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(71) Applicant and
(72) Inventor: NUUTINMÄKI, Pasi, Veli, Matias [FI/FI]; Saprantie 331 B, FI-43270 Kalmari (FI).

(74) Agent: KESPAT OY; P.O. Box 601, FI-40101 Jyväskylä (FI).

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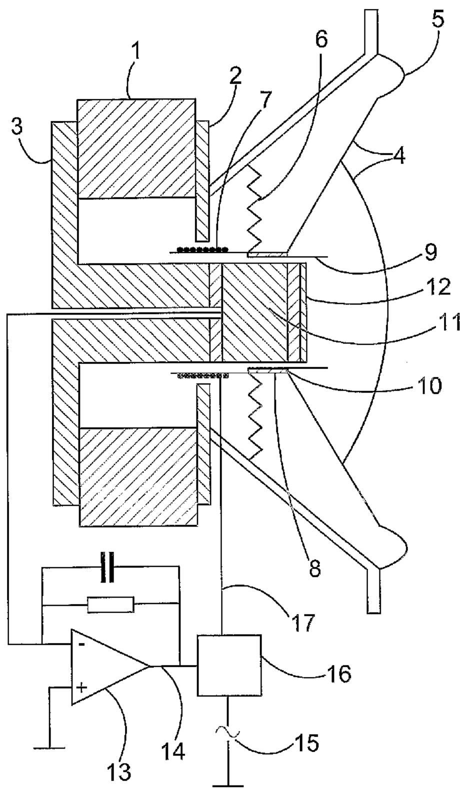
(54) Title: LOUDSPEAKER EQUIPPED WITH MEASUREMENT OF THE MOVEMENT OF THE LOUDSPEAKER UNIT AND A METHOD FOR MEASURING THE MOVEMENT OF THE LOUDSPEAKER UNIT IN A LOUDSPEAKER



(57) Abstract: The invention relates to a loudspeaker equipped with measurement of the movement of the loudspeaker unit. The loudspeaker includes a loudspeaker unit (1-8) and a component (4) arranged to vibrate in it. In addition, there is in the loudspeaker at least one capacitor including conducting surfaces (9, 11), for measuring the movement of the said component (4), with the aid of the change in capacitance. The normals of the conducting surfaces (9, 11) of the capacitor are essentially at right angles to the direction of movement of the vibrating component (4) in the area in which the change of capacitance takes place, which is used to measure the movement. The invention also relates to a method for measuring the movement of the loudspeaker unit in a loudspeaker.

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LOUDSPEAKER EQUIPPED WITH MEASUREMENT OF THE MOVEMENT OF THE LOUDSPEAKER UNIT AND A METHOD FOR MEASURING THE MOVEMENT OF THE LOUDSPEAKER UNIT IN A LOUDSPEAKER

The present invention relates to a loudspeaker equipped with measurement of the movement of the loudspeaker unit, which loudspeaker includes

- a loudspeaker unit and a component arranged to vibrate in it, in order to produce sound and
- at least one capacitor including conducting surfaces, for measuring the movement of the said component, with the aid of the change in capacitance.

The invention also relates to a method for measuring the movement of the loudspeaker unit in a loudspeaker.

Typical dynamic loudspeakers have various drawbacks, which cause undesirable characteristics in the sound produced by the loudspeaker, such as harmonic distortion, uneven frequency response, and ringing. Attempts have been made to eliminate these problems by implementing various methods, which have been used to measure the sound produced by the loudspeaker in reality and to correct it to correspond as closely as possible to the desired sound. One way of measuring the sound produced by a loudspeaker is to measure the movement of the sound-producing unit (usually a cone) and to use the result obtained as a basis to correspondingly correct the control signal fed to the loudspeaker.

Previous methods have attempted to implement the feedback of the movement by, among other ways, using an acceleration sensor (patents US 4 573 189 and US 4 727 584), a series resistance, or some other corresponding method based on measuring the current flowing through the loudspeaker (among others, patent 5 542 001), or with the aid of a coil moving in a magnetic field (among others, patents US 4 550 430 and US 5 493 620).

Methods more closely related to the present invention are disclosed in patents US 2 857 461 and US 3 057 961, in which the movement of the loudspeaker unit is measured using capacitors parallel to the surface of the cone. In addition, the sound produced by the loudspeaker can be measured, for example, using a microphone (patent US 3 009 991).

In previous methods based on the change in capacitance, a drawback has been the non-linearity of the change in capacitance relative to the deflection of the cone and the diminution of the capacitance at large deflections, when the gap between the plates of the capacitor becomes great.

