Technical note
TN-WSL20020601

Metal Plate Current Shunt Resistor, Model WSL

Shigeru Hidaka, Nikkohm Co., Ltd. June 1, 2002

1. Introduction

Model WSL8, a shunt resistor for an electric current of metal plate is a useful resistor in terms of price competitiveness and measurement of several ten amperes of electric current. Resistor for metal plate is used in surface mounting. Therefore both ends of terminals are made of copper that is efficient in electric conductivity.

It is desirable for the cross-section that the resistive material shall be butt-welded to electrode material as shown by Figure 1. However, it has such disadvantages that resistive material properties of are affected by welding and brazing in high temperature and resistance value varies in each finished products of resistors due to an unstable configuration at joints.

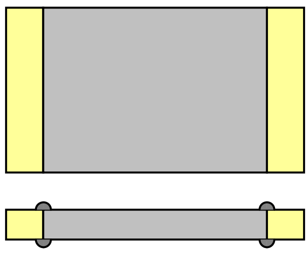

Figure 1. Metal plate resistor with butt-welded electrodes

Usage of copper-plated electrode has been considered for many years to solve this problem. The application of plating forms copper electrode with the uniform thickness on the surface of resistive material, therefore, it facilitates the formation of electrode whose cross-section shape is like a horseshoe, which wraps up an edge of the metal plate of the resistive material. Figure 2 shows the state. At the terminal of metal plate resistor with horseshoe-shaped electrodes attached, electric current never flow uniformly in the metal plate. Therefore, a certain deflection occurs in it. Accordingly when using a resistor or measuring precise resistance value, Issue that measured resistance value depends on the point where a terminal is in touch arises. A conclusion as a result of reviewing current distribution (distribution of electric power consumption) of Shunt Resistor for an electric current of metal plate with horseshoe-shaped electrodes attached is described.

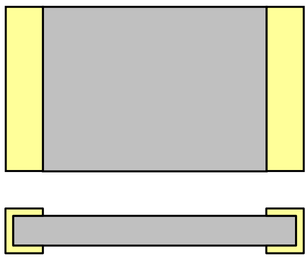

Figure 2. Metal plate resistor with horseshoe-shaped electrodes.

2. Simulation for distribution of electric power consumption at the point of horseshoe-shaped electrodes

When simulating a construction of electrode and resistor, current distribution shall be a solution; however, because the solution of current distribution is expressed in vector, it takes a certain period of time. Current distribution is reasoned here by analogy by finding distribution of electric power consumption.
Two-dimensional simulator divided into 20x20 squares is used for the simulation. Element breakdown of electrode and resistance card is shown in Figure 3. One mesh corresponds to approximately 100 micrometers.

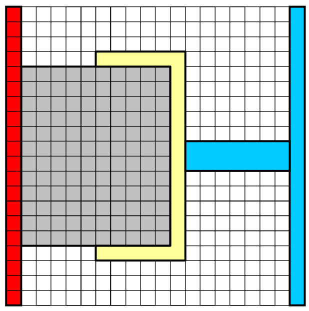

Figure 3. Horseshoe-shaped electrodes and joint part of metal plate resistor.
Red and blue: 0Ω, gray: 40Ω, Orange: 1.5Ω (copper electrodes).

3. Results of simulation

It is a model that is used for identifying the symmetric property by simulation, although it is never employed in a practical mounting. Figure 4 shows the layout diagram of elements and the distribution of electric power consumption where the current outflow point is placed at the center of the thickness direction of card in the electrode terminal. Each electrode thickness shows the first and third layers. Figure 5 shows the results of simulation.

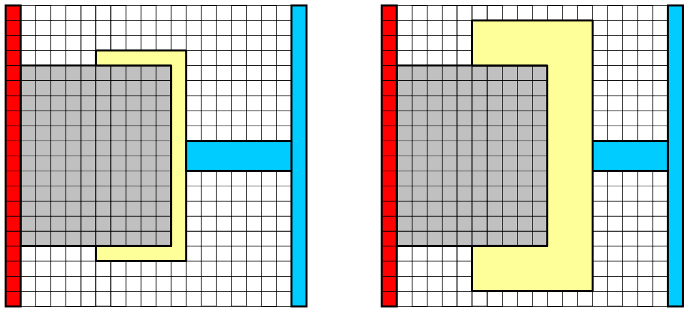

Figure 4. Cross-section surface of shunt resistor for electric current. Elements layout diagram when placing the current outflow point at the center of the thickness direction of card in the electrode terminal
Left shows single layer in electrode thickness and right shows three layers in electrodes thickness.

