Piezoceramic Materials

General Description

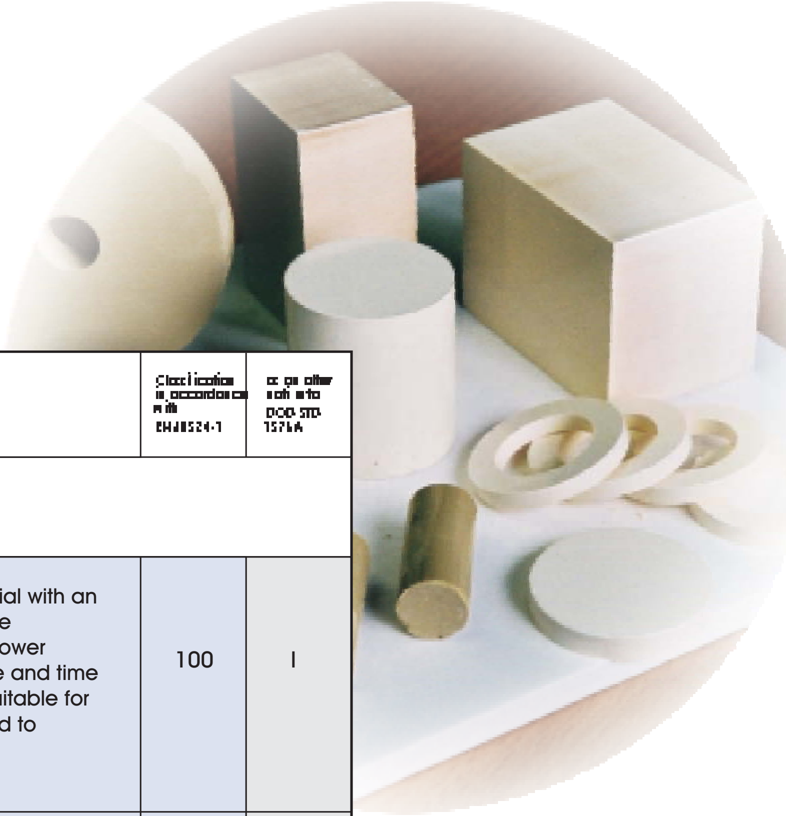
PI Ceramic offers a wide selection of piezoelectric ceramic materials based on modified lead zirconate titanate (PZT) and barium titanate, tailor-made for diverse applications. Apart from the standard types described in detail below, we can perform a multitude of application-specific and custom-engineered modifications. PIC materials compare favorably with the best materials internationally available today. The properties are specified according to the EN 50324 European Standard.

On an international basis, it is usual to divide piezo ceramics into two groups. The antonyms “soft” and “hard” PZT ceramics refer to the ferro-electric properties, i.e. the mobility of the dipoles or domains and hence also to the polarization / depolarization behavior.

“Soft” piezo ceramics are characterized by a comparitively high domain mobility and a resulting “ferroelectrically soft” behavior, i.e. relatively easy polarization.

In contrast, ferroelectrically “hard” PZT materials can be subjected to high electrical and mechanical stresses. The stability of their properties destines them for high-power applications.

Material designation	General description of the material properties	Classification in accordance with EN 50324-1	Corresponds to DOD STD 1376A
	"Soft" PZT		
PIC 151	PIC 151 is a modified lead zirconate - lead titanate material with high permittivity, high coupling factor and high piezoelectric charge constant. This material is the standard material for actuators (PICA Series) and suitable for low-power ultrasonic transducers and low-frequency sound transducers.	600	II
PIC 255	PIC 255 is a modified PZT material with extremely high Curie temperature, high permittivity, high coupling factor and high charge constant. The material has been optimized for actuator applications under dynamic conditions and high ambient temperatures. The high coupling factor, low mechanical quality factor and low temperature coefficient make this material particularly suitable for low-power ultrasonic transducers, nonresonant broadband systems, and for force and acoustic pickups.	200	II
PIC 155	PIC 155 is a modification of the PIC 255 material distinguished by high piezoelectric stress coefficients and lower frequency constants. It is used in applications where a high g-constant is required, such as in microphones and vibration pickups with preamplifier.	200	II
PIC 153	PIC 153 is a modified lead zirconate - lead titanate material with extremely high permittivity and coupling factors, a high charge constant, and a Curie temperature of around 185 °C. This material is suitable for hydrophones, transducers in medical diagnostics and PZT translators.	600	VI
PIC 152	PIC 152 is a PZT material whose permittivity has an especially low temperature coefficient.	200	II



