Resistor Specifications and How to Interpret Them

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Resistor Specifications and How to Interpret Them

In electronic circuits, resistors are used to limit the amount of current flowing to a circuit, divide voltages, adjust signal levels and terminate transmission lines, among other applications. Without resistors other circuits or modules will not work as intended. These diverse uses mean that if you take a look at a circuit board chances are better than excellent you’re going to find resistors.

These resistors come in different types and with different properties. Some can withstand high temperatures, others can withstand high voltage. Some are mechanically rugged, others offer a very high degree of precision. Some are suitable for high-speed applications and some for measurement circuits.

Among the common parameters associated with a resistor are: Resistance, Temperature Coefficient Rating of Resistance, Voltage Rating, Power Rating, Derating, Tolerance, Maximum Temperature, Resistor Construction Type and Mounting Configuration.

A reliable source of information such as a manufacturer’s datasheet should be consulted when choosing resistors. Datasheets can be viewed as instruction guides for electronic components. They are meant to guide the engineer by showing the design limits of the component. But you must first fully understand the information being presented. In this paper we will look at the key terms that turn up in datasheets and review what they really mean.

Let’s look at these one at a time.

**RESISTANCE**

*Resistance* is the main specification for resistor elements. The resistance of an element measures its opposition to electric flow, expressed in ohms (Ω). It is
the property of an electric circuit which determines the rate at which electric energy is converted into heat or radiant energy. In the general case, resistance is a function of the current, but the term is most commonly used in connection with circuits where the resistance is independent of the current.

Using Ohm’s law, the voltage (V) and current (I) of the system can be used to find the required resistance value for the resistor element.

\[ V = IR \]

Therefore:

\[ R = \frac{V}{I} \]

**TEMPERATURE COEFFICIENT OF RESISTANCE**

Temperature Coefficient of Resistance (TCR) is also provided in the datasheet. This is an indicator on how the resistance varies in terms of the operating temperatures. Resistance varies since the passage of current through the resistance produces heat, which in turn, produces a rise in temperature of the resistor above ambient temperature. TCR is a measure of the increase or decrease in resistance of a resistive conductor due to change in temperature in parts per million (ppm) per degree Celsius, or ppm/°C. It is assumed, and is generally true, that the lower the TCR, the more precise the resistor. The physical ability of the resistor to withstand, without deterioration, the temperature attained determines the operating temperature which can be permitted. As an example

\[ TCR = \frac{R_2 - R_1}{R_1(T_2 - T_1)} \times 10^4 \]

Where TCR is in ppm/°C, R1 is in ohms at room temperature, R2 is resistance at operating temperature in ohms, T1 is the room temperature in °C and T2 is the operating temperature in °C.

**POWER RATING**

An important spec to take note of in selecting a resistor is the power rating, which is the maximum power supported by the resistor. This rating is measured in watts (W) to describe how much heat energy a resistor can dissipate without overheating and sustaining damage. A Watt is a unit of electric power. It is the power expended when one ampere of direct current flows through a resistor of one ohm. Resistors can be operated at any combination of voltage and current as long as the power rating is not exceeded, and provided that neither the current rating nor the voltage rating is exceeded. The power rating of a resistor is the specification that serves to tell the maximum amount of power that the resistor can withstand. Thus, if a resistor has a power rating of 0.25 watts, 0.25 watts is the maximum amount of power that should be fed into the resistor.

Using Joule’s law – the heat produced by an electric current I flowing through a resistance R for a time t is proportional to I^2R – the voltage (V) and current (I) of the system can also be used to find the power in the system.

\[ P = IV \]

By substituting Ohm’s law in the equation, power can be determined using the resistance and system current.

\[ P = I (IR) = I^2R \]

**DERATING**

Resistors are used to control the flow of current. This results in a loss of power in the resistor, dissipated as heat. That heat causes a temperature rise which if excessive can lead to device failure. Most manufacturers specify the power rating at 70°C in free airflow conditions. At temperatures above 70°C the resistor is derated. Derating a component is the act of operating at less than rated maximum parameters. Derating increases the margin of safety between part design limits and applied stresses. This increases the component’s life expectancy and reliability. Derating also allows the component to work in harsher environments than their test conditions but at less than their rated maximum.

