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(54) **Vibrator device for an electronic apparatus**

(57) A vibrator device and a method for generating a drive signal for a vibrator. A signal generating unit is adapted to generate a drive signal having a varying frequency for driving the vibrator is responsive to the drive signal. The varying frequency may include the resonance frequency of the vibrator.

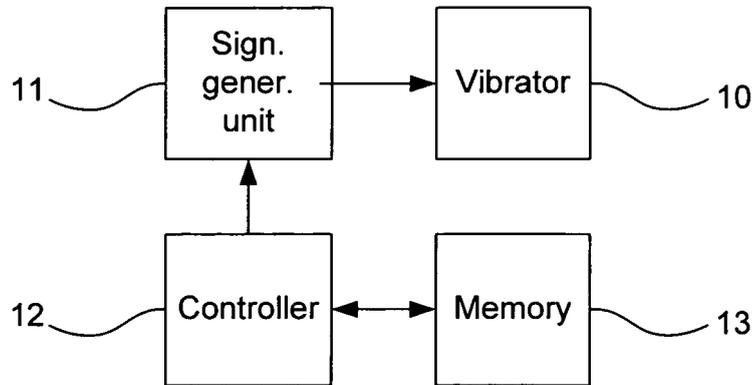


Fig. 2

Description

Technical Field of the Invention

[0001] The present invention relates to a vibrator device for an electronic apparatus, and a method for generating a drive signal for such a vibrator device.

Description of Related Art

[0002] An electronic apparatus, such as a portable electronic device, a mobile terminal or a personal digital assistant, may comprise a vibrator. The vibrator may be activated in response to e.g. an incoming call or message to give a tactile signal to the user of the electronic apparatus.

[0003] A vibrator known in the art and that may be used in an electronic apparatus includes a DC motor having a weight for unbalancing the motor mounted on the drive shaft. A DC drive signal is supplied to the DC motor for its activation.

[0004] The vibrator including a DC motor requires a relatively large space, which may be a problem if it is used in a portable electronic device, in which the available space is limited. The constantly present desire for additional functions of a portable electronic device entails that it is desirable that each component requires as little space as possible. Another problem with the vibrator including a DC motor is that it accelerates relatively slowly. This is a problem if it is desirable to generate a tactile signal in response to another event occurring in the electronic apparatus, wherein the experienced interrelationship between the tactile signal and the event becomes poor.

[0005] Another vibrator that may be used in an electronic apparatus is a linear vibrator. The linear vibrator includes a mass, which moves in a generated magnetic field. The magnetic field is generated in response to an AC or pulsed signal supplied to the vibrator. To operate efficiently, the frequency of the drive signal for the linear vibrator should be substantially equal or close to the resonance frequency of the linear vibrator.

[0006] It is a problem with a linear vibrator that the actual resonance frequency may vary between different vibrators of the same type due to production tolerances. Furthermore, the actual resonance frequency of a single vibrator may vary over time depending on external and/or internal factors, such as the temperature in which the vibrator currently is operating, or the length of a time period during which the vibrator is in an operative state. Furthermore, the resonance frequency of a single vibrator may vary during its life cycle, e.g. due to wear and tear. Therefore, it is difficult to generate a drive signal having a frequency for operating a linear vibrator efficiently, as the actual resonance frequency of the linear vibrator is not known. A feedback loop including external components may be used to detect the resonance frequency of the vibrator. However, this solution is complex.

Summary of the Invention

[0007] It is one object of the invention to overcome the above mentioned and other problems of providing a vibrator.

[0008] According to a first aspect, a vibrator device comprises a signal generating unit, which is adapted to generate a drive signal having varying frequency; and a vibrator, which is responsive to the drive signal.

[0009] The signal generating unit may be adapted to generate a drive signal having varying frequency within a predetermined frequency range.

