Multilayer Ceramic Capacitors

Technical Summary

Definitions of Ultra-Stable and Stable

Multilayer Ceramic Capacitors are generally divided into classes which are defined by the capacitance temperature characteristics over specified temperature ranges.

These are designated by alpha numeric codes. Code definitions are summarised below and are also available in the relevant national and international specifications.

1. C0G - Ultra Stable Class 1 Ceramic (EIA Class 1)

Spec.	Classification	Temperature range °C	Maximum capacitance change	Syfer dielectric code
CECC	1B/CG	-55 +125	0 ± 30ppm/°C	C
EIA	C0G (NP0)	-55 +125	0 ± 30ppm/°C	C
MIL	CG (BP)	-55 +125	0 ± 30ppm/°C	C

Capacitors within this class have a dielectric constant range from 10 to 100. They are used in applications which require ultra stable dielectric characteristics with negligible dependence of capacitance and dissipation factor with time, voltage and frequency. They exhibit the following characteristics:-

a) Time does not significantly affect capacitance and dissipation factor (Tan δ) – no ageing.
b) Capacitance and dissipation factor are not affected by voltage.
c) Linear temperature coefficient.

2. X7R – Stable Class II Ceramic (EIA Class II)

Spec.	Classification	Temperature range °C	Maximum capacitance change % over temperature range		Syfer dielectric code
			No DC volt applied	Rated DC Volt	
CECC	2C1	-55 +125	±20	+20 -30	R
	2R1	-55 +125	±15		X
	2X1	-55 +125	±15	+15 -25	B
EIA	X7R	-55 +125	±15	-	X
MIL	BX	-55 +125	±15	+15 -25	B
	BZ	-55 +125	±20	+20 -30	R

Capacitors of this type have a dielectric constant range of 1000-4000, and also have a non-linear temperature characteristic which exhibits a dielectric constant variation of less than ±15% (2R1) from its room temperature value, over the specified temperature range. Generally used for by-passing (decoupling), coupling, filtering, frequency discrimination, DC blocking and voltage transient suppression with greater volumetric efficiency than Class I units, whilst maintaining stability within defined limits.

Capacitance and dissipation factor are affected by:-

Time (Ageing)
Voltage (AC or DC)
Frequency

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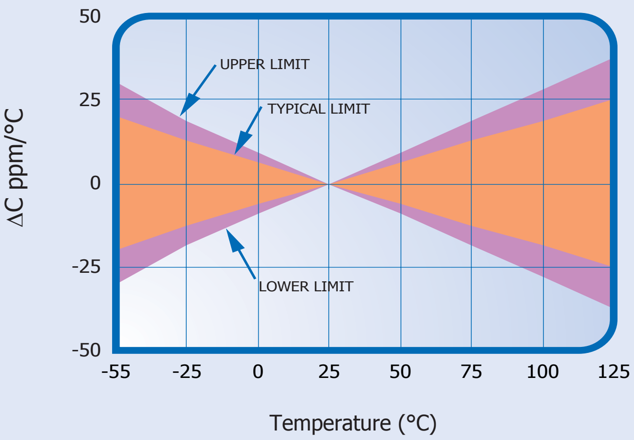
Dielectric Characteristics

