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Remarks:
Amended claims in accordance with Rule 137(2) EPC.

(54) OPERATION ELEMENT WITH EXCITER SPRING

(57) An operation element comprising: a frame, an operation surface, a first exciter comprising a first mass and a first force-generating unit, a first spring coupling the operation surface and the first mass, a second spring connecting the first mass and the frame, wherein the first force-generating unit is configured to exert a force to at least one of the first mass and the operation surface and to change a physical quantity of the first force-generating unit based on the position of the first mass.

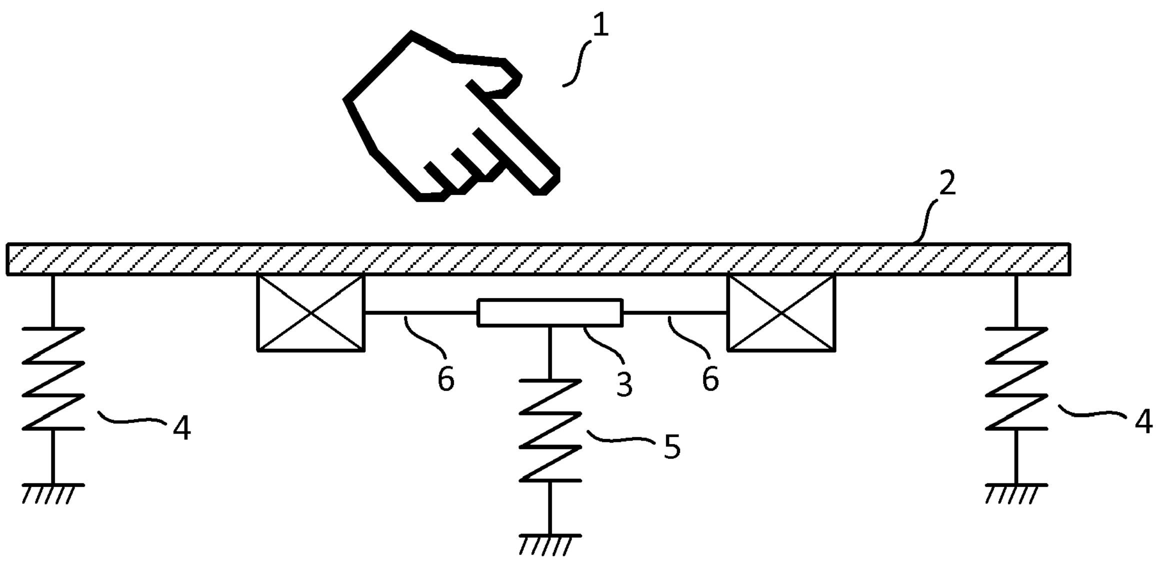

FIG. 3

Description

Technical Field

[0001] The present invention relates to an operation element, in particular an operation element with an exciter spring. The present invention can for example find an application in the context of operation surfaces, as e.g., common in many fields including mobile devices, smartphones, automotive dashboards, touch screens, consumer products, etc.

Technical Background

[0002] In many, if not all, modern products including an input element to be used by a user, this element is a touch display and/or a smart surface. Apart from the obvious example of smartphones whose operation almost exclusively works by means of such a touch display, touch displays are also present in many other consumer products such as washing machines, cars, refrigerators, etc. In many cases, these displays are not only able to receive input from the user but also able to output active haptic feedback back to the user, for example to confirm that an input has been received or a certain action has been performed. These types of surfaces are called "active haptic surfaces" as they provide an active haptic signal to the user, in particular in response to the user providing an input to the application, e.g., by touching the surface.

[0003] For the implementation of active haptic surfaces, exciters are an often-used solution as they can generate multispectral vibration depending on the operating situation. An exciter in the context of the present disclosure can be understood as a voice-coil-actuator with an elastic suspension between a magnetic circuit and a coil. A typical operation involves an actuation by a finger touching the surface, this actuation usually being measured capacitively. If an actuation threshold is reached, a haptically perceptible impulse is triggered by the exciter. This exciter is usual mounted below the surface, but not necessarily in the vicinity of the operation point.

[0004] In order to improve active haptic surfaces, it is advantageous if the threshold of the actuation depends substantially depends on the actuation force, in other words if the measurement of the actuation threshold is improved. Moreover, in some cases, in order to detect false positives and to ensure functional safety, a second measurement of the operation of the finger is desired. While various methods have been suggested to this end, they are either very inaccurate or require additional sensors increasing costs and introducing further error sources. For example, one proposed solution involves measuring a displacement of the elastically suspended surface to a basically elastic surface by means of a reflex light barrier or further capacitive sensor; this, however, introduces additional complexity into the system, thus increasing both costs and error sources. An alternative proposal is to interpret the change in the contact area between the finger providing the input and the surface such that the compression of the finger and the resulting changing surface can be used as a measure. However, due to the large variability of fingers and the measurement uncertainty of the touch surface, this proposal is very inaccurate.

