Piezo Material Data

SPECIFIC PARAMETERS OF THE STANDARD MATERIALS

				"Soft"				
			Unit	PIC151	PIC255	PIC155	PIC153	PIC152
Physical and dielectric properties								
Density		ρ	g / cm³	7.80	7.80	7.80	7.60	7.70
Curie temperature		T_c	°C	250	350	345	185	340
Relative permittivity	in the polarization	$\varepsilon_{33}^T / \varepsilon_0$		2400	1750	1450	4200	1350
	direction ⊥ to polarity	$\varepsilon_{11}^T / \varepsilon_0$		1980	1650	1400		
Dielectric loss factor		$\tan \delta$	10^{-3}	20	20	20	30	15
Electro-mechanical properties								
Coupling factor		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 voltage coefficient		d_{31}		-210	-180	-165		
		d_{33}	10^{-12} C / N	500	400	360	600	300
		d_{15}			550			
Piezoelectric voltage coefficient		g_{31}	10^{-3} Vm / N	-11.5	-11.3	-12.9		
		g_{33}		22	25	27	16	25
Acousto-mechanical properties								
Frequency coefficients		N_p		1950	2000	1960	1960	2250
of the series resonance frequency		N_1	Hz · m	1500	1420	1500		
		N_3		1750		1780		
		N_t		1950	2000	1990	1960	1920
Elastic compliance coefficient		S_{11}^E	10^{-12} m² / N	15.0	16.1	15.6		
		S_{33}^E		19.0	20.7	19.7		
Elastic stiffness coefficient		C_{33}^D	10^{10} N / m²	10.0		11.1		
Mechanical quality factor		Q_m		100	80	80	50	100
Temperature stability								
Temperature coefficient of ε^T_{33} (in the range -20 °C to +125 °C)		$TK\ \varepsilon_{33}$	10^{-3} / K	6	4	6	5	2
Time stability (relative change of the parameter per decade of time in %)								
Relative permittivity		C_ε	%		-1.0	-2.0		
Coupling factor		C_K			-1.0	-2.0		

	"Hard"					Lead-free materials	
	PIC181	PIC141	PIC241	PIC300	PIC110	PIC050[1]	PIC700[2]
	7.80	7.80	7.80	7.80	5.50	4.7	5.6
	330	295	270	370	150	>500	200[3]
	1200	1250	1650	1050	950	60	700
	1500	1500	1550	950		85	
	3	5	5	3	15	<1	30
	0.56	0.55	0.50	0.48	0.30		0.15
	0.46	0.48	0.46	0.43	0.42		0.40
	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	40	120
	475	475	265	155		80	
	-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		

Recommended operating temperature:
50 % of Curie temperature.

1) Crystalline material
2) Preliminary data, subject to change
3) Maximum operating temperature

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

Specific heat capacity:
WK = approx. 350 J kg^{-1} K^{-1}

Specific thermal conductivity:
WL = approx. 1.1 W m^{-1} K^{-1}

Poisson's ratio (lateral contraction):
σ = approx. 0.34

Coefficient of thermal expansion:
α_3 = approx. -4 bis -6 x 10^{-6} K^{-1}
(in the polarization direction, shorted)
α_1 = approx. 4 bis 8 x 10^{-6} K^{-1}
(perpendicular to the polarization direction, shorted)

Static compressive strength:
larger than 600 MPa

The data was determined using test pieces with the geometric dimensions laid down in EN 50324-2 standard and are typical values.

All data provided was determined 24 h to 48 h after the time of polarization at an ambient temperature of 23±2 °C .

A complete coefficient matrix of the individual materials is available on request. If you have any questions about the interpretation of the material characteristics please contact PI Ceramic (info@piceramic.de).