In practice, chip resistor of electric shunt is mounted on the surface of a printed wiring board with insulated metal or a printed wiring board with ceramics. Figure 6 shows the layout diagram of elements where mounting on the surface. Resistance value of a printed wiring board with copper is the same as the electrodes and shows each 1.5 Ω. However, this simulation employed extremely close value to zero Ω for a resistance value in the blue part that corresponds to the wiring of Figure 6. Figure 7 shows the results of simulation.

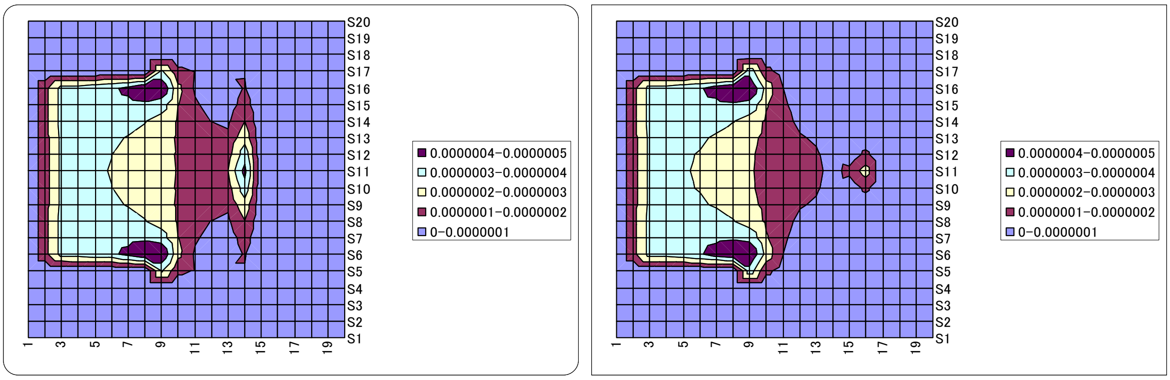

Figure 5. Left shows single layer of electrodes, right shows three layers of electrodes. Current flows in from the left hand. Current flows out from the middle of right electrode. Distribution of electric power consumption at the cross-section surface of horseshoe-shaped electrodes

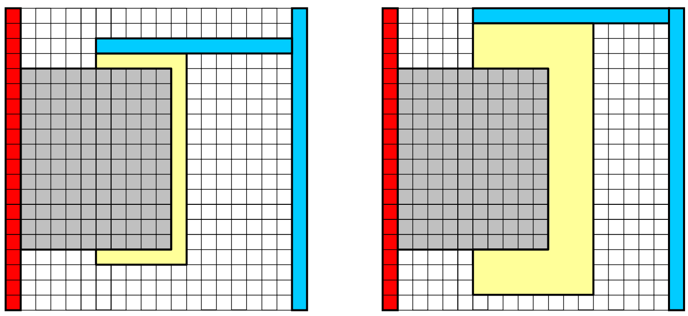

Figure 6. Element layout diagram at the cross-section surface of shunt resistor for electric current mounted on the surface. Left shows single layer in electrode thickness and right shows three layers in electrodes thickness. Blue indicates current outflow conductor of which sheet resistivity is quite lower than that of copper and is extremely close to zero.

Figure 8 shows the layout diagram of elements where the length of upper and lower electrode is different. If you look into the side of shunt resistor for an electric current mounted on surface, you can see three layers on the electrode in both right and left figures. The left figure shows when lower electrode attached to the board is long. The right figure shows when upper electrode is long. The blue part shows the conductor for electric current outflow of which sheet resistivity value is quite lower than that of copper and is extremely

