(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
16 September 2021 (16.09.2021)

WIPO | PCT

(10) International Publication Number
WO 2021/182766 A1

(51) International Patent Classification:
G01R 1/20 (2006.01) *G01R 19/00* (2006.01)
G01R 1/30 (2006.01)

(21) International Application Number:
PCT/KR2021/002162

(22) International Filing Date:
22 February 2021 (22.02.2021)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10 2020 106 447.0
10 March 2020 (10.03.2020) DE

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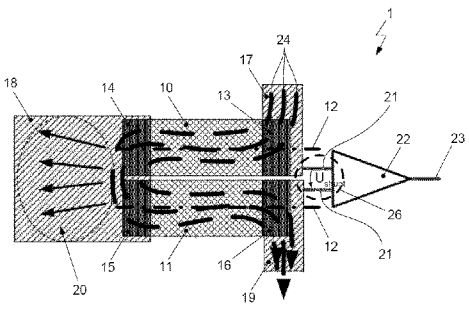
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, IT, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

(54) Title: ARRANGEMENT FOR CURRENT MEASUREMENT



(57) Abstract: It is the object of the invention, which relates to an arrangement for current measurement, to specify an arrangement for current measurement which is inexpensive and simple to manufacture, has a high level of robustness with respect to interference signals and enables improved heat dissipation. The object is achieved in that at least a first partial shunt resistor (10) and a second partial shunt resistor (11) are arranged in a series circuit, wherein the partial shunt resistors (10, 11) are arranged together on one side of a circuit board (9) or on different, opposite sides of the circuit board (9). The partial shunt resistors (10, 11) are arranged with longitudinal axes (12) in parallel and closely spaced apart from one another.

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Description

Title of Invention: ARRANGEMENT FOR CURRENT MEASUREMENT

Technical Field

[1] The invention relates to an arrangement for current measurement, in which a shunt resistor is arranged in a current path in which a current is measured.

Background Art

[2] In many areas of technology, it is necessary to measure currents in lines in order, for example, to make statements about these currents or to be able to control machines or electrical arrangements according to their requirements.

[3] In particular in areas in which high currents, for example up to the order of magnitude of 20 A or more, are to be measured, the requirements for such arrangements for current measurement are correspondingly high. On the one hand, the current flowing in a current path should not be influenced by the arrangement for current measurement and, on the other hand, the measurement should have high accuracy.

[4] Such current measurements are also carried out, for example, in vehicles, wherein this is necessary on the one hand for the proper operation of assemblies and on the other hand corresponding statements can be made, for example about the range of an electric vehicle or hybrid vehicle.

[5] Methods for current detection are known from the prior art, in which at least one so-called shunt resistor R_{shunt} is used to measure a voltage U_{shunt} across the shunt resistor R_{shunt} and subsequently to calculate a current I_{shunt} therefrom. Such a current detection takes place, for example, in a DC to AC converter.

[6] DC to AC converters, also referred to inverters, are required, for example, to convert an input-side direct voltage into an output-side alternating voltage. Such DC to AC converters are used, among other things, to drive electric motors, in particular in motor vehicles with on-board network voltages of 48 V or more than 60 V. The electric motor can be utilized, for example, in an electric refrigerant compressor of an air conditioning system of a motor vehicle.

[7] To control a three-phase electric motor controlled by a DC to AC converter, such as a motor of the electric refrigerant compressor, a current detection is required in at least two motor phases. A third phase can be determined mathematically. A known method for such a current measurement is to measure the currents of the three motor phases via a shunt resistor each. In this case, certain currents can be extrapolated mathematically in the individual motor phases by means of currents determined in so-called half

bridges of an inverter utilizing a shunt resistor each for each half bridge.

[8] The term shunt resistor refers to a low-resistance electrical measuring resistor or current measuring resistor, which is inserted directly into the current-carrying line.

[9] The current I_{shunt} flowing through a shunt resistor R_{shunt} generates a voltage drop U_{shunt} at the shunt resistor, which is amplified and measured, for example, by means of a measuring amplifier. Both analog and digital measurement technology can be used to detect the voltage drop U_{shunt}. There is also the option of converting an analog measured value into a digital measured value later on. Such a digital measured value, for example, can be detected via a central control unit, which among other things also controls the DC to AC converter, and the current I_{shunt1}, I_{shunt2}, I_{shunt3} for each motor phase of the DC to AC converter can be determined in this way. The currents I_{shunt1}, I_{shunt2}, I_{shunt3} are used to regulate the control of the motor by the DC to AC converter.

