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(54) Title: AN ACTUATOR AND A METHOD OF MANUFACTURING THE SAME

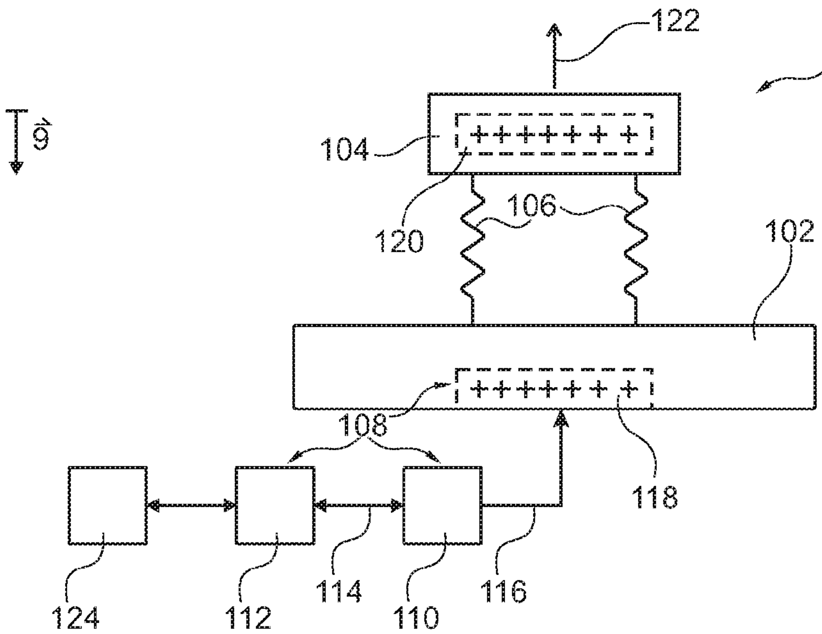

Fig. 1

(57) Abstract: An actuator (100) comprising a substrate (102), a movable mass (104), a spring element (106) resiliently mounting the movable mass (104) on the substrate (102), and a drive unit (108) for driving the movable mass (104) to move upon application of a pulsed drive trigger.

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An actuator and a method of manufacturing the same

FIELD OF THE INVENTION

The invention relates to an actuator.

Furthermore, the invention relates to a portable electronic equipment.

Moreover, the invention relates to a method of manufacturing an actuator.

BACKGROUND OF THE INVENTION

An actuator may be a mechanical device for moving or controlling a mechanism or system.

Interface devices between humans and electronic apparatuses may provide tactile and/or haptic feedback to the user. These types of interface devices can provide physical sensations to the user manipulating a user manipulable object of the interface device.

US 5,959,613 discloses a system for shaping force signals for a force feedback device. A source wave is provided and is defined by a set of control parameters (including a steady state magnitude, a frequency value and a duration value) and modified by a set of impulse parameters (including an impulse magnitude, and a settle time representing a time required for the impulse magnitude to change to the steady-state magnitude). Optionally, application parameters specifying a direction of force signal and trigger parameters specifying activating buttons can also be provided for the source wave. Using a host processor or a local processor, the force signal is formed from the source wave and the sets of control parameters and impulse parameters, where the force signal includes an impulse signal followed by a continual steady-state signal after an expiration of the settle time. A feel sensation is generated to a user of the force feedback device as physical forces produced by actuators on the force feedback device in response to the force signal. The steady-state magnitude value is lower than a magnitude value of a non-impulse-shaped force signal required to create a corresponding feel sensation having a similar apparent sensation to the user.

A vibration signal or alert is a standard feature for mobile telecommunication means like mobile phones, personal digital assistants etc.. Known devices for generating vibration signals inside the mobile phone are often DC-motors comprising an eccentric weight.

EP 1,233,505 discloses a method for driving an electrodynamic vibration device for outputting a vibration signal with predetermined vibration strength for a mobile telecommunication means, wherein the electrodynamic vibration device is driven by an alternating current driving signal. The driving signal comprises time successive sine wave signals of varying periods, whereby the variation of the periods is set so, that the duration of each alternating current signal with constant period is shorter than 25 ms. Further, a driving means is provided for driving an electrodynamic vibration device for outputting a vibration signal with a predetermined vibration strength for a mobile telecommunication means for carrying out the method.

However, conventional actuators may lack sufficient functionality.

OBJECT AND SUMMARY OF THE INVENTION

It is an object of the invention to provide an actuator system operable with sufficient functionality.

In order to achieve the object defined above, an actuator, a portable electronic equipment, and a method of manufacturing an actuator structure according to the independent claims are provided.

