomeric material forming web 97 is formed first and a second shot forms a higher durometer material of the actuators 36. Alternatively, concentrators 36 maybe insert-molded in a softer elastomer. The upper surfaces of concentrators 36 may be shaped to form letters or other symbols identifying key regions.

[0052] Fig. 6 shows a decoding method that simplifies the software, reduces the processing steps necessary to operate an IACK keypad and enables high quality tactile feedback in an IACK keypad. In step 100 two classes of keys are created in software. These may be as simple as lists of the two types of keys (11 and 22), or also a list of one type of key and the remaining keys are (by default) of the second type. Independent keys 11 are assigned to a secondary class and combination keys 22 are assigned to a dominant class. Notably, the relative locations of specific independent 11 and combination keys 22 are not part of the decoding algorithm, rather absolute location and class are used to define the intended output. Conversely, with some earlier IACK keypads, knowing the relative position of each key was fundamental to operation. In step 102, the system senses the user pressing a secondary key, such as independent key 11. The system may post this key, or wait a designated delay period. In step 104 the user presses (and the system senses) another key actuation before the secondary key is released. The software does not need to analyze which diagonals are involved and perform a correlation between the selected diagonals and the combination key between them, as any key of the dominant class will supercede any key of the secondary class. Referring briefly to Fig 9, in some prior art IACK keypads, activation of the 'A' key would have required activation of elevated key regions 1 and 6, or 2 and 5. However, in this algorithm any of numeric keys 1 through 12, in combination with 'A' will yield an 'A' output, as will key 'A' by itself. The locations of the independent keys are immaterial. In step 106 the system abandons the secondary key for the primary key. This algorithm may not be as useful with some prior art IACK keypad structures having a high-quality tactile feedback and that operated on the principle of opposite adjacent independent keys 11 indicating intent to actuate a combination key 22. In those cases, operation of a combination key necessitated the actuation of at least two snap domes 12 (in keypads with snap domes) because the independent keys were spaced apart less than half of an adult finger width apart for overall size reduction. This algorithm (or that of Fig. 7) used in combination with the convex combination key structure of Fig. 11 allows for individual high-quality tactile feedback in IACK keypads.

[0053] Fig. 7 shows another decoding method that simplifies the software, reduces the processing steps necessary to operate an IACK keypad and enables high quality tactile feedback in an IACK keypad. This method (like that of Fig. 6) is suitable for use with printed circuit board layouts as shown in Figs 8 and 9. In step 110, two classes of keys are identified, analogous to step 100 in Fig. 29. However, in step 112, additional lists are created in which each dominant key is associated with the adjacent secondary keys. Referencing Fig. 9, 'A' is associated with 1, 2, 5 and 6; 'B' with 2, 3, 6 and 7; 'C' with 3, 4, 7 and 8; 'D' with 5,6,9 and 10; 'E' with 6, 7,10 and 11; and 'F' with 7, 8, 11 and 12. Note that the same result may be

achieved by creating a single set of lists in which a pre-defined element is of a particular class, such as: 'A, 1,2,5,6'; 'B,2,3,6,7'; 'C, 3,4,7,8'; 'D, 5, 6, 9, 10'; 'E, 6,7,10,11'; and 'F, 7, 8,11, 12' in which a particular character of each list (in this case the first character) is the dominant key. The other characters, identifying physically adjacent keys, may be listed in a random order, as location with respect to the dominant (combination 22) key is immaterial. In step 115 a plurality of keys are pressed by the user and sensed by the system. In step 117 the system references the classifications and prioritizations made in steps 110 and 112. If one or more secondary keys are sensed during the initial instant of an input stroke, and the system later senses a dominant key prior to the deactivation of all the secondary keys, the system will abandon the secondary keys in favor of the dominant key, step 106. As with the method of Fig 6, output is not based exclusively on combinations of opposite-adjacent keys, as with many prior IACK keypads. This method in combination with the PCB layout of Fig. 8 also allows successful differentiation between independent, combination and ambiguous key groupings in a single cycle by driving adjacent drive lines simultaneously. Specifically, in some prior art IACK keypads it was possible to drive adjacent lines simultaneously and thereby determine a combination key in a single step, an approach that can yield ambiguous results if two adjacent horizontal or two adjacent vertical keys are pressed. This ambiguity required a second cycle to determine the true state of the switch matrix. This problem is now solved in that adjacent drive lines may be pulsed simultaneously to provide non-ambiguous information of the matrix and accurately determining both independent and valid combination key combinations in a single cycle. This method also works for keypads in which keys are independently addressable, such as keypads in which each switch as an associated diode.

[0054] Fig. 8 shows a hardware configuration for implementing the methods of Figs 6 and 7. Sense lines 26 have been added to measure output from combination keys 22. Switches 21 that are dedicated to combination key 22 input are driven through the drive lines 24 of the independent keys 11. The input is provided to combination keys 22 by bridge 31 that taps a signal from the drive line 24 of independent keys 11. Sense lines 26 lead to processor 151. An electrical word on the drive lines 24 can be read on the sense lines 26 to identify any combination key 22 or independent key 11 switches. This information is used preferably with the methods of Figs 6 and 7.

