



## Position-free, multiple output capacitive power transfer system

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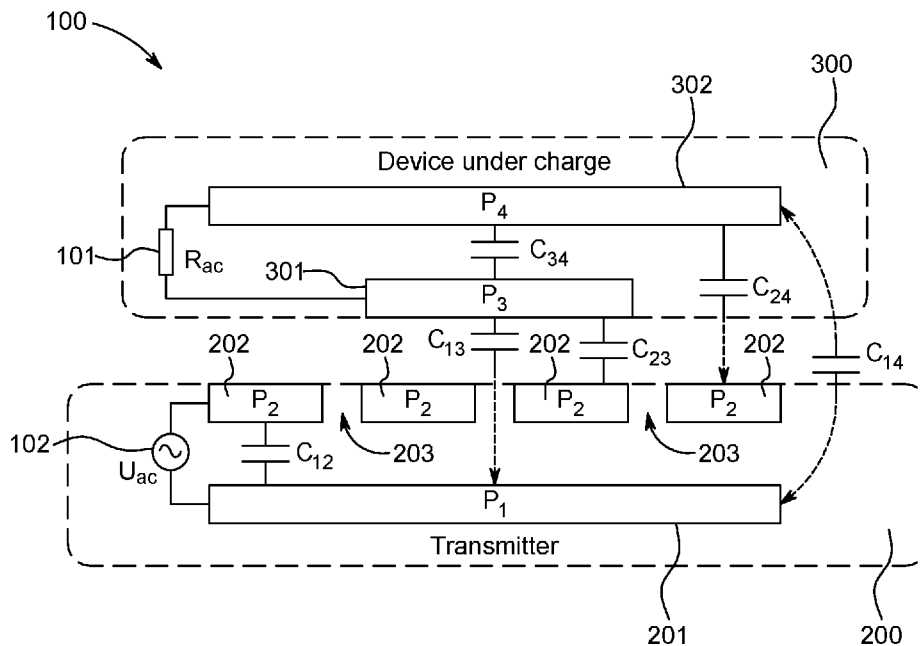


FIG. 2

(57) Abstract: The present disclosure relates to a capacitive power transfer system comprising a power transmitter and a power receiver for wirelessly transferring power from the power transmitter to a load of the power receiver, wherein the power transmitter comprises: a first solid conductive layer; and a second conductive layer having one or more openings, wherein the second conductive layer is stacked on and spaced from the first solid conductive layer, wherein the first and second conductive layers are configured to be connected to an AC power source, and wherein the power receiver comprises: a third conductive layer; and a fourth conductive layer, wherein the third and fourth conductive layers are stacked and spaced, and connected by the load, and wherein the system is configured for wirelessly transferring power from the power transmitter to the load of the power receiver. The present disclosure further relates to a method of transferring power capacitively from a power transmitter to a load of a power receiver.



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## **Position-free, multiple output capacitive power transfer system**

The present disclosure relates to a capacitive power transfer system and a method of transferring power capacitively from a power transmitter to a load of a power receiver. The power transfer system and method can be used for various electronic devices and may support multiple output devices simultaneously.

### **Background**

Wireless power transfer (WPT) is the transmission of electrical energy without wires as a physical link. In a wireless power transmission system, a transmitter device, driven by electric power from a power source, generates a time-varying electromagnetic field, which transmits power across space to a receiver device, which extracts power from the field and supplies it to an electrical load.

Inductive Power Transfer (IPT) has been widely applied in the charging of devices. The aim of a charging system based on inductive power transfer is to provide power across a gapped magnetic structure. Its theoretical development relies on both magnetic and power electronics together as an integrated system. An inductive power transfer system uses inductive coupling between two circuits as the basis of its operation. The system is effectively a two part transformer - the primary being contained within the power sourcing element, and the secondary being contained within the item in which the batteries are to be charged. Both the transmitter and receiver are fitted with electrical coils.

Capacitive Power Transfer (CPT) has been introduced more recently as a promising wireless power transfer technology offering simple and flexible coupling designs, low electromagnetic interference and less critical alignment requirements between the transmitter and receiver and low cost.

In a typical CPT system, power is transferred by two pairs of parallel conductive plates on the transmitter and receiver side, as shown in fig. 1. In order to achieve efficient power transfer, the plates of the receiver device, which may be, for example, an electronic device with a rechargeable battery, are aligned with the plates of the transmitter device.

## Summary

The present disclosure relates to, in a first aspect, an improved capacitive power transfer system comprising a power transmitter and a power receiver, which supports charging of multiple output devices simultaneously and is position-free in the sense that devices being charged on the receiver side can be placed anywhere on a large surface and in any orientation without the capacitive charging being affected. The present disclosure therefore relates to, according to a first embodiment, a capacitive power transfer system comprising a power transmitter and a power receiver for wirelessly transferring power from the power transmitter to a load of the power receiver, wherein the power transmitter comprises:

- a first solid conductive layer; and
- a second conductive layer having one or more openings, wherein the second conduction layer is stacked on and spaced from the first solid conductive layer, wherein the first and second conductive layers are configured to be connected to an AC power source, and

wherein the power receiver comprises:

- a third conductive layer; and
- a fourth conductive layer,

wherein the third and fourth conductive layers are stacked and spaced, and connected by the load, and

wherein the system is configured for wirelessly transferring power from the power transmitter to the load of the power receiver. Preferably, all of the first, second third and fourth conductive layers are arranged substantially parallel to each other when power is transferred from the power transmitter to the power receiver.

The 'openings' in the second conductive layer shall be seen as internal openings, i.e. openings somewhere inside an outer edge of the conductive layer. For example, openings in the form of stripes carved out from the rectangular plate may form the openings. The space outside the conductive layer are not 'openings'.

Non-limiting examples of the power transmitter are shown in fig. 2 and fig. 4 (cross-sectional). In the examples, the power transmitter comprises two conductive layers  $P_1$  (201) and  $P_2$  (202), wherein the bottom layer is a first solid conductive layer (201) and may implemented, for example, as a rectangular plate. The second layer has openings

and may be implemented, for example, in the form of a rectangular plate, wherein the openings have the shape of stripes carved out from the rectangular plate.

