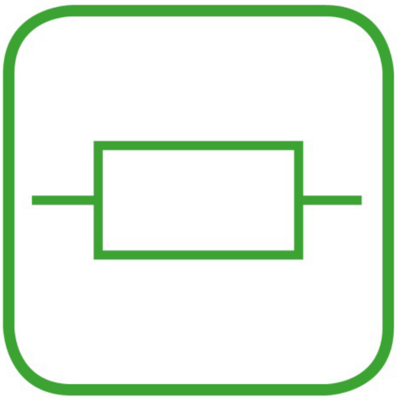
ISABELLENHÜTTE

Whitepaper

Correctly Using Data Sheets

Using clear facts to find the right component: Isabellenhütte Heusler explains the benefits of data sheets when selecting resistors



Isabellenhütte Heusler offers detailed data sheets for its precision and power resistors with values and characteristic curves similar to a specification. Only with the help of such data sheets are users able to select the resistor that precisely meets their requirements. The technical parameters are clear and comprehensive so that specific calculations can be carried out. The room for interpretation is reduced to a minimum.

The white paper uses realistic calculation examples to clearly illustrate how a data sheet can be used to choose the appropriate resistor and what information is important.

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1. Introduction: About data sheets

Developers are frequently face with the task of choosing a suitable component for a technical application. Given the abundance of products from different suppliers, it is worth looking at the data sheet to compare the parameters. A data sheet contains all the important technical information about a certain component. This includes specifications about their load, the component size, the application conditions, the technical properties and the delivery form. However, comparing different variables does not always automatically lead to the best suitable component. It raises the question of how the most suitable product can be chosen for the application from the variety of "similar products." Some background information and calculations make it possible to determine the right component - often also while saving money. Developers must know and be able to use the parameters for this purpose. With an example calculation for the selection of a resistor for certain application conditions, Isabellenhütte Heusler shows in this white paper what matters when using a data sheet and how the parameters it contains can help you make your selection.

The most important component specifications for this purpose are summarized in a "Technical Data" overview as the following overview of Isabellenhütte Heusler shows:

Technical data [1]		
Resistance values	**mOhm**	**0.3 to 6.8**
Tolerance	**%**	1 / 5
Temperature coefficient (20-60 °C)	**ppm/K**	from 50
Applicable temperature range	**°C**	-55 to +170
Power rating $P_{100°C}$	**W**	up to 3
Power rating $P_{70°C}$	**W**	up to 6
Internal heat resistance (R_{thi})	**K/W**	from 4
Inductance	**nH**	<2
Stability (at rated power) deviation after 2000h, T_K = Terminal temperature		<0.5% (T_K=110 °C) <1.0% (T_K=140 °C)

Figure 1: The technical data that is relevant for selecting a resistor – shown in an example of the low-ohmic resistor series BVx.

2. Selection of an SMD resistor based on the application conditions and requirements of the component – a calculation example

The search for a component can easily be limited if you know the application conditions and the requirements such as the application temperature, installation size and the current to be measured within the application. In the following example, the requirements for the searched requirement (shunt) are determined with the accuracy of the measurement signal for the current.

The calculation example is based on parameters that are common for a resistor in an electronic control unit of a fan control unit in the vehicle:

A current of 60 amps is to be measured with the greatest possible accuracy. For spatial reasons, the component should not be larger than the 2512 design. The heating in the area of the soldered component should be kept as low as possible. Furthermore, the component should be used up to a temperature of 105°C at the soldering point. For the application, the long-term stability should be <1% seen over the life cycle.

The accuracy of the measurement also has to do with the available resolution of the measuring circuit. The highest possible voltage signal should therefore be made available. The voltage drop that is measured at the resistor is linear to the current flow in the resistor and is calculated as follows according to Ohm's law:

U (electric voltage) = R (electric resistance) x I (current rating)

It is to be noted during the calculation that the maximum output of the component is not exceeded. The aim of the calculations is thus to obtain a correspondingly high measuring signal, but also to keep the power loss $P = I^2 \times R$ within the required limits. Every developer will try to limit the power loss through lower resistance values, but since the measuring voltage is simultaneously lower, the resistance value is often limited by the finite resolution and quality of the evaluation electronics.

2.1 An initial approximation with an assumed resistance value of 5 mOhm

The power loss and the associated heating of the component are crucial criteria for the application. With a high value of 60 amps for the current to be measured, the user assumes a low-ohmic resistor based on experience. For an initial approximately, a low resistance value of 5 mOhm or lower is assumed in order to check whether the required framework conditions (high measuring signal, low power loss) can be met.

