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The use of Knowles HiT range Multilayer Ceramic Capacitors from 160ºC to 250°C

Knowles Industry standard Multilayer Ceramic Capacitors are approved for use at temperatures up to 125°C and Knowles X8R Multilayer Ceramic Capacitors up to 150°C.
*This application note provides information on Knowles **Hi**gh **T**emperature **HiT** range products which are approved for use at elevated temperatures of up to 250ºC.*

Introduction

The HiT range of multilayer ceramic capacitors are manufactured to exacting standards using our unique screen printing process which provides a high quality component suitable for a variety of high temperature demanding applications including: oil exploration, geothermal, military, automotive under-hood and avionics.

Knowles Industry standard Multilayer Ceramic Capacitors and X8R products are rated over the temperature range of -55ºC to +150ºC as shown below:

Dielectric Classification	Lower Temperature	Upper Temperature	Maximum Cap Change
C0G/NP0 (1B)	-55˚C	+125˚C	±30ppm/ºC
X7R (2R1)	-55˚C	+125˚C	±15%
X8R	-55˚C	+150˚C	±15%

However extensive component testing of the C0G/NP0 (1B) and X7R (2R1) dielectric materials has shown it to be reliable at 200°C and 250°C. However it should be noted that although parts will function reliably at temperatures up to 250°C the electrical properties will not meet the normal C0G/NP0 (1B) or X7R (2R1) specifications at these elevated temperatures.

Background

The reliability of multilayer ceramic capacitors is a function of the voltage and temperature applied. The application of higher than rated voltages and maximum operating temperatures over a period of time is known as accelerated testing. The acceleration factor is calculated using the formula in Figure A.

Figure A

$$Acceleration\ Factor\ (AF) = AF_{voltage} \times AF_{temperature}$$

$$Acceleration\ Factor_{voltage} = \left[\frac{V_{stress}}{V_{use}}\right]^{2.7}$$

Where

$$Acceleration\ Factor_{temperature} = e^{\left(\frac{E_a}{k}\left[\frac{1}{T_{use}} - \frac{1}{T_{stress}}\right]\right)}$$

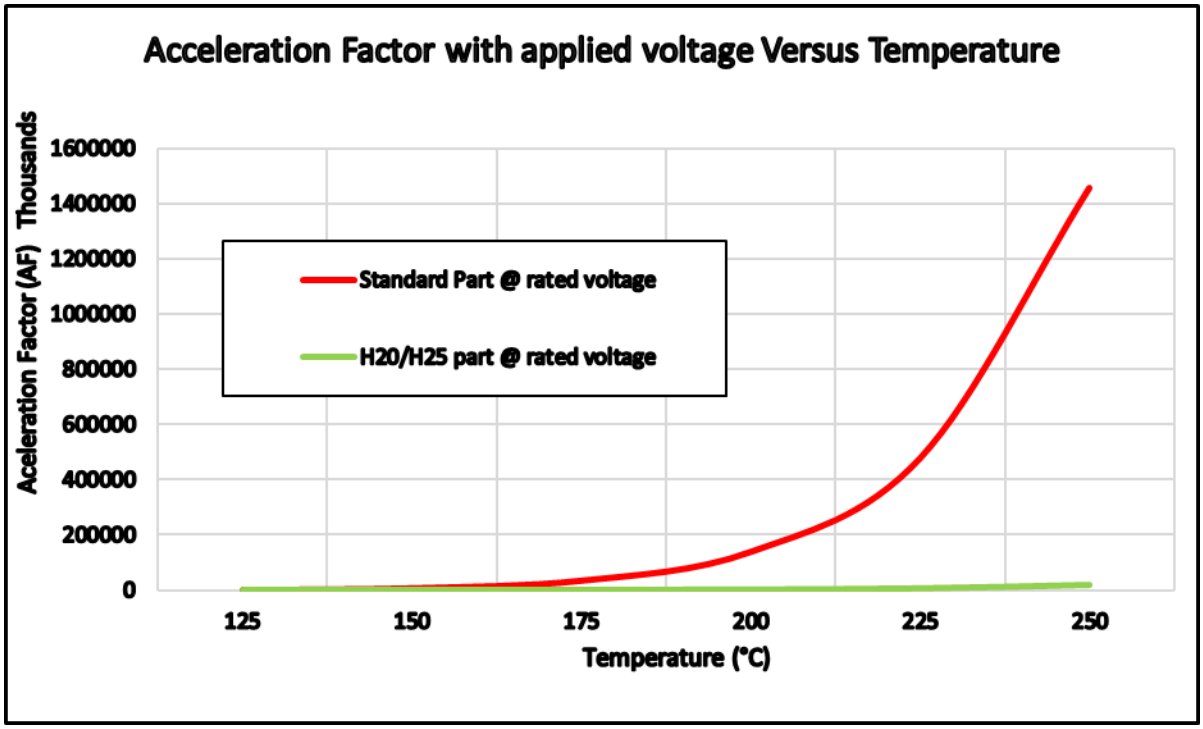
Thus taking the temperature acceleration factor alone the effect on Multilayer Ceramic Capacitors when taken above standard X7R (2C1) and C0G (B1) maximum operating temperature of 125°C can be calculated and is shown in Table A.