[0010] It may also be adapted to generate a drive signal in a frequency range, which includes the nominal resonance frequency of the vibrator. The frequency range may be in the range of -5% to -20% up to +5% to +40% relative the nominal drive frequency of the vibrator. Alternatively, frequency range is in the range of $\pm 1-5\%$ relative the nominal drive frequency of the vibrator.

[0011] The signal generating unit may be adapted to repeatedly generate the drive signal with a frequency in the range of 1-10 Hz. Alternatively, the signal generating unit may be adapted to repeatedly generate the drive signal with a frequency in the range >10 Hz.

[0012] According to a second aspect, an electronic apparatus comprises the vibrator device according to the invention.

[0013] The apparatus may be a portable mobile radio communication equipment, a mobile radio terminal, a mobile telephone, a pager, a communicator, an electronic organizer, or a smartphone.

[0014] According to a third aspect, a method for generating a drive signal for a vibrator device, comprises generating a drive signal having varying frequency; and supplying the drive signal to a vibrator.

[0015] The step of generating may comprise generating a drive signal having varying frequency within a predetermined frequency range. It may also comprise generating a drive signal in a frequency range, which includes the nominal resonance frequency of the vibrator.

[0016] The step of generating may comprise generating a drive signal in a frequency range of -5% to -20% up to +5% to +40% relative the nominal drive frequency of the vibrator. Alternatively, it comprises generating a drive signal in a frequency range of $\pm 1-5\%$ relative the nominal drive frequency of the vibrator.

[0017] The step of generating may comprise repeatedly generating the drive signal with a frequency in the range of 1-10 Hz. Alternatively, it comprises repeatedly generating the drive signal with a frequency in the range of >10 Hz.

[0018] According to a fourth aspect, a computer program product comprising computer program code means for executing the method for generating the drive signal, when said computer program code means are run by an electronic device having computer capabilities.

[0019] Further embodiments of the invention are defined in the dependent claims. It is an advantage of the

invention that it provides an efficient vibrator device.

[0020] It should be emphasized that the term "comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

Brief Description of the Drawings

[0021] Further objects, features and advantages of the invention will appear from the following detailed description of the invention, reference being made to the accompanying drawings, in which:

Fig. 1 is a front view of an electronic device;

Fig. 2 is a block diagram of a first embodiment of the vibrator device;

Fig. 3 is cross-sectional view of a linear vibrator;

Fig. 4 is a graph illustration the spread of resonance frequency of linear vibrators; and

Fig. 5 is a flow-chart of one embodiment of a method for generating a drive signal for the vibrator device.

Detailed Description of Embodiments

[0022] Fig. 1 illustrates an electronic apparatus 1, in which the present invention may be provided. The electronic apparatus may be a portable mobile radio communication equipment, a mobile radio terminal, a mobile telephone, a pager, a communicator, an electronic organizer, a handheld electronic device, or a smartphone. These examples of an electronic apparatus in which the invention may be provided are not exhaustive. The invention may be implemented in any electronic device including a vibrator driven by an AC drive signal.

[0023] Fig. 2 illustrates a first embodiment of a vibrator device. The vibrator device 1 comprises a vibrator 10 to be driven by an AC drive signal, a signal generating unit 11, a controller 12 and a memory 13.

[0024] The vibrator 10 to be driven by an AC signal may be a linear vibrator having a mass to be driven by a magnetic field generated in response to applying the drive signal to the vibrator 10.

[0025] The signal generating unit 11 is adapted to generate a drive signal, which has a varying frequency. The signal generating unit 11 may be implemented by means of a standalone hardware unit, such as a signal generator. Alternatively, the signal generating unit 11 may be implemented by software including software code portions to be run by a processor, such as a CPU, a resonance circuit, an ASIC (Application Specific Integrated Circuit), or an FPGA (Field Programmable Gate Array). A CPU implementing the signal generating unit 11 may possibly also implement controller 12. The controller 12 is not necessary in all embodiments of the invention, such as if the signal generating unit 11 is implemented by a standalone hardware component.