[0055] Fig. 9 shows another PCB design useful for implementing the methods of Figs. 6 and 7. In this case, switches of combination key 22 are fed directly by drive lines 24, labeled as DR2, DR4, and DR6.

[0056] Referring next to Fig. 10, the force applied by the finger 55 is concentrated at its center region 34, at the peak of the curvature and centered under the bone. The force is transmitted through center region 34 and the

outer portions of finger 55 conform around elevated key region 11. Local depression 136 is formed between the independent key 11 on one side and a convex surface 38 of combination key region 22. Depressed region 136 provides a tactile distinction between the independent keys 11 and combination keys 22.

[0057] Fig. 11 shows a finger 55 pressing against combination key 22. Combination key 22 is crowned, with a convex shape 38, presenting an elevated surface to meet the center region 34, but not elevated as compared to the independent key regions 11, which are at least effectively elevated over the combination key regions 22 in that a fleshy finger 55 will advance farther into the keypad to activate a combination key region 22 as placed in Fig. 11, than the same finger would to activate an adjacent independent key region 11 when placed as in Fig. 10. Directly distal to center region 34 of combination key 22 is a depressed region 136 that dissociates force from the finger, with the result of further concentrating the force in the center region 34 and to help avoid distributing force over a greater area and onto the adjacent independent keys 11. This increases the force transmission through convex shape 38, and thereby allows the finger 55 to actuate combination key 22 (which includes a single and independently operable switch below to provide a clearly defined tactile response) while reducing the chance of actuating adjacent independent keys 11. The optimal relationship between the diameter of the independent keys 11 and the diameter of the combination keys 22 is approximately 1:2. However, the inadvertent actuation of one of more of the adjacent independent keys 11, such as by inaccurate finger placement or a large finger, may be accommodated by the electronics of Fig. 8 or 9 and the algorithm of Figs 6 or 7. Tactile feedback (preferably, one distinct sensory feedback for one input sensed) is an important aspect of any keypad. These structures provide a single, well-defined tactile feedback in an IACK keypad when either a combination key 22 or an independent key 11 is pressed.

[0058] Fig. 12 shows a finger pressing against a combination key region 22 with an effectively flat shape 140. Again, a single and independently operable switch below the combination key region provides a clearly defined tactile response.

[0059] Fig. 13 shows a finger pressing against an elevated key region 11 of a keypad in which the keypad surface is basically planar, with the independent keys 11 identified by a tactile element 142 such as a ring or edge definition and combination key 22 is concave.

[0060] Fig. 14 shows a keypad disassembled from the housing 90 of the associated electronic device. Separate combination keys 22 and independent keys 11 are adhered to an elastomeric sheet 41. In order to increase the reliability of consistent mechanical contact between the actuators 36 and snap domes 12, the elastomeric sheet 41 is manufactured undersized with respect to the restraint elements 143, so that elastomeric sheet 41 is placed in tension when assembled, as shown in Fig. 15.

In other words, the elastomeric sheet is stretched (i.e., placed in tension) to fit onto the restraint elements. That is to say that the distance across the housing between the restraint elements 143 is greater than the distance between the corresponding location features 49 in the sheet 41. The keys in the center (such as the center one here) are located as they will be after assembly, however in one embodiment; keys increasingly near the periphery are adhered to the sheet 41 at an increasingly proximal location to their post-manufactured position, so that upon assembly (and stretching of the sheet 41), the keys are correctly positioned. Dimension "x" shows the gap between adjacent keys prior to assembly. Likewise, in one embodiment, the position of either the actuators 36, or the metal domes 12 and the dome's switches 48 are displaced (misaligned) relative to the non-assembled sheet 41, such that the actuator 36, metal dome 12 and dome switches 48 printed on PCB 23 align only after assembly (as shown in Fig. 15).

[0061] Referring to Fig. 15, when the keypad is assembled the gap between adjacent keys is denoted as "y". At the edge of a typical keypad, (the keys most effected) the difference between "x" and "y" is over 20 percent, typically on the order of 20 to 80 percent. After assembly the keys and actuators 36 align with the switches 48. The keypad is designed undersized to the opening in the housing 90. Alternatively, the key structures may be secured to the elastomeric sheet with the sheet in its stretched state, to control inter-key gap distances. The elastomeric sheet 41 a of the keypad of Fig. 16 is molded to have a pleat 47 or other resilient formation that acts as a means to maintain tension in the elastomeric sheet over a wider range of temperatures for a given tension. The distance between the restraint elements 143 is larger than the distance between the corresponding location features 49 in the sheet 41, such that in the assembled keypad, flexure 47 is somewhat distended from its molded state.

