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Advances in Class II MLCC with regard to Temperature and DC Bias Stability

Temperature Coefficient

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All Class II dielectric's (X7R, X8R, X5R etc.) will exhibit a change capacitance over the working temperature range.

Generally all Class II MLCC dielectrics will use Barium Titanate (BaTiO2) as their main raw material due to its high dielectric Constant (K) however the maximum K is achieved at approximately +125°C – Curie Point

Temperature Coefficient

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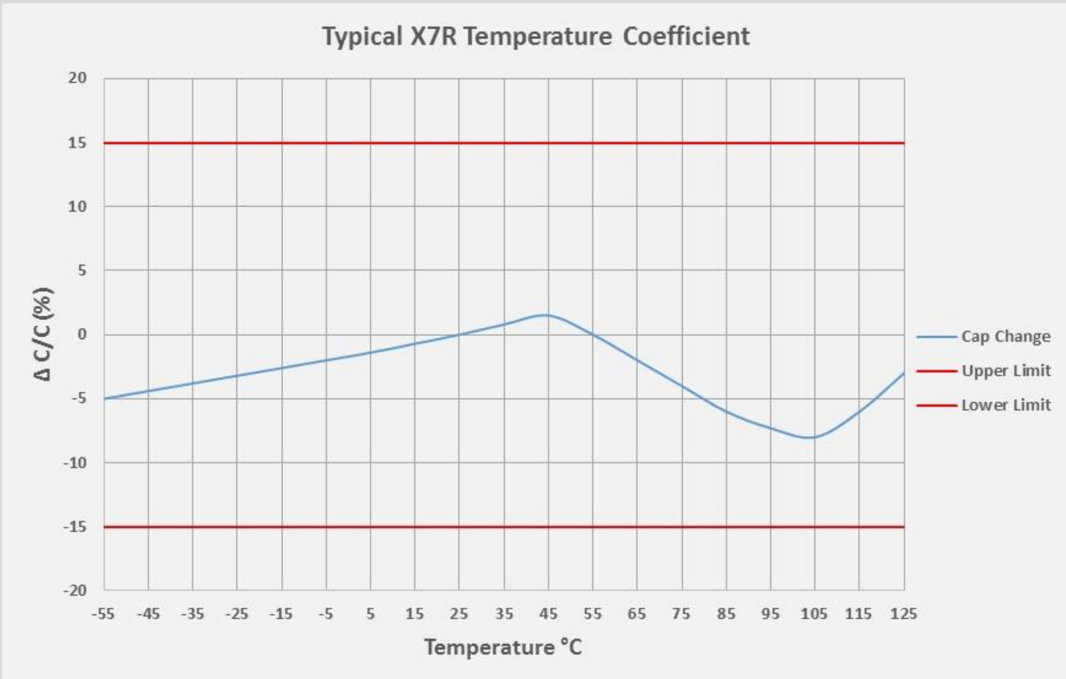
Clearly is it not practical to manufacture capacitors where they are designed to be used at +125°C therefore the TC od BaTiO3 needs to be modified.

1) **The peak 'K' needs to be 'Shifted' down to +25°C**
2) **The large change in capacitance needs to be smoothed or 'Flattened'**

This is achieved by additives such as Cobalt, lead (historical)-



Voltage Coefficient or DC Bias

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All Class II dielectric’s (X7R, X8R, X5R etc.) will exhibit a loss of capacitance under an applied DC voltage due to their ferroelectric/piezoelectric properties.

Generally all MLCC manufacturers will provide DC bias (Voltage Coefficient) curve for their parts.

The degree of capacitance loss will depend on:

Dielectric Material
Internal layer thickness
Applied dc voltage or Volts/uM relative to dielectric thickness

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Voltage Coefficient or DC Bias

Internal layer thickness will probably have the biggest effect on DC bias

Advances in materials and manufacturing processes have allowed MLCC manufacturers to reduce the internal layer thickness for any given DC voltage rating resulting in increased capacitance values being achieved.