[0026] The electronic apparatus 1 may comprise a plurality of memories, such as a RAM (Random Access Memory), a ROM (Read Only Memory), a flash memory, and or a non-volatile memory, which are jointly illustrated by memory 13. Also memory 13 may be optional.

[0027] The frequency of the drive signal generated by the signal generating unit 11 has varying frequency. The frequency of the drive signal may be varied from a few Hz to virtually infinity, wherein it will be ascertained that the resonance frequency of the vibrator 10 will be included within this frequency range.

[0028] It is an advantage of the embodiment of Fig. 1 that the resonance frequency of the vibrator 1 may be included in the drive signal without any feedback connection, whereby the complexity of the vibrator device is decreased. Also, the number of connectors, such as pins, may be decreased compared to prior art solutions.

[0029] In another embodiment, the signal generating unit 11 may be adapted to generate a drive signal having varying frequency within a predetermined frequency range. The resonance frequency (or center frequency), at which the vibrator is designed to vibrate optimally, i.e. the nominal resonance frequency, may be known. Then, the signal generating unit 11 may be adapted to generate a drive signal having varying frequency in a frequency range overlapping the nominal resonance frequency of the vibrator 11. The actual resonance frequency of the vibrator 11 may vary between different vibrators of the same type, such as vibrators from different batches. If it is known that the resonance frequency of the vibrator 10 varies a certain amount, e.g. a certain number of Hz or certain percentage, the predetermined frequency range could be in the range of $\pm 1-5$ Hz or $\pm 1-5\%$ relative the nominal drive frequency of the vibrator 10, wherein it is ascertained that the resonance frequency of the vibrator 10 always is included in the predetermined frequency range. A few Hz may be added to the predetermined frequency range for providing a safety margin. Thus, for a vibrator having a nominal resonance frequency and a nominal drive frequency of 150 Hz, and having a spread of +3Hz, the frequency of the drive signal may vary between 145-155 Hz.

[0030] The signal generating unit 11 may also be adapted to generate a drive signal having a broader frequency range, such as in the range of $\pm 5-20$ Hz or -5% to -20% up to $+5\%$ to $+40\%$, relative the nominal drive frequency of the vibrator 10. This has the advantage that the tolerances of the resonance frequency of the vibrator may be more relaxed, wherein it may be cheaper to manufacture. The frequency range of the drive signal may be varied in any ranges, which has to be tested and evaluated in each specific case.

[0031] In another embodiment, the predetermined frequency range does not overlap the nominal resonance frequency of the vibrator 11. However, the predetermined frequency range includes frequencies at which the vibrator 11 vibrates. By generating a drive signal having a varying frequency sufficiently close to the nominal reso-

nance frequency of the vibrator, e.g. at least partly within a frequency range determined by the cut-off frequencies of the vibrator 11, it is ascertained that the vibrator 11 vibrates.

[0032] The drive signal may be generated during a predetermined time period. During this time period, the frequency of the drive signal may be varied continuously or in discrete steps. If the drive signal is varied continuously, the frequency may be continuously increased during a predetermined time interval corresponding to the duration of the drive signal. For example, the frequency of the drive signal may be continuously increased from 145 Hz to 155 Hz during 1 second. If the frequency is varied in discrete steps, the controller 13 may control the signal generating unit 11. The step size may be dependent on the size of the predetermined frequency range and may e.g. be a fraction of or a single Hz. For example, the frequency of the drive signal may be varied from 145 to 155 Hz in step sizes of 1 Hz during 1 second, wherein the duration of each frequency will be 1/11 second. The values give above are only examples and other values may apply in other embodiments, which has to be tested and evaluated in each specific case. The voltage and current of the drive signal should be adapted to satisfy any requirements set by the vibrator.