I = 60 A

R = 5 mΩ

U = R x I results in a measuring signal of 300 mV, i.e. a fairly high voltage signal as is required. The power loss is calculated with $P = I^2 \times R = 60\ A^2 \times 0.005\ \Omega = 18\ W$. Accordingly, a SMD resistor would have to be found that has a power rating $P_{70\,°C}$ of 18 watts ($P_{70\,°C}$ is a standard consideration for the terminal temperature in the application in the industrial field. 2.3 explains what influence the terminal temperature has on the selection). This is an extremely high output, which an SMD resistor cannot process. In addition, a power loss of 18 watts would lead to a heating of the component that is much too high. The design 2512 can also in no way be realized for this load.

A resistance value of 5 mΩ is therefore clearly too high. So that an SMD component can handle the load adequately, the power must be reduced by about ten times as experience has shown, e.g. 18 W/10 = 1.8 W.

2.2 Reduce the power

By reducing by tenfold, the formula above can be converted as follows and solved for R, the resistance value: $R = P/I^2 = 1.8\ W / 60\ A^2 = 0.5\ m\Omega$. According to the power loss, the resistance value has also been reduced tenfold, from 5 to 0.5 mΩ. For a current of 60 A, this therefore results in a power loss of P = 1.8 W. An SDM resistor of R = 0.5 mΩ.must now be found, which can handle a power of 1.8 W. For this purpose, it is worth looking at the product overview on Isabellenhütte's website: Some of the sought after requirements are met with the component family BVT: Design 2512, a resistance value of 0.5 mΩ lies in the range and the component has a power of $P_{70\,°C}$ of 6 watts.

Typ	Bild	Beschreibung	Bauform	Leistung	Toleranz	Widerstand (min)	Widerstand (max)	TK
BVR		4-Leiter-Widerstand aus Verbundmaterial. Ideal für den Einsatz auf DCB.	4026	5 W	1%	0.0002 Ω	0.003 Ω	20 ppm/K
BVS		2-Leiter-Widerstand aus Verbundmaterial.	3920	12 W	1%	0.0002 Ω	0.005 Ω	50 ppm/K
BVT		2-Leiter-Widerstand aus Verbundmaterial.	2512	6 W	1%	0.0003 Ω	0.0068 Ω	50 ppm/K

Figure 2: The required component of the design 2512 in the overview of the BVx component family

Has the optimal solution for the application thus been found?

The resolution of the measuring signal may not be neglected. Because: A smaller resistance value automatically also leads to a smaller measuring signal. The signal strength of 300 mV has now dropped to 30 mV due to the reduction of the resistance value to 0.5 mΩ. A higher signal, however, would significantly improve the resolution of the measuring signal as required.

The data sheet for the component family BVT (size 2512) shows that a slightly higher resistance value can also be selected. The overview has the resistance values that are available as well as the associated technical data (see figure 3).

Type	Value [mΩ]	Thickness [mm]		R_{thi} [K/W]	TC [ppm/K]	$P_{100\,°C}$	$P_{70\,°C}$
		D1	D2			[W]	[W]
BVT-K-R000	0	0.42	0.42			I_{max} = 100 A	
BVT-Z-R0003	0.3	1.00	1.00	4	<175	3.0	6.0
BVT-M-R0005	0.5	0.85	0.84	7	<115	3.0	6.0
BVT-M-R001	1.0	0.42	0.42	14	<100	3.0	5.0
BVT-V-R002	2.0	0.46	0.64	20	<50	3.0	5.0
BVT-I-R002	2.0	0.72	0.64	20	<50	3.0	5.0
BVT-I-R003	3.0	0.48	0.42	30	<50	2.0	4.0
BVT-I-R004	4.0	0.36	0.42	40	<50	2.0	3.0
BVT-I-R005	5.0	0.36	0.42	50	<50	1.5	2.5
BVT-I-R0068	6.8	0.36	0.42	60	<50	1.5	2.0

Material type I=ISAOHM®, K=SF-copper tinned, M=MANGANIN®, Z=ZERANIN®30, V=NOVENTIN®

Figure 3: The data sheet for the component BVT with the relevant technical parameters

A higher resistance is required for a higher measuring signal, i.e. the next-higher BVT-M-R001 with 1 mΩ may be the component of choice. The review of the requirements shows:

Measuring signal: U = R x I = 0.001 Ω x 60 A^2 = 60 mV

Power loss P = I^2 x R = 60 A^2 x 0.001 Ω = 3.6 W (corresponds to twice the power loss).

A power of $P_{70\,°C}$ = 5 W is specified in the data sheet for the component. Thus the BVT-M-R001-1.0 can be used accordingly. This component is thus optimally chosen for the application mentioned.

