

1 Definition and construction

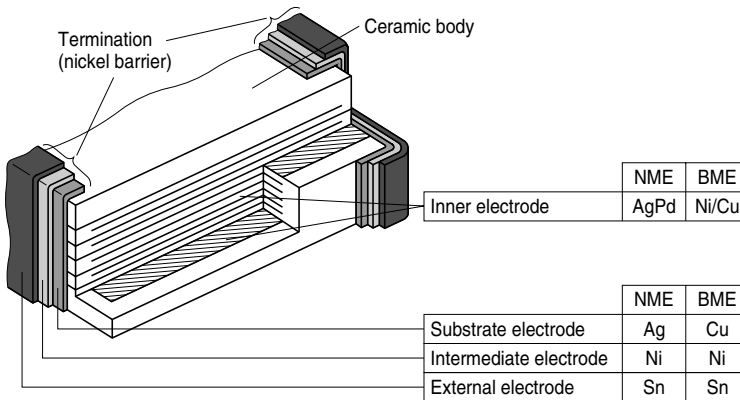
1.1 Introduction

The term ceramic capacitors covers a large group of capacitors. Their properties may be quite different, but they all have the oxide ceramic dielectric in common.

Ceramic generally means that an inorganic polycrystalline body is formed by sintering at high temperatures. By means of special production methods, extremely thin layers of ceramic materials can be obtained. These layers are stacked to construct capacitors whose electrical and mechanical properties meet stringent requirements.

The multilayer capacitors consist of a monolithic ceramic block with comb-like sintered electrodes. These electrodes come to the surface at the face ends of the ceramic block where an electrical contact is made by burnt-in metallic layers.

Schematic construction of a multilayer capacitor with nickel-barrier termination:



$$C = \frac{\epsilon_0 \cdot \epsilon_r \cdot (n-1) \cdot A}{d}$$

NME: Noble Metal Electrode
BME: Base Metal Electrode

KKE0362-U-E

- C Capacitance of capacitor [As/V = F]
- $\epsilon_0 \approx 8,85 \cdot 10^{-12}$ As/Vm Absolute dielectric constant
- ϵ_r Relative dielectric constant (material dependent)
- A Effective electrode area per electrode [m²]
- n Number of electrodes (metal layers)
- d Electrode spacing [m]

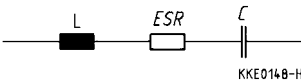
1.2 Capacitance

The unit of capacitance is the farad. One farad is the capacitance of a capacitor in which a charge of one coulomb produces one volt potential difference between the terminals.

$$C = \frac{Q_{el}}{V}$$

Q_{el} charge stored in the capacitor [C = As]
 V voltage applied to the capacitor [V]

Practical equivalent circuit diagram for a real capacitor



L inductance [H = Vs/A]
 C capacitance [F = As/V]
 ESR equivalent series resistance [Ω]

The magnitude of the impedance for this configuration can be calculated as follows:

$$|Z| = \sqrt{ESR^2 + (1/(2\pi fC) - 2\pi fL)^2}$$

Z impedance (AC resistance) [Ω]
 f frequency of applied voltage [Hz]

1.3 Type classification and application

Depending on the chemical composition of their ceramic dielectrics, which determine the main electric properties, ceramic capacitors are classified as follows:

Class 1 capacitors

- The dielectric ($\epsilon < 200$) primarily consists of a mixture of metal oxides and titanates.
- Defined linear temperature coefficient with reversible temperature dependence
- Capacitance does not vary with voltage.
- Low losses at frequencies up to the UHF range
- High insulation resistance