[0005] Therefore, there is a need for improving the active haptic surface in such a way that no additional costs and/or error sources are introduced into the system and the accuracy of the added elements is satisfactory for typical operations.

Summary

[0006] The above problems are solved by the subject-matter of the independent claims. Further preferred embodiments are given by the subject-matter of the dependent claims.

[0007] According to an embodiment of the present invention, there is provided an operation element comprising: a frame, an operation surface, a first exciter comprising a first mass and a first force-generating unit, a first spring coupling the operation surface and the first mass, a second spring connecting the first mass and the frame, wherein the first force-generating unit is configured to exert a force to at least one of the first mass and the operation surface 2 and to change a physical quantity of the first force-generating unit based on the position of the first mass.

Brief description of the drawings

[0008] Embodiments of the present invention, which are presented for better understanding the inventive concepts, but which are not to be seen as limiting the invention, will now be described with reference to the figures in which:

Fig. 1 shows a schematic view of a finger on an operation element with an operation surface and an exciter provided below the operation surface;

Fig. 2 shows a schematic view of an operation element with an operation surface and an exciter provided below the operation surface, the exciter being implemented using a coil and a permanent magnet;

Fig. 3 shows a schematic view of a finger on an operation element with an operation surface, an exciter provided below the operation surface and a second spring according to an embodiment of the present invention;

Fig. 4 shows a schematic circuit diagram of a finger on an operation element with an operation surface 2, an exciter provided below the operation surface and a second spring according to an embodiment of the present invention;

Fig. 5 shows a schematic view of a finger on an operation element with an operation surface, an exciter provided below the operation surface, a second spring and a second exciter according to an embodiment of the present invention; and

Fig. 6 shows a schematic circuit diagram of a finger on an operation element with an operation surface, an exciter provided below the operation surface, a second spring and a second exciter according to an embodiment of the present invention.

Detailed Description

[0009] Fig. 1 shows a schematic view of a finger 1 on an operation element 100 with an operation surface 2 (herein also simply "surface 2") and a first exciter 3 provided below the operation surface 2. As indicated above, exciters are a possible solution for an active haptic surface 2 to be able to generate a multispectral vibration. In this context, "vibration" is to be understood as any vibration irrespective of the frequency range. In other words, a vibration in the sense of the present disclosure also includes a vibration in a frequency range leading to an acoustic signal instead of a haptic feedback/haptic signal. Generally, frequency ranges may thus go from 30 Hz to 16 kHz, wherein typically frequencies up to 1 kHz are considered haptic. Further, ranges of particular interest may be 2 to 5 kHz, 4 to 5 kHz as well as 60 to 200 Hz.

[0010] The first exciter 3, or exciters in general, may comprise a first spring 6 (or two such springs as shown in Fig. 1) and a first force-generating unit 7, wherein the first spring 6 is connecting the surface 2 with the first force-generating unit 7 such that the force generated by the first force-generating unit 7 can be transmitted via the first spring 6 to the surface, thus generating the haptic feedback experienced by the user.

[0011] A typical operation as shown in Fig. 1 includes a finger 1 touching an operation surface 2. In terms of elements of an electric circuit diagram, the finger 1 may be modelled using a damping, a stiffness and a mass. One possibility to measure this touch is by means a capacitive measurement and an actuation of the exciter is executed if an actuation threshold is reached/exceeded. The actuation of the exciter then leads to a vibration, for example a haptically perceptible impulse. It is noted that while in the present case the finger 1 is provided in the vicinity of the exciter provided below the surface 2, this is not required and the exciter may also be distant from, that is, not in the vicinity of the point where the finger 1 touches the surface 2.

[0012] Fig. 2 shows a schematic view of an operation element 100 with an operation surface 2 and an exciter provided below the operation surface 2, the exciter being implemented using a coil 11 and a permanent magnet 7, wherein the permanent magnet 7 encloses the coil 11 and may have a ferromagnetic extension such as an iron core extension (or simply "iron core") which may, for example, serve the purpose of increasing the Lorentz force generated. Fig. 2 can thus be understood as a more detailed example of the operation element 100 shown in Fig. 1. The first exciter 3 in Fig. 2 comprises a mass, which may be formed by the permanent magnet 7 and the iron core, connected elastically via a first spring 6 to the surface 2. The coil 11 is fixed to the surface 2 and thus, if the coil 11 energized, due to the Lorentz force, the iron core is dynamically accelerated, and the resulting forces mediated via the first spring 6 onto the surface 2 generate the perceptible vibration at the surface 2. It is noted that if the first exciter 3 is not used actively, that this, the entire operation element 100 is in a passive state, i.e., in a state not providing any active feedback, the only influence of the first exciter 3 on the remaining system is an increased total weight.

[0013] Fig. 3 shows a schematic view of a finger 1 on an operation element 100 with an operation surface 2, a first exciter 3 provided below the operation surface 2 and a second spring 5 according to an embodiment of the present invention.