If the aspect of heat development is more focused on when selecting the component, additional calculations may be productive.

2.3 Influence of heat development in the component

For some applications, such as in the automotive sector, the consideration at $P_{70\,°C}$ is insufficient, because significantly higher application temperatures are achieved here. In the example, 105°C is required.

The data sheets of Isabellenhütte always refer to the terminal temperature in the application case. This may be easy to remeasure. Infra-red images also show the temperature difference here between the hot spot and contact point. Isabellenhütte names the parameter "Internal Heat Resistance" (R_{thi} for short) in the data sheet, which describes the thermal conductivity of the component design. The temperature increase in the component can be calculated with this parameter. It is comparable to the inner heat resistance of a semiconductor or the heat transfer resistance of a heat sink. It ultimately indicates how well the heat generated in the component can be dissipated.

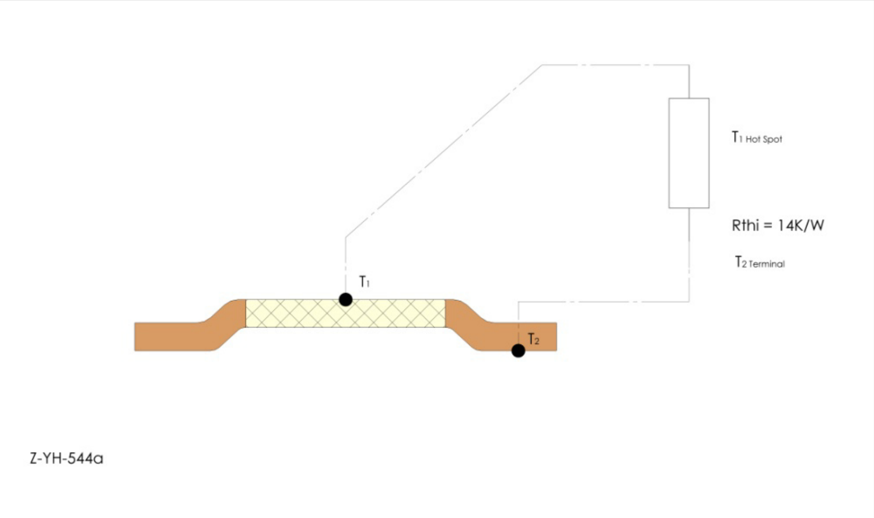

Figure 4: The heat development in the component: Temperature difference between the hot spot and contact point

The current flow through the resistance material (see sketch above) results in a power loss inside the resistance material, which is noticeable in the heating of the component. The spot that is furthest removed from the copper connections (the hot spot) is heated the most. A R_{thi} of 14 K/W is specified in the data sheet for the component chosen in the calculation example.

What does this mean for the application?

The inner heat resistance is determined by the inner setup, the material, the design as well as the actual resistance value R_{shunt}. This value is a parameter for the inner heat flow in the component and has nothing to do with the external influences on the component, such as the ambient temperature or contacting to the PC board. The following applies: R_{thi} is linear to R_{shunt}. A power loss of 3.6 watts was calculated in the example. I.e. that the component in the hot spot has

$\Delta T = P \times Rthi$ -> 3.6 W x 14 K/W = 50.4 K higher temperature than the contact point.

If other additional requirements are placed on the component, such as the maximum temperature at a certain power or the effects of high temperatures on the long-term stability, additional calculations may be required in order to select the optimal resistor. These calculations are explained using examples in chapters 2.4 and 2.5.

2.4 Power derating curve to determine the maximum temperature of the component at a certain power

In order to find out whether the BVT-M-R001 with a temperature increase by 50.4 K in the hot spot is also suitable for a required temperature measurement of 105°C, the power derating curve in the data sheet can still be consulted. It indicates at which temperature the power must be reduced so as not to exceed the maximum temperature in the hot spot. The desired long-term stability of <1% is also to be taken into consideration here. Since this very much depends on the application temperature, two values are specified here for the long-term stability:

At a maximum temperature of 140°C in the resistance material, a stability of <0.5% is achieved. At a maximum temperature of 170 °C in the resistance material, a stability of < 1.0 % is achieved.

According to the data sheet, the component may not exceed the maximum temperature of 170°C. The requirement of a long-term stability of <1% is thus ensured. The terminal temperature T2 (terminal) would then be

T1 (hot spot) – ΔT -> T2 = 170 °C – 50.4 °C = 119.6 °C.

Thus the component with 3.6 watts can still be used at a required temperature of 105°C.

