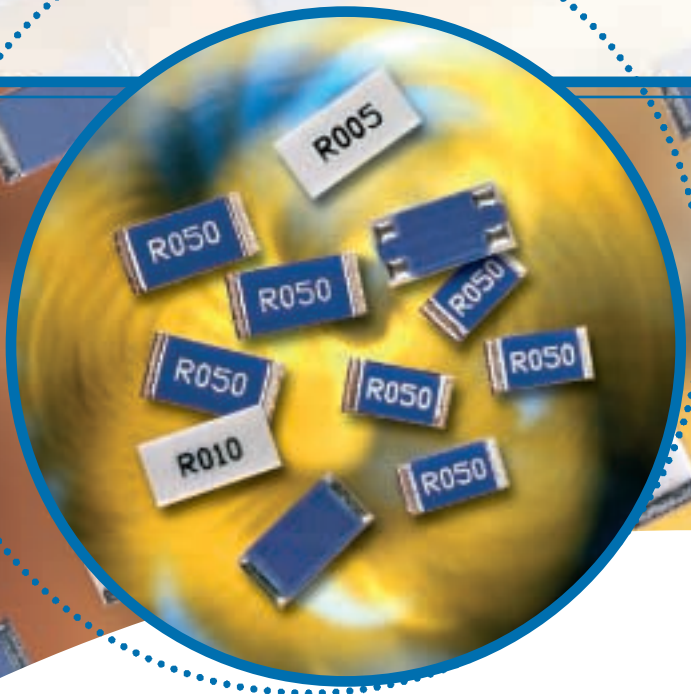


# Low Range Chip Resistors vs Metal Strip Resistors



## Background

Modern battery operated equipment often requires the use of very low ohmic value current sense resistors for monitoring power usage and battery life. TT electronics has developed a family of surface mount low value chip resistors specifically for these applications, throughout many market sectors including automotive. Although metal ribbon (or 'strip') elements and other "old fashioned" resistor technologies have been used, TT electronics LR Series chip resistors offer superior performance.

The LR Series display excellent power handling capability, low temperature coefficient of resistance, low inductance, and resistance tolerances down to 1%. These characteristics make disk drive, computer, power supply, battery pack, and other low resistance, current sensing applications ideally suited to the LR Series. The LRF3W Series offers 3 Watt power dissipation using a 1 Watt size footprint.

- TT electronics offers an array of low range chip resistors in the standard 1206, 2010 and 2512 sizes as well as a flip chip and precision Kelvin terminal chip
- High thermal conductivity results in a significantly lower operating temperature and the potential for higher power dissipation



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## Construction

The LR family of resistors all utilize TT electronics patented low resistance thick film materials which offer the capability of achieving resistances down to 0.003 Ohms with a low temperature coefficient of resistance. Since these materials are processed on an alumina ceramic substrate, superior thermal conductivity over metal strip and other technologies is

demonstrated. High thermal conductivity results in significantly lower operating temperature and the potential for higher power dissipation. Additionally, the planar resistance path results in excellent high frequency characteristics, regardless of resistance range or size.

## Power Handling Capability

The LR Series displays superior power handling capability in comparison to metal strip and other technologies. Depending on the solder pad layout and operating ambient temperature, up to 2 Watts can be dissipated in a standard 1 Watt (2512) size package and 3 Watts in the 1225 (solder pads along the edge of the part). This is due to the superior thermal conductivity of the ceramic and copper construction of the LR Series in comparison to nichrome or other resistance alloys used on metal strip resistors. Thermal conductivity is a very important characteristic for chip resistors and other surface mount components due to their often small size. Because of this, very little heat is dissipated directly into the air, but is conducted out through the solder lands. The thermal conductivity of the LR Series is superior to metal strip and other technologies. Heat generated by the resistor is more readily dissipated, preventing "hot spots" which contribute to TCR and thermal EMF errors, premature aging and possible scorching of the PC board.