Applications: resonant circuits, filters, timing elements

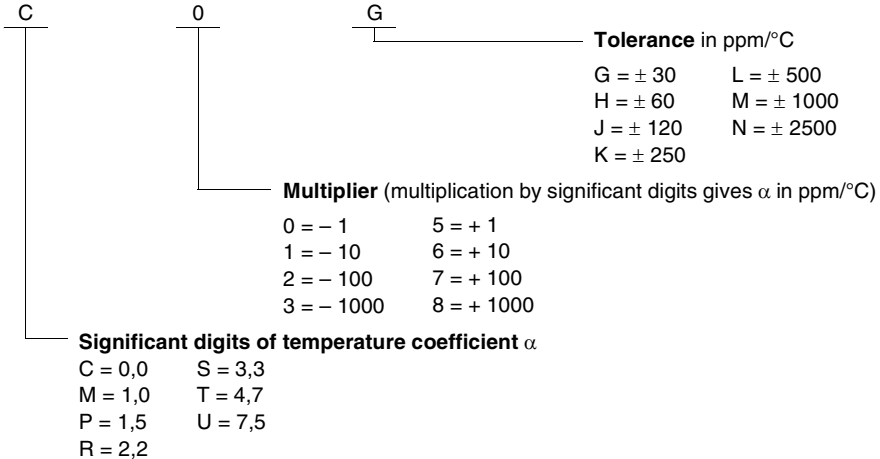
Class 2 capacitors

- The dielectric ($\epsilon \approx 200$ to 10000) primarily consists of titanates (barium, calcium, strontium) and zirconates.
- Non-linear dependence of capacitance on temperature and voltage
- Somewhat higher losses and lower insulation resistance than class 1 capacitors
- Capacitance decreases according to a logarithmic function (ageing).
- High capacitance values even with small-size capacitors are possible

Applications: coupling, blocking, filtering.

2 Temperature characteristics of capacitance for class 1 ceramics

To EIA-198-1; -2; -3



Temperature characteristic "NP0" covers "C0G".

To EN 132100/ IEC 60384-8

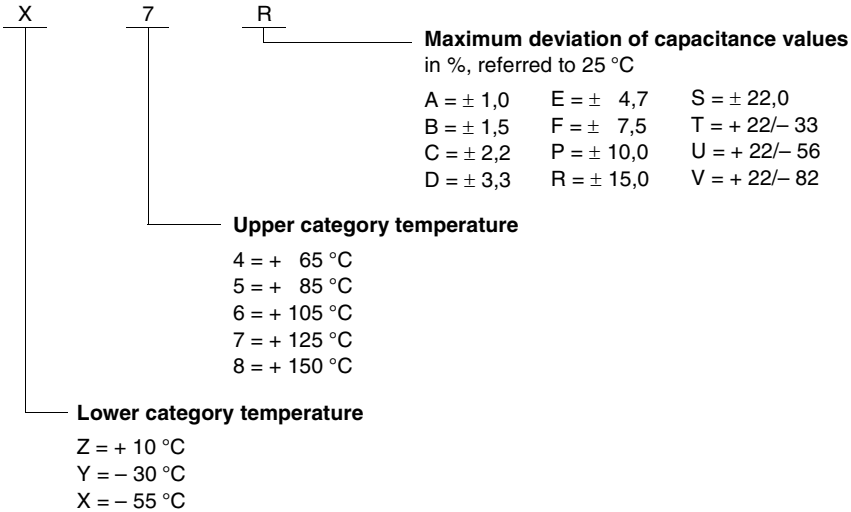
Rated temperature coefficient α ($10^{-6}/^{\circ}\text{C}$)	Limit deviations for temperature coefficient ($10^{-6}/^{\circ}\text{C}$)	Class	Code letters for	
			α	Limit deviations
+ 100	± 30	1B	A	G
0	± 30	1B	C	G
- 33	± 30	1B	H	G
- 75	± 30	1B	L	G
- 150	± 30	1B	P	G
- 220	± 30	1B	R	G
- 330	± 60	1B	S	H
- 470	± 60	1B	T	H
- 750	± 120	1B	U	J
- 1000	± 250	1F	Q	K
- 1500	± 250	1F	V	K
$- 1000 \leq \alpha \leq + 140$		1C	SL	-
$- 1750 \leq \alpha \leq + 250$		1D	UM	-

Notes:

- The rated values of the temperature coefficient α and the accompanying limit deviations are defined using the capacitance change between the temperatures 20 °C and 85 °C.
- A capacitor having a temperature coefficient of zero and a limit deviation of $\pm 30 \cdot 10^{-6}/^{\circ}\text{C}$ is given the code letters CG (class 1B).