Example:

X7R 50Vdc rated voltage layer thickness

Year 2000	Year 2017
25uM	8uM

DC Bias

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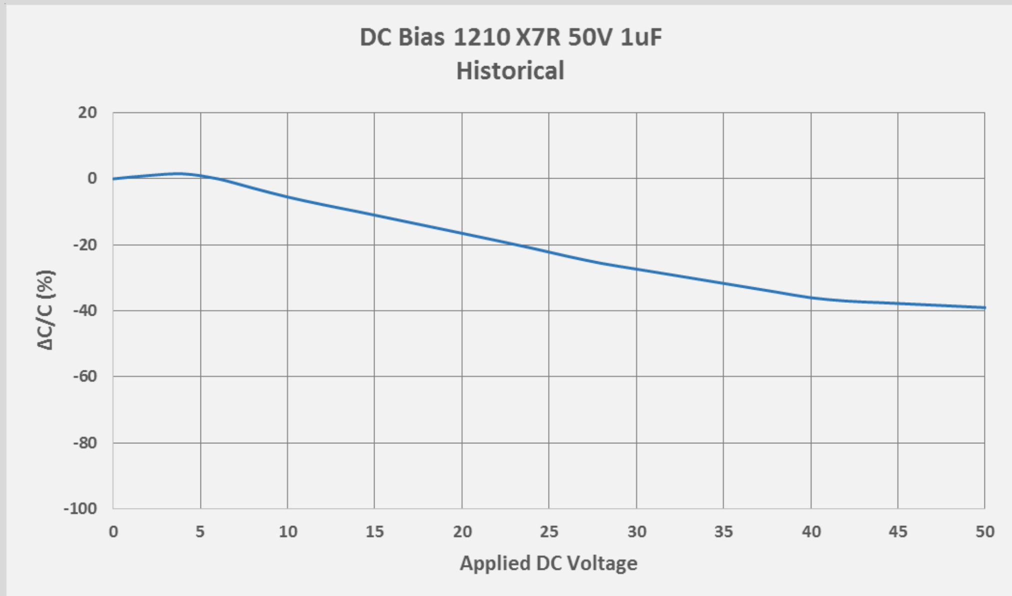
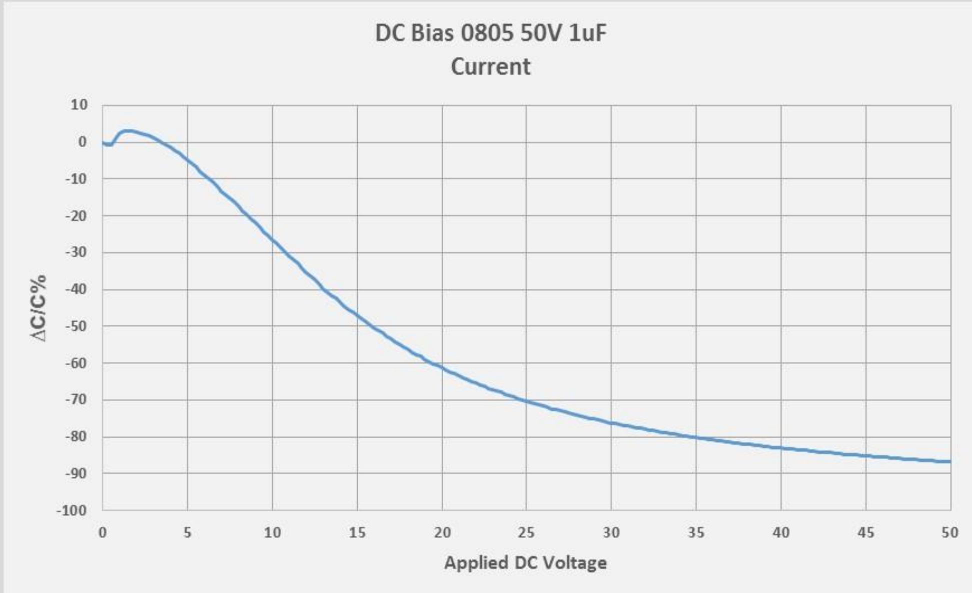
This reduction in the internal layer thickness which allows significant increases in achievable capacitance values also has a dramatic effect on the DC bias.





