FlexiCap™ overview

FlexiCap™ termination

MLCCs are widely used in electronic circuit design for a multitude of applications. Their small package size, technical performance and suitability for automated assembly makes them the component of choice for the specifier.

However, despite the technical benefits, ceramic components are brittle and need careful handling on the production floor. In some circumstances they may be prone to mechanical stress damage if not used in an appropriate manner. Board flexing, depanelisation, mounting through hole components, poor storage and automatic testing may all result in cracking.

Careful process control is important at all stages of circuit board assembly and transportation - from component placement to test and packaging. Any significant board flexing may result in stress fractures in ceramic devices that may not always be evident during the board assembly process. Sometimes it may be the end customer who finds out - when equipment fails!

Knowles has the solution - FlexiCap™

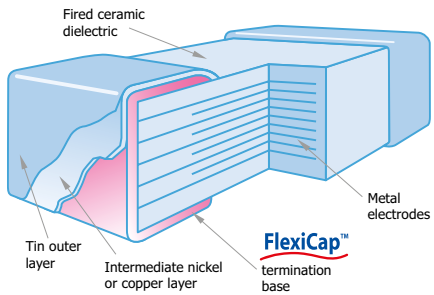
FlexiCap™ has been developed as a result of listening to customers' experiences of stress damage to MLCCs from many manufacturers, often caused by variations in production processes.

Our answer is a proprietary flexible epoxy polymer termination material, that is applied to the device under the usual nickel barrier finish. FlexiCap™ will accommodate a greater degree of board bending than conventional capacitors.

Knowles FlexiCap™ termination

Ranges are available with FlexiCap™ termination material offering increased reliability and superior mechanical performance (board flex and temperature cycling) when compared with standard termination materials. Refer to Knowles application note reference AN0001. FlexiCap™ capacitors enable the board to be bent almost twice as much before mechanical cracking occurs. Refer to application note AN0002.

FlexiCap™ is also suitable for Space applications having passed thermal vacuum outgassing tests. Refer to Syfer application note reference AN0026.



FlexiCap™ MLCC cross section

FlexiCap™ benefits

With traditional termination materials and assembly, the chain of materials from bare PCB to soldered termination, provides no flexibility. In circumstances where excessive stress is applied - the weakest link fails. This means the ceramic itself, which may fail short circuit.

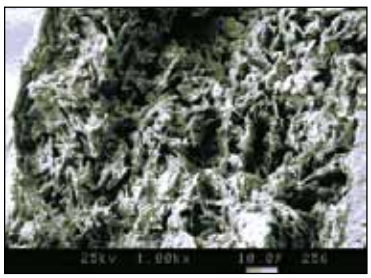
The benefit to the user is to facilitate a wider process window - giving a greater safety margin and substantially reducing the typical root causes of mechanical stress cracking.

FlexiCap™ may be soldered using your traditional wave or reflow solder techniques including lead free and needs no adjustment to equipment or current processes.

Knowles has delivered millions of FlexiCap™ components and during that time has collected substantial test and reliability data, working in partnership with customers world wide, to eliminate mechanical cracking.

An additional benefit of FlexiCap™ is that MLCCs can withstand temperature cycling -55ºC to 125ºC in excess of 1,000 times without cracking.

FlexiCap™ termination has no adverse effect on any electrical parameters, nor affects the operation of the MLCC in any way.



- Picture taken at 1,000x magnification using a SEM to demonstrate the fibrous nature of the FlexiCap™ termination that absorbs increased levels of mechanical stress.

Available on the following ranges:

- All High Reliability ranges
- Standard and High Voltage Capacitors
- Open Mode and Tandem Capacitors
- Safety Certified Capacitors
- Non-magnetic Capacitors
- 3 terminal EMI chips
- X2Y Integrated Passive Components
- X8R High Temperature capacitors

Summary of PCB bend test results

The bend tests conducted on X7R have proven that the FlexiCap™ termination withstands a greater level of mechanical stress before mechanical cracking occurs.