Disclosure of Invention

Technical Problem

[10] Since high currents, for example in a range of up to about 100 A, flow when such shunt resistors are utilized to detect a current in a DC to AC converter, an undesirable heating of the shunt resistor also inevitably occurs. In order to ensure that the current measuring arrangements function correctly, the shunt resistor must be dimensioned sufficiently powerful. In addition, measures must be provided to dissipate the heat generated from the area of the shunt resistor. All of this leads to higher costs for a shunt resistor and the additional means to be formed for heat dissipation.

[11] One way of reducing the amount of heat generated is to reduce the resistance value of the shunt resistor. In this case, however, the voltage drop U_{shunt} measured across the shunt resistor becomes also lower, so that interferences, such as so-called noise, lead to greater measurement errors or a lower accuracy of the current detection.

[12] Another problem of the known prior art is the so-called interference immunity in the case of a current detection. Electrical assemblies temporarily or permanently located in the vicinity of such a current measuring arrangement cause interference signals. The interference signals occur due to an unwanted capacitive, inductive or galvanic coupling on the lines or the shunt resistor itself and influence the useful signal of the current detection. Appropriate measures must be taken to reduce the generation of interference signals.

[13] The known relevant prior art can be found, for example, in the book "EMV - Storungssicherer Aufbau elektronischer Schaltungen" by Joachim Franz; 5th edition; Springer Vieweg; ISBN978-3-8348-1781-5. Reference is made here to pages 43, 48 and 55 in particular.

[14] Based on the prior art, there is a need for an improved arrangement for current mea-

surement.

Solution to Problem

[15] It is the object of the invention now to specify an arrangement for current measurement which is inexpensive and simple to manufacture, has a high level of robustness with respect to interference signals and enables improved heat dissipation. In addition, the arrangement for current measurement should be able to utilize only standard components.

[16] The object is achieved by a subject having the features according to claim 1 of the claims. Further developments are given in the dependent claims.

[17] The object is achieved by an arrangement for current measurement according to the invention, in which a shunt resistor is arranged in a flow path in which a current is measured. The shunt resistor is formed from at least two partial shunt resistors, wherein the two partial shunt resistors can have the same resistance value. According to a special configuration of the invention, a partial shunt resistor has half the resistance value of the shunt resistor required for the current measurement.

[18] According to a further development of the invention, the at least two partial shunt resistors are arranged in a meandering shape, wherein the partial shunt resistors are arranged in parallel and at a small distance from one another, for example on a circuit board. The parallel arrangement of the at least two partial shunt resistors is to be understood as meaning that the cuboid or cylindrical partial shunt resistors are aligned in parallel to one another, with a longitudinal axis each extending in the direction of the greatest extension.

[19] According to an advantageous configuration of the invention, in the case of two partial shunt resistors arranged in parallel or in a meandering shape, both partial shunt resistors are electrically conductively connected to one another at one end. In this case, for example, a soldering pad is formed on a circuit board, with which both partial shunt resistors are soldered at the respective first ends. The respective second ends of the two partial shunt resistors are preferably soldered to separate, electrically separated soldering pads which establish the connections to the current path in which the current I_{shunt} is to be measured. This results in a meandering arrangement of the two partial shunt resistors with regard to the path to be covered by the current to be measured.

[20] The partial shunt resistors are preferably formed as SMD components, short for surface-mounted device, which have no connection wires and are soldered directly onto the circuit board by means of solderable terminal surfaces. In this case, the terminal surfaces are soldered onto soldering pads or contact surfaces arranged on the circuit board. This technique is also known as surface mount.

[21] According to an advantageous configuration of the invention, the partial shunt

resistors arranged in parallel or in a meandering shape are arranged on a first side or a first surface of the circuit board.

[22] Alternatively, the partial shunt resistors arranged in parallel or in a meandering shape can be provided on two opposite sides of the circuit board. Here, to produce an electrically conductive connection of the respective first ends of the partial shunt resistors, one or more vias are formed which, for example, connect corresponding soldering pads to one another onto which the respective first ends of the partial shunt resistors are soldered.

