

Bulk Metal[®] Foil Technology Glossary of Terms

ACCEPTABLE QUALITY LEVEL (AQL): The maximum percent defective (or maximum number of defects per hundred units) that, for the purpose of sampling inspection, can be considered satisfactory as a process average. Defects may be both major and minor, according to definition, and may have different AQLs. AQLs of 1 % major and 2.5 % minor are common. A sampling plan should have a low Producer's Risk for quality which is equal to or better than the AQL.

ACCURACY: The degree to which the measured value of resistance approximates the specified value of resistance. This is normally expressed in percent deviation but in precision resistor work, the percent is often so small that the results are reported in parts per million. Thus the measured value could be for example, - 50 ppm deviation from the nominal value of 5000 Ω for a measured resistance of 4999.75. Note that it takes a minimum of seven significant figures to properly measure a precision resistor of 50 ppm accuracy.

ALLOWABLE SPREAD: The limits to which a given parameter can range.

AQL: Acceptable quality level.

BACKLASH: The amount of reverse rotation of an adjustment control required to cause an electrical change in the opposite direction.

BULK PROPERTIES (primarily applicable to metals and their alloys): Bulk properties are the characteristics of the parent metal and/or alloy from which a resistive element is to be made. These bulk properties are degraded by rolling, drawing, winding, evaporating, sputtering, heat treating and laminating. Various compensating techniques permit the finished devices to display properties similar to the parent metal and foil resistors provide the most faithful reproduction of bulk properties in a commercially available resistor.

CONTACT RESISTANCE: A variation in the electrical output of a trimmer not present in the electrical input, evident when the wiper traverses the element. Expressed in ohms or as a percentage of the total resistance.

CONTACT RESISTANCE VARIATION - CRV (NOISE): The instantaneous change in contact resistance that may occur as a result of wiper movement. Typically, it is given as a percentage of total resistance or as some maximum number of ohms.

CROSS TALK: A signal received in a nearby component caused by the signal in a transmitting component. This is primarily a result of RF radiation and may be eliminated by shielding to ground.

CURRENT NOISE: An AC component of voltage appearing across a resistor when a direct current is passed through it. Usually expressed in RMS microvolts (μ V) per volt applied to

the resistor, it may also be expressed in noise index figures of - dB.

CURRENT RATING: The highest current that may be passed through the device (usually continuously) over a long period of time without causing the component to fail or shift outside of allowable limits. Applicable to low values particularly because the power rating limits the current in higher values.

DERATING: The intentional restriction of power application below the manufacturers stated power rating. Some military programs require derating all resistors to half power but this is not necessary with foil resistors. (Request technote #13 for the actual gain in stability of foil resistors for various degrees of derating).

DIELECTRIC WITHSTANDING VOLTAGE (DWV): As applied to resistors this is the maximum voltage, between leads tied together and the external case, that can be withstood without breakdown (arc - over) or other harm to the device. It is normally specified in DC volts for a specified period of time and with some margin of safety.

DWV: Dielectric withstanding voltage.

ELECTROMECHANICAL INTERFERENCE (EMI): Radiation from an external source causing signal distortion.

ELECTROMOTIVE FORCE (EMF): The voltage output produced continuously from a generating source. The voltage produced by the heating of joint dissimilar metals due to differences in molecular activity. This is considered a parasitic undesirable effect in resistors.

ELECTROSTATIC DISCHARGE (ESD): The application of a high voltage and low current to a device as a result of its coming in contact with or in proximity to a charged object. In very dry climates, charges build up on any moving object including people. These charges pass to any object or electrical ground when the charged body comes into proximity with the uncharged body. Thus the device is said to be ESD sensitive if this passage of charge in any way does harm to the device.

END RESISTANCE (ER): The resistance measured between the wiper terminal and an end terminal when the wiper is positioned against the stop at that particular end terminal.

EQUIVALENT NOISE RESISTANCE - ENR (Zero Based CRV): The change in contact resistance made up of a dc offset plus CRV. The resistance measured between the wiper and the resistance element when one milliamperes of current is passed through the wiper as it is adjusted.

ESTABLISHED RELIABILITY (ER): The demonstrated ability of an item to perform a required function under stated conditions for a stated period of time. As a practical matter it is not possible to demonstrate item reliability under all conditions so load-life testing is relied upon to speak for other

demands and a failure rate demonstration is conducted. Qualification and Maintenance testing over an extended period of time demonstrate failure rates such as 0.1 % failures per 1000 hours of testing. This equates to a MTBF of 1 million hours.