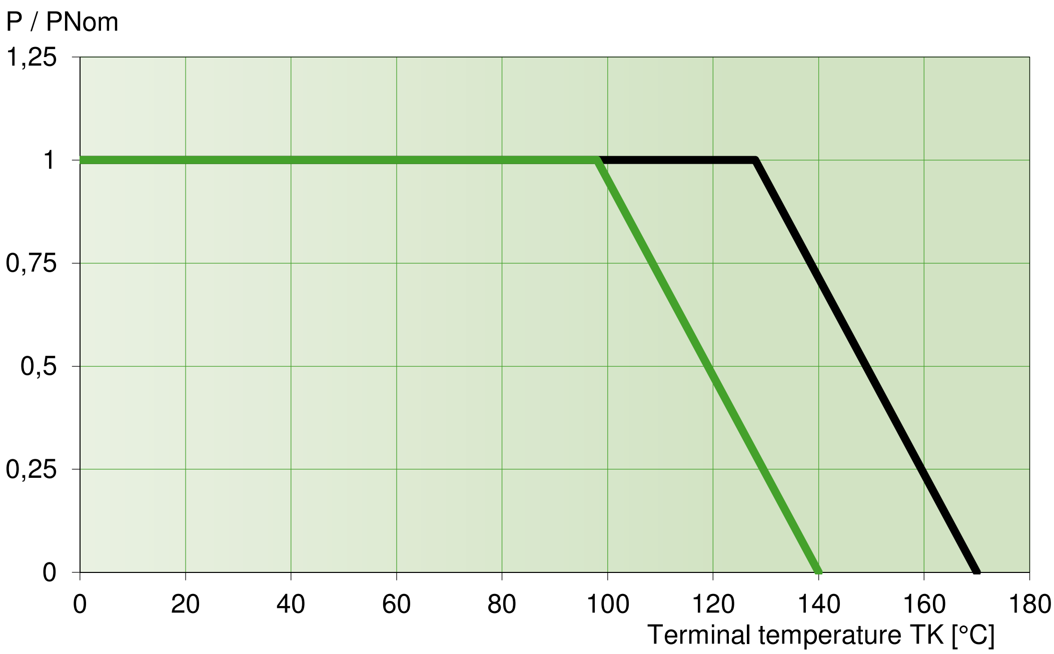

Figure 5: Power derating curve for the component BVT-M-R001

2.5 Effects of an improved long-term stability

For the required long-term stability of <1%, the resistor can be operated at 3.6 watts at 105°C terminal temperature as derived. However, what happens if the requirement is much more rigorous here and a long-term drift of no more than 0.5% is required over the life cycle or 2,000 hours?

In order to achieve the "improved stability" of <0.5% shown in the power derating curve, the hot spot temperature may not exceed the value of 140°C. The new calculation of the maximum terminal temperature if T1 is reduced from 170°C to 140°C results in:

T2 = 140 °C - 50.4 °C = 89.6 °C

This means that the power loss must be reduced at a temperature of about 90°C. Unrestricted use at 105°C terminal temperature is then no longer possible.

(See figure 6)

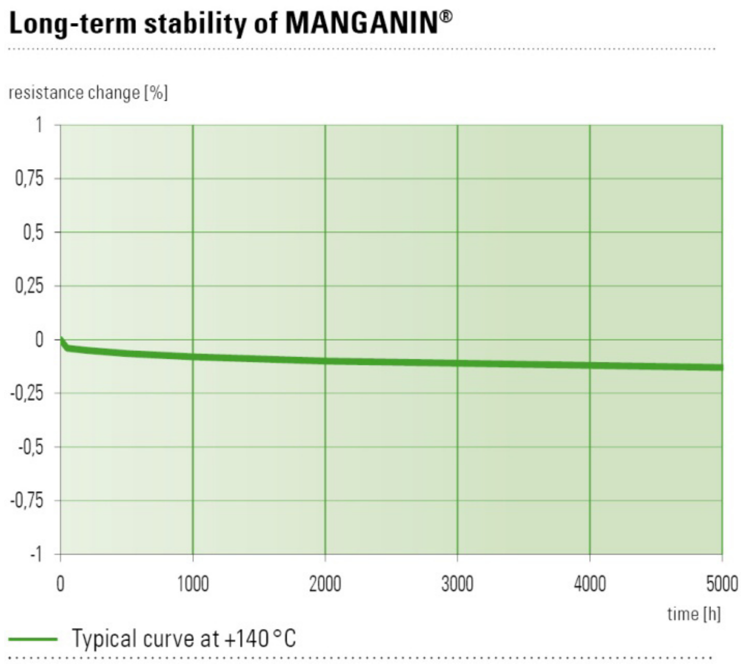

Figure 6: Typical wave form for the long-term stability of MANGANIN

2.6 Other application-specific parameters - Pulse load example

Not all parameters named in the data sheet are relevant for selecting a certain component. The application has a big impact on which component is used and which data is used for the calculations. If criteria such as the temperature coefficient, the influence of the layout, the inductance or the pulse load are decisive for selecting the component, the corresponding values must be taken as a basis for this.