A preferred embodiment of the presently disclosed the power transmitter comprises:

- 5
- a first solid conductive layer; and
  - a second conductive layer having one or more openings, on the transmitter side; and:
  - a third conductive layer; and
  - a fourth conductive layer, on the receiver side,

10 wherein the third and fourth conductive layers are symmetric, such as circular, and overlapping such that the fourth conductive layer overlaps the third conductive layer.

In this configuration the receiver can be freely rotated around an axis (Z) perpendicular to the extension of the conductive plates, and positioned anywhere on the transmitter  
15 without the charging being affected.

The power receiver comprises two conductive layers P<sub>3</sub> (301) and P<sub>4</sub> (302). Preferably, the fourth conductive layer (302), which is the layer facing away from the power transmitter, has a fourth surface area which is larger than the third surface area of the  
20 third conductive layer (301), which is the layer towards the power transmitter.

The inventors have realized that by configuring the plates according to the presently disclosed capacitive power transfer system, six coupling capacitors C<sub>12</sub>, C<sub>13</sub>, C<sub>14</sub>, C<sub>23</sub>, C<sub>24</sub> and C<sub>34</sub> are formed by the first, second third and fourth conductive layers, as

25 shown in fig. 2. By calculating the coupling capacitances  $C = \frac{\epsilon_r S}{d}$  and drawing an

equivalent circuit of fig. 2, the equivalent circuit of which is shown in fig. 3A, and simplified in fig. 3B, it can be realized that the charging is not affected when the power receiver moves or turns as long as the first, second third and fourth conductive layers are kept substantially parallel to each other and at the same distance.

30

The present disclosure further relates to a power transmitter for capacitively transferring power to a load of a power receiver, comprising:

- a first solid conductive layer; and
- a second conductive layer having one or more openings, wherein the second  
35 conduction layer is stacked on and spaced from the first solid conductive layer,

wherein the first and second conductive layers are stacked and are configured to be connected to an AC power source, and wherein the first and second conductive layers are configured to each capacitively connect to a third conductive layer and a fourth conductive layer of a power receiver.

5

The power transmitter may be any embodiment disclosed as being part of the presently disclosed capacitive power transfer system. Accordingly, the power transmitted may be configured to be used with any power receiver described in the present disclosure.

10 The present disclosure further related to a method of transferring power capacitively from a power transmitter to a load of a power receiver, the method comprising the steps of:

15

- providing a power transmitter having a first solid conductive layer, and a second conductive layer having one or more openings, wherein the first conductive layer and the second conductive layer are spaced and stacked;
- providing an AC power source for supplying AC power to the first conductive layer and the second conductive layer;
- positioning a power receiver on top of or adjacent the power transmitter, the power receiver having a third conductive layer and a fourth conductive layer, wherein the third and fourth conductive layers are connected by a load, wherein the second and third conductive layers face each other and the first and fourth conductive layers turn away from each other, wherein the first, second, third and fourth conductive layers capacitively connect to each other.

20

25

A person skilled in the art will recognize that the method may be performed using any embodiment of the presently disclosed capacitive power transfer system.

### **Description of drawings**

30

Fig. 1 shows the basic principle of a capacitive power transfer system.

Fig. 2 shows a cross-sectional view of an embodiment of the presently disclosed capacitive power transfer system.

Fig. 3 shows an equivalent circuit of the presently disclosed capacitive power transfer system.

Fig. 4 shows a top view of an embodiment of the presently disclosed capacitive power transfer system.

Fig. 5 shows an embodiment of the presently disclosed method of transferring power capacitively from a power transmitter to a load of a power receiver.

## 5 Detailed description of the invention

A first aspect of the present disclosure relates to a capacitive power transfer system comprising a power transmitter and a power receiver for wirelessly transferring power from the power transmitter to a load of the power receiver. The power transmitter comprises a first conductive layer and a second conductive layer stacked on and spaced from the first conductive layer. Preferably, the first conductive layer is a solid  
10 conductive layer, such as a conductive rectangular plate. The second conductive layer may have openings, preferably a plurality of openings. The first and second conductive layers may be connected to an AC power source as shown in fig. 2. Accordingly, the power receiver comprises a third conductive layer and a fourth conductive layer.  
15 Preferably, the third and fourth conductive layers are stacked and spaced, and may be connected to a load, which may be, for example, a battery of an electronic device. The electronic device may be, but is not limited to, a mobile phone, laptop, tablet, keyboard, mouse, load speaker, headphones and smart glasses . In a charging configuration, the capacitive power transfer system may be set up to transfer power from the power  
20 transmitter to the load of the power receiver wirelessly.

Examples of the power transmitter are shown in fig. 2 and fig. 4 (cross-sectional). The power transmitter comprises two conductive layers  $P_1$  (201) and  $P_2$  (202), wherein the bottom layer is a first solid conductive layer (201) and may implemented, for example,  
25 as a rectangular plate. The second layer has openings and may be implemented, for example, in the form of a rectangular plate, wherein the openings have the shape of stripes carved out from the rectangular plate. As described above, and as shown in the equivalence circuit of figs. 3A and 3B, with the proposed setup all layers may form coupling capacitors with each other ( $C_{12}$ ,  $C_{13}$ ,  $C_{14}$ ,  $C_{23}$ ,  $C_{24}$  and  $C_{34}$ ). The first solid  
30 conductive layer has a first conductive surface area. The second conductive layer has a second conductive surface area. In order to achieve efficient power transfer, the ratio between the first conductive surface area and the second conductive surface area may be between 10:9 and 10:1, preferably between 10:8 and 10:2, and more preferably between 10:7 and 10:3. As can be seen in fig. 2, the ratio between the surfaces of the



first conductive layer and second conductive layer influences not only  $C_{12}$  but also  $C_{13}$  and  $C_{14}$ .