The AEC-Q200 test for X7R requires a bend level of 2mm minimum and a cap change of less than 10%.

Product X7R	Typical bend performance under AEC-Q200 test conditions
Standard termination	2mm to 3mm
FlexiCap™	Typically 8mm to 10mm

Application notes

FlexiCap™ may be handled, stored and transported in the same manner as standard terminated capacitors. The requirements for mounting and soldering FlexiCap™ are the same as for standard SMD capacitors.

For customers currently using standard terminated capacitors there should be no requirement to change the assembly process when converting to FlexiCap™.

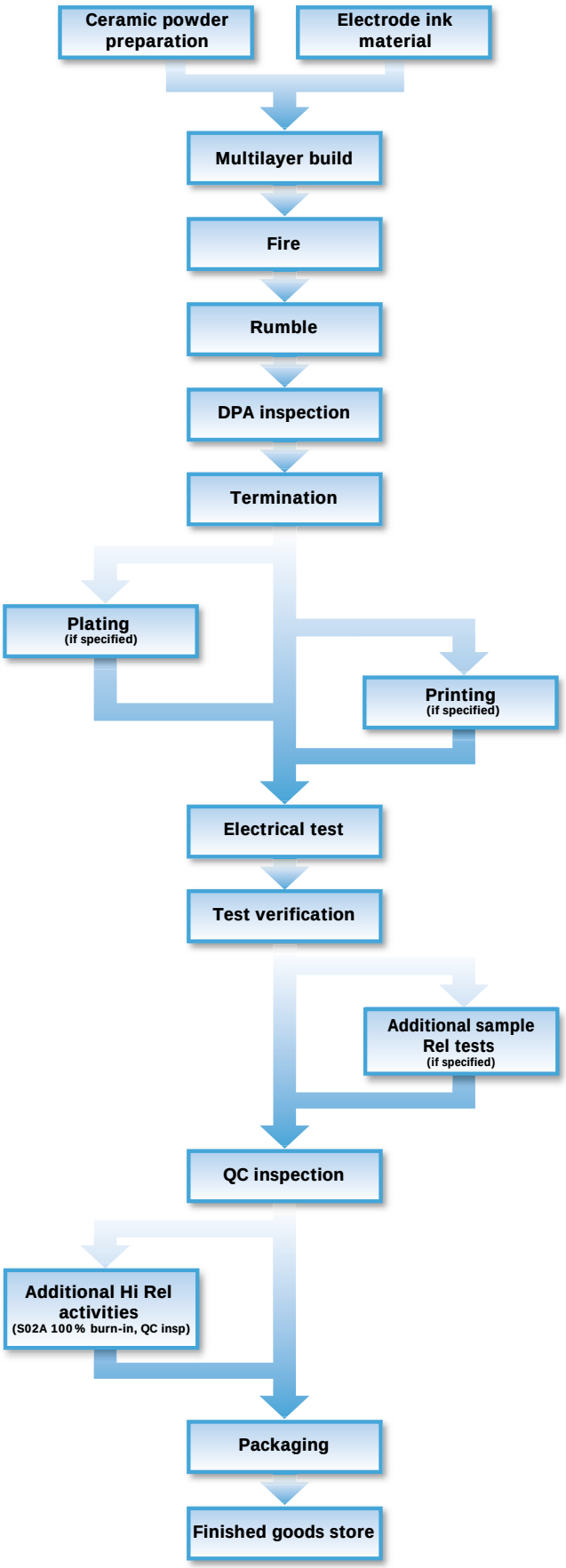
Based upon board bend tests in accordance with IEC 60384-1 the amount of board bending required to mechanically crack a FlexiCap™ terminated capacitor is significantly increased compared with standard terminated capacitors.

It must be stressed however, that capacitor users must not assume that the use of FlexiCap™ terminated capacitors will totally eliminate mechanical cracking. Good process controls are still required for this objective to be achieved.