[0033] The drive signal may be repeatedly generated until it is desirable to end the vibrating signal produced by the vibrator 10. For example, the signal generating unit 11 may be adapted to repeatedly generate each frequency of the drive signal. The drive signal may be generated with a frequency in the range of 1-10 Hz. In this range, the vibrator 10 will vibrate intermittently with a low enough frequency such that it is experienced by the user of the electronic device 1a as pulsing vibration signal. Alternatively, the drive signal may be generated with a frequency in the range of >10 Hz, wherein it may vibrate intermittently with a high enough frequency such that it is experienced as continuous vibration signal by the user of the electronic apparatus 1.

[0034] Fig. 3 illustrates one embodiment of a linear vibrator 20 in cross section. The linear vibrator 20 comprises an electromagnet including an iron core 21 with a winding 22. A weight 23 and a magnet 24 are arranged circumferentially around the iron core 21 and the winding 22. The weight 23 and the magnet 24 are suspended by a spring and bearing arrangement 25a, 25b. When the drive signal is applied to the winding, the weight 23 and magnet 24 will move downwards and upwards in response to the alternating drive signal. Thus, the vibrator 20 will vibrate.

[0035] Fig. 4 schematically illustrates four vibration output curves 30, 31, 32, 32 for four different linear vibrators. The curves are simplified for illustrative purposes. The maximum variation of the resonance frequency f_r of the linear vibrators are denoted V_v . the variation of the frequency f_{ds} of the drive signal is denoted V_{ds} . If $V_{ds} \geq V_v$ and V_{ds} and V_v are centered it is ascertained that f_r for each linear vibrator is included in f_{ds} .

[0036] Fig. 5 illustrates one embodiment of a method for generating a drive signal for a vibrator device including a detector and a frequency registration unit.

[0037] In a first step 100, an initiation signal is received from an application of the electronic apparatus 1. In response to receiving the initiation signal, in step 101 the drive signal is generated including frequencies in a predetermined frequency range. The frequencies may be generated by the signal generating unit 11 by stepwise altering the frequency of the drive signal in discrete steps. The frequency value to be generated after the last frequency value of the predetermined frequency range has been generated may be the previously generated or the firstly generated frequency value in the predetermined frequency range. For example, if the predetermined frequency range is 145-155 Hz, the first value is 145 Hz and the final value is 155 Hz. After having generated frequency value 155 Hz, frequency value 145 or 154 Hz may be generated. The same applies at the beginning of the predetermined frequency range if the latter is chosen, wherein frequency value 146 Hz may be generated after frequency value 145 Hz has been generated. The frequency of the drive signal may alternatively be altered continuously. At the end of the predetermined frequency range, the frequency may be lowered or be restarted from the beginning corresponding to altering the frequency stepwise. In step 102 it is determined whether a stop signal to stop generating the drive signal has been received. If the answer in step 102 is no, the procedure returns to step 101. If the answer in step 102 is yes, the procedure ends.

[0038] The frequency range of the drive signal may be preset. Alternatively, the frequency range may be changed for adapting it to linear vibrator of different batches of the same model, or to different models. Furthermore, the frequency range of the drive signal may be different depending on the marked, on which the electronic apparatus should be sold. The resonance frequency of the vibrator 10 may vary in dependence of humidity and temperature, which is different in different countries.

[0039] The invention may at least partly be embedded in a computer program product, which enables implementation of the method and functions described herein. The invention may be carried out when the computer program product is loaded and run in a system having computer capabilities. Computer program, software program, program product, or software, in the present context mean any expression, in any programming language, code or notation, of a set of instructions intended to cause a system having a processing capability to perform a particular function directly or after conversion to another language, code or notation.

[0040] It is an advantage of the invention that it provides a cheap implementation of linear vibrator, as it eliminates the impact of the spread of the resonance frequency of the vibrator 10. Furthermore, it is smaller and lighter compared to a vibrator including a DC motor, wherein it is easier to arrange it in an electronic device. Also, it is

easy to control the direction of vibration of the vibrator device, as it vibrates in an axial direction of the vibrator.

[0041] The alteration of the drive signal has been described as being made in the frequency domain. However, the alteration of the drive signal may also be made in the time domain by altering the period of the drive signal.