5 The capacitive power transfer system may be part of an electronic assembly comprising a charging device and an electronic device, wherein presently disclosed power transmitter is incorporated in the charging device, and the presently disclosed power receiver is incorporated in the electronic device. The charging device may have a substantially flat shape, which can be, for example, a stand-alone charger or a charge integrated into a table or desk. In this embodiment the first solid conductive  
10 layer may extend between edges of the substantially flat charging device to cover the whole, or substantially the whole, surface of the charger/table/desk. The second layer, i.e. the layer having openings, for example in the form of stripes, may also extend between edges of the substantially flat charging device.

15 The present disclosure further relates to a charging device comprising the presently disclosed capacitive power transfer system. In a preferred embodiment, the power transmitter is incorporated in the charging device, wherein the charging device has a substantially flat shape, wherein the charging device has a first solid conductive layer extending between edges of the substantially flat charging device, and wherein the  
20 charging device has a second conductive layer having one or more openings, the second conductive layer extending between edges of the substantially flat charging device.

In one embodiment the openings are substantially rectangular and/or have the shape  
25 of stripes. In this embodiment the openings may have a length to width ratio of at least 2:1. More preferably the openings have a length to width ratio of at least 3:1, or at least 5:1, more preferably at least 10:1, even more preferably at least 30:1, and most preferably at least 100:1.

30 Alternatively, the one or more openings may be circular, diamond shaped, honeycomb shaped or take the shape of a grid or mesh. In any of these embodiment, including the substantially rectangular and stripes openings, the second conductive layer can be said to be divided into a conductive portion and a non-conductive portion, wherein the conductive portion separates the openings. The conductive portion may comprise an  
35 arrangement of bars that are parallel and/or cross each other to form the openings which constitute the non-conductive portion. The ratio between the conductive portion

and a non-conductive portion determines may affect several of the coupling capacitors. In particular it can be noted that this ratio does not only affect the coupling capacitors directly related to the second conductive layer ( $C_{12}$ ,  $C_{23}$  and  $C_{24}$ ) but also, indirectly,  $C_{13}$  and  $C_{14}$ . The ratio between the conductive portion and the non-conductive portion may  
5 be between 10:1 and 1:10, preferably between 5:1 and 1:5, more preferably between 2:1 and 1:2, even more preferably between 3:1 and 1:1, most preferably between 2:1 and 1:1.

The power transmitter may comprises a first dielectric/insulating layer in-between the  
10 first and second conductive layers to separate the layers from each other.

On the receiver side the third conductive layer has a third surface area and the fourth  
conductive layer has a fourth surface are. Preferably, fourth surface area is larger than  
the third surface area. Preferably, the third and fourth conductive layers are  
15 overlapping. In one embodiment, the third and fourth conductive layers are each  
substantially circular in shape. Examples of overlapping conductive layers with  
substantially circular shapes are shown in fig. 4. Both Device #1 and Device #2, which  
are electronic devices, have power receivers including a third conductive layer (301)  
and a fourth conductive layer (302), wherein the third and fourth conductive layers are  
20 overlapping and wherein the fourth surface area of the fourth conductive layer is larger  
than the third surface area of the third conductive layer. The circular third conductive  
layer and circular fourth conductive layers share the center of respective circles. In one  
embodiment, the ratio of the fourth surface area and the third surface area is between  
5:4 and 11:4, preferably between 4:3 and 8:3, and most preferably between 3:2 and  
25 5:2. As can be seen in fig. 2, the ratio of the fourth surface area and the third surface  
area may influence several of the coupling capacitors, not only  $C_{34}$  but also, for  
example,  $C_{24}$  and  $C_{14}$ .

The power transmitter may comprises a second dielectric/insulating layer in-between  
30 the first and second conductive layers to separate the layers from each other.

The capacitive power transfer system may further comprise a third dielectric/insulating  
layer on the second conductive layer towards the third conductive layer and/or a fourth  
dielectric/insulating layer on the third conductive layer towards the second conductive  
35 layer.

The presently disclosed capacitive power transfer system is position-free in the sense that devices being charged on the receiver side, incorporating the power receiver, can be placed anywhere and in any position on a large surface that incorporates the power transmitter. Position-free refers to position-free within the extension of the conductive plates, i.e. in an X-Y plane, i.e. moving in the X-Y plane and/or rotating around an axis (Z) perpendicular to the extension of the conductive plates. It can be noted that the power transmitter, i.e. the first solid conductive layer and the second conductive layer may be integrated in, for example, a table or desk, i.e. an area considerably larger than the third and fourth conductive layers of the power receiver. Devices, such as mobile phones, mice, headphones, computers etc. can then simply be placed on the table or desk to be charged or powered. The user does not have to worry about where the devices are placed and in which orientation.

One possible structure of the presently disclosed capacitive power transfer system is shown in fig. 4. The first solid conductive layer (201) and the second conductive layer (202) are used as transmitter and the third conductive layer (301) and the fourth conductive layer (302) are used as receiver. Six coupling capacitors ( $C_{12}$ ,  $C_{13}$ ,  $C_{14}$ ,  $C_{23}$ ,  $C_{24}$  and  $C_{34}$ ) are formed between the conductive layers. Generally, the coupling capacitance of two parallel plates can be calculated as  $C = \frac{\epsilon_r S}{d}$  where S is an overlapping plate area and d is the distance between the plates.

The first solid conductive layer may be capacitively connected to the third conductive layer through the openings of the second conductive layer. This corresponds to  $C_{13}$ . The first solid conductive layer may capacitively connected to the fourth conductive layer through the openings of the second conductive layer, possible also outside the second conductive layer. This corresponds to  $C_{14}$ . The second conductive layer may capacitively connected to the third conductive layer. This corresponds to  $C_{23}$ . The second conductive layer may capacitively connected to the fourth conductive layer. This corresponds to  $C_{24}$ . There may also be capacitive coupling between the first solid conductive layer and the second conductive layer,  $C_{12}$ , and between the third solid conductive layer and the fourth conductive layer,  $C_{34}$ .

In the example shown in fig. 2, an equivalent circuit may be redrawn schematically as fig. 3A, which corresponds to a variant of a Wheatstone bridge. The device under charge (receiver side) may then be simplified as an AC resistance  $R_{ac}$  and connected

to the middle points of the Wheatstone bridge (points  $P_3$  and  $P_4$ ). The voltage source  $U_{ac}$  is connected to  $P_1$  and  $P_2$ . Thus, in one embodiment of the presently disclosed capacitive power transfer system, the first solid conductive layer, the second conductive layer, the third conductive layer, the fourth solid conductive layer and the load are arranged to form a Wheatstone bridge.