Table 1 shows the relative thermal conductivities of the materials used in construction of the LR Series and metal strip resistors. The superior power handling capability of the LR Series is further exemplified when charted with the resistor body temperature versus power as shown in figure 1. This graph compares the LR2010 with a comparable size (2010) metal strip resistor. (Similar differences are seen when comparing other sized LR and metal strip resistors.) Charts of temperature rise versus power for other size LR parts is given in appendix A.

Material	Thermal Conductivity (W/m-K)
96% Alumina - LR Series	20.9
Copper - LR Series	391.0
Nichrome - Metal Strip Resistors	9.5

Table 1. Thermal Conductivity of Resistor Materials

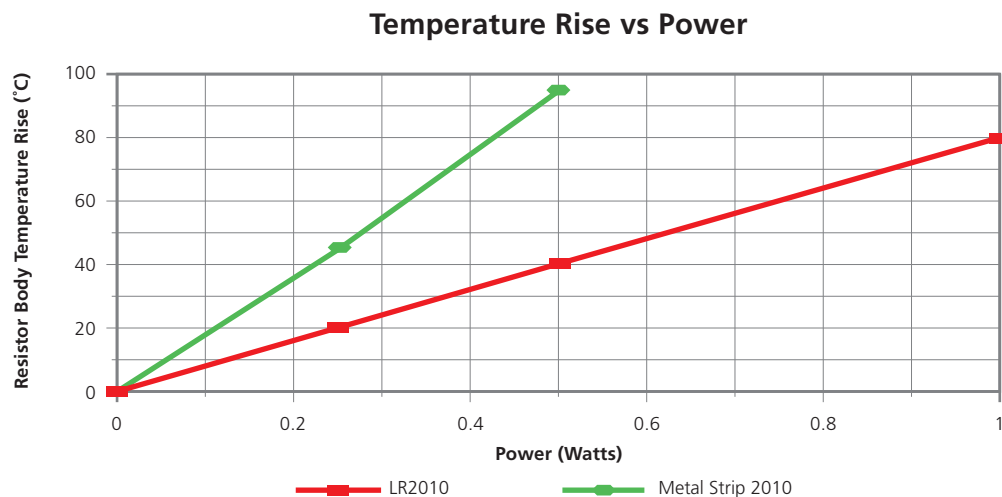


Figure 1

## Extended Power Rating

One of the many advantages of the LR Series is the possibility of higher power dissipation through the use of larger solder lands. Again, the excellent thermal conductivity of the substrate and resistor body allow heat to be readily removed from the resistor and conducted to the solder lands and circuit board traces. A slight increase in the solder land size can result in a significant increase in power handling capability as shown in figure 2.

This advantage is not available with metal strip resistors as their low thermal conductivity makes it more difficult for generated heat to escape from the resistor. Operating a metal strip resistor at the extended power levels shown for the LR Series would cause hot spots (localized heating) resulting in charring of the printed circuit board, significant changes in resistance, and a reduction in reliability.