[0062] Fig. 17 shows an IACK keypad 10 including a plastic (predominantly rigid) web, approximately 0.5 to 1.0 millimeter thick, forming a continuous surface over the area of the keypad, with holes through which the combination keys 22 are exposed. The dashed area designates the extent of the web 40. Because the web 40 is a plastic material it can be made of the same material as the housing 90 of the product itself, and furthermore, can be made continuous with the housing 90 of the product. This can provide a significant advantage in design flexibility, aesthetics (by virtue of being the same material the problems of color matching dissimilar material, potentially manufactured in different facilities, is eliminated), durability, and cost. No tilings are used, eliminating edges which could catch on a fibrous material, such as a sweater. Independent keys 11 are defined by local elevations of the material of the web 40, and are activated by flexure of the hard plastic. The combination keys 22 are discrete plastic (predominantly rigid) keys located in the holes in the web 40. The result is a predominantly rigid keypad

with sufficient flexure to allow tactile feedback to be felt by the user. Additional troughs may be provided in the backside of the web to increase its flexibility, preferably oriented along a common direction allows for the flow of fluid plastic during the manufacturing process. The transition region between the housing and keymat may be thinned, or formed of a lower durometer material such as polyurethane, to allow for additional compliance at the edge of the keymat. The relatively non-motile portions (in this case the independent keys 11 and web 40) can be referred to jointly as the face plate of the keypad.

[0063] Referring also to Fig. 18, combination keys 22 include a slight (convex) protrusion, or small hill, although notably shorter than the height of the independent keys 11. The independent keys 11 are taller than the combination keys 22 by approximately 0.25 to 0.75 millimeter. The overall heights of the keys, as measured from the lowest surface of the actuator 36 to the highest surface above it, is such that the bulk of the force profile (center region 34) provided by the curvature of a user's finger (higher in the center and progressively less toward the edges) fits within the region of the combination key 22, including the state after the snap dome 12 has been actuated. In another embodiment, independent keys 11 and combination keys 22 are nearly the same height. The discontinuous keys are held to the keypad 10 by an elastomeric sheet 41. Although web 40 is rigid, the overall structure can displace relative to PCB 23 and the web 40 can displace relative to the combination keys 22. This flexure/displacement allows operation of IACK keypads with a rigid plastic face.

[0064] Fig. 19 shows an example in which the combination keys 22 are integrally molded with the web 40, and independent keys 11 are discontinuous. The relatively non-motile portions (in this case the combination keys 22 and web 40) can be referred to jointly as the face plate of the keypad 10. While pressing combination keys 22, the face plate deflects.

[0065] Referring also to Fig. 20, the extent of the oval of the combination key 22, along its major axis, is labeled as "W". In this embodiment, the contiguous extra width of the web 40 (beyond W) provides an effective increase in the size of the combination key 22 relative to the embodiment of Figs. 17 and 18, thereby assisting the designer to keep the bulk of the force profile of the users finger away from actuating the hill keys. Note also that accidental actuation of hill keys 11 is acceptable, as the only detriment is additional tactile feedback. The extra signal provided to the system does not cause a problem. Although web 40 is rigid, the overall structure can displace relative to PCB 23 and the web 40 can displace relative to the independent keys 11. This flexure/displacement allows operation of IACK keypads with a rigid plastic face plate. The discontinuous keys are held to the keypad 10 by an elastomeric sheet 41. It is also possible to implement the embodiments of Figs. 18 and 20 in the same product by providing independent motility in both independent keys 11 and combination key 22 as long as

web 40 is allowed low-force flexure at least as long as the stroke of key actuation.

[0066] Referring next to Figs. 21 and 22, a metal snap dome 12 has an elevated central region 212 forming a downwardly facing cavity 13 defined at its edge by a geometric discontinuity 214 such as a ridge as shown. The discontinuity 214 is disposed above at least two switch contacts 16 that are normally electrically isolated from each other, disposed on printed circuit board 23. Metal snap dome 12 includes edge 118, which rests upon another electrically distinct switch element, signal reference 224. Actuator 36 is located to apply force to, and thereby displace, elevated central region 212. Note that forces applied by the actuator 36 are not transmitted to the PCB 23 downward (below the center of the actuator 20), but by material located off-center, in this case the underside of discontinuity 214 located radially outward from the center 17 of the actuator. The result is that the bulk of the force applied by the actuator 36 is not applied in a point, but distributed over a line, in this case a line curved to form a circular contact zone 230. Contact zone 230 is approximately 1/3 the nominal diameter of the metal dome 12, creating "third" points, or contact points (in the contact zone 230) approximately equidistance between edges 118 and each other. Therefore as one side of discontinuity 214 touches a first switch element 16 a torque will be placed upon that contact point, acting to force the other side of discontinuity 214 into contact with a second switch element 16. The objective is to reliably connect two or more separate electrical lines to a common signal reference 224. The discontinuity 214 may be in the form of a downward ring-like indentation, such that the elevated central region 212 is elevated relative to the lower edge of the discontinuity 214, but not distinctly the rest of the snap dome 12.