The pulse load aspect, for example, is about finding out how long the component can process the current pulse. Calculations for this occur based on the value for the maximum pulse energy.

In the following example, calculations are done based on the pulse load curve.

In addition to the rated current (in this example 60 amps), there may also be short-term pulses in certain applications for which the selected component must be designed.

A malfunction in the control module could be responsible for this, which may lead to short-term currents of 150 amps, for example. However, this current is only present for a maximum of 10 ms before the system shuts down.

Can the resistor process this energy?

First we calculate the power loss via the current and the resistance value.

$P=I^2xR = 150^2 \text{ x } 0.001$ mOhm

This results in a power loss of 22.5 watts.

Figure 7: The maximum pulse energy for the component BVT during continuous operation

The following can be determined in the graphic for the "maximum pulse energy for the component BVT during continuous operation:" On the right axis of the graphic the value of 22.5 watts is read and connected to the limiting curve in the diagonal direction (orange line). The low curve was chosen, although the 1 mOhm will be slightly higher. This procedure ensures that the component is designed for the load.

At the intersection of both lines, you go vertically downward and read the max. pulse duration.

In this example, this is about 25 msec. This means that the component can process the required pulse load without being damaged.

If the load is in the limit range, Isabellenhütte is able to provide a pulse power curve for the corresponding component that is tailored to the resistance value.

3. Conclusion: The optimal solution – an interplay of technical, commercial and application-specific requirements

The data sheet forms the essential basis for the selection of the right resistor. With the specified parameters, this offers a valuable aid for being able to determine the extent to which the component optimally meets the technical requirements. However, the selection of the right component occurs between the technical parameters, the requirements that are dictated by the application and the resulting price. The optimal solution is based on an interplay between these factors. Since these are closely related, the customer must decide which conditions are the most important. This ultimately results in the suitable resistor.

The data sheet from Isabellenhütte Heusler are designed so that the user has all parameters required to determine a component. Maximum requirements are usually placed on the component. The task of the technical consultation is now to develop a proposal for how most of the requirements can be met. This means finding the physically best-possible solution among the framework conditions, such as the installation size and price. The question arises of what is feasible for the application under these conditions.

With the data sheet, you can select the technically optimal component. In cooperation with the technical consultants of Isabellenhütte, it can be considered how much power the component actually needs and which power you could do without in light of the financial framework conditions. A data sheet can help to find the optimal component. In combination with the well-founded consultation, you will not lose sight of the price on the way to finding the best technical solution.

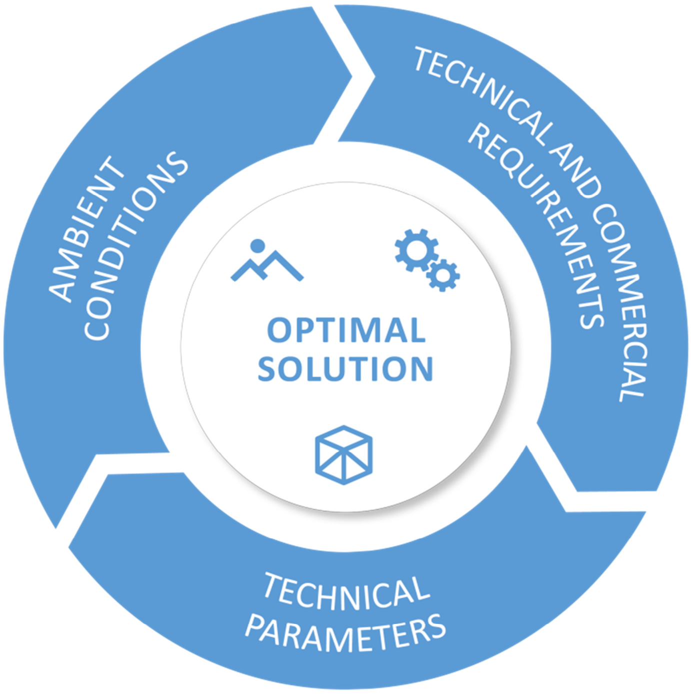

Figure 8: The interplay between requirements, ambient conditions and technical parameters

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List of figures