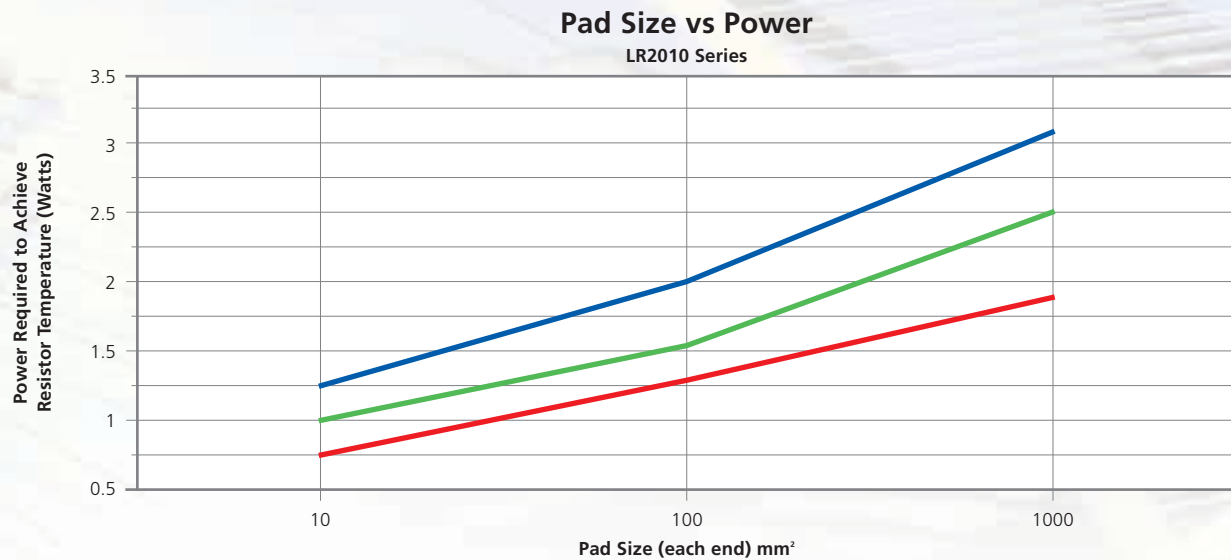
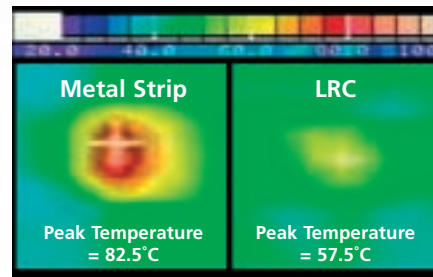


Figure 2

Resistor temperature rise of: — 75°C — 100°C — 125°C

## Three Watt Dissipation

The LRF3W Series is unique in offering 3 Watt power dissipation (at up to 70°C ambient) in a 1225 component size. The high power capability is made possible by heavy copper end terminations, which help draw the heat from the part, and the arrangement of putting the solder terminations along the long sides of the part. This configuration is also beneficial in high current applications to avoid having to “neckdown” the circuit board trace at the component solder joints



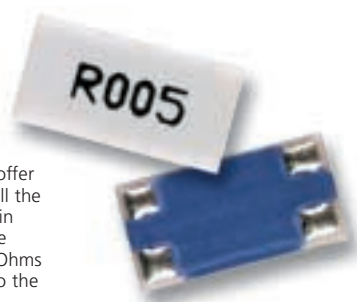
Thermograph showing comparably related Metal Strip and LR Series resistors operating at one Watt. The photo left clearly shows the superior thermal characteristics of the LR Series. Higher overall thermal conductivity results in more heat being conducted from the part and sharply lower operating temperatures.

## High Frequency Characteristics

With its planar construction, the LR Series exhibits excellent high frequency characteristics. Unlike metal strip resistors which utilize multiple lateral trims to adjust the resistance value, the LR Series uses a single computer controlled laser cut to adjust the resistor to value. The absence of multiple cuts reduces capacitance and parasitic inductance inside the resistor, contributing to its high frequency performance. Frequency response of 0.5 Ohm LRC and metal strip resistors are shown in figure 4.

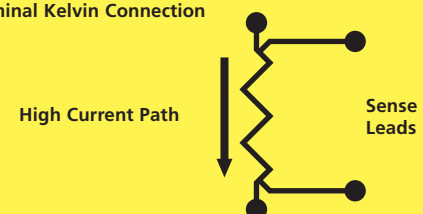
## Very Low Resistance Capabilities

When applications require resistance values below the 30 milliohm range, the use of standard two-terminal resistors can lead to inaccuracies in the installed resistance value. Variations in lead or trace resistance, solder resistance, etc. contribute to errors in current sensing. To cancel these effects, a four-terminal (Kelvin) connection is required. A Kelvin connection is a type of connection that avoids the error caused by voltage drops in the high current path. In this connection (fig. 3), sense leads are attached directly across the resistive element intentionally excluding the high current path leads. Since these sense conductors carry negligible current (these are usually high impedance voltage measurements), there is no voltage drop to induce errors in the  $V = I \times R$  measurement.



TT electronics LRK chip resistors offer a Kelvin connection along with all the other superior qualities inherent in the LR Series. The LRK is available with resistances down to 0.003 Ohms and 1% tolerance. Please refer to the product datasheet for additional information.

