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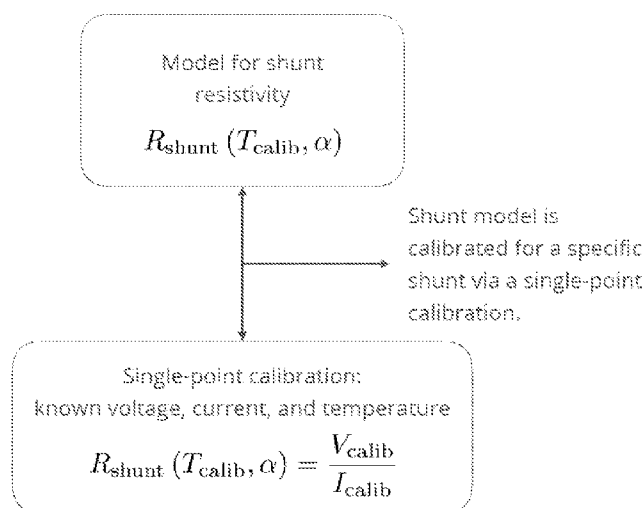


Fig. 11

(57) Abstract: The invention draws upon an insight that if the distance between the Sensing Points of a shunt is precisely defined and is repeatable (for example, due to the punching tool used to create the holes for the Sensing Points), then accurate calibration and determination of the Thermal Compensation function of the shunt can be done by means of a single measurement at room temperature. Saying this differently, once the calibration according to the invention has been carried out, the shunt can be used to achieve very accurate current measurements at any of a range of temperatures, and yet (perhaps counter-intuitively) the calibration itself only needs to be carried out at a single temperature.



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Method of predicting thermal resistive behavior of shunts

Background

The invention relates to the general goal of accurate current measurements in a shunt, with the measurements being accurate at any of a range of temperatures of the shunt, while minimizing the number of calibration measurements that were previously needed to bring about the desired level of accuracy.

Resistive shunts are used extensively as current measurement devices in a wide variety of applications. When current passes through a resistive shunt, a voltage which is proportional to the shunt's resistance develops across it, according to Ohm's law $V=I \cdot R$. This voltage is typically read by a microcontroller, through an analog-to-digital converter, and if the shunt resistance value is known it is converted to a current value.

A typical shunt suitable for measuring large values of current is shown in Figure 1.

The main resistive element of the shunt is constructed by a strip of manganin, or another alloy with similar properties, which is welded to copper plates on both sides. Measurement points are created via any of several methods (welding, inserted pins, soldered pins, direct soldering on PCB or copper extrusions) to provide connections with the measurement circuit electronics.

Manganin (or a material with similar properties) exhibits a much higher specific resistance than copper, so its utilization contributes to a smaller overall size for a shunt of a given resistance value. In addition, manganin has a very low temperature coefficient, so its resistance value changes very little with temperature. Figure 2 shows a typical temperature coefficient of resistance for manganin. The alert reader appreciates that the vertical axis is stretched, and that over wide ranges of temperature the curve shown is actually very close to being flat.

Copper is a very good conductor of both electricity and heat and its main contribution in the shunt utilization is the efficient dissipation of heat without any significant contribution toward the generation of heat. A typical dependency of resistivity upon temperature for copper is depicted in Figure 3. Typical values for high current shunts such as are being discussed herein are in the range of 10s or 100s of $\mu\Omega$.

In applications where accuracy of current measurement is critical, it is desirable to compensate for temperature effects in measurement. As can be seen from the above charts, copper resistivity has much more dependence on temperature than manganin. At high temperatures (which happen for example because of high currents) the contribution of copper paths between the “measurement points” and the manganin edges can introduce a relatively significant error contribution in current measurements.

Measurements of large currents (in the range of hundreds of Amperes) are difficult. Various techniques are typically utilized, including sensing of magnetic field around the conductor (for example Hall-effect-based instruments and the like), and measurements based on the voltage drop across a known resistor (shunt). The former method has some specific advantages, one of them being the relative insensitivity to external magnetic fields. Indeed a shunt-base current measurement system is often preferred over other methods.

As was mentioned above, a typical shunt is constructed from two different materials: a first material is made from a “proper” resistive material with very small TCR (Temperature Coefficient of Resistance), and a second material with high conductance (typically copper) is used for the terminals of the shunt, for connection into the circuit. A simplified make-up of a typical shunt is shown in Figure 4.

The dissimilar materials are attached (mechanically and electrically) to each other with welding, with electron-beam welding often used for the creation of strong and well-defined (narrow) weld lines. Such weld lines are pointed out in Figure 4. However, no matter how good and consistent the welding process may be, the exact dimensions of the Main Resistive Element cannot be controlled exactly.

It will be appreciated by the alert reader that it is desirable to have as small resistance of the high-current shunt, as possible, to minimize the so-called resistive or Joule heat losses. Therefore, the width of the Main Resistive Element is made to be very narrow, as to reduce the overall resistance. But this leaves extant the situation that variations of the width of the Main Resistive Element due to welding process result in variations of the resistance of the whole shunt, from one shunt to the next. Furthermore, as the Sensing Points are typically located on the copper material of the shunt's terminals, the TCR of the whole shunt depends on the resistance of the Main Resistive Element and on the resistance of the (copper) portions of the terminals between the welding lines to the Main Resistive Element and the Sensing Points.

As was discussed above, typically the Main Resistive Element virtually does not vary its resistance with temperature, while copper exhibits (at room temperature) a non-negligible resistance change with temperature. It is often approximately $0.393\% / ^\circ\text{C}$. What will be appreciated then is that variations from one shunt to the next of the width of the Main Resistive Element due to welding process also result in variations of the TCR of the whole shunt, from one shunt to the next.

With this general background, what is appreciated is that if a particular shunt is to be used in production at any of a range of temperatures, what is needed is some kind of calibration. The legacy approach for such a calibration is, for each shunt that is produced in a manufacturing process, the shunt is carefully brought to each of several predetermined temperatures, and the resistance of the shunt is carefully and accurately measured. But using such a legacy approach for accurate calibration and determination of the Thermal Compensation function of the shunt with varying TCR requires a time-consuming process of measurements at multiple temperatures.

It would be extremely helpful if an approach could be devised for arriving at an accurate thermal compensation function for each individually manufactured shunt, and if this approach could be achieved by means of a single measurement at room temperature.