According to an exemplary embodiment of the invention, an actuator is provided comprising a substrate, a movable mass, a spring element resiliently mounting the movable mass on the substrate, and a drive unit for driving the movable mass to move upon application of a pulsed drive trigger (that is particularly an electrical or mechanical trigger in response to which the actuator is brought into a movable mode).

According to another exemplary embodiment of the invention, a method of manufacturing an actuator is provided, the method comprising resiliently mounting a movable mass on a substrate by a spring element, and arranging a drive unit for driving the movable mass to move upon application of a pulsed drive trigger (for instance in a discontinuous or discrete manner).

According to still another exemplary embodiment of the invention, a portable electronic equipment (such as a consumer electronics device) is provided which comprises an actuator having the above mentioned features.

According to an exemplary embodiment of the invention, an actuator is provided which comprises a movable mass which can reciprocate, rotate, pivot or move in another manner relative to a substrate with a spring mediating between the movable mass and the substrate, wherein a drive characteristic of the movable mass is definable by a pulse or a sequence of pulses. Thus, in contrast to conventional motor-driven actuators, no permanent repeated motion of the mass element has to be effected, but in contrast to this, a defined pattern of individual pulses may be exerted on the mass to thereby allow to increase the flexibility and the functionality of the actuator and to provide for a fast application of any desired motion pattern.

In contrast to conventional acceleration actuators, which are operated using a motor that has to be set in motion at the beginning of an operation and which therefore require a long start-up time until they are brought into or sufficiently close to a resonance state in which they operate with sufficient performance or quality, embodiments of the invention are capable of providing a vibration function with a short start-up time and with a freely selectable motion pattern by providing a system, which may oscillate at or close to its resonance frequency immediately upon (for instance pulse controlled) activation on demand. When such a system is biased prior to activation, the system may oscillate immediately after activation with a maximum stroke. Furthermore, embodiments of the invention may be operated at lower frequency values than conventional approaches, which lower frequency values may be perceivable in a better manner by a human being (for instance operating a man machine interface). In an embodiment, it is possible to allow a system to freely oscillate for a predetermined number of cycle periods (for instance 20 to 40 cycle periods, for example several 100 ms in the time domain) before being biased or wound up again.

According to an exemplary embodiment of the invention, many different acceleration patterns may be achieved with one system. A very high efficiency is realizable when operating in or close to resonance. The required volume for such a component may be very small. A very simple construction of the actuator as compared to conventional motor systems may be achieved. Different drive concepts and technologies are employable, such as piezo, inertia motor, an electrodynamic principle, etc.

Next, further exemplary embodiments of the actuator will be explained. However, these embodiments also apply to the portable electronic equipment and to the method.

The drive unit may be adapted for driving the movable mass in a discontinuous manner. Thus, no permanent or continuous motion is affected, but a motion of the mass is only affected at one or more specific points of time at which a pulse drive trigger such as a drive signal is applied.

The actuator may be adapted for driving the movable mass in accordance with an acceleration pattern which is variable in time and which can be predefined by the system or selected by a user. Thus, for achieving a desired motion characteristic, a desired pattern or time sequence of pulses may be defined by a user or a control unit so as to increase the degree of freedoms employable.

The drive unit may be adapted for driving the movable mass to move in at least two different directions. Thus, not only a motion in one direction is possible, but also a direction in two, three or more directions may be effected by the pulsed operation, thereby increasing the variety of a haptic system. For example, the two different directions may be opposite to one another, or may have an angle different from 180° from one another.

According to an exemplary embodiment, the drive unit may be adapted for driving the movable mass based on an electrical drive trigger. For example, an electric signal, a magnetic signal or an electromagnetic signal may be used for promoting a motion of the mass move in a desired manner.

Still referring to the previously described embodiment, the drive unit may comprise a magnetic element (such as a permanent magnet or an electromagnet) attached (for instance in a fixed manner) to the mass or formed by the mass, which may be manufactured at least partially from a magnetic material. The drive unit may further comprise a magnetic field generation unit such as a coil or an electromagnet activatable for driving the movable mass. In other words, the magnetic field generation unit may be controlled to generate a magnetic force which has an impact on the magnetic element fixedly connected to the mass which moves the mass in a desired manner, for instance using attracting or repulsive forces. The drive unit may further comprise an activation circuit (which may be a conventionally wired circuit or an integrated circuit) for activating the magnetic field generation unit by supplying an electric activation signal. The activation circuit may, for instance, supply the magnetic field generation unit with a pulse or a sequence of pulses to thereby generate, in turn, a motion pulse or a sequence of motion pulses of the magnetic element. Thus, a contactless control system may be achieved.