Advantageous Effects of Invention

[23] Regardless of the arrangement of the partial shunt resistors on one or both sides of the circuit board, it is provided that the one soldering pad in the case of a one-sided arrangement or the two opposing soldering pads in the case of a two-sided arrangement of the partial shunt resistors are formed to be larger than necessary for contacting in order to enable or improve heat dissipation from the partial shunt resistors at the common connection point of the first ends of the partial shunt resistors. The correspondingly large-surface soldering pad or the two opposing, correspondingly large-surface soldering pads each provide a surface via which heat transferred from the partial shunt resistors into the soldering pad or the soldering pads can be released to the environment. This improves the heat dissipation of the shunt resistor, which consists of at least two partial shunt resistors.

[24] The improvement in heat dissipation leads to a reduced thermal load on the components and enables a selection of elements with lower thermal requirements or a reduced power loss, which greatly reduces the costs of the elements needed.

[25] The soldering pads connected to the respective second ends of the partial shunt resistors can also be formed to be larger than necessary for contacting, in order to provide a further possibility for an improved heat dissipation from the partial shunt resistors.

[26] Another advantage of the parallel or meandering arrangement of the partial shunt resistors is that the inductance of such an arrangement, in particular of the shunt resistor, is reduced. By arranging the partial shunt resistors in a small space on one side or both sides of the circuit board, the smallest possible magnetically effective surface is created or an antenna effect of the arrangement is reduced. This reduces the effect of interference fields or interferences from other assemblies, since this effect is always related to the antenna effect of the arrangement. The susceptibility to interference of the parallel or meandering arrangement of the partial shunt resistors is reduced, while the robustness of the arrangement for current measurement is increased.

[27] The lower inductance of the arrangement for current measurement also leads to an

advantageous reduction in the interference signals emanating from the arrangement.

[28] Furthermore, measuring lines as connecting lines between the corresponding soldering pads and a measuring amplifier for amplifying the voltage U_{shunt} to be measured across the partial shunt resistors can be placed at a short distance from one another on the circuit board, since the soldering pads of the respective second ends of the partial shunt resistors can be arranged closely adjacent to one another. In this case, the soldering pads can be arranged closely adjacent to one another both on one side of the circuit board and on the opposite sides of the circuit board. In the latter case, the minimum distance between the soldering pads is specified by the material thickness of the circuit board.

[29] The arrangement of the measuring pickoffs at a very short distance from one another, in conjunction with short measuring lines between the soldering pads and the measuring amplifier, also reduces the magnetically effective surface or the antenna effect and leads to improved interference immunity.

[30] Overall, the improvement in the interference immunity of the arrangement for current measurement leads to an improvement in the accuracy when measuring the current I_{shunt}. An arrangement of this type can therefore be used for current measurement in areas in which there are high requirements with regard to the accuracy of the current measurement and the robustness.

Brief Description of Drawings

[31] Further details, features and advantages of configurations of the invention are apparent from the following description of exemplary embodiments with reference to the associated drawings.

[32]

[33] Figure 1: shows a DC to AC converter from the prior art,

[34] Figure 2: shows an arrangement for current measurement according to the invention in a first embodiment,

[35] Figure 3: shows a further arrangement for current measurement according to the invention in a second embodiment and

[36] Figure 4: shows an illustration of soldering pads and measuring lines of the arrangement according to the invention.

Mode for the Invention

[37] The arrangement for current measurement according to the invention can be utilized, for example, to measure the phase currents or the currents I_{shunt1}, I_{shunt2}, I_{shunt3} of motor phases U, V and W in a DC to AC converter 2 shown as an example in **Figure 1**. However, there is no limitation to the utilization of the arrangement for current measurement in a DC to AC converter.

[38] A very common circuit arrangement for the regulated control of electrical drives by means of a DC to AC converter 2 is shown in Figure1 with a so-called B6 bridge or B6 bridge circuit.

[39] The B6 bridge comprises three half bridges 3a, 3b, 3c, each consisting of a high-side power switch 4 and a low-side power switch 5. The power switches 4, 5 or semi-conductor power switches are, for example, MOSFET, short for: metal-oxide-semiconductor field-effect transistor or as IGBT, short for insulated-gate bipolar transistor.

[40] Within a half bridge 3a, 3b, 3c, a connection of the high-side power switch 4 is directly connected to a connection of the low-side power switch 5 as well as an output of the half-bridge 3a, 3b, 3c or of the DC to AC converter 2. The voltage of a phase U, V, W generated by the half bridge 3a, 3b, 3c, for example for operating a connected electric motor 6, is output via the output.

