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(54) **DEVICE FOR AUTOMATIC DETECTION OF STATES OF MOTION AND REST, AND PORTABLE ELECTRONIC APPARATUS INCORPORATING IT**

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G01C 21/00 (2006.01)

(52) **U.S. Cl.** .... **701/220**; 700/245; 74/5 R

(58) **Field of Classification Search** .... 700/245, 700/258, 108, 67; 701/220; 74/5 R, 5.34, 74/5.46
See application file for complete search history.

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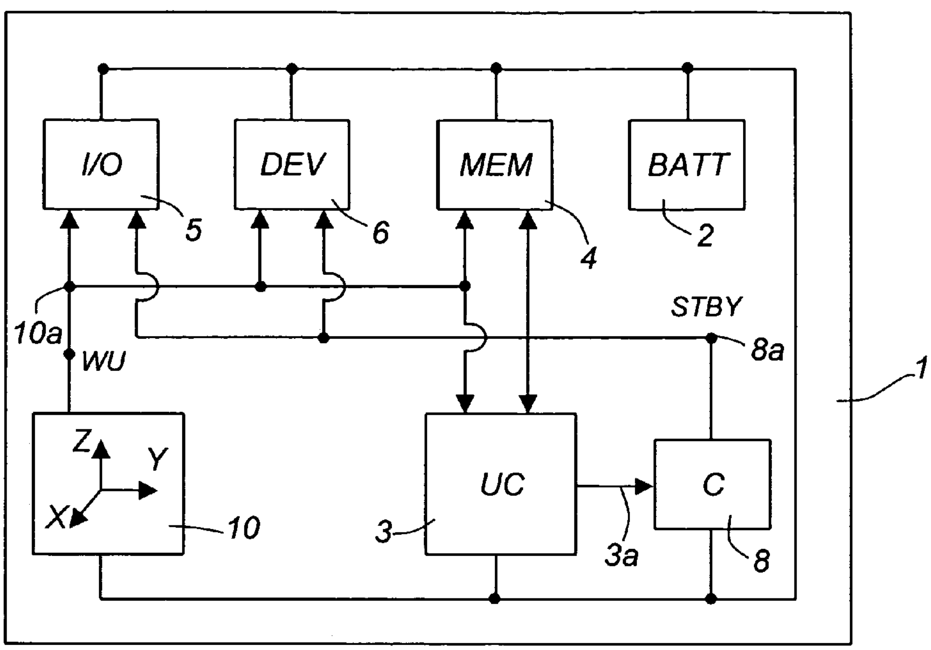
(57) **ABSTRACT**

A device for automatic detection of states of motion and rest includes at least one inertial sensor, having at least one preferential detection axis, and a converter, which is coupled to the inertial sensor and supplies a first signal correlated to forces acting on the first inertial sensor according to the preferential detection axis; the device further includes at least one processing stage for processing the first signal, which supplies a second signal correlated to a dynamic component of the first signal, and at least one threshold comparator, which supplies a pulse when the second signal exceeds a pre-determined threshold.