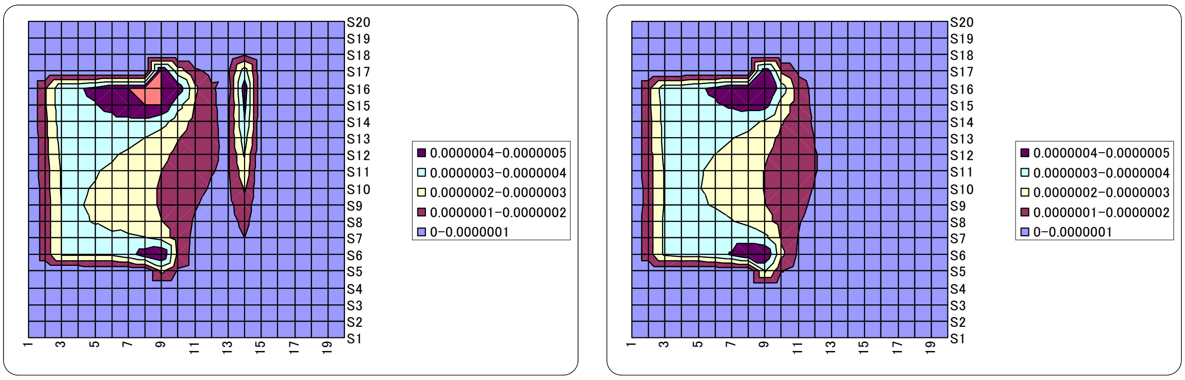

Figure 7. Distribution of electric power consumption of shunt resistor for electric current mounted on the surface. Current flows in from the left hand. Current flows out from the upward surface of the right electrode mounted on the surface. Distribution of electric power consumption at the cross-section surface of horseshoe-shaped electrodes

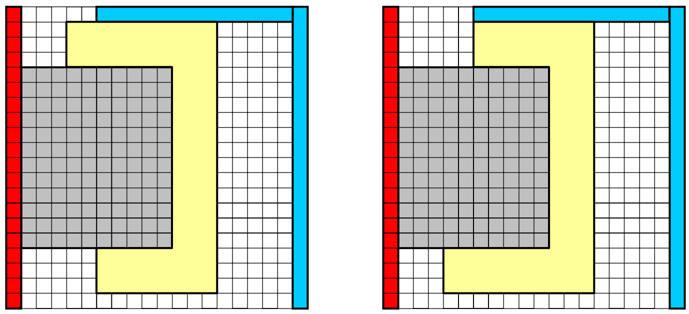

Figure 8. Element layout diagram when the length of upper and lower electrodes is different. Cross-section surface of shunt resistor for electric current mounted on the surface. Both left and right electrodes have three layers in thickness. Left figure shows when the lower electrode attached to the board is longer and right figure shows when the upper electrode is longer. Blue color indicates current outflow conductor where sheet resistivity is quite lower than that of copper and is extremely close to zero.

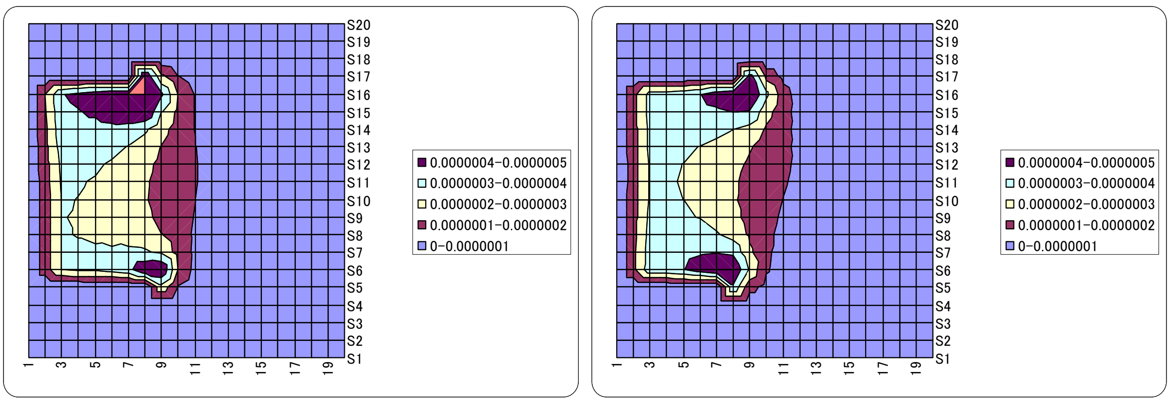

Figure 9. Left shows three layers of the lower longer electrodes, and right shows three layers of the upper longer electrodes. Current flows in from the left hand. Current flows out from the upward surface of the right electrode mounted on the surface. Distribution of electric power consumption at the cross-section surface when width of horseshoe-shaped electrodes is unbalanced

close to zero. Figure 9 shows the results of simulation.