[0014] An alternative concept to the conventional approach or the alternative proposals discussed above is to use the variability of the inductance of the coil 11 when then the surface 2 is touched: Touching and moving the surface 2 moves the coil 11 which then interacts with the magnetic field of the permanent magnet 7, namely influences its inductance. By measuring the latter, the force applied to the surface 2 by the finger 1 can be measured.

[0015] For this concept to work, it is necessary that the mass of the exciter is mechanically connected to the frame such that the relative movement between coil 11 and permanent magnet 7 can be measured, in particular measured reliably. To this end, it is suggested to provide a further spring, a second spring 5, between the first exciter 3 and the frame.

[0016] In the passive case, i.e., when no current is applied to the coil 11, the second spring 5 acts like a parallel connection of the first spring 6. However, the coil 11, the permanent magnet 7 and the first spring 6 are provided in series with respect to the second spring 5 such that a measurement of the inductance and in turn of the force applied by the finger 1 touching the surface 2 can be achieved. In other words, the second spring 5 can be understood as a counterpart to the first exciter 3 such that it cannot only be used to generate haptic feedback but to also can be used for measurement. Further, the surface 2 is connected with two frame springs 4 to the frame. It is noted that these springs 4 do not have to be two springs but may a single spring (or more than two springs) as well.

[0017] Fig. 4 shows a schematic circuit diagram of a finger 1 on an operation element 100 with an operation surface 2, a first exciter 3 as discussed above and comprising a first mass 7 and a first force-generating unit 11, as indicated by a dashed line, provided below the operation surface 2 and a second spring 5 according to an embodiment of the present invention. In particular, this schematic circuit diagram includes both the operation element 100 with its constituents as well as the finger 1 applied a force to the surface 2 of the operation element 100. Specifically, Fig. 4 shows a contact point 10, elements right (upstream) of which correspond to the finger 1 applying a force while elements left (downstream) of it correspond to the operation element 100. As discussed above, the finger 1 can be modelled as a mass, a damping (or spring) and a stiffness. Further, the finger 1 also applies a force onto the system. The surface 2 may be elastically connected to the frame via a frame spring 4 and has a mass. As discussed above, a first spring 6 connects the first exciter 3 with the surface 2. In this circuit diagram, the first exciter 3 is represented by a mass 7 and a first force-generating unit 11, which may be realized by a coil 11 as discussed above; in fact, it can be understood that the coil 11 is seen to correspond to the first force-generating unit 11 while the permanent magnet 7, potentially including the iron core, is seen to correspond to the mass 7. Further, the first exciter 3 is connected via the second spring 5 with the frame.

[0018] In addition to the passive case in which the first exciter 3 can here be used to measure the force applied to the surface 2 via an inductance measurement, this configuration can also be used in an active case. In this case, the coil 11 of the first exciter 3 is driven as an active force source and this force is provided via the first spring 6 and the contact point 10 to finger 1, thus leading to haptic feedback. In other words, also in the case of the second spring 5 being present, the first exciter 3 can be driven to provide haptic feedback to the user via the surface 2.

[0019] It is furthermore noted that the above concept is not tied to the user of an exciter using a coil 11 and an iron core. In fact, any force-generating unit that can exert a force at the first mass and/or the surface 2 and that can change a physical quantity of the force-generating unit based on the position of the mass can be used.

[0020] In other words, in an embodiment of the present invention, there is provided an operation element 100 comprising: a frame, an operation surface 2, a first exciter comprising a first mass 7 and a first force-generating unit 11, a first spring 6 coupling the operation surface 2 and the first mass 7, a second spring 5 connecting the first mass 7 and the frame, wherein the first force-generating unit 11 is configured to exert a force to at least one of the first mass 7 and the operation surface 2 and to change a physical quantity of the first force-generating unit 11 based on the position of the first mass 7.

[0021] Further, as also discussed above, in an embodiment according to the present invention the first force-generating unit 11 may be a coil 11 configured to exert the force following the Lorentz force.

[0022] Further, in an embodiment according to the present invention, the first force-generating unit 11 may be a lifting magnet.

[0023] Further, in an embodiment according to the present invention the physical quantity may be at least one of an inductance, a voltage, a current or a resistance.

[0024] Further, in an embodiment according to the present invention the first force-generating unit 11 may be configured to activate at least one dynamic signal based on a change of the physical quantity. In this case, the at least one dynamic signal can be seen as the force exerted by the force-generating unit. In other words, the dynamic signal refers to a specific profile of force exerted by the first force-generating unit 11 such that creating a specific haptic or acoustic feedback can be realized. Further, the change of the physical quantity and the activation based thereon may refer to the actuation threshold. That is, this may refer to the above-described circumstance that the actuation leading to the haptic feedback being provided depends on reaching/exceeding a predetermined actuation threshold.

[0025] Further, in an embodiment according to the present invention the at least one dynamic signal may have a duration of less than 500ms, preferably less than 50ms.