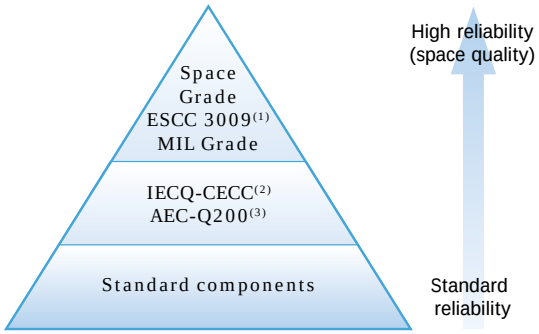
FlexiCap™

Manufacturing processes

Production process flowchart



Knowles reliability grades

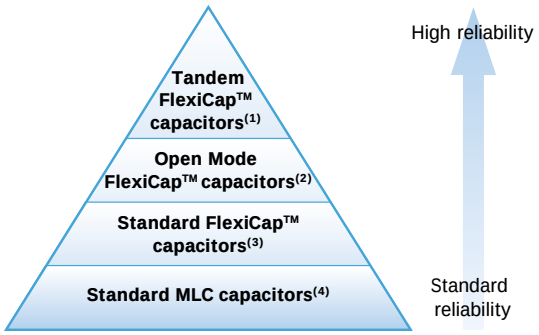


Notes:

1) Space grade tested in accordance with ESCC3009 (refer to Knowles Spec S02A 0100) or MIL Grade (in accordance with MIL-PRF-123, MIL-PRF-55681).
2) IECQ-CECC. The International Electrotechnical Commission (IEC) Quality Assessment System for Electronic Components. This is an internationally recognised product quality certification which provides customers with assurance that the product supplied meets high quality standards.

   View Knowles IECQ-CECC approvals at http://www.iecq.org or at www.knowlescapacitors.com
3) AEC-Q200. Automotive Electronics Council Stress Test Qualification For Passive Components. Refer to Knowles application note reference AN0009.

Knowles reliability surface mount product groups



Notes:

1) "Tandem" construction capacitors, ie internally having the equivalent of 2 series capacitors. If one of these should fail short-circuit, there is still capacitance end to end and the chip will still function as a capacitor, although capacitance maybe affected. Refer to application note AN0021. Also available qualified to AEC-Q200.
2) "Open Mode" capacitors with FlexiCap™ termination also reduce the possibility of a short circuit by utilising inset electrode margins. Refer to application note AN0022. Also available qualified to AEC-Q200.
3) Multilayer capacitors with Knowles FlexiCap™ termination. By using FlexiCap™ termination, there is a reduced possibility of the mechanical cracking occurring.
4) "Standard" capacitors includes MLCCs with tin finish over nickel but no FlexiCap™.

Testing

Tests conducted during batch manufacture

	Knowles reliability SM product group			
	Standard SM capacitors	IECQ-CECC / MIL grade	AEC-Q200	S (Space grade) High Rel S02A ESCC 3009 MIL-PRF-123
Solderability	●	●	●	●
Resistance to soldering heat	●	●	●	●
Plating thickness verification (if plated)	●	●	●	●
DPA (Destructive Physical Analysis)	●	●	●	●
Voltage proof test (DWV / Flash)	●	●	●	●
Insulation resistance	●	●	●	●
Capacitance test	●	●	●	●
Dissipation factor test	●	●	●	●
100% visual inspection	❍	❍	●	●
100% burn-in. (2xRV @125ºC for 168 hours)	❍	❍	❍	●
Load sample test @ 125ºC	❍	❍	●	LAT1 & LAT2 (1000 hours)
Humidity sample test. 85ºC/85%RH	❍	❍	●	240 hours
Hot IR sample test	❍	❍	❍	❍
Axial pull sample test (MIL-STD-123)	❍	❍	❍	❍
Breakdown voltage sample test	❍	❍	❍	❍
Deflection (bend) sample test	❍	❍	❍	❍
SAM (Scanning Acoustic Microscopy)	❍	❍	❍	❍
LAT1 (4 x adhesion, 8 x rapid temp change + LAT2 and LAT3)	-	-	-	❍
LAT2 (20 x 1000 hour life test + LAT3)	-	-	-	❍
LAT3 (6 x TC and 4 x solderability)	-	-	-	❍

● Test conducted as standard.
❍ Optional test. Please discuss with the Sales Office.

