关于 MS 系列电阻高频下阻值变化研究

Study on the Change of Resistance Value under High Frequency of MS Series Resistors

§0. 摘要
Abstract

我司 MS 电阻，即合金箔电阻，属于合金电阻系列，在客户端的电路使用中大部分是承担电流检测片的作用，所以耐电流能力是衡量合金箔电阻性能的一大指标，但是作为一个电阻使用，阻值的稳定性和准确性就至关重要，在不同频率的工作环境下，由于合金箔电阻本身电感值的存在，会产生不同大小的感抗，如果是一个高阻电阻，感抗对产品阻值的影响可以忽略不计，但作为一个低阻电阻产品，感抗对测量阻值的影响是显著的，特此针对关于 MS 的高频下阻值变化做以下研究。

Our MS resistor, also known as metal foil chip resistor, belongs to the metal resistor series and is mostly used as a current detection chip resistor in the circuit at customer end. Therefore, current resistance is a major indicator to measure the performance of metal foil chip resistors. However, as a resistor, the stability and accuracy of the resistance value are crucial. In working environments at different frequencies, due to the presence of the inductance values of the metal foil resistors, different sizes of inductive reactance will be generated. If it is a high resistance resistor, the influence of inductive reactance on the resistance value of the product can be ignored. However, as a low resistance resistor, the influence of inductive reactance on the measured resistance value is significant. Therefore, the following research is conducted on the changes of resistance values of MS resistors at high frequencies.

§1. 感抗存在的机理
The mechanism of the presence of inductive reactance

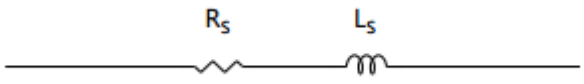

图 1：低阻值 电流检测电阻器的等效电路

Fig.1: Equivalent circuit of low resistance current detection resistor

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电感值不仅会在环绕线路中产生，直线电路中也会有微小的感值存在，既然是电感值，就有电感的特性，通直流，阻交流，当通入交流电时，会产生感抗，线路中体现的阻值就是电阻本身的直流阻抗加上感抗，感抗计算公式如下：

The inductance value not only occurs in the surrounding circuit, but also in the linear circuit. Since it is the inductance value, it has the characteristics of inductors, allowing DC to go through while blocking AC. When AC power is applied, inductive reactance is generated. The resistance value reflected in the circuit is the DC impedance of the resistor itself plus inductive reactance. The inductive reactance calculation formula is as follows:

$$XL=2\pi fL$$

XL 表示感抗，单位欧姆，符号Ω； π 表示圆周率；f 表示输入交流电的频率，单位赫兹，符号 Hz；L 表示电感值，单位亨利，符号 H。

XL represents inductive reactance, in ohms, with the symbol Ω; π represents pi; f represents the frequency of the input AC power, in hertz, with the symbol Hz; L represents the inductance value, in Henry, with the symbol H.

§2. 实测不同频率下 MS 电阻的阻值

Measure the resistance value of MS resistor at different frequencies

表 1：MS06 10mΩ不同频率电流下阻值测量记录表

Table One: Measured resistance values at different frequencies of MS06 10mΩ

阻值 Resistance value（Ω）										
频率 Frequency（Hz）	1	2	3	4	5	6	7	8	9	10
100	0.25251	0.02971	0.09841	0.37069	0.03465	0.02798	0.08405	0.02639	0.0296	0.02674
1K	0.02434	0.02457	0.02489	0.02449	0.02876	0.02469	0.02442	0.02405	0.02457	0.02432
10K	0.02471	0.02492	0.02528	0.02486	0.02913	0.02506	0.02476	0.02444	0.02493	0.0247
100K	0.02713	0.02732	0.02774	0.02726	0.03157	0.02474	0.02719	0.02686	0.02735	0.02712
1M	0.04739	0.04769	0.04801	0.04756	0.05182	0.04776	0.04738	0.04709	0.04754	0.04741