In a normal Wheatstone bridge a current meter would typically be connected between  $P_3$  and  $P_4$ . The impedance of the current meter would typically be considered high enough to be viewed as open circuit. For the present capacitive power transfer system, however, a relative low resistance is connected, cannot be viewed as an open circuit. Moreover, the target of a Wheatstone bridge is typically to reach a balanced state where the voltage difference between  $P_3$  and  $P_4$  is zero. However, for the presently disclosed capacitive power transfer system, it is an advantage to make the Wheatstone bridge as unbalanced as possible to give a high voltage  $U_{34}$  to the load. In one embodiment of the presently disclosed capacitive power transfer system, the capacitive power transfer system is configured, i.e. the physical dimensions and arrangement of the first, second, third and fourth conductive layers, to provide a maximum voltage difference between  $P_3$  and  $P_4$ , i.e. between the third conductive layer and fourth conductive layer through the load. To calculate the gain of the circuit ( $U_{34}/U_{ac}$ ) in Fig. 3A, the circuit may be further simplified to the circuit shown in fig. 3B. The gain can

$$\text{Gain} = \frac{U_{34}}{U_{ac}} = \frac{(Z - Z_c)(Z_a Z_3 - Z_b Z_1)}{Z(Z_3 + Z_b)(Z_1 + Z_a)}$$

### Detailed description of drawings

The invention will in the following be described in greater detail with reference to a selection of the accompanying drawings. The drawings are exemplary and are intended to illustrate some of the features of the presently disclosed capacitive power transfer system and method of transferring power capacitively from a power transmitter to a load of a power receiver, and are not to be construed as limiting to the presently disclosed invention.

Fig. 2 shows a cross-sectional view of an embodiment of the presently disclosed capacitive power transfer system (100). A power transmitter (200) comprises a first solid conductive layer (201) and a second conductive layer (202) having one or more openings (203). A power receiver (300) comprises a third conductive layer (301) and a

fourth conductive layer (302). Six coupling capacitors ( $C_{12}$ ,  $C_{13}$ ,  $C_{14}$ ,  $C_{23}$ ,  $C_{24}$ ,  $C_{34}$ ) are formed between the conductive layers (201, 202, 301, 302). A load  $R_{ac}$  is serially connected between the third conductive layer (301) and the fourth conductive layer (302). An AC power source  $U_{ac}$  is serially connected between the first solid conductive layer (201) and the second conductive layer (202).

Fig. 4 shows a top view of an embodiment of the presently disclosed capacitive power transfer system (100). A power transmitter comprises a first solid conductive layer (201) and a second conductive layer (202) having one or more openings (203), in this embodiment in the form of rectangular stripes (203). Two electronic devices (500) each have a power receiver comprising a third conductive layer (301) and a fourth conductive layer (302). The power transmitter is configured to charge both devices (500) simultaneously. The power transmitter can be integrated in, for example, a table or desk.

Fig. 5 shows an embodiment of the presently disclosed method (400) of transferring power capacitively from a power transmitter to a load of a power receiver. The power transmitter and power receiver may be any power transmitter and power receiver described in the present disclosure. The method comprises the steps of:

- providing a power transmitter having a first solid conductive layer, and a second conductive layer having one or more openings, wherein the first conductive layer and the second conductive layer are spaced and stacked; (410)
- providing an AC power source for supplying AC power to the first conductive layer and the second conductive layer; (420) and
- positioning a power receiver on top of or adjacent the power transmitter, the power receiver having a third conductive layer and a fourth conductive layer, wherein the third and fourth conductive layers are connected by a load, wherein the second and third conductive layers face each other and the first and fourth conductive layers turn away from each other, wherein the first, second, third and fourth conductive layers capacitively connect to each other. (430)

### Further Details

1. A capacitive power transfer system comprising a power transmitter and a power receiver for wirelessly transferring power from the power transmitter to a load of the power receiver, wherein the power transmitter comprises:
  - 5 - a first solid conductive layer; and
  - a second conductive layer having one or more openings, wherein the second conductive layer is stacked on and spaced from the first solid conductive layer, wherein the first and second conductive layers are configured to be connected to an AC power source, and10 wherein the power receiver comprises:
  - a third conductive layer; and
  - a fourth conductive layer,wherein the third and fourth conductive layers are stacked and spaced, and connected by the load, and
- 15 wherein the system is configured for wirelessly transfer power from the power transmitter to the load of the power receiver.
  
2. The capacitive power transfer system according to item 1, wherein the first solid conductive layer has a first conductive surface area and wherein the second  
20 conductive layer has a second conductive surface area, wherein the ratio between the first conductive surface area and the second conductive surface area is between 10:9 and 10:1, preferably between 10:8 and 10:2, more preferably between 10:7 and 10:3.
  
- 25 3. The capacitive power transfer system according to any of the preceding items, wherein the one or more openings are substantially rectangular and/or have the shape of stripes.
  
4. The capacitive power transfer system according to item 3, wherein the openings  
30 have a length to width ratio of at least 5:1, preferably at least 10:1, more preferably at least 30:1, and most preferably at least 100:1.
  
5. The capacitive power transfer system according to item 1, wherein the one or  
35 more openings are circular, diamond shaped, honeycomb shaped.

