# Application Based Resistor Selection Criteria

Industrial Applications have high demands on resistors, especially in terms of power, precision and stability. Depending on the application, the designer starts the selection of a resistor on a top down approach with his most important parameters. These could be power rating, precision or size. The power rating highly depends on the size, but also on the technology used. The precision of a resistor is defined by more than one specification, i.e. tolerance, temperature dependent changes of resistance, ageing, noise and frequency stability. This article focuses on SMT resistors specifications, as they are the most used technology today.

**Benjamin Blume and Arne Albertsen, KOA Europe GmbH, Dägeling, Germany**

Many high power applications use low ohmic resistors (also known as shunts) for current detecting purposes, but high value resistors are also available for power applications. High power also implies high temperatures due to the power dissipation. Higher temperatures have some negative effects on the resistor that have to be taken into account and increase the requirements, both electrically and mechanically, on shunt resistors compared to standard flat chip resistors.

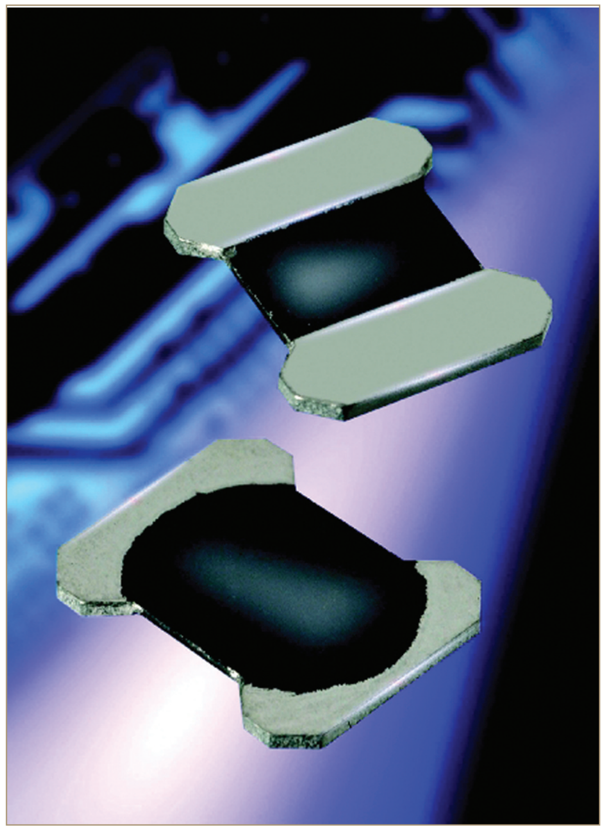

**Figure 2: Special shape of PSB resistor series**

## Precision of shunts

Shunts are used to represent the magnitude of a current by a proportional voltage drop. The self-heating induced by the current through the shunt increases the temperature of the shunt. Thus, the temperature dependent changes of resistance (represented by the TCR) is required to be small to ensure a precise measurement. The elimination of hot spots (see Figure 1) helps to increase accuracy. The temperature is spread more equally over the surface of the resistor and the heat conduction is improved, hence the effect of TCR is reduced. KOA's TLR, PSI and PSB shunt series combine low TCR down to ±50ppm/K and cut less trimming what eliminates hot spots.

The special trimming also reduces the mechanical stress on the resistor. With the change of temperature, the resistor material expands and constricts, which implies a mechanical stress on the solder joint. By reducing temperature peaks, the expansion is reduced and evenly spread over the resistor. Laboratory tests showed that the main impact of mechanical shear stress is acting on the corners of the soldering

