(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 March 2018 (15.03.2018)

WIPO | PCT

(10) International Publication Number
WO 2018/046937 A1

(51) International Patent Classification:
G06F 3/01 (2006.01) *G06F 3/02* (2006.01)

(21) International Application Number:
PCT/GB2017/052628

(22) International Filing Date:
08 September 2017 (08.09.2017)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

1615276.1	08 September 2016 (08.09.2016)	GB
1617152.2	10 October 2016 (10.10.2016)	GB
1618153.9	27 October 2016 (27.10.2016)	GB
1619376.5	16 November 2016 (16.11.2016)	GB
1707228.1	05 May 2017 (05.05.2017)	GB
1708619.0	31 May 2017 (31.05.2017)	GB
1709011.9	06 June 2017 (06.06.2017)	GB
1712434.8	02 August 2017 (02.08.2017)	GB

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP,

(54) Title: HAPTIC FEEDBACK CONTROL ASSEMBLY

Fig. 1

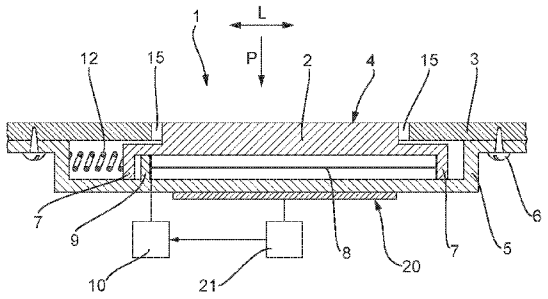
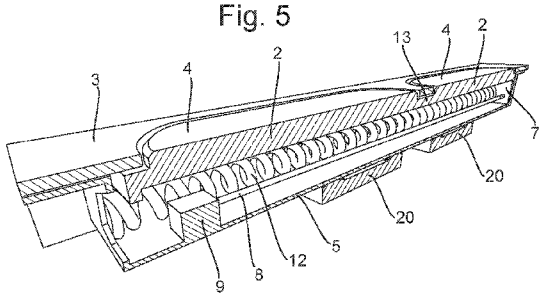


Fig. 5



(57) Abstract: A control assembly provides haptic feedback to the user of a device such as a smartphone. The button includes a shape memory alloy actuator which moves the button laterally with respect to the finger press. The actuator can be programmed and controlled to provide a variety of haptic waveforms. The control assembly may be used in combination with a capacitive sensor provides a tactile feedback which is not otherwise present with a capacitive control. The control assembly used in combination with a mechanical control provides a range of haptic waveforms not otherwise possible with a mechanical control. The control assembly can be used in smartphones, wearables, keyboards and other portable electronic devices.

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KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

Haptic Feedback Control Assembly

The present invention is related to a user-operated control assembly for electrical and electronic products. In particular, it is related to a user-operated control assembly that provides haptic feedback to the user when operated.

User-operated controls on electronic products come in many forms for example a button, a switch, a key (as on a keyboard) or a highlighted area on a touch screen. Such controls serve to provide input to or interact with electronic circuits, typically as a switch to make or break an electrical circuit or otherwise affect such a circuit. In this document, the term 'smart control' is taken to mean any such user-operated control assembly which provides haptic effect in addition to the input or switching function.

Consumer electronics devices employ different designs of controls to give users feedback that they have successfully created the electrical contact inside the button. In the case of computer keyboards and smartphone controls, the most popular designs are 'dome switches' and 'leaf springs'. The exact force profile during operation itself can be tuned in the design to satisfy a target user preference, however it is noted that preferences can vary significantly from user to user.

There is a huge selection of button designs and variants to satisfy the varying preferences of users. However, a given button design can only provide a single response. As such, it is implicit that a given button choice will satisfy a certain number of users but will leave a significant proportion dissatisfied having preferred a different experience.

Computer keyboard buttons are typical depressed just once to select a particular character. However, in the case of smartphone buttons, buttons may be pressed either quickly or held down for a sustained time to access different functions. For instance, in the case of the 'power' button, it may be pressed quickly to remove power from the display or held down longer to remove power from the entire handset. As smartphone buttons employ similar, derivative designs to computer keyboard buttons, the haptic feedback for a sustained press is identical to that of a quick operation despite wishing to carry out a completely different operation. This is counterintuitive and as such is prone to user annoyance and mistakes being made.

Commonly used mechanical buttons such as the dome switch and the leaf spring switch have been replaced on the front face of many smartphones by capacitive buttons. In this technology, the button is not required to protrude from the device and has zero force requirement to create the electrical contact. This allows smooth mechanical designs of the

smartphone casework and prevents fatigue of the user if pressing the button many times over a short time. However, unlike the mechanical designs, these products are entirely passive mechanically and as such do not in themselves provide any mechanical haptic feedback.

It would be desirable to address the problems outlined above, or at least to provide an alternative to the devices currently used.

According to the present invention, there is provided a control assembly comprising: a button suspended in casework; and an actuator arranged to deliver haptic feedback by moving the button relative to the casework

Thus, current limitations of mechanical and capacitive buttons are addressed by including an actuator for moving the button in the control assembly, thereby forming a 'smart' control. Movement of the button by the actuator delivers haptic (tactile) feedback to the user, that is an effect which is perceived by the user by touch. Such haptic feedback may, for example, augment the mechanical response profile of a standard mechanical button or add a haptic effect to a capacitive button.

As electronic devises are miniaturised, such an actuator is required to be of a very small size. For example, a typical smartphone buttons has a space envelope, both outside the phone as a typical button but also with the associated fixings, electronics and connections inside the phone, typical envelope dimensions are of the order of 15 x 4 x 1mm. In addition, the actuator needs to be able to deliver rapid motion. The motion requirement is expected to be typically between 50um to 300um over a time of 2ms to 10ms. In addition the actuator needs to be able to deliver enough force to be easily sensed by a user. The required force will depend on the size and use case scenarios of the smart control, but is expected to be between 200mN and a few Newtons. While standard electromagnetic actuators (EM motors or VCMs) are available and used in many applications, including applications in smartphones, they are unable to achieve the smallest size or adequate force.

Advantageously, the actuator is a shape memory alloy (SMA) actuator, preferably an SMA actuator that comprises at least one SMA wire.