6. The capacitive power transfer system according to any of the preceding items, wherein the second conductive layer is a grid or mesh.
- 5 7. The capacitive power transfer system according to any of the preceding items, wherein the second conductive layer comprises a conductive portion separating the one or more openings, the one or more openings constituting a non-conductive portion, wherein the ratio between the conductive portion and the non-conductive portion is between 10:1 and 1:10, preferably between 5:1 and 1:5, more preferably between 2:1 and 1:2, even more preferably between 3:1 and 1:1, most preferably between 2:1 and 1:1.  
10
8. The capacitive power transfer system according to item 7, wherein the conductive portion comprises an arrangement of bars that are parallel and/or cross each other.  
15
9. The capacitive power transfer system according to any of the preceding items, wherein the power transmitter comprises a first dielectric/insulating layer in-between the first and second conductive layers, and/or the power receiver comprises a second dielectric/insulating layer in-between the third and fourth conductive layers.  
20
10. The capacitive power transfer system according to any of the preceding items, further comprising a third dielectric/insulating layer on the second conductive layer towards the third conductive layer and/or a fourth dielectric/insulating layer on the third conductive layer towards the second conductive layer.  
25
11. The capacitive power transfer system according to any of the preceding items, wherein a fourth surface area of the fourth conductive layer is larger than a third surface area of the third conductive layer.  
30
12. The capacitive power transfer system according to item 11, wherein the ratio of the fourth surface area and the third surface area is between 5:4 and 11:4, preferably between 4:3 and 8:3, and most preferably between 3:2 and 5:2.

13. The capacitive power transfer system according to any of the preceding items, wherein the third and fourth conductive layers are each substantially circular in shape or circular symmetric.
- 5 14. The capacitive power transfer system according to any of the preceding items, wherein the third and fourth conductive layers are overlapping.
15. The capacitive power transfer system according to any of the preceding items, wherein the load is a battery.
- 10 16. The capacitive power transfer system according to any of the preceding items, wherein the first solid conductive layer is capacitively connected to the third conductive layer through the openings of the second conductive layer.
- 15 17. The capacitive power transfer system according to any of the preceding items, wherein the first solid conductive layer is capacitively connected to the fourth conductive layer through the openings of the second conductive layer.
- 20 18. The capacitive power transfer system according to any of the preceding items, wherein the second conductive layer is capacitively connected to the third conductive layer.
- 25 19. The capacitive power transfer system according to any of the preceding items, wherein the second conductive layer is capacitively connected to the fourth conductive layer.
- 30 20. The capacitive power transfer system according to any of the preceding items, wherein the first solid conductive layer, the second conductive layer, the third conductive layer, the fourth solid conductive layer and the load are arranged to form a Wheatstone bridge.
21. A power transmitter for capacitively transferring power to a load of a power receiver, comprising:
- a first solid conductive layer; and



- a second conductive layer having one or more openings, wherein the second conductive layer is stacked on and spaced from the first solid conductive layer,  
wherein the first and second conductive layers are stacked and are configured to be connected to an AC power source, and wherein the first and second conductive layers are configured to each capacitively connect to a third conductive layer and a fourth conductive layer of a power receiver.
- 5
22. A power transmitter according to item 21, wherein the power transmitter is the power transmitter according to any of items 1-20.
- 10
23. A method of transferring power capacitively from a power transmitter to a load of a power receiver, the method comprising the steps of:
- providing a power transmitter having a first solid conductive layer, and a second conductive layer having one or more openings, wherein the first conductive layer and the second conductive layer are spaced and stacked;
  - providing an AC power source for supplying AC power to the first conductive layer and the second conductive layer;
  - positioning a power receiver on top of or adjacent the power transmitter, the power receiver having a third conductive layer and a fourth conductive layer, wherein the third and fourth conductive layers are connected by a load, wherein the second and third conductive layers face each other and the first and fourth conductive layers turn away from each other, wherein the first, second, third and fourth conductive layers capacitively connect to each other.
- 15
- 20
- 25
24. The method according to item 23, wherein the power transmitter is the power transmitter according to any of items 1-20 and/or the power receiver is the power receiver according to any of items 1-20.
- 30

## Claims

1. A capacitive power transfer system comprising a power transmitter and a power receiver for wirelessly transferring power from the power transmitter to a load of the power receiver, wherein the power transmitter comprises:
- 5
- a first solid conductive layer; and
  - a second conductive layer having one or more openings, wherein the second conductive layer is stacked on and spaced from the first solid conductive layer, wherein the first and second conductive layers are
- 10
- configured to be connected to an AC power source, and
- wherein the power receiver comprises:
- a third conductive layer; and
  - a fourth conductive layer,
- 15
- wherein the third and fourth conductive layers are stacked and spaced, and
- connected by the load, and
- wherein the system is configured for wirelessly transfer power from the power transmitter to the load of the power receiver.
2. The capacitive power transfer system according to claim 1, wherein the first solid conductive layer has a first conductive surface area and wherein the second conductive layer has a second conductive surface area, wherein the ratio between the first conductive surface area and the second conductive surface area is between 10:9 and 10:1, preferably between 10:8 and 10:2, more preferably between 10:7 and 10:3.
- 20
- 25
3. The capacitive power transfer system according to any of the preceding claims, wherein the one or more openings are substantially rectangular and/or have the shape of stripes.
- 30
4. The capacitive power transfer system according to claim 3, wherein the openings have a length to width ratio of at least 5:1, preferably at least 10:1, more preferably at least 30:1, and most preferably at least 100:1.
- 35
5. The capacitive power transfer system according to any of the preceding claims, wherein the second conductive layer comprises a conductive portion separating the one or more openings, the one or more openings constituting a non-

conductive portion, wherein the ratio between the conductive portion and the non-conductive portion is between 10:1 and 1:10, preferably between 5:1 and 1:5, more preferably between 2:1 and 1:2, even more preferably between 3:1 and 1:1, most preferably between 2:1 and 1:1.

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6. The capacitive power transfer system according to any of the preceding claims, wherein a fourth surface area of the fourth conductive layer is larger than a third surface area of the third conductive layer.

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7. The capacitive power transfer system according to claim 6, wherein the ratio of the fourth surface area and the third surface area is between 5:4 and 11:4, preferably between 4:3 and 8:3, and most preferably between 3:2 and 5:2.

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8. The capacitive power transfer system according to any of the preceding claims, wherein the third and fourth conductive layers are each substantially circular in shape or circular symmetric.

9. The capacitive power transfer system according to any of the preceding claims, wherein the third and fourth conductive layers are overlapping.

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10. The capacitive power transfer system according to any of the preceding claims, wherein the first solid conductive layer is capacitively connected to the third conductive layer through the openings of the second conductive layer, and wherein the first solid conductive layer is capacitively connected to the fourth conductive layer through the openings of the second conductive layer, and wherein the second conductive layer is capacitively connected to the third conductive layer, and wherein the second conductive layer is capacitively connected to the fourth conductive layer.