[0067] As shown in Fig. 22, along the contact zone 230 the dome contacts three switch elements 16. Signal reference 224 acts as the fourth element. Vias 32 connect switch elements 16 to traces on lower layers of the PCB. Each switch element 16 extends over an angle α , in this example about 20 degrees, equating to a total of approximately 1/6 of the circumference of contact zone 230 comprised of switch elements 16. Reducing the value of α furthers the objectives of the theory of operation explained in Fig. 21 by making contact with one or two switch elements 16 an unstable configuration. Therefore a force applied to the center axis 17 will apply an increased torque to assist with establishing contact between the metal dome 10 and each switch element 16, even if two contacts are already established. The instability provided by contacting the snap dome 12, the torque provided by contacting near the trip point and the narrowness of the traces, thereby increasing local pressure, are among the envisioned potential advantages of this approach. Note that three switch elements 16 are shown, two (and to a lesser extent four) switch elements 16 may also benefit from this design. Discontinuity 214 may be formed as a ring of spaced ridge segments, as shown in

Fig. 23, with ridge lengths and gaps selected to facilitate reliable contact with each switch element 16.

5 Claims

1. An electrical key switch comprising

a printed circuit board (23) with multiple switch contacts (16) and a reference trace (224) that are normally electrically isolated from each other; and

a metal snap dome (12) disposed above the printed circuit board (23) and having an outer edge (118) in electrical contact with the reference trace (224), the dome (12) having an elevated central region (212) forming a downwardly facing cavity (13) defined at its edge by a ridge (214) disposed above the switch contacts (16), such that when the snap dome is actuated the ridge (214) about the central region (212) engages the printed circuit board in an annular contact zone (230) across the switch contacts, making electrical contact between the snap dome (12) and the switch contacts (16) to electrically connect the reference trace (224) with the multiple switch contacts (16).

2. The key switch of claim 1 wherein the annular contact zone (230) is about one-third of a nominal diameter of the metal dome (12).

3. The key switch of claim 1 or claim 2 wherein the switch contacts (16) are wedge-shaped.

4. The key switch of claim 3 wherein each switch contact (16) extends across about 20 degrees (α) of the circumference of the contact zone (230).

5. The key switch of any of claims 1 through 4 wherein the switch contacts (16) are disposed approximately equidistant from each other about the contact zone (230).

6. The key switch of any of claims 1 through 5 wherein the ridge (214) forms a continuous ring.

7. The key switch of any of claims 1 through 5 wherein the ridge (214) comprises a ring of spaced ridge segments.

8. The key switch of any of claims 1 through wherein the snap dome (12) overlays three spaced apart switch contacts (16).

Patentansprüche**1. Elektrischer Tastschalter, der umfasst:**

eine gedruckte Leiterplatte (23) mit mehreren 5
Schalter- bzw. Schaltkontakten (16) und einer
Referenzspur bzw. Leiterbahn (224), die im All-
gemeinen gegeneinander elektrisch isoliert
sind; und
einen Metallschnappdom (12), der über der ge- 10
druckten Leiterplatte (23) angeordnet ist und ei-
nen Außenrand (118) in elektrischem Kontakt
mit der Referenzspur (224) hat, wobei der Dom
bzw. die Rundung (12) einen erhöhten zentralen
Bereich (212) hat, der eine nach unten gewand- 15
te Kavität bzw. einen Hohlraum (13) bildet, der
an seinem Rand durch einen Kamm bzw. Grat
(214) definiert bzw. begrenzt ist, welcher über
den Schaltkontakten (16) angeordnet ist, so
dass, wenn der Schnappdom betätigt wird, der 20
Grat (214) um den zentralen Bereich (212) in
die gedruckte Leiterplatte in einer ringförmigen
Kontaktzone (230) über die Schaltkontakte ein-
greift, wobei ein elektrischer Kontakt zwischen
dem Schnappdom (12) und den Schaltkontak- 25
ten (16) hergestellt wird, um die Referenzspur
(224) mit den mehreren Schaltkontakten (16)
elektrisch zu verbinden.

2. Tastschalter nach Anspruch 1, wobei die ringförmige 30
Kontaktzone (230) etwa ein Drittel eines Nenndurch-
messers des Metalldoms (12) ist.

3. Tastschalter nach Anspruch 1 oder Anspruch 2, wo- 35
bei die Schaltkontakte (16) keilförmig sind.

4. Tastschalter nach Anspruch 3, wobei sich jeder 40
Schaltkontakt (16) über etwa 20 Grad (α) des Um-
fangs der Kontaktzone (230) erstreckt.

5. Tastschalter nach einem der Ansprüche 1 bis 4, wo- 45
bei die Schaltkontakte (16) in ungefähr gleichen Ab-
ständen voneinander um die Kontaktzone (230) an-
geordnet sind.