Material Designation	General description of the material properties	Classification in accordance with EN 50324-1	according to DOD-STD 1376A
"Hard" PZT			
PIC 181	PIC 181 is a modified lead zirconate - lead titanate material with an extremely high mechanical quality factor and a high Curie temperature. This material is destined for the use in high-power acoustic applications. Furthermore, the good temperature and time stability of its dielectric and elasticity constants makes it suitable for resonance-mode ultrasonic applications and it has proved to be particularly successful in piezomotor drives.	100	I
PIC 141	PIC 141 is a modified PZT material with high a mechanical quality factor and a comparatively moderate permittivity. This material is designed for use in high-power acoustic applications and is also used for pharmaceutical atomizers.	100	I
PIC 241	PIC 241 PZT ceramic is distinguished by its high mechanical quality factor and comparatively high permittivity. Its fields of application lie in high-power ultrasonic devices and it is used for piezomotor drives.	100	I
PIC 300	PIC 300 is a modified lead zirconate - lead titanate material with a very high Curie temperature. It is suitable for applications at temperatures up to 250°C (300°C for short durations).	100	I
Barium lead titanate			
PIC 110	PIC 110 is a modified barium titanate material with a Curie temperature of 150°C. Its low acoustic impedance makes this material especially suitable for sonar and hydrophonic applications.	400	IV

Material Data

Material type			PIC 151	PIC 255	PIC 155	PIC 153	PIC 152
Parameter							
Physical and dielectric properties							
Density	ρ	(g/cm³)	7.80	7.80	7.80	7.60	7.70
Curie temperature	Tc	(°C)	250	350	345	185	340
Permittivity in the polarization direction	$\varepsilon_{33}^{T} / \varepsilon_0$		2400	1750	1450	4200	1350
perpendicular to the polarity	ε ε		1980	1650	1400		
Dielectric loss factor	tanδ		20	20	20	30	15
Electromechanical properties							
Coupling factors	k_p		0.62	0.62	0.62	0.62	0.48
	k_t		0.53	0.47	0.48		
	k_{31}		0.38	0.35	0.35		
	k_{33}		0.69	0.69	0.69		0.58
	k_{15}			0.66			
Piezoelectric charge constants	d_{31}	(10^{-12} C/N)	-210	-180	-165		
	d_{33}		500	400	360	600	300
	d_{15}			550			
Piezoelectric voltage constants	g_{31}	(10^{-3} Vm/N)	-11.5	-11.3	-12.9		
	g_{33}		22	25	27	16	25
Acousto-mechanical properties							
Frequency constants	N_p	(Hzm)	1950	2000	1960	1960	2250
	N_1		1500	1420	1500		
	N_3		1750		1780		
	N_t		1950	2000	1990	1960	1920
Elastic constants (compliance)	S_{11}^{E}	(10^{-12} m²/N)	15.0	16.1	15.6		
	S_{33}^{E}		19.0	20.7	19.7		
Elastic constants (stiffness)	C_{33}^{D}	(10^{10} N/m²)	10.0		11.1		
Mechanical quality factor	Qm		100	80	80	50	100
Temperature stability							
Temperature coefficient of ε_{33} (in the range -20°C up to +125°C)	TK ε_{33}	($x10^{-3}$/K)	6	4	6	5	2
Aging stability (relative change of the parameter per decade in %)							
Relative dielectric constant	C	(%)		-1.0	-2.0		
Coupling factor	C_K			-1.0	-2.0		

Further information:

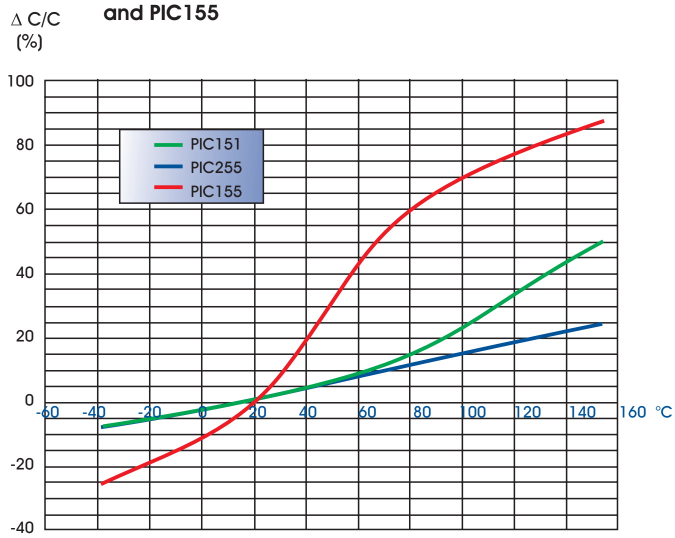
The following values are valid approximations for all PZT materials from PI Ceramic.

Specific heat capacity HC = approx. 350 J / kg K
Specific thermal conductivity TC = approx. 1.1 W / m K
Poisson's ratio σ = approx. 0.34
Coefficient of thermal expansion α_3 = approx. -4 to -6 x 10^{-6} / K (in the polarization direction, shorted)
α_1 = approx. 4 to 8 x 10^{-6} / K $\perp$ to the polarization direction, shorted)
Static compressive strength larger than 600 Mpa

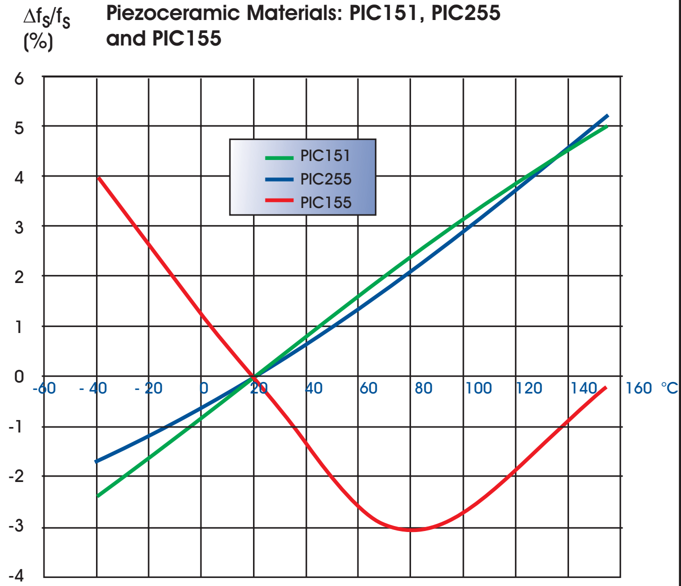
PIC 181	PIC 141	PIC 241	PIC 300	PIC 110
7.80	7.80	7.80	7.80	5.50
330	295	270	370	150
1200	1250	1650	1050	950
1500	1500	1550	950	
3	5	5	3	15
0.56	0.55	0.50	0.48	0.30
0.46	0.48	0.46	0.43	0.42
0.32	0.31	0.32	0.25	0.18
0.66	0.66	0.64	0.46	
0.63	0.67	0.63	0.32	
-120	-140	-130	-80	-50
265	310	290	155	120
475	475	265	155	
-11.2	-13.1	-9.8	-9.5	
25	29	21	16	-11.9
2270	2250	2190	2350	3150
1640	1610	1590	1700	2300
2010	1925	1550	1700	2500
2110	2060	2140	2100	
11.8	12.4	12.6	11.1	
14.2	13.0	14.3	11.8	
16.6	15.8	13.8	16.4	
2000	1500	1200	1400	250
3	5		2	
	-4.0			-5.0
	-2.0			-8.0

