Precision Measuring Shunts Under Load

What developers should observe when choosing a shunt

Data sheets should make things as simple as possible for developers: all important values should be outlined clearly. Nevertheless, certain parameters are often not stated in the same way as they appear in everyday use under load. Electric propulsion technology however requires high performance and therefore also resistors that will continue to work well under high loads.

Measuring shunts are a simple, inexpensive and robust current sensor option for measuring current. Well and suitably designed, these shunts combine many desirable and essential features expected from a good sensor: linearity, no-offset, low temperature dependency, small size, low interferences and many others. Choosing a shunt suitable for a certain application, however, is not always easy. Just looking at the data sheet and focusing on particular specification aspects often results in the wrong decisions.

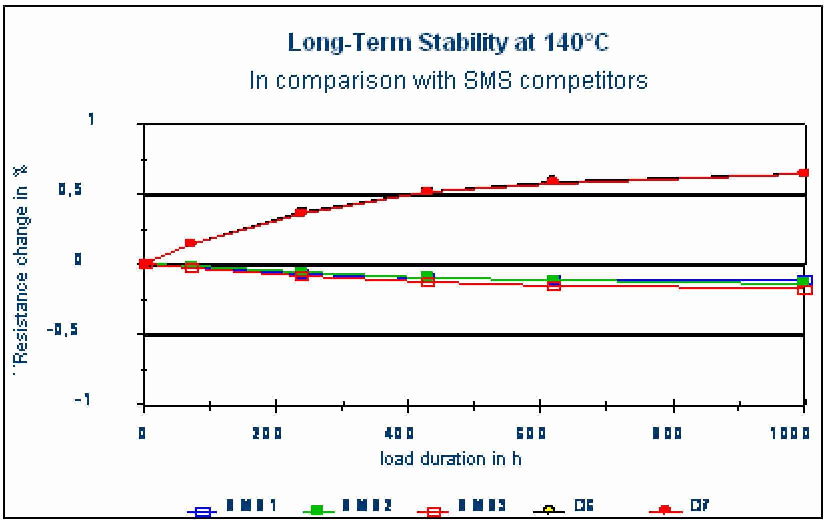
Temperature coefficient, power loss, inner heat resistance and resulting self-heating and long-term stability are factors that influence precise measurements.

$$dR = R0 * Tk * d(T_{ext} + T_{int}) + dR(t)$$

applies for the resistance change under load

Of course this change should be as close to zero as possible for precision shunts, and at the very least considerably below tolerance limits.

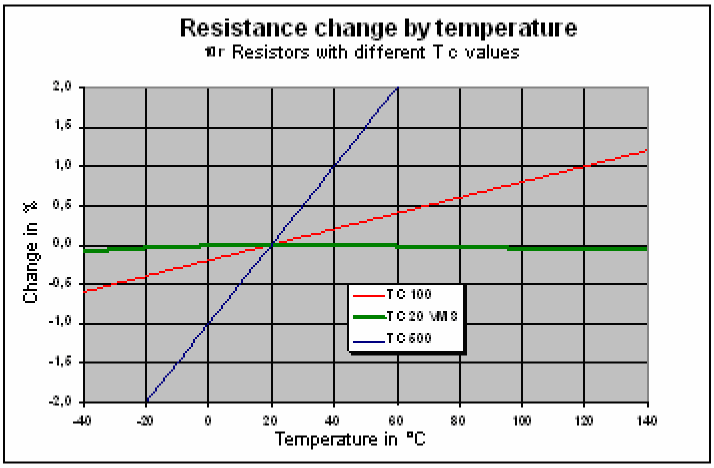
The last term dR(t) describes irreversible resistance value changes due to slow processes (drift) as they happen by aging under "normal" load. These resistance changes can be minimised by choosing the right materials and pre-treatment.
Example Figure 1: an aging curve over 1000h at 140°C. This curve shows the typical development of Isabellenhütte SMS components and one competitor.



As can be seen, certain measures can lead to a very low long-term drift and substantially increase measurement accuracy during the component's lifetime.

The temperature coefficient determines the resistance value change subject to temperature and is usually given for temperatures between 20°C and 60°C.

For the VMx line (size 2512), Isabellenhütte states a temperature coefficient of +-20ppm/K at a maximum power loss of 3 Watts. Figure 2 compares various materials to show what keeping a temperature coefficient below ten ppm means.



A temperature increase from 20°C to 70°C already causes a resistance change of 0.5% in a resistor with a 100 ppm temperature coefficient.

