



Tech Note

Dictionary: Know Your Resistors

Adhesion: The ability of dissimilar metals or particles to cling together as a joint is referred to as adhesion. Adhesion in thick film is created by either a chemical (oxide bonded) or mechanical (Frit) bonds. Peel test can be used to measure adhesion between lead and substrate and dielectric.

Alpha coefficient: In a thermally sensitive resistor or Thermistor applications, the alpha (α) coefficient is a material characteristics which defines the percentage resistance change per degree centigrade. It is also known as the temperature coefficient and it's calculated by the following relationship;

$$\alpha = \frac{1}{RT} \times \frac{dR}{dT}$$

Where RT is the resistance of the component at the relevant temperature in ($^{\circ}\text{C}$), dR/dT is the gradient of the R vs. T curve at that temperature point and alpha is expressed in ($\%/^{\circ}\text{C}$)

Annealing: Annealing is a heat process whereby a material (metal or glass) is heated to a specific temperature (annealed point) and then allowed to cool slowly in order to maintain ductility and prevent crack and internal stress.

Aspect Ratio (AR): The ratio of resistor length to resistor width is the aspect ratio. It's also known as the number of squares.

Amplitude Balance: The maximum deviation or difference in amplitude between the output ports of a power divider across the operating frequency range. It's measured in dB

AQL (Acceptable Quality Limit): This is a statistical measurement of the maximum number of defective goods considered acceptable in a particular sample size or lot.

Attenuation: The loss of signal (Power or Amplitude level) in transmission through the use of attenuators or a filter; It's measured in decibels (dB). Attenuators are passive (There are active component attenuators also) two ports component which are generally used in radio, communication and transmission line applications to weaken or attenuate the power being supplied by a source to a level that is suitable for the connected load. The attenuator could be fixed or variable with switchable steps. They are designed in different configurations such as pi (π) or T or L etc

Avalanche Breakdown: This is a phenomenon that causes breakdown in both insulating and semiconducting materials due to current increase caused by electric current (avalanche) multiplication of charge carriers in the region featuring very high electric field.

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Bandwidth: Bandwidth is a measure of how much spectrum a microwave system can respond to in an application. It is expressed in Hertz to several megahertz or gigahertz

Beta Value: Thermistor material is typically identified by its Alpha coefficient, Beta value or the ratio between the resistances at two specified temperatures. The amount of change per degree Celsius ($^{\circ}\text{C}$) in Thermistor technology is defined by the material constant known as the Beta value and it is expressed in degree Kelvin (K).

Bifilar Winding: in a wire wound resistor technology, the resistive elements are constructed such that the magnetic field effect of one winding cancels out or opposes the magnetic field effect of adjacent winding in order to minimize parasitic self-inductance of the resistor. The term bifilar describes two strands parallel coil.

Boella Effect: In high valued carbon-composition resistors, additional internally distributed capacitances between the conducting particles of the resistor forms a kind of noise (Boella effect named after Mario Boella) which lowers the effective value of the resistance as the frequency increases.

Breakdown Voltage: This is the minimum voltage that causes a portion of an insulator to become electrically conductive. For example, in a semiconductor diode, the minimum voltage required to make the diode conduct in the reverse direction is called the diode's breakdown voltage.

Cermet: A cermet is a composite thick film resistive paste typically made from the mixture of ceramic and metallic oxide, like ruthenium oxide (RuO_2). It's ideally designed to have the optimal properties of composition materials.

Chiller: Device used to lower the temperature of cooling fluids. Found in dicing water cooling and in "air-cooled" laser systems.

Critical Resistance Value: For a given resistor voltage and power rating, there exists a value of resistance that would dissipate full rated power at rated voltage. The value of this resistance is known as "critical resistance value". It is the maximum nominal resistance value at which the rated power can be applied continuously without exceeding the maximum working voltage. The rated voltage is equal to the maximum working voltage at the critical resistance value.

Cryogenic Thermistor: This is the type of Thermistor that is used for liquid level detection in cryogenic (very low temperature- from -150°C to absolute zero) applications.

Current Sensing: The act of sensing current is ubiquitous and a fundamental requirement in applications like DC-DC and AC-DC power converters, voltage regulator modules (VRM), battery chargers, motor control and other wide range of electronic circuitry and applications. A current sensor is a device that detects and converts current to a measurable voltage that is proportional to the current flowing through the measured path. The most common way to sense current is using Current Sensing Resistors. The current sense resistor must exhibit certain characteristics like; low temperature coefficient of resistance, low ohmic value- in the milliohm range, tight tolerance to maintain accuracy and low parasitic inductance for reduced emf among others.