Figure 3. Four-Terminal Kelvin Connection



## Pulse / Surge Performance

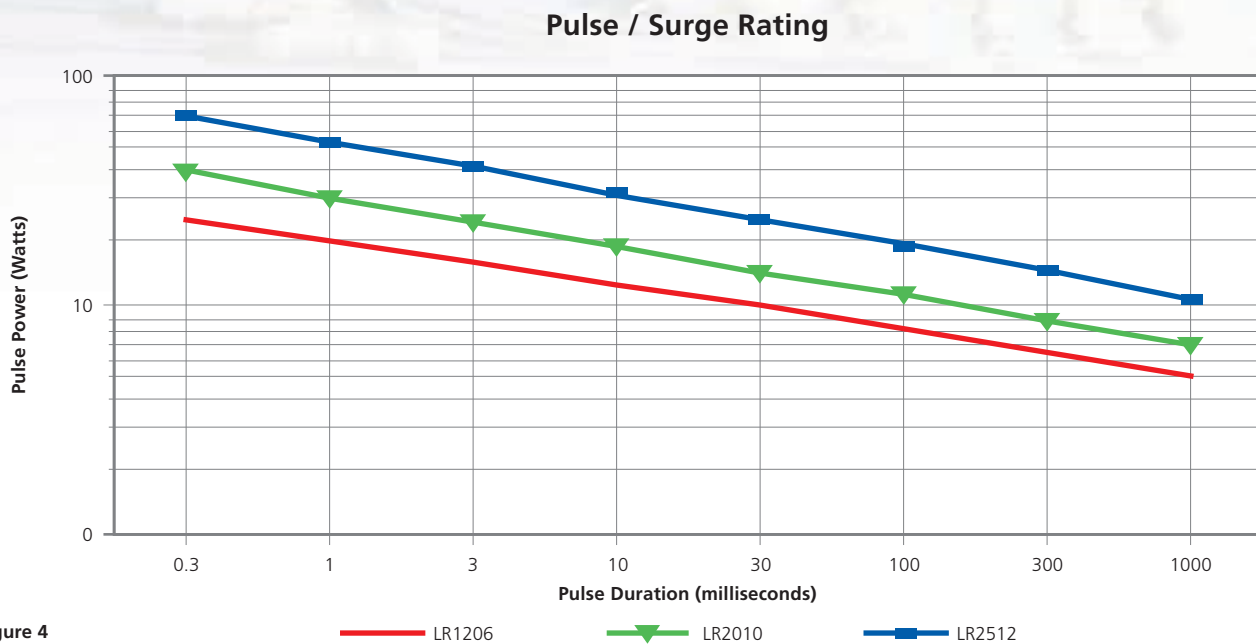
The excellent thermal conductivity of TT electronics LR construction allows the part to exhibit very good surge and pulse performance. In many applications such as disk drives and power supplies, current sense resistors must withstand significant overloads for short durations of time. The chart shown in figure 4 shows the continuous pulse ratings for the LR Series. Please note that under continuous pulse applications, the average power dissipation should not exceed the normal 70°C rating. The temperature rise for the LR Series under repetitive pulse conditions can be found by calculating the average power dissipation and using the charts in Appendix A.

## Temperature Coefficient of Resistance

The LR family of resistors display very low temperature coefficient of resistance (TCR) characteristics. TCRs are usually less than  $\pm 100\text{ppm}/^\circ\text{C}$  down to 0.050 Ohms. Please refer to the individual product datasheets for additional information.