6. Tastschalter nach einem der Ansprüche 1 bis 5, wo-
bei der Grat (214) einen kontinuierlichen Ring bildet.

7. Tastschalter nach einem der Ansprüche 1 bis 5, wo- 50
bei der Grat (214) einen Ring aus beabstandeten
Gratsegmenten umfasst.

8. Tastschalter nach einem der Ansprüche 1 bis 7, wo- 55
bei der Schnappdom (12) drei voneinander beab-
standete Schaltkontakte (16) überlagert.

Revendications**1. Bouton-poussoir comprenant :**

une carte de circuit imprimé (23) avec de multi-
ples contacts de commutateurs (16) et une piste
de référence (224) qui sont normalement isolés
électriquement l'un de l'autre ; et
un dôme de pression métallique (12) disposé
au-dessus de la carte de circuit imprimé (23) et
ayant un bord extérieur (118) en contact électri-
que avec la piste de référence (224), le dôme
(12) ayant une région centrale élevée (212) for-
mant une cavité faisant face vers le bas (13)
définie à son bord par une saillie (214) disposée
au-dessus des contacts de commutateurs (16),
de sorte que lorsque le dôme de pression est
actionné la saillie (214) autour de la région cen-
trale (212) se met en prise avec la carte de circuit
imprimé dans une zone de contact annulaire
(230) à travers les contacts de commutateurs,
en établissant un contact électrique entre le dôme
de pression (12) et les contacts de commu-
tateurs (16) pour connecter électriquement la
piste de référence (224) aux multiples contacts
de commutateurs (16).

2. Bouton-poussoir selon la revendication 1, dans le-
quel la zone de contact annulaire (230) a un diamètre
égal à environ un tiers du diamètre nominal du dôme
métallique (12).

3. Bouton-poussoir selon la revendication 1 ou 2, dans
lequel les contacts de commutateurs (16) sont en
forme de coin.

4. Bouton-poussoir selon la revendication 3, dans le-
quel chaque contact de commutateur (16) s'étend à
travers 20 degrés (α) de la circonférence de la zone
de contact (230).

5. Bouton-poussoir selon l'une quelconque des reven-
dications 1 à 4, dans lequel les contacts de commu-
tateurs (16) sont disposés de manière approxima-
tivement équidistante l'un de l'autre autour de la zone
de contact (230).

6. Bouton-poussoir selon l'une quelconque des reven-
dications 1 à 5, dans lequel la saillie (214) forme un
anneau continu.

7. Bouton-poussoir selon l'une des revendications 1 à
5, dans lequel la saillie (214) comprend un anneau
de segments de saillie espacés.

8. Bouton-poussoir selon l'une quelconque des reven-
dications 1 à 7, dans lequel le dôme de pression (12)
recouvre trois contacts de commutateurs (16) espa-

cés l'un de l'autre.