3 Temperature characteristics of capacitance for class 2 ceramics

To EIA 198-1; -2; -3



Temperature characteristic “B” (JIS) covers “X7R” (EIA).

Temperature characteristic “F” (JIS) covers “Y5U” and “Z5U” (EIA).

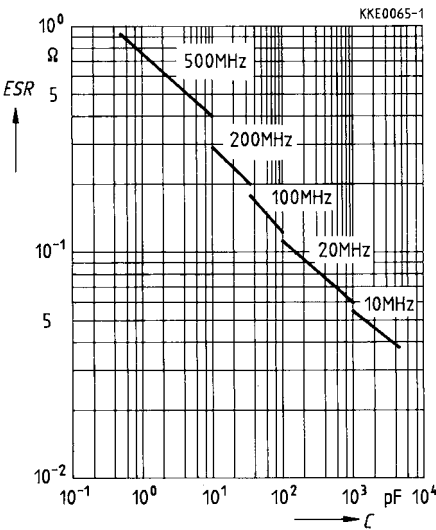
To EN 132100/ IEC 60384-10

Code letter for sub-class	Max. capacitance change in % over specified temperature range		Symbol for specified temperature range (°C)				
			- 55/+ 125	- 55/+ 85	- 40/+ 85	- 25/+ 85	+ 10/+ 85
	without DC voltage	with DC voltage	1	2	3	4	6
2B	± 10 %	+ 10/- 15 %	-	x	x	x	-
2C	± 20 %	+ 20/- 30 %	x	x	x	-	-
2D	+ 20/- 30 %	+ 20/- 40 %	-	-	-	x	-
2E	+ 22/- 56 %	+ 22/- 70 %	-	x	x	x	x
2F	+ 30/- 80 %	+ 30/- 90 %	-	x	x	x	x
2R	± 15 %	-	x	-	-	-	-
2X	± 15 %	+ 15/- 25 %	x	-	-	-	-

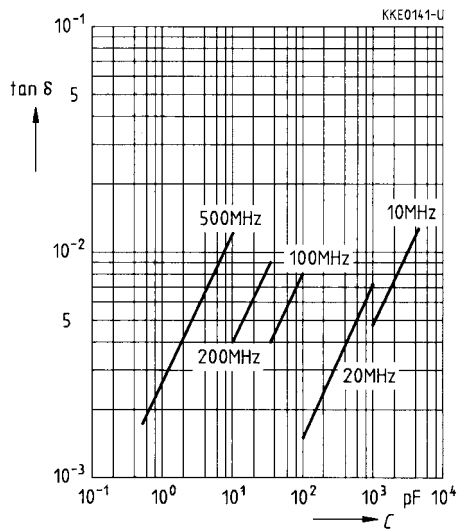
4 Important terms

4.1 Frequency response

Equivalent series resistance versus capacitance for COG capacitors (typical values)

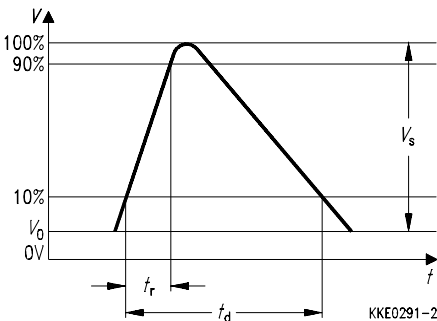


Dissipation factor versus capacitance for COG capacitors (typical values)



The type-related impedance characteristics of chip capacitors are to be found in the data sheets.