Periodic tests conducted for IECQ-CECC and AEC-Q200

Test ref	Test	Termination type	Additional requirements	Sample acceptance			Reference
				P	N	C	
P1	High temperature exposure (storage)	All types	Un-powered. 1,000 hours @ T=150ºC. Measurement at 24 ± 2 hours after test conclusion	12	77	0	MIL-STD-202 Method 108
P2	Temperature cycling	C0G/NP0: All types X7R: Y and H only	1,000 cycles -55ºC to +125ºC Measurement at 24 ± 2 hours after test conclusion	12	77	0	JESD22 Method JA-104
P3	Moisture resistance	All types	T = 24 hours/cycle. Note: Steps 7a and 7b not required. Un-powered. Measurement at 24 ± 2 hours after test conclusion	12	77	0	MIL-STD-202 Method 106
P4	Biased humidity	All types	1,000 hours 85ºC/85%RH. Rated voltage or 50V whichever is the least and 1.5V. Measurement at 24 ± 2 hours after test conclusion	12	77	0	MIL-STD-202 Method 103
P5	Operational life	All types	Condition D steady state TA=125ºC at full rated. Measurement at 24 ± 2 hours after test conclusion	12	77	0	MIL-STD-202 Method 108
P6	Resistance to solvents	All types	Note: Add aqueous wash chemical. Do not use banned solvents	12	5	0	MIL-STD-202 Method 215
P7	Mechanical shock	C0G/NP0: All types X7R: Y and H only	Figure 1 of Method 213. Condition F	12	30	0	MIL-STD-202 Method 213
P8	Vibration	C0G/NP0: All types X7R: Y and H only	5*g's* for 20 minutes, 12 cycles each of 3 orientations. Note: Use 8" x 5" PCB 0.031" thick 7 secure points on one long side and 2 secure points at corners of opposite sides. Parts mounted within 2" from any secure point. Test from 10-2,000Hz	12	30	0	MIL-STD-202 Method 204
P9	Resistance to soldering heat	All types	Condition B, no pre-heat of samples: Single wave solder - Procedure 2	3	12	0	MIL-STD-202 Method 210
P10	Thermal shock	C0G/NP0: All types X7R: Y and H only	-55ºC/+125ºC. Number of cycles 300. Maximum transfer time - 20 seconds, dwell time - 15 minutes. Air-Air	12	30	0	MIL-STD-202 Method 107
P11	Adhesion, rapid temp change and climatic sequence	X7R: A, F and J only	5N force applied for 10s, -55ºC/ +125ºC for 5 cycles, damp heat cycles	12	27	0	BS EN132100 Clause 4.8, 4.12 and 4.13
P12	Board flex	C0G/NP0: All types X7R: Y and H only	3mm deflection Class I 2mm deflection Class II	12	30	0	AEC-Q200-005
P13	Board flex	X7R: A, F and J only	1mm deflection.	12	12	0	BS EN132100 Clause 4.9
P14	Terminal strength	All types	Force of 1.8kg for 60 seconds	12	30	0	AEC-Q200-006
P15	Beam load test	All types	-	12	30	0	AEC-Q200-003
P16	Damp heat steady state	All types	56 days, 40ºC / 93% RH 15x no volts, 15x 5Vdc, 15x rated voltage or 50V whichever is the least.	12	45	0	BS EN132100 Clause 4.14

Test results are available on request.
P = Period in months.
N = Sample size.
C = Acceptance criteria.