Table A

Stress Temperature	125˚C	150˚C	175˚C	200˚C	225˚C	250˚C
Acceleration Factor Temperature	17.6K	98.5K	455K	1.79M	6.12M	18.6M

You can see that the Thermal stress applied at 200°C and 250°C is considerably higher than it is at 125°C. Thus when the voltage stress is also applied as per Figure A, the Total Acceleration Factor (AF) is increased again as shown by the "Standard part @ rated voltage" line in Figure B.

Figure B



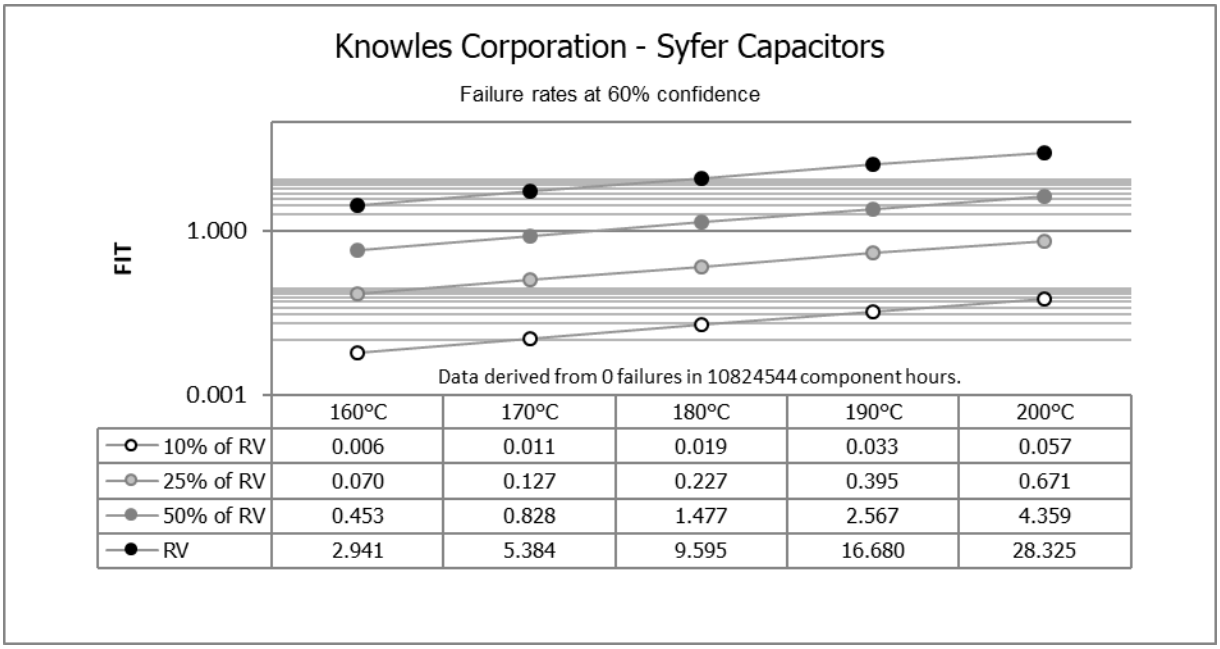
Component Testing

Knowles has undertaken extensive testing of standard components made from each dielectric material type used in the manufacture of multilayer chip capacitors. The basic electrical properties of Knowles components at high temperatures are exhibited graphically in the "Basic Electrical Properties at High Temperatures" section of this document.