Summary of the invention

As will be described in some detail, the invention draws upon an insight that if the distance between the Sensing Points is precisely defined and is repeatable (for example, due to the punching tool used to create the holes for the Sensing Points), then accurate calibration and determination of the Thermal Compensation function of the shunt can be done by means of a single measurement at room temperature. Saying this differently, once the calibration according to the invention has been carried out, the shunt can be used to achieve very accurate current measurements at any of a range of temperatures, and yet (perhaps counter-intuitively) the calibration itself only needs to be carried out at a single temperature.

Description of the drawing

The invention is described with respect to a drawing in several figures.

Figure 1 shows a typical shunt suitable for measuring large values of current.

Figure 2 shows a typical temperature coefficient of resistance for manganin.

Figure 3 shows a typical dependency of resistivity upon temperature for copper.

Figure 4 shows a simplified make-up of a typical shunt.

Figure 5 depicts thermal characteristics of several shunts that are nearly identical.

Figure 6 shows a plurality of sloped lines each representing the resistance dependence of a particular shunt that differs from other shunts.

Figure 7 shows how other shunts (among many shunts) compare with a nominal-center shunt in terms of deviations due to temperature change.

Figure 8 shows manufacturing variations from one shunt to the next in thermal behavior of each of the shunts.

Figure 9 shows which shows in block diagram form a shunt resistance model.

Figure 10 shows a number of curves each modeling resistance as a function of temperature, each curve tied to a particular geometry of a particular shunt.

Figure 11 shows in block diagram form the sequence of steps for arriving at a resistance model for a particular shunt.

Figure 12 shows selection of one curve based upon one resistance measurement of a shunt at one temperature.

Detailed description

As mentioned above, a single calibration measurement takes place for a particular shunt (typically a shunt that has just been manufactured). With the insights described herein, that single measurement permits later use of the shunt to carry out accurate current measurements across a range of temperatures differing substantially from that single temperature at which the calibration measurement was carried out.

The process and relevant points are described below.

It will be appreciated that there is a correlation (and in the simplest form – a linear dependency) for the TCR of the shunt and its resistance. The reader is reminded that this is for the particular case when the distance between the Sensing Points is rigidly fixed.

Figure 5 depicts thermal characteristics of several shunts that are nearly identical but with the variation of the resistance due to variations of the width for the Main Resistive Element. Each angled line on the graph shows dependence of resistance upon temperature for each of a number of particular shunts, each different from the next due to non-identical values for the width of the Main Resistive Element.

It can be seen in Figure 5 that the overall resistance increases with the temperature for all variations of the shunt; however, the slope (or TCR) of the various shunts is subtly different. The slightly varying slopes are perhaps not easy to perceive in Figure 5. Because the slightly varying slopes may not be easily perceived, it may be helpful to present the same information in a different way, which the resistance changes are expressed as percentile points, normalizing the curves for an arbitrary ambient temperature of 25 degrees C. In Figure 6, we see a plurality of sloped lines, each sloped differently from the next, each representing the resistance dependence of a particular shunt that differs from other shunts because its Main Resistive Element has a different width than that of the other shunts. Another way to say this is that in Figure 6, what is depicted are resistance changes (deviations) expressed as

percentile points, for all variations of the shunts; these curves have been normalized at the room temperature of 25 C.

Even in Figure 6, perhaps the differences from one shunt to the next may not be quite as easily perceived as would be desired. Thus in Figure 7 we pick one shunt among many, as a shunt having a nominal center value for its resistance dependence upon temperature, and we show how other shunts (among the many shunts) compare with the nominal-center shunt in terms of deviations due to the temperature change. The other shunts that are not the selected nominal-center value shunt are referenced to the shunt with the nominal-center value in Figure 7, and thus the difference in TCR can be clearly observed.

The insight relied upon for the present invention will now be understood by the alert reader. The alert reader will recognize that the individual curves for individual shunts among many, can be readily rotated, based on the initial room-temperature resistance for each particular shunt, with the result that only a single pre-computed Compensation Table or Formula has to be discovered (specifically, and only for the shunt with the nominal room-temperature resistance).

All variations of the shunt due to the varying width of the Main Resistive Element can be accommodated with an adjustment based on a single measurement of the initial room-temperature resistance.

It is therefore desirable to compensate for this error during the course of measurements. Measuring the thermal behavior of a representative shunt and using it as a model for any other shunt will not work, as can be seen in Figure 8, because of manufacturing variations.

Once again, we remind ourselves that the legacy approach for each shunt being manufactured is to measure the resistance of each shunt at any of a number of temperatures, followed by which during actual use for measurements of currents, resistance values are interpolated from those measured calibration values. But as was mentioned earlier, while this legacy approach can deliver satisfactorily results, it has the drawback it makes the shunt expensive. The shunt

has to be brought to any of a number of temperatures, each temperature has to be stabilized, and only then can a calibration measurement of resistance be carried out.

It will thus be helpful to review the background for the calibration method according to the invention. We understand that a key parameter in shunt-based current measurement systems is the resistance of the shunt as a function of the shunt temperature. The temperature of a particular shunt when in use for actual current measurements is likely to change from time to time; for example the temperature of the shunt can increase for the very reason that a high current has recently flowed through the shunt. As current flows in the measurement systems, the temperature of the shunt can increase due to various physical effects.

The shunt is of course necessarily thermally coupled with its environment, and thus this also affects the temperature of the shunt. Said differently, if the temperature nearby to the shunt goes higher or lower, this may tend to raise or lower the temperature of the shunt accordingly.

The changes in the temperature of the shunt that happen in the ordinary course of operational use of the shunt, leads to changes in the resistance of the shunt during operations. If the current passing through the shunt is to be accurately measured in operation, there is no choice but to account for the dependence of the shunt resistance on the shunt temperature.

The assumption is that for each particular shunt that has been manufactured, some table of values of resistance as a function of temperature is available, so that interpolation can be carried out, or that some ad-hoc function is assumed to model the resistance accurately, either of which draws upon actual resistances measured at calibration time for that particular shunt, at each of a number of predetermined temperatures. Again it is recalled that mechanical (for example dimensional) variations in each particular shunt that has been manufactured, due to the manufacturing process, can introduce changes in the way the shunt resistance depends on the shunt temperature.