[41] To measure the phase currents, phase current measuring shunt resistors or shunt resistors 7a, 7b, 7c are arranged in a series circuit with the half bridges 3a, 3b, 3c. The first shunt resistor 7a is assigned to the first half bridge 3a, while the second shunt resistor 7b is assigned to the second half bridge 3b, and the third shunt resistor 7c is assigned to the third half bridge 3c.

[42] As is known from the prior art, the respective phase currents i_{ph1}, i_{ph2}, i_{ph3}, which correspond to the currents I_{shunt1}, I_{shunt2}, I_{shunt3} shown in Figure 1, are determined by means of the voltage drop across the respective shunt resistor 7a, 7b, 7c. For this purpose, a measuring amplifier 8a, 8b, 8c is arranged across the shunt resistor 7a, 7b, 7c to detect the voltages. On the basis of the voltages determined in this way and the known magnitude of the respective shunt resistor 7a, 7b, 7c, Ohm's law is used and the respective phase current i_{ph1}, i_{ph2}, i_{ph3} or the illustrated currents I_{shunt1}, I_{shunt2}, I_{shunt3} is/ are calculated. The calculation can already take place in the measuring amplifiers 8a, 8b, 8c if they are equipped with the appropriate logic. This means that the measuring amplifiers 8a, 8b, 8c can already output values for the currents I_{shunt1}, I_{shunt2}, I_{shunt3} at the respective output of the measuring amplifiers 8a, 8b, 8c, for example in digital form, by means of which a central control unit not shown in Figure 1 controls the DC to AC converter 2. Alternatively, the signals at the outputs of the measuring amplifiers 8a, 8b, 8c are fed to a corresponding processing unit, which is likewise not shown in Figure 1.

[43] A unit consisting of the shunt resistor 7a, 7b, 7c and the associated measuring amplifier 8a, 8b, 8c is referred to as an arrangement 1' for current measurement according to the prior art, as shown by way of example in Figure 1 with the shunt resistor 7c and the associated measuring amplifier 8c as arrangement 1'. In the formation of the arrangement 1' for current measurement according to the prior art, the

disadvantages already described at the beginning occur, which are overcome by the present invention.

[44] **Figure 2** shows an arrangement 1 for current measurement according to the invention in a first embodiment. A first partial shunt resistor 10 and a second partial shunt resistor 11 are arranged on a first side of a circuit board not shown. Here, the first partial shunt resistor 10 and the second partial shunt resistor 11 are aligned with the longitudinal axes 12 in parallel to one another. In one embodiment, the partial shunt resistors 10, 11 have the same resistance value and thus in each case half the resistance value of the shunt resistance needed for the current measurement. However, such a half division of the resistance value is not mandatory.

[45] According to the embodiment of the arrangement 1 according to Figure 2, the two partial shunt resistors 10, 11 are formed as SMD components which have corresponding solderable terminal surfaces for contacting. The first partial shunt resistor 10 is electrically conductively connected or soldered with a first terminal surface 13 to a first soldering pad 17.

[46] Such a soldering pad provides a soldering surface which establishes a connection between a component, such as a partial shunt resistor 10, 11, and a conducting path on the circuit board 9.

[47] The first partial shunt resistor 10 is electrically conductively connected or soldered with a second terminal surface 14 to a common soldering pad 18, to which a first terminal surface 15 of the second partial shunt resistor 11 is also soldered. A second terminal surface 16 of the second partial shunt resistor 11 is connected to a second soldering pad 19.

[48] The first soldering pad 17 and the second soldering pad 19 establish the connections of the arrangement 1 for current measurement in the current path in which the current is to be measured, like the current I_{shunt3} shown in Figure 1.

[49] As shown in Figure 2, the common soldering pad 18 is dimensioned with appropriate dimensions in order to maximize the dissipation of the heat generated in the partial shunt resistors 10, 11. The arrows shown illustrate the heat spread 20 or the heat dissipation 20 from the partial shunt resistors 10, 11.

[50] To measure the voltage U_{shunt}, which drops across both partial shunt resistors 10, 11 and is measured to determine the current, the soldering pads 17, 19 are connected to the inputs of a measuring amplifier 22 by means of conductor tracks formed as measuring lines 21. At an output 23 of the measuring amplifier 22, either a value for the current to be measured, such as I_{shunt3}, or a signal intended for further processing is output.