Embodiments of the present invention will now be described by way of non-limitative example with reference to the accompanying drawings, in which:

Fig. 1 is a cross-sectional side view of a button assembly;

Figs. 2 to 4 are side views of alternative arrangements for the SMA actuator in the button assembly;

Fig. 5 is a cut-away perspective view of a modified form of the button assembly;

Figs. 6 and 7 are side views of modified forms of the button assembly;

Fig. 8 is a perspective view of a modified form of the button assembly; and

Figs. 9 to 12 are side views of modified forms of the button assembly.

A button assembly 1 that is an example of a control assembly is shown in Fig. 1 and arranged as follows. Herein, various modifications of the button assembly 1 are also described and may be applied to the button assembly 1 in any combination.

The button assembly 1 comprises a button 2 suspended in casework 3 of an electronic device such as a handset, the button 2 including a contact surface 4 that is presented to the user through the casework 3 to be pressed by a user's finger in a pressing direction P. The button assembly 1 includes a housing 5 that is attached rigidly to the casework 2 by a fixing 6, or alternatively by any other suitable means. The button 2 is suspended in the housing 5 on moving fixtures 7 which protrude rearwardly and bear on the housing 5, so acting as a suspension system. The moving fixtures 7 act as a sliding bearing (although other bearings could alternatively be used) and thereby allow the button 2 to move laterally with respect to the casework 3, that is in a lateral direction L that is lateral to the pressing direction P. In this example, the lateral direction L is perpendicular to the pressing direction P, that is parallel to the contact surface 4, but that is not essential and in general the lateral direction L could be angularly offset from that.

Although, a moving fixture 7 acting as a sliding bearing forms the suspension in this example, more generally it may be replaced by any suspension system that allows the button 2 to move with respect to the casework 3 in the desired manner, for example at least one plain bearing; at least one ball bearing; or at least one flexure.

Underneath the button 2, the button assembly 1 includes an SMA wire 8 that forms an SMA actuator. Good performance may be achieved using an SMA wire 8 having a diameter less than 100μm. The SMA wire 8 is connected between the button 2 and the housing 5 by being connected at one end (right-hand end in Fig. 1) to a moving fixture 7 and at the other end (left-hand end in Fig. 1) to a stationary fixture 9 formed on the housing 5. Thus, contraction of the SMA wire 8 drives the relative movement of the button 2 with respect to the casework 3.

A spring 12 is also connected between the button 2 and the housing 5, by being connected at one end (right-hand end in Fig. 1) to the opposite moving fixture 7 from that to which the SMA wire 8 is connected, and at the other end (left-hand end in Fig. 1) to the housing 8. The spring 12 is in compression and so acts as a resilient biasing element against the SMA wire 8, which extends the SMA wire 8 and provides movement of the button 2 in the opposite direction from the SMA wire 8. The spring 12 could be replaced by any other resilient biasing element providing a similar effect, for example a spring in tension, a resilient member or a flexure.

The button assembly 1 includes a driver integrated circuit (IC) 10 electrically connected to the SMA wire 8. The driver IC 10 provides an electrical signal to the SMA wire 8 which causes the SMA wire 8 to heat up and contract, thereby causing the button 2 to move in the lateral direction L in a first sense (towards the left in Fig. 1). When the power of the electrical signal is reduced or ceased after heating, the SMA wire 8 cools and is stretched by the spring 12, moving the button 2 in the opposite sense (to the right in figure 1). In this way, the SMA wire 8 move the button 2 back and forth laterally, controlled by the driver IC 9.

The electrical signal is chosen so that the movement of the button 2 delivers haptic feedback that is perceptible to a user touching the button 2. Surprisingly, the lateral movement of the button 2 gives a tactile sensation to the user that may be perceived as a change in the resistance force against pressing of the button 3, even though downwards movement of the button is minimal.

It may be desirable for the contact surface 4 of the button 2 to be flush with the casework 3 for aesthetic reasons or to protrude from the casework.

Since the button 3 needs to move laterally, clearance is needed between the button 2 and the casework 3. This is small and reasonably well sealed, but can be perceived to be unsightly and allow some ingress of dirt and/or water, so is undesirable. As an optional feature, the button assembly 1 may include a sealing membrane 15 between the button 2 and the casework 3. The sealing membrane 15 may fill or cover the clearance between the button 2 and the casework 3. The sealing membrane 15 may be formed from any suitable compliant material, for example an elastomer such as a silicone. The sealing membrane 15 may be a labyrinth membrane to provide a full seal while allowing full movement. Desirably, the sealing membrane 15 provides a smooth surface to the user while allowing lateral motion of the button 2 for the haptic feedback.

The button 2 may be designed to enhance the haptic feedback, for example as follows.

The size and height of the button 2 may be selected to provide the optimum tactile effect. For example the button 2 may sit proud of the casework, for example by up to 1mm.

The contact surface 4 may have a variety of shapes. For example, the contact surface 4 may be circular and 7mm or more in diameter or more, or it may be any other shape, for example oval, square, rectangular or rod shaped, but desirably having extends by 5mm or more in at least one direction.

The contact surface 4 may be textured texture, as for example: a rough surface; a contoured surface; varying textures across its extent; one or more sharp edges on the surface or at the edge of the surface; a concertina construction; one or more ridges running across part or all of the button.

As an alternative, the single SMA wire 8 may be replaced by plural SMA wires 8, as for example in some of the modified forms of the button assembly 1 below. In that case the plural SMA wires 8 may be oriented so that some SMA wires 8 are arranged to pull the button 2 in a substantially different direction from other SMA wires 8, i.e. the SMA wires 8 are opposed. In this arrangement the button 2 can be moved in different directions by heating different SMA wires 8 or combinations of SMA wires 8. In this case, the spring 12 may not be required as SMA wires 8 can be used to move the button 2 to any desired position.

Preferably, the electrical connections between the SMA wire 8 and the driver IC 10 are on the stationary part of the button assembly 1, that is, on the stationary fixture 9. This means that no moving electrical leads are necessary, thus simplifying the product design and optimising operational reliability. This is most readily achieved by modifying the button assembly 1 to replace the single SMA wire 8 by an arrangement of a plural even number of lengths of SMA wire spanning the gap between the button 2 and the casework 3 and connected in electrical series. Such lengths of SMA wire may be different SMA wires or different parts of the same SMA wire.

Some examples of modifying the button assembly 1 in this manner are shown in Figs. 2 to 4. which show replacements for the SMA wire 8 connected between the moving fixture 7 and the stationary fixture 9 (the other components of the button assembly 1 being omitted for clarity.