A rise in temperature can be caused internally and externally. External temperature changes can occur without current flow, for example if nearby components heat up.
Internal temperature changes occur when the measuring shunt is included in the current path. Part of the power source's electric energy is transformed into thermal energy within the shunt, heating the resistor's material. The transformed thermal output is given as

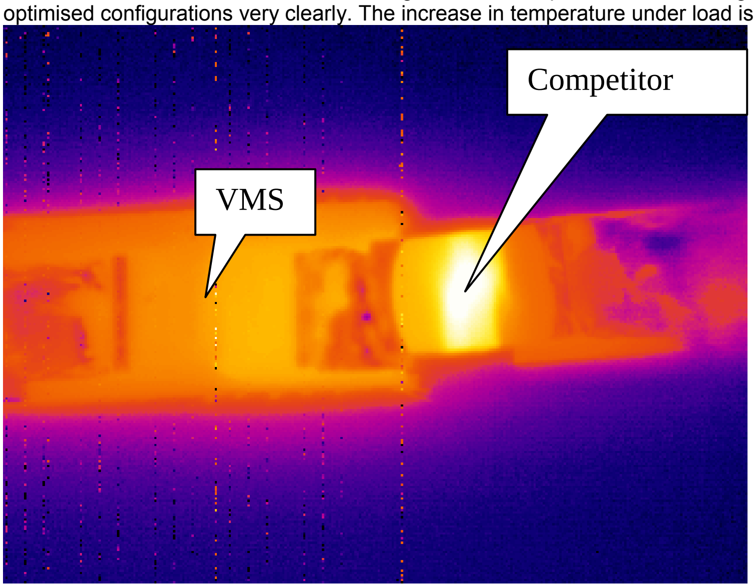
$$P = U * I = R I^2$$

The increase in thermal loss is a quadratic function of the current, e.g.:

P = 10mOhm * (10A *10A) = 1 Watts
P = 10mOhm * (20A *20A) = 4 Watts

This means that if the current doubles, power loss and heating associated with it quadruples.

This internal temperature change can be influenced by transferring thermal energy to the outside as efficiently as possible. Without this, several material limits and threshold values stated in the data sheet may be exceeded. As these components tend to be very small and lacking substantial thermal capacity, thermal conduction within the component is crucial. Cooling by convective flows of heat or radiation is insignificant in comparison. The IR image (Figure 3) shows the capabilities of thermally optimised configurations very clearly. The increase in temperature under load is significantly lower compared to competitors.



Type	ΔT / °C	P / W
VMS	20	1
Competitor	100	

Thermally optimised configurations and a good temperature coefficient both lead to high measurement accuracy even under load and high outside temperatures.

Assuming an outside temperature of 70°C and a load of only one Watt, this leads to the following values (Figure 4):
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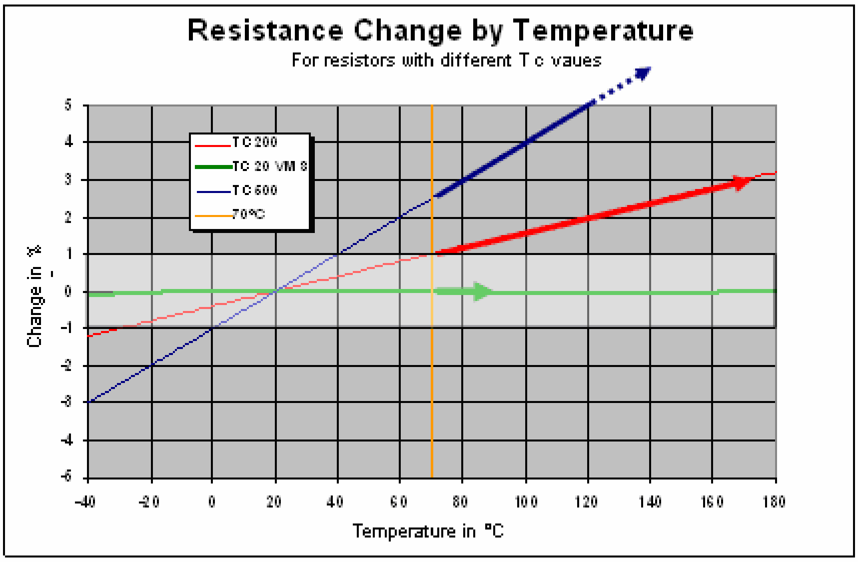
VMS:		ΔT = 20°C	Tmax = 90°C,	dR < 0.05%
Competitor	200ppm:	ΔT = 100°C,	Tmax = 170°C,	dR = 2.0%
	500ppm:	ΔT = 100°C,	Tmax = 170°C,	dR = 5.0%

Figure 4:



The starting temperature in this example (70°C) would already exceed the often indicated tolerance limit of 1% in a resistor with a 200ppm temperature coefficient.
Stability over time is also substantially better at 90°C than it is at 170°C. This shows that the Isabellenhütte VMS component offers more total “reserve”, even under high load.

Conclusion
A high measuring accuracy can be achieved even under load and during the whole component lifespan if the component's internal design and materials used for the resistor are optimised accordingly. The most important factors are a low temperature coefficient, low inner heat resistance and good long-term stability under load, as well as a high adjusting accuracy. Isabellenhütte resistors meet these requirements and allow for tolerance even under full load, throughout the operating temperature range and during the component's whole lifespan.

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