The present invention is intended to create a new type of loudspeaker equipped with measurement of the movement of the loudspeaker unit, which has a simple construction and precise operation. In addition, the invention is intended to create a new type of method for measuring the movement of the loudspeaker unit in a loudspeaker, by means of which the problems appearing in previous measurement based on the change in capacitance can be avoided. More specifically, the loudspeaker according to the invention is characterized by what is stated in the accompanying Claim 1. Correspondingly, the method according to the invention is characterized by what is stated in the accompanying Claim 7. According to the invention, the capacitor is arranged in such a way that its capacitance is directly proportional to the deflection of the cone. The value of the capacitance is also bigger than in previously used loudspeakers. The said loudspeaker is created in such a way that the conducting surfaces of the capacitor are positioned parallel to the direction of movement of the loudspeaker unit and the value of the capacitor is altered either by changing the surface area between the plate-like conducting surfaces, or by moving the insulating material between the plate-like conducting surfaces. Other possible construction solutions for implementing the loudspeaker and method according to the invention are also itemized later.

In the following, the invention is described in detail with reference to the accompanying drawings showing some embodiments of the invention, in which

Figure 1 shows a cross-section of the loudspeaker according to the invention,

Figure 2 shows part of the circuit diagram of the loudspeaker according to the invention, for exploiting the measurement signal in the motional feedback of the loudspeaker.

Figure 1 shows the loudspeaker unit according to the invention, which is constructed from a magnet 1, a front plate 2, a combined rear plate and centre piece 3, a component 4 arranged to vibrate, the component's outer suspension 5, the component's inner suspension 6, a voice coil 7 moving in a magnetic field, and the voice coil's cylinder 8. A dynamic loudspeaker is created by fitting the loudspeaker unit according to the invention into a loudspeaker cabinet. In this embodiment, the component arranged to vibrate is constructed from a cone and a dust cap.

According to the invention, a cylindrical measurement capacitor is added to the centre of this loudspeaker. The conducting surface 9 of this capacitor, connected to the constant voltage, in the case of the example 1200 V, is insulated by insulation 10 from the voice-coil cylinder 8 made of electrically conductive material, but is, however, mechanically connected to the movement of the cylinder. In the case of the example, the voice-coil cylinder 8 is made from aluminium and is connected to a voltage of 0 V, i.e. to earth. The inner circumference of the capacitor is formed of a cylindrical conducting surface 11, made from a conductive material and attached mechanically to the centre piece of the magnet, and which is electrically insulated from both the centre piece 3 of the magnet and the interference protection 12 connected to the constant voltage. The inner conducting surface 11 of the capacitor, i.e. the cylinder, is connected to an operational amplifier 13, which, being equipped with suitable component values, produces a reference signal 14 proportional to the velocity of the cone 4. The usable frequency range of the measurement depends on the values of the feedback resistor and capacitor. In the case of the example, the value of the resistor is 1 MΩ and that of the capacitor 100 pF. A capacitor is also created between the cylinder 8 and centre piece of the voice coil, the capacitance of which changes on the basis of the movements of the cone 4. The change in this capacitor too can be used for measurement purposes. In the case of the example, however, this possibility is not used.

During measurement, the capacitor is generally connected to voltage with a magnitude of 500 - 5000 V. According to the invention, the mutual distance between the conducting surfaces of the capacitor remains the same, despite the movement of the loudspeaker unit. Even a high voltage can then be used, without the danger of punch-through or corona discharge.

The reference signal obtained is typically exploited by using it to correct the non-ideal characteristics of the loudspeaker, for example, to eliminate distortion and to create the desired frequency response. In the case of the example, a control signal 17 is produced for the loudspeaker with the aid of the sound signal 15 fed in and the correction circuit 16. The implementation of this correction circuit 16 depends a greatly on both the loudspeaker unit and the cabinet used. Figure 2 shows one possible example of a circuit. Figure 2 also shows the actual operational amplifier 13.