In the example of Fig. 2, two SMA wires 8 are connected between the moving fixture 7 and the stationary fixture 9, each providing a length of SMA wire. In this case, the two SMA wires 8 are electrically connected together at the moving fixture 7, so that the lengths of SMA wire are connected in electrical series.

In the example of Fig. 3, a single SMA wire is connected at both ends to the stationary fixture 7 and hooked over a retaining feature 11 on the moving fixture 7. Thus, the parts of the SMA wire on either side of the retaining feature 11 are lengths of SMA wire that are connected in electrical series.

There may be further pairs of lengths of SMA wire, for example four lengths of SMA wires in total, connected in series or parallel. In the example of Fig. 4, four SMA wire 8 are connected between the moving fixture 7 and the stationary fixture 9, but are electrically connected in series.

The configuration of the SMA wire or wires 8, including their number, length and diameter is selected not only to provide the desired range of movement, but also to match the device resistance to the specification of the driver IC 10. For example, the configuration of the SMA wire or wires 8 may be adapted to match the power output of the driver IC 10. The driver IC 10 typically contains a control chip and a power stage that is fed into the SMA wire or wires 8. The control chip may uses pulse width modulation to control the power that is fed into the wire. Pulses are output as a square wave, and amplified through a power stage to heat the wire. As the resistance of the SMA wire 8 changes as it is heated, the power stage is configured to maintain a constant voltage for the duration of the pulse. The resistance of the SMA wire 8 varies as it is heated and may rise or fall as the wire gets hotter depending on its position of the resistance temperature curve, the power required from the power stage therefore varies as the SMA wire 8 is actuated.

The configuration of the SMA wire or wires 8 is chosen to achieve the required force for the haptic feedback to be detected by a user, whilst remaining within the power envelope that is available from the power stage. For example, a higher force is generated by a thicker SMA wire 8 than a thinner SMA wire 8, but the thicker SMA wire 8 has a lower resistance and may need to be lengthened, for example by using two SMA wires 8 arranged mechanically in parallel and electrically in series. However, the thicker SMA wire 8 has a larger mass and the response time will be increased as there is more wire to be heated. Depending on the requirements of the design, judicious choice of wire length,

number of SMA wires 8, whether they are arranged in series or parallel can be used to match the power envelope of the driver IC 10.

For example, calculations have shown that four SMA wires 8 having a diameter of 25μm where there are two pairs of SMA wires 8 connected in parallel and these pairs are connected in series provide a suitable balance of force, power and operation window time requirements, and deliver an electrical resistance of an appropriate value to be compatible with a typical driver IC 10. Similarly two wires having a diameter of 35μm connected in series provide a suitable balance of force, power and operation window time requirements, and deliver an electrical resistance of an appropriate value to be compatible with a typical driver IC 10.

The button assembly 1 also includes a capacitive sensor 20 behind the button 2. The capacitive sensor 20 senses pressing of the button 2 in a conventional manner. In this example, the capacitive sensor 20 is fixed to the housing 5 and so is located on a surface that is stationary with respect to the casework 3. This allows stationary electrical connections, providing the same benefits as for the SMA wire 8, as discussed above. A capacitive sensor IC 21 is connected to the capacitive sensor 20 to detect the capacitance of the capacitive sensor 20 and from that to derive an output signal indicating pressing of the button 2.

The capacitive sensor IC 21 is connected to the driver IC 10. When pressing of the button 2 is detected, the capacitive sensor IC 21 communicates with the driver IC 10. In response thereto, the driver IC 10 applies the electrical signal to the SMA wire 8 to move the button 8 so as to deliver the haptic effect to the user who is at that time touching the button 2.

More generally, the capacitive sensor 20 may be replaced by any other sensor that senses pressing of the button 2. Even more generally, the capacitive sensor 20 may be replaced by a sensor that senses some other operation of the button 2 other than pressing, for example lateral motion or force. For example, the capacitive sensor 20 could be replaced by a switch of the type typically used in a mechanical button or by a force-sensitive sensor such as a piezoelectric sensor, resistance strain sensor or other type of sensor.

However, one benefit of using a capacitive sensor 20 is that there is no requirement for the button 2 to travel into the direction of the casework 3 by a significant distance, such as 0.5mm, to activate. This means the button 2 need not protrude from the casework and

allows the button to be flush with the main product surfaces and result in an appealing handset casework design.

Another benefit of using a capacitive sensor 20 is that it requires low force, or no force. This ensures that the casework 3 is not deformed or displaced when operating the button assembly 1. This is particularly appropriate in the case of wearable devices such as augmented reality or virtual reality glasses and headsets.

The driver IC 10 may derive a measurement that varies with ambient temperature. For example, the measurement may be derived from a temperature sensor such as thermistor or thermocouple. Alternatively, the measurement may be derived from an electrical characteristic of the electrical signal supplied to the SMA wire 8, for example by measuring the power or energy required to change the resistance of the SMA wire 8 by a certain amount or the power of energy required for the resistance to start to decrease with increasing wire temperature. Thus, information about the ambient temperature of the environment around the button assembly 2 may be either directly measured or inferred from the behaviour of the SMA wire 8. The driver IC 10 may change the electrical signal supplied to the SMA wire 8 depending on the measurement. In this manner the electrical signal may be adapted in dependence on the ambient temperature.

It is a goal of the design to use the minimum possible power to heat the SMA wire 8 to achieve the transition temperature to change from the martensite to the austenite phase. The power required to reach the transition temperature depends on the difference between the temperature of the SMA wire 8 and the transition temperature. If the SMA wire 8 has been recently actuated then it is likely to be at a higher temperature than the ambient temperature and therefore a model is used that calculates the required power (and hence drive pulse duration) based on ambient temperature and the difference between the power used in the most recent actuation and the power lost since that actuation. The power loss term will depend on the structure of the SMA wire 8. When the SMA wire 8 is heated by power input, that temperature dissipates by radiative transmission through air, but also through heating of mechanical components such as a crimp attached to the SMA wire 8. The rate of cooling of the SMA wire 8 and the temperature of the SMA wire 8 therefore depends on the configuration of the SMA wire 8 and the design of the device to which it is attached.