FREQUENCY RESPONSE: The ability of a resistor to faithfully replicate a signal at specified frequency. In an AC circuit the voltage drop and the current passed are a function of not just the DC resistance but also the reactance at specified frequency. Foil resistors are good at frequencies into the megahertz range.

HERMETIC SEALING: The placement of a device in an enclosure impervious to gas transmission generally for the purpose of protecting it from moisture. The degree of hermeticity is usually determined by exposure to pressurized Helium and then measuring the rate at which the Helium escapes. Acceptable leak rates normally are equal to or less than 1×10^{-7} atmospheric cc per second (Helium is used because it has one of the smallest mean molecular paths of any gas and is easy to handle and detect in production.)

HOP-OFF: The resistance change measured between the wiper and an end terminal as the wiper moves off that end terminal and initially comes in contact with the resistance element.

HUMIDITY COATING: The application of various coating materials (resins, silicones, polymers, etc.) for the purpose of retarding the ingress of moisture to components and circuitry.

IMPEDANCE: The vector sum of the resistance and inductive and capacitive reactances of a circuit or device.

IMPROVED PERFORMANCE TESTING (IPT): The enhanced stability that can be achieved through screen testing and/or exercising a resistor prior to shipment. Generally it is preferred to design the product for a given level of stability but in precise work where a few parts per million shift can be objectionable, conditioning of a part prior to shipment becomes a necessary alternative. Vishay has a specific IPT routine for this purpose but offers a variety of test plans.

INSULATION RESISTANCE (IR): The resistance presented to a direct voltage applied between the trimmer terminals and all other external conducting parts such as shaft, housing and mounting hardware.

LIMITING QUALITY (LQ) : The lowest product quality that the consumer is willing to accept, usually expressed as a maximum percent defective allowed.

LOAD-LIFE STABILITY: The measured change in resistance resulting from the application of specified power at specified temperature for a specified time interval. Commonly used time intervals are 1000, 2000, and 10 000 hours and commonly used temperatures are 60, 70, 85 and 125 °C. Allowable changes depend on the resistor element technology. Foil elements exhibit the least change (most stable) under comparable conditions.

LOT AVERAGE: The arithmetic mean of a test lot distribution of n quantities each having an individual value.

MATCH OR MATCHING: Two or more resistors grouped into narrower limits within the total tolerance span.

MAXIMUM WORKING VOLTAGE: The highest voltage that may be applied (usually continuously) over a long period of time without causing the component to fail or shift outside of allowable limits. This voltage may be further limited in lower values by the power rating which must not be exceeded.

MECHANICAL STOPS: Limits to wiper motion at each end of the wiper travel.

MICROHENRY (μH): 10^{-6} henry. The Henry is the unit of inductance. The smaller microhenry is more in keeping with the range of inductance exhibited by resistors.

MOISTURE RESISTANCE: The ability to retain initial characteristics through specified moisture and voltage application. Unless hermetically sealed all resistors experience some change in value due to moisture. Because of the bulk properties, foil resistors experience the least change of commercially available precision resistors.

NOISE: An unwanted signal inserted by the flow of current in a resistor. This current noise depends on the structure of the resistive element. Alloys such as foil and wire exhibit the least current noise.

NOMINAL: The specified value of resistance or TCR or other parameter to which a tolerance or spread is applied.

PARTS PER MILLION (ppm): (Conversion of % to ppm)

%	ppm
0.0001	1
0.0002	2
0.0005	5
0.001	10
0.0025	25
0.005	50
0.01	100
0.02	200
0.025	250
0.05	500
0.1	1000
1.0	10 000

Formula is: $\frac{0.0001 \% \times 10^6}{100} = 1 \text{ ppm}$

OPERATING TEMPERATURE RANGE: The lowest to the highest ambient temperature range within which a device is expected to operate for a prescribed period of time and remain within prescribed limits.

PERCENT DEFECTIVES ALLOWED (PDA): The limiting number of defects in one inspection lot that will permit acceptance of the lot. Tightened inspection may be permitted with a larger PDA and additional samples in the inspection plan.

Example: If more than 3 % of the lot fails, reject lot.

PHASE SHIFT: The result of capacitive and/or inductive reactance causing the resistor output signal to lead or lag the input.

PICOFARAD (pF): 10^{-12} Farads. The Farad is the unit of capacitance. The smaller picofarad is more in keeping with the range of lumped capacitance exhibited by resistors.