[0042] The q factor of the vibrator sets vibration response of the vibrator 10, and it may be determined by the resonance frequency (or center frequency) divided by the bandwidth Δf (defined by the upper and lower cutoff frequencies) of the vibrator. A vibrator having a high q-factor provides a high vibration output at the resonance frequency, whereas a vibrator having a lower q-factor provides a lower vibration output at the resonance frequency. However, if the frequency of the drive signal deviates from the resonance frequency, the vibrator having the lower q-factor relatively quickly performs better than the vibrator having the higher q-factor. Thus, by employing the present invention, it is possible to utilize a vibrator having a high q-factor, as it is ascertained that the resonance frequency will be included in the drive signal even if the actual resonance frequency deviates from the nominal resonance frequency of the vibrator. In prior art vibrator devices, a vibrator having a lower q-factor may need to be utilized, so as to ascertain that the frequency of the drive signal hits a frequency at which the vibrator vibrates at the expense of vibration output. Furthermore, the resonance frequency of a single vibrator may change over time. According to the invention, it is ascertained that the resonance frequency will be included in the drive signal even if the resonance frequency change over time.

[0043] Another advantage of the invention is that it is possible to repeatedly generate the drive signal. Thus, if other frequencies than the resonance frequency of the vibrator 10 are included in the drive signal, the vibration output will vary slightly, but the maximum vibration output will always be generated. This provides an improved vibration feeling for the user of the electronic apparatus 1 compared to providing a drive signal only comprising the resonance frequency of the vibrator 10.

[0044] It is a further advantage of the invention that it provides a flexible solution for providing a drive signal including the resonance frequency of the vibrator. Thus, it is ascertained that the resonance frequency is hit for vibrators from different batches from a single manufacturer, or even from different manufacturers.

[0045] The present invention has been described above with reference to specific embodiments. However, other embodiments than the above described are equally possible within the scope of the invention. Different method steps than those described above, performing the method by hardware or software, may be provided within the scope of the invention. The different features and steps of the invention may be combined in other combinations than those described. The scope of the invention is only limited by the appended patent claims.

Claims

1. A vibrator device, comprising
a signal generating unit (11) adapted to generate a drive signal having varying frequency; and
a vibrator (10, 20) responsive to the drive signal.
2. The vibrator device according to claim 1, wherein the signal generating unit (11) is adapted to generate a drive signal having varying frequency within a predetermined frequency range.
3. The vibrator device according to claim 2, wherein the signal generating unit (11) is adapted to generate a drive signal in a frequency range of $\pm 5\text{-}20\%$ relative the nominal drive frequency of the vibrator (10, 20).
4. The vibrator device according to claim 2, wherein the signal generating unit (11) is adapted to generate a drive signal in a frequency range of -5% to -20% up to $+5\%$ to $+40\%$ relative the nominal drive frequency of the vibrator (10, 20).
5. The vibrator device according to any of the previous claims, wherein the signal generating unit (11) is adapted to repeatedly generate the drive signal with a frequency in the range of 1-10 Hz.
6. The vibrator device according to any of claims 1-4, wherein the signal generating unit (11) is adapted to repeatedly generate the drive signal with a frequency in the range >10 Hz.
7. An electronic apparatus comprising the vibrator device according to any of the claims 1-6.
8. The electronic apparatus according to claim 7, wherein the apparatus is a portable mobile radio communication equipment, a mobile radio terminal, a mobile telephone, a pager, a communicator, an electronic organizer, or a smartphone.
9. A method for generating a drive signal for a vibrator device, comprising:
generating a drive signal having varying frequency; and
supplying the drive signal to a vibrator.
10. The method according to claim 9, wherein the step of generating comprises generating a drive signal having varying frequency within a predetermined frequency range.
11. The method according to claim 10, wherein the step of generating comprises generating a drive signal in a frequency range of -5% to -20% up to $+5\%$ to $+40\%$

relative the nominal drive frequency of the vibrator.