One of the benefits of the button assembly 1 is that the haptic effect may be varied by selecting an appropriate form for the electrical signal. Thus, the haptic effect may have

a variety of haptic waveforms. This allows the button assembly 1 to be tuned to preferences of the users and/or vary motion profile and magnitude replicating various designs of dome switch, leaf spring or waveforms not able to be delivered by conventional mechanical designs. The preferred haptic waveform can be designed in advance or can be variable, in which case it may be selectable or tuneable by the user. For example, plural haptic waveforms may be stored in the button assembly 1, in which case the driver IC 10 may be arranged to provide an electrical signal that delivers haptic feedback in accordance with one of the stored haptic waveforms that is selectable by the user. In that manner, the haptic effect may be selected by the user, for example on the electronic device so each electronic device can deliver a unique user experience, tailored to the users' preferences.

Precise control of the haptic waveform may be achieved by the driver IC 10 provide the electrical signal using resistance feedback control to control the haptic waveform that is delivered. In that case, the driver IC 10 derives a measure of the resistance of the SMA wire 8 and uses that measure as a feedback signal to drive the resistance to a target value that follows a desired haptic waveform. In this case, the resistance feedback control may further maintains the SMA material within safe mechanical and temperature limits of operation.

Optionally, the haptic effect may comprise repeated haptic waveforms following a single press of the button 2. In this manner, there may be multiple motions for a single press. This allows improved feedback to be provided to the user through the haptic effect. For instance, when holding the volume button to increase or decrease volume, the haptic effect may be a tactile impulse to recognise the user has pressed the button and then another, potentially different, waveform when the maximum or minimum volume has been achieved. This would be particularly useful when the user is holding the electronic device to their ear or in their pocket and cannot see the screen for other feedback of this event. Additionally, when the power button is pressed, a single haptic waveform could be generated to recognise the user has pressed the button and then another, potentially different, waveform if the button is continuously pressed and a handset shutdown event is imminent.

Alternatively, where the button assembly is arranged to operate as a toggle switch, the feedback could be used to notify the user of the toggle status of a control. For example, a short press achieves an on or off and produces tactile feedback that represents the feeling of a button click. However, upon an extended press the button could lock on giving a set

haptic feedback to indicate the lock has been achieved. Further short presses to the button would have no effect and give no feedback; a second extended press would be required to unlock the button, giving again a lock or unlock waveform to indicated to the user that the button is unlocked.

The haptic effect could also give a different or additional waveform to notify the user of the status of the handset or a particular application. For instance, a different or multiple impulse could be applied to the power button to notify the user that the device power is low or that there are waiting messages. Additionally, when the button assembly 1 is used to control a camera, then the haptic effect could generate a waveform to notify the user that the image has achieved focus so the user can concentrate on the subject rather than icons and notifications on the screen.

It is expected other use cases could be generated, limited only by the number and type of applications.

The button assembly 1 may be applied to an electronic device of any type, for example any consumer electronics product with buttons and controls, particularly mobile or handheld devices such as smartphones, tablets and wearables. In addition, the button assembly 1 may be applied to remote controls, styluses, earphones and headphones, particularly in wireless products.

The button assembly 1 may also be applied to produce a very thin computer keyboard, which would be well suited to slim laptops and combination devices of a tablet with detachable keyboard.

Various modified forms of the button assembly 1 will now be described. The modified forms are illustrated in Figs. 5 to 12, wherein for clarity only the modified components of the button assembly 1 are shown, the other components being as described above.

The button assembly 1 may comprising two (or more) buttons 2 that are both actuated by the same actuator. In this case, the two buttons 2 may be are formed by a common member. A modified form of the button assembly 1 of this type is shown in Fig. 5 which illustrates the two buttons 2 formed by a common member 13. As a result, there are two contact surfaces 4 and two capacitive sensors 30 to detect pressing thereof. The SMA wire 8 is connected to the common member and so a haptic effect is delivered in response to pressing of either button 2. Since in the typical usage scenario the buttons 2 are only

operated one at a time, the user will not notice that both buttons 2 are being actuated together.

In the modified form of the button assembly shown in Fig. 5, the spring 12 is connected between the button 2 and the housing 5, by being connected at one end to the same moving fixture 7 as to which the SMA wire 8 is connected, which allows the spring 12 to be longer than in Fig. 1.

In the example of the button assembly 1 shown in Fig. 1, the button 2 moves in a lateral detection L that is perpendicular to the pressing direction P. This allows the SMA wires to be oriented in this lateral direction to allow a button to be designed with a slim form factor, such as 1mm. It is understood that lateral motions such as this are perceived by users as similar or identical to more standard, perpendicular motions and will deliver a suitable user experience. However, other designs are possible with SMA wires orientated so as to provide motion in other directions, for example lateral directions that are offset from perpendicular to the pressing direction P or in the pressing direction P itself, i.e. perpendicular to the contact surface 4.

Modified forms of the button assembly 1 which provide movement in the pressing direction are shown in Figs. 6 to 8.

In the modified form of the button assembly 1 shown in Fig. 6, the SMA wire 8 is arranged in a V-shape oriented to provide movement of the button 2 in the pressing direction P. Specifically, the button 2 is provided on its rear side with a protrusion 31. The SMA wire 8 is attached at both of its ends to the casework 3 (optionally via a component attached to the casework 3), and arranged in tension across the protrusion 31 in a V-shape. Thus, the V-shape of the SMA wire 8 lies in a plane that is perpendicular to the contact surface 4 of the button 2.

On actuation, the SMA wire 8 heats and contracts, lifting the button 2 upwards in the pressing direction P. A return spring and suspension (not shown) may be provided. The movement may provide haptic effect to the user pressing the button 2. In addition, the SMA wire 8 of this arrangement may be used to detect the user's finger, in that force applied by the user will press the button down and lengthen the wire, causing a change to the resistance of the SMA wire 8, such that detection of the resistance change can be used to detect the user's button press.

In the modified form of the button assembly 1 shown in Fig. 7 there are two inclined SMA wires 8 wires that are inclined relative to the contact surface 4 of the button

2. Each SMA wire 8 extends across the width of the button 2, connected between the button 2 and the casework 2. Compared to Fig. 6, this allows the SMA wires 8 to be longer, providing greater stroke. The two SMA wires 8 may be operated in opposition, that is with one SMA wire 8 being heated while the other SMA wire 8 cools, so that each SMA wire 8 acts to extend the other SMA wire 8. This also improves the frequency response. As above, a suspension system may also be provide.