These robust standard higher voltage designs have been de-rated and then undergone testing at either 200°C or 250°C with accelerated voltages above the High temperature de-rated voltage as per Knowles Reliability requirements. This component test data has allowed Knowles to set a range of parts with rated voltages at temperature.

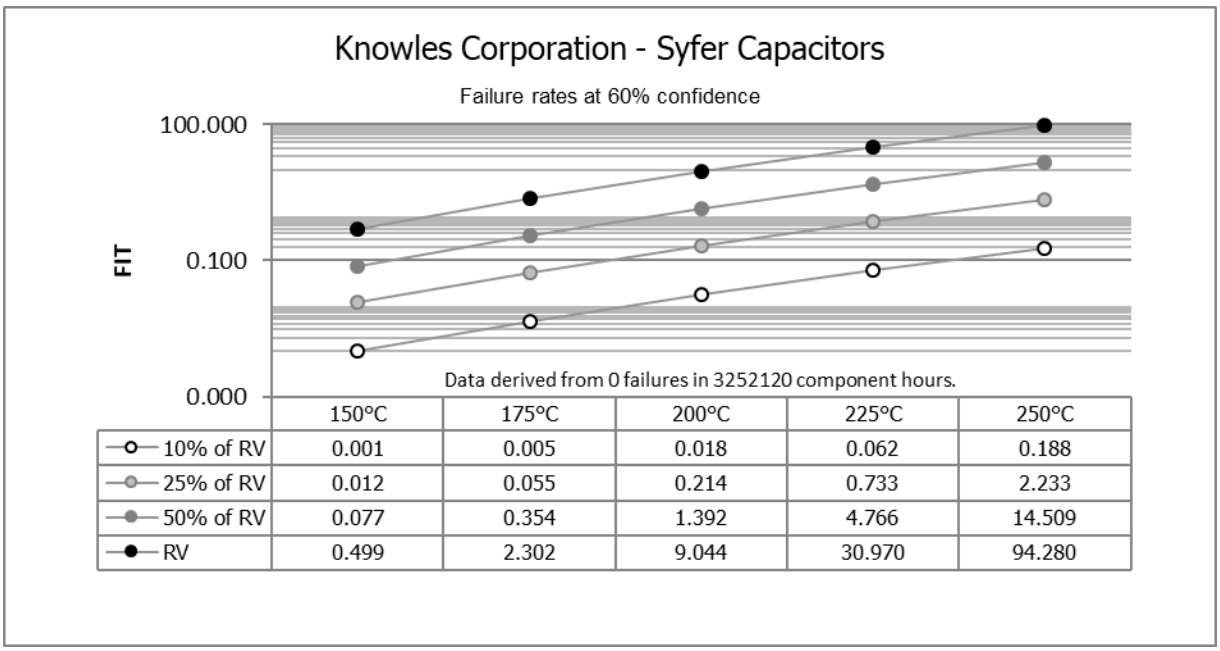
Reliability data is shown below;

FIT curves for HiT (200°C) Range



	160°C	170°C	180°C	190°C	200°C
10% of RV	0.006	0.011	0.019	0.033	0.057
25% of RV	0.070	0.127	0.227	0.395	0.671
50% of RV	0.453	0.828	1.477	2.567	4.359
RV	2.941	5.384	9.595	16.680	28.325

FIT curves for HiT250 (250°C) Range



	150°C	175°C	200°C	225°C	250°C
10% of RV	0.001	0.005	0.018	0.062	0.188
25% of RV	0.012	0.055	0.214	0.733	2.233
50% of RV	0.077	0.354	1.392	4.766	14.509
RV	0.499	2.302	9.044	30.970	94.280

The FIT (**F**ailure **I**n **T**ime) rate graph provides an indication of component reliability in relation to a customer's application with respect to temperature and voltage being applied. For example, at 160ºC and 50%RV (200°C Rated Voltage range), the FIT rate graph indicates 0.077 FITs.
As a comparison, an automotive customer specifies maximum of 0.1 FITs at 25ºC and 50%RV (125°C Rated Voltage range).