Having reviewed this background we return again to the insights offered by the invention. The insight is that for each particular shunt that has been manufactured, a single-point calibration method can be performed at a single temperature point. The method described

here makes it possible in a shunt-based current measurement system to account for variations in the shunt dimensional properties due to the manufacturing process (for example the above-mentioned variations in welding). In particular, it accounts for variations in the geometric parameters of the shunt. For a copper-manganin shunt it will account for variations in the ratio of the two components. This method enhances the accuracy of the shunt-based current measurement system while maintaining a fast calibration time.

We turn now to Figure 9, which shows in block diagram form a shunt resistance model. A model for shunt resistance as a function of temperature is constructed from physics-based and knowledge-based approaches. The outcome is a model for resistance that takes two inputs – the temperature of the shunt T , and a value α that pulls together the geometrical (dimensional) parameters of the particular shunt. The knowledge-based approach draws upon data collected from a large number of shunts, to validate the physics-based model. Figure 10 shows a number of curves (functions) predicting resistance of a particular shunt over a range of temperatures, and each curve takes into account variations in geometry of particular shunts. For each particular shunt that has been manufactured, we carry out just one resistance measurement at some predetermined temperature, and this permits selecting one or another of the curves depicted in Figure 10 for that shunt.

Figure 11 shows in block diagram form the sequence of steps for arriving at a resistance model for a particular shunt. The first block assumes that we have arrived at a functional model for resistivity as a function of temperature, the model yielding a shunt resistance based upon a temperature at which the calibration took place, and the value α that is based upon the known geometry of the shunt, here assumed to be a precise knowledge of the distance between Sensing Points.

Figure 12 shows selection of one curve based upon one resistance measurement of a shunt at one temperature. For the newly manufactured shunt, one resistance measurement is carried out, and this permits selecting one curve from the model. That curve is relied upon subsequently to permit accurate current measurements in actual operation.

It will thus be helpful to make a distinction between calibration and operation. A particular shunt, perhaps newly manufactured, will get calibrated. After that, it is placed into operation. The operational phase involves many current measurements, each of which involves passing a current through the shunt and measuring voltage at sensing points, and making note of the temperature of the shunt at the time of the voltage measurement. What we can describe is a method for carrying out operational current measurements at various temperatures using a first shunt, the method carried out with respect to a plurality of other shunts in addition to the first shunt, each shunt comprising a first region made of a first material having a first specific resistivity, each shunt having to one side of the first region a second region made of a second material having a second specific resistivity, the second region mechanically connected to the first region, each shunt having to an opposite side of the first region a third region made of the second material, the third region mechanically connected to the first region, the second specific resistivity being lower than the first specific resistivity, the second material varying in resistivity as a function of temperature more than the first material, the second region and third region each having a respective first and second sensing point, for each shunt the first and second sensing points defining a known respective distance therebetween.

One part of the calibration process is that for for each shunt among the plurality of other shunts in addition to the first shunt, measurements of resistance between the sensing points are carried out at each of a plurality of temperatures, and a note is made of the distance between the sensing points for the each shunt.

Another part of the calibration process is that a model is devised for shunt resistance as a function of temperature and as a function of the distance between the sensing points.

Another part of the calibration process is that for some particular shunt, typically a shunt that has just been manufactured, a single calibration defined by a measurement of resistance between the sensing points at a single predetermined temperature is carried out, and a note is made of the distance between the sensing points for the first shunt.

The first shunt is then placed into operational service. During this operational service, a first operation is carried out with the first shunt, measuring a first operational current at a first

operational temperature that is different from the single predetermined temperature, the first operational current arrived at by measuring a first voltage between the sensing points and dividing it by a first resistance derived from the model based upon the first operational temperature. It will be borne in mind that the derivation of the first resistance from the model does not depend upon geometric measurements at the first shunt other than the distance between the sensing points for the first shunt.

Eventually what will happen is that the shunt, in operation, arrives at some second operational temperature that is different from the single predetermined temperature and that is different from the first operational temperature. At that time, a second operation is carried out with the first shunt, measuring a second operational current. The second operational current is arrived at by measuring a second voltage between the sensing points and dividing it by a second resistance derived from the model based upon the second temperature. It is again borne in mind that the derivation of the second resistance from the model does not depend upon geometric measurements at the first shunt other than the distance between the sensing points for the first shunt.

Then after the passage of more time the shunt, in operation, arrives at some third operational temperature that is different from the single predetermined temperature and that is different from the first operational temperature and that is different from the second operational temperature. At that time, a third operation is carried out with the first shunt, measuring a third operational current. The third operational current is arrived at by measuring a third voltage between the sensing points and dividing it by a third resistance derived from the model based upon the third temperature. It is yet again borne in mind that the derivation of the third resistance from the model does not depend upon geometric measurements at the first shunt other than the distance between the sensing points for the first shunt.

As mentioned above, in a typical embodiment of the invention, the first material is manganin and the second material is copper.

As mentioned above, it may be very desirable to try to simplify the modeling and calibration and by trying very hard to make the physical distance between the sensing points as close as

possible to being the same from one shunt to the next. One way to try to control this is by using a precise tool to construct the sensing points.

As mentioned above, in a typical manufacturing process the mechanical connection between the first and second region is a welded connection, and the mechanical connection between the first and third regions is a welded connection.

In a typical sequence of events, the carrying-out of measurements with respect to each shunt among the plurality of other shunts in addition to the first shunt will take place chronologically prior to the carrying out of the single calibration of the first shunt defined by a measurement of resistance between the sensing points at a single predetermined temperature. But nothing about the invention requires this sequence. It might happen that the calibration measurements for the first shunt might happen first, and then some later measurements of other shunts might be taken into account for development of, or revision of, the model.