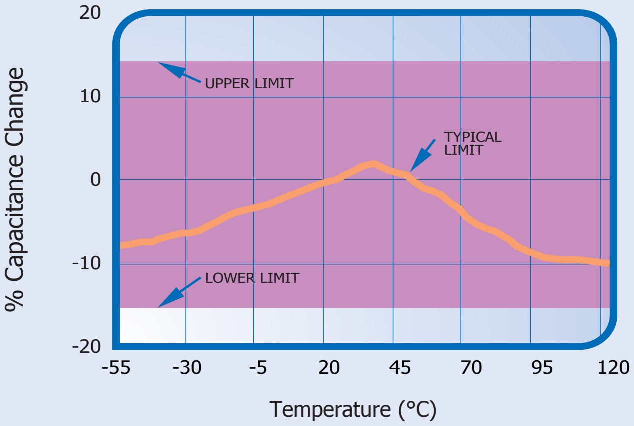
	C0G			X7R		
Dielectric classification	Ultra stable			Stable		
CECC	1B/CG			2C1	2R1	2X1
EIA		C0G(NPO)			X7R	
MIL			CG(BP)	BZ		BX
Rated temperature range	-55°C to +125°C			-55°C to +125°C		
Maximum capacitance change over temperature range No DC voltage applied	0 ± 30 ppm/°C			±20%	±15%	±15%
Rated DC voltage applied				+20-30%	-	+15-25%
Syfer dielectric ordering code	C			R	X	B
Tangent of loss angle (tan δ)	Cr > 50pF ≤ 0.0015 Cr ≤ 50pF = $0.0015 \left(\frac{15}{Cr} + 0.7\right)$			≤ 0.025		
Insulation resistance (Ri) Time constant (Ri X Cr) (whichever is the less)	100G Ω or 1000s			100G Ω or 1000s		
Capacitance tolerance	Cr < 10pF ± 0.10pF (B) ± 0.25pF (C) ± 0.50pF (D) ± 1.0pF (F) Cr ≥ 10pF ± 1% (F) ± 2% (G) ± 5% (J) ± 10% (K)			± 5% (J) ± 10% (K) ± 20% (M)		
Dielectric strength	Voltage applied for 5 seconds. Charging current limited to 50 mA maximum.					
16-200V	2.5 times			2.5 times		
>200V <500V	Rated voltage + 250V			Rated voltage + 250V		
500V/630V	1.5 times			1.5 times		
≥1kV	1.25 times			1.25 times		
Climatic category (IEC)						
Chip	55/125/56			55/125/56		
Dipped	55/125/21			55/125/21		
Discoidal	55/125/56			55/125/56		
Ageing characteristic (Typical)	Zero			1% per time decade		
Approvals Chip	CECC 32 101 801			CECC 32 101 801		
Dipped radial	CECC 30 601 008			CECC 30 701 013		