Curie Point: In ferroelectric dielectrics, the temperature at which the dielectric constant reaches peak values is the Curie point or temperature. The Curie point, named after Pierre Curie, is the critical temperature at which a material's permanent magnetism changes to induced magnetism or vice versa.

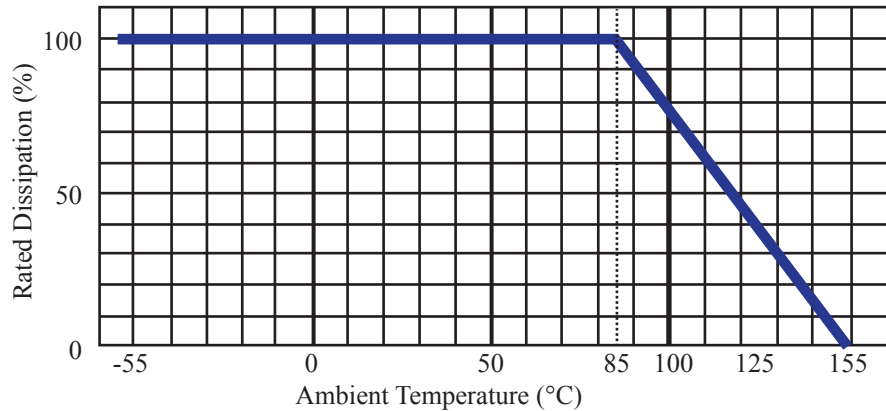
Current Noise: The current noise is expressed in RMS microvolt per volt ($\mu\text{V}/\text{V}$) or in dB and it is the AC component of voltage across a resistor when current flows through it.

dB (decibel) : In acoustic applications or high frequency physics or electronics, the logarithmic unit of measurement that expresses the magnitude of a physical quantity, such as power or sound level is the decibel.

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Derating Curve: The derating curve of a device is the curve that typically shows the relationship between the operating ambient temperature and the power (current) dissipation. It is typically used in design to keep components in its safe operating region.



Typical power derating curve

Dicing: The process of singularization by sawing with a blade. This method scraps the material removed by the blade.

Dielectric Constant: The Dielectric constant of a material is also known as it's relative permittivity. It is the ratio of the amount of electrical energy stored in a material by an applied voltage relative to that stored in a vacuum.

$$\epsilon_r = \epsilon_{(w)} / \epsilon_0$$

Dielectric Strength/ Dielectric Withstand Voltage: This is the maximum electrical stress that a material can withstand without experiencing breakdown.

Dissipation Constant: The dissipation constant defines the amount of power which, when dissipated in a thermistor, will increase its body temperature by 1°C above the ambient temperature. It's a feature that quantifies the self heating of a Thermistor and it's expressed in mW/°C.

Energy: The amount of power dissipated within a unit of time is the Energy. The energy dissipated in a resistor is expressed as

$$V^2/Rt = I^2Rt \text{ (Joules)}$$

Far-field: The far-field is a region of the time-varying electromagnetic field that is farther away from the source (e.g an antenna) than the near reactive field.

FR-4: This is a composite material of woven fiberglass with an epoxy resin binder. It's a glass reinforced epoxy flame resistant laminated sheets, used in PCBs and other electrical and mechanical applications.

Furnace: Manufacturing equipment used to fire thick film materials on thick film substrates at operating temperatures of up to 800 degrees Celsius or greater.

GaAs (Gallium-Arsenide): This is a group III/V compound of gallium and arsenic that is used in the manufacture of MMIC (monolithic microwave integrated circuit) and other microwave applications and component. It has higher electron mobility than silicon which makes it suitable for high frequency (greater than 250GHZ) semiconductor applications.

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Hi-Meg: These are resistors with high value resistance that can typically range from several Giga-ohms to Tera-ohms range. IMS regards 200 megohms as the starting point for high meg. After this point resistors cannot be laser trimmed and must be sorted instead.

Hybrid Couplers: Hybrid couplers are four-port directional coupler that is designed for a 3-dB (equal) power split. There are two types of this type of couplers; 90 degree (quadrature) Couplers and 180 degree hybrids couplers.

Hot-Spot Temperature: The hot-spot temperature of a resistor or a device is the maximum temperature measured on any part or area of the resistor as a result of internal heating and the ambient operating temperature contributions. It can also be the highest temperature on the derating curve at which the device is derated to zero power.

Impedance: The complex (it's a vector) ratio of the voltage to the current in an alternating circuit is the impedance. Typically denoted by Z and expressed in ohms just as resistance, the reciprocal of impedance is the Admittance which is expressed in Siemens.