POWER RATING: The maximum power that can be applied, under specified conditions of environment and duration, which will not produce a permanent change in excess of specified limits. Foil resistors are capable of considerable overload for short periods of time and exhibit the least drift of any commercially available resistors when subjected to rated power. Drift reduction is obtainable through derating and/or power conditioning.

QUALIFIED PRODUCTS LIST (QPL): A government listing of products and suppliers currently qualified to a military specification.

REACTANCE: Inductance, due to coil effect, and capacitance, due to capacitor effect, pass current vectorially normal to the passage of current through the resistance and are called reactances. The lagging inductive reactance and the leading capacitive reactance are combined vectorially with the DC resistance to calculate the AC resistance or impedance of the resistor at a given frequency. Vishay foil resistors have extremely low reactances and thus have fast rise time and good frequency response.

RELIABILITY: The ability of an item to perform a required function under stated conditions for a stated period of time. In practice, the mean time between failures (MTBF) is a more precise mathematical way of defining reliability.

RESISTANCE RANGE: The spectrum of resistance values that can be manufactured within a particular product style and still comply with a common set of specifications.

RISE AND DECAY TIME: The length of time between the initial imposition of a voltage across a resistor and the time that the resistor is passing a constant current. It is measured between the points in time when the current reaches 10 % and 90 % of its final steady state value.

ROOT MEAN SQUARE (RMS): The effective value of a current wave calculated by the root mean square method produces the same heating in a given resistance as a direct current of the same value. The root mean square calculation consists of dividing the wave into segments, squaring the segment lengths, adding the squared lengths and extracting the square root of the sum of the squares. For a sine wave this is a 0.707 x peak current.

$$I \text{ (RMS)} = I \text{ effective} = \sqrt{\frac{I_m^2}{2}} = 0.707 I_m$$

$$E \text{ (RMS)} = E \text{ effective} = \sqrt{\frac{E_m^2}{2}} = 0.707 E_m$$

Where I_m and E_m are the peak values of current and voltage.

ROTATIONAL LIFE: The relative change of resistance due to a number of traverses (back and forth) or complete rotations of the adjustment screw of a trimmer before the trimmer fails to meet prescribed performance criteria.

SELF HEATING: The heat generated within the resistive element caused by the application of voltage. Self heating raises the device temperature above the ambient temperature and the internal hot spot temperature is kept within safe limits by adherence to the power rating and derating curves.

SETTABILITY: The degree of accuracy to which a trimmer can be adjusted to a previously determined point in 20 seconds. This point can be either an output voltage ratio or some specific value of resistance expressed as a percentage of the trimmer's total resistance.

SETTING STABILITY: The ability of a trimmer's wiper contact to remain stationary when the trimmer is subjected to various environmental stress.

Expressed as:

$$\text{setting (\%)} = \frac{E_1}{E_2} \times 100$$

Where:

E_1 = Voltage across one end terminal and the wiper terminal

E_2 = Voltage across the end terminals

The difference between the initial measurement made before the environmental test and the measurement made after the test indicates the setting stability in %.

SHELF-LIFE STABILITY: The change in resistance value when an item is stored under standard conditions, such as + 25 °C, ± 15 °C and 10 % to 75 % Relative Humidity for a stated period of time. Foil resistors undergo no significant permanent change due to shelf conditions but may see some small change due to humidity fluctuation. This humidity effect is completely reversible by drying.

SHORT TIME OVERLOAD (STOL): The application of a specified extra power for a short period of time. Usually used as a screen test or qualifying test. Foil resistors can sustain considerable overload without damage and routinely receive 6-1/4 x rated power for five seconds during final inspection.

SOURCE CONTROL DRAWING (SCD): A user generated specification usually in the absence of a military specification but embracing much of the discipline of a military specification. May require non-standard parts approval before proceeding.

SPEED OR SPEED OF RESPONSE: The time interval necessary for the current to pass from 10 % to 95 % of full current following a voltage application. This is generally in the nanosecond time range. Foil resistors are the fastest of any precision resistors and require less than 1 nanosecond rise time.

SPREAD: The total range of values within a lot.

STABILITY: The ability of any device to retain its initial characteristics through one or more imposed stresses. Foil resistors are uniquely stable through all environmental.