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表 2：MS12 10mΩ不同频率电流下阻值测量记录表

Table Two: Measured resistance values at different frequencies of MS12 10mΩ

阻值 Resistance value（Ω）										
频率 Frequency（Hz）	1	2	3	4	5	6	7	8	9	10
100	0.02437	0.02487	0.02439	0.02467	0.02527	0.02423	0.02486	0.02487	0.0244	0.02674
1K	0.02454	0.02485	0.02451	0.02507	0.02458	0.02435	0.02459	0.02462	0.02433	0.02476
10K	0.02492	0.02521	0.02486	0.02543	0.02472	0.02472	0.02495	0.02496	0.02468	0.02508
100K	0.02744	0.02773	0.02804	0.02791	0.02742	0.02725	0.02747	0.02747	0.02721	0.02759
1M	0.04826	0.04863	0.04879	0.04872	0.04823	0.04812	0.04826	0.04831	0.04805	0.04842

表 3：数据分析

Table Three: Data analysis

频率 Frequency（Hz）	MS06 10mΩ			MS12 10mΩ		
	Max	Min	Avg	Max	Min	Avg
100	0.37069	0.02639	0.098073	0.02674	0.02423	0.024867
1K	0.02876	0.02405	0.024910	0.02507	0.02433	0.024620
10K	0.02913	0.02444	0.025279	0.02543	0.02468	0.024953
100K	0.03157	0.02474	0.027428	0.02804	0.02721	0.027553
1M	0.05182	0.04709	0.047965	0.04879	0.04805	0.048379

§3. 结论
Conclusion

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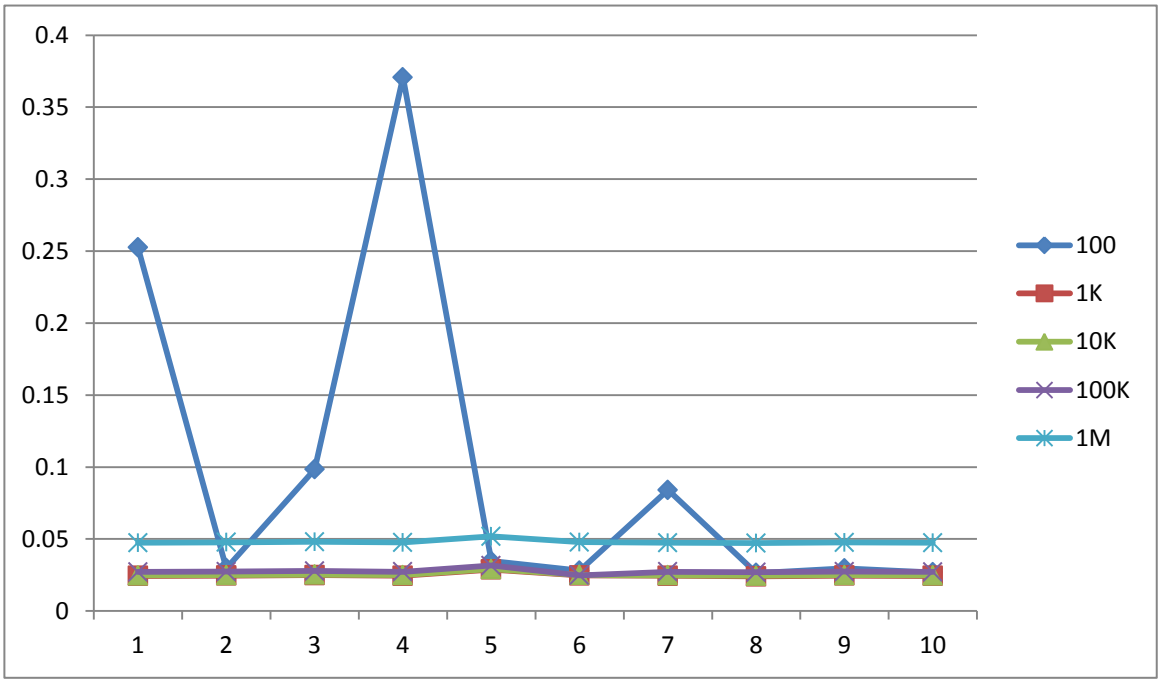
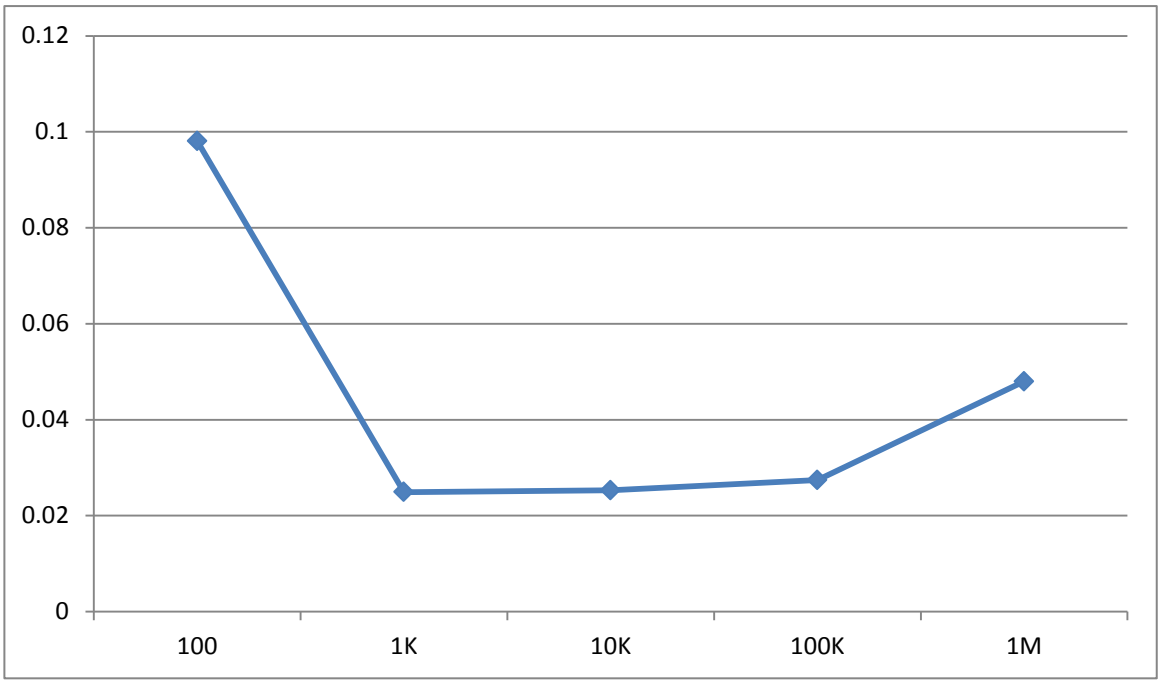
图表 1：MS06 10mΩ不同频率电流下阻值测量折线图