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Fig. 1

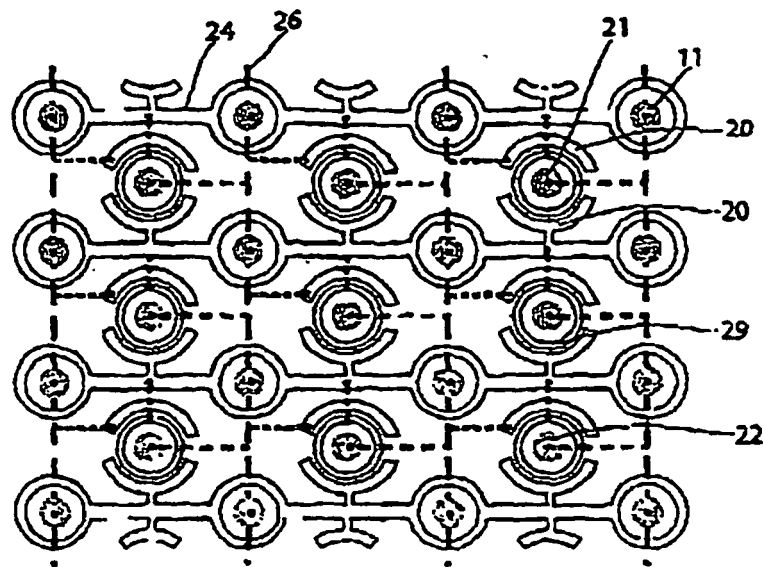


Fig. 2

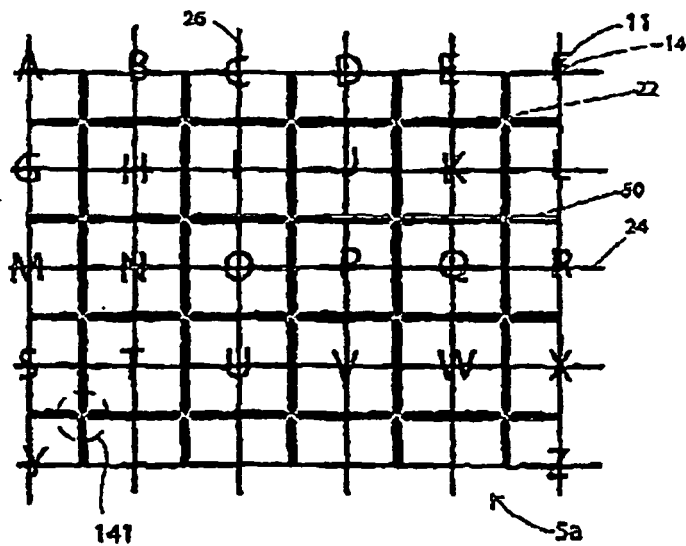
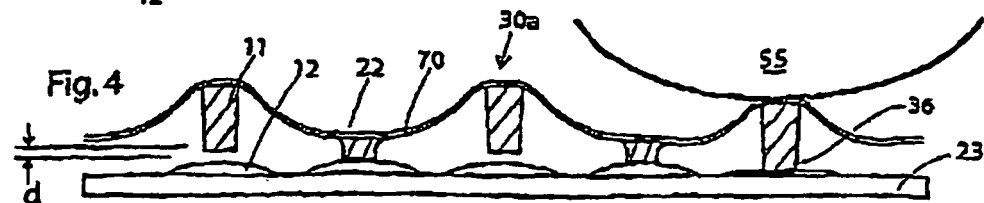
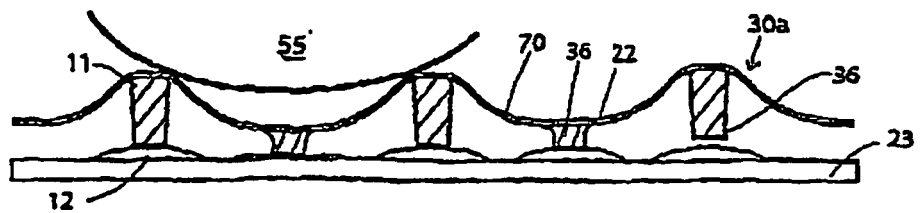