Material Properties and Classification

Material designation	General description of the material properties "Soft"-PZT	Classification in accordance with EN 50324-1	ML-Standard DOD-STD-1376A
PIC151	**Material:** Modified Lead Zirconate-Lead Titanate **Characteristics:** High permittivity, large coupling factor, high piezoelectric charge coefficient **Suitable for:** Actuators, low-power ultrasonic transducers, low-frequency sound transducers. Standard material for actuators of the PICA series: PICA Stack, PICA Thru	**600**	**II**
PIC255	**Material:** Modified Lead Zirconate-Lead Titanate **Characteristics:** Very high Curie temperature, high permittivity, high coupling factor, high charge coefficient, low mechanical quality factor, low temperature coefficient **Suitable for:** Actuator applications for dynamic operating conditions and high ambient temperatures (PICA Power series), low-power ultrasonic transducers, non-resonant broadband systems, force and acoustic pickups, DuraAct patch transducers, PICA Shear shear actuators	**200**	**II**
PIC155	**Material:** Modified Lead Zirconate-Lead Titanate **Characteristics:** Very high Curie temperature, low mechanical quality factor, low permittivity, high sensitivity (*g* coefficients) **Suitable for:** Applications which require a high *g* coefficient (piezoelectric voltage coefficient),e.g. for microphones and vibration pickups with preamplifier, vibration measurements at low frequencies	**200**	**II**
PIC153	**Material:** Modified Lead Zirconate-Lead Titanate **Characteristics:** extremely high values for permittivity, coupling factor, high charge coefficient, Curie temperature around 185 °C **Suitable for:** Hydrophones, transducers in medical diagnostics, actuators	**600**	**VI**
PIC152	**Material:** Modified Lead Zirconate-Lead Titanate **Characteristics:** Especially low temperature coefficient of permittivity **Suitable for:** Force and acceleration transducers	**200**	**II**

Material designation	General description of the material properties "Hard"-PZT	Classification in accordance with EN 50324-1	ML-Standard DOD-STD-1376A
PIC181	**Material:** Modified Lead Zirconate-Lead Titanate **Characteristics:** Extremely high mechanical quality factor, good temperature and time constancy of the dielectric and elastic values **Suitable for:** High-power acoustic applications, applications in resonance mode	**100**	**I**
PIC141	**Material:** Modified Lead Zirconate-Lead Titanate **Characteristics:** High mechanical quality factor, permittivity between PIC181 and PIC241 (can be exchanged for comparable types) **Suitable for:** High-power acoustic applications, e.g. atomizing pharmaceuticals	**100**	**I**
PIC241	**Material:** Modified Lead Zirconate-Lead Titanate **Characteristics:** High mechanical quality factor, higher permittivity than PIC181 **Suitable for:** High-power acoustic applications, piezomotor drives	**100**	**I**
PIC300	**Material:** Modified Lead Zirconate-Lead Titanate **Characteristics:** Very high Curie temperature **Suitable for:** Use at temperatures up to 250 °C (briefly up to 300 °C).	**100**	**I**

	Barium Lead Titanate		
PIC110	**Material:** Modified Barium Titanate **Characteristics:** Curie temperature 150 °C, low acoustic impedance **Suitable for:** Sonar and hydrophone applications	**400**	**IV**

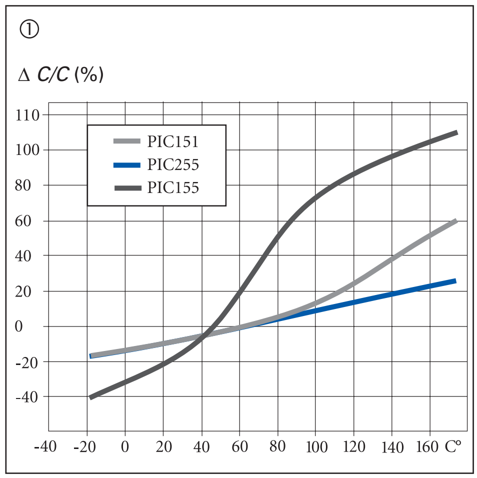
	Lead-Free Materials		
PIC050	**Material:** Spezial crystalline material **Characteristics:** Excellent stability, Curie temperature >500 °C **Suitable for:** High-precision, hysteresis-free positioning in open-loop operation, Picoactuator®		
PIC700	**Material:** Modified Bismuth Sodium Titanate **Characteristics:** Maximum operation temperature 200 °C, low density, high coupling factor of the thickness mode of vibration, low planar coupling factor **Suitable for:** Ultrasonic transducers > 1MHz		