For instance, the activation circuit may comprise a voltage source and switching means (for instance a transistor switch) operable (for instance closable) to selectively supply the magnetic field generation unit with an electric activation signal generated by the voltage source. For example, the voltage source may provide a constant voltage, which may be converted into one or more pulses by a sequence of alternatively closing or opening the switch.

Alternatively, the activation circuit may comprise a capacitor, a capacitor charging unit (i.e. an electric member which has the capability of charging the capacitor with electric charge), and switching means (such as a transistor switch) operable (for instance closable) to selectively supply the magnetic field generation unit with an electric activation signal generated by the discharging capacitor. In such an embodiment, a protection diode may be connected in parallel to the magnetic field generation unit.

The drive unit may be adapted for driving the movable mass based on a mechanical drive trigger. In such an embodiment, the drive unit applies a direct mechanical force (particularly in a contacting manner) and thereby affects a mechanical motion of the mass in a desired direction.

Such a drive unit may comprise a lever (for instance a cocking lever) for selectively engaging the mass for biasing the mass, for example for generating a bias force, or disengaging the mass for moving the mass. In other words, when the lever engages the mass, the spring element (which may be a flat spring/leaf spring or a spiral spring/coil spring) may be already in an elongated (or non-equilibrium) state, so that upon releasing the lever from engaging with the mass, the spring and the mass perform the desired motion.

The drive unit may also comprise a piezo beam for selectively fixing the mass in place or moving the mass. For example, a pair of piezo beams may be employed which may be moved in two directions which are perpendicular to one another to thereby elongate the mass or to fix the mass. For this purpose, it is also possible to use different piezo beams, one of which being capable of fixing the mass and the other one being capable of moving the mass.

The drive unit may also comprise a wedge (which may have a triangular cross section) for selectively biasing the mass to an adjustable extent or releasing the biased mass for moving the mass. Such a wedge may have a triangle cross-section and may be movable with an inclined surface relative to the mass, thereby allowing to change a position of the mass based on a lateral shift of the wedge.

The spring element may be adapted to drive back the movable mass into a force-free stationary position (for instance only) in the absence of a drive trigger of the drive unit. In such an embodiment, the spring element is configured to bring back the movable mass into a non-elongated (or equilibrium) state when no drive trigger is present. A desired value of the damping of the spring can be adjusted.

Alternatively, the spring element may be adapted to drive back a biased movable mass into a force-free stationary position (for instance only) in the presence of a drive trigger of the drive unit. In such an embodiment, the spring element may be pre-biased and therefore a force is exerted on the spring element when no drive trigger is present. The mechanical motion is then achieved by removing the biasing impact, allowing the spring element to move back to the stationary or non-elongated position, thereby activating the actuator.

The actuator may be adapted to generate a tactile alarm signal perceivable by a human user. For example in a mobile phone, a vibration of the mobile phone may indicate without the emission of acoustic waves that a certain event has occurred, for instance a call is incoming.

The actuator may also be adapted to generate a tactile feedback signal perceivable by a human user in response to a user operation. For instance when a user presses a touch screen, the successful operation of touching or selecting an item on the touch screen may be indicated by a haptic signal generated by the moving mass.

Such a system may be implemented in any portable electronic equipment, for instance in a mobile phone, a personal digital assistance, an MP3 player, a game console, a hand-held device, a man machine interface device (such as a joystick, a trackball or a computer mouse), a portable computer or a laptop. However, other applications are possible as well.

According to an exemplary embodiment of the invention, a pulsed drive of an actuator may be initiated. Such an actuator may be configured according to the MEMS technology. The term “Micro-Electro-Mechanical System” (MEMS) may denote the technology of integrating mechanical elements, sensors, actuators, and electronics on a common semiconductor substrate (for instance a silicon substrate) through microfabrication technologies. Micro-electro-mechanical systems may be devices and machines fabricated using techniques generally used in microelectronics, particularly to integrate mechanical or hydraulic functions, etc. with electrical functions.

According to an exemplary embodiment of the invention, a resonant mechanical system may be provided which can be biased, i.e. a spring element may be elongated and can be released when a mechanical motion is desired. Then, the system may swing freely upon activation. When the biasing procedure is short in time, it is possible to define desired patterns. This may be achieved by a real mechanical biasing of a spring (for instance inertia drive with piezo), and releasing this system. Alternatively, this may be realized using a very short and strong pulse, for instance a current pulse applied to a coil, so as to generate an electromagnetic excitation. Thus, a pulse driven resonator may be provided.

According to an exemplary embodiment of the invention, a multifunctional and efficient acceleration actuator using a pulsed operation may be provided.