28 Claims, 2 Drawing Sheets



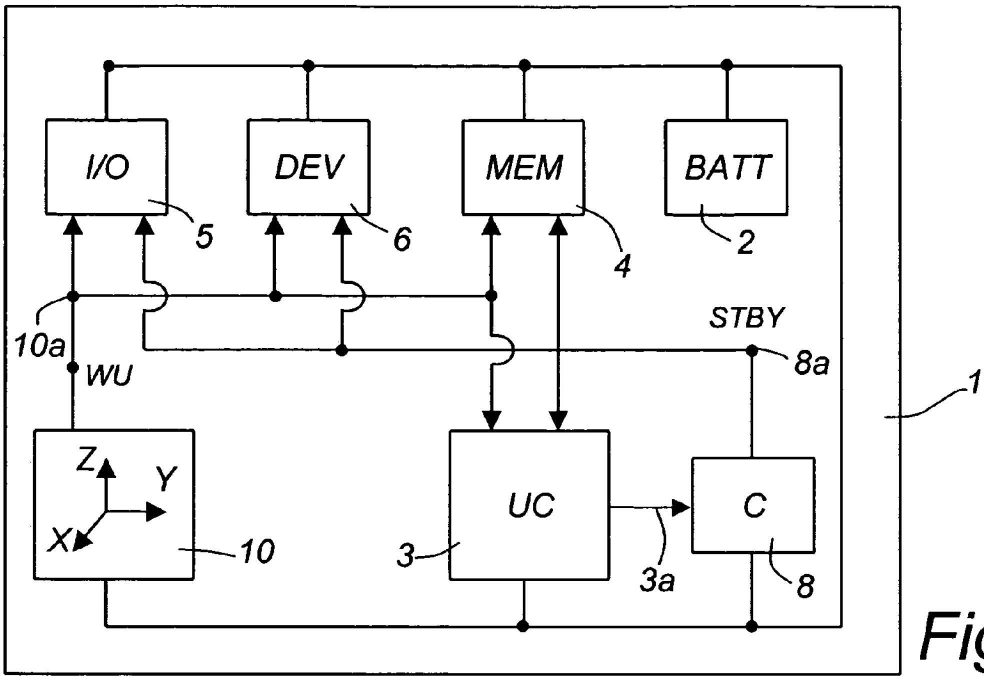

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Fig. 1

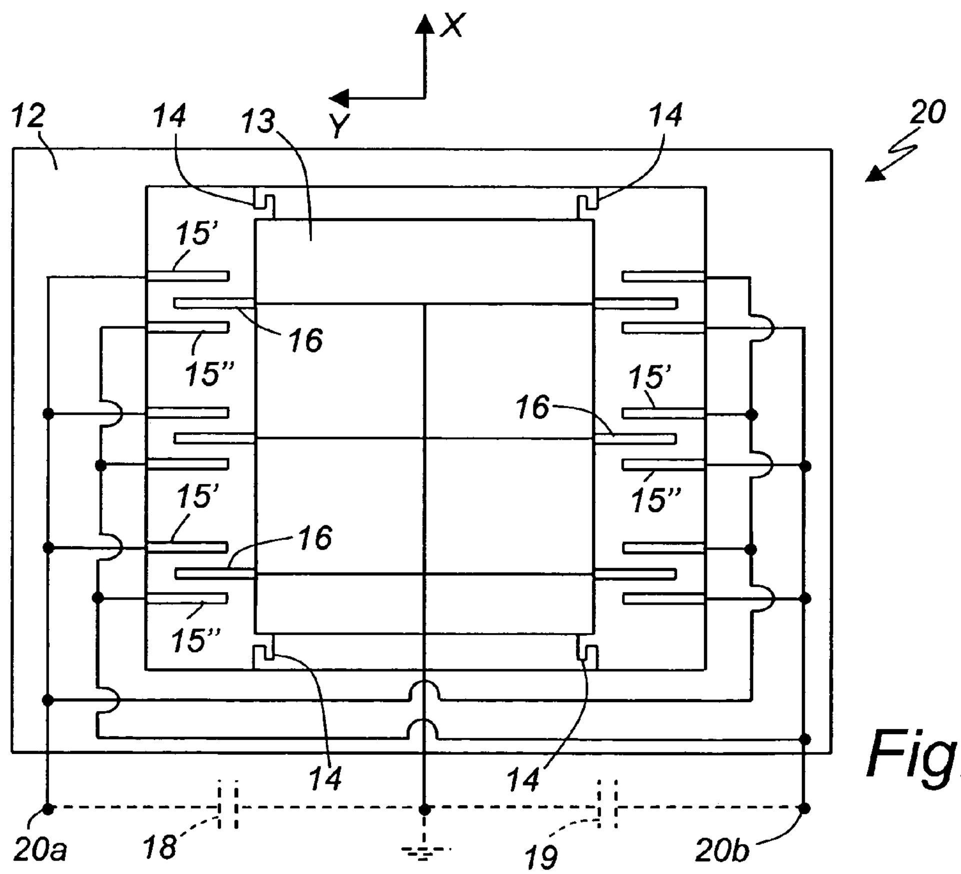
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Fig. 2