It will be helpful to say a bit more about the model that is devised for this inventive approach to predicting thermal resistive behavior of shunts. The benefits of the invention do not require the use of any particular model other than that the model require and depend upon the limited inputs described, such as a resistance measurement of a newly manufactured shunt at a single temperature as distinguished from some other model that would require measurements at each of several distinct temperatures. Thus, for example, the model could be as simple as the selection of one or another of the sloped lines depicted in Figure 5, depending on the resistance that was measured in the newly manufactured shunt. The model could, as discussed above, be a model based upon physics, taking into account the dimensions and geometry of the various parts of the shunt, the known electrical properties of the material from which each of the parts of the shunt is made, and the physical locations of the sensing points. The model could, as discussed above, be a model based upon a methodical empirical measurement of resistances in various shunts at various temperatures, with an assumption that the manufacturing process that yielded the shunts is fairly consistent in the resulting geometry of the parts of the shunt, and is fairly consistent in the places where the sensing points are connected to the shunt. Desirably the model can be a blend of these

two approaches. But it should be emphasized that the alert reader will have no difficulty selecting a model among these possible approaches, or devising a model that is a blend of two or more of these possible approaches. Again as the steps of the method are detailed above, and in the claims, it is not intended that the method be limited to any one exact detailed model, but instead it is intended merely that the model be a suitable model which, for a particular newly manufactured shunt, takes as its input only a resistance measurement at a single temperature, and does not require, for that particular newly manufactured shunt, a plurality of resistance measurements at a plurality of respective temperatures.

The alert reader, having received the benefit of the disclosures herein, will readily arrive upon obvious variants and improvements upon the invention, all of which are intended to be encompassed by the claims which follow.

Claims

1. A method for carrying out operational current measurements at various temperatures using a first shunt, the method carried out with respect to a plurality of other shunts in addition to the first shunt, each shunt comprising a first region made of a first material having a first specific resistivity, each shunt having to one side of the first region a second region made of a second material having a second specific resistivity, the second region mechanically connected to the first region, each shunt having to an opposite side of the first region a third region made of the second material, the third region mechanically connected to the first region, the second specific resistivity being lower than the first specific resistivity, the second material varying in resistivity as a function of temperature more than the first material, the second region and third region each having a respective first and second sensing point, for each shunt the first and second sensing points defining a known respective distance therebetween, the method comprising the steps of:

for each shunt among the plurality of other shunts in addition to the first shunt, carrying out measurements of resistance between the sensing points at each of a plurality of temperatures, and making note of the distance between the sensing points for the each shunt;

arriving at a model for shunt resistance as a function of temperature and as a function of the distance between the sensing points;

for the first shunt, carrying out a single calibration defined by a measurement of resistance between the sensing points at a single predetermined temperature, making note of the distance between the sensing points for the first shunt; and

in a first operation carried out with the first shunt, measuring a first operational current at a first operational temperature that is different from the single predetermined temperature, the first operational current arrived at by measuring a first voltage between the sensing points and dividing it by a first resistance derived from the model based upon the first operational temperature, the derivation of the first resistance from the model not depending upon

geometric measurements at the first shunt other than the distance between the sensing points for the first shunt;

in a second operation carried out with the first shunt, measuring a second operational current at a second operational temperature that is different from the single predetermined temperature, and that is different from the first operational temperature, the second operational current arrived at by measuring a second voltage between the sensing points and dividing it by a second resistance derived from the model based upon the second temperature, the derivation of the second resistance from the model not depending upon geometric measurements at the first shunt other than the distance between the sensing points for the first shunt; and

in a third operation carried out with the first shunt, measuring a third operational current at a third operational temperature that is different from the single predetermined temperature, and that is different from the first operational temperature, and that is different from the second operational temperature, the third operational current arrived at by measuring a third voltage between the sensing points and dividing it by a third resistance derived from the model based upon the third temperature, the derivation of the third resistance from the model not depending upon geometric measurements at the first shunt other than the distance between the sensing points for the first shunt.

2. The method of claim 1 wherein the first material is manganin and the second material is copper.

3. The method of claim 1 wherein the distances between the first and second sensing points are substantially identical for the first shunt and for the plurality of other shunts.

4. The method of claim 1 wherein the mechanical connection of the second region to the first region is a welded connection, and wherein the mechanical connection of the third region to the first region is a welded connection.

5. The method of claim 2 wherein the mechanical connection of the second region to the first region is a welded connection, and wherein the mechanical connection of the third region to the first region is a welded connection.
6. The method of claim 1 wherein the carrying out of measurements with respect to each shunt among the plurality of other shunts in addition to the first shunt takes place chronologically prior to the carrying out of the single calibration of the first shunt defined by a measurement of resistance between the sensing points at a single predetermined temperature.
7. An apparatus for current measurement, the apparatus comprising a first shunt having first and second sensing points, and comprising a voltage measurement means connected with the first and second sensing points, and comprising a temperature measurement means for measuring the temperature of the first shunt, the apparatus characterized in that it arrives at a measurement of current based upon a model stored therein, the model drawing upon the temperature of the first shunt and drawing upon a distance between the first and second sensing points, the model not drawing upon geometric measurements of the first shunt other than the distance between the first and second sensing points, the model drawing upon previous resistance measurements carried out on a plurality of other shunts in addition to the first shunt, the measurements of resistance between the sensing points carried out at each of a plurality of temperatures, note having been made of the distance between the sensing points for the each shunt, the first shunt and the each shunt each comprising a first region made of a first material having a first specific resistivity, each shunt having to one side of the first region a second region made of a second material having a second specific resistivity, the second region mechanically connected to the first region, each shunt having to an opposite side of the first region a third region made of the second material, the third region mechanically connected to the first region, the second specific resistivity being lower than the first specific resistivity, the second material varying in resistivity as a function of temperature more than the first material.

8. The apparatus of claim 7 wherein the mechanical connection of the second region to the first region is a welded connection, and wherein the mechanical connection of the third region to the first region is a welded connection.
9. The apparatus of claim 7 wherein the distances between the first and second sensing points are substantially identical for the first shunt and for the plurality of other shunts.
10. The apparatus of claim 7 wherein the first material is manganin and the second material is copper.
11. The apparatus of claim 8 wherein the first material is manganin and the second material is copper.