Acceleration actuators may be used in mobile applications like mobile phones, game consoles, etc. and may particularly be used for two functions. One function is a noise-free alarm (vibration function) and the other one is a haptic feedback (simulation of pressed button in a touch screen, keypad, etc.). Such devices may generate a perceivable acceleration, which shall be achieved in a fast manner allowing to adjust one of a plurality of different acceleration sequences.

Due to the continued miniaturization of such devices, the volume available for the actuators is strongly limited. Conventional systems apply motors with eccentric masses. Such masses may have a very long reaction time and only allow for one non-adjustable acceleration pattern (sinusoidal actuator signal by the rotation of the eccentric mass with a constant rotation velocity). Exemplary embodiments of the invention overcome these and other limitations by accelerating a mass not only as in case of a motor or an oscillator in a continuous manner, but by accelerating it with pulses or a timely limited force effect (one time or periodic or aperiodic repetition) in one or more directions.

According to an exemplary embodiment of the invention, a pulsed drive of a mass mounted on a spring is possible. According to one aspect of such an embodiment, the mass to be accelerated can be kept by pulses in opposing directions close to the “zero” position, and a drift of the position of the mass can be prevented by a spring mounting. In such a configuration, the resonance frequency of the spring-mass systems may be significantly smaller than the pulse repeat frequency. According to another sub-aspect of such an embodiment, the pulse may always be directed in one direction and the mass may oscillate by a spring (which can have an adjusted damping characteristic) with the resonance frequency of the system. In such a scenario, the system resonance may be higher than the pulse repeat frequency. According to a third aspect of such an embodiment, the system resonance frequency and the pulse repeat frequency may be selected to be equal so that a resonance effect with very high acceleration values can be used.

According to another exemplary embodiment, a mass mounted on a spring can be biased. In such an embodiment, the mass does not only have to be activated when a motion is needed, but can be released in a biased position. This may result in a short reaction time with high acceleration. Depending on how fast the tuned mass can be elongated again and how large the damping of the spring mass system is, acceleration pulses can be produced one after the other in a short time and with differently perceivable acceleration patterns.

The aspects defined above and further aspects of the invention are apparent from the examples of embodiment to be described hereinafter and are explained with reference to these examples of embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described in more detail hereinafter with reference to examples of embodiment but to which the invention is not limited.

Fig. 1, Fig. 2, Fig. 5 to Fig. 7 illustrate actuators according to exemplary embodiments of the invention.

Fig. 3 and Fig. 4 illustrate drive circuits for an electrically operating actuator according to exemplary embodiments of the invention.

Fig. 8 illustrates a portable electronic equipment according to an exemplary embodiment of the invention.

DESCRIPTION OF EMBODIMENTS

The illustration in the drawing is schematical. In different drawings, similar or identical elements are provided with the same reference signs.

In the following, referring to Fig. 1, an actuator 100 according to an exemplary embodiment of the invention will be explained.

The actuator 100 comprises a substrate 102, a movable mass 104 movably mounted on the substrate 102, and two spring elements 106 symmetrically supporting the movable mass 104 with regard to the substrate 102 and resiliently or flexibly mounting the movable mass 104 on the substrate 102. A drive unit 108 is provided for driving the movable mass 104 to move upon application of a pulsed drive trigger signal.

The drive unit 108 comprises a controllable voltage source 110 which can be controlled by a control unit 112. The control unit 112 can be a central processing unit (CPU) or a microprocessor. The control unit 112 may generate control signals 114 which can be supplied to the voltage source 110 which in turn generates voltage pulses 116 to electrically charge a chargeable portion 118 of the substrate 102 with electrical charge carriers of a desired polarity. In the shown scenario, positively charged carriers are injected by a voltage signal 116 into the chargeable region 118.

As can further be taken from Fig. 1, the movable mass 104 has a permanently and fixedly charged internal portion 120 in which positive charge carriers are permanently stored in a non-volatile manner. The region 120 can be electrically insulated with regard to the environment.

In the scenario of Fig. 1, the voltage source 110 has, upon receipt of a control signal 114 of the CPU 112, positively charged region 118. Due to the repulsive electric force between the regions 118, 120, the mass 104 moves in an upward direction in the shown scenario, which is indicated by reference numeral 122. When a downward motion is desired, the voltage source 110 can inject negatively charged particles into the portion 118.

Furthermore, an input/output unit 124 is provided which is in bidirectional communication with the control unit 112. Via the input/output unit 124, a user may provide the control unit 112 with instructions or commands to generate a specific acceleration pattern or the like. For example, a user of a mobile phone may define in a menu one or more parameters of a vibration mode which haptically indicates an incoming call without emitting acoustic waves. The input/output unit 124 may comprise input elements such as a button, a joystick, etc. and may comprise an output element such as a display (for instance a liquid crystal display or the like).