Fig. 3



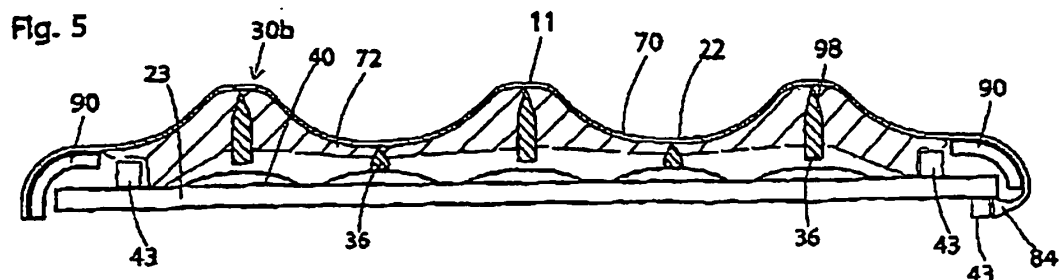


Fig. 6

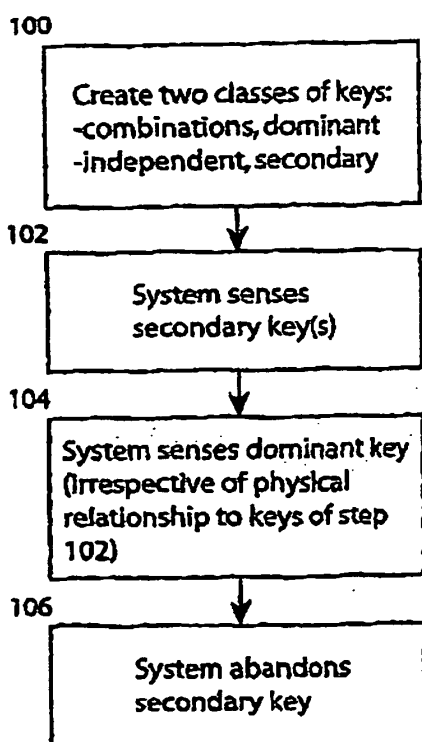


Fig. 7

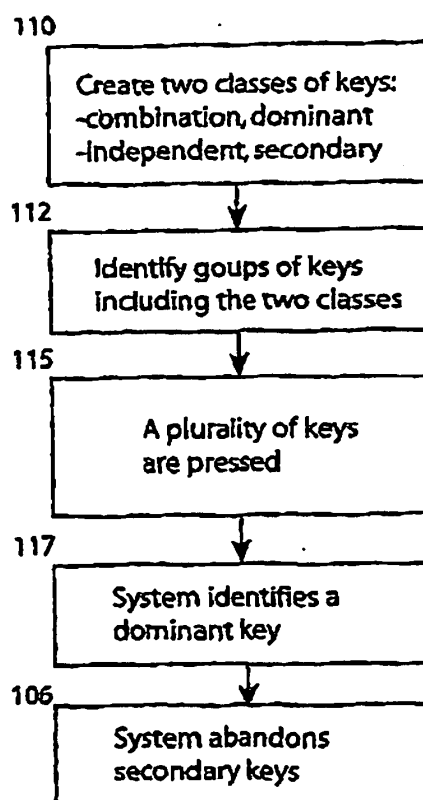


Fig. 8

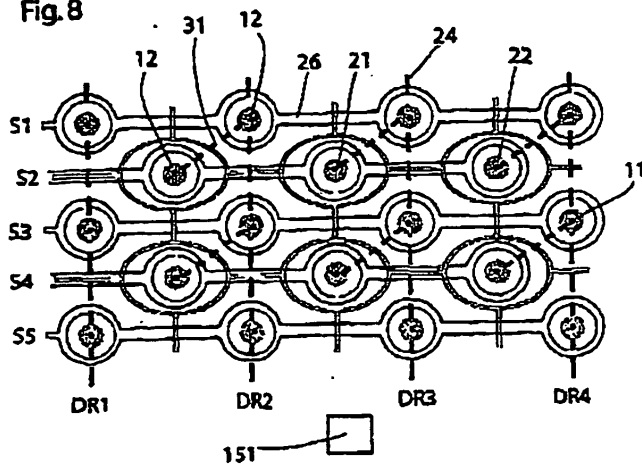


Fig. 9

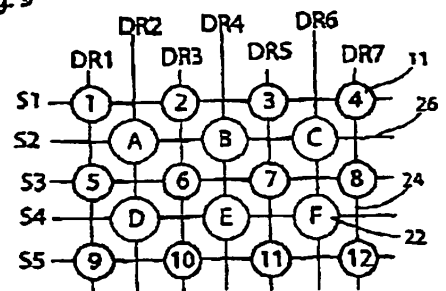


Fig. 10

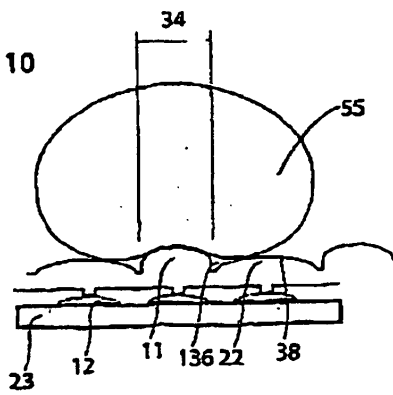


Fig. 11

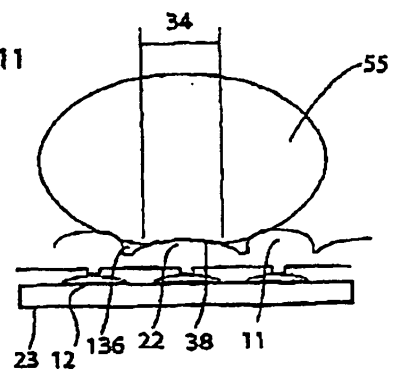


Fig. 12

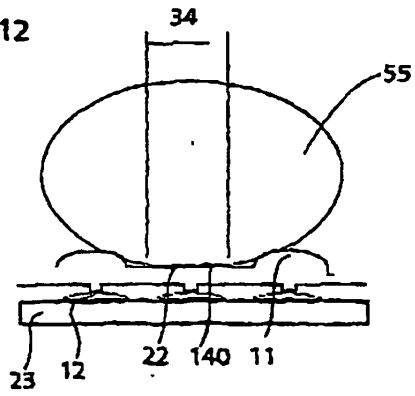


Fig. 13

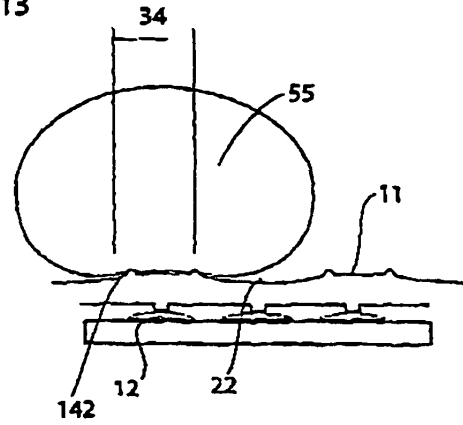


Fig. 14

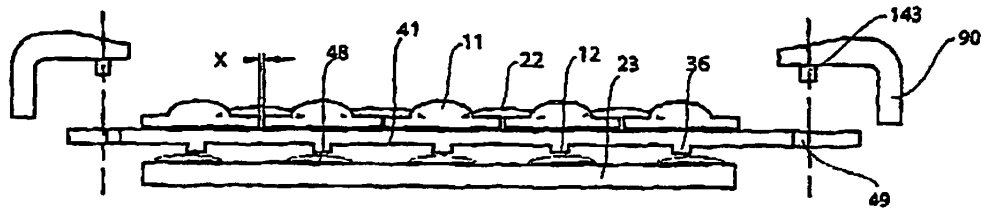


Fig. 15