In the circuit, the sound signal 15 fed in is first taken to an integrator-high-pass filter made around the operational amplifier 18, which alters the sound signal to correspond to the desired velocity of the loudspeaker unit. Integration is performed, because the momentary sound pressure is directly proportional to the acceleration of the cone 4, which is in turn the derivative of the velocity. In the case of the example, the resistances between the inverting input and the signal fed into the operational amplifier 18 and in the feedback loop of the operational amplifier 18 have values of 10 kΩ while the capacitances of the capacitors are 1 μF. Using these component values, the circuit filters out frequencies of less than about 16 Hz, with a steepness of 12 dB/octave. The reference signal 14 depicting the velocity of the cone 4 is obtained from the operational amplifier 13, to the input of which the inner conducting surface 11 of the capacitor, i.e. in this case the cylinder, is connected. The outer conducting surface 9 is connected to a constant voltage, obtained from a voltage source 22. The signal 19 depicting the desired velocity and the reference signal 14 corresponding to the velocity of the measured unit are taken to a differential amplifier 20, which produces a signal 21 depicting the error in the velocity. Depending on the characteristics of the loudspeaker unit and the cabinet, the loudspeaker unit control signal 17 is obtained from this signal, either directly with the aid of a booster amplifier or by otherwise processing it. It may be necessary to process the control signal, for example, to eliminate vibration in the system caused by excessive phase shift in the feedback loop. In the case of the example, a signal 21 directly depicting the error in the velocity is used as the control signal 17, however, after being taken through an amplifier stage with a current output sufficient to drive the loudspeaker unit.

Because in the method according to the example the movement of the cone alters the surface area between the capacitor's conducting surfaces in direct proportion to the deflection of the cone, the value of the capacitance is also directly proportional to the deflection of the cone. In addition, the gap between the conducting surfaces of the capacitor may be quite small (in the order of millimetres), in order for the change in the capacitance of the capacitor to be sufficiently great for the measurement to be sufficiently reliable and free of disturbance.

Within the scope of this invention, the capacitor can be envisaged as being implemented in very many different ways. For example, the capacitor need not have cylindrically shaped conducting surfaces, but can be implemented using, for example, a honeycomb or other similar shape, which will provide a greater capacitance per unit of length of the movement of the loudspeaker. The capacitor can also be implemented in such a way that the conducting surfaces of the actual capacitor remain stationary, but that the insulating material between them, which is connected to the movements of the cone, is moved. In this case it will be advantageous, in terms of obtaining a measurement result that is proportional to the deflection, that the amount of insulating material between the conducting surfaces will change in direct proportion to the deflection of the vibrating piece. In terms of the method according to the invention, it will also be advantageous for the capacitor to be constructed in such a way that the normals of the conducting surfaces of the capacitor are sufficiently at right angles to the direction of movement of the vibrating piece, for the change in capacitance to be proportional to the deflection of the cone, to the required degree of accuracy. There are also many different ways of measuring the capacitor's capacitance, or a change in it. For example, the capacitor can be used as part of an electronic vibration circuit, which has a natural frequency that is influenced by the capacitance of the capacitor, or else the impedance of the capacitor can be measured using the alternating voltage or current. A combination of the methods referred to above may also be considered, for example, if is wished to know the precise value of the deflection of the cone, for example, in order to limit the deviation of movement and at the same time the velocity or acceleration of the cone.

Though the example cases concern a dynamic loudspeaker, the same method can also be used in other types of loudspeaker. The measurement results can also be used in very many different ways. For example, the measurement can be used to implement protection of the loudspeaker against excessive deflection values.

CLAIMS

1. A loudspeaker equipped with measurement of the movement of the loudspeaker unit, which loudspeaker includes
- a loudspeaker unit (1-8) and a component (4) arranged to vibrate in it, in order to produce sound and
- at least one capacitor including conducting surfaces (9,11), for measuring the movement of the said component (4), with the aid of the change in capacitance,

characterized in that the conducting surfaces (9,11) of the capacitor are arranged in such a way that their normals are essentially at right angles to the direction of movement of the vibrating component (4) in the area in which the change of capacitance takes place, which is used to measure the movement.

2. A loudspeaker according to Claim 1, characterized in that the loudspeaker is a dynamic loudspeaker.

3. A loudspeaker according to Claim 1 or 2, characterized in that the first of the conducting surfaces (9,11) of the capacitor is mechanically attached to the vibrating component (4) and the second to the body (3) of the loudspeaker.

4. A loudspeaker according to Claim 1 or 2, characterized in that insulating material, which is connected to the component (4), is arranged between the conducting surfaces (9,11) of the capacitor, in such a way that it can move relative to them.

5. A loudspeaker according to any of Claims 1 - 4, characterized in that the conducting surfaces (9,11) of the capacitor are cylindrical.

6. A loudspeaker according to Claim 5, characterized in that the cylindrical conducting surfaces (9,11) of the capacitor are arranged coaxially relative to each other and the first (9) of the conducting surfaces is mechanically connected to the

component (4), the second (11) of the conducting surfaces being attached to the body (3) of the loudspeaker.