The drive unit 108 is adapted for driving the movable mass 104 in a discontinuous manner. Thus, an acceleration pattern that is variable in time may be performed by the movable mass 104. The movable mass 104 in the present embodiment may be moved in an upward direction (see arrow 122) or in a downward direction (opposite to the arrow 122), depending on the type of charge carriers injected in the region 118. The drive unit 108 drives the movable mass 104 based on an electrical drive trigger, thereby generating an electrical force between the regions 118, 120.

The spring elements 106 are adapted to drive back the movable mass 104 into a force-free stationary position in the absence of a drive trigger signal of the drive unit 108. This stationary phase is defined by the spring stiffness of the springs 106 and by the gravitational force (see gravity vector g).

Fig. 2 shows an actuator 200 according to another exemplary embodiment of the invention.

In this embodiment, a drive unit 202 comprises a permanent magnetic element 204 (which can be a permeable magnetic material like iron to get the right magnetic field direction within a coil 206) attached to the mass 104 (which can also be a permanent magnetic element), for instance by gluing, or integrally formed therewith. In one embodiment, the magnetic system (permanent magnet and magnetic material) may be the moving mass; but in another embodiment it is possible to split these “functions” into two different parts. Furthermore, the drive unit 202 comprises the actuation coil 206 (shown in a cross-section in Fig. 2) which can be supplied with an electric activation signal to thereby generate a magnetic field in a vertical direction of Fig. 2, thereby exerting a retracting or repulsive force on the magnetic element 204 resulting in a motion in an upward or downward direction, as indicated by an arrow 208. Moreover, the mass 104 is connected to a button-shaped member 210, which is mounted on the substrate 102 via an enclosing spring element 106. As mentioned above, this part may be used again to get the right magnetic field distribution around the coil 206, therefore again a permeable magnetic material like iron may be used. For example, when a user presses the button-shaped member 210, a successful operation of the button-shaped member 210 may be indicated to the user by a downward motion of the magnet 204, which may be initiated by correspondingly activating the coil 206 upon receipt of the press signal by the user. It is possible to combine the button-shaped member 210 and its haptic feedback device but in other embodiments these functions may be split because the acceleration device may be quit large in size.

An exemplary activation circuit 300 for activating the coil 206 is shown in Fig. 3.

Such an activation circuit 300 comprises a voltage source 302 and a transistor switch 304 closable to supply the magnetic field generation unit 206 with an electric activation signal generated by the voltage source 302.

An alternative activation circuit 400 for activating the coil 206 is shown in Fig. 4.

Fig. 4 shows an activation circuit 400 which comprises a capacitor 402, a capacitor charging unit 404 and a transistor switch 304 closable to supply the coil 206 with an electric activation signal generated by the discharging capacitor 402. Parallel to the coil 206, a protection diode 406 is shown.

The embodiments of Fig. 2 to Fig. 4 show an electrodynamic principle (similar to a loudspeaker function). The pulse may be generated by a very short but intense current peak. The latter can be generated by voltage source 302 with a high voltage and a short switch on time (see embodiment of Fig. 3) or by a pre-charged capacitor 402 discharging upon activation (see Fig. 4).

Fig. 2 therefore shows an exemplary embodiment for the construction of an electrodynamic vibration or force feedback device. The circuit of Fig. 3 allows to obtain a high voltage and a fast switching. The embodiment of Fig. 4 allows for a capacitor discharging.

Fig. 5 shows an activator 500 according to another exemplary embodiment of the invention.

In this embodiment, a drive unit 502 is provided which drives a movable mass 104 based on a mechanical drive trigger. For this purpose, the drive unit 502 comprises a lever 502 having a supporting section 504 and a hook-shaped engaging section 506 which lever 502 selectively engages the mass 104 for biasing the mass 104 (see scenario of Fig. 5) or disengages the mass 104 for moving the mass 104. The latter operation mode is not shown in the figures, but can be adjusted by moving the engagement portion 506 of the lever 502 along an arrow direction 508. Since the leaf spring 106 is biased in the operation mode shown in Fig. 5, motion of the lever 502 in direction 508 allows the mass 104 connected to the substrate 102 or base plate 102 via the leaf spring 106 to move in a downward direction. Thus, the embodiment of Fig. 5 shows a mechanical oscillator with a biased spring 106. The mass 104 (capable of swinging) can be elongated against the spring force and can be released when a motion is desired.

Thus, the spring element 106 of Fig. 5 is adapted to drive back the biased movable mass 104 into a force free stationary position in the presence of a drive trigger of the drive unit 502.

Fig. 6 shows an actuator 600 according to another exemplary embodiment of the invention.

