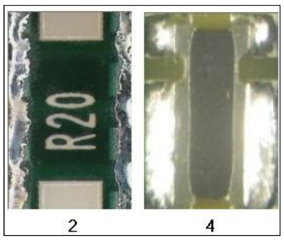
CURRENT SENSING - 2-TERMINAL VS. 4-TERMINAL

Purpose:

This paper will review the differences between 2-terminal current sensing resistors mounted to a 4-wire land pattern and 4-terminal current sensing resistors mounted to a 4-wire land pattern. It will then explain why, even with the slightly higher price, 4-terminal resistors are the better choice.

Current and Power:



Picture of typical 2-terminal and 4-terminal current sense resistors

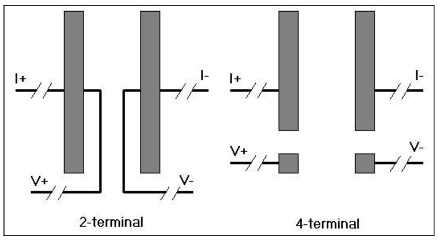


Diagram of typical 2-terminal land pattern with 4-wire connections and 4-terminal land pattern with 4-wire connections

Ohm's Law dictates that, all other things being equal, a higher current will result in a higher power. In the case of a current sensing resistor this becomes important for more than one reason. First, a higher applied power results in greater heat generation and also requires a larger physical size in order to handle the applied power. Most available current sense resistors are designed to dissipate powers of 5 watts or less, with the vast majority of them being designed to dissipate 1 watt or less. In order to increase this, the physical size needs to be increased and/or special materials, which come with higher costs, need to be employed. Second, higher applied power results in increased power draw on the circuit and will reduce battery performance and energy costs.

Table 1 shows some examples of the amount of power applied to current sensing resistors with varying resistances and different levels of applied current.

Current Sense Resistance	**Applied Current (amps)**				
	1	**5**	**10**	**20**	**30**
0.050 Ω	50mW	1.25W	5.0W	20.0W	45.0W
0.020 Ω	20mW	500mW	2.0W	8.0W	18.0W
0.010 Ω	10mW	250mW	1.0W	4.0W	9.0W
0.005 Ω	5mW	125mW	500mW	2.0W	4.5W
0.001 Ω	1mW	25mW	100mW	400mW	900mW

Table 1

The results clearly show the advantage of lower resistance current sensing resistors for the amount of power consumed by the current sensing resistor as well as the ability for standard offering current sense resistor to be able to handle higher current levels.

2-Terminal vs 4-Terminal for Low Resistances:

Although current sense resistors with lower resistances clearly show an advantage, the lower the resistance, the greater the impact that relatively small resistance errors associated with the component construction and board mounting will have on the accuracy of the measurements. Shown below are some of the issues that can contribute to measurement errors with the current sensing resistor.

4-Wire Connection with 2-Terminal Product:

The problem with using 2-terminal current sensing resistors with a 4-wire board layout is that the 4-wire connection point occurs at the circuit board land pattern (Figure 1) and not within the component like it would when using a true 4-terminal resistor (Figure 2).

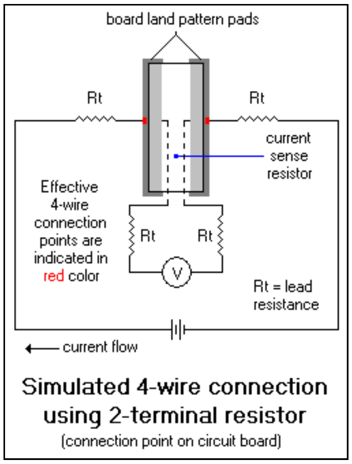


Figure 1

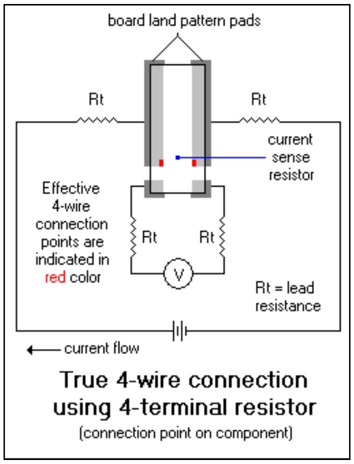


Figure 2

This creates several problems. First is that the true 4-wire connection stops at the point where the trace lines meet the land pattern. This allows the resistance of the circuit board electrode pads and the resistance of the products wraparound electrodes to induce errors in the current measurements. This can be a significant percentage when using a very low resistance current sense resistor.

Table 2 shows the *minimum* expected errors of the current measurements associated with the effect of including the land pattern and wraparound electrodes into the measurements.

Current Sense Resistance	Cu Pad Resistance	Solder Joint Resistance	Total Mount Resistance	Error
0.050 Ω	0.4μΩ	13.0μΩ	13.4μΩ	0.03%
0.020 Ω	0.4μΩ	13.0μΩ	13.4μΩ	0.07%
0.010 Ω	0.4μΩ	13.0μΩ	13.4μΩ	0.13%
0.005 Ω	0.4μΩ	13.0μΩ	13.4μΩ	0.26%
0.001 Ω	0.4μΩ	13.0μΩ	13.4μΩ	1.30%

Table 2

Second is that the points of contact are at different locations then when the product is trimmed to value during the manufacturing process. These variations in the measurement location can lead to errors in the current measurements, especially in low resistance resistors.

Table 3 shows measured data for ten pieces of a 4-terminal, 3 milliohm current sense resistor. The parts were first measured using the recommended measurement locations which forces the 4-wire connection point to the inside of the component as intended. The same parts were then re-measured with the probes moved to simulate the measurement position of a 2-terminal part (Figure 3).

Part #	True 4-Wire Resistance (mΩ)	Simulated 4-Wire Resistance (mΩ)	Error
1	3.022	3.084	2.02%
2	3.025	3.044	0.62%
3	3.008	3.070	2.02%
4	3.004	3.038	1.11%
5	2.988	2.996	0.27%
6	3.012	3.061	1.59%
7	3.026	3.079	1.72%
8	3.025	3.082	1.87%
9	3.008	3.034	0.85%
10	3.019	3.022	0.11%
Average			1.22%
Std Dev			0.73
Maximum			2.02%
Minimum			0.11%

Table 3

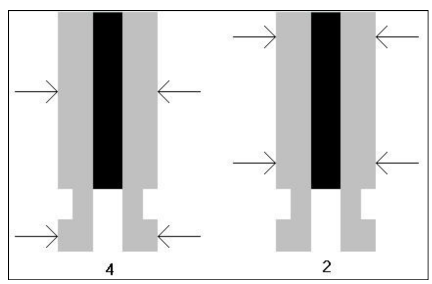


Figure 3

Conclusions:

While lower value current sense resistors can provide many benefits, it is essential to use true 4-terminal resistors and proper 4-wire land patterns in order to take full advantage of the benefits. Failure to do so can lead to measurement errors which can erase any benefit that these components have to offer.