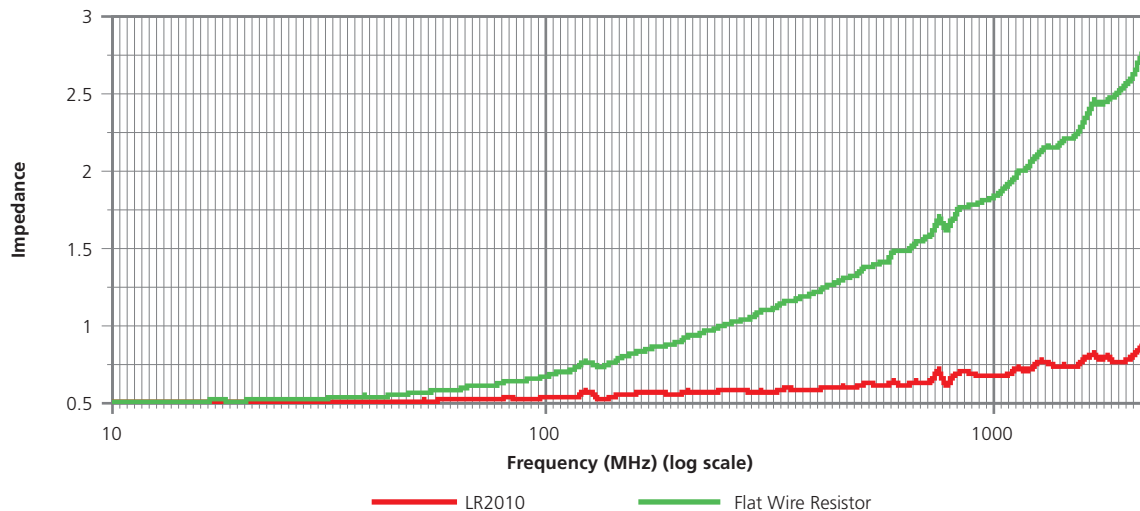
## Conclusion

Ceramic based low resistance chip resistors offer superior performance over metal strip technologies in many areas. TT electronics offers the right chip for your low range, current sense applications.



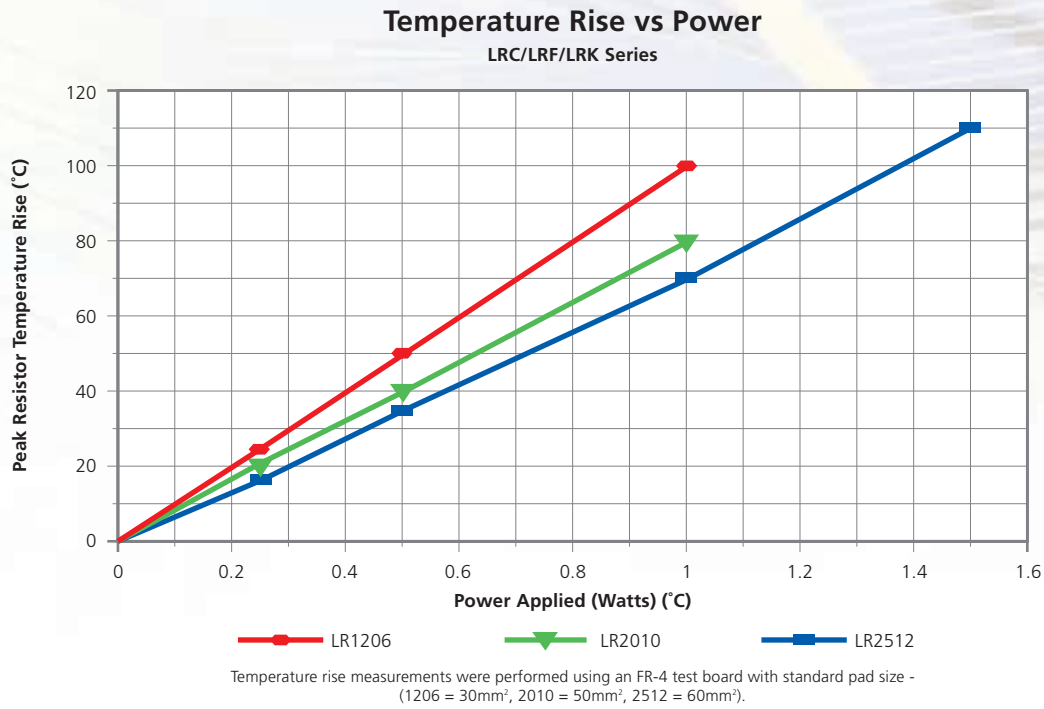
## Frequency Response

LR2010 vs Flat Metal Element (R500)