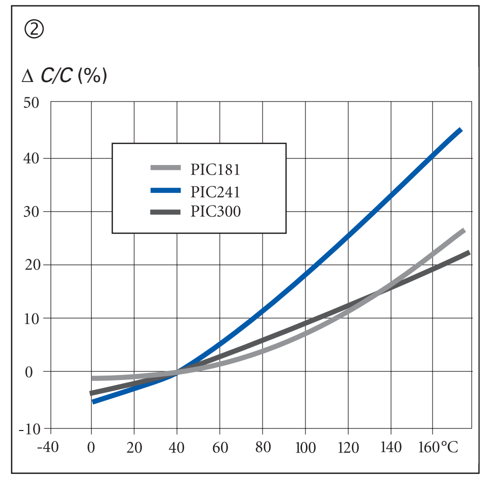
Temperature Dependence of the Coefficients

Temperature curve of the capacitance *C*

① Materials: PIC151, PIC255 and PIC155

② Materials: PIC181, PIC241 and PIC300

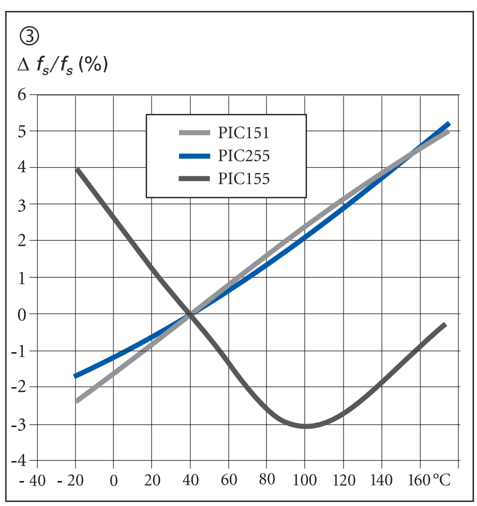


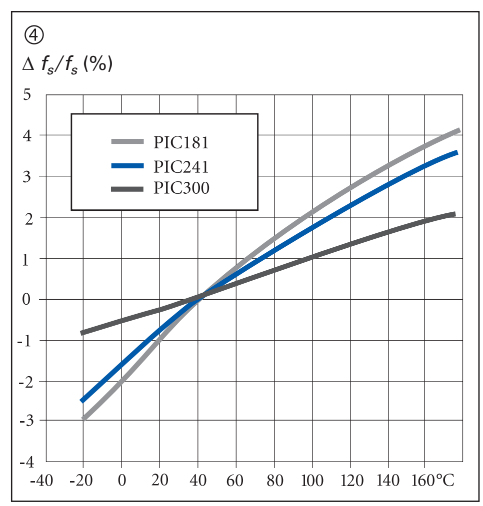


Temperature curve of the resonant frequency of the transverse oscillation f_s

③ Materials: PIC151, PIC255 and PIC155

④ Materials: PIC181, PIC241 and PIC300

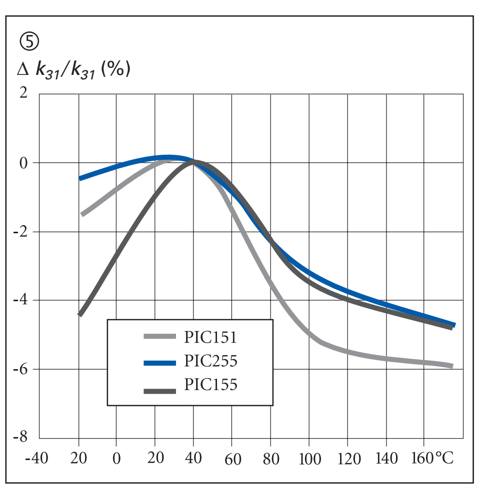


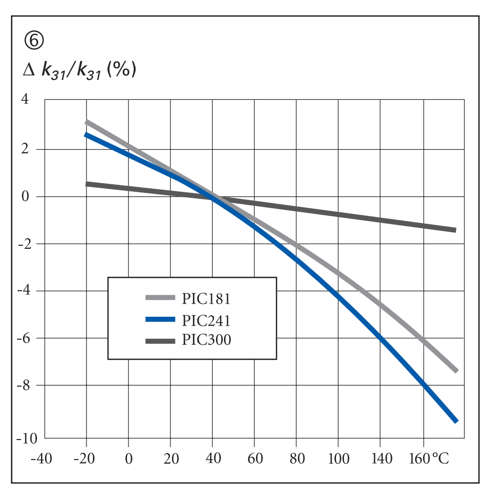


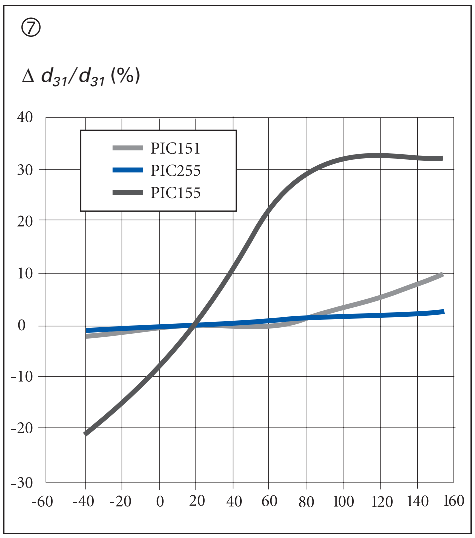
Temperature curve of the coupling factor of the transverse oscillation k_{31}

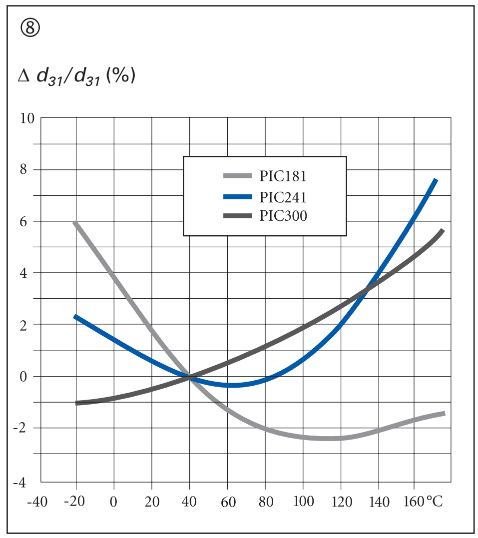
⑤ Materials: PIC151, PIC255 and PIC155

⑥ Materials: PIC181, PIC241 and PIC300









Temperature curve of the piezoelectric charge coefficient d_{31}

⑦ Materials: PIC151, PIC255 and PIC155