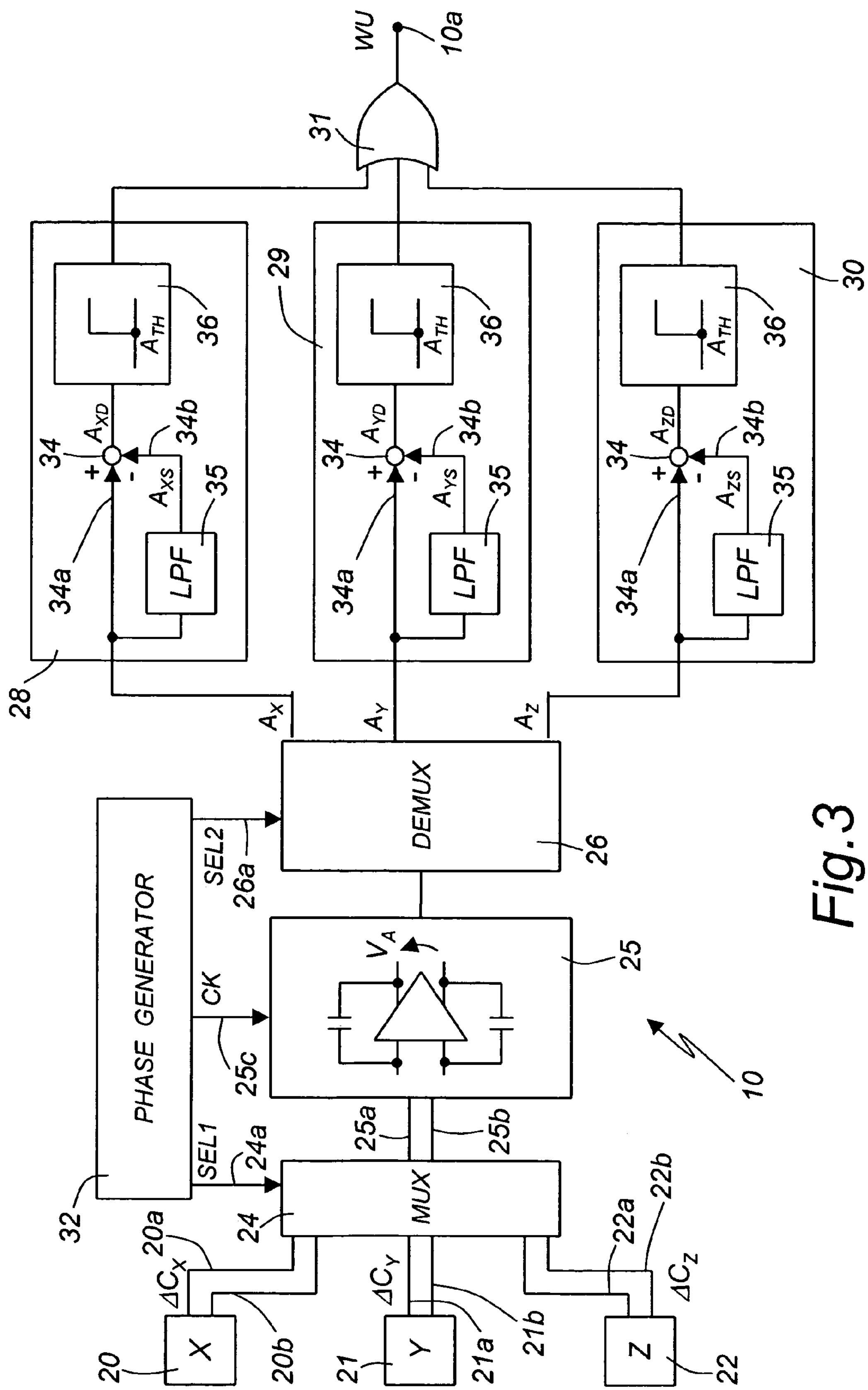
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Fig.3

DEVICE FOR AUTOMATIC DETECTION OF STATES OF MOTION AND REST, AND PORTABLE ELECTRONIC APPARATUS INCORPORATING IT

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a device for automatic detection of states of motion and rest and to a portable electronic apparatus incorporating it.