[51] The adjacent arrangement of the soldering pads 17, 19 makes it possible for the measuring lines 21 and the measuring amplifier 22 to be arranged very closely spaced.

It is also possible to place the measuring amplifier 22 very close to the soldering pads 17, 19 so that the length of the measuring lines 21 is minimal. The measures also have the effect that an area 26 creating a magnetically effective surface, via which interference can be coupled in, is minimized. By means of the arrangement 1 for current measurement, the resulting antenna effect is also minimized and the heat dissipation from the partial shunt resistors 10, 11 is maximized.

[52] In Figure 2, the current flow 24 through the arrangement 1 for current measurement is visualized by means of dash-dash lines, wherein a meandering current flow 24 can be seen, which also supports the concept of a meandering arrangement of the partial shunt resistors 10, 11.

[53] No provision is made for limiting the arrangement 1 to two partial shunt resistors 10, 11. Four or more partial shunt resistors could also be arranged, which in aggregate provide the value of the shunt resistance needed for current measurement. Even if four partial shunt resistors are formed, the partial shunt resistors are preferably arranged with the longitudinal axes aligned in parallel to one another.

[54] **Figure 3** shows another embodiment of the arrangement 1 for current measurement, in which the two partial shunt resistors 10, 11 are not arranged on a common side of a circuit board 9, according to the embodiment of the arrangement 1 according to Figure 2, but on two different sides of the circuit board 9.

[55] The first partial shunt resistor 10 is arranged on a first side of the circuit board 9, while the second partial shunt resistor 11 is arranged on a second side of the circuit board 9 opposite the first side. The partial shunt resistors 10, 11 are thus arranged opposite one another with the smallest possible distance from one another. The longitudinal axes 12 of the partial shunt resistors 10, 11 are aligned in parallel to one another.

[56] The first partial shunt resistor 10 is electrically conductively connected or soldered with the first terminal surface 13 to the first soldering pad 17 and with the second terminal surface 14 to a first part of a common soldering pad 18a.

[57] The first terminal surface 15 of the second partial shunt resistor 11 is electrically conductively connected to a second part of a common soldering pad 18b, while the second terminal surface 16 of the second partial shunt resistor 11 is electrically conductively connected to a second soldering pad 19.

[58] Several vias 25 are formed between the first part of the common soldering pad 18a and the second part of the common soldering pad 18b, which connect both parts of the common soldering pad 18a, 18b to one another in an electrically conductive manner and thus form a common soldering pad. The vias 25 enable both an electrically conductive and a thermally conductive connection of the parts of the common soldering pad 18a, 18b. The parts of the common soldering pad 18a, 18b are formed to

be larger than necessary for contacting the terminal surfaces 14, 15 of the partial shunt resistors 10, 11 in order to maximize the heat dissipation 20, for example.

[59] The meandering current flow 24 through the arrangement 1 for current measurement is also visualized in Figure 3 by means of dash-dash lines.

[60] The first soldering pad 17 and the second soldering pad 19 in turn establish the connections of the arrangement 1 for current measurement in the current path in which the current is to be measured, like the current I_{shunt3} shown in Figure 1.

[61] The adjacent arrangement of the soldering pads 17, 19 makes it possible to arrange the measuring lines 21 to the measuring amplifier 22 very closely spaced apart from one another. It is also possible to place the measuring amplifier 22 not shown in Figure 3 very close to the soldering pads 17, 19, which results in a minimal length of the measuring lines 21. In addition, these measures lead in turn to the fact that the area 26 creating a magnetically effective surface, via which interference can be coupled in, is minimized. The resulting antenna effect is also minimized by means of the arrangement 1 for current measurement and the heat dissipation from the partial shunt resistors 10, 11 is maximized.

[62] Also in the embodiment of the arrangement 1 for current measurement according to Figure 3, the arrangement 1 can be expanded by a further two or more partial shunt resistors. For example, two partial shunt resistors could be arranged on the first side of the circuit board 9 and two partial shunt resistors could be arranged on the second side of the circuit board 9. In this case, a series circuit of the partial shunt resistors arranged in parallel to one another is provided, which in aggregate provides the shunt resistance needed for current measurement in the current path.