Reduced layer thickness has enabled a 50Vdc 1uF part to now be made in an 0805 case size where previously a 1210 case size was required, but….

At full rated voltage the 1210 loses 40% of the initial capacitance compare to 85% for the 0805

DC Bias

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The EIA definition of X7R, X5R etc has no specification for DC Bias limits.

Statement:
In theory a 25Vdc rated capacitor can lose 99% of its capacitance with 2Vdc applied and be within specification

With no specification for DC bias many design Engineers do not realise the effect of reducing the case size for a given voltage rating and capacitance value

DC Bias

Effect over time - Ageing

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The general assumption is that when a DC bias is applied to a Class II capacitor the resultant drop in capacitance remains constant providing the applied DC voltage remains constant.

However when a constant DC bias is applied there is a ‘ageing’ effect where the capacitance continues to drop over time.

The amount of this ‘ageing’ will depend on the percentage of rated voltage applied

DC Bias

Effect over time - Ageing

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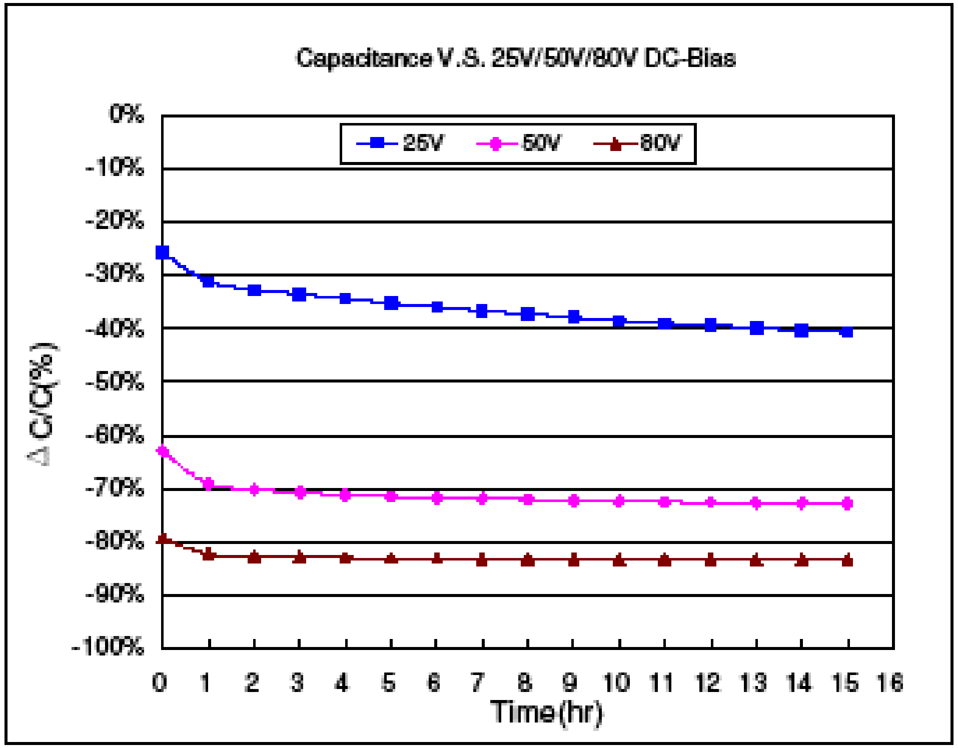
Part No. : C1206X105K101TX
1.Capacitance-DC Bias