2. Description of the Related Art

As is known, reduction of power consumption is one of the main objectives in any sector of modern microelectronics. In some fields, however, power consumption has an even determining importance in the evaluation the quality of a product. Many widely used electronic devices, in fact, are provided with a stand-alone battery supply and are normally disconnected from the mains supply; this is, for example, the case of cell phones and cordless phones, of palm-top computers and radio frequency pointer devices for computers (mouses and trackballs). It is clear that the reduction both of supply voltages and of currents advantageously involves an increase in the autonomy of the device and hence a greater convenience of use.

Furthermore, frequently the cited above devices are effectively used just for brief periods, whereas for most of the time in which they are on they remain inactive. Consider, for example, the ratio between the duration of a call from a cell phone and the average time between two successive calls. It is clear that, for almost the entire period of operation, the cell phone remains inactive, but is in any case supplied and thus absorbs a certain power. In effect, the autonomy of the device is heavily limited.

Some devices, after a pre-determined interval of inactivity, can be automatically set in a wait state (stand-by), in which all the functions not immediately necessary are deactivated; for example, in a cell phone it is possible to turn off the screen and all the circuitry that is not involved in identifying an incoming call.

To reactivate the devices from stand-by, it is advantageous to exploit a signal linked to an event (such as, for example, reception of a call signal, in the case of cell phones). However, since it is not always possible to associate a signal to an event (for example, in the case where it is the user who wants to make a call), normally a reactivation key is provided, that the user can press for bringing back the device into a normal operative state.

In this case, however, one drawback lies in that the device is not immediately ready for use: the user must in fact pick up the device, press the reactivation key and wait for the extinction of a transient in which the functions previously deactivated are restored. Although this transient is relatively brief (at the most in the region of one second), it is not however negligible and in some cases can render the device altogether inefficient. For example, in a radio frequency mouse, the restore time would be so long that the advantage of having low consumption in stand-by would be basically nullified by the lower efficiency of use.

It would, instead, be desirable to have available a device incorporated in an apparatus that is able to generate automatically a reactivation signal when the apparatus is to be used.

BRIEF SUMMARY OF THE INVENTION

One embodiment of the present invention provides a device and an apparatus that enables the problem described above to be solved.

includes an inertial sensor having a preferential detection axis and a converter coupled to the inertial sensor and supplying a first signal correlated to forces acting on the first inertial sensor according to the preferential detection axis. The device also includes a processing stage structured to process the first signal and supply a second signal correlated to a dynamic component of the first signal; and a threshold comparator supplying a pulse when the second signal exceeds a predetermined threshold.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention, an embodiment thereof is now described, purely by way of non-limiting example and with reference to the attached drawings, in which:

FIG. **1** illustrates a simplified block diagram of an apparatus incorporating a device made according to the present invention;

FIG. **2** illustrates a more detailed circuit block diagram of the device according to the present invention; and

FIG. **3** is a schematic plan view of a detail of the device of FIG. **2**.

DETAILED DESCRIPTION OF THE INVENTION

With reference to FIG. **1**, designated, as a whole, by the reference number **1** is a portable electronic apparatus, which, in the example illustrated herein, is a palm-top computer; this must not, however, be considered in any way limiting, in so far as the apparatus **1** could also be of a different type. The apparatus **1** comprises at least one battery **2**, a control unit **3**, a memory **4**, an input/output (I/O) unit **5** (for example an infrared serial port), a screen **6**, a counter **8** and an activation device **10**.

An output **2***a* of the battery **2**, which supplies a supply voltage V_{DD}, is connected to respective supply inputs of the control unit **3**, the memory **4**, the I/O unit **5**, the screen **6**, the counter **8** and the activation device **10**.

