J. CLASSES OF DIELECTRICS

Dielectric formulations are identified and classified in the industry by the capacitance temperature coefficient of materials. Two basic groups (Class I and Class II) are used in the manufacture of ceramic chip capacitors. A third (Class III) identifies the reduced barium titanate barrier-layer formulations utilized in the production of disc capacitors.

The temperature coefficients are determined by measurement of the capacitance change at various temperatures from reference room temperature (25°C), using an environmental chamber. The temperature coefficient (T.C.) is expressed as the percent capacitance change (%ΔC) or parts per million per degree C (ppm/°C) change from reference. The T.C. characteristic is usually illustrated graphically over the standard EIA and MIL temperature ranges (-55°C to 85°C, and -55°C to 125°C respectively). The method of calculation of the temperature coefficient is described in Section K-1.

Class I Dielectrics

This group identifies the linear dielectrics described in Section 1. These materials display the most stable characteristics, as they are non-ferroelectric (paraelectric) formulations, based mostly on TiO_2, with dielectric constants under 150. The "extended" temperature compensating ceramics are a subgroup of formulations which utilize small additions of other (ferroelectric) oxides, such as $CaTiO_3$ or $SrTiO_3$ and which display near-linear and predictable temperature characteristics with dielectric constants ranging up to 500. Both categories are used in circuitry requiring stability of the capacitor, i.e. negligible or no aging of the dielectric constant, low loss (DF<.001, or <.002 for the extended T.C. bodies), negligible or no change in capacitance or dielectric loss with voltage or frequency, and predictable linear behavior with temperature within prescribed tolerances.

A letter-number-letter code which defines the temperature coefficients of Class I dielectrics has been developed and is defined in the Electronic Industries Association (EIA) Standard 198, as shown in Table J-1.

The most common Class I dielectric for chip capacitors is the COG designation, i.e. 0 ppm/°C ±30 ppm/°C temperature coefficient, which is the NPO (negative-positive-zero) MIL specification, for flat temperature coefficient.

TABLE J - 1
EIA DESIGNATIONS FOR CLASS I DIELECTRICS

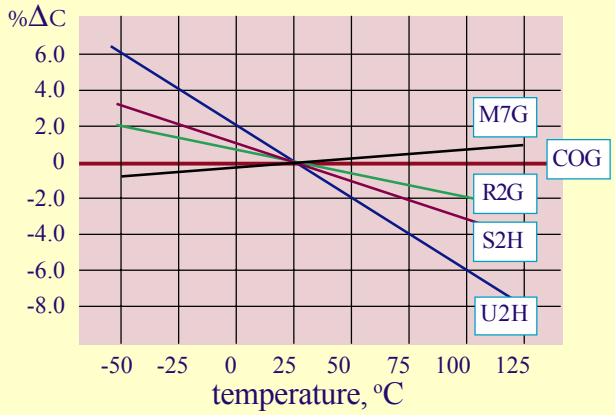
(a) significant figure of temp. coeff. of capacitance (ppm/°C)	(b) letter code for (a)	(c) multiplier applicable to column (a)	(d) numerical codes for column (c)	(e) tolerance of temp. coeff. (ppm/°C)	(f) letter code for column (e)
0.0	C	-1.0	0	30	G
1.0	M	-10	1	60	H
1.5	P	-100	2	120	J
2.2	R	-1000	3	250	K
3.3	S	-10000	4	500	L
4.7	T	+1	5	1000	M
7.5	U	+10	6	2500	N
		+100	7		
		+1000	8		
		+10000	9		

Some examples from Table J-1:

R2G	Negative	220 ppm/°C	±30 ppm/°C	(N220)
S2H	Negative	330 ppm/°C	±60 ppm/°C	(N330)
U2H	Negative	750 ppm/°C	±60 ppm/°C	(N750)
M7G	Positive	100 ppm/°C	±30 ppm/°C	(P100)