[0026] Fig. 5 shows a schematic view of a finger 1 on an operation element 100 with an operation surface 2, an exciter provided below the operation surface 2, a second spring 5 and a second exciter 12 according to an embodiment of the present invention.

[0027] One consequence of the second spring 5 is that the force generated by the first force-generating unit 11 of the first exciter 3 is not applied to the contact point 10 in its entirety but rather a part of it is diverted by the second spring 5. In terms of the energy considerations, that means the first exciter 3 in such a system with the second spring 5 may be required to be powerful if the same haptic feedback is to be generated when compared to the system without the second spring 5.

[0028] One way to address this situation can be to provide an additional exciter, that is, a second exciter 12, mechanically in series to the first exciter 3. This second exciter 12 comprises the second spring 5 discussed above as well as a second mass 14 and a second force-generating unit 13.

[0029] Fig. 6 shows a schematic circuit diagram of a finger 1 on an operation element 100 with an operation surface 2, a first exciter 3 as discussed above and comprising a first mass 7 and a first force-generating unit 11, as indicated by a dashed line, provided below the operation surface 2, a second spring 5 and a second exciter 12 according to an embodiment of the present invention. As mentioned above and indicated by the dashed line in Fig. 6, the second exciter comprises the second mass 14 and the second force-generating unit 13.

[0030] In this combination, it becomes possible to devise an improved actuation algorithm in which, for example, when capacitive contact with the operating surface

2 is detected, a current is applied to the second exicter 12 which is thus fixed and the second spring 5 is fully effective, that is, can effectively be considered to be connected to the frame as the potential leeway due to the second exciter 12 is zero or at least negligible. Then, when the actuation threshold is reached, and the first exciter provide the haptic feedback, the second exciter 12 can be driven such that the second spring 5 is effectively fixed. This leads in turn to the energy of the first exciter being completely transferred to the surface 2 and thus the energetic losses mentioned above can be reduced and mitigated entirely.

[0031] Furthermore, the second exciter 12 may also be designed to act in parallel to the first exciter. That is, instead of fixation the second spring 5, the second exciter 12, more specifically the second force-generating unit 13, may exert a force in combination with the first force-generating unit. This may allow to generate completely new types of haptic feedback, thus enriching the amount of possible profiles of the dynamic signal.

[0032] In other words, in an embodiment according to the present invention, the operation module further comprises a second exciter 12 comprising a second force-generating unit 13 and a second mass 14. As discussed above, the second force-generating unit influences the second spring 5. Moreover, this configuration may optionally comprise a further spring 15. This spring 15 may resemble the membrane of the second exciter 12 and may be advantageous when tuning the resonance of the overall dynamic response.

[0033] As regards the position of the second force-generating unit, it may be provided between the second spring 5 and the frame, before the second spring 5 and the frame, or on the same level as the second spring 5, and configured to exert a force to the second spring 5.

[0034] Further, in an embodiment according to the present invention, the operation element 100 may comprise a controller configured to activate the second force-generating unit upon a first actuation of the operation surface 2 such that the second spring 5 is effectively mechanically connected to the frame and to cause, upon determination that a change in the physical quantity has exceeded a predetermined threshold, the first force-generating unit 11 and the second force-generating unit 13 to activate the at least one dynamic signal in a joint movement, or by at least releasing the second spring 5 from the connection to the frame. Moreover, as discussed above, part of the joint movement may be that the second force generating unit 13 is activated such that the second spring 5 is stiff and the force generated by the first force-generating 11 is applied, applied entirely or at least applied to a large extent to the surface 2.

[0035] Further, in an embodiment according to the present invention, the second force-generating unit 13 comprises a coil 11 configured to exert the force following the Lorentz force. This concept is similar to the above detailed description of the first force-generating unit 11 and thus a detailed description is omitted.

[0036] Further, in an embodiment according to the present invention, the second force-generating unit 13 is an electromagnetic clutch.

[0037] Further, in an embodiment according to the present invention, the second force-generating unit 13 is a magneto-rheological actuator.

[0038] Further, in an embodiment according to the present invention, the ratio between a spring constant of the first spring 6 and a spring constant of the second spring 5 is in the range of 0.3 to 3.

[0039] This choice of the ratio may depend on the presence or absence of the second exciter 12. Specifically, if the second exciter 12 is not present, it is preferred that the first spring 6 is stiffer than the second spring 5 and thus that the ratio between the spring constant of the first spring 6 and the spring constant of the second spring 5 is greater than 1. This is because in this case, less of the force provided by the first force-generating unit is diverted into the second spring 5 and more is provided as haptic feedback to the surface 2.

[0040] On the other hand, if the second exciter 12 is present, it is preferred that the ratio between the spring constant of the first spring 6 and spring constant of the second spring 5 is smaller than 1. This is because first the above requirement for reducing energy losses can be addressed by the second exciter 12 and second in case that the haptic feedback should originate from the first force-generating unit only, this configuration makes setting the second spring 5 stiff easier.