Furthermore, the control unit **3**, the memory **4**, the I/O unit **5** and the screen **6** have: respective stand-by inputs connected to an output **8***a* of the counter **8**, which supplies stand-by pulses STBY; and respective activation inputs, connected to an output **10***a* of the activation device **10**, which supplies activation pulses WU ("Wake-Up"). Furthermore, the counter **8** has a counting input connected to an output **3***a* of the control unit **3**, which supplies a counting signal CT. In the presence of a first value of the counting signal CT, the counter **8** is disabled; when the counting signal CT switches from the first value to a second value, the counter **8** is reset and then incremented at each clock cycle. If the counter **8** reaches a pre-determined threshold counting value, a stand-by pulse STBY is generated.

During normal operation of the apparatus **1** (active state), the control unit **3** maintains the counting signal CT at the first value, disabling the counter **8**. When, instead, the control unit **3** recognizes a condition in which the apparatus **1** is turned on, but is not used (for example, when the control unit **3** must execute only wait cycles), the counting signal is set at the second value, and the counter **8** is thus activated. After a pre-determined period of inactivity, the counter **8** reaches the threshold counting value and supplies at output a stand-by pulse STBY; in this way, the control unit **3**, the screen **6**, the I/O unit **5** and the memory **4** are set in a stand-by state, i.e., in an inoperative mode in which power consumption is minimized.

which the apparatus **1** is subjected, preferably along a first axis X, a second axis Y and a third axis Z orthogonal to one another and fixed to the apparatus **1**. More precisely, the activation device **10** detects both the static accelerations (due to constant forces, like the force of gravity) and dynamic accelerations (due to non-constant forces) to which the apparatus **1** is subjected.

When the apparatus **1** is not used, it usually remains substantially immobile or in any case subjected to forces of negligible intensity, for example because it is resting on a shelf. As has been mentioned previously, after a pre-determined time interval, the apparatus **1** goes into a stand-by state. In these conditions, the activation device **10** detects dynamic accelerations which are practically zero and maintains its output **10***a* constant at a resting logic value; the apparatus **1** thus remains in stand-by.

When the dynamic accelerations directed along at least one of the three axes X, Y, Z exceed a pre-determined threshold, the activation device **10** generates an activation pulse WU thus bringing its output **10***a* to an activation logic value. In the presence of an activation pulse WU, any possible standby pulses STBY are ignored, and the control unit **3**, the screen **6**, the I/O unit **5** and the memory **4** are set in the active state. The activation pulse WU terminates when all the dynamic accelerations along the first axis X, the second axis Y and the third axis Z return below the pre-determined threshold.

The activation device **10** is based upon capacitive-unbalance linear inertial sensors, made using MEMS (Micro-Electro-Mechanical Systems) technology. For greater clarity, FIG. **2** illustrates a first inertial sensor **20**, having a preferential detection axis parallel to the first axis X.

In detail, the first inertial sensor **20** comprises a stator **12** and a moving element **13**, connected to one another by means of springs **14** in such a way that the moving element **13** may translate parallel to the first axis X, whereas it is basically fixed with respect to the second axis Y and the third axis Z (in FIG. **2**, the third axis Z is orthogonal to the plane of the sheet).

The stator **12** and the moving element **13** are provided with a plurality of first and second stator electrodes **15'**, **15"** and, respectively, with a plurality of mobile electrodes **16**, which extend basically parallel to the plane Y-Z. Each mobile electrode **16** is comprised between two respective stator electrodes **15'**, **15"**, which it partially faces; consequently, each mobile electrode **16** forms with the two adjacent fixed electrodes **15'**, **15"** a first capacitor and, respectively, a second capacitor with plane and parallel faces. Furthermore, all the first stator electrodes **15'** are connected to a first stator terminal **20***a* and all the second stator electrodes **15"** are connected to a second stator terminal **20***b*, while the mobile electrodes **16** are connected to ground. From the electrical standpoint, hence, the first inertial sensor **11** can be idealized by means of a first equivalent capacitor **18** and a second equivalent capacitor **19** (illustrated herein with a dashed line), having first terminals connected to the first stator terminal **20***a* and to the second stator terminal **20***b*, respectively, and second terminals connected to ground. Furthermore, the first and second equivalent capacitors **18**, **19** have a variable capacitance correlated to the relative position of the moving element **13** with respect to the rotor **12**; in particular, the capacitances of the equivalent capacitors **18**, **19** at rest are equal and are unbalanced in the presence of an acceleration oriented according to the preferential detection axis (in this case, the first axis X).