4.2 Pulse handling capability



Pulse definition to DIN 40839-1

Rate of voltage rise: $S_V = 0,8 \cdot V_s / t_r$

Max. permissible rate $S_V = 1000 \text{ V}/\mu\text{s}$

Max. voltage amplitude: $V_s + V_0 = 2,5 \cdot V_R$

4.3 Thermal characteristic and electrical ratings

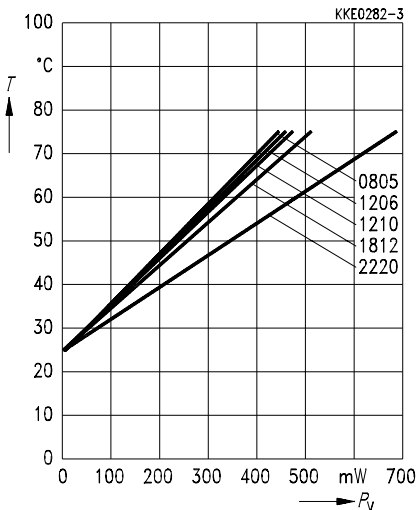
Ceramic capacitors change their capacitance more (class 2) or less (class 1) with temperature. Graphs in the data sheet section show the respective characteristic curves.

Basically, ceramic multilayer capacitors may also be operated at higher temperatures than specified by the upper category temperature. But in such cases some specific features of the ceramic material systems must be taken into account.

Due to a change in the crystalline structure, the capacitance value of high K materials (with a high dielectric constant, e.g. X7R, Z5U) drastically decreases above the Curie point (order of magnitude approximately 50 % at 150 °C). With low K materials (with a low dielectric constant, e.g. C0G) the dissipation factor increases considerably at high temperatures.

Owing to the high temperature, moreover, an acceleration of failure mechanisms and thus a shorter service life of the capacitor is to be expected. As the activation energy, necessary for calculating the service life, is subject to some uncertainty, the numerical estimation may be incorrect. In the most favorable case ($E_a = 0,5 \text{ eV}$) it can be assumed that the failure rate at 150 °C is approximately 125 times higher than under standard conditions $T = 40 \text{ °C}$.

In addition to the high ambient temperature, the high electrical energy exchange contributes to heating the capacitor.



Heating of capacitors as a function of power dissipation (Parameter: size)

4.4 Ageing

The capacitance of class 2 capacitors (X5R, X7R, X8R and Z5U (Y5U)) decreases with time. This process, known as ageing, follows a logarithmic law, which is expressed in terms of an ageing constant. The ageing constant is defined as the percentage loss of capacitance during a “time decade”, i.e. during a period of time, in which the capacitor is subject to a tenfold increase in age (e.g. from 1 h to 10 h).

The law of capacitance ageing is expressed by the following equation:

$$C_t = C_1 \cdot (1 - k \cdot \log_{10} t)$$

C_t capacitance, t hours after start of ageing [F]

C_1 capacitance, 1 hour after start of ageing [F]

k ageing constant (capacitance decrease per decade)

t time in hours from start of ageing [h]

Because of ageing, it is necessary to specify an age for reference measurements at which the capacitance shall be within the prescribed tolerances.

Since the capacitance significantly decreases during the first hours after production, the capacitance value for all shipped capacitors (except HighCap capacitors) refers to 1000 hours ($t = 1000$ h). The capacitance value for HighCap capacitors refers to 48 hours ($t = 48$ h).

By heating the capacitors above the Curie temperature (approximately 130 – 150 °C) the capacitance decrease can be reversed. Ageing then starts anew.

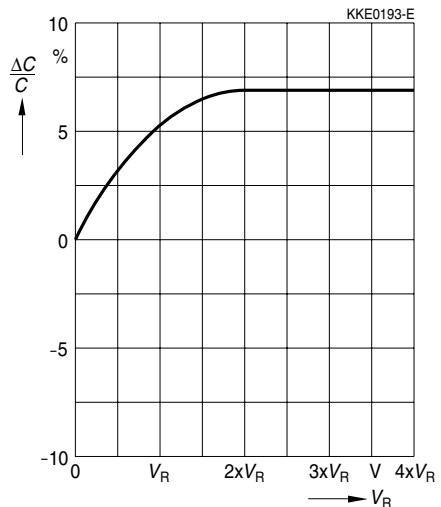
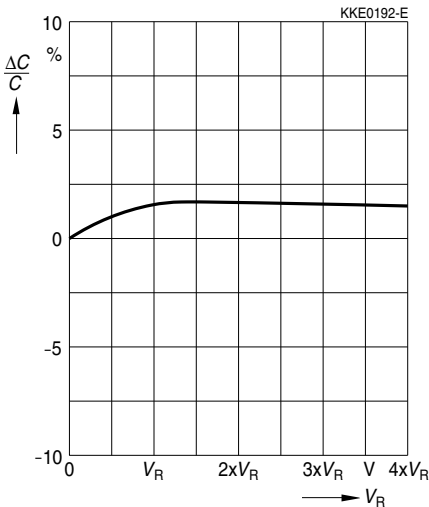
SMDs will be completely de-aged by each soldering process; subsequently a new ageing process begins. For details refer to chapter “Soldering Directions“, page 215.