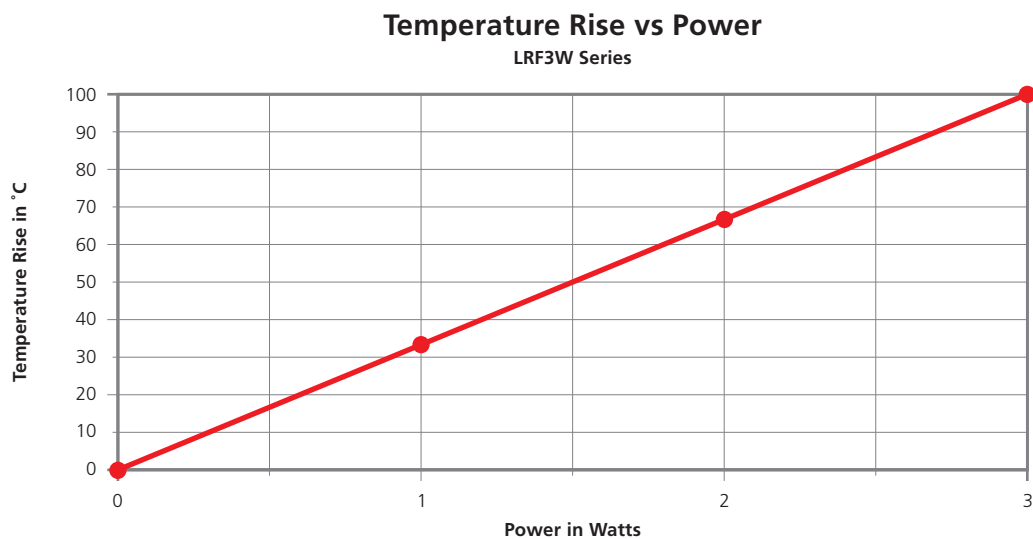


Test Equipment: HP4291 RF Impedance Analyzer

## Appendix A



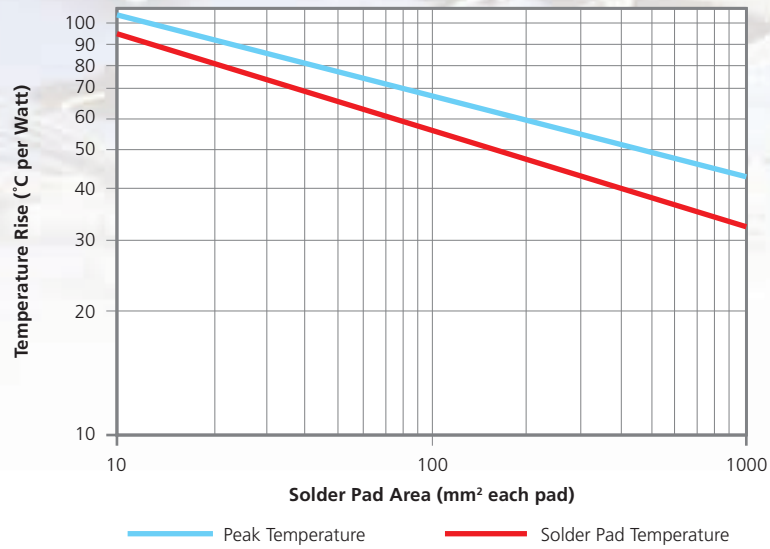
Note: On all LR Series products, the charts and graphs shown are applicable to all parts with the same physical size and lead configuration (i.e. Graphs for the LR2512 may be used for the LRC2512, LRK2512, or the LRF2512 product).