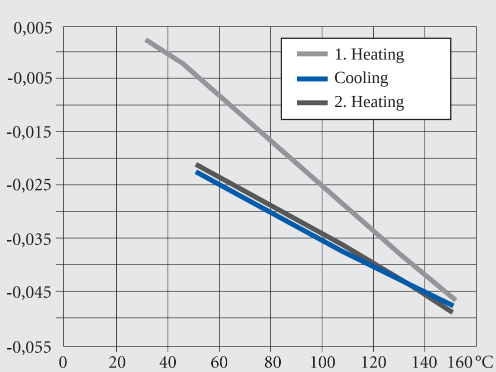
⑧ Materials: PIC181, PIC241 and PIC300

Specific Characteristics

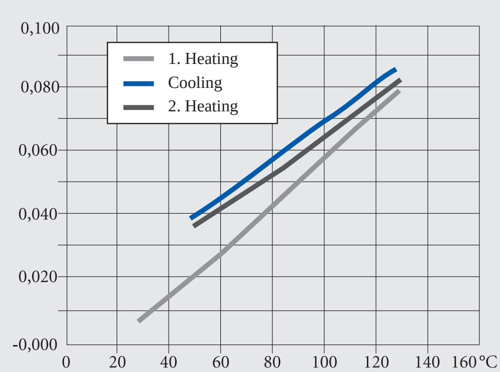
Thermal properties using the example of the PZT ceramic PIC 255

- 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 piezoceramic elements are isotropic. The coefficient of expansion is approximately linear with a TK of approx $2 \cdot 10^{-6}$ / K.
- The effect of successive temperature changes must be heeded particularly in the application. Large changes in the curve can occur particularly in the first temperature cycle.
- Depending on the material, it is possible that the curves deviate strongly from those illustrated.

Thermal strain in the polarization direction
Δ d_{31}/d_{31} (%)



Thermal strain perpendicular to the polarization direction Δ L/L (%)



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