4.5 Influence of measuring conditions and preconditioning

High DC voltages applied to class 2 capacitors also result in capacitance changes (depending on the material system used):

Capacitance change after DC voltage applied to X7R capacitors (typical values)

Capacitance change after DC voltage applied to Z5U capacitors (typical values)



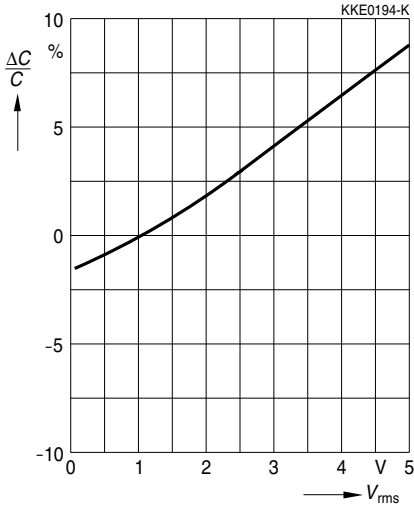
These voltage effects can only be reversed by de-ageing.

The capacitance of class 2 capacitors changes with voltage and/or temperature load. If measurements are made immediately after a voltage test, an insulation test or a test under thermal stress, the capacitance may be exceeded.

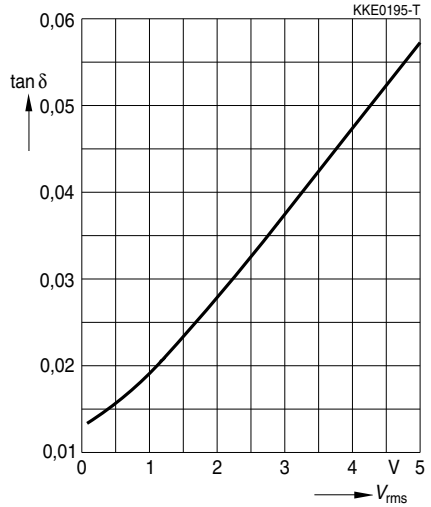
General Technical Information

The following curves show the effects of deviations from the standard measurement conditions (V_{rms} , f_{meas} , T_{meas} acc. to measuring and test conditions), taking an X7R capacitor as an example.

Capacitance change $\Delta C/C$ versus measuring AC voltage V_{rms}



Dissipation factor $\tan \delta$ versus measuring AC voltage V_{rms}



5 Climatic categories

The test class or climatic category to IEC 60068-1 is indicated by 3 groups of figures, e.g.: 55/125/56

1st group of figures:

corresponds to lower category temperature (test for resistance to cold)

2nd group of figures:

corresponds to upper category temperature (test for resistance to dry heat)

3rd group of figures:

number of days denoting duration of damp heat test at 93 % relative humidity and 40 °C

6 Storage of chip capacitors

Solderability is guaranteed for one year from date of delivery (half a year for chips with AgPd terminations), provided that the components are stored in the original packages.