High Reliability Testing

Our High Rel products are designed for optimum reliability and are burned in at elevated voltage and temperature levels. They are 100% electrically inspected to ascertain conformance to a strict performance criteria.

Applications for High Reliability products include medical implanted devices, aerospace, airborne, various military applications, and consumer uses requiring safety margins not attainable with conventional product.

We have the ability to test surface mount and leaded capacitors to High Reliability standards as detailed below, or to customer SCD.

Military performance specifications are designed and written for the voltage/capacitance ratings of the individual product slash numbers associated with the specification.

Some of the requirements of the military document may not apply to the High Reliability product. The following details the intent of the individual military specifications available for test and the deviations that may apply.

Product voltage ratings outside of the intended military specification will follow the voltage test potential outlined.

Contact the Sales Office with any requirements or deviations that are not covered here.

Environmental Testing

We also have the capability to perform all the Environmental Group B, Group C and Qualification testing to the referenced military specifications.

Testing abilities include the following:

- Nondestructive internal examination
- Destructive physical analysis
- Radiographic inspection
- Terminal strength
- Resistance to soldering heat
- Voltage-temperature limits
- Temperature coefficient
- Moisture resistance
- Humidity, steady state, low voltage
- Vibration
- Resistance to solvents
- Life
- Thermal shock and immersion
- Low temperature storage
- Barometric pressure
- Shock, specified pulse
- Mechanical shock
- Constant acceleration
- Wire bond evaluation
- Partial discharge (corona)
- 200°C Voltage Conditioning

Military Performance Specifications

MIL-PRF-55681 (GROUP A)

General purpose military high reliability specification for surface mount sizes 0805 through 2225 in 50V and 100V.

- VOLTAGE CONDITIONING
- 100 HRS, 2X VDCW, 125°C
- DWV, IR, 125°C IR, CAP, DF TEST
- VISUAL & MECH. INSPECTION (AQL SAMPLE PLAN)
- SOLDERABILITY, SAMPLE 13(0)
- 8% PDA MAXIMUM

MIL-PRF-123 (GROUP A)

The specification affords an increased reliability level over MIL-PRF-55681 for space, missile and other high reliability applications such as medical implantable or life support equipment. The specification covers surface mount sizes 0805 through 2225 in 50V rating and various radial / axial leaded products in 50V, 100V and 200V ratings.

- THERMAL SHOCK, 20 CYCLES
- VOLTAGE CONDITIONING 168/264 HRS, 2X VDCW, 125°C
- DWV, IR, 125°C IR, CAP, DF TEST
- VISUAL & MECH. INSPECTION SAMPLE 20(0)
- DPA(1)
- PDA, 3% (0.1%), 5% (0.2%) MAX(2)

MIL-PRF-39014 (GROUP A)

The specification covers general military purpose radial / axial leaded and encapsulated product in 50V, 100V, and 200V ratings.

- THERMAL SHOCK, 5 CYCLES
- VOLTAGE CONDITIONING 96 HRS, 2X VDCW, 125°C
- DWV, IR, 125°C IR, CAP, DF TEST
- VISUAL & MECH. INSPECTION (AQL SAMPLE PLAN)
- SOLDERABILITY, SAMPLE 13(0)
- 8% PDA MAXIMUM

MIL-PRF-49467 (GROUP A)

General purpose military high reliability specification for radial leaded epoxy coated. The specification covers sizes 1515 through 13060 with 600V, 1kV, 2kV, 3kV, 4kV and 5kV ratings.

- THERMAL SHOCK, 5 CYCLES
- VOLTAGE CONDITIONING 96 HRS, RATED VDCW, 125°C
- PARTIAL DISCHARGE (OPTION) (3)
- DWV, IR, 125°C IR, CAP, DF TEST
- VISUAL & MECH. INSPECTION SAMPLE 13(0)
- SOLDERABILITY, SAMPLE 5(0)
- 10% PDA MAXIMUM

MIL-PRF-49470 (DSCC 87106) (GROUP A)

General purpose military high reliability specification for stacked and leaded capacitors for switch mode power supplies. The specification covers sizes 2225 through 120200 in 50V, 100V, 200V and 500V ratings.