In the modified form of the button assembly 1 shown in Fig. 8, the SMA wire 8 is arranged in a V-shape that lies in a plane that is inclined relative to the contact surface 4 of the button 2. Specifically, the button 2 is provided with a protrusion 51 at the rear at an outer edge of the button 2. In this example, the button 2 has a square shape and the protrusion 51 is at a corner 52 of the square shape. The SMA wire 8 extends across the protrusion 51 and is fixed to the casework 3, in such a way that the plane containing the SMA wire 8 is inclined with respect to the contact surface 4.

When actuated, the wire 8 contracts and moves the button 2 in a direction with components in both the vertical and horizontal direction. This may provide an improved haptic effect to the user. Additionally, the length of the SMA wire 8 is greater compared to the other forms of the button assembly described above which may give greater stroke. A return spring and suspension (not shown) may be provided.

In the modified form of the button assembly 1 shown in Fig. 9, the button assembly 1 includes a hinge 61 connecting one side of the button 2 to the casework 3. In this example, the hinge 61 is a simple pivot, but in general the hinge 61 could be of any type. The SMA wire 8 is attached at one end to the casework 3 and at the other end to the button 2. Contraction of the SMA wire 8 causes the button 2 to rotate about the hinge 61 and moves in the direction R. This may give an improved haptic effect. The lever effect of the hinge 61 amplifies the contraction of the SMA wire 8, giving increased stroke. A return spring and suspension (not shown) may be provided.

In the modified form of the button assembly 1 shown in Fig. 10, the button 2 moves in a lateral direction that is inclined with respect to the contact surface 4. The rear surface 71 of the button 2 is inclined with respect to the contact surface 4 of the button 2. The casework 3 comprises a recess 72 having a bearing surface 73 that is inclined similarly to the rear surface 71 of the button 2. As a suspension system for the button 2, the button assembly 1 includes two ball bearings 74 between the rear surface 71 of the button 2 and the bearing surface 72. More generally the ball bearings 74 may be replaced by any

number of bearings of any type, for example one plain bearing or ball bearing. The SMA wire 8 is attached at one end to the casework 3 and at the other end to the button 2. This allows the button 2 to move in an inclined direction parallel to the rear surface 71 of the button 2 when SMA wire 8 contracts, in the direction I.

In the modified forms of the button assembly 1 shown in Figs. 11 and 12, the SMA wire 8 is combined with a spring 121 to provide a modified haptic feedback. In a known button with a mechanical spring, when a user depresses the button, the spring is compressed and then springs back on release, giving a click or bump sensation to the user. In the modified form of the button assembly 1 shown in Fig. 11, the SMA wire 8 alters the force profile of such a button. The user then feels both the mechanical bump and some other haptic sensation generated by the SMA wire 8, giving a richer experience.

Specifically, the button 2 is located in a recess 82 in the casework 3. There is a smaller recess 83 in the rear of the button 2 which serves to locate the spring 121, which is a coil spring, so that the spring 121 stretches from the recess 83 in the button 2 to the base of the recess 82 in the casework 3. The button 2 is suspended by the spring 121 and optionally also a suspension system (not shown), in such a way that when a user presses the button 2, the button 2 travels down into the recess 82 in the casework 3 and compresses the spring 121. When the user releases pressure on the button 2, the spring 121 expands back and provides a haptic effect on the user's finger. In such a button assembly 1, the haptic effect may in general be enhanced by causing the button 2 to travel over a mechanical feature such as a bump or ridge (not shown), to provide the user with a click feel.

In the modified forms of the button assembly 1 shown in Fig. 11, the SMA wire has the same configuration as in Fig. 1. In the modified forms of the button assembly 1 shown in Fig. 12, there are two SMA wires 8 in the same configuration as in Fig. 7. The SMA wire or wires 8 can act both as a detector, to detect that the button 2 has been pressed by a change in length, tension or resistance, and as an actuator to provide a haptic waveform and a modified tactile sensation to the user. The SMA wire or wires 8 may mimic the feel of a mechanical bump.

CLAIMS

1. A control assembly comprising:
a button suspended in casework; and
an actuator arranged to deliver haptic feedback by moving the button relative to the casework.

2. A control assembly according to claim 1, wherein the actuator is a shape memory alloy actuator.

3. A control assembly according to claim 2, wherein the shape memory alloy actuator comprises at least one shape memory alloy wire.

4. A control assembly according to claim 3, wherein the diameter of the shape memory alloy wire is less than 100 microns.

5. A control assembly according to claim 3 or 4, wherein the shape memory alloy wire is arranged in a V-shape.

6. A control assembly according to claim 5, wherein the V-shaped shape memory alloy wire lies in a plane that is inclined relative to a contact surface of the button.

7. A control assembly according to claim 6, wherein the at least one shape memory alloy wire comprises two shape memory alloy wires that are inclined relative to a contact surface of the button.

8. A control assembly according to any one of claims 3 to 7, wherein the at least one SMA wire comprises a plural number of lengths of SMA wire spanning the gap between the button and the casework.

9. A control assembly according to claim 8, wherein the plural number is an even number.

10. A control assembly according to claim 8 or 9, further comprising a driver integrated circuit arranged to provide an electrical signal to the actuator for causing the button to move, wherein the number, length and diameter of the shape memory alloy wire matches the device resistance to the specification of the driver integrated circuit.

11. A control assembly according to any one of claims 1 to 10, further comprising a driver integrated circuit arranged to provide an electrical signal to the actuator for causing the button to move.

12. A control assembly according to claim 10 or 11, where driver integrated circuit is arranged to change the electrical signal depending on a measurement that varies with ambient temperature.

13. A control assembly according to any one of the claims 10 to 12, wherein plural haptic waveforms are stored in the control assembly, and the driver integrated circuit arranged to provide an electrical signal that delivers haptic feedback in accordance with one of the stored haptic waveforms that is selectable by the user.

14. A control assembly according to any one of claims 10 to 11, wherein the driver integrated circuit arranged to provide the electrical signal using resistance feedback control to control the haptic waveform that is delivered.

15. A control assembly according to claim 14 , wherein the resistance feedback control further maintains the SMA material within safe mechanical and temperature limits of operation.

16. A control assembly according to any one of the preceding claims, wherein the actuator is arranged to deliver haptic feedback with a haptic waveform that is variable.