Note: Up to 15% additional capacitance loss can occur

DC Bias

Worst case capacitance loss

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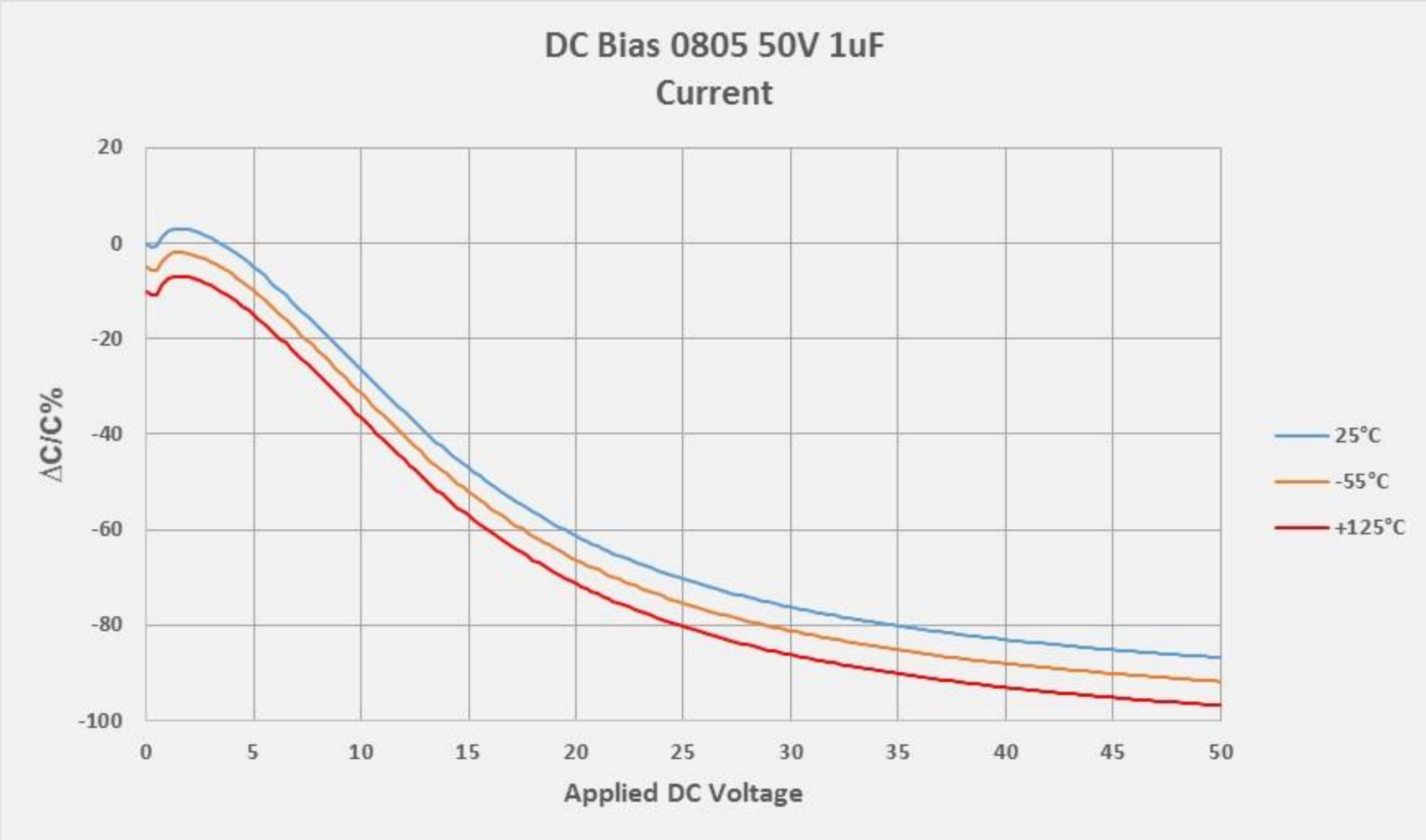

Note: At the extremes of the temperature range an additional 10% capacitance loss can be expected

Applications

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In many applications the capacitance value with applied DC voltage (DC bias) or DC voltage plus AC ripple is critical in the circuit.