- THERMAL SHOCK, 5 CYCLES
- VOLTAGE CONDITIONING 96 HRS, 2X VDCW(4), 125°C
- DWV, IR, 125°C IR, CAP, DF TEST
- VISUAL & MECH. INSPECTION SAMPLE 13(0)
- SOLDERABILITY, SAMPLE 5(0)
- 10% PDA MAXIMUM

MIL-PRF-38534

Specification for Hybrid Microcircuits with a section for Element Evaluation on passive components.

There are two classification levels of reliability. Class H is for a standard military quality level. Class K is for the highest reliability level intended for space application.

Knowles will perform a 100-hour burn-in on all Class K products and assumes Class K Subgroup 3 samples will be unmounted and Subgroup 4 (wirebond) shall not apply unless otherwise stated.

TEST VOLTAGE (VDC)

This test potential shall be used on all High Reliability Testing unless otherwise specified.

WVDC	DWV	V/C*
<200	2.5X Rated	2.0X Rated
250	500V	400V
300	500V	400V
400	600V	500V
500	750V	600V
600	750V	600V
>700	1.2X Rated	1.0X Rated

*V/C Is Voltage Conditioning.

Notes:

1. MIL-PRF-123 DPA shall be per TABLE XIV AQL requirements unless otherwise specified.
2. MIL-PRF-123 allowable PDA shall be 3% overall and 0.1% in the last 48 hours for capacitance/voltage values listed in MIL-PRF-123, and be 5% overall and 0.2% in the last 48 hours for capacitance/voltage values beyond MIL-PRF-123.
3. MIL-PRF-49467 standard Group A is without Partial Discharge. Partial Discharge test is optional and must be specified.
4. MIL-PRF-49470 (DSCC 87106) 500V rated product has Voltage Conditioning at 1.2X VDCW.

Regulations and Compliance

Release documentation

	Knowles reliability SM product group			
	Standard SM capacitors	IECQ-CECC	AEC-Q200 MIL grade	S (Space grade) High Rel S02A
Certificate of conformance	●	-	●	●
IECQ-CECC Release certificate of conformity	-	●	-	-
Batch electrical test report	❍	❍	❍	Included in data pack
S (space grade) data documentation package	-	-	-	●

● Release documentation supplied as standard.
❍ Original documentation.

Periodic tests conducted and reliability data availability

Standard Surface Mount capacitors

Components are randomly selected on a sample basis and the following routine tests are conducted:

- Load Test. 1,000 hours @125ºC (150ºC for X8R). Applied voltage depends on components tested.
- Humidity Test. 168 hours @ 85ºC/85%RH.
- Board Deflection (bend test).

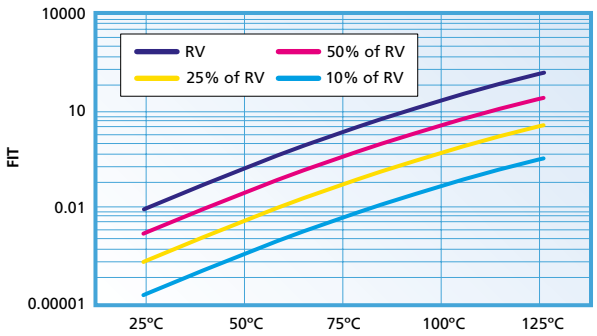
Test results are available on request.

Conversion factors

From	To	Operation
FITS	MTBF (hours)	$10^9 \div$ FITS
FITS	MTBF (years)	$10^9 \div$ (FITS x 8760)

FITS = Failures in 10^9 hours.
MTBF = Mean time between failures.

Example of FIT (Failure In Time) data available:



Component type: 0805 (C0G/NP0 and X7R).
Testing location: Knowles reliability test department.
Results based on: 16,622,000 component test hours.