Inductance: The measure of the magnitude of the magnetic flux produced per electric current is the inductance. The unit of inductance is the Henrys (typically mili-henry or micro-Henry) and the symbol is L.

Insertion Loss: The loss of power resulting from the insertion or installation of a device in transmission applications is the insertion loss. It's expressed in dB and follows the following relationship;

$$IL = 10 \log_{10} \frac{P_t}{P_r}$$

where P_t is the power transmitted before insertion and P_r is the power transmitted after insertion.

Insulation Resistance: This is the DC resistance measured between all terminals connected together and the device's case - usually very high.

Junction Temperature: The junction temperature of a device (typically a semiconductor component or IC) is the highest temperature of the device during operation. The difference between the junction temperature and the case temperature can be determined using the junction-case thermal resistance.

Kirkendall Void: The effect of the motion of the boundary layer between two metals or between metal and metal alloys as a result of the difference in the diffusion rates of the metal atoms is known as the Kirkendall effect. The resulting voids formed at the interface are known as the Kirkendall voids, also known as Purple Plague.

Laser Trim: The process of cutting through or burning away a portion of resistors in order to change the resistance using a laser (Light Amplification by Simulated Emission of Radiation) device. Selection of proper operating parameters like beam power, pulse frequency, trim speed etc is very important to achieve accurate laser trimming results.

Loss-less: This is an RF device that does not have inherent resistive losses. A reactive power divider can be designed using either Microstrip or Stripline. A Wilkinson power divider designed with a Microstrip is an example of loss-less device.

Low-pass Filter: A low-pass filter passes or allows low-frequency signals and attenuates or rejects higher frequency (higher than cut-off frequency) signals.

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Microstrip Line: Microstrip consists of a thin-flat conductor above a ground plane and a dielectric spacer sandwiched in between. Microstrip are typically used in the construction of passive microwave components such as power splitters, combiners and filters, etc., as alternatives to lumped element construction.

Negative Temperature Coefficient (NTC): A resistor or a Thermistor or any electronic component that decreases in resistance as a result of increase in temperature is referred to as NTC component.

Oven: Manufacturing equipment used to bake or dry thick film materials. This is typically done at temperatures of less than 200 degrees Celsius and is often a preparation step for firing.

PIM (Passive Inter-modulation): This is a form of interference or distortion that occurs in RF systems comprised of passive components such as antenna, switch, isolator or RF interconnects when multiple and high power signal inputs with non-linear characteristics are present. The non-linearity could be as a result of dissimilar metals, or loose interconnections, contact dirt or oxidation, poorly prepared RF terminations, misaligned parts, contact impurities etc. PIM degrades the quality of a communication system. Ferro-magnetic materials or plating are very susceptible to PIM.

Positive Temperature Coefficient (PTC): A resistor or a Thermistor or any electronic component that increases in resistance as a result of increase in temperature is referred to as PTC component.

Plating: Plating is a method of depositing metallic layer (Typically Gold, silver, tin etc) on a conductor to improve the electrical conductive performance and or for the protection of the conductive surface.

Power Splitter: A resistive power splitter is a passive device which accepts an input signal and divides or splits into multiple output signals. The output signals would have specific phase and amplitude characteristics as well as default insertion loss that is dependent on the number of output ports. This is also referred to as lossy power splitters. Power splitter can also be used as power combiner, but each input signal must be in phase to function properly.

Purple Plague: Purple plague is an inter-metallic joint of the compound of gold and aluminum (AU-Al). It's a brittle bright purple compound that can cause cavity and increased resistance at the interface of the two metals.

Reach Compliant: REACH (Registration, Evaluation and Authorization of Chemicals) is a European Union regulation that requires manufacturers of substances to provide safety data and manage related hazards of their product.

Re-flow: The Reflow soldering is commonly employed in the surface mount device (SMT) technology whereby a solder paste is applied to the contact pads of the SMT device and then subjected to controlled heat or Reflow oven for permanent joint.

Resistance Tolerance: This is the permissible deviation (in percent) of the resistance value from the specified nominal resistance value at the stated conditions.

Return Loss: The Return loss of a transmission system is a measure of the effectiveness of power delivered to a load such as an antenna. Assuming the power incident to a load is P_{in} and the power reflected back to the source is P_{ref} , the degree of mismatch between the incident and reflected power is the ratio P_{in}/P_{ref} . The higher this power ratio is, the better the load and line are matched. The $RL = 10\text{Log}_{10} \left(\frac{P_{in}}{P_{ref}} \right)$ and it is expressed in dB

RoHS: This is the acronym for (The Restriction of Hazardous Substances). It is a European Union Directive 2011/65/EU (also known as RoHS2) that limits or restricts the use of six hazardous substances (Lead, Mercury, Cadmium, Hexavalent Chromium, Polybrominated biphenyl (PBB) and Polybrominated diphenated ether (PBDE) in the manufacturing of electrical and electronic equipment.