17. A control assembly according to claim 16, wherein the haptic waveform is selectable or tuneable by the user.

18. A control assembly according to any one of the preceding claims, wherein the actuator is arranged to deliver haptic feedback with repeated haptic waveforms following a single operation of the button.

19. A control assembly according to any one of the preceding claims, wherein the actuator is arranged to move the button relative to the casework parallel to a contact surface of the button.

20. A control assembly according to any one of the preceding claims, further comprising a sensor for sensing operation of the button.

21. A control assembly according to claim 20, wherein the sensor is a capacitive sensor.

22. A control assembly according to claim 20 or 21, wherein the sensor is located on a surface that is stationary with respect to the casework.

23. A control assembly according to any one of the previous claims, comprising plural buttons that are each actuated by the same actuator.

24. A control assembly according to claim 23, wherein the two buttons are formed by a common member.

25. A control assembly according to any one of the preceding claims, further comprising a suspension system that suspends the button in the casework.

26. A control assembly according to claim 25, wherein the suspension system comprises: at least one plain bearing; at least one ball bearing; or at least one flexure.

27. A control assembly according to claim 25, wherein the rear of the button is inclined with respect to the front of the button, the casework comprises a similarly inclined recess, and the suspension system comprises at least one bearing between the rear of the button and the recess.

28. A control assembly according to claim 27, wherein the bearing comprises at least one plain bearing or ball bearing.

29. A control assembly according to any one of the preceding claims, further comprising a sealing membrane between the button and the casework.

30. A control assembly according to claim 29, wherein the sealing membrane is an elastomer.

31. A control assembly according to any one of the preceding claims, wherein the button has a contact surface that extends by 5mm or more in at least one direction.

32. A control assembly according to any one of the preceding claims, wherein the button at rest protrudes from the casework.

33. A control assembly according to preceding claims, wherein the button has a textured contact surface.

34. A control assembly according to claim 33, wherein the textured contact surface comprises: a rough surface; a contoured surface; varied textures across the surface; one or more sharp edges; one or more ridges; a concertina construction.

35. A control assembly according to any one of the preceding claims, further comprising a hinge connecting one side of the button to the casework.