Failure Rates at the Specified Confidence Level (60%) are derived from:

$$FR = \frac{X^2}{2} \times \frac{1}{AF \times H}$$

Where; FR = Estimated Failure Rate at Use Stress

X^2 = Chi Square calculated for number of rejects at test stress

H = Component test hours

Conversion Factors

From	To	Operation
FITS	MTBF (Hours)	$10^9 \div$ FITS
FITS	MTBF (Years)	$10^9 \div$ (FITS $\times$ 8760)

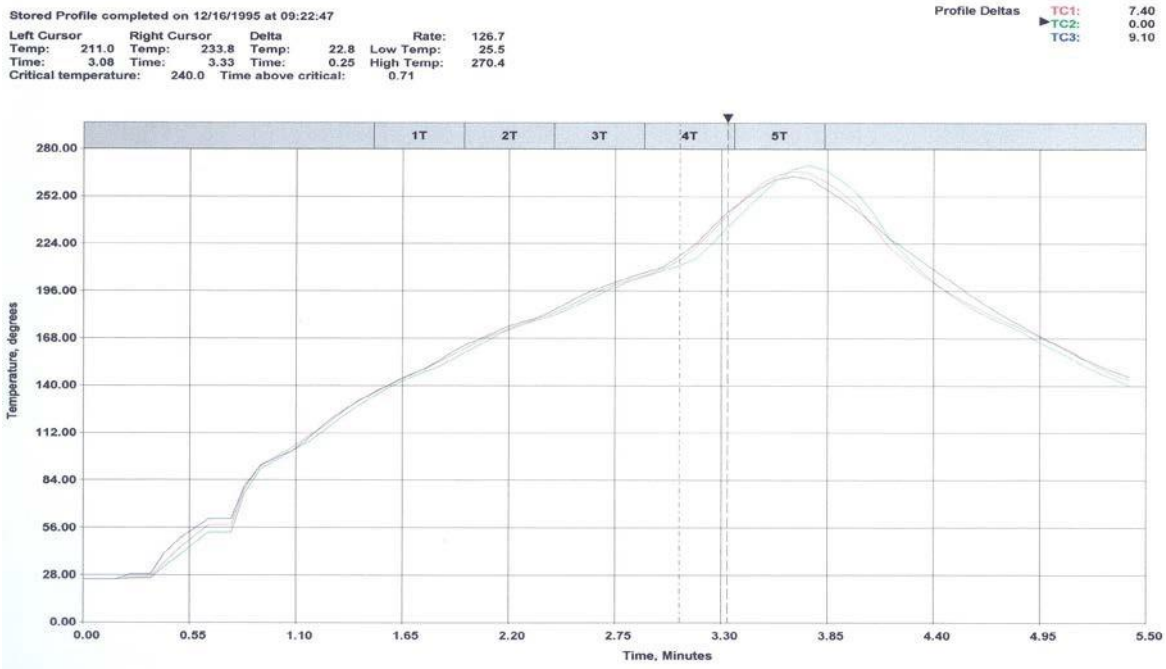
Thermal stress is sufficient to cause electrical failure. Thermal breakdown takes place when heat is generated in the dielectric at a higher rate than it can be conducted away. This leads to increased conductivity, more heat generation and eventually to instability in the form of an uncontrolled, often very rapid temperature rise. The temperatures attained when a capacitor discharges through a region of localised thermal runaway can be high enough to melt the dielectric material.

Component attachment

Termination Syfer	Termination Novcap	Description	Max. Operating Temp	Solder type for attachment
J	N	Standard Nickel with Tin	200°C	SAC or similar Pb free alloy
G	NG	Standard Nickel with Gold	250°C	HMP

All parts in the HiT and HiT250 ranges are offered with solderable plated finishes, combined with Nickel undercoat, making them suitable for use with all conventional reflow soldering operations using Pb free and Pb containing soldering alloys

HiT range parts for operation at 200ºC are commonly soldered using Pb free alloys such as SnAgCu, SnAg or SnSb. For the purposes of component qualification testing, parts were soldered using SAC305 solder, using a standard Pb free soldering profile, similar to that defined in J-STD-020 and as per the typical measured profile reproduced below.