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Rubber Packs: Rubberized epoxy pads made to fit a chip array in order to rework individual chips. Often used to laser trim film resistors or hold parts for number screening.

Scribing: The process of partial singularization by partial cutting or pulsing with a laser, which results in a “scrap-less” singularization.

Singularization: The act of separating parts from plate form to piece form.

Snap and Inspect: Singularization of substrates prepared by scribing.

Stripline: The Stripline is different from the Microstrip in that a second ground plane is added above the conductor strip such that the center conductor is equal-distance from the pair of the parallel ground planes. One of the advantages of this type of line is that it has better shielding than Microstrip.

Substrate: The resistive substrate like Alumina, Aluminum Nitride, and Gallium Nitride etc is the material upon which the resistive element or layer is applied and adhered to.

Tape and Reel: An alternative packaging method which places a part in a depression of a plastic or paper strip. The parts are secured with a heat or contact sealed cover tape which keeps the individual parts in separate depressions along the tape.

TCR: The temperature coefficient of resistance (TCR) is one of the key parameters in the specifications of a resistor. It is defined as the magnitude of change in resistance per degree change in temperature. TCR is typically expressed in $\%/^{\circ}\text{C}$ or PPM/ $^{\circ}\text{C}$ (parts per million per degree Celsius). For example a Resistor rated as having a TCR of 10ppm will experience a resistance change of 0.1% over a 100°C change and 0.01% over 10°C change

ThermaBridge™: In applications where conventional heat sink and fan are not viable, the ThermaBridge™, which is an electrical insulating but thermally conductive device, may be used as a conducting path for heat transfer. Additional info about the IMS ThermaBridge™ is available here: <http://www.ims-resistors.com/therma-bridge/>

ThermaPlane™: The ThermaPlanes™ are attached to a heat generating device as a means of heat transfer path to a ground plane or heat-sink. It is mountable directly to the device generating the heat and the destination of the heat. The ThermaPlane™ is similar to the ThermaBridge™ in that they are both used for thermal management solutions. Additional info about the IMS ThermaPlane™ is available here: <http://www.ims-resistors.com/therma-plane>

Thick Film: The thick film passive devices like the chip resistors are very prolific in electronics devices and are made by screen printing a resistive element like ruthenium oxide paste onto a ceramic substrate. The thick film resistive element is 1000 times thicker than the thin film element. Standard tolerance of thick film resistors are 1% or 5%.

Thin Film: Thin film resistors are manufactured by sputtering process whereby a very thin metallic film is deposited (by sputtering) on a substrate under vacuum conditions. The resistive element for thin film resistors is approximately 1000 angstroms (Å) thick and provides for a uniform resistive film without micro-cracks during trimming. Thin film resistors are able to achieve much tighter tolerances and resistor temperature coefficients than their thick film counterparts.

Tolerance (value): The maximum resistance deviation under the resistor’s specified conditions is the tolerance of the resistor. Typical values are 0.1%, 1%, 5% and 10% of nominal values.

Transients: The instantaneous change from a steady state leading to burst of energy for a short period of time is referred to as transient. Transient response and stability is one of the key features that a power system must specify.

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VCR: The voltage coefficient of resistance (VCR) is defined as the magnitude of change in resistance per 1V change in voltage applied across the resistor. VCR is typically expressed in %/V or PPM/ V (parts per million per voltage).

VSWR: The voltage standing wave ratio (VSWR) is a measure of how efficiently an RF power is transmitted from the source through the transmission lines to the load (like an Antenna). $VSWR = \frac{1+\Gamma}{1-\Gamma}$ where Γ is the reflection coefficient. The closest the ratio to unity (1:1), the better.

Waffle Packs: Typically a plastic tray designed with individual compartments to hold one chip each. This is an alternative packing option to bulk pack or tape and reel.

Waveguide: Electromagnetic wave propagation in open space without a means to guide or confine it results in loss of power that is proportional to the square of the distance. A waveguide is used to transmit or carry radio frequency energy from one point to another. There are different types of waveguides based on applications and structures.

Wire Bond: This is a type of interconnection between integrated circuit or other semiconductor devices and its packaging during the device's fabrication. Bond wires could be Au (gold), Cu (copper) or Al (aluminum).

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