36. A control assembly according to any one of the preceding claims, further comprising a mechanical spring.

37. A control assembly according to any one of the preceding claims, arranged to operate as a toggle switch.

38. A portable electronic device equipped with a control assembly according to any one of the preceding claims.

39. A computer keyboard in which at least one key is a control assembly according to any one of the preceding claims.

Fig. 1

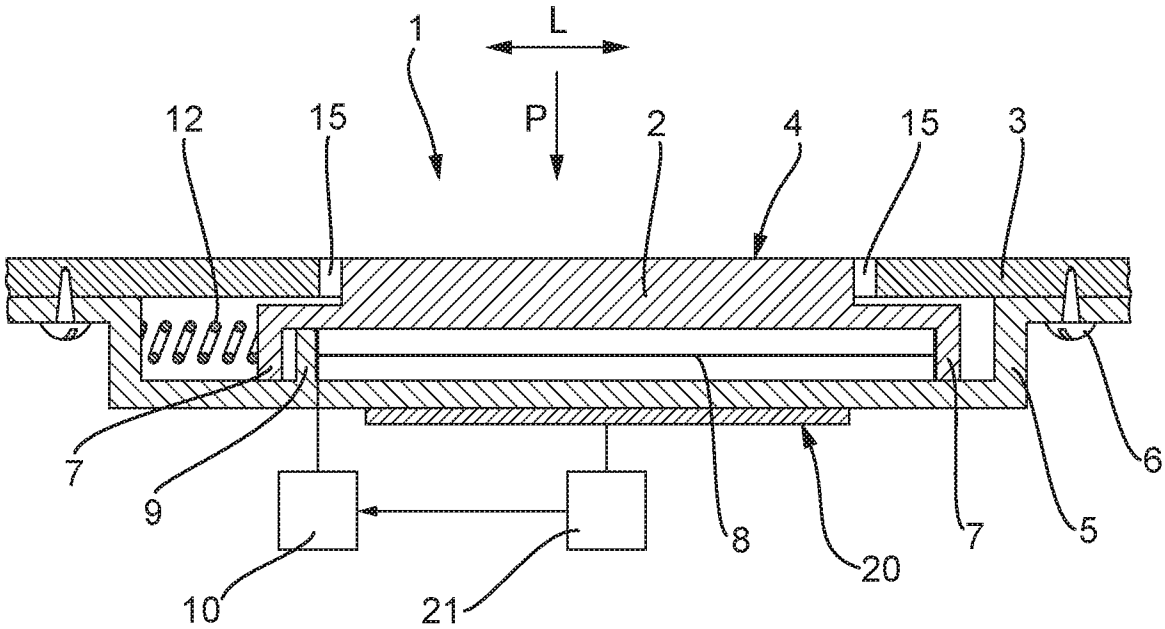


Fig. 2

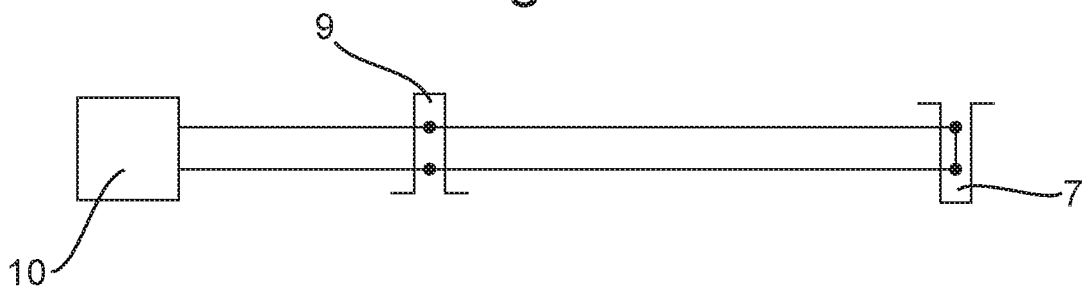


Fig. 3

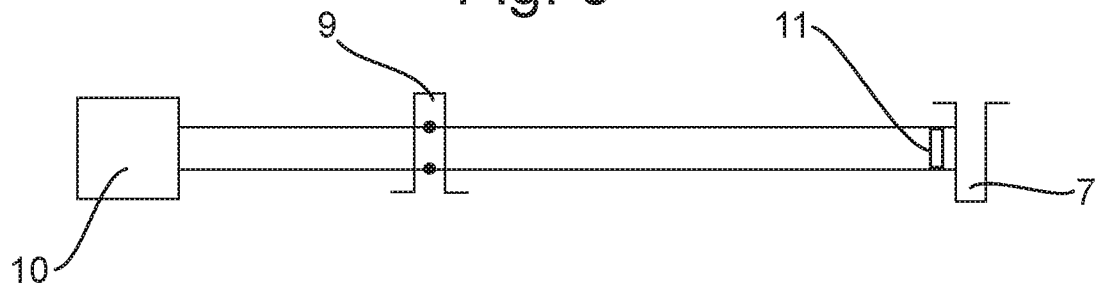


Fig. 4

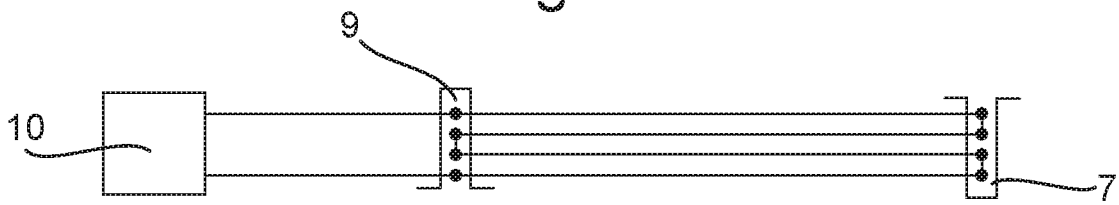


Fig. 5

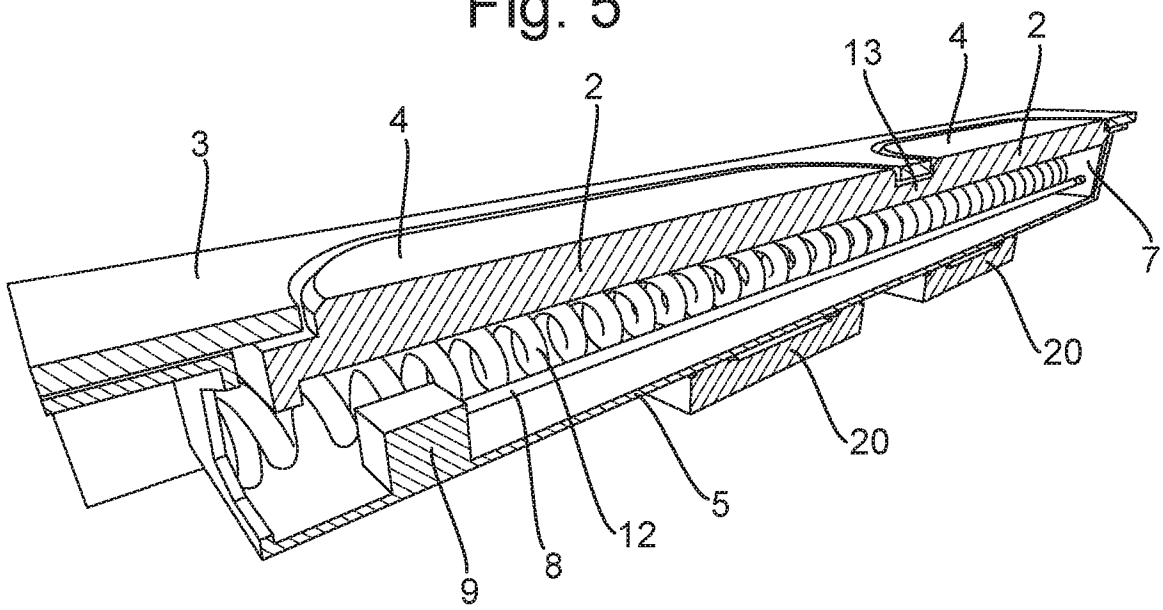


Fig. 6

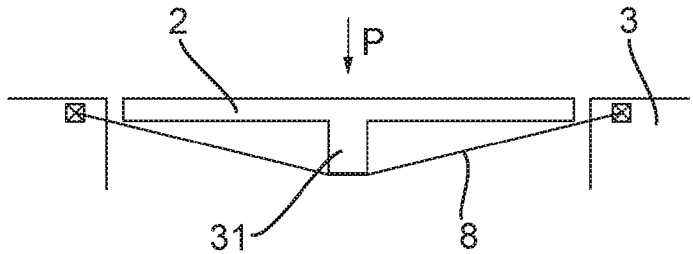


Fig. 7

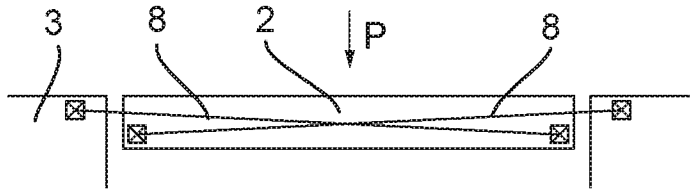


Fig. 8

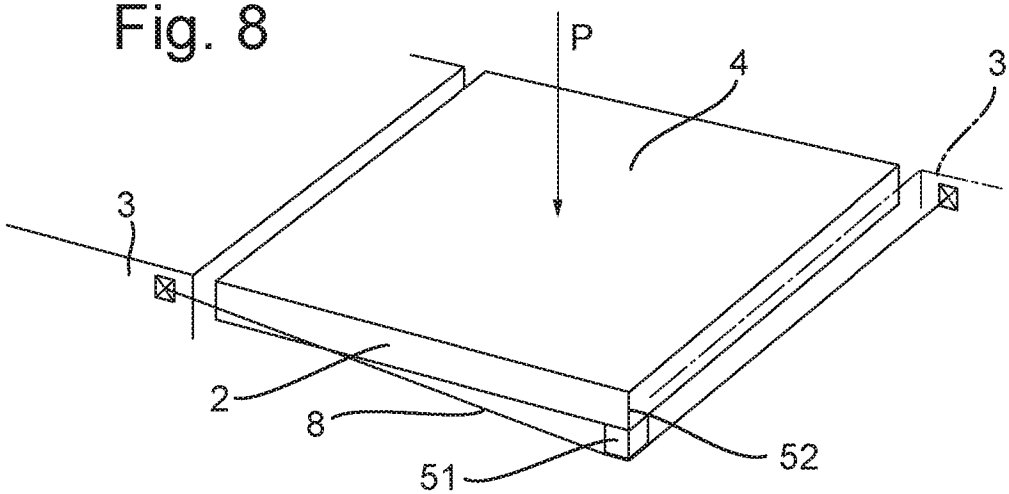


Fig. 9

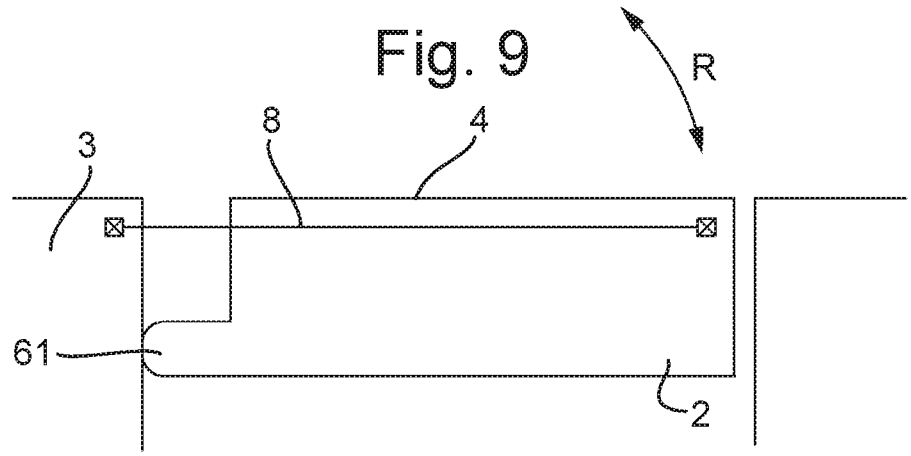


Fig. 10

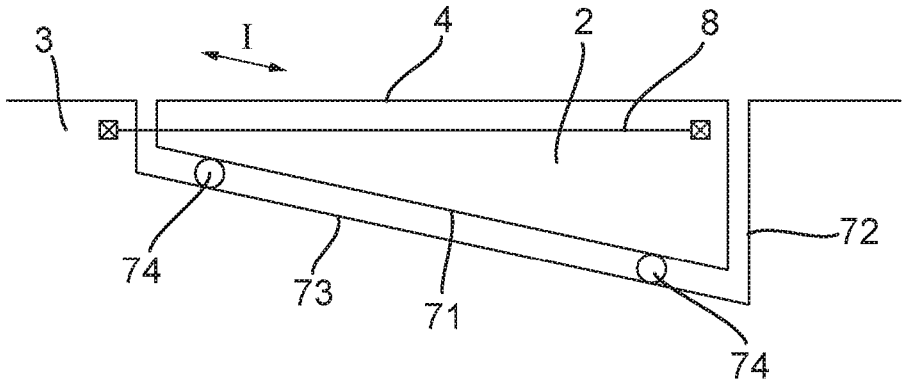


Fig. 11

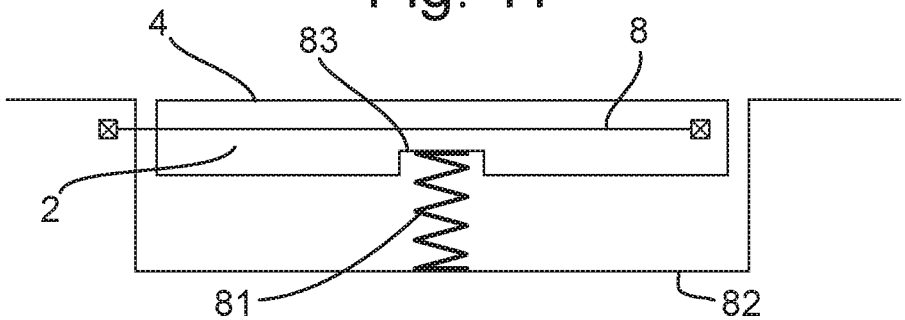
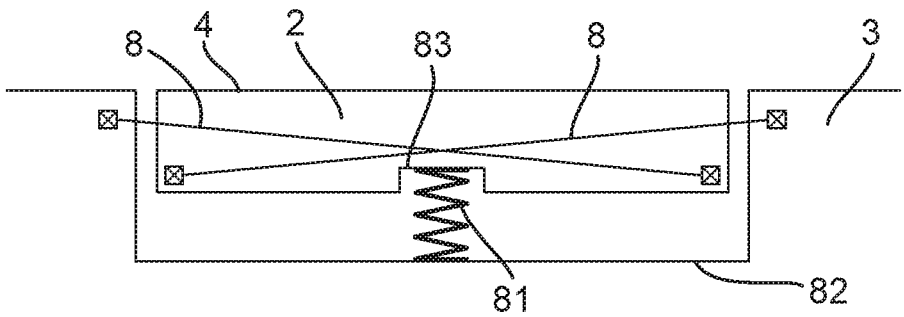


Fig. 12



INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2017/052628

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06F3/01 G06F3/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G06F H01H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012/212442 A1 (UCHIDA KEIJI [JP] ET AL) 23 August 2012 (2012-08-23) paragraphs [0008], [0022], [0035], [0056], [0067], [0078] - [0083]; figures 10-12 -----	1-11,18, 20-22, 25,38,39

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 November 2017	18/01/2018

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	del Rey, Marco

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB2017/052628

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-11, 18, 20-22, 25, 38, 39

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-11, 18, 20-22, 25, 38, 39

(a) the subject-matter of claim 1,
further comprising,
(i) a shape-memory alloy actuator.

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2. claims: 12-17

(a) the subject-matter of claim 1,
further specifying,
(ii) the provision and modification of different activation signals by a driver integrated circuit.

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3. claims: 26-28, 35-37

(a) the subject-matter of claim 1,
further specifying,
(iii) constructional aspects of the suspension system for the button.

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4. claims: 29, 30

(a) the subject-matter of claim 1,
further detailing,
(iv) a sealing membrane.

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5. claims: 19, 23, 24, 31-34

(a) the subject-matter of claim 1,
further detailing,
(v) multiple constructional details of the control assembly unrelated to (i)-(iv).

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2017/052628

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2012212442 A1	23-08-2012	CN 102597925 A	18-07-2012
		JP 5292655 B2	18-09-2013
		JP WO2011052484 A1	21-03-2013
		KR 20120083472 A	25-07-2012
		US 2012212442 A1	23-08-2012
		WO 2011052484 A1	05-05-2011