With the actual capacitance in the circuit will change depending on…

1) **Capacitance Tolerance**
2) **Temperature Coefficient**
3) **DC Bias**

The actual capacitance in the application may be very different to what was originally expected

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Applications

1) Starting with a 1µF capacitor in X7R at a 10% tolerance the actual minimum capacitance could be 900nF

2) At +125°C this 900nF could be as low as 765nF due to the ± 15% temperature Coefficient.

3) If full rated voltage is applied to the capacitor the DC bias loss can be up to 86%. This will give a resultant capacitance of 107.1nF.

4) Finally due to DC Bias ageing a further 10% capacitance loss can be expected leaving only 96.4nF

So under extreme conditions our 1µF capacitor may have less than 100nF of residue capacitance.

X7P

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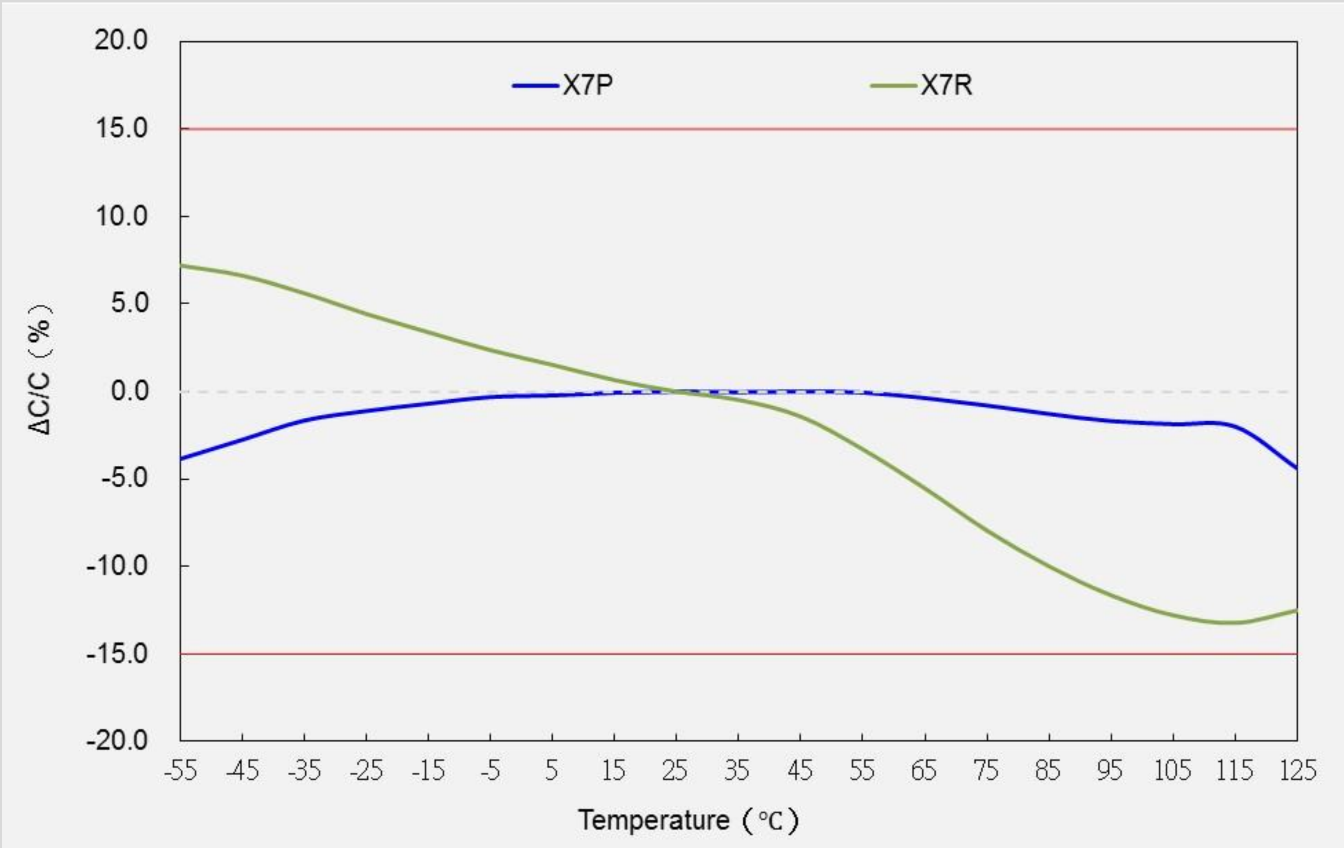
To overcome these issues with capacitance loss wrt Temperature and DC bias Holy Stone has developed a new dielectric X7P.