4. Considerations

(1) Thickness of copper

Since electric resistivity of copper shows as large as 3.75% in comparison with the resistivity of resistive element, the electric resistivity of electrodes cannot be ignored. Thickness of copper electrodes needs to be thicker as far as possible to allow the electric resistivity of electrode to be ignored.
However, even in case of increasing the thickness of copper electrode, when mounting on the surface, the current path tends to concentrate between two lower electrodes due to the effect by the cross-sectional property of electrodes. This effect cannot be neglected. Where the width of the horseshoe-shaped electrodes is different between the front and the rear surfaces, the property further affects the resistor. In consideration of the results of simulation and these facts, Figure 10 is obtained to show the electrically equivalent circuit of the shunt resistor for electric current mounted on the surface. Figure 10 will give us the following facts.

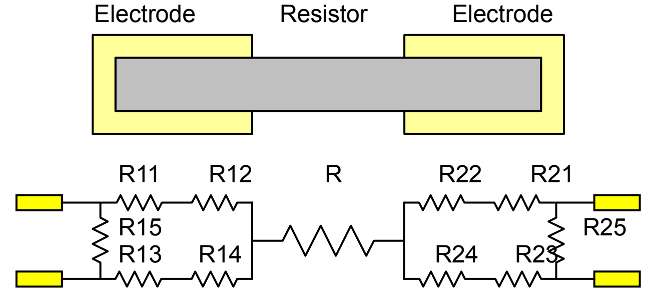

Figure 10. Equivalent circuit of shunt resistor for electric current R shows the resistance value of resistive element. R11, R13, and R15 show the resistance value of electrodes. R12 and R14 show the resistive difference due to tolerance of electrode width.

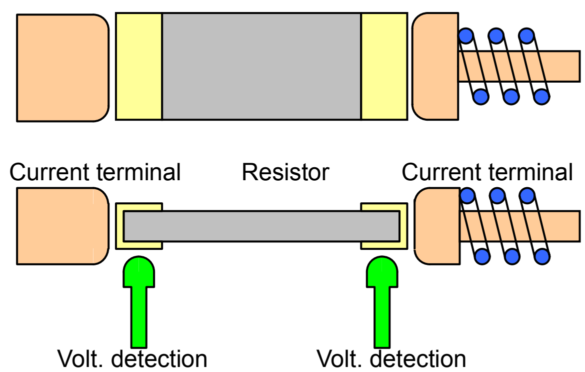

Figure 11. Measuring the resistance value of shunt resistor for electric current of horseshoe-shaped electrodes. Mechanism and terminal direction

- Resistance values vary when measured at four terminals of the front surface, four terminals of the rear surface and four terminals of both sides of surface.
- Electrodes are required to achieve the copper uniformity in 0.1mm thickness, keep good linearity without contact failure and electro deposit with good parallelism of both upper and lower sides and achieve the tolerance of electrodes width within 0.01mm. However, the testing condition shall be specified not by the electrodes width but width of the resistive element.
- Electrodes are required to achieve the copper uniformity in 0.1mm thickness, keep good linearity without contact failure and electrodeposit with good parallelism of both upper and lower sides and achieve the tolerance of electrodes width within 0.01mm. However, copper thickness of a printed circuit board usually employed in practical use is 0.035mm, adequate recommendation regarding thickness, width and cross-section area of a printed circuit board must be provided to users.

(2) Method of measuring resistance value of shunt resistor for electric current.

Apply pressure not from both upper and lower sides but from the end face to contact with the current flow as shown by Figure 11. Contact the voltage terminal from either sides of upward surface or downward surface. Where measurement of resistance value and stamping test are performed at one time, voltage terminals should be contacted from a downward side. In this way, measurement of resistance value should be performed at the fixed point and pressure should be applied to the current flow from the side surface.

(3) Treatment of the side surface of electrodes in the shunt resistor for electric current mounted on surface.

It is desirable that electrodes are not attached on the side surface because the mechanic control of dimensional tolerance of the distance between upper and lower electrodes is difficult. The addition of electrodes on the side surface and the distance between electrodes on the side surface will result in further varying the fixed resistance value. Therefore, it is recommended that the electrodes is not mounted on the side surface and that the width of recommended land pattern of the shunt resistor for electric current mounted on the surface is adjusted as same as that of the chip. The side surface of chip resistor should be kept cut off and the land should be kept off from soldering.

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Please call,
Shigeru Hidaka PhD, Customer Service, Nikkohm Co., Ltd.
info@nikkohm.co.jp