Table One: Line chart of measured resistance values at different frequencies of MS06 10mΩ



图表 2：MS06 10mΩ不同频率电流下阻值测量平均值折线图

Table Two: Line chart of average measured resistance values at different frequencies of MS06 10mΩ



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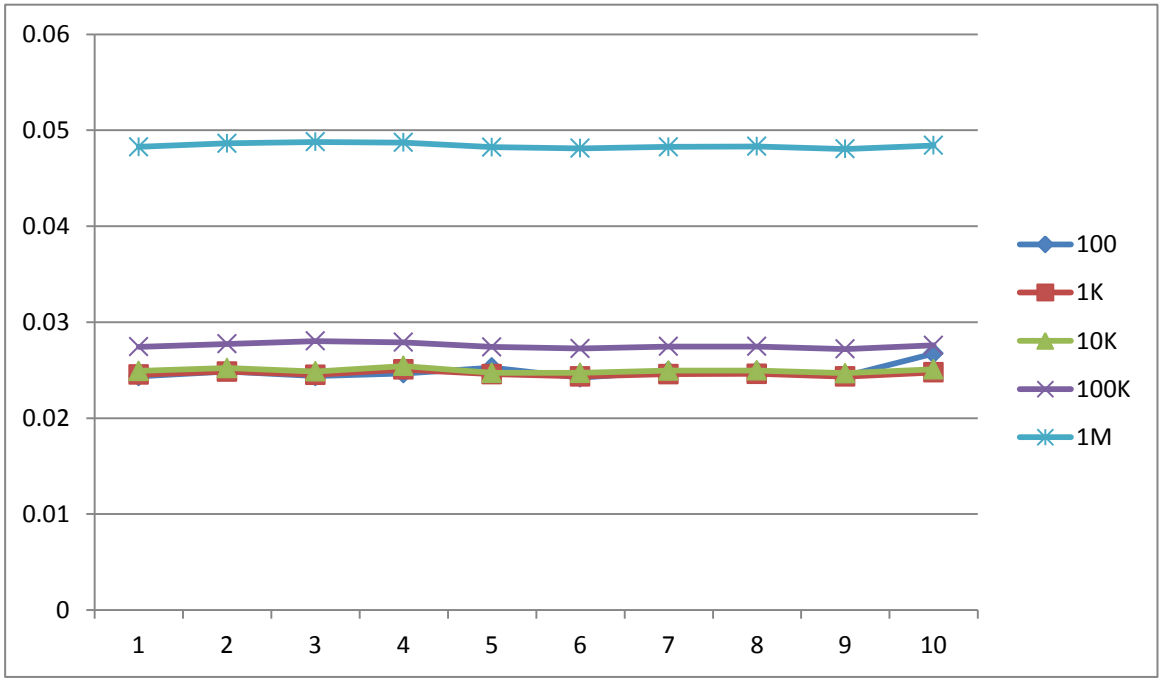
结论 1：MS06 10mΩ在 1KHz~1M 频率下测量都很稳定，1K~1MHz 下测量阻值基本持平，都在 24mΩ~31mΩ之间，到 1MHz 测量，阻值在 47mΩ~51mΩ之间，与 1K~1MHz 下测量相比平均有 22mΩ的增长；100Hz 阻值测量颗与颗之间差异较大，（最大-最小）有 344.3mΩ的差异。

Conclusion 1: The measurements of MS06 10mΩ are stable when measured at frequencies between 1KHz and 1MHz. Resistance values measured at this frequency range are basically the same, ranging from 24m Ω to 31m Ω. When at 1MHz, the resistance values measured are ranging from 47mΩ to 51m Ω, with an average increase of 22mΩ compared to that measured at frequencies between 1KHz and 1MHz; When at 100Hz , the difference in measured resistance values among resistors is significant, with a difference of 344.3m Ω (maximum-minimum).

图表 3：MS12 10mΩ不同频率电流下阻值测量折线图

Table Three: Line chart of measured resistance values at different frequencies of MS12 10mΩ



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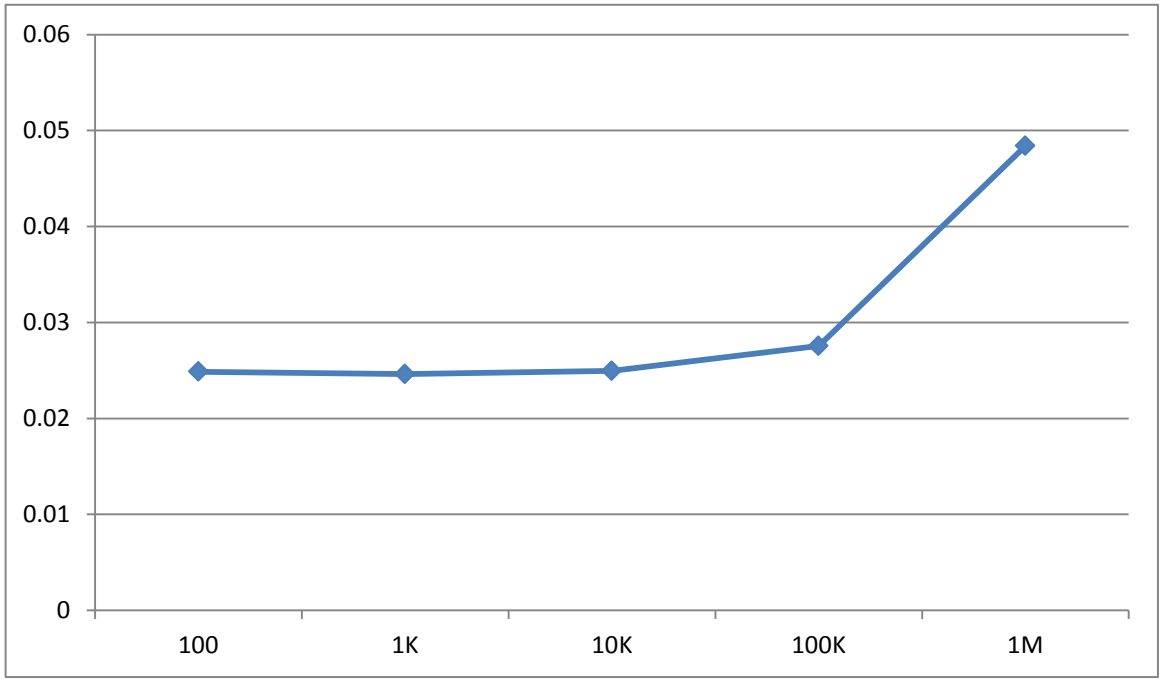
图表 4：MS12 10mΩ不同频率电流下阻值测量平均值折线图

