Stackpole Electronics, Inc.
Resistive Product Solutions

Technical Article

Thick Film Chip Resistor Trim Designs and Their Effects on Performance

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Surface mount thick film chip resistors are the predominant resistor in most electronic circuits today. This technology is inexpensive as the initial processes can be done in substrate form where, depending on the size of the chip, hundreds or thousands of parts may be processed at once. Screen printing in mass production is generally only effective in providing resistors within 5% to 20% of the required value. Calibration trimming by laser allows manufacturers to utilize the maximum number of parts from a screen printed lot by calibrating them to value without slowing down the printing processes in an attempt to achieve better initial accuracy.

There are different laser trim designs and shapes which present different manufacturing challenges and that yield different characteristics. This article will examine the different trim shapes and discuss the strengths and weaknesses of each and their reasons for being used.

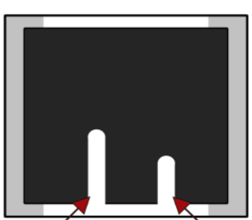
Laser Calibration Trimming

Laser trimming thick film resistors involves pulsing a round laser beam into the cured thick film material which vaporizes the material under and around the beam. By removing the material, the resistance value is adjusted slightly higher. Subsequent pulses remove more material and further increase the value of the part. The purpose of this article is not to get into the details of bite size, Q rate, kerf width, or other specifics about the laser trimming process, but instead to focus on the merits and properties of the resulting trim designs.

Single Plunge or Straight Cut

The simplest and most obvious trim shape is the single plunge or straight cut. It is the fastest of the trim shapes but is also less precise than some other trim designs. This trim type is challenging for high precision because as the trim extends further into the element, the effect becomes greater. If the initial element value is far below the desired value, then this trim type is not practical as it will be difficult to adjust the resistance value without overshoot. However, for resistor types that begin close to the final resistance value needed, this trim type provides the best economy because the trim cut will stop before the resistance change becomes too large and resistance value control becomes too difficult. To accomplish this, the trim speed for single plunge trim tends to be somewhat slower.

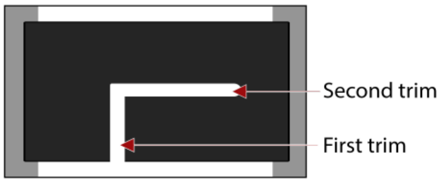
For pulse handling resistors, the least amount of trimming, if any, is desired. It is the area around the trim where current crowding occurs and is the failure point for thick film resistors under pulse conditions. Therefore, pulse handling resistors are generally printed to resistance values very close to the desired value and require little or no trim. The single plunge is a very effective trim shape for these types of resistors. For general purpose and commodity chip resistors however, this trim method is often too imprecise.



Double Plunge

The double plunge cut provides much more precision than single plunge cuts. The first cut brings the resistance value close to the desired final value. Since the second cut is in an area with less current flow, the change in resistance is much less, allowing for precise resistance control. The second trim length is kept between 50% to 80% of the length of the first cut to ensure stable electrical performance and continuous power handling. Because the precision for this trim shape depends only on the second cut, the trim speed can be faster than the single plunge. Many thick film resistors are trimmed in this manner, especially those with smaller size elements.

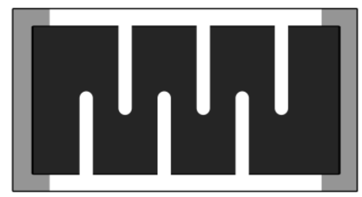
L Trim



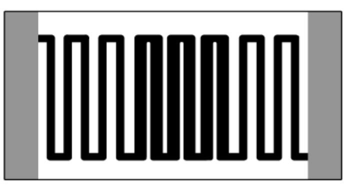
L trim is another very common trim shape. This trim shape can provide precision values while also providing a greater resistance value adjustment range. The initial trim into the part stops when the resistance value begins to change rapidly. Then the trim changes direction and proceeds toward the opposite termination. The second part of the trim allows for precision control because the current crowding occurs along the first part of the trim, so the change in resistance for the second part is much less. L trimming can usually be done at the same speed as a double plunge trim. The L trim is generally regarded as a more stable trim than the single or double plunge trim, but requires a somewhat larger resistor area for effective value calibration. Most thick film resistors currently on the market will have either.

Serpentine Cut

Serpentine cuts may be used to adjust a resistor value up significantly from its printed resistance value. Trims are spaced equally apart and continue until the resistance value is reached. This trim type will have higher parasitic noise, lower overall stability, poorer pulse performance, and requires a long element length for adequate value adjustment. Therefore, it is effective for high resistance value requirements, where power and current handling requirements are irrelevant. It is also occasionally used for adjustment of metal plate sense resistors since their element mass maintains continuous and pulse capability despite the length of the trims and the substantial amount of material removed.



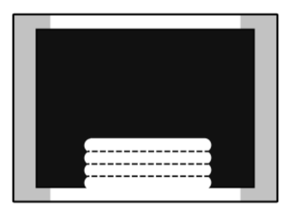
Top Hat Trim



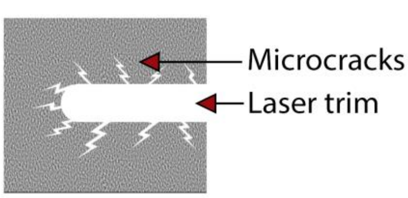
For better high voltage and high resistance value accuracy, the top hat trim provides the best accuracy and stability. Top hat trims require a precise serpentine resistance element and are best suited to larger chip sizes. The serpentine resistance pattern dramatically increases both the voltage capability and resistance value of the element. The top hat portion of the element provides a wider area for the laser trim, allowing precision value control without harming the voltage capability of the resistor. Most precision high voltage resistor series utilize the top hat type of trim.