REACH (Registration, Evaluation, Authorisation and restriction of Chemicals) statement

The main purpose of REACH is to improve the protection of human health and the environment from the risks arising from the use of chemicals.

Knowles maintains both ISO14001, Environmental Management System and OHSAS 18001 Health and Safety Management System approvals that require and ensure compliance with corresponding legislation such as REACH.

For further information, please contact the Knowles Capacitors Sales Office at www.knowlescapacitors.com

RoHS compliance

Knowles routinely monitors world wide material restrictions (e.g. EU/China and Korea RoHS mandates) and is actively involved in shaping future legislation.

All standard C0G/NP0, X7R, X5R and High Q Knowles MLCC products are compliant with the EU RoHS directive (see below for special exceptions) and those with plated terminations are suitable for soldering using common lead free solder alloys (refer to 'Soldering Information' for more details on soldering limitations). Compliance with the EU RoHS directive automatically signifies compliance with some other legislation (e.g. China and Korea RoHS). Please refer to the Knowles Capacitors Sales Office for details of compliance with other materials legislation.

Breakdown of material content, SGS analysis reports and tin whisker test results are available on request.

Most Knowles MLCC components are available with non RoHS compliant tin lead (SnPb) solderable termination finish for exempt applications and where pure tin is not acceptable. Other tin free termination finishes may also be available – please refer to the Knowles Capacitors Sales Office for further details.

Radial components have tin plated leads as standard but tin/lead is available as a special option. Please refer to the radial section of the catalogue for further details.

X8R ranges <250Vdc are not RoHS 2011/65/EU compliant. Check the website, www.knowlescapacitors.com for latest RoHS update.

Export controls and dual-use regulations

Certain Knowles catalogue components are defined as 'dual-use' items under international export controls - those that can be used for civil or military purposes which meet certain specified technical standards.

The defining criteria for a dual use component with respect to Knowles Capacitor products is one with a voltage rating of >750Vdc and a capacitance value of >250nF when measured at 750Vdc and a series inductance <10nH. Components defined as dual-use under the above criteria may require a licence for export across international borders. Please contact the Sales Office for further information on specific part numbers.

Explanation of Ageing of MLC

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 values
Ultra Stable C0G/NP0	Negligible capacitance loss through ageing
Stable X7R	<2% per decade of time

Capacitance measurements

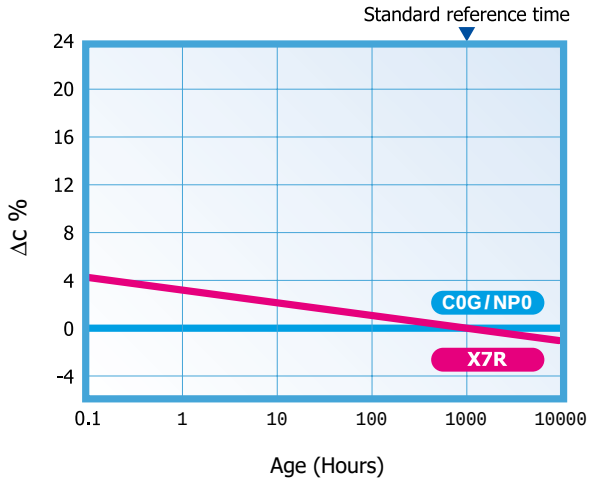
Because of ageing it is necessary to specify an age for reference measurements at which the capacitance shall be within the prescribed tolerance. This is fixed at 1000 hours, since for practical purposes there is not much further loss of capacitance after this time.

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 X7R @ <2% per decade)



Tight tolerance

One of the advantages of Knowles' unique 'wet process' of manufacture is the ability to offer capacitors with exceptionally tight capacitance tolerances.

The accuracy of the printing screens used in the fully automated, computer controlled manufacturing process allows for tolerance as close as +/-1% on C0G/NP0 parts greater than or equal to 10pF. For capacitance values below <4.7pF, tolerances can be as tight as +/-0.05pF.