Storage temperature: – 25 ... + 45 °C

Relative humidity: ≤ 75 % annual average, ≤ 95 % on 30 days in a year

7 Standards and specifications

CECC 00802	Guideline: CECC standard method for the specification of surface-mount devices (SMDs) of assessed quality
EN 130000	Generic specification: Fixed capacitors
EN 130600	Sectional specification: Fixed ceramic capacitors, type 1
EN 130700	Sectional specification: Fixed capacitors with ceramic dielectric, class 2
EN 132100	Sectional specification: Multilayer ceramic chip capacitors
EN ISO 9000	Quality management systems: Fundamentals and vocabulary
EN ISO 9001	Quality management systems: Requirements
EN ISO 9004-1	Quality management and quality system elements Part 1: Guidelines
ISO/TS 16949	Quality management systems: Automotive suppliers; Particular requirements for the application of ISO 9001: 2000
IEC 60063	Preferred number series of resistors and capacitors
IEC 60068	Electrical engineering Basic environmental testing procedures
IEC 60384-1	Fixed capacitors for use in electronic equipment Part 1: Generic specificatio

General Technical Information

IEC 60384-8	Fixed capacitors for use in electronic equipment Part 8: Sectional specification: Fixed capacitors of ceramic dielectric, class 1
IEC 60384-8-1	Fixed capacitors for use in electronic equipment Part 8-1: Blank detail specification: Fixed capacitors of ceramic dielectric, class 1. Quality assessment level E
IEC 60384-9	Fixed capacitors for use in electronic equipment Part 9: Sectional specification: Fixed capacitors of ceramic dielectric, class 2
IEC 60384-9-1	Fixed capacitors for use in electronic equipment Part 9-1: Blank detail specification: Fixed capacitors of ceramic dielectric, class 2. Quality assessment level E
IEC 60384-10	Fixed capacitors for use in electronic equipment Part 10: Sectional specification: Fixed multilayer ceramic chip capacitors
IEC 60384-10-1	Fixed capacitors for use in electronic equipment Part 10-1: Blank detail specification: Fixed multilayer ceramic chip capacitors. Quality assessment level E
DIN ISO 2859-1	Sampling procedure for inspection by attributes Part 1: Sampling plans indexed by acceptable quality level (AQL) for lot-by-lot inspection
DIN 40839-1, -2; -3; -4	Electromagnetic compatibility in motor vehicles
EIA 198-1, -2; -3	Ceramic dielectric capacitors Class I, II, III and IV
QS 9000	Quality System Requirements (including supporting documents)
VDA	VDA (Verband der Automobilindustrie e.V.) Quality management in the automotive industry

Herausgegeben von EPCOS AG

Unternehmenskommunikation, Postfach 80 17 09, 81617 München, DEUTSCHLAND

☎ ++49 89 636 09, FAX (0 89) 636-2 26 89

© EPCOS AG 2002. Vervielfältigung, Veröffentlichung, Verbreitung und Verwertung dieser Broschüre und ihres Inhalts ohne ausdrückliche Genehmigung der EPCOS AG nicht gestattet.

Bestellungen unterliegen den vom ZVEI empfohlenen Allgemeinen Lieferbedingungen für Erzeugnisse und Leistungen der Elektroindustrie, soweit nichts anderes vereinbart wird.

Diese Broschüre ersetzt die vorige Ausgabe.

Fragen über Technik, Preise und Liefermöglichkeiten richten Sie bitte an den Ihnen nächstgelegenen Vertrieb der EPCOS AG oder an unsere Vertriebsgesellschaften im Ausland. Bauelemente können aufgrund technischer Erfordernisse Gefahrstoffe enthalten. Auskünfte darüber bitten wir unter Angabe des betreffenden Typs ebenfalls über die zuständige Vertriebsgesellschaft einzuholen.

Published by EPCOS AG

Corporate Communications, P.O. Box 80 17 09, 81617 Munich, GERMANY

☎ ++49 89 636 09, FAX (0 89) 636-2 26 89

© EPCOS AG 2002. Reproduction, publication and dissemination of this brochure and the information contained therein without EPCOS' prior express consent is prohibited.

Purchase orders are subject to the General Conditions for the Supply of Products and Services of the Electrical and Electronics Industry recommended by the ZVEI (German Electrical and Electronic Manufacturers' Association), unless otherwise agreed.

This brochure replaces the previous edition.

For questions on technology, prices and delivery please contact the Sales Offices of EPCOS AG or the international Representatives.

Due to technical requirements components may contain dangerous substances. For information on the type in question please also contact one of our Sales Offices.