Typical Dielectric Temperature Characteristics

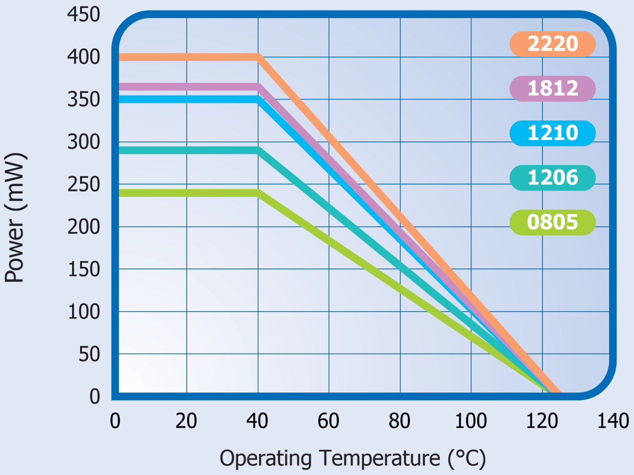
C0G Capacitance Vs Temperature



X7R Capacitance Vs Temperature



Power Ratings for C0G and X7R



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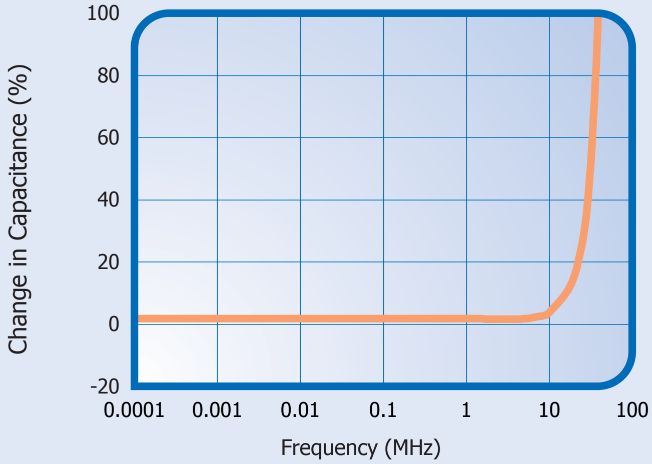
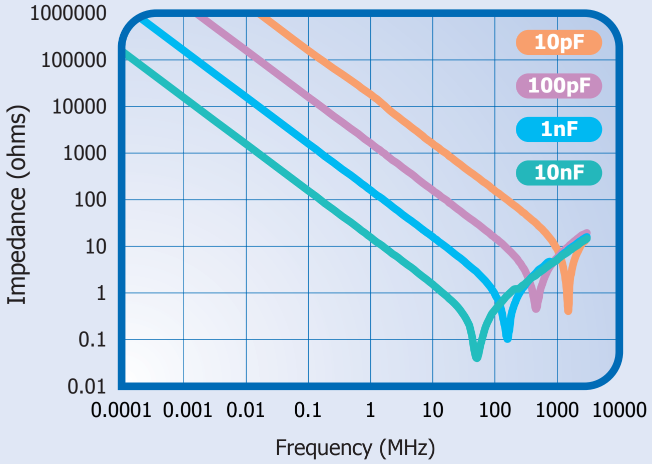
Capacitance vs Frequency - 10nF chip