X7P Classification: ± 10% capacitance change from -55°C to +125°C



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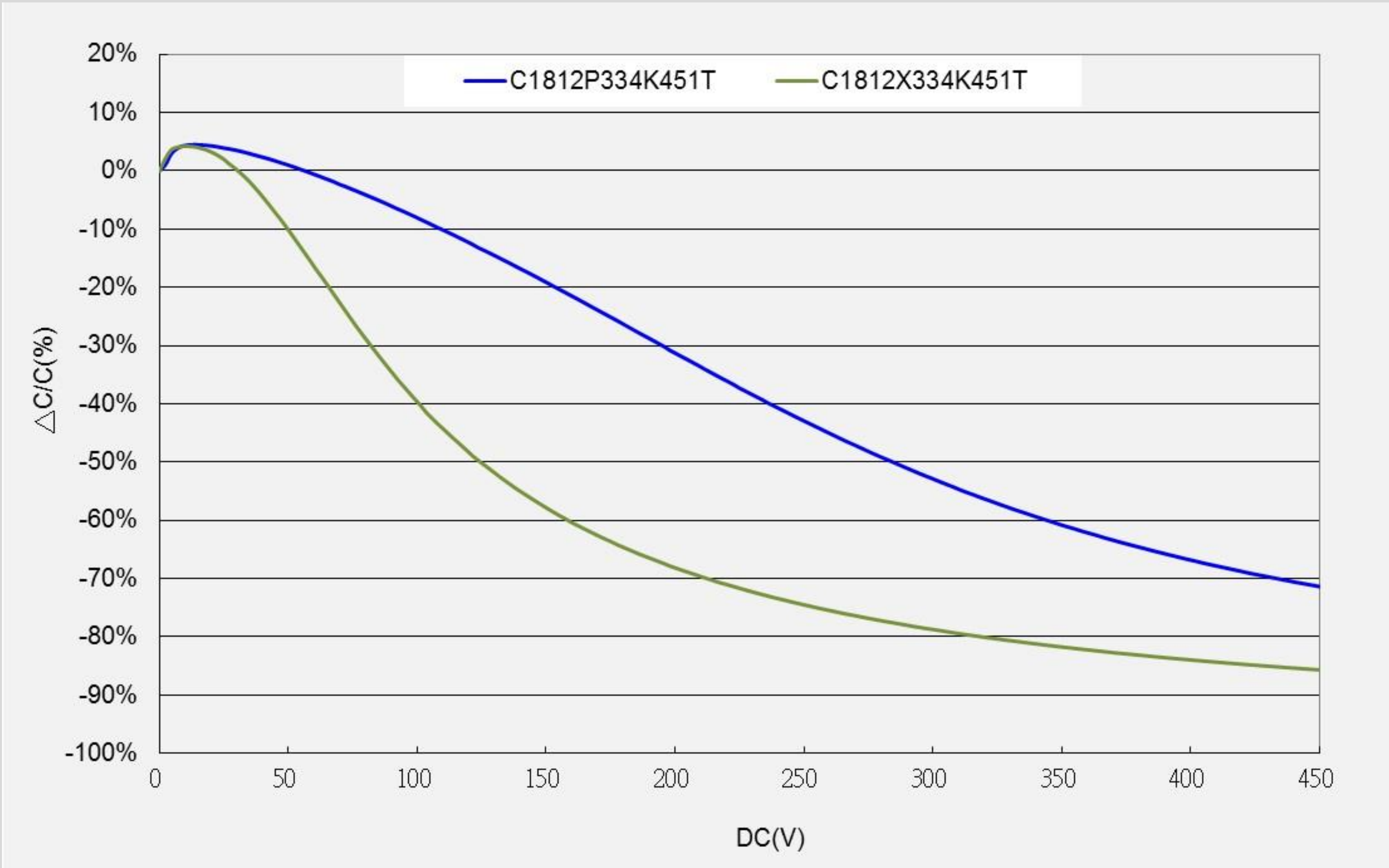
X7P