[0041] As a further remark, it is noted that generally the parameters and properties of the various elements of the operating elements have to be provided in accordance with each other. For example, it has to be taken into account that the displacement at the coil 11 is within the measuring range of suitable inductance measuring systems (such as a simple resonant circuit with a capacitive element, a voltage divider at a fixed frequency with an ideal resistor, RLC measuring bridge, etc.). Typically, movements of 0.3mm are allowed for surface 2 displacement with a typical actuating force of between 2 and 6 N. In this case it is preferred that the coil 11 moves by at least 0.1mm, which would correspond to an elasticity ratio for static actuation of 1/3 of the sum spring constant of springs 5 and 6.

[0042] Further, the first spring 6 5 and the second spring 5 6 are in mechanical parallel connection to the spring 4. Accordingly, the changes in the overall configuration and working concept should be taken into account accordingly for the spring 4, which may lead to a reduction of the stiffness of this spring 4.

[0043] The same applies to the scenario in which the force-generating unit is not limited to the system comprising a coil 11 and an iron core but is a more general force-generating unit.

[0044] Although detailed embodiments have been described, these only serve to provide a better understanding of the invention defined by the independent claims and are not to be seen as limiting.

Claims

1. An operation element comprising:

a frame,
an operation surface,
a first exciter comprising a first mass and a first force-generating unit,
a first spring coupling the operation surface and the first mass,
a second spring connecting the first mass and the frame,
wherein the first force-generating unit is configured to exert a force to at least one of the first mass and the operation surface and to change a physical quantity of the first force-generating unit based on the position of the first mass.

2. The operation element according to claim 1, wherein the first force-generating unit is a coil configured to exert the force following the Lorentz force.

3. The operation element according to claim 1 or 2, wherein the first force-generating unit is a lifting magnet.

4. The operation element 100 according to any one of claims 1 to 3, wherein the physical quantity is at least one of an inductance, a voltage, a current or a resistance.

5. The operation element according to any one of claims 1 to 4, wherein the first force-generating unit is configured to activate at least one dynamic signal based on a change of the physical quantity.

6. The operation element according to claim 5, wherein each of the at least one dynamic signal has a duration of less than 500ms, preferably less than 50ms.

7. The operation element according to any one of claims 1 to 6,

further comprising a second exciter comprising a second force-generating unit and a second mass,
wherein the second force-generating unit is provided between the second spring and the frame, before the second spring and the frame, or on the same level as the second spring, and configured to exert a force to the second spring.

8. The operation element according to claim 7, further comprising a controller configured to activate the second force-generating unit upon a first actuation of the operation surface such that the second spring is effectively mechanically connected to the frame and to cause, upon determination that a change in the physical quantity has exceeded a predetermined threshold, the first force-generating unit and the second force-generating unit to activate the at least one dynamic signal in a joint movement, or by at least releasing the second spring 5 from the connection to the frame.

9. The operation element according to claim 7 or 8, wherein the second force-generating unit is a coil configured to exert the force following the Lorentz force.

10. The operation element according to any one of claims 7 to 9, wherein the second force-generating unit is an electromagnetic clutch.

11. The operation element according to any of claims 7 to 10, wherein the second force-generating unit is a magneto-rheological actuator.

12. The operation element according to any one of claims 1 to 11, wherein the ratio between a spring constant of the first spring and a spring constant of the second spring is in the range of 0.3 to 3.

Amended claims in accordance with Rule 137(2) EPC.

1. An operation element (100) comprising:

a frame,
an operation surface (2),
a first exciter (3) comprising a first mass (7) and a first force-generating unit (11),
a first spring (6) coupling the operation surface (2) and the first mass (7),
a second spring (5) connecting the first mass (7) and the frame,
wherein the first force-generating unit (11) is configured to exert a force to at least one of the first mass (7) and the operation surface (2) and to change a physical quantity of the first force-generating unit (11) based on the position of the first mass (7),
characterized by
further comprising a second exciter (12) comprising a second force-generating unit (13) and a second mass (14),
wherein the second force-generating unit (13) is provided between the second spring (5) and the frame, before the second spring (5) and the frame, or on the same level as the second spring

(5), and configured to exert a force to the second spring (5), and by

further comprising a controller configured to activate the second force-generating unit (13) upon a first actuation of the operation surface (2) such that the second spring (5) is effectively mechanically connected to the frame and to cause, upon determination that a change in the physical quantity has exceeded a predetermined threshold, the first force-generating unit (11) and the second force-generating unit (13) to activate the at least one dynamic signal in a joint movement, or by at least releasing the second spring (5) from the connection to the frame.

2. The operation element (100) according to claim 1, wherein the first force-generating unit (11) is a coil configured to exert the force following the Lorentz force.

3. The operation element (100) according to claim 1 or 2,
wherein the first force-generating unit (11) is a lifting magnet.

4. The operation element (100) according to any one of claims 1 to 3,
wherein the physical quantity is at least one of an inductance, a voltage, a current or a resistance.