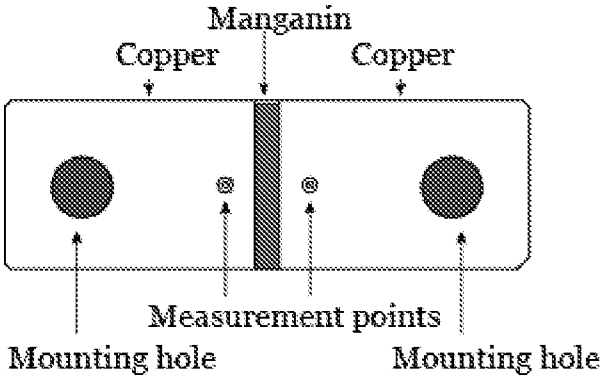


Fig. 1

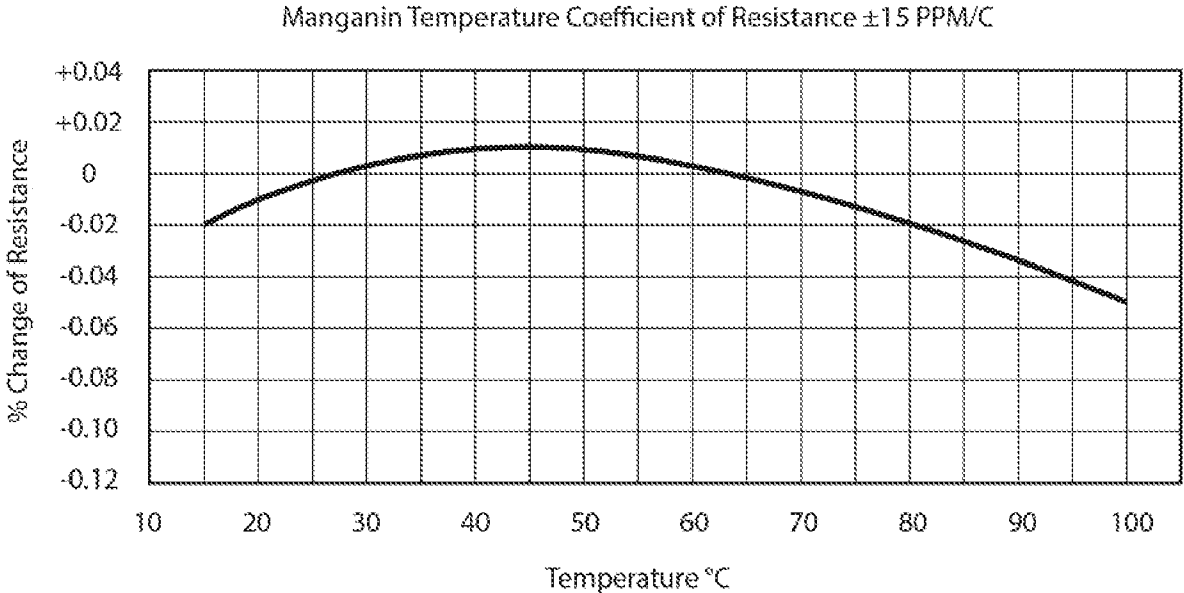


Fig. 2

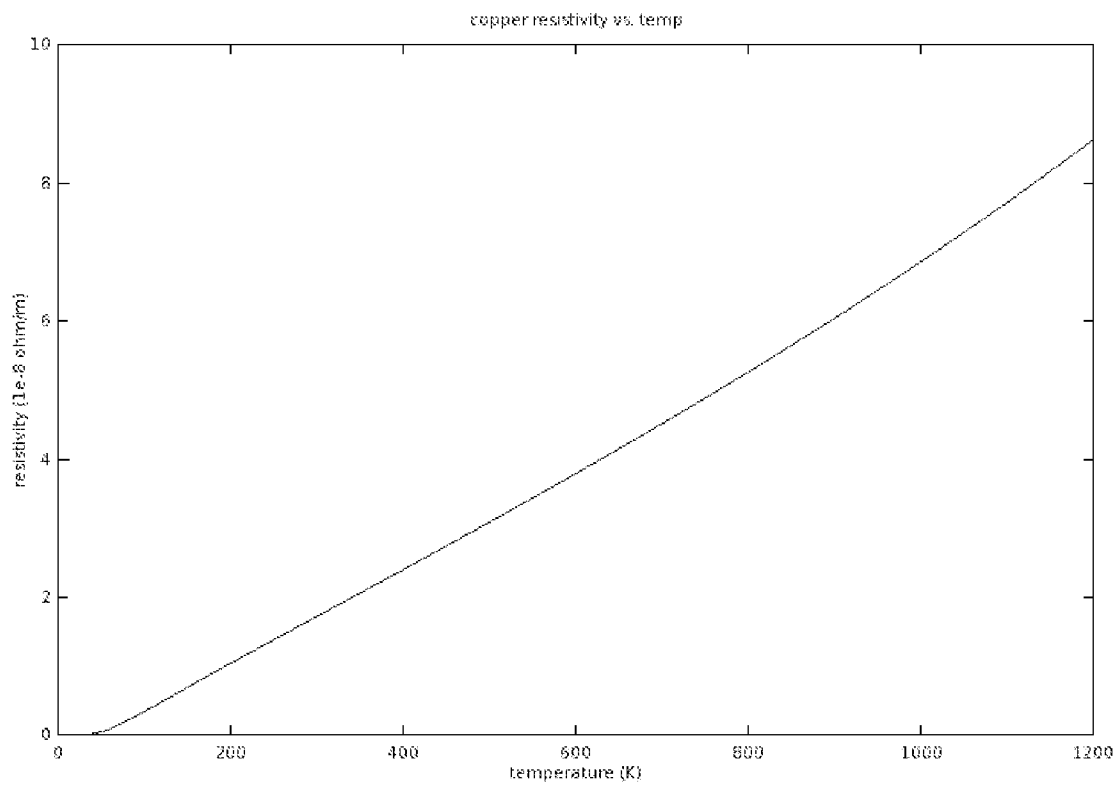


Fig. 3

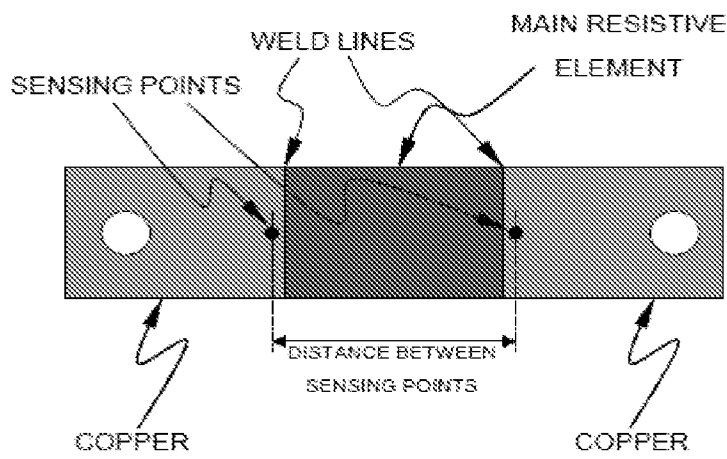


Fig. 4

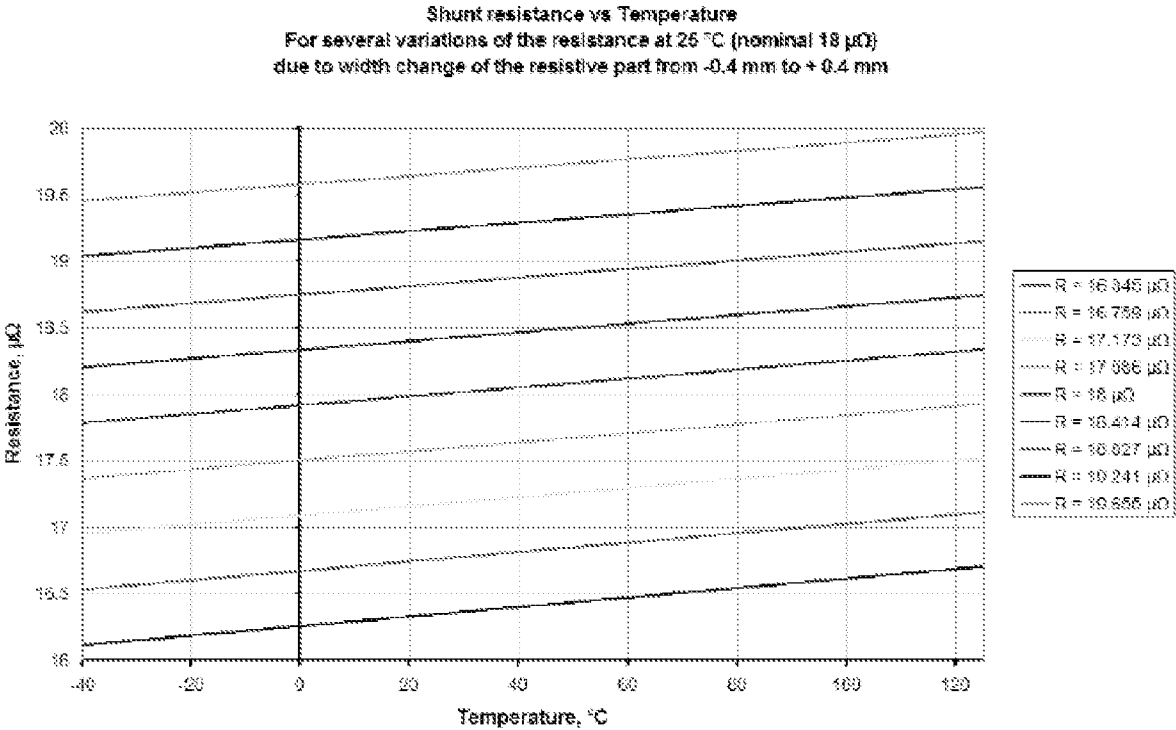


Fig. 5

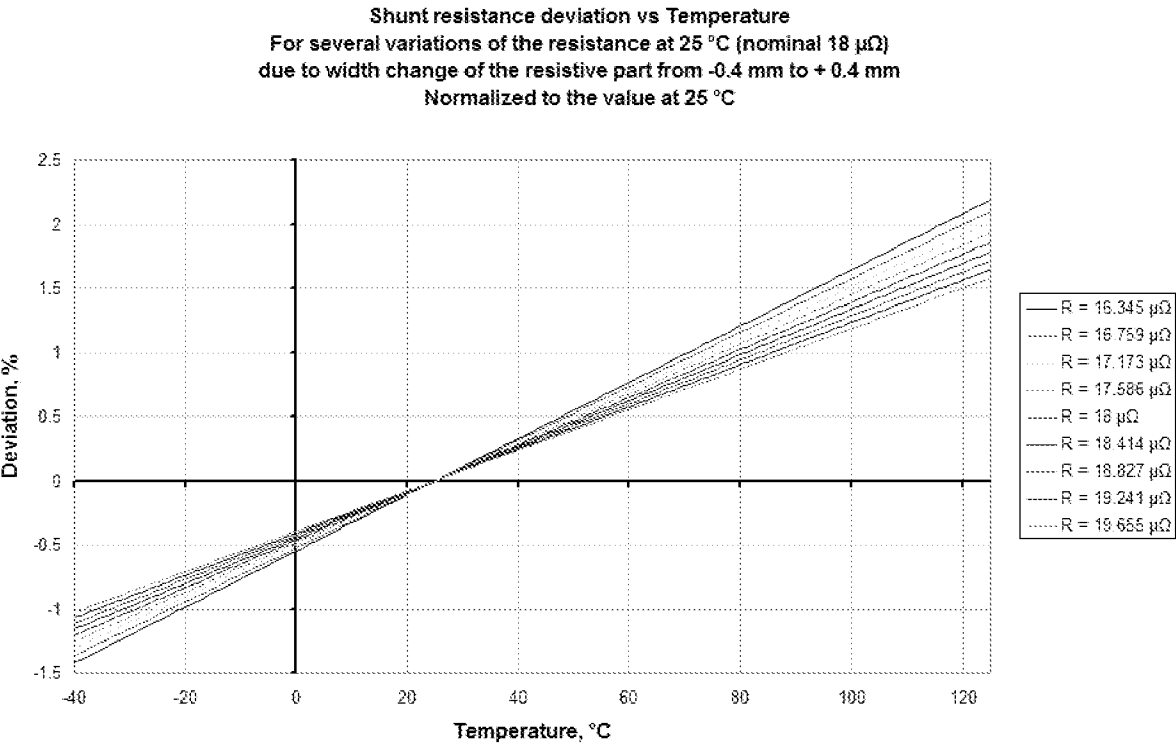


Fig. 6

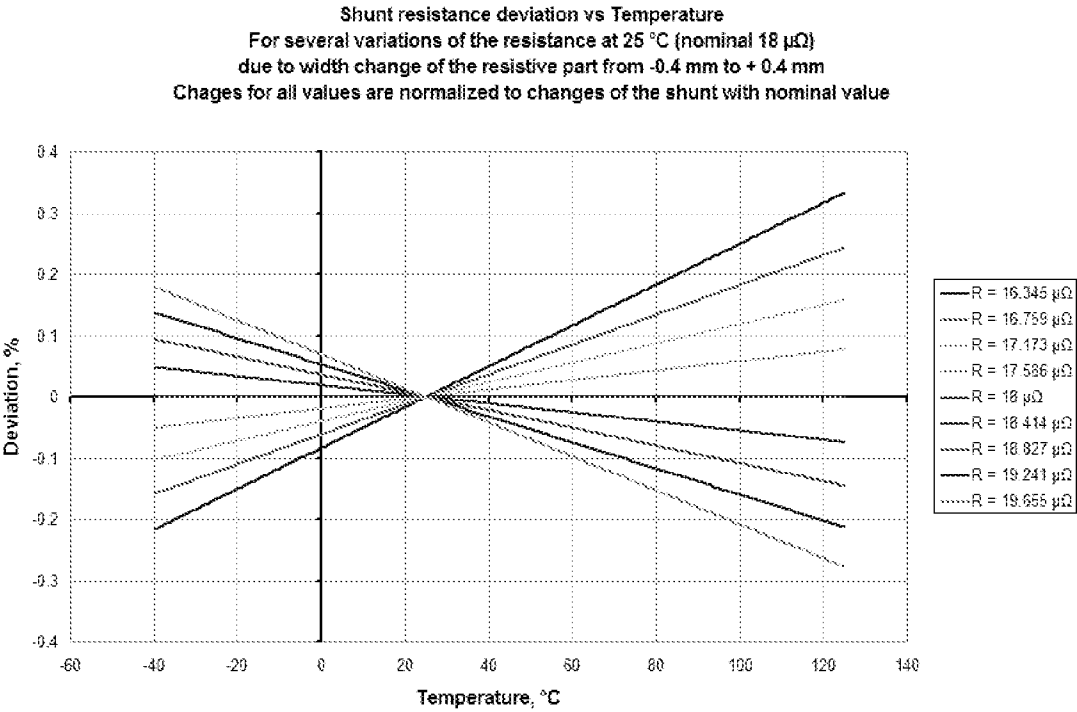


Fig. 7

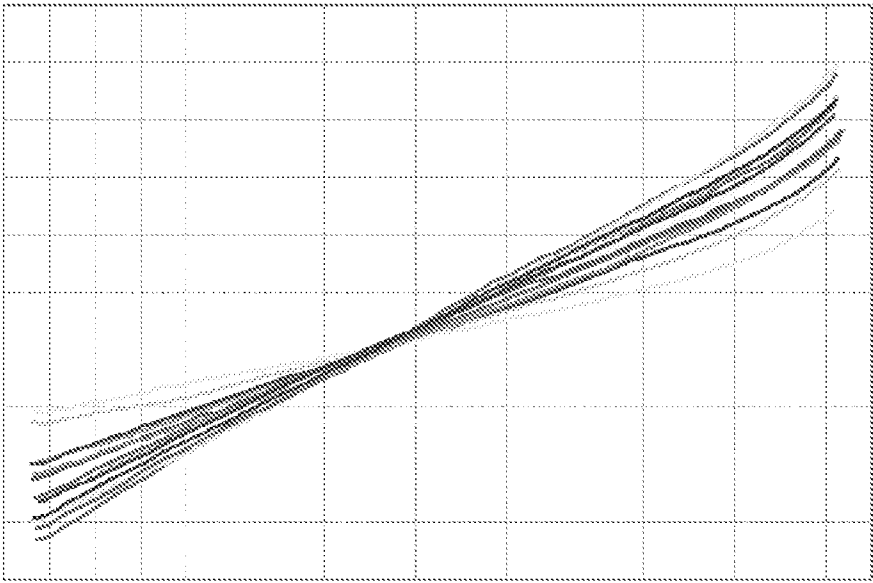


Fig. 8

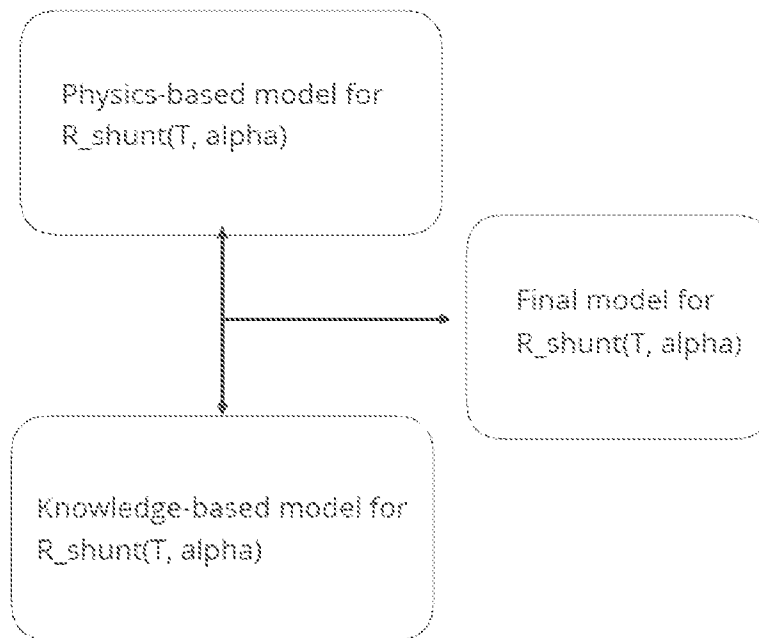


Fig. 9

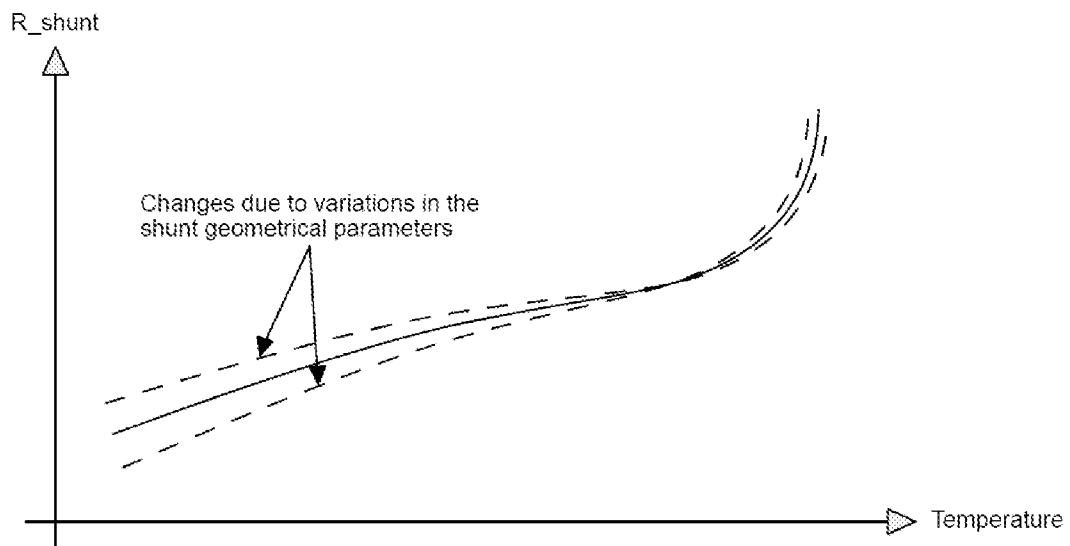


Fig. 10