[63] For better understanding, **Figure 4** provides an illustration of soldering pads 17, 18, 19 and measuring lines 21 of the arrangement 1 for current measurement without the partial shunt resistors 10, 11 on a surface of the circuit board 9, according to the embodiment of the arrangement 1 shown in Figure 2.

[64] The small distance between the first soldering pad 17 and the second soldering pad 19 as well as the closely spaced apart routing of the measuring lines 21 to the measuring amplifier 22 with the output 23 made possible thereby become clear.

[65] Both the two soldering pads 17, 19 and the common soldering pad 18 are formed with larger surfaces than are necessary for contacting the partial shunt resistors 10, 11 in order to maximize the heat dissipation 20 in this way.

Industrial Applicability

[66] The invention relates to an arrangement for current measurement, in which a shunt resistor is arranged in a current path in which a current is measured.

Claims

[Claim 1] An arrangement (1) for current measurement, in which a shunt resistor (7a, 7b, 7c) is arranged in a current path in which a current is measured, **characterized in that** at least a first partial shunt resistor (10) and a second partial shunt resistor (11) are arranged in a series circuit, wherein the partial shunt resistors (10, 11) are arranged together on one side of a circuit board (9) or on different, opposite sides of the circuit board (9), wherein the partial shunt resistors (10, 11) are arranged with longitudinal axes (12) in parallel and spaced apart from one another.

[Claim 2] The arrangement (1) according to claim 1, **characterized in that** the partial shunt resistors (10, 11) have the same resistance values.

[Claim 3] The arrangement (1) according to claim 1 or 2, **characterized in that** the first partial shunt resistor (10) is electrically conductively connected to a first soldering pad (17) with a first terminal surface (13) and to a common soldering pad (18) with a second terminal surface (14), and in that the second partial shunt resistor (11) is electrically conductively connected to the common soldering pad (18) with a first terminal surface (15) and to a second soldering pad (19) with a second terminal surface (16).

[Claim 4] The arrangement (1) according to claim 1 or 2, **characterized in that** the first partial shunt resistor (10) is electrically conductively connected to a first soldering pad (17) with a first terminal surface (13) and to a first part of a common soldering pad (18a) with a second terminal surface (14), and that the second partial shunt resistor (11) is electrically conductively connected to a second part of a common soldering pad (18b) with a first terminal surface (15) and to a second soldering pad (19) with a second terminal surface (16).

[Claim 5] The arrangement (1) according to claim 4, **characterized in that** vias (25) are arranged between the first part of the common soldering pad (18a) and the second part of the common soldering pad (18b).

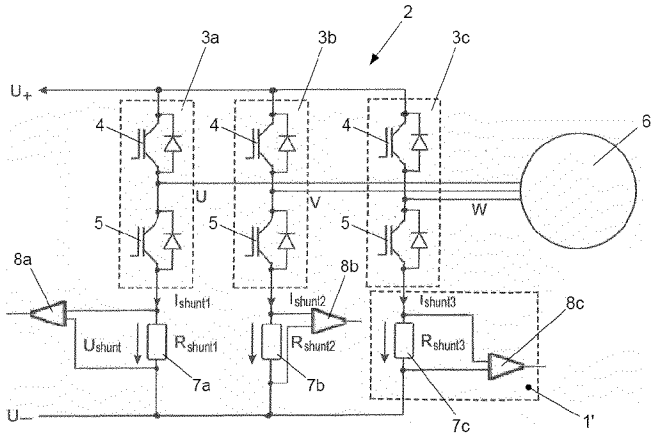
[Claim 6] The arrangement (1) according to any one of claims 1 to 5, **characterized in that** measuring lines (21) are arranged between the first soldering pad (17) and the second soldering pad (19) as well as a measuring amplifier (22).

[Claim 7] The arrangement (1) according to claim 6, **characterized in that** the measuring amplifier (22) has an output (23) via which a measured value for the current to be measured is output.

[Claim 8] The arrangement (1) according to claim 6 or 7, **characterized in that** an arrangement for analog-to-digital conversion is arranged in the measuring amplifier (22).