Other solder alloys may be suitable as well, but we recommend a proper evaluation is conducted to confirm there are no compatibility problems.

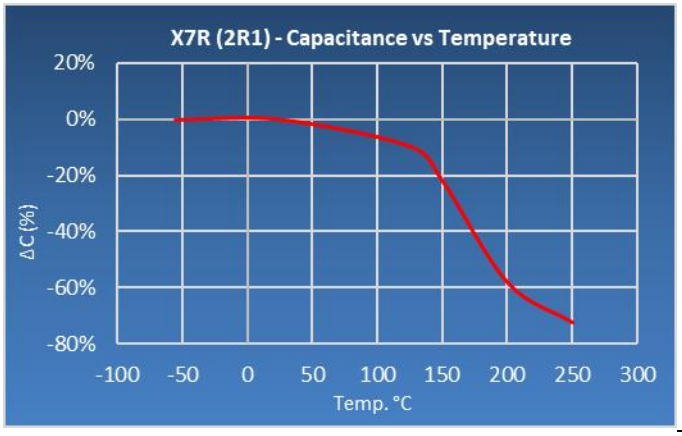
HiT250 range parts for operation at up to 250ºC are commonly soldered using High Melting Point solder alloys, typically PbSnAg and typically having melting points in the 285ºC to 310ºC range. Approval testing was conducted using Pb92.5Sn5Ag2.5. Note that there is some indication that Sn10 (88Pb10Sn2Ag) solder can form localised areas of the SnPbAg eutectic. Some solder manufacturers do not recommend it for use at temperatures above 125ºC because of this – we recommend you consult your own supplier for advice.

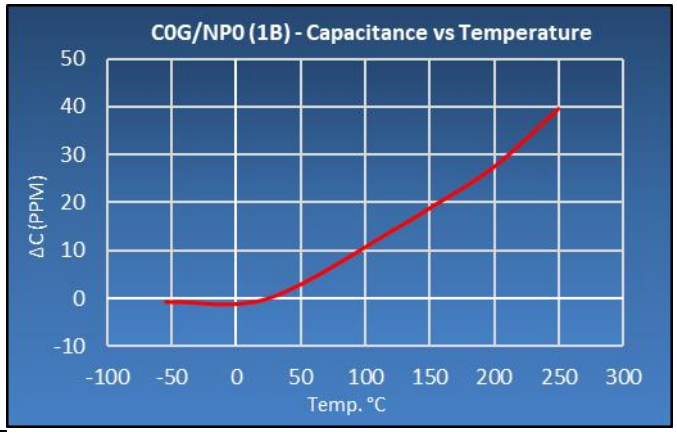
To avoid issues with doping of the HMP solder joint with Sn from a component plating finish, these parts are supplied with Au plated terminations.

HiT250 parts are typically soldered using convection or direct contact hot-plate soldering. The use of inert gas is common to prevent oxidisation issues. Approval testing used parts mounted to substrates using a direct contact hot plate method, with inert nitrogen atmosphere.

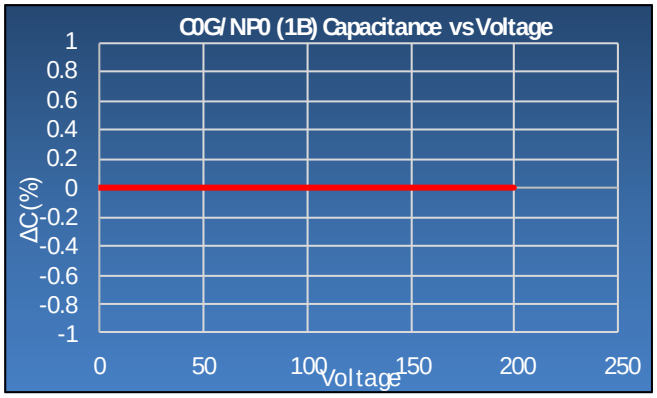
As with any MLCC, due care to avoid thermal shocks such as may induce cracks to the ceramic body of the capacitor should be avoided. We always recommend trials are conducted and that a proper evaluation is conducted to confirm the desired assembly process is compatible with the component.