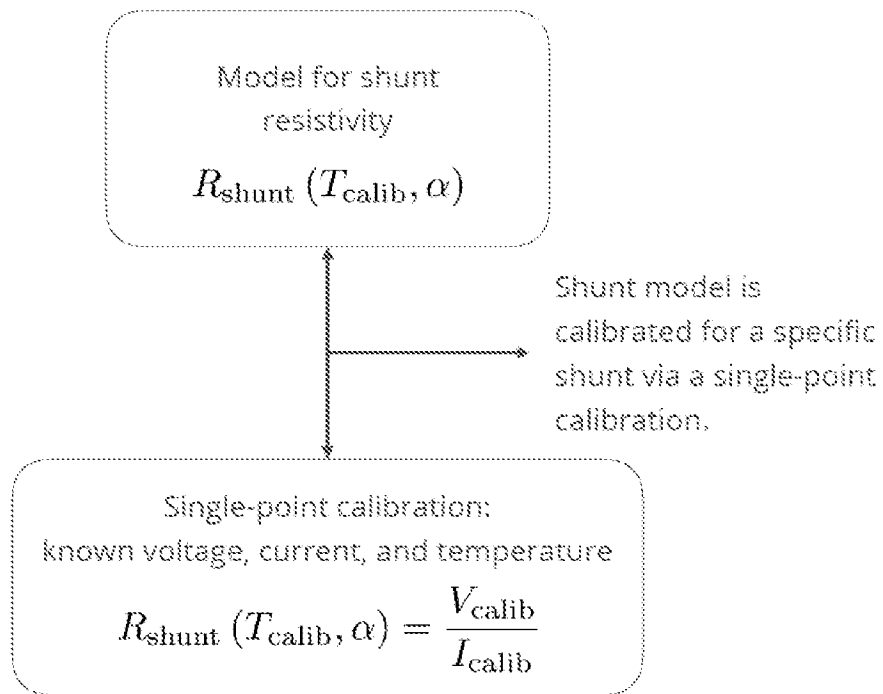


Fig. 11

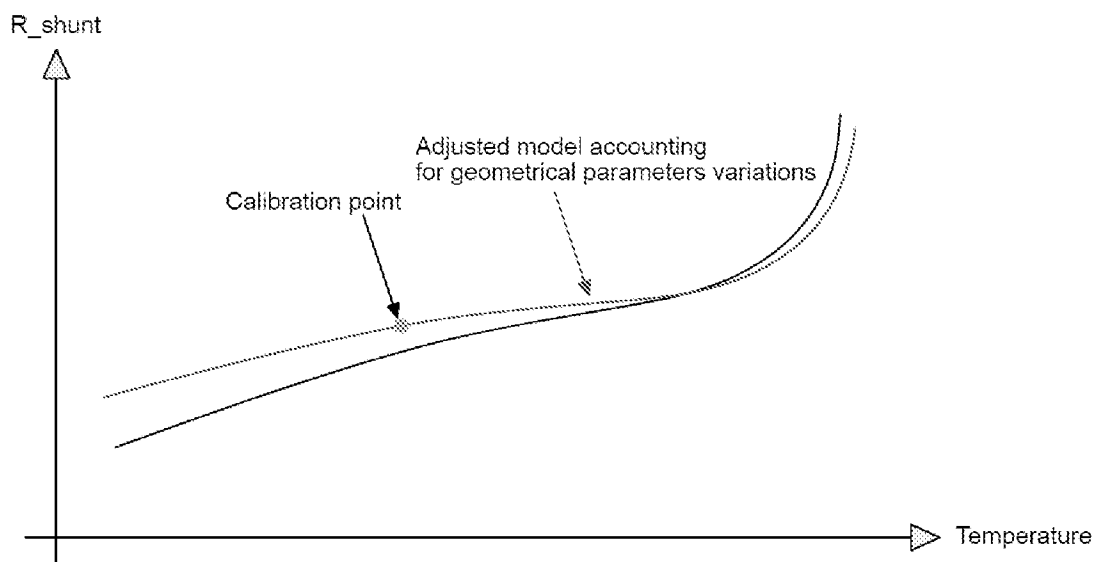


Fig. 12

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB2021/051168

A. CLASSIFICATION OF SUBJECT MATTER G01R 15/14(2006.01)i; G01R 1/20(2006.01)i; G01R 27/02(2006.01)i; G01K 1/02(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 15/14(2006.01); G01R 1/20(2006.01); G01R 35/00(2006.01); H01C 7/06(2006.01); H01M 10/02(2006.01); H01M 10/48(2006.01); H01M 10/667(2014.01); H05K 1/03(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: current, measure, temperature, shunt, resistivity, distance		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "D" document cited by the applicant in the international application "E" earlier application or patent but published on or after the international filing date "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) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "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 "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 "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 "&" document member of the same patent family		
Date of the actual completion of the international search 18 May 2021		Date of mailing of the international search report 18 May 2021
Name and mailing address of the ISA/KR Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon 35208, Republic of Korea Facsimile No. +82-42-481-8578		Authorized officer PARK, Hye Lyun Telephone No. +82-42-481-3463

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