1. The data in the following tables was determined using test bodies with geometries and dimensions in accordance with European Standard EN 50324 2, and are typical values.
2. The data given represents nominal values which were determined on these test bodies 24 h - 48 h after polarization and at an ambient temperature of 23 ± 2 °C.
3. Conformance to these typical values is documented by constant testing of the individual material batches before they are released.
4. The properties of the products are determined in relation to the geometry, variations of the manufacturing process and measurement or control conditions.
5. Questions regarding interpretation of the material properties of a product are best clarified with PI Ceramic's specialists.
6. A complete coefficient matrix of the materials is available on request.

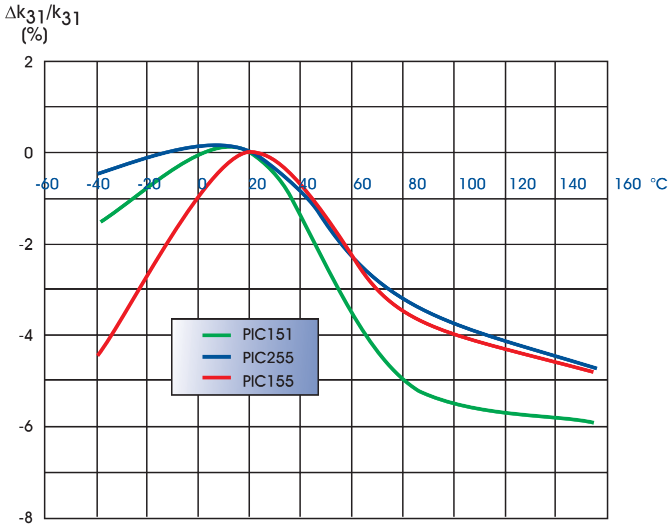
Temperature dependence of capacitance C Piezoceramic Materials: PIC151, PIC255 and PIC155



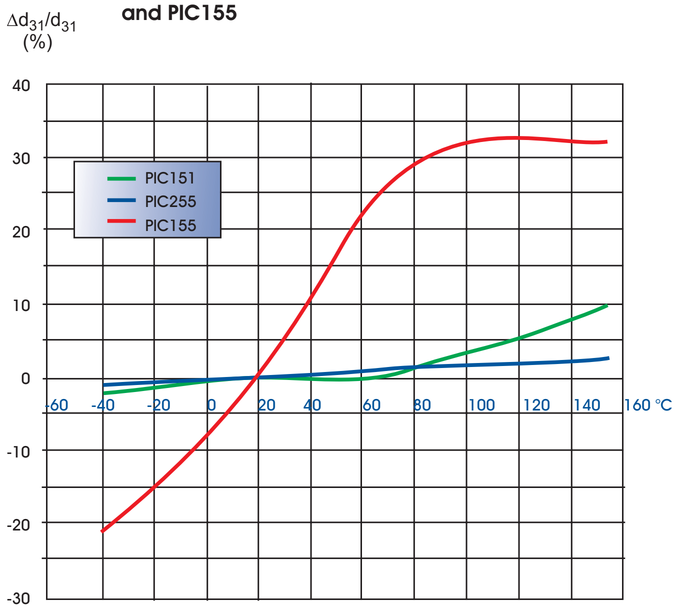
Temperature dependence of resonant frequency for the longitudinal oscillation f_s Piezoceramic Materials: PIC151, PIC255 and PIC155