DC Bias

The DC bias of X7P is considerably better than X7R with up to 40% less capacitance decrease



Power Circuits

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In any circuit where the capacitor is subjected to an AC voltage/current or even a changing DC voltage the capacitor is dissipate energy in the form of heat.

The ESR (Equivalent Series Resistance) is critical in power circuits as it will determine the level of AC current the capacitor can handle.

Generally we define the AC current capability of a capacitor by specifying a Power Rating

For example:-

Size 0805 = 100mW
Size 1206 = 160mW
Size 1210 = 250mW
Size 1812 = 360mW

Power rating therefore = I^2R

Where:
I = Reactive Current
R = ESR

Power Circuits

ESR

X7R vs X7P

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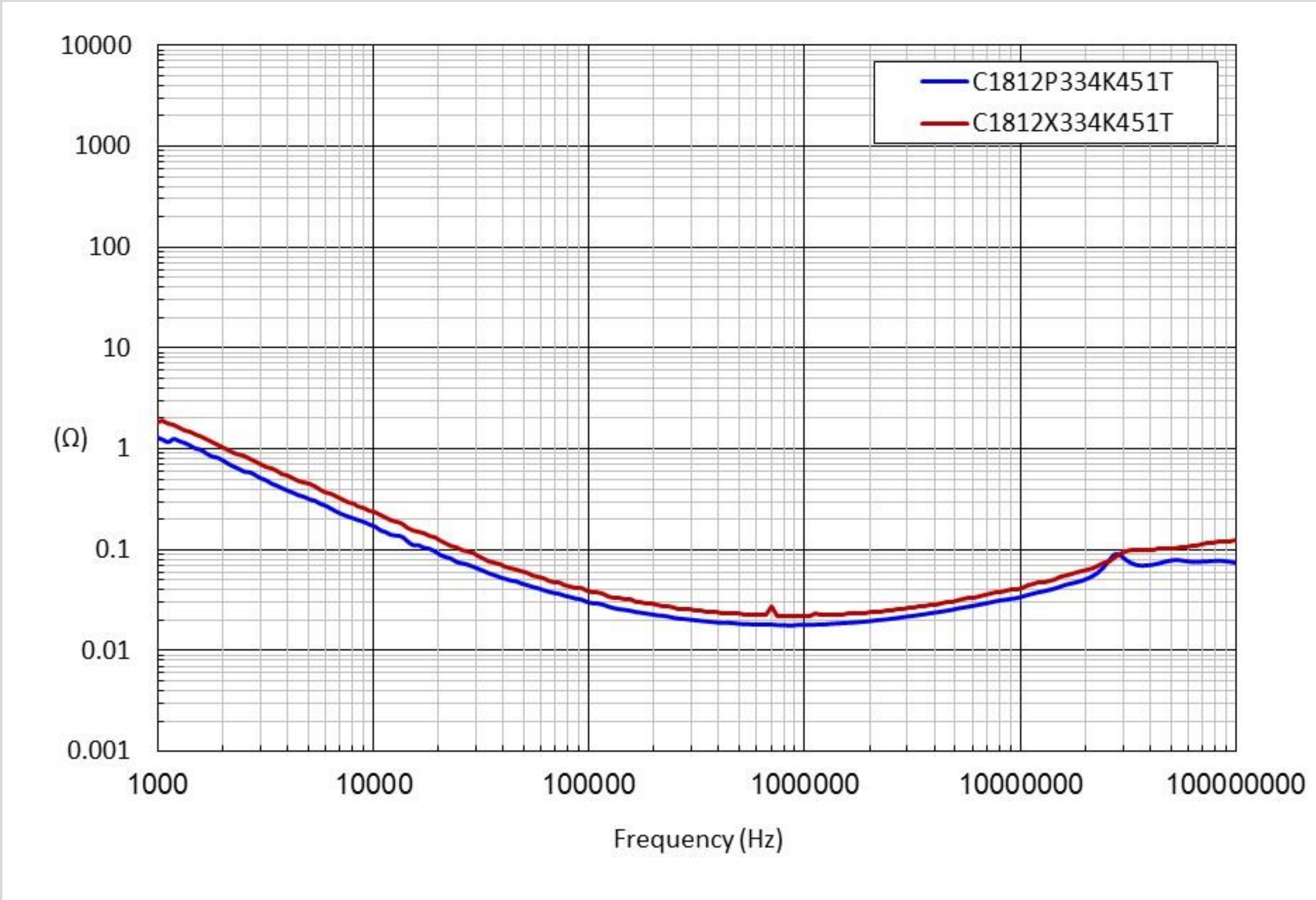