Scan Trim

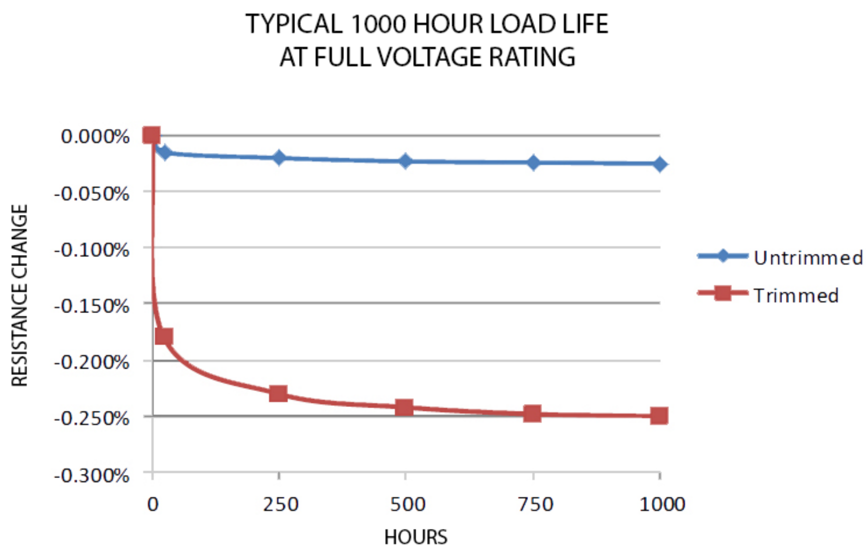
Scan cut trims are generally used when the adjustment range is small and high precision is required. This trim type is significantly slower and requires subsequent laser trim scans to overlap to ensure that all the material from each trim is completely removed. The best stability is achieved when the scan trims begin and end in the conductors on the ends of the element. This type of trim requires materials that are compatible with this trim operation. Because unique material requirements and of the time and control required for this type of trim, it is not commonly used.

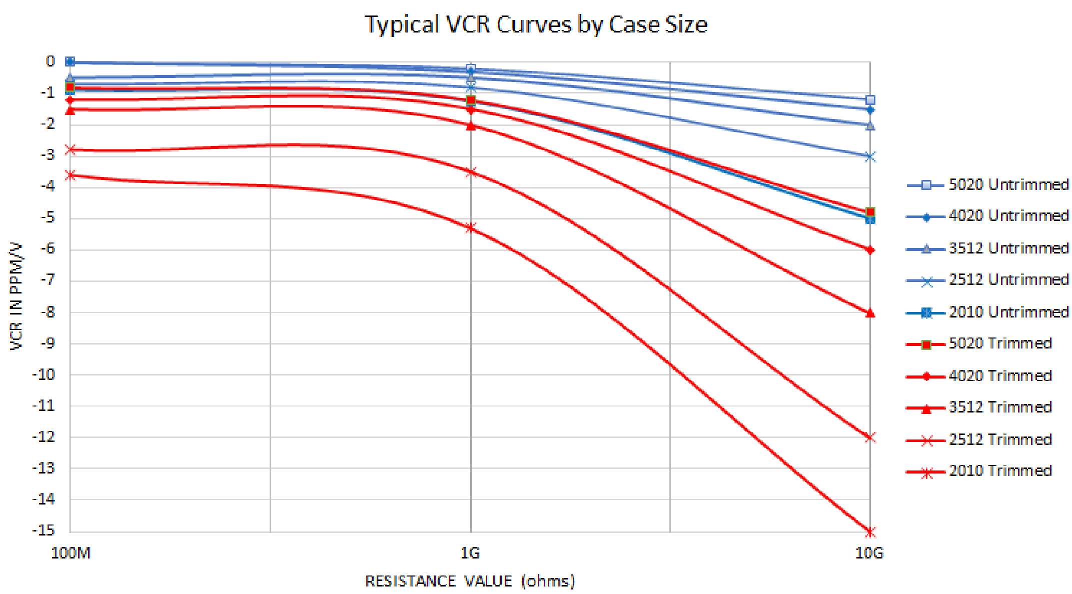


Laser Trimming Effects



It should be noted that all laser trim designs start with the basic rule that the trim itself should be minimized. For thick film resistive elements, the process of laser trimming has some detrimental effects which can't be overcome. As the laser moves through the element, the material adjacent to the laser trim permanently changes. The thick film material increases in temperature proportional to the distance from the laser trim. As this material cools, microcracks develop due to the relatively poor heat conduction of the cured thick film material. These microcracks lead to poorer TCR, poorer lifetime stability, increased parasitic noise, and increased VCR. It is also at the edge of the trim that the dielectric glass layer becomes critical. The material at the edge is referred to as laser slag and has a very non-uniform appearance. The dielectric glass layer helps to stabilize this material at the edges and prevent it from falling into or across the trim line.





Further evidence of the effect of trimming can be seen in the graphs above which show the relationship between trimmed and untrimmed high voltage resistors. The improvement in VCR and load life stability for an untrimmed resistive element is dramatic.

Summary

Laser calibration trimming for thick film resistors is a necessary process allowing manufacturers to produce the massive number of parts required for today's electronic circuits. Each trim shape has its unique uses and advantages which must be considered relative to the design goal of each thick film resistor series. It is important to minimize the amount of trim in any given manufacturing lot. Minimizing the trim length ensures the best possible TCR, overall stability, and lowest noise.