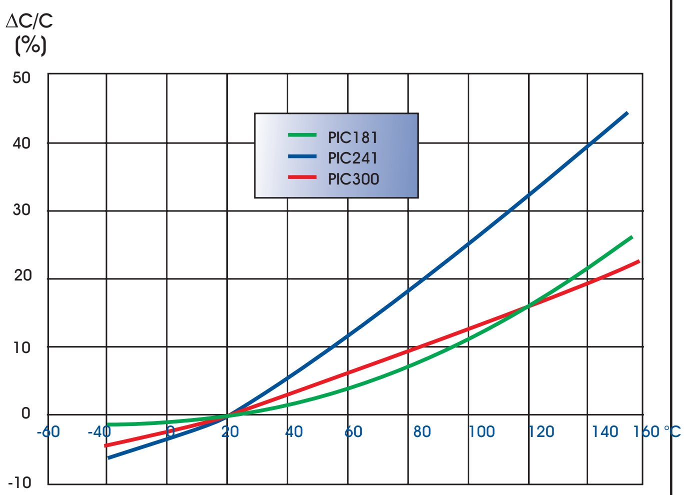
Temperature dependence of transverse oscillation coupling factor k_{31}: Piezoceramic Materials: PIC151, PIC255 and PIC155



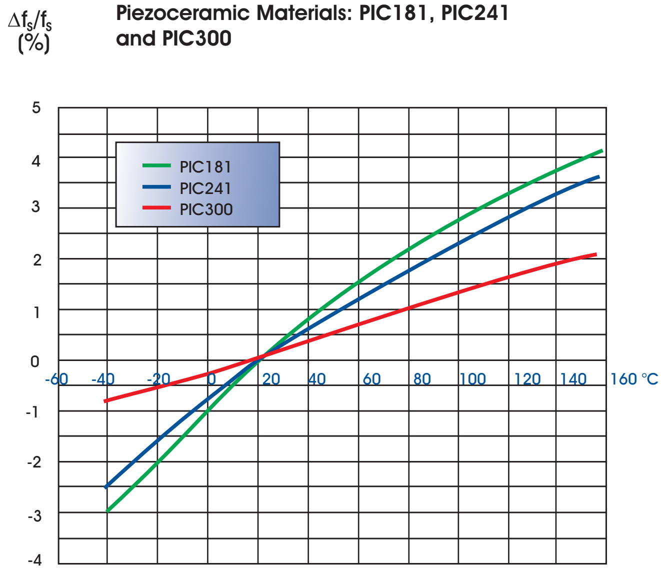
Temperature dependence of the piezoelectric charge constant d_{31}: Piezoceramic Materials: PIC151, PIC255 and PIC155



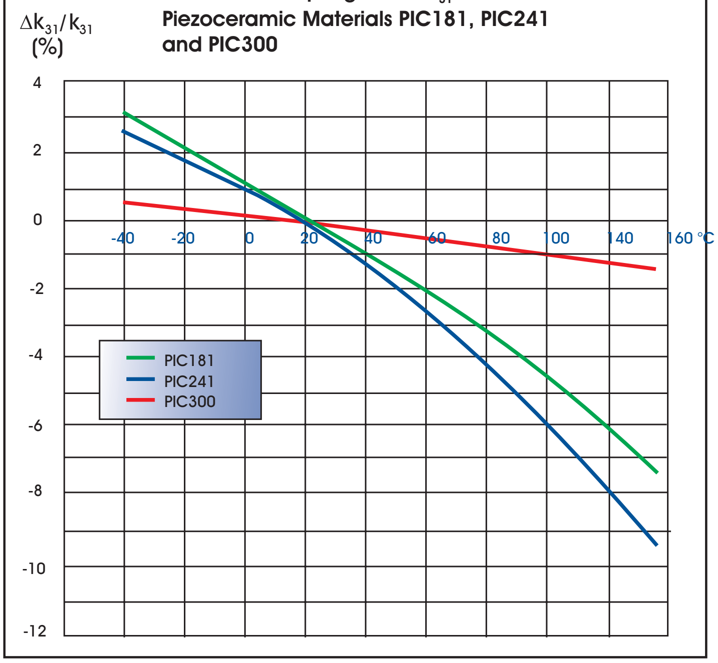
Temperature dependence of capacitance C
Piezoceramic Materials: PIC181, PIC241
and PIC300