100KHz X7R ESR = 39mΩ
100KHz X7P ESR = 28mΩ

X7P

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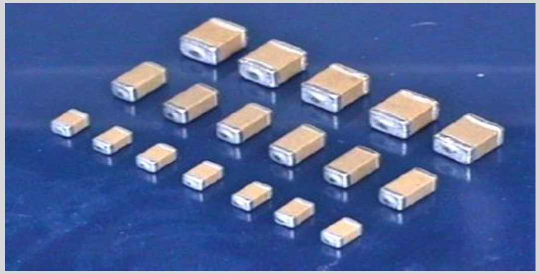
HCP Series – Low DC Bias MLCC's

HCP Series

Multilayer Ceramic Chip Capacitors
250V ~ 630V High Voltage & Low DC Bias



Holy Stone high voltage products are designed and manufactured to meet the general requirements of international standards. The X7P product offering is ideally suited for LED driver, lighting, power adapter and USB charger applications where effective capacitance at working voltage is critical to circuit design.

◆ Features

+/-10% Temperature Coefficient from -55° C to+125° C

Low DC Bias characteristics

Competitive price compared to X7T dielectric

1206, 1210, 1812, 2220 sizes, other sizes and voltages available upon request

◆ Applications

- ❑ LED Drivers
- ❑ Power Adapters/USB Chargers
- ❑ Lighting
- ❑ Power Supplies
- ❑ General telecommunications equipment

X7P

Capacitance Range

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Temperature Characteristic	Voltage	Size	EIA Capacitance Code																		
			103	123	153	183	223	273	333	393	473	563	683	823	104	154	224	334	394	474	684
X7P	250V	1206	B		B		B		B	B	C		C		D		E				
		1210							C		C		C		C		F	F	F		
	400V	1206	B		B		C		D	D	E		E		E						
		1210							C		D		D		E	F		F			
		1812															F	F			
		2220																		F	F
	450V	1206											E		E						
		1210															F				
		1812															F	F		G	
	630V	1206	B		B		C		D	D	E		E								
		1210							C		D		D		E	F					