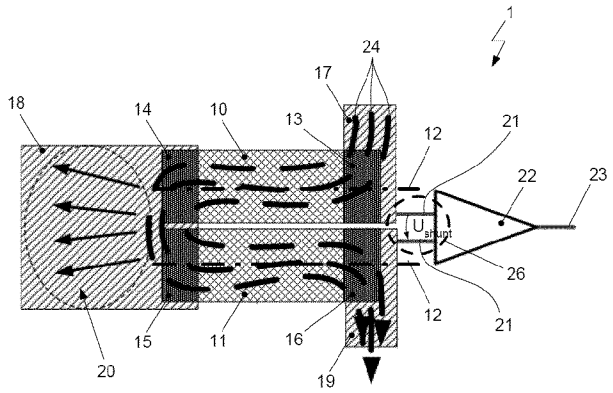
[Claim 9] The arrangement (1) according to any one of claims 1 to 8, **characterized in that** the partial shunt resistors (10, 11) are formed as SMD components.

[Fig. 1]

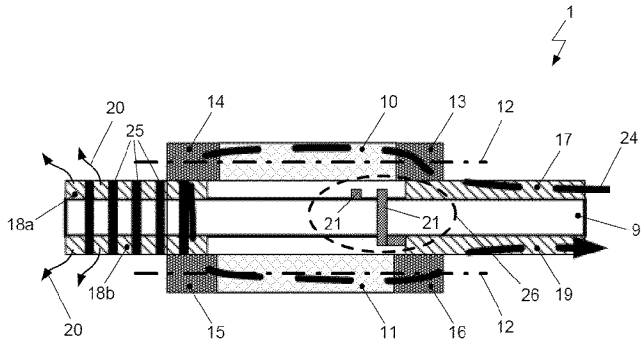


Prior art

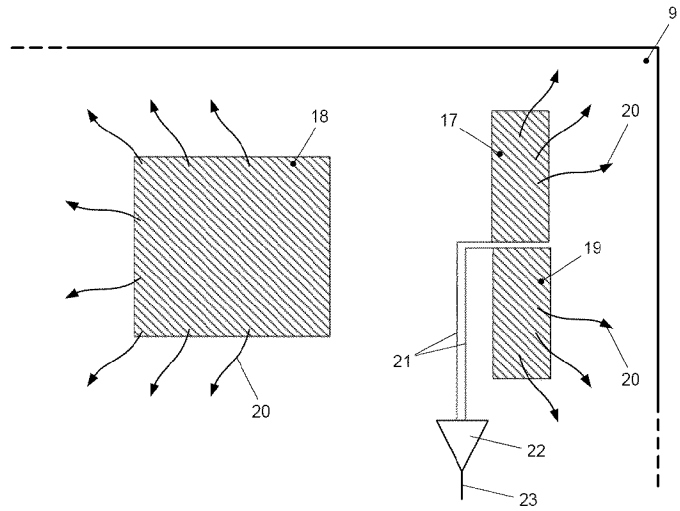
[Fig. 2]



[Fig. 3]



[Fig. 4]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2021/002162

A. CLASSIFICATION OF SUBJECT MATTER

G01R 1/20(2006.01)i; **G01R 1/30**(2006.01)i; **G01R 19/00**(2006.01)i

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)

G01R 1/20(2006.01); B60L 3/00(2006.01); G01R 15/14(2006.01); G01R 19/00(2006.01); H01C 1/084(2006.01); H01C 13/00(2006.01); H05K 7/20(2006.01)

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

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: shunt resistor, series, circuit board, surface mount

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014-0266269 A1 (INFINEON TECHNOLOGIES AG) 18 September 2014 (2014-09-18)	1-3,6-9
Y	paragraphs [0046]-[0092] and figures 3, 5	4,5
Y	US 2004-0263150 A1 (ULLRICH HETZLER) 30 December 2004 (2004-12-30) paragraphs [0052], [0060] and figure 2	4,5
Y	JP 2016-115834 A (DAIKIN IND. LTD.) 23 June 2016 (2016-06-23) paragraphs [0026], [0027], claim 1 and figure 3	5
A	US 2017-0089955 A1 (SANYO ELECTRIC CO., LTD.) 30 March 2017 (2017-03-30) paragraphs [0018]-[0021] and figures 2, 5	1-9
A	JP 2014-049516 A (MITSUBISHI ELECTRIC CORP.) 17 March 2014 (2014-03-17) paragraphs [0027], [0028] and figure 6	1-9

☐ Further documents are listed in the continuation of Box C. ☑ 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
18 June 2021	**18 June 2021**

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2021/002162

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