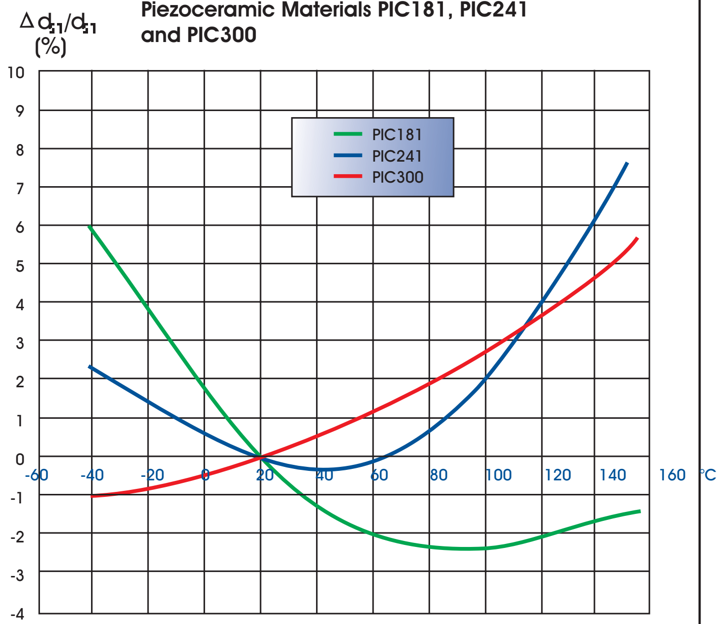
Temperature dependence of resonant frequency
for the longitudinal oscillation f_s
Piezoceramic Materials: PIC181, PIC241
and PIC300



Temperature dependence of transverse
oscillation coupling factor k_{31}:
Piezoceramic Materials PIC181, PIC241
and PIC300



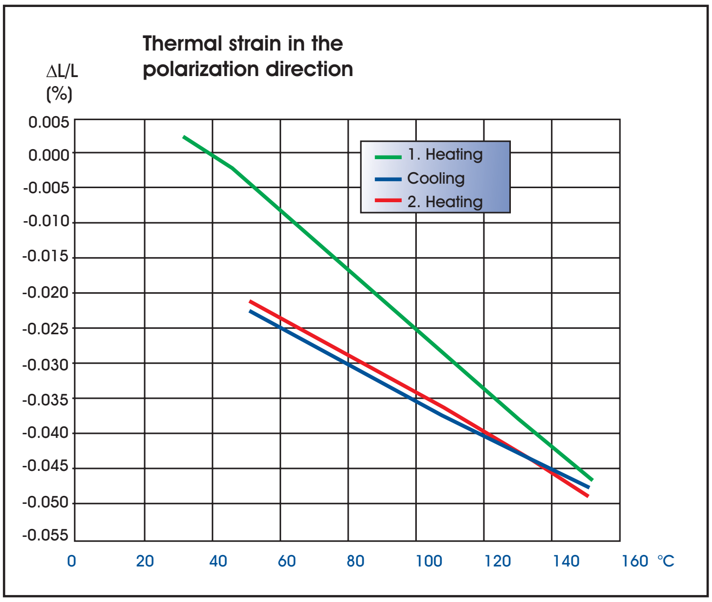
Temperature dependence of the piezoelectric
charge constant d_{31}:
Piezoceramic Materials PIC181, PIC241
and PIC300