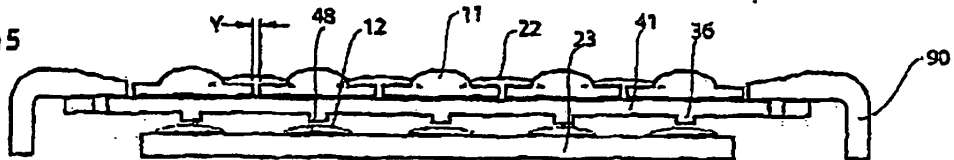


Fig. 16

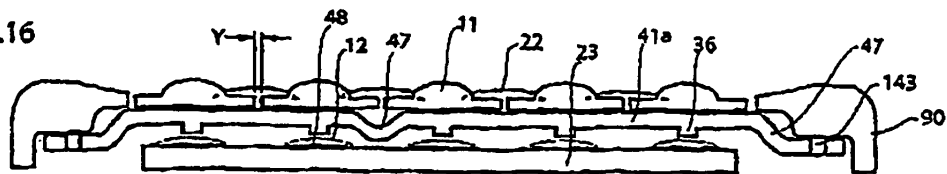


Fig. 17

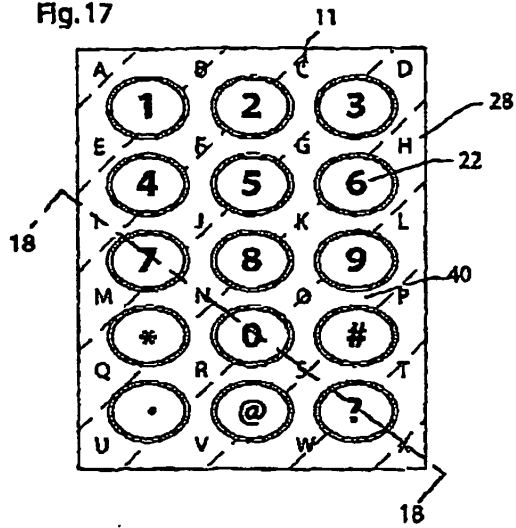


Fig. 19

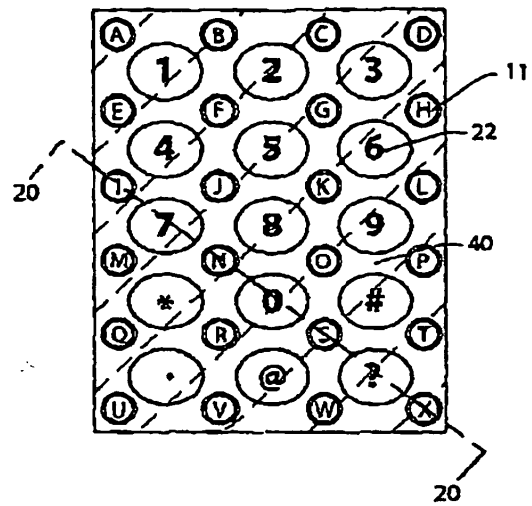


Fig. 18

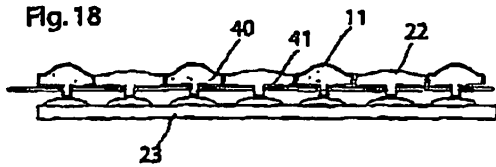


Fig. 20

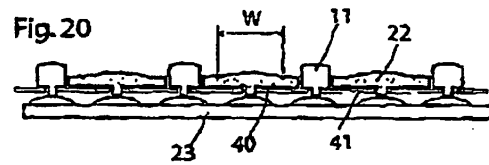


Fig. 21

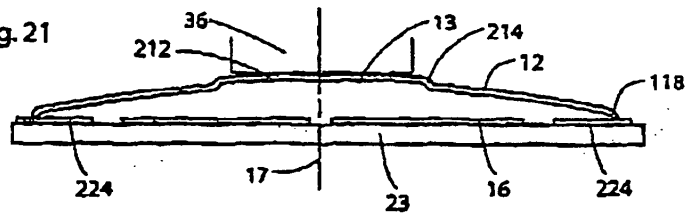


Fig. 22

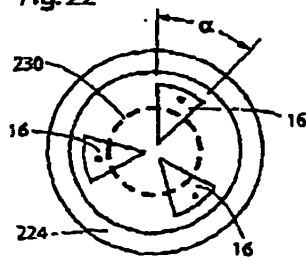
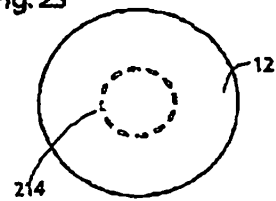


Fig. 23



REFERENCES CITED IN THE DESCRIPTION

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