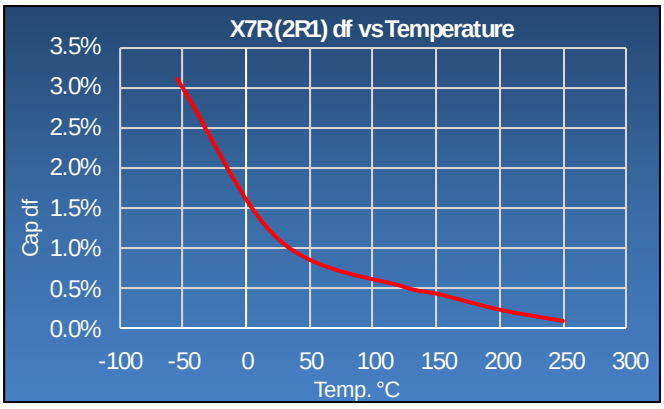
Basic Electrical Properties at High Temperatures

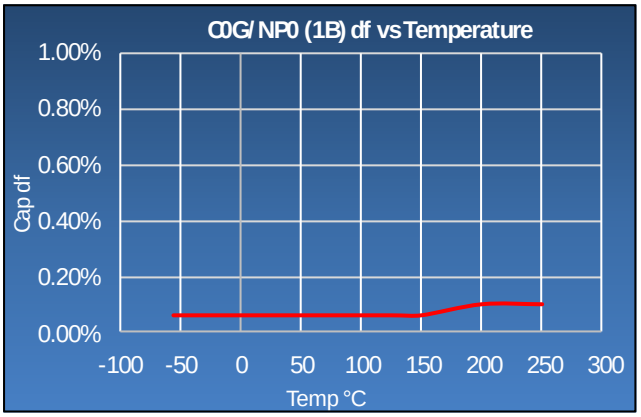




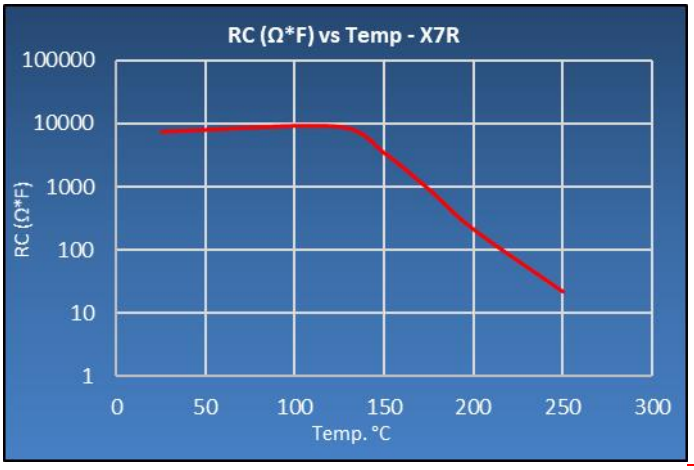
Note:
VCC performance of X7R (1B) parts is design specific.
Consult factory for more information.