5. The operation element (100) according to any one of claims 1 to 4,
wherein the first force-generating unit (11) is configured to activate at least one dynamic signal based on a change of the physical quantity.

6. The operation element (100) according to claim 5, wherein each of the at least one dynamic signal has a duration of less than 500ms, preferably less than 50ms.

7. The operation element (100) according to any one of claims 1 to 6,
wherein the second force-generating unit (13) is a coil configured to exert the force following the Lorentz force.

8. The operation element (100) according to any one of claims 1 to 7,
wherein the second force-generating unit (13) is an electromagnetic clutch.

9. The operation element (100) according to any of claims 1 to 8,
wherein the second force-generating unit (13) is a magneto-rheological actuator.

11. The operation element (100) according to any one of claims 1 to 10,
wherein the ratio between a spring constant of the first spring (6) and a spring constant of the second spring (5) is in the range of 0.3 to 3.

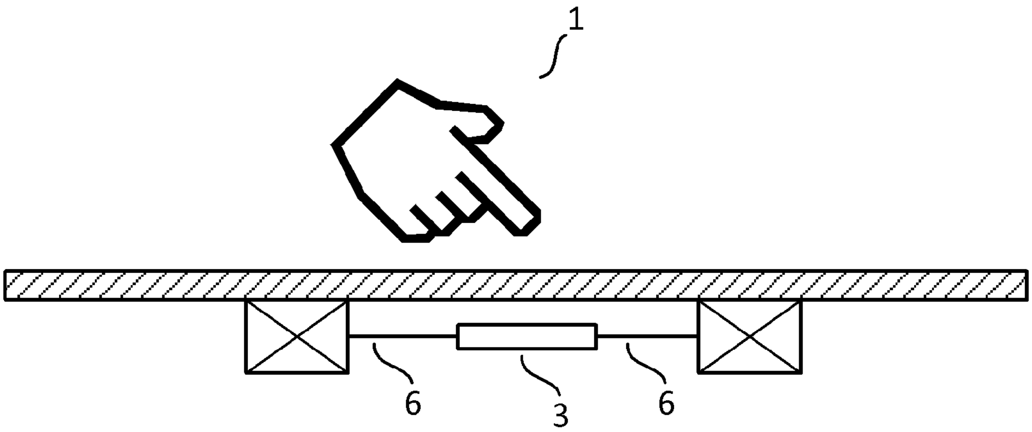

FIG. 1

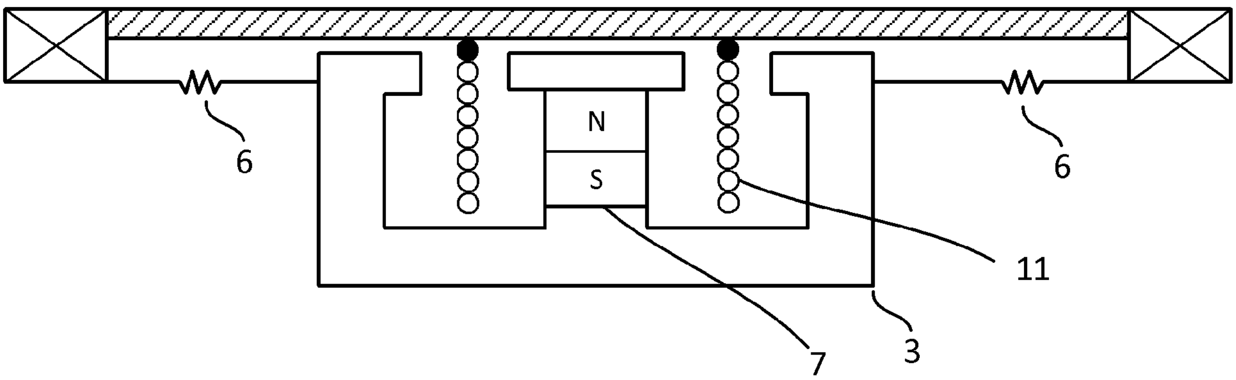

FIG. 2

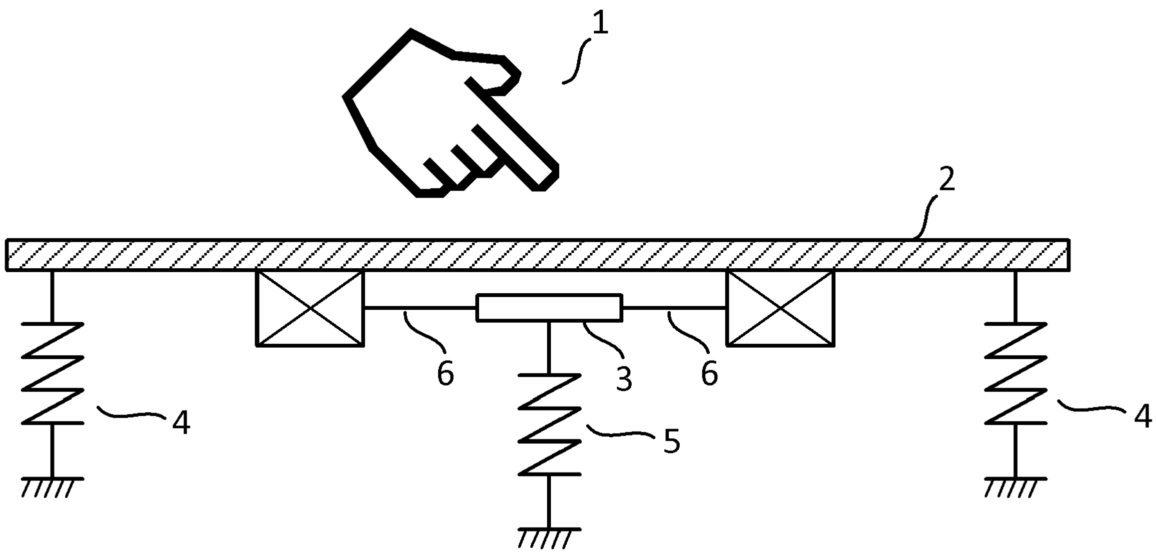

FIG. 3

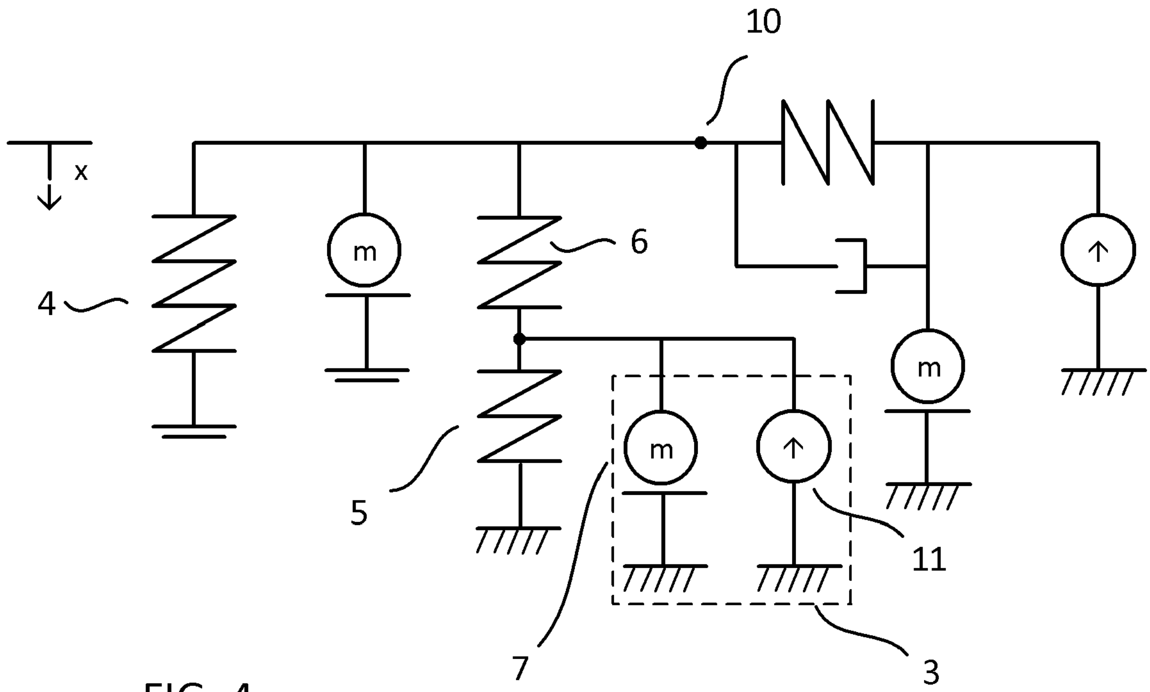

FIG. 4

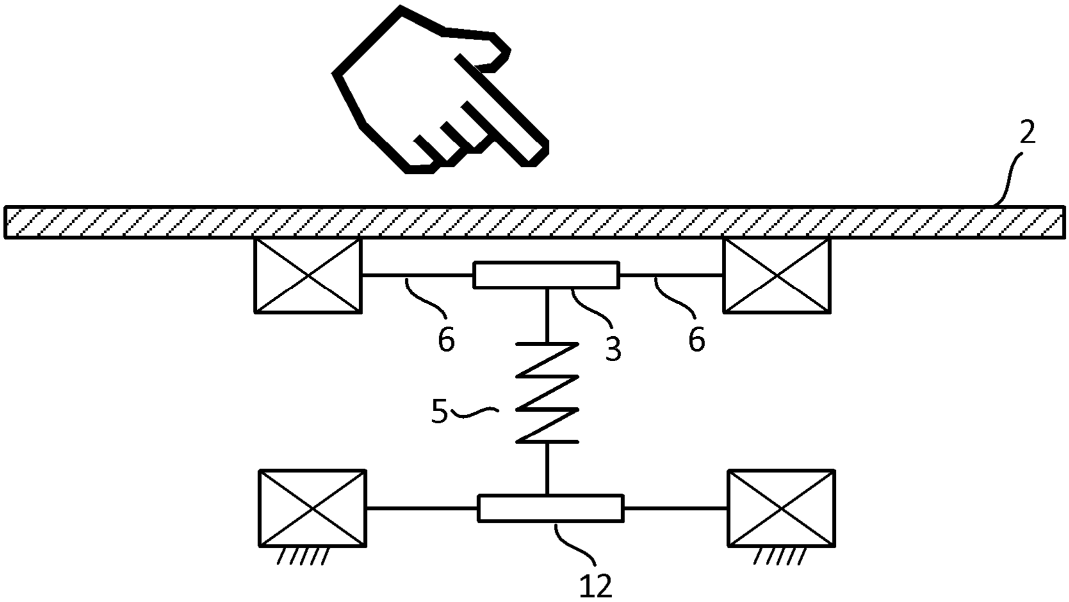

FIG. 5

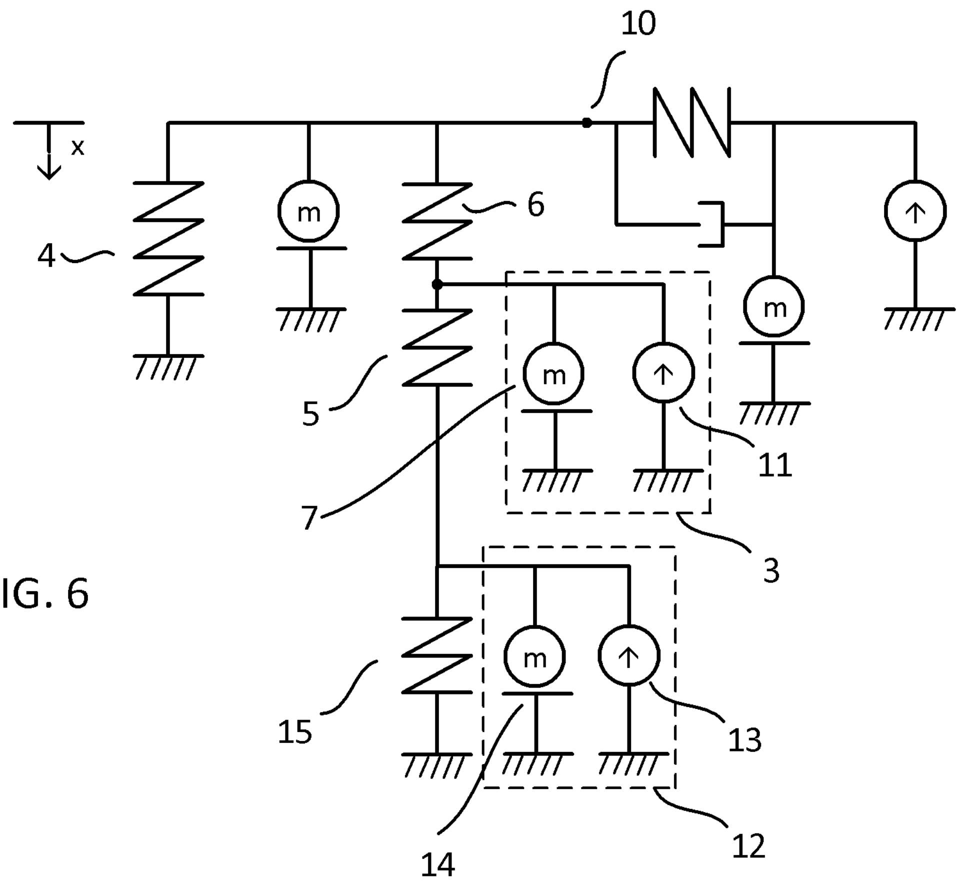

FIG. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 22 20 5047

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X A	EP 3 444 948 A1 (ALPINE ELECTRONICS INC [JP]) 20 February 2019 (2019-02-20) * paragraphs [0015], [0016], [0022] - [0025], [0035] - [0037]; figure 3 * -----	1-6,12 7-11	INV. B06B1/04
X A	US 2020/004337 A1 (HENDREN KEITH J [US] ET AL) 2 January 2020 (2020-01-02) * paragraphs [0101] - [0103]; figure 11 * -----	1-6,12 7-11	
X	EP 2 286 930 A1 (SONY ERICSSON MOBILE COMM JP [JP]; SONY CORP [JP]) 23 February 2011 (2011-02-23) * paragraphs [0044] - [0047]; figure 4 * -----	1	
X	US 2019/372446 A1 (ODAJIMA SHIN [JP]) 5 December 2019 (2019-12-05) * paragraphs [0008] - [0015]; figure 1 * -----	1	

TECHNICAL FIELDS SEARCHED (IPC)

B06B
H04R

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
The Hague	14 March 2023	Vollmer, Thorsten

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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