In this embodiment, a piezo beam 602 for selectively fixing the mass 104 in place or moving the mass 104 substitutes the lever 502 of Fig. 5. The two piezo beams 602 shown in Fig. 6 may be bent in an alternating manner in the direction of the elongation, or they may fix the mass 104 during a backward motion.

In another embodiment, one piezo beam is responsible for the motion of the mass 104, and another piezo beam is responsible for the fixing of the mass 104. This may have the advantage that each piezo beam does only have to be configured for one motion control task.

According to a further exemplary embodiment, fixing and moving the mass 104 may be performed by one piezo beam (inertia principle). Due to a very fast backward motion, the piezo beam may slide over the contact portion. The forward direction may be performed so slowly that the mass can follow the motion of the piezo beam.

Fig. 7 shows an actuator 700 according to another exemplary embodiment of the invention.

In this embodiment, the drive unit comprises a wedge 702 for selectively biasing the mass 104 to an adjustable extent or releasing the biased mass 104 for moving the mass 104.

Using the wedge 702, the mass 104 or spring 106 may be elongated.

The wedge 702 which is movable in two directions as indicated by a double arrow 704 can be moved back during the oscillation of the mass 104 in a lateral way (for instance according to a ball point pen principle). In such a manner, the reaction time for the pulse pattern may be maintained very short. The drive of the wedge 702 motion in this embodiment is performed by an electromagnetic principle. It may as well be performed by a piezo or using an SMA (Shaped Memory Alloy). In the latter case, the high negative temperature dependency of the elongation may be used. An advantage of this embodiment is a very simple construction, since the temperature can be controlled very easily using a current via an SMA.

Fig. 8 shows a mobile phone 800 as an example for a portable electronic equipment according to an exemplary embodiment of the invention.

The mobile phone 800 comprises a housing 802, an antenna 804, a display 806, a keypad 808 and an actuator 200 integrated in the housing 200 of the mobile phone 800. When the mobile phone 800 receives a call and a user has selected a mute mode of the mobile phone 800, the incoming call can be indicated to the user via a vibration generated by the actuator 200 integrated in the housing 200.

It is also possible to implement one or more actuators 200 in the keypad 808. When the user has pressed a button of the keypad 808 successfully, this can be indicated to a user by a feedback force generated by such an actuator 200 in the keypad 808 in a perceivable manner for the user.

Finally, it should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be capable of designing many alternative embodiments without departing from the scope of the invention as defined by the appended claims. In the claims, any reference signs placed in parentheses shall not be construed as limiting the claims. The word "comprising" and "comprises", and the like, does not exclude the presence of elements or steps other than those listed in any claim or the specification as a whole. The singular reference of an element does not exclude the plural reference of such elements and vice-versa. In a device claim enumerating several means, several of these means may be embodied by one and the same item of software or hardware. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

CLAIMS:

1. An actuator (100), the actuator (100) comprising

a substrate (102);

a movable mass (104);

a spring element (106) resiliently mounting the movable mass (104) on the substrate (102);

a drive unit (108) for driving the movable mass (104) to move upon application of a pulsed drive trigger.

2. The actuator (100) according to claim 1, wherein the drive unit (108) is adapted for driving the movable mass (104) in a discontinuous manner.

3. The actuator (100) according to claim 1, wherein the drive unit (108) is adapted for driving the movable mass (104) in accordance with an acceleration pattern which is variable in time.

4. The actuator (100) according to claim 1, wherein the drive unit (108) is adapted for driving the movable mass (104) to move in at least two different directions.

5. The actuator (100) according to claim 1, wherein the drive unit (108) is adapted for driving the movable mass (104) based on an electrical drive signal.

6. The actuator (200) according to claim 5, wherein the drive unit (202) comprises

a magnetic element (204) attached to the mass (104) or forming the mass (104);

a magnetic field generation unit (206) activatable for driving the magnetic element (204); and

an activation circuit (300, 400) for activating the magnetic field generation unit (206) by supplying the electric drive signal to the magnetic field generation unit (206).

7. The actuator (200) according to claim 6, wherein the activation circuit (300) comprises

a voltage source (302); and

switching means (304) operable to selectively supply the magnetic field generation unit (206) with the electric drive signal generated by the voltage source (302).

8. The actuator (200) according to claim 6, wherein the activation circuit (400) comprises

a capacitor (402);

a capacitor charging unit (404); and

switching means (304) operable to selectively supply the magnetic field generation unit (206) with the electric drive signal generated by the discharging capacitor (402).

9. The actuator (500) according to claim 1, wherein the drive unit (502) is adapted for driving the movable mass (104) based on a mechanical drive force.

10. The actuator (500) according to claim 9, wherein the drive unit comprises a lever (502) for selectively engaging the mass (104) for biasing the mass (104) or disengaging the mass (104) for moving the mass (104).