The amount of derating required because of, for example, enclosure is affected by a number of factors, most of which are hard to determine accurately. Therefore, it is good advice to follow standards and guidelines from the derating curves provided by the manufacturer, the military, or other regulatory agencies.

**VOLTAGE RATING**

Another important rating to consider is the voltage rating. This is the voltage that can be applied to the resistor without arcing or degrading the resistor. Physically small devices have low working voltage ratings because the...
contacts are close. Resistor datasheets will contain a specification for the maximum voltage that should be applied. Typically it is not good practice to run a resistor close to its rated voltage specification to ensure reliability is maintained.

**TOLERANCE**

Tolerance is a significant selection parameter when searching for a resistor. The tolerance of a resistor is the deviation that a resistor may vary from its normal value with no load applied. The most common way of specifying resistor tolerance is by percentage, such as 10%, 5%, 1%, 0.1% and so on. For example, a resistor which has a tolerance of 10% may vary up to 5% below and 5% above the specified value. For example a 100 ohm resistor can have a value range of 95 ohms to 105 ohms. The higher the percentage, the higher the resistance can vary. A lower tolerance indicates a resistance with less possible deviation from the indicated resistance value.

**MAXIMUM TEMPERATURE**

Resistors are designed to operate within a specified temperature range. The resistor specification for temperature needs to be adhered to since under extreme conditions damage could result and the overall circuit may fail. The maximum operating temperature in the application is required for determining the correct component size. The maximum permissible operating temperature for a given resistor is basically determined by the temperature limitations imposed by the materials used in its construction.

**RESISTOR CONSTRUCTION TYPE & MOUNTING STYLE**

Physical parameters include the resistor element’s construction and mounting options.

To meet the demands of multiple applications, Ohmite produces resistors in multiple constructions. Wirewound, Composition, Thick Film, and Thin Film are just a few of the popular constructions offered by Ohmite.

Mounting style is a factor in resistor selection. Common configurations for mounting include through-hole mounts, surface mounts, and heatsinkable/chassis mounts. As the power requirements rise the type of mounting will change. Lower wattage parts come in SMD form, typically below 3 watts. As power rises, axial thru-hole mounting is used up to 10 watts.

Through Hole Technology (THT) mounts resistors on a printed circuit board (PCB) by inserting the component leads through holes in the board and then soldering the leads in place on the opposite side of the board. It provides stronger mechanical bonds than surface mount techniques, but requires more expensive boards due to the additional drilling required.

Heat Sinkable/Chassis Mount. Smaller than standard parts of the same wattage heatsinkable/chassis mount resistors typically release their heat in one plane. The single side is attached to a heatsink and the heat generated is absorbed. Once the heat is absorbed it is released into the air through the heatsink. An advantage of heatsinkable/chassis mount resistors is the ability to get custom leads, which provides the engineer design flexibility and may increase voltage potential of the resistor.

Surface Mount Technology (SMT) parts adds resistors to a printed circuit board (PCB) by soldering component leads or terminals to the top surface of the board, mounted on one side. This offers space savings as the other side is free from a solder connection. The solder traces used for the surface mount parts offer a small thermal advantage absorbing some heat produced by the part. SMT resistors normally have very low power dissipation. Their main advantage is that very high component density can be achieved on a PCB.

Finally, to select a resistor for a specific application, the following steps are recommended:

- Determine the Resistance.
- Determine the watts to be dissipated by the resistor.
- Determine the proper physical size as controlled by watts, volts, permissible temperatures, mounting conditions and circuit conditions.
- Choose the most suitable unit, including type, terminals and mounting.

For more information go to www.ohmite.com.