## Appendix A *(Continued)*

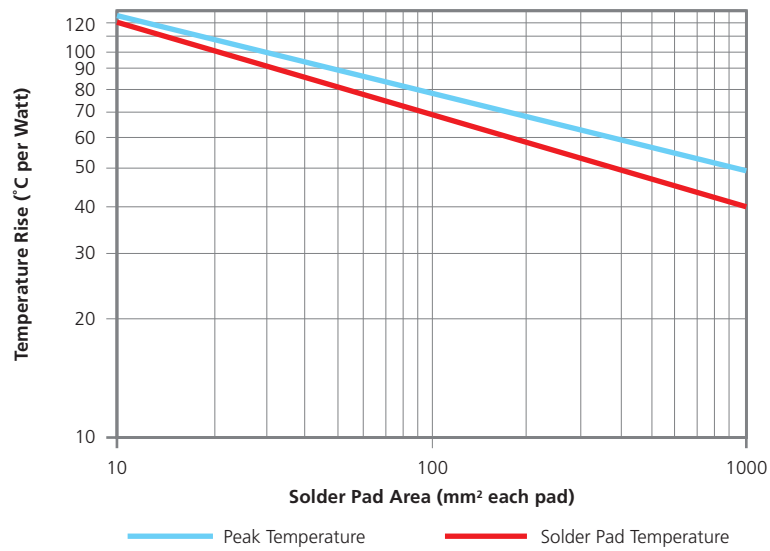
### Temperature Rise vs Pad Area

LR2010 Series



### Temperature Rise vs Pad Area

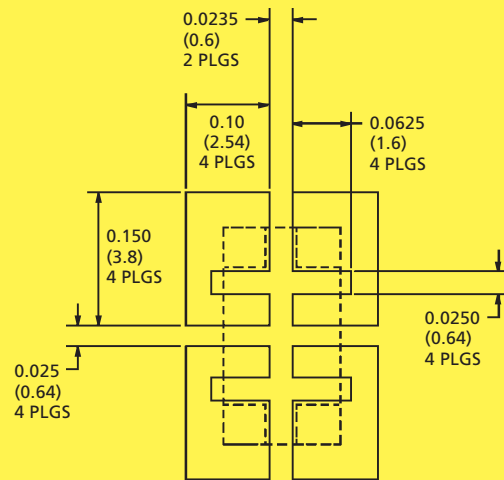
LR1206 Series



## Appendix B

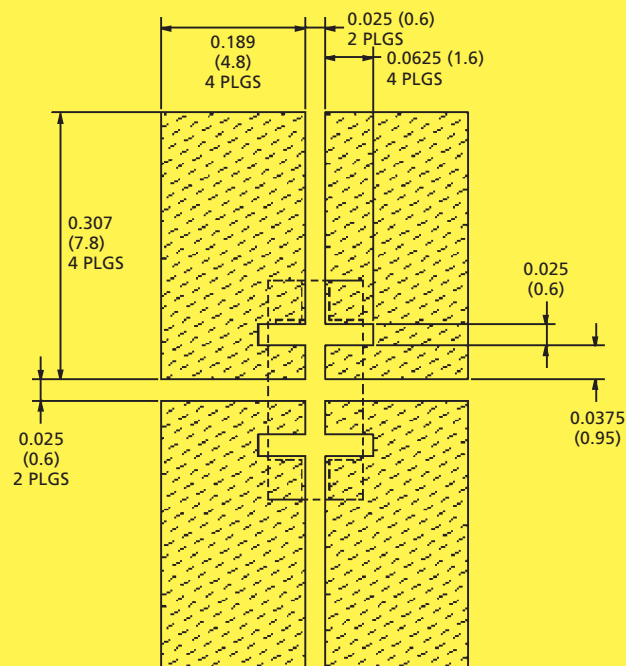
### Recommended Four Terminal (Kelvin) Solder Pad Layout for the LRK Series