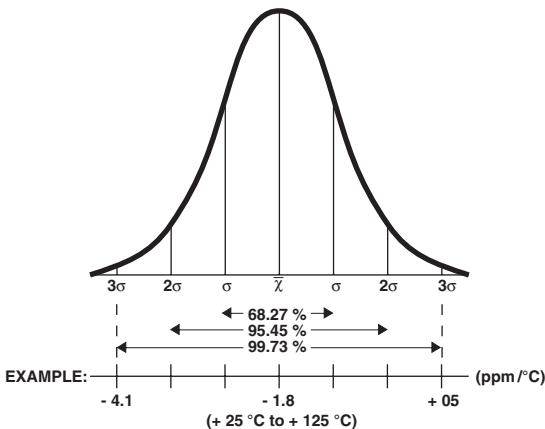
STANDARD DEVIATION (σ): The standard deviation (root mean square deviation) is used to measure the dispersion of a group of quantities about the mean (\bar{x}). Based upon the Normal Law Integral, approximately 68 % of the quantities in the group will be within $\bar{x} \pm \sigma$ (known as the 2 σ limit) as shown in the graph below. The formula for finding the standard deviation is:

$$\sigma = \sqrt{\frac{\sum(x - \bar{x})^2}{n}}$$

Where \bar{x} = arithmetic mean value of all quantities
 x = value of any quantity
 n = total number of quantities in the population

The normal distribution curve is a pictorial representative of the distribution of readings about the mean. Pictured is a representation of the TCR values of Vishay foil resistors from + 25 °C to + 125 °C.

Nominal Distribution Curve



(TCR): TEMPERATURE COEFFICIENT OF RESISTANCE

This coefficient relates the change in resistance to any change in temperature. The general equation is:

$$TCR = \frac{R_2 - R_1}{R_1(T_2 - T_1)}$$

Where R_1 = Resistance at Temperature T_1
 R_2 = Resistance at Temperature T_2

Negative TCRs are possible when R_2 is less than R_1 . TCR is generally expressed as parts per million per degree C (ppm/°C).

Foil resistors have the lowest and most consistent nominal and the least spread of any commercially available resistor.

TCR – NOMINAL : The mean of a production distribution of n quantities each having an individual value x . For Vishay products, the nominal value is independent of the lot

manufactured, the time of manufacture or resistance value of the trimming potentiometer.

TCR – END-TO-END: The temperature coefficient relating a change in the trimmer end-to-end resistance (pin 1 to pin 3 with the wiper on an end pad) to the difference in temperature producing the change.

TCR – THROUGH THE WIPER: The temperature coefficient relating a change in the trimmer wiper to end resistance (pin 2 to pin 1 or 3) to the difference in temperature producing the change.

THERMAL ELECTROMOTIVE FORCE (THERMAL EMF):

The temperature dependent voltage output produced continuously from two dissimilar metals or alloys joined together to form a metallurgical junction or thermocouple. Various metals and their alloys have different output levels in combination with other metals and alloys according to their position in the periodic table of elements. Since resistors commonly have copper leads, the various metals employed in making resistors have their thermal EMFs identified in $\mu V/°C$ vs copper. Foil resistors have very low thermal EMF outputs because the foil alloy has a low output versus copper and the two lead connectors are close together precluding any significant temperature difference between them. (One has positive polarity and the other negative polarity in the equivalent circuit so if they are at the same temperature there is zero output).

THERMAL SHOCK: A major temperature change with specified rate of change imposed on the device. Foil resistors can sustain considerable thermal shock including the accelerating effect of liquid nitrogen to hot oil testing. Many other constructions require a ramp up and dwell to avoid destruction of internal connections.

TOLERANCE: The permissible resistance deviation from nominal expressed in percent; e.g. $\pm 0.005\%$. Note that the tolerance normally permits deviation either side of nominal but circumstances could call for deviation on the + side only in which case the spread allowed by the previous tolerance becomes 0 % to + 0.01 %.

TRACK OR TRACKING: Two or more resistors exhibiting similar responses to temperature within specified limits or "track". While tracking with temperature is the most frequent use of the term, there may be occasions when tracking with load, environmental and time are required. Foil resistors offer the best available tracking with all stresses in addition to temperature.

TYPICAL: A designers reference which represents that 85 % of the units supplied, over a long period of time, will be at least the figure shown or better.

VOLTAGE COEFFICIENT: This coefficient relates the anticipated change in resistance to any change in voltage. The voltage coefficient of foil resistors is so low it is largely ignored in practice. Some other resistors do not follow Ohm's law and may have a different resistance value when measured under different voltages.