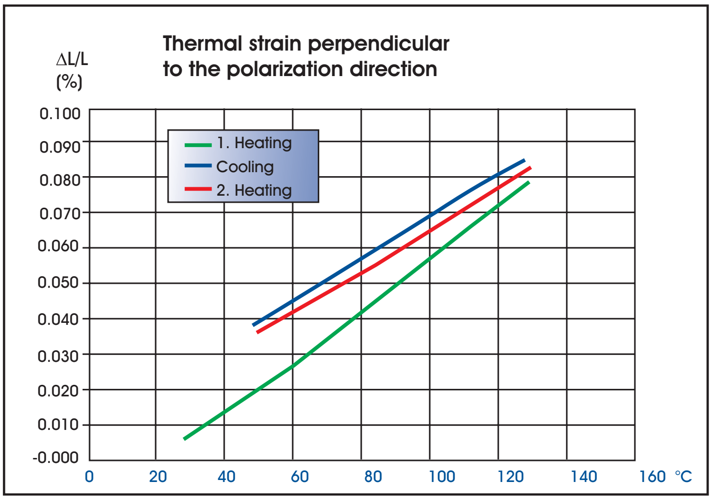


Specific Characteristics

Thermal expansion
example with PZT ceramic PIC 255

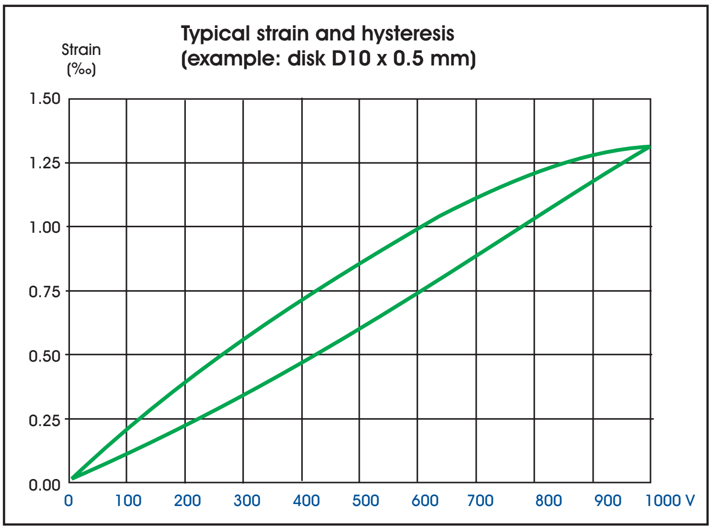
- The thermal strain exhibits different behavior in the polarization direction and perpendicular to it.
- The preferred orientation of the domains in a polarized PZT body leads to an anisotropy. This is the cause of the varying thermal expansion behavior.
- Non-polarized piezo ceramic is isotropic. The coefficient of expansion is approximately linear with a CTE of approx. 2×10^{-6} / K.
- The effect of successive temperature changes must be given particular consideration in the application. Large changes in the curve can occur especially in the first temperature cycle.
- Depending on the material, it is possible that the curves deviate substantially from those illustrated.

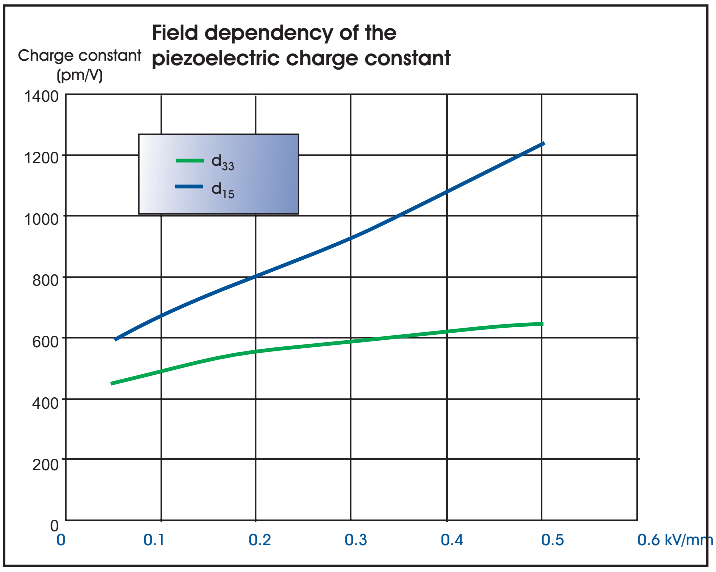




Deformation behavior
example with PZT ceramic PIC 255

- In the case of large-signal fields (max. 2 kV/mm), the strain of a piezoceramic is associated with reversible and irreversible domain reorientation processes.
- The domain reorientations cause larger deformations in the ceramic elements than can be calculated from the piezo coefficients given in the table (small-signal values).
- The irreversible domain reorientations lead to hysteresis in the strain behavior.