7. A method for measuring movement in a loudspeaker, which loudspeaker includes a loudspeaker unit (1-8) and a component (4) in it arranged to vibrate, in order to produce sound, as well as at least one capacitor (9,11) including conducting surfaces (9,11), with the aid of the change in the capacitance of which the movement of the said component (4) is measured, characterized in that the conducting surfaces (9,11) of the capacitor are arranged in such a way that their normals are essentially at right angles to the direction of movement of the vibrating component (4) in the area in which the change in capacitance, used to measure the movement, takes place.

8. A method according to Claim 7, characterized in that the change in capacitance is determined on the basis of the mutual movement of the conducting surfaces (9,11) of the capacitor.

9. A method according to Claim 7, characterized in that the change in capacitance is determined on the basis of the movement of insulating material arranged between the conducting surface (9,11) of the capacitor.

10. A method according to any of Claims 7 - 9, characterized in that the change in the capacitance of the capacitor is arranged to be linear, on the basis of which the signal (17) led to the voice coil (7) of the loudspeaker unit (1-8) is regulated.

11. A method according to any of Claims 7 - 10, characterized in that, during the measurement, a voltage of magnitude 500 - 5000 V is connected to the capacitor.

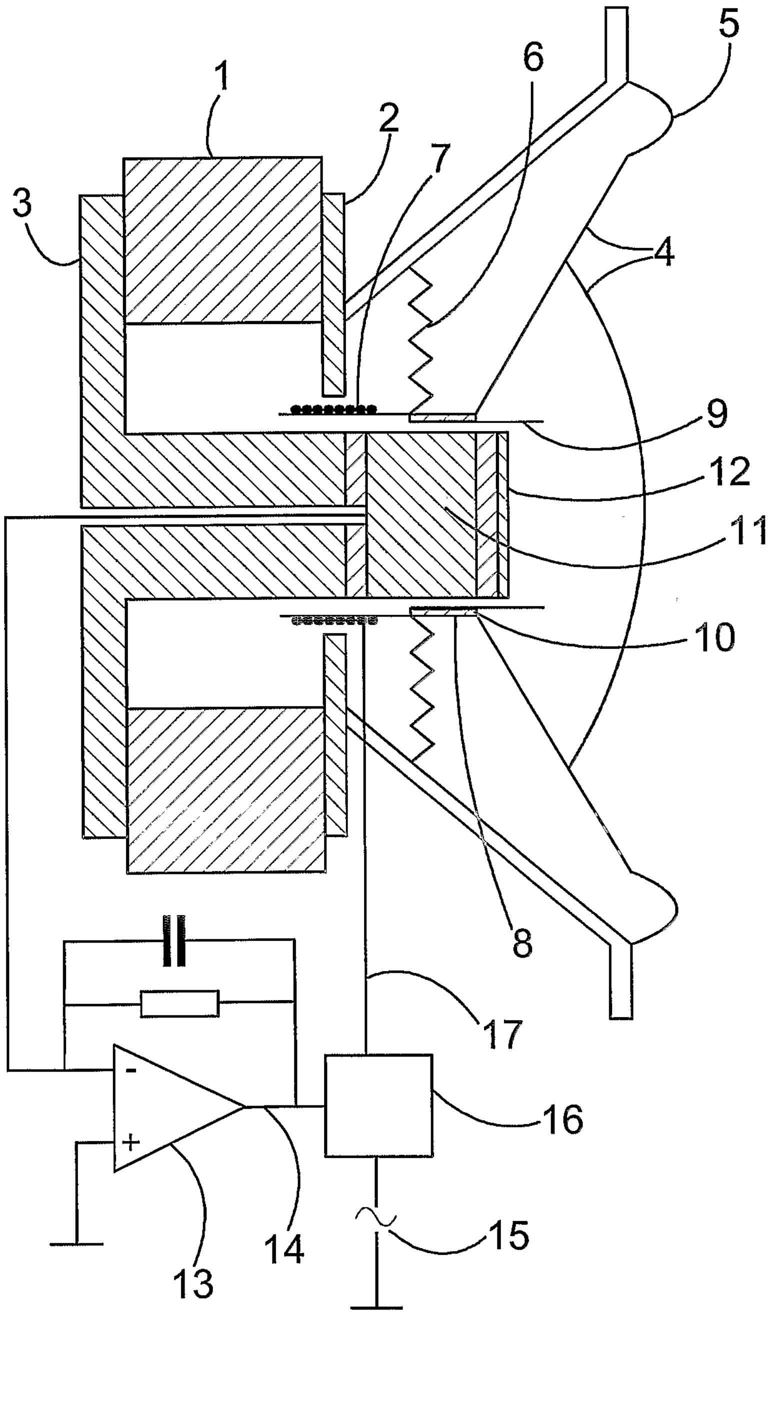

Fig. 1

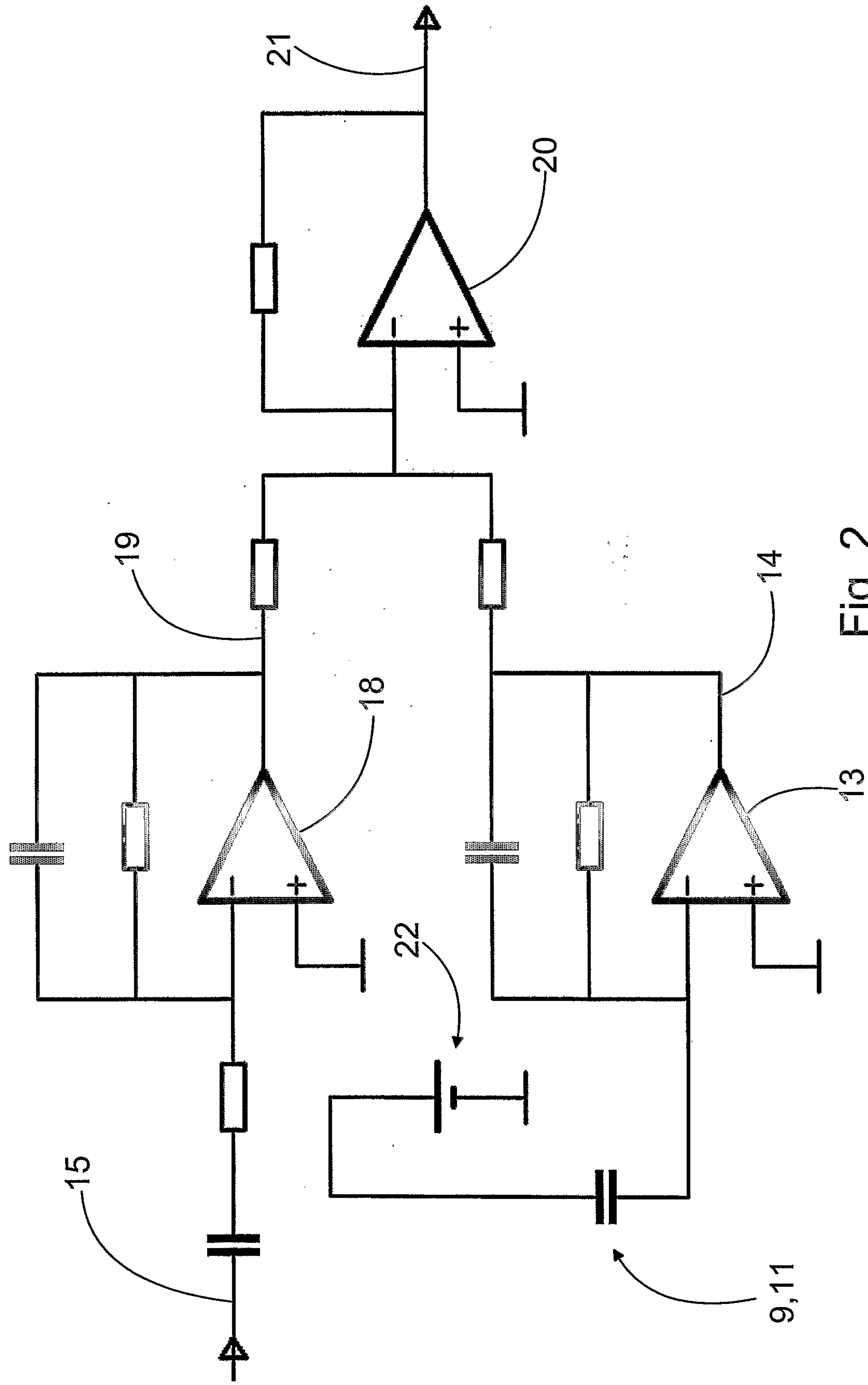

Fig. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 2004/050027

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04R 3/00, H04R 29/00 // G01D 5/24

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H04R, G01D

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

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 4573189 A (HALL), 25 February 1986 (25.02.1986) --	1-11
A	SE 452238 B (BO HÅKANSSON ET AL), 16 November 1987 (16.11.1987) --	1-11
P,A	US 20030086576 A1 (HLIBOWICKI), 8 May 2003 (08.05.2003) --	1-11

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA/	Authorized officer
Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Henrik Andersson/EK Telephone No. +46 8 782 25 00

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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