11. The actuator (600) according to claim 9, wherein the drive unit comprises a piezo beam (602) for selectively fixing the mass (104) in place or moving the mass (104).

12. The actuator (700) according to claim 9, wherein the drive unit comprises a wedge (702) for selectively biasing the mass (104) to an adjustable extent or releasing the biased mass (104) for moving the mass (104).

13. The actuator (100) according to claim 1, wherein the spring element (106) is adapted to drive back the movable mass (104) into a force-free stationary position in the absence of a drive trigger of the drive unit (108).

14. The actuator (500) according to claim 1, wherein the spring element (106) is adapted to drive back a biased movable mass (104) into a force-free stationary position in the presence of a drive trigger of the drive unit (502).

15. The actuator (100) according to claim 1, adapted to generate a tactile alarm signal perceivable by a human user.

16. The actuator (100) according to claim 1, adapted to generate a tactile feedback signal perceivable by a human user in response to a user operation.

17. A portable electronic equipment (800), the portable electronic equipment (800) comprising an actuator (200) according to claim 1.

18. The portable electronic equipment (800) according to claim 17, adapted as one of the group consisting of a mobile phone, a personal digital assistant, an MP3 player, a game console, a hand-held device, a man machine interface device, a portable computer, and a laptop.

19. A method of manufacturing an actuator (100), the method comprising

resiliently mounting a movable mass (104) on a substrate (102) by a spring element (106);

arranging a drive unit (108) for driving the movable mass (104) to move upon application of a pulsed drive trigger.