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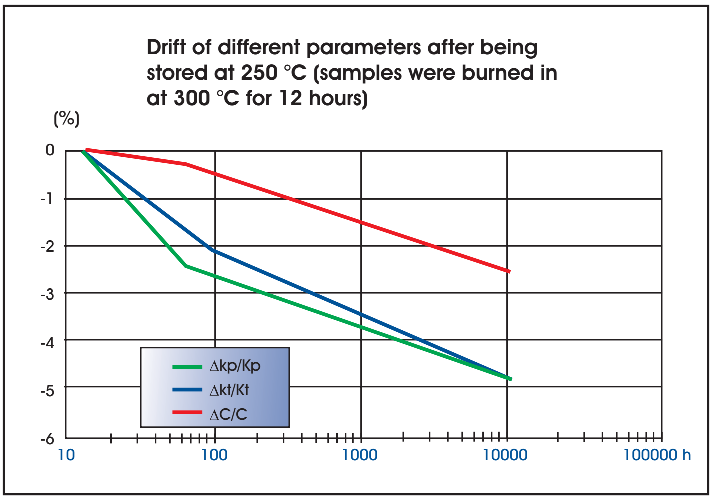
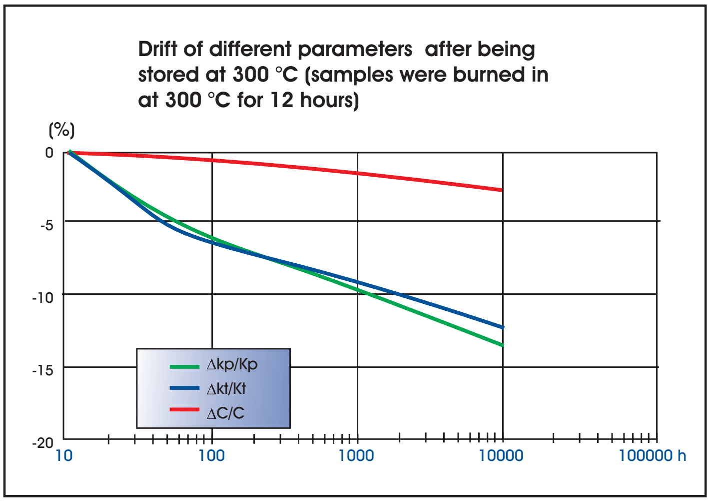
Parameter stability at high temperatures: example with PIC300

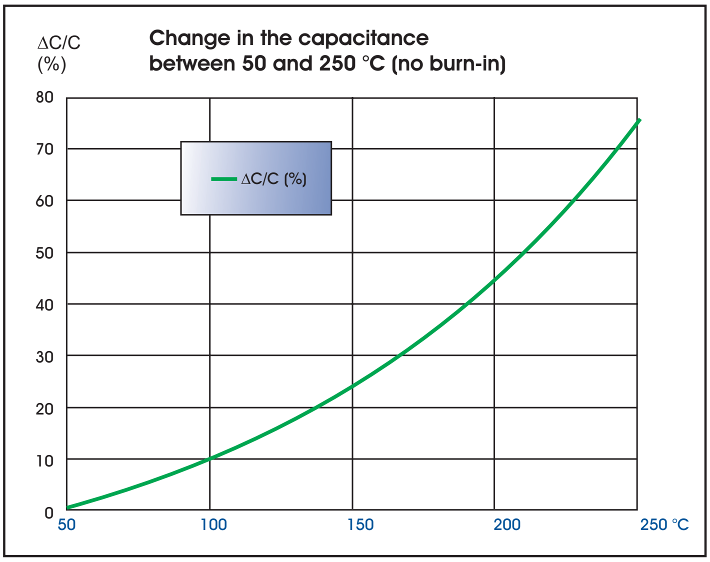
- PIC300 is suitable for use at temperatures up to 250 °C (for short durations, to 300 °C).
- The drift of the measured value for the coupling factor and the capacitance can be significantly reduced by burn-in of over 12 h at 300 °C.
- The expected percentage changes are shown in diagrams A and B.
- PIC300 capacitance exhibits a low temperature dependency in the temperature range up to 250 °C (Diagram C).



A



B



C