Table Four: Line chart of average measured resistance values at different frequencies of MS12 10mΩ



结论 2： MS12 10mΩ在 100Hz~1M 频率下测量都很稳定，100~10KHz 下测量阻值基本持平，都在 24mΩ~27mΩ之间；到 100KHz 测量，阻值在 27mΩ~28mΩ之间，与 100~10KHz 下测量相比平均有 1mΩ的增长;到 1MHz 测量,阻值在 48mΩ~49mΩ之间,与 100~10KHz 下测量相比平均有 23.5mΩ的增长。

Conclusion 2: The measurements of MS12 10mΩ are very stable at frequencies between 100Hz and 1M, and the resistance values measured at frequencies between 100Hz and 10KHz are basically the same, ranging from 24mΩ to 27mΩ; When at 100KHz, the resistance values measured are between 27mΩ and 28mΩ, with an average increase of 1mΩ compared to that measured at frequencies between 100Hz and 10KHz; When at 1MHz, the resistance values measured are between 48mΩ and 49mΩ, with an average increase of 23.5mΩ compared to that measured at frequencies between 100Hz and 10KHz.

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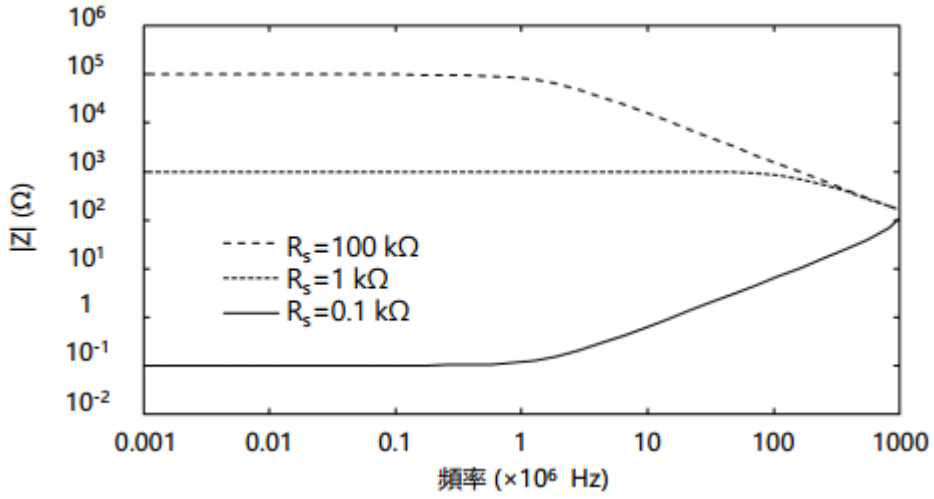
§4. 与 KOA 对比

Compared with KOA



我司实际测试 MS06　10mΩ 和 MS12　10mΩ 不同频率大电流下阻值测量折线图走势与 KOA 走势相同，不同点在于走势图的拐点不同，我司产品测试拐点在 100KHz，KOA 等效电路模拟测试拐点在 1MHz。

Our company actually tested the resistance values of MS06 10mΩ and MS12 10mΩ at different high current frequencies. The trend of the resistance measurement line chart is the same as that of KOA, but the difference lies in the different inflection points of the trend chart. Our company's product test inflection point is at 100KHz, and the inflection point of KOA equivalent circuit simulation test is at 1MHz.