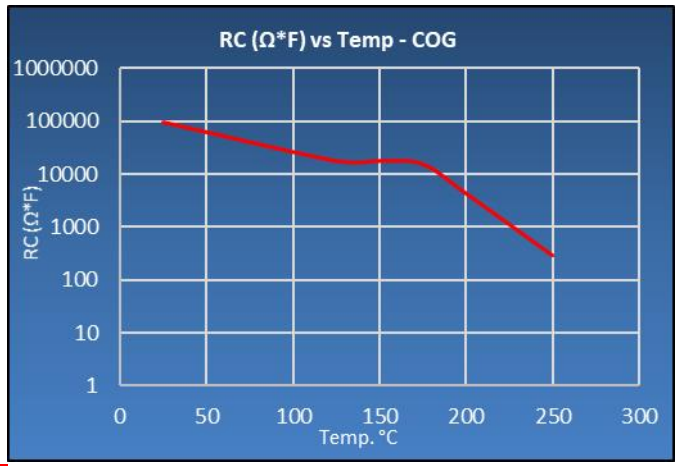




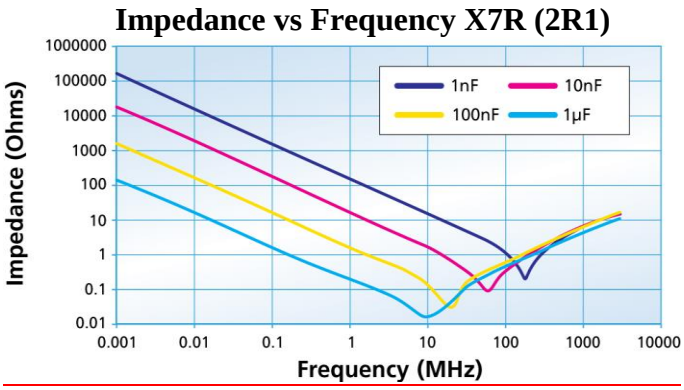


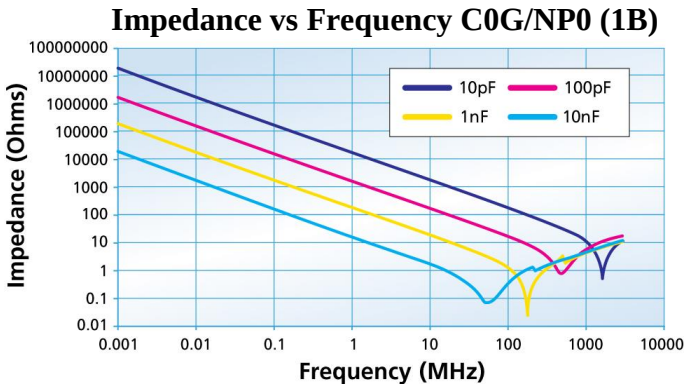
Note: 200°C C0G/NP0 (1B) parts life tested at maximum rated voltage and temperature for 4000Hr duration.

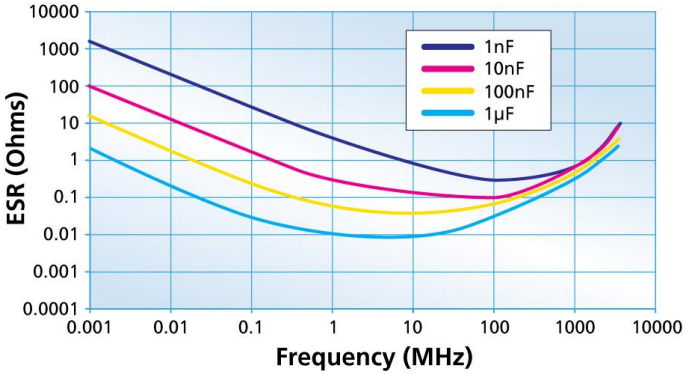


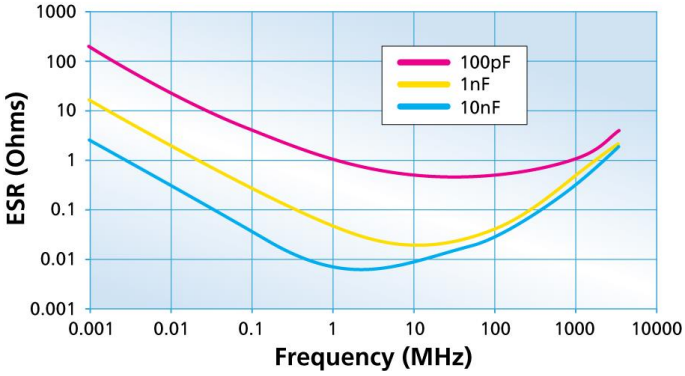


Frequency Graphs









Note: Data is typical only and does not constitute a specification. Knowles Precision Devices reserves the right to modify or substitute with equivalent parts that meet or exceed the specification.

Component selection

All HiT and HiT250 parts are both RoHs and Reach compliant, with the maximum rated voltage at temperature as shown in the Range of maximum capacitance values.

Knowles Range of High Temperature capacitors

When determining whether a particular component is suitable for use at high temperatures, customers must consider the thermal stress, and the effect of the elevated temperature on basic electrical properties such as capacitance, dissipation factor and insulation resistance.

The full range of Knowles components can be found at www.knowlescapacitors.com