- 12.** The method according to claim 10, wherein the step of generating comprises generating a drive signal in a frequency range of $\pm 1-5\%$ relative the nominal drive frequency of the vibrator. 5
- 13.** The method according to any of claims 9 to 12, wherein the step of generating comprises repeatedly generating the drive signal with a frequency in the range of 1-10 Hz. 10
- 14.** The method according to any of claims 9 to 12, wherein the step of generating comprises repeatedly generating the drive signal with a frequency in the range of >10 Hz. 15
- 15.** A computer program product comprising computer program code means for executing the method according to any of claims 9 to 14, when said computer program code means are run by an electronic device having computer capabilities. 20

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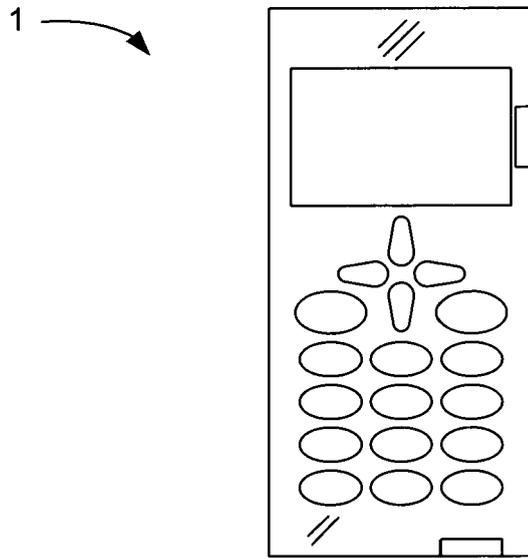