Ultra Stable C0G dielectric

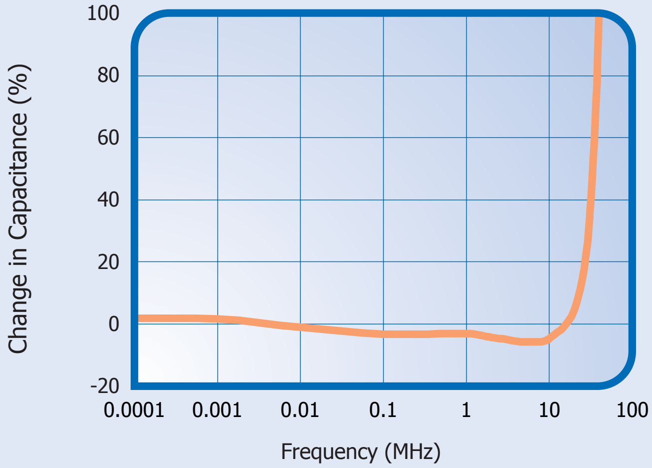


Impedance vs Frequency - chips

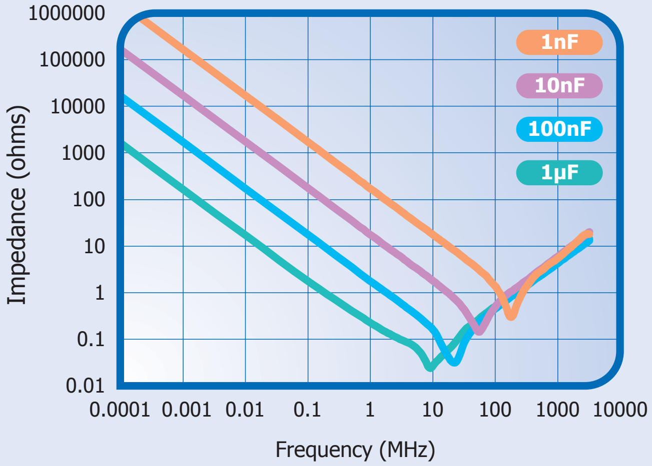
Ultra Stable C0G dielectric



Stable X7R dielectric

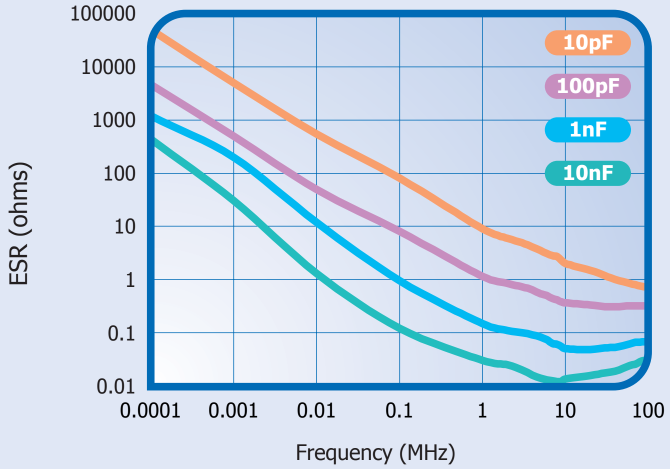


Stable X7R dielectric

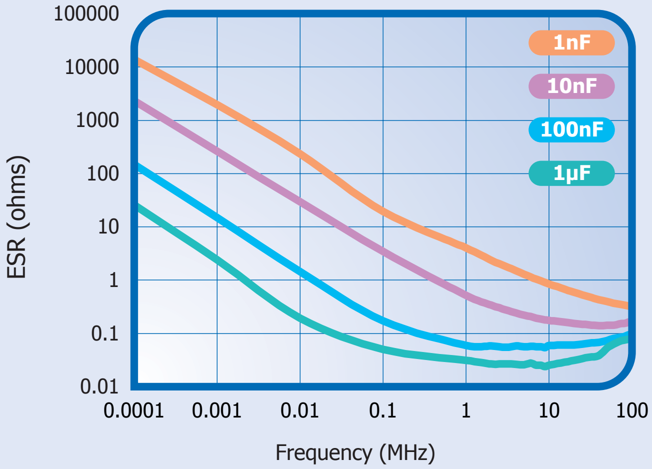


E.S.R. vs Frequency - chips

Ultra Stable C0G dielectric



Stable X7R dielectric



Ageing of Ceramic Capacitors

Ageing

Capacitor ageing is a term used to describe the negative, logarithmic capacitance change which takes place in ceramic capacitors with time. The crystalline structure for barium titanate based ceramics changes on passing through its Curie temperature (known as the Curie Point) at about 125°C. This domain structure relaxes with time and in doing so, the dielectric constant reduces logarithmically; this is known as the ageing mechanism of the dielectric constant.
The more stable dielectrics have the lowest ageing rates.
The ageing process is reversible and repeatable.
Whenever the capacitor is heated to a temperature above the Curie Point the ageing process starts again from zero.
The ageing constant, or ageing rate, is defined as the percentage loss of capacitance due to the ageing process of the dielectric which occurs during a decade of time (a tenfold increase in age) and is expressed as percent per logarithmic decade of hours. As the law of decrease of capacitance is logarithmic, this means that in a capacitor with an ageing rate of 1% per decade of time, the capacitance will decrease at a rate of:

a) 1% between 1 and 10 hours
b) An additional 1% between the following 10 and 100 hours
c) An additional 1% between the following 100 and 1000 hours
d) An additional 1% between the following 1000 and 10000 hours etc
e) The ageing rate continues in this manner throughout the capacitor's life.

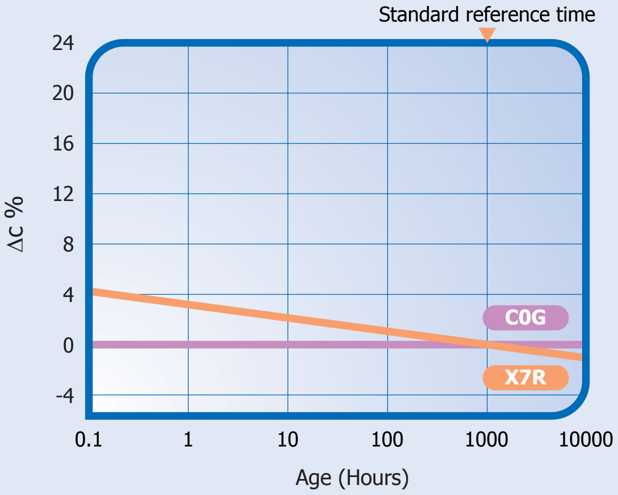
Typical values of the ageing constant for our Multilayer Ceramic Capacitors are:

Dielectric class	Typical agreed value
Ultra Stable C0G	Negligible capacitance loss through ageing
Stable X7R	1% per decade of time

Capacitance Measurements

Because of ageing it is necessary to specify an age for referee measurements at which the capacitance shall be within the prescribed tolerance. This is fixed at 1000 hours, since for practical purposes there is not much further loss of capacitance after this time.
All capacitors shipped are within their specified tolerance at the standard reference age of 1000 hours after having cooled through their Curie temperature.
The ageing curve for any ceramic dielectric is a straight line when plotted on semi-log paper.

Capacitance vs Time - Ageing



Summary and Conclusions

1.0 The recommended sequence of testing Multilayer Ceramic Capacitors is as follows:

a) Capacitance. Applying factors based on the manufacturer's ageing rate and the time elapsed since the last Curie temperature excursion.

b) Dissipation factor

c) Voltage proof test

d) Insulation resistance

e) Other tests. If any limits are specified for change in capacitance during a long term test (life test, for example), the capacitor should be de-aged before both initial and final measurements. De-ageing is accomplished by exposure of the capacitors to 150°C for 1 hour (without voltage) and stabilised at room temperature for 24 hours before capacitance measurements are made.

2.0 The ageing process is completely repeatable and predictable for a given capacitor.

3.0 Capacitance change is negative and logarithmic in respect to time.

4.0 Class C0G dielectric has a negligible ageing rate.

5.0 Class 2 ceramic dielectrics have ageing rates which will vary from 0.8 to 8%, dependent upon particular ceramic composition employed. This wide capacitance change, as a result of 'shelf' ageing and temperature cycling, illustrates why close-tolerance (less than ±5%) high dielectric constant ceramics should not be specified.

6.0 Soldering both leaded and chip class 2 capacitors into a circuit will, because of the ageing phenomenon, give a temporary increase in capacitance value. The magnitude of this change will be dependent on the soldering temperature, time and dielectric class.