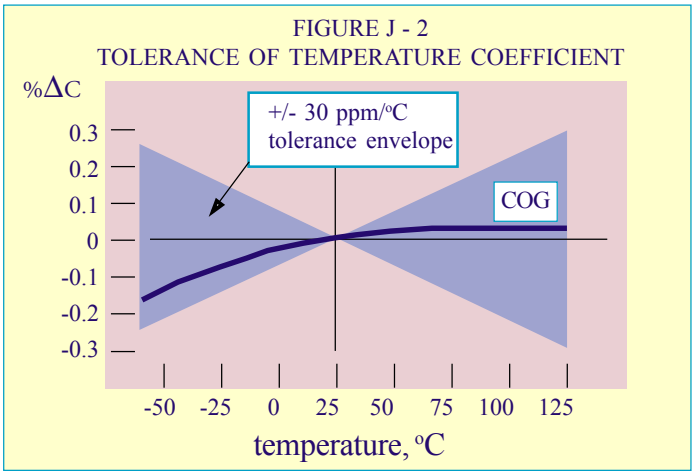
Some of the above examples are illustrated graphically in Figure J-1.

FIGURE J - 1
T. C. OF LINEAR DIELECTRICS



Actual measurements of temperature coefficient may not necessarily be perfectly linear, but are acceptable if the data fall within the permissible tolerance limits specified by the last letter of the EIA code, as illustrated for COG dielectric in Figure J-2.

FIGURE J - 2
TOLERANCE OF TEMPERATURE COEFFICIENT



CLASS II DIELECTRICS

Class II dielectrics comprise the ferroelectric formulations described in Section H. These materials offer much higher dielectric constants than Class I dielectrics, but with less stable properties with temperature, voltage, frequency and time. The diverse range of properties of the ferroelectric ceramics requires a subclassification into two categories, defined by the temperature characteristics:

"Stable Mid-K" Class II, which display a maximum temperature coefficient of ±15% from 25°C reference over the temperature range of -55°C to 125°C. These materials typically have dielectric constants in the range of 600 to 4000, and meet EIA X7R characteristics.

"High K" Class II dielectrics, with temperature coefficients exceeding the X7R requirements. High K formulations display dielectric constants from 4000 to 18,000, with very steep temperature coefficients, due to the fact that the Curie Point is shifted towards room temperature for maximization of the dielectric constant.

Table J-2 shows the EIA 198 descriptions for these dielectrics. The most common Mid-K characteristic used in chip capacitor manufacture is the X7R designation (±15% maximum ΔC from -55°C to 125°C). In the High-K category, the Z5U characteristic (+22% to -56% maximum ΔC from +10°C to +85°C) and Y5V (+22% to - 82% maximum ΔC from -30°C to +85°C) are common.

The military specification for ceramic chip capacitors (MIL-C-55681) also defines the Mid-K stable

TABLE J - 2
EIA DESIGNATIONS FOR CLASS II DIELECTRICS

(a) low temperature requirement	(b) letter code for (a)	(c) high temp. requirement	(d) numerical codes for column (c)	(e) Max. (+/-)%ΔC over temp.	(f) letter code for column (e)
+10	Z	+45	2	1.0	A
-30	Y	+65	4	1.5	B
-55	X	+85	5	2.2	C
		+105	6	3.3	D
		+125	7	4.7	E
				7.5	F
				10.0	P
				15.0	R
				22.0	S
				+22-33	T
				+22-56	U
				+22-82	V

dielectric and is designated as “BX” characteristic. The BX specification has voltage temperature limits in addition to the standard temperature limits discussed previously. BX dielectric is limited to a ±15% maximum capacitance change from -55˚C to 125˚C, and to a +15% -25% maximum change with working voltage applied. In effect, the BX characteristic is similar to the X7R designation, with the added condition that the voltage coefficient and temperature coefficient combined do not exceed +15% -25%ΔC. Typical Class II T.C. curves are shown in Figure J-3.

FIGURE J - 3
T. C. OF CLASS II DIELECTRICS