Fig. 1

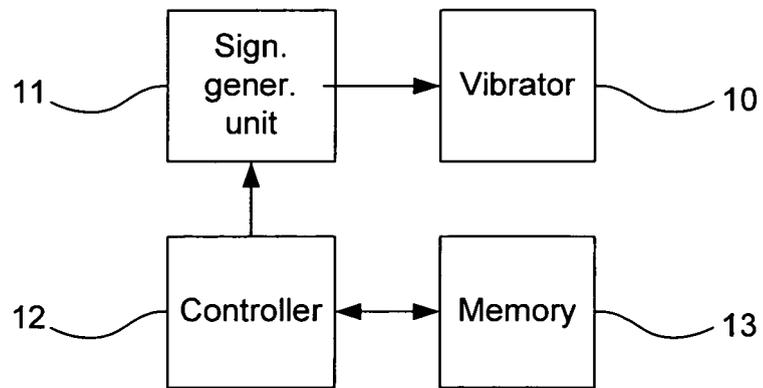


Fig. 2

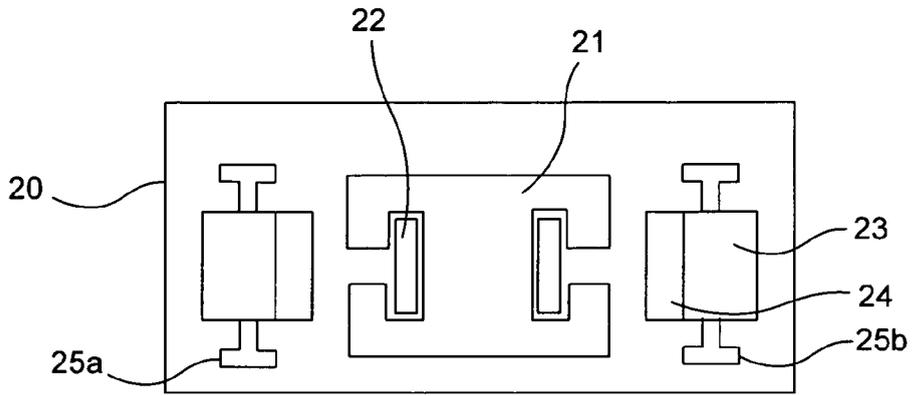


Fig. 3

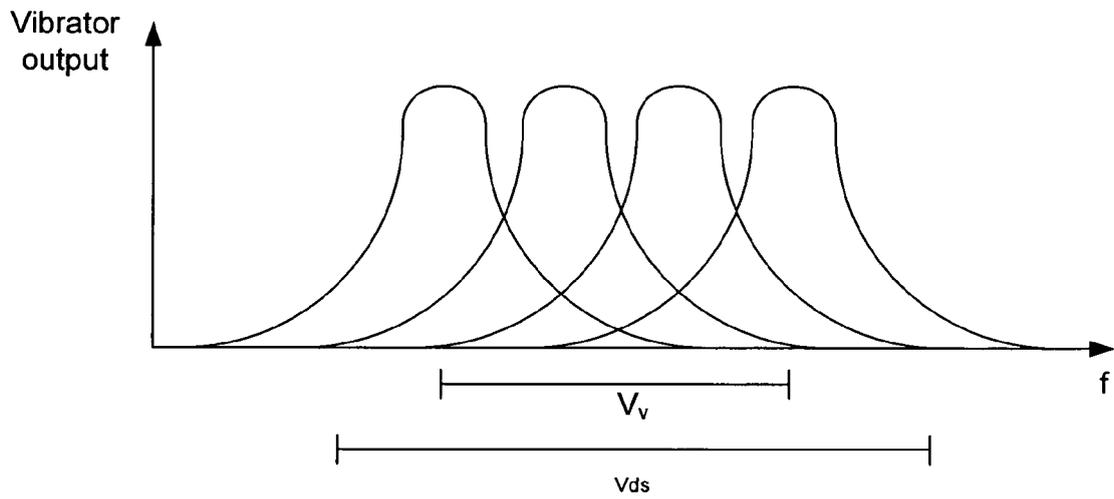


Fig. 4

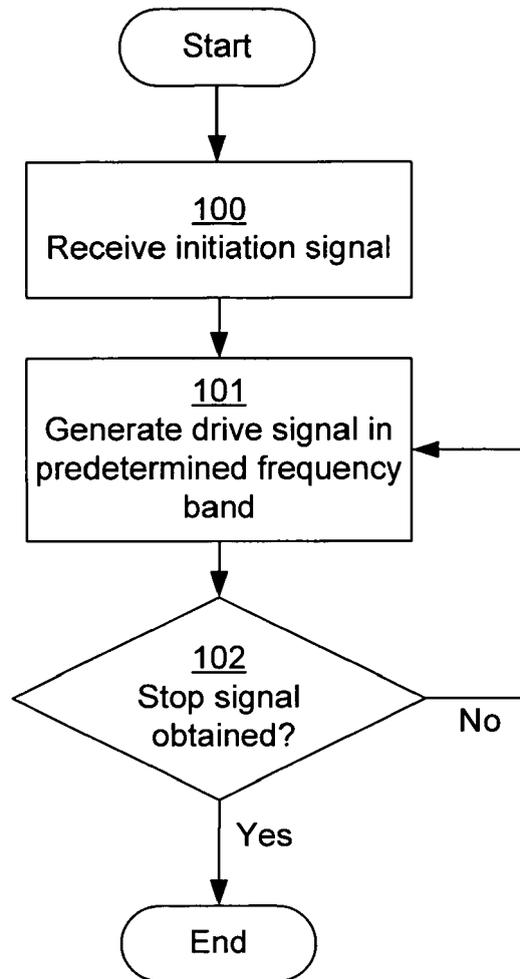


Fig. 5



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	US 2005/085275 A1 (HUGUNIN DERICK) 21 April 2005 (2005-04-21) * paragraphs [0005], [0007] - [0011] * * paragraph [0019] - paragraph [0020]; figure 1 * * paragraph [0027] - paragraph [0030]; claims 1-4; figures 3,5 * -----	1-15	B06B1/02
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			B06B G08B
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		22 November 2005	Häusser, T
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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 05 00 9067

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82