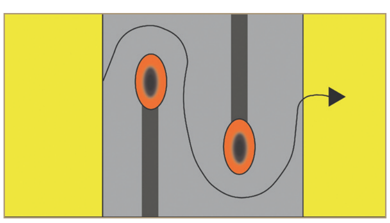

**Figure 1: Laser trimming of the resistor's resistance material eliminates hot spots**

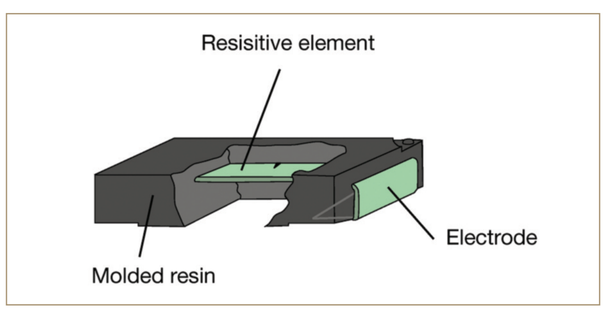


**Figure 3: SL type construction to reduce mechanical stress**

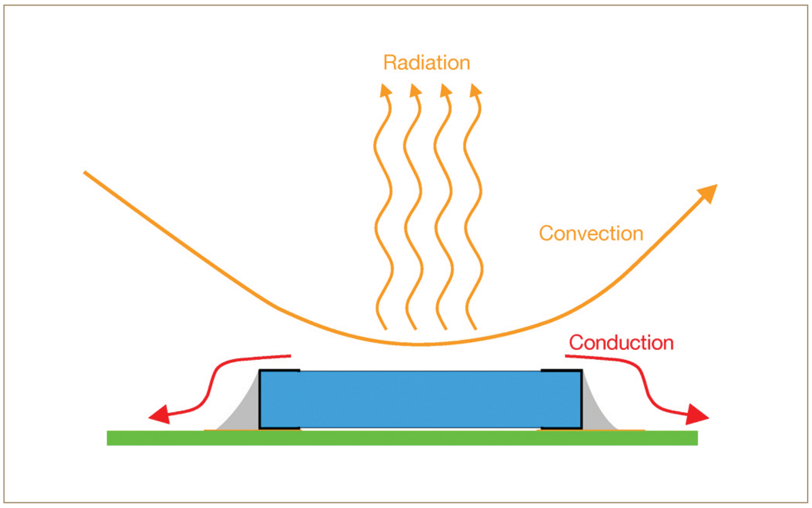


**Figure 4: Inverse geometry improves temperature conduction**

joints. This knowledge led to the development of the PSB resistor with specially shaped electrodes and high power in relation to its size (see Figure 2). The smaller size itself also reduces the mechanical stress, as the total possible expansion is less.

The SL(N) resistor series (see Figure 3) takes another approach to reduce the mechanical stress. The specially shaped wrap around electrodes act like a spring and absorb the elongation. The moulding of the part improves its temperature capability up to 180°C. These construction details yield to the superiour high temperature and temperature cycling performance of this resistor type.

The rated power of a resistor depends strongly on the maximum available heat transport capability, which mainly relies on heat conduction through the solder joint to the PCB. The temperature dissipation through air convection and radiation can be neglected. Knowing this, KOA offers the WK73 flat chip resistor with inverse geometry. Instead of using the short sides for the electrodes, like standard flat chip, the long sides of the resistors are used (see Figure 4). Due to the improved temperature conduction, the power rating is 30 to 50% higher compared to a standard flat chip of the same size. In the shunt sector, the metal film resistors like TLR have improved power capability due to the better heat conductivity and spread, compared to thick-film shunts.

For high voltage applications there is also a special resistor series available, the HV73. This series is specially improved to withstand higher voltages; in the size 0805 this results in a higher working voltage of 400VAC.

In applications with pulse or surge voltages, it is often desirable to take resistors which withstand high peak power, whereas the rated average power is much smaller. This can lead to space saving, due to reduced resistor sizes. The SG73 P/S series resistors are thick-film resistors specially improved to cope with high surges or pulses. For example, the pulse power of a 1ms pulse can be more than 10 times higher using the SG73 compared to a standard thick-film resistor of the same size. The high pulse resistance is