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11. The capacitive power transfer system according to any of the preceding claims, wherein the first solid conductive layer, the second conductive layer, the third conductive layer, the fourth solid conductive layer and the load are arranged to form a Wheatstone bridge.

12. An electronic assembly comprising a charging device and an electronic device comprising a rechargeable battery, the electronic assembly comprising the capacitive power transfer system according to any of the preceding claims.
- 5 13. The electronic assembly according to claim 12, wherein the power transmitter is incorporated in the charging device, and the power receiver is incorporated in the electronic device.
- 10 14. The electronic assembly according to claim 13, wherein the charging device has a substantially flat shape, wherein the charging device has a first solid conductive layer extending between edges of the substantially flat charging device, and wherein the charging device has a second conductive layer having one or more openings, the second conductive layer extending between edges of the substantially flat charging device.
- 15 15. A power transmitter for capacitively transferring power to a load of a power receiver, comprising:
- a first solid conductive layer; and
  - a second conductive layer having one or more openings, wherein the
- 20 second conduction layer is stacked on and spaced from the first solid conductive layer,
- wherein the first and second conductive layers are stacked and are configured to be connected to an AC power source, and wherein the first and second conductive layers are configured to each capacitively connect to a third
- 25 conductive layer and a fourth conductive layer of a power receiver.
16. A power transmitter according to claim 15, wherein the power transmitter is the power transmitter according to any of claims 1-11.
- 30 17. A charging device comprising the capacitive power transfer system according to any of claims 15-16.
- 35 18. The charging device according to claim 17, wherein the power transmitter is incorporated in the charging device, wherein the charging device has a substantially flat shape, wherein the charging device has a first solid conductive layer extending between edges of the substantially flat charging device, and

wherein the charging device has a second conductive layer having one or more openings, the second conductive layer extending between edges of the substantially flat charging device.

- 5 19. A method of transferring power capacitively from a power transmitter to a load  
of a power receiver, the method comprising the steps of:
- providing a power transmitter having a first solid conductive layer, and a  
second conductive layer having one or more openings, wherein the first  
conductive layer and the second conductive layer are spaced and  
10 stacked;
  - providing an AC power source for supplying AC power to the first  
conductive layer and the second conductive layer;
  - positioning a power receiver on top of or adjacent the power transmitter,  
the power receiver having a third conductive layer and a fourth  
15 conductive layer, wherein the third and fourth conductive layers are  
connected by a load, wherein the second and third conductive layers  
face each other and the first and fourth conductive layers turn away from  
each other, wherein the first, second, third and fourth conductive layers  
capacitively connect to each other.
- 20 20. The method according to claim 19, wherein the power transmitter is the power  
transmitter according to any of claims 1-11 and/or the power receiver is the  
power receiver according to any of claims 1-11.