#### One Watt Operation



Note: Dimensions shown in inches

#### Two Watt Operation



Note: Dimensions shown in inches

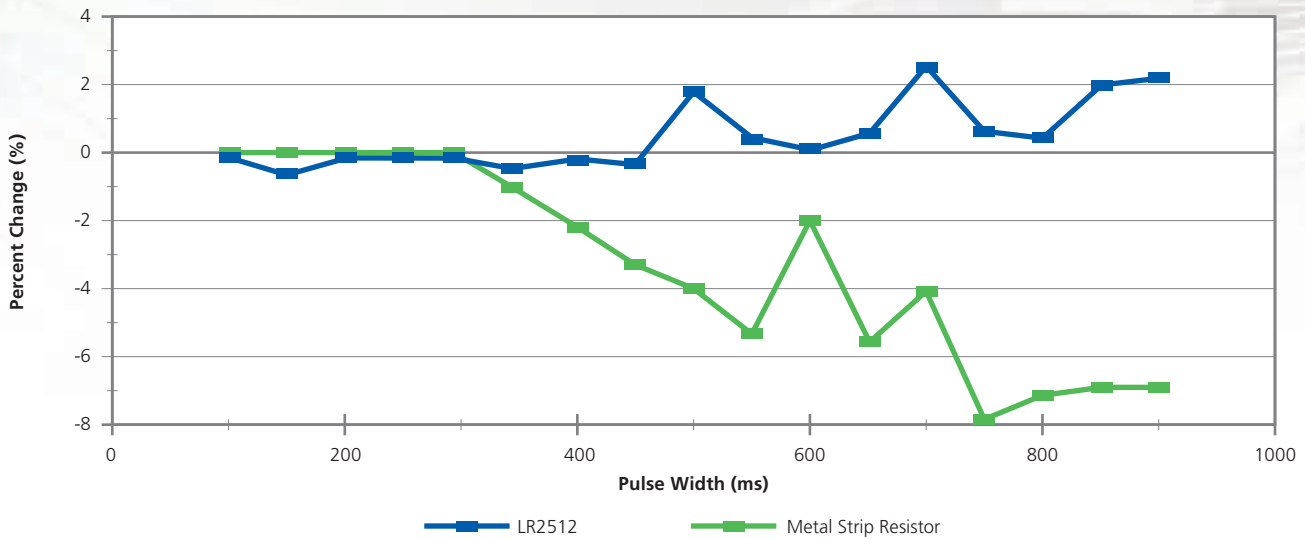
## Appendix C

### Single Pulse / Overload Performance

The LR Series displays superior pulse performance in comparison to metal strip resistors at intermediate power levels. The chart below details the amount of resistance change experienced on an LR2512, 0.015 Ohm resistor when subjected to a single

square wave pulse of 32 Watts (46.7 amperes) of varying pulse width. Because of the excellent thermal conductivity of the LR Series, performance exceeds that of metal strip resistors.

**Single Pulse Performance**  
LR2512 vs Metal Strip Resistor



### Range Summary

Image	LRC/LRF Series		Low Value Flat Chip Resistor				
	Type	Power (Watts)	Res. Range (Ohms)	Tolerance %	Max Volts	TCR (ppm/°C)	Dim.(mm) l, w, h
	1206	0.5	0R003 - 1R	1, 2, 5	-	±100	3.2, 1.63, .8
	2010	1.0	0R003 - 1R	1, 2, 5	-	±100	5.23, 2.64, .8
	2512	1.5/2.0	0R003 - 1R	1, 2, 5	-	±100	3.25, 6.5, .8
	1225	2.0	0R003 - 0R10	1, 2, 5	-	±100	.8, 6.5, 3.25
	LRK Series		Thick Film Low Resistance Kelvin Flip Chip				
	Type	Power (Watts)	Res. Range (Ohms)	Tolerance %	Max Volts	TCR (ppm/°C)	Dim.(mm) l, w, h
	2512	2.0	R003 - R100	±1	-	±100	6.5, 3.250, .74
	LRF3W Series		Low Range 3 Watt SMT Chip Resistor				
	Type	Power (Watts)	Res. Range (Ohms)	Tolerance %	Max Volts	TCR (ppm/°C)	Dim. (mm) l, w, h
	LRF3W	3	0.003 - 0.100R	to ±1%	50	±100	3.25, 6.5, .8

For more detailed product information and data sheets or to discuss your specific requirements please contact Welwyn Components Ltd.

**TT electronics has over 60 years experience in designing and manufacturing resistive components.**

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