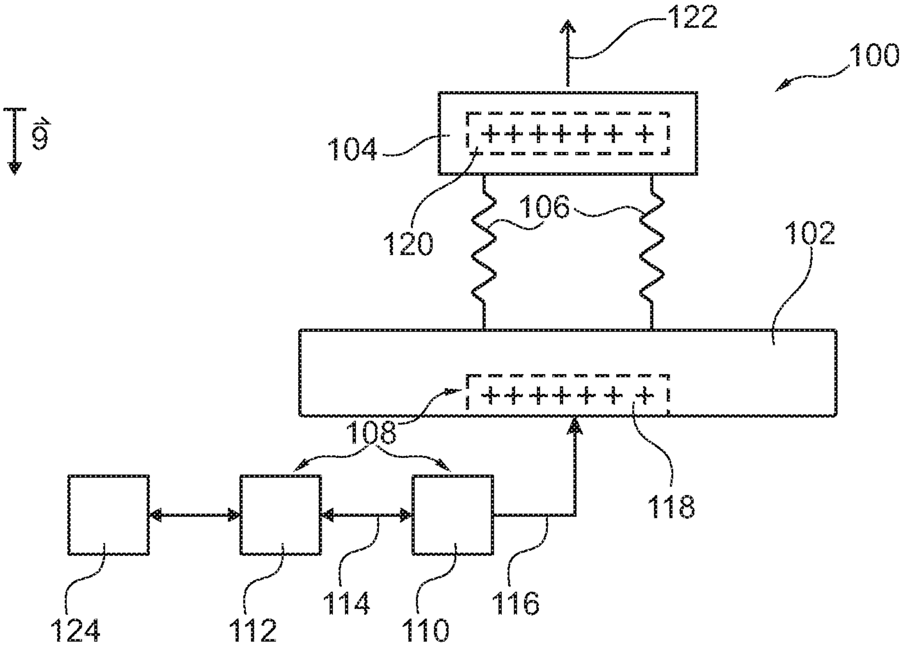

Fig. 1

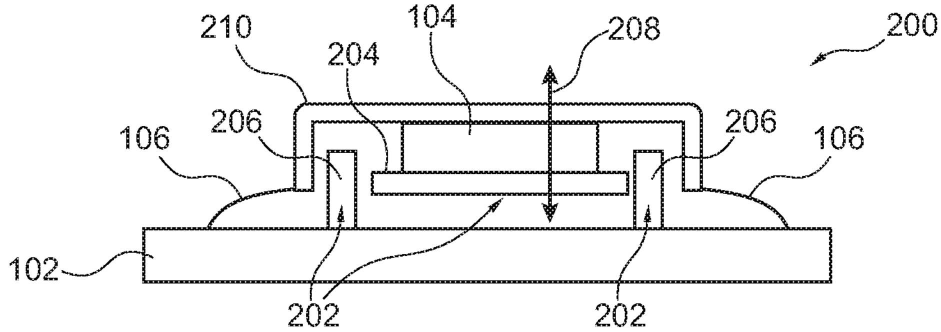

Fig. 2

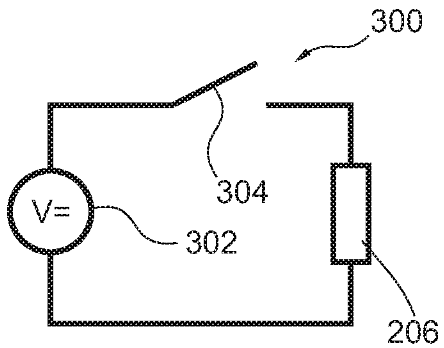

Fig. 3

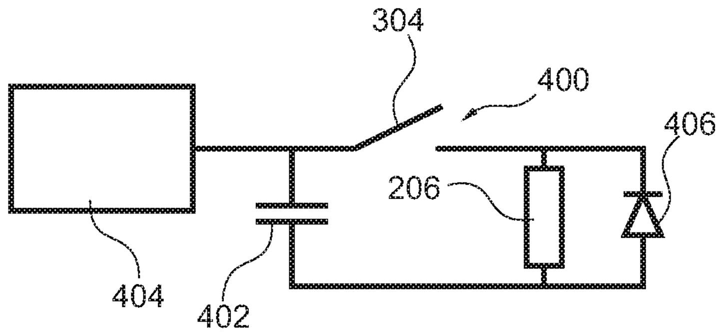

Fig. 4

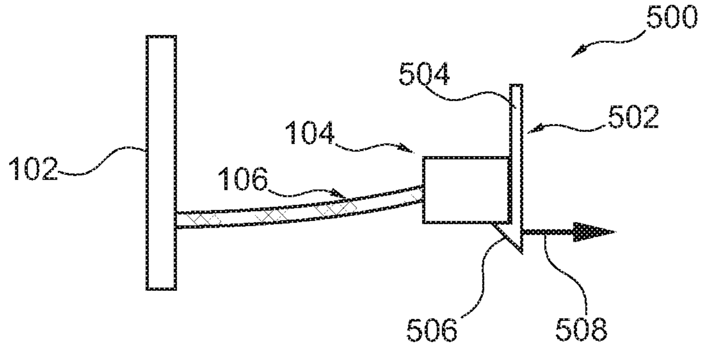

Fig. 5

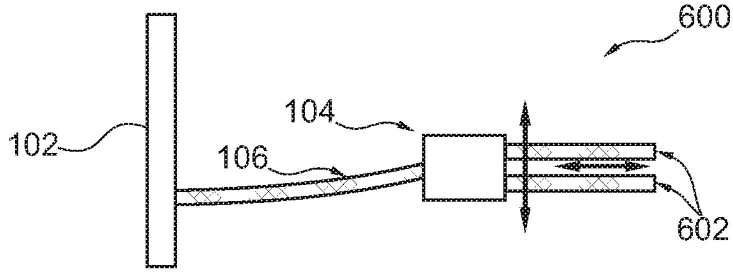

Fig. 6

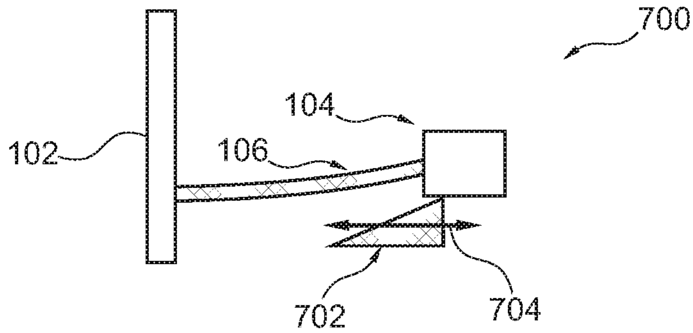

Fig. 7

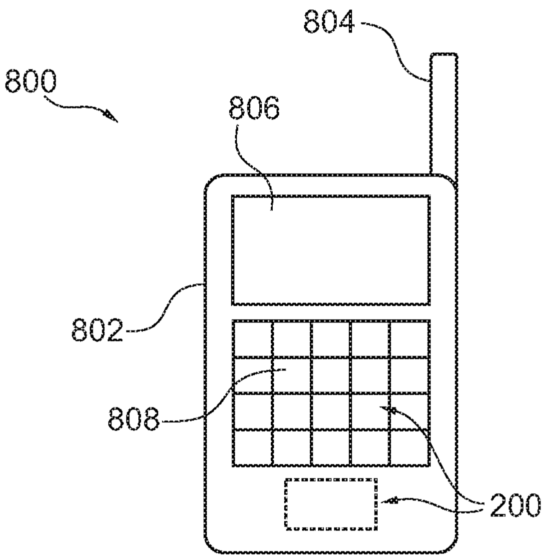

Fig. 8