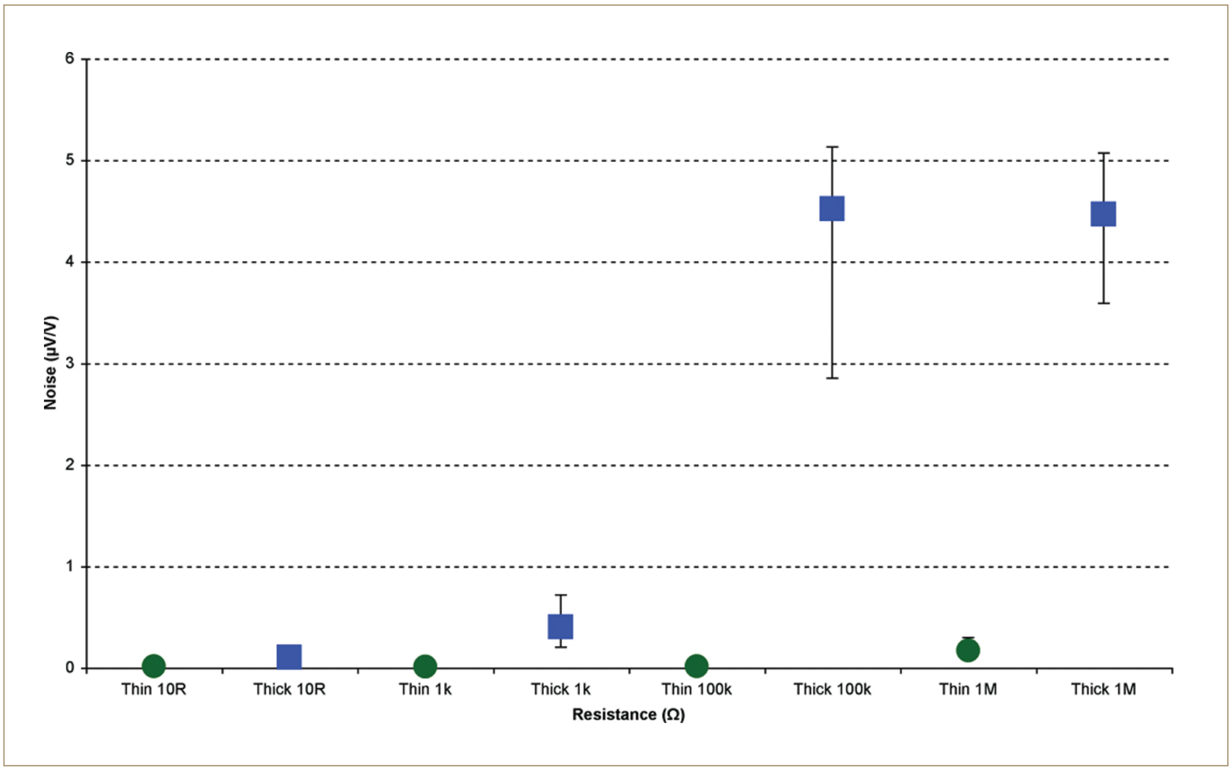


**Figure 5: Noise generation of thin and thick-film resistors**

achieved by omitting the trimming. On the downside, this increases the tolerance of the resistor.

For tighter tolerances KOA developed the SG73 P and S types. A special trimming permits tolerances down to 0.5% available with pulse resistance close to resistors with no trimming cut.

### Tolerance and TCR

Precise resistors are traditionally the domain of the thin-film technology. The RN73(H) thin-film resistor series is available with initial tolerances down to ±0.05% and a temperature coefficient as low as ±5ppm/K. The long-term stability is defined as a maximum resistance change in time. For the RN73H it is less than ±0.1% in 1000h. If one or more of the following items are required, resistors in thin film technology offer the best solution featuring < ±0,5% tolerance and < ±50 ppm/K TCR.

An example shows the influence of the TCR: a resistor with R = 100Ω and a TCR = ±5ppm/K is changed in temperature between 30 and 80°C. Hence, the temperature change is 50K and the resistance change = 50K * ±5ppm/K * 100Ω = ±0.025Ω. Whereas a thick-film resistor with ±400ppm/K, shows a resistance change of ±2Ω.

At the borders of these specifications other technologies, i.e. metal film and thick-film resistors, also come into play. Today, special thick-film resistors, like KOA's RK73G, reach into the thin-film resistor domain with a tolerance down to ±0.5% and a TCR of ±50ppm/K. The RK73 series also has improved environment resistance, especially against sulphur, compared to other standard flat chip resistors. Nevertheless, the long-term stability of thin- film resistors like RN73H is better. The maximum resistor change over time for the RK73G is specified to ±2% over 1000h.

The thin-film technology does not allow very small ohmic values for a reasonable price; the RN73 starts at 10Ω, depending on the size. Low ohm resistors with small tolerance and low temperature coefficient are manufactured in metal plate technology. The TLR series covers the ohmic range from 1mΩ to 200mΩ. They are available with TCR down to ±50ppm/K and an initial tolerance of 1%. The SL(N) series is available for values between 3m and 1MΩ with TCR down to ±100ppm/K and an initial precision of 0.5%. They are suitable for high power applications up to 3W.

### Noise generation and high frequencies

Low noise is a strong criterion for thin-film or metal plate resistors. The thermal noise, generated by the thermal agitation of the electrons, is inevitable in every resistor and only depends on its temperature and ohmic value. Depending on the technology, other noise sources also become important. Standard thick-film resistors at values above 1kΩ especially generate high current noise, which can be neglected in other technologies. Figure 5 compares the total noise generated by thin-film and thick-film resistors.

More and more applications operate at high frequencies; therefore the frequency stability of all components becomes important. In current detection circuits, the parasitic inductance of the shunt resistor influences the result significantly at high frequencies. To reduce the parasitic inductance KOA's shunt series TLR, PSI and PSB have a cut less trimming. The special trimming allows the current to flow on a straight line through the resistor. Up to 100MHz, thin-film resistors stay at their nominal resistance, whereas high ohmic thick-film resistors already change their value significantly. For frequencies up to 15GHz, there are special resistor series available, like KOA's SHDR. The reason for its good frequency stability is the very low inductance of 0.5nH.

### Conclusion

Selecting the right resistor is driven by application requirements and by cost efficiency. Standard thick-film resistors cover many applications, where accuracy and stability play a minor role. But special needs, like high voltages, can also be solved by the use of thick-film products. As soon as precision, power or stability are critical criteria, specialised resistors provide efficient and reliably solutions. For higher demands in accuracy, power and stability, improved thick-film resistors are available. They cover a wide ohmic range from some milliohms up to megohms and offer medium precision and stability. For highest demands, two technologies are available - metal film resistors in the low ohmic range and thin-film resistors for standard range.