With reference to FIG. **3**, the activation device **10** comprises, in addition to the first inertial sensor **20**, a second inertial sensor **21** and a third inertial sensor **22**, identical to the

tively. Moreover, the activation device **10** comprises: a multiplexer **24**; a capacitance-voltage (C-V) converter **25**; a demultiplexer **26**; a first detection line **28**; a second detection line **29** and a third detection line **30**, associated respectively to the first inertial sensor **20**, to the second inertial sensor **21** and to the third inertial sensor **22**; an output logic gate **31**; and a phase generator **32**.

First stator terminals **20***a*, **21***a*, **22***a* and second stator terminals **20***b*, **21***b*, **22***b* respectively of the first, second and third inertial sensors **20**, **21**, **22** are selectively connectable in sequence to detection inputs **25***a*, **25***b* of the C-V converter **25** via the multiplexer **24**. For this purpose, a control input **24***a* of the multiplexer **24** is connected to a first output of the phase generator **32**, which supplies a first selection signal SEL**1**.

The C-V converter **25** is based upon a differential charge-amplifier circuit, of a type in itself known, and has a timing input **25***c*, connected to a second output of the phase generator **32**, which supplies timing signals CK, and an output **25***d*, which supplies, in sequence, sampled values of a first acceleration signal A_X, a second acceleration signal A_Y and a third acceleration signal A_Z, correlated to the accelerations along the first, second and third axes X, Y, Z, respectively.

The demultiplexer **26** connects the output of the C-V converter **25** selectively and in sequence to respective inputs of the first, second and third detection lines **28**, **29**, **30**, which thus receive respectively the first, second and third acceleration signals A_X, A_Y, A_Z. For this purpose, the demultiplexer **26** has a control input **26***a* connected to a second output of the phase generator **32**, which supplies a second selection signal SEL**2**.

Each of the detection lines **28**, **29**, **30** comprises a subtractor node **34**, a filter **35**, of a low-pass type, and a threshold comparator **36**. In greater detail, the input of each detection line **28**, **29**, **30** is directly connected to a non-inverting input **34***a* of the adder node **34** and is moreover connected to an inverting input **34***b* of the adder node **34** itself through the respective filter **35**.

In practice, the filters **35** extract the d.c. components of the acceleration signals A_X, A_Y, A_Z and supplies at output a first static-acceleration signal A_{XS}, a second static-acceleration signal A_{YS} and a third static-acceleration signal A_{ZS}, respectively. The subtractor nodes **34** subtract the static-acceleration signals A_{XS}, A_{YS}, A_{ZS} from the corresponding acceleration signals A_X, A_Y, A_Z. A first dynamic-acceleration signal A_{XD}, a second dynamic-acceleration signal A_{YD} and a third dynamic-acceleration signal A_{ZD}, which are correlated exclusively to the accelerations due to variable forces, are thus provided on the outputs of the subtractor nodes **35** of the first, second and third detection lines **28**, **29**, **30**, respectively.

The threshold comparators **36** have inputs connected to the outputs of the respective subtractor nodes **34** and outputs connected to the logic gate **31**, which in the embodiment described is an OR gate. Furthermore, the output of the logic gate **31** forms the output **10***a* of the activation device **10** and supplies the activation pulses WU. In particular, an activation pulse WU is generated when at least one of the dynamic-acceleration signals A_{XD}, A_{YD}, A_{ZD} is higher than a pre-determined threshold acceleration A_{TH} stored in the threshold comparators **36**; the activation pulses WU terminate when all the dynamic-acceleration signals A_{XD}, A_{YD}, A_{ZD} return below the threshold acceleration A_{TH}. The threshold acceleration A_{TH} is moreover programmable and is preferably so selected as to be exceeded in the presence of the stresses that the user impresses on the apparatus **1** during normal use.

In practice, the C-V converter **25** reads the capacitive

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