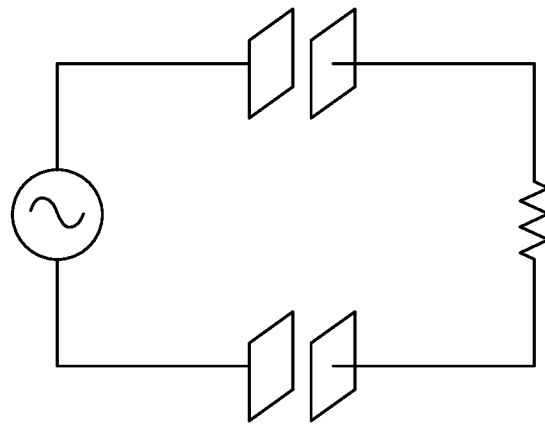


FIG. 1

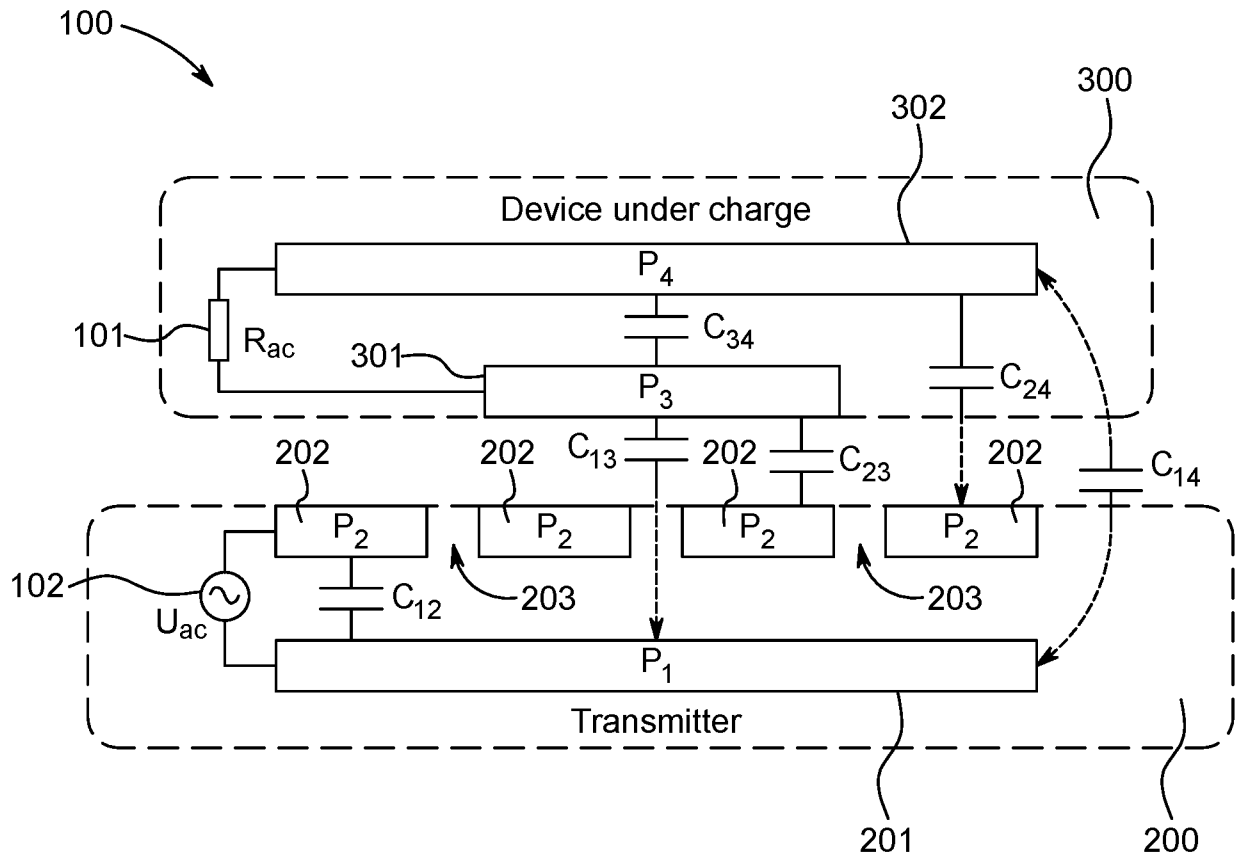


FIG. 2

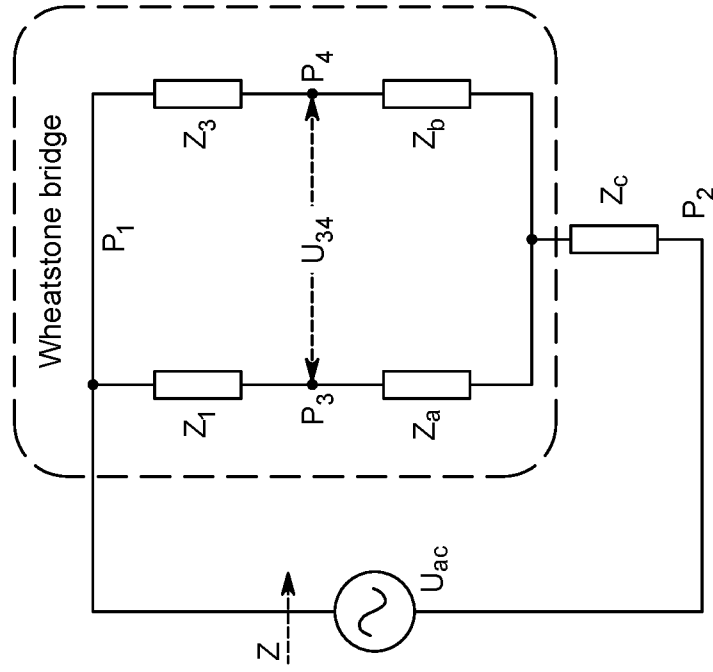


FIG. 3B

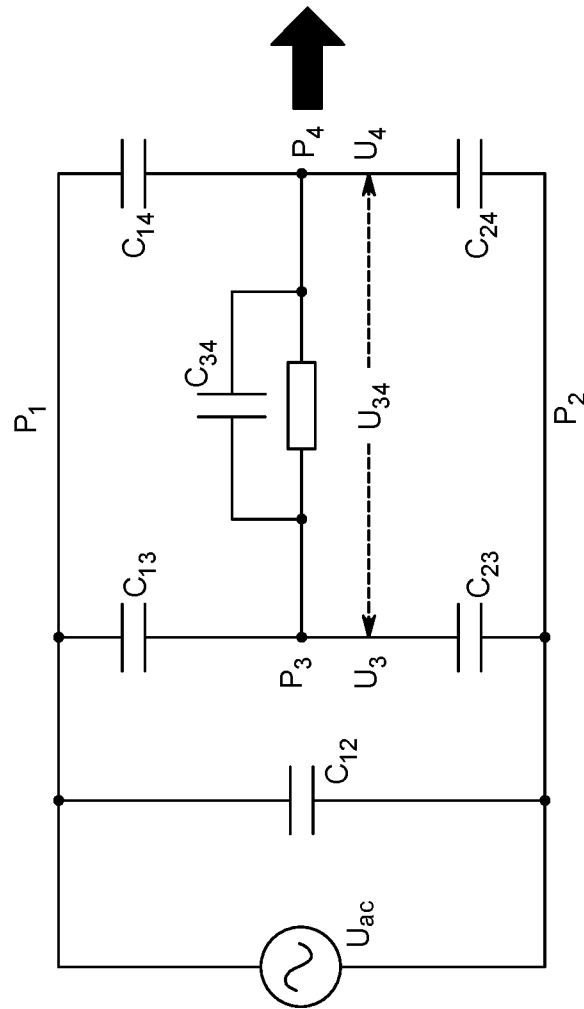


FIG. 3A

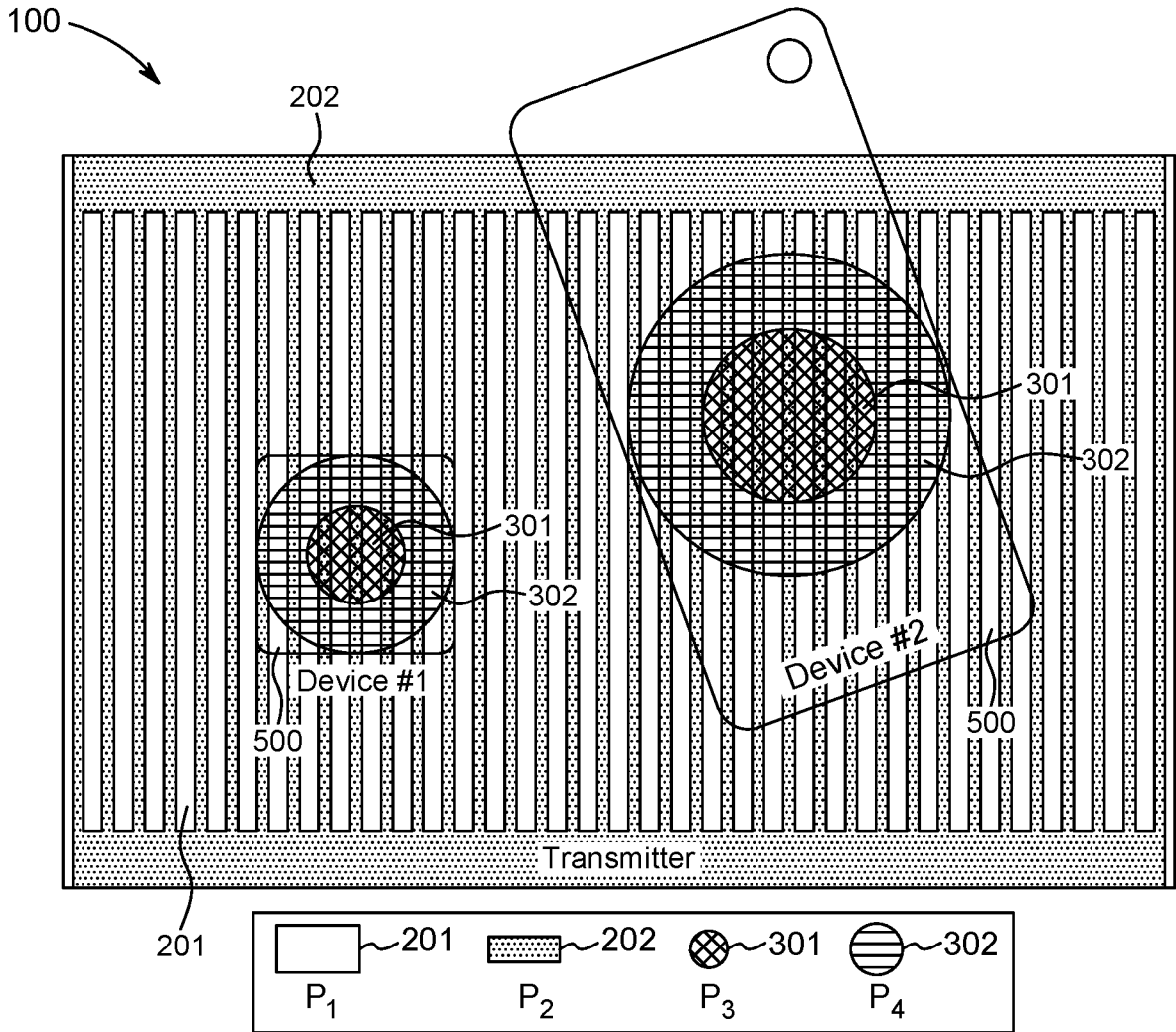


FIG. 4

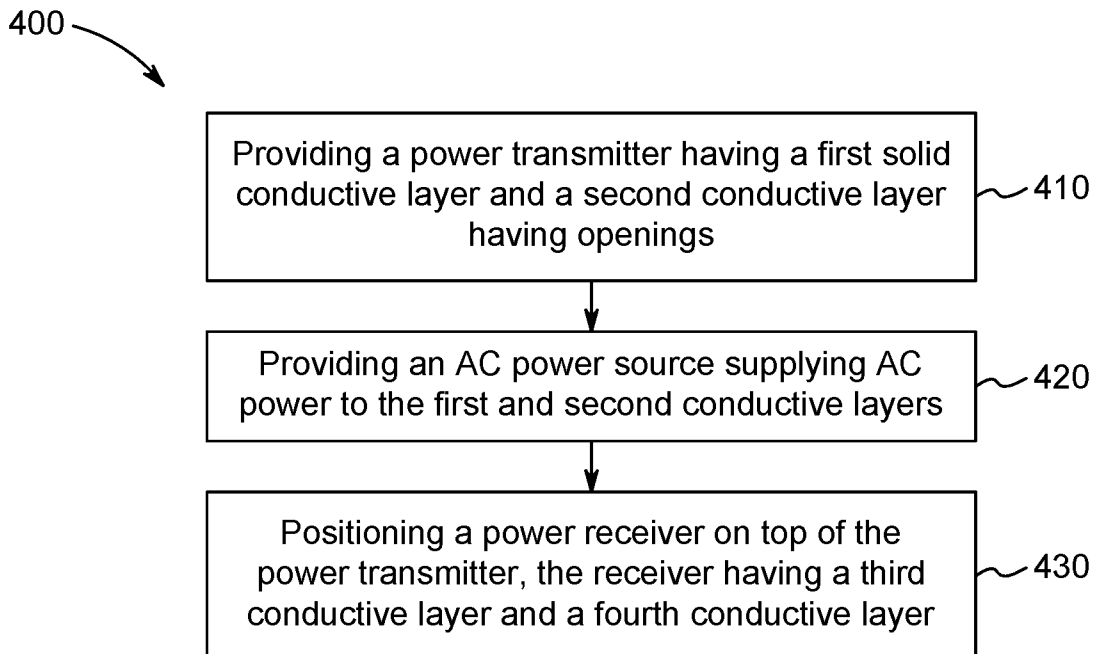


FIG. 5



**INTERNATIONAL SEARCH REPORT**

International application No  
PCT/EP2021/051416

**A. CLASSIFICATION OF SUBJECT MATTER**  
 INV. H02J50/00 H02J50/05  
 ADD.  
 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)  
 H02J  
 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2014/208683 A1 (SHOWA DENKO KK [JP]) 31 December 2014 (2014-12-31)	1,2,6-9, 11-20
Y	figure 3	1-20
Y	EP 2 745 421 A2 (KONINKL PHILIPS NV [NL]) 25 June 2014 (2014-06-25)	1-20
Y	US 2016/372978 A1 (ICHIKAWA KEIICHI [JP] ET AL) 22 December 2016 (2016-12-22)	1-20
Y	KR 101 527 565 B1 (KRRI [KR]) 11 June 2015 (2015-06-11)	1
	figure 2	

Further documents are listed in the continuation of Box C.

See patent family annex.

\* Special categories of cited documents :

<p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier application or patent but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p>	<p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"&amp;" document member of the same patent family</p>
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Date of the actual completion of the international search <b>22 March 2021</b>	Date of mailing of the international search report <b>08/04/2021</b>
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer <b>Bourdon, Jérémy</b>
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