Voltage	Dielectric	0603	0805	1206	1210	1808	1812	2220	2225	3640	5550	8060
16V	C0G	0.47p-1.5n	1.0p-6.8n	1.0p-22n	3.9p-33n	4.7p-33n	10p-100n	10p-150n	10p-220n	n/a	n/a	n/a
	X7R	100p-100n	100p-330n	100p-1.0µ	1.0n-1.5µ	15p-1.5µ	3.9n-3.3µ	10n-5.6µ	18n-6.8µ	n/a	n/a	n/a
25V	C0G	0.47p-1.0n	1.0p-4.7n	1.0p-15n	3.9p-22n	4.7p-27n	10p-68n	10p-100n	10p-150n	n/a	n/a	n/a
	X7R	100p-56n	100p-220n	100p-820n	1.0n-1.2µ	15p-1.2µ	3.9n-2.2µ	10n-4.7µ	18n-5.6µ	n/a	n/a	n/a
50/63V	C0G	0.47p-470p	1.0p-2.7n	1.0p-10n	3.9p-18n	4.7p-18n	10p-33n	10p-68n	10p-100n	10p-220n	390p-390n	680p-680n
	X7R	100p-47n	100p-180n	100p-470n	1.0n-1.0µ	15p-680n	3.9n-1.5µ	10n-2.2µ	18n-3.3µ	390p-4.7µ	560p-8.2µ	10n-15µ
100V	C0G	0.47p-330p	1.0p-1.8n	1.0p-6.8n	3.9p-12n	4.7p-12n	10p-27n	10p-47n	10p-68n	10p-180n	390p-330n	680p-560n
	X7R	100p-10n	100p-47n	100p-150n	1.0n-470n	15p-330n	3.9n-1.0µ	10n-1.5µ	18n-1.5µ	390p-3.3µ	560p-6.8µ	10n-10µ
200/250V	C0G	0.47p-100p	1.0p-680p	1.0p-2.2n	3.9p-4.7n	4.7p-4.7n	10p-12n	10p-22n	10p-27n	10p-82n	390p-120n	680p-270n
	X7R	100p-5.6n	100p-27n	100p-100n	1.0n-180n	15p-180n	3.9n-470n	10n-680n	18n-1.0µ	390p-1.5µ	560p-3.9µ	10n-8.2µ
500V	C0G	n/a	1.0p-330p	1.0p-1.5n	3.9p-3.3n	4.7p-3.3n	10p-10n	10p-15n	10p-22n	10p-56n	390p-100n	680p-180n
	X7R	n/a	10p-8.2n	10p-33n	15p-100n	15p-100n	22p-270n	180p-560n	180p-820n	390p-1.0µ	560p-1.8µ	10n-3.3µ
630V	C0G	n/a	1.0p-180p	1.0p-1.0n	3.9p-1.8n	4.7p-2.2n	10p-5.6n	10p-10n	10p-15n	10p-39n	390p-68n	680p-150n
	X7R	n/a	n/a	10p-10n	15p-27n	15p-33n	22p-150n	180p-330n	180p-390n	390p-680n	560p-1.2µ	10n-2.2µ
1kV	C0G	n/a	n/a	1.0p-470p	3.9p-1.0n	4.7p-1.2n	10p-3.3n	10p-8.2n	10p-10n	10p-22n	390p-39n	680p-68n
	X7R	n/a	n/a	10p-4.7n	15p-15n	15p-18n	22p-56n	180p-120n	180p-150n	390p-180n	560p-390n	10n-1.0µ
2kV	C0G	n/a	n/a	1.0p-100p	3.9p-220p	4.7p-220p	10p-820p	10p-1.8n	10p-2.2n	10p-5.6n	390p-10n	680p-18n
	X7R	n/a	n/a	10p-1.0n	15p-2.2n	15p-2.2n	22p-4.7n	180p-12n	180p-15n	390p-47n	560p-82n	10n-150n
3kV	C0G	n/a	n/a	n/a	n/a	4.7p-100p	10p-390p	10p-820p	10p-1.0n	10p-2.2n	390p-4.7n	680p-8.2n
	X7R	n/a	n/a	n/a	n/a	15p-1.0n	22p-1.8n	180p-5.6n	180p-6.8n	390p-18n	560p-39n	10n-68n
4kV	C0G	n/a	n/a	n/a	n/a	1.0p-150p*	2.2p-390p*	10p-1.0n*	10p-1.2n*	10p-1.0n	390p-2.2n	680p-4.7n
	X7R	n/a	n/a	n/a	n/a	100p-1.0n*	100p-2.2n*	100p-4.7n*	100p-5.6n*	390p-6.8n	560p-15n	10n-33n
5kV	C0G	n/a	n/a	n/a	n/a	1.0p-82p*	2.2p-270p*	10p-680p*	10p-820p*	10p-560p	390p-1.5n	680p-3.3n
	X7R	n/a	n/a	n/a	n/a	100p-680p*	100p-1.2n*	100p-3.9n*	100p-4.7n*	n/a	560p-8.2n	10n-18n
6kV	C0G	n/a	n/a	n/a	n/a	1.0p-56p*	2.2p-220p*	10p-470p*	10p-560p*	n/a	n/a	n/a
	X7R	n/a	n/a	n/a	n/a	68p-390p*	100p-1.0n*	100p-2.2n*	100p-2.7n*	n/a	n/a	n/a
		0603	0805	1206	1210	1808	1812	2220	2225	3640	5550	8060

* These parts may require conformal coating post soldering.

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