NAVY I TYPE PIEZOELECTRIC CERAMICS

PROPERTY NO OF DAYS AFTER POLING	SYMBOL	UNIT	PZT401 I	PZT402 I	PZT403 I	PZT404 I	PZT405 I	PZT406 I
ELECTRICAL - LOW FIELD								
Relative Permittivity	$\varepsilon^T_{r\,33}$		1470	1200	1350	1450	1450	1325
Relative Permittivity	$\varepsilon^T_{r\,11}$		-	-	1475	-	-	-
Dielectric Loss	tan δ		0.002	0.003	0.003	0.004	0.003	0.0035
Resistivity (at 25°C)	ρ el	Ωm	10^{10}	$>10^{10}$	-	-	-	10^{10}
Resistivity (at 100°C)	ρ el	Ωm	-	$10^{8.5}$	-	-	-	-
Resistivity (at 200°C)	ρ el	Ωm	-	$10^{5.5}$	-	-	-	-
ELECTRICAL - HIGH FIELD								
Increase in $\varepsilon^T_{r\,33}$ @ 2KV/cm		%	5.1	-	-	-	-	-
Dielectric Loss @ 2KV/cm	tan δ		0.01	-	-	-	-	-
Increase in $\varepsilon^T_{r\,33}$ @ 4KV/cm		%	12.7	-	25	-	25	-
Dielectric Loss @ 4KV/cm	tan δ		0.02	-	-	-	-	-
ELECTRO-MECHANICAL								
Coupling Factors	k_p		0.60	0.56	0.58	0.60	0.62	0.61
	k_{15}		0.70	0.71	0.60	-	-	-
	k_{31}		-0.35	-0.33	-0.33	-0.34	-	-0.34
	k_{33}		0.67	0.70	0.68	0.71	-	0.70
	k_t		-	-	-	-	-	-
Charge Constants	d_{33}	x 10^{-12} C/N	315	285	315	315	350	315
or Strain Constants	d_{31}	x 10^{-12} C/N or m/V	-132	-122	-135	-135	-	-130
	d_h	x 10^{-12} C/N	51	41	45	45	-	-
	d_{15}	x 10^{-12} C/N or m/V	511	495	-	-	-	-
Voltage Constants	g_{33}	x 10^{-3} Vm/N	26.8	24.8	26.4	24.6	27.3	27
or Stress Constants	g_{31}	x 10^{-3} Vm/N	-12	-10.6	-10.5	-10.5	-	-11
	g_h	x 10^{-3} Vm/N	2.8	3.7	3.6	3.6	-	-
	g_{15}	x 10^{-3} Vm/N	-	38	-	-	-	-
	$d_h g_h$	x 10^{-15}	143	152	162	162	-	-
Frequency Constants	N_p	Hz.m	2190	2180	2120	2110	2160	2200
	N_l	Hz.m	1636	1650	1515	1515		
	N_3	Hz.m	1576	-	-	-	-	2015
	N_a	Hz.m	-	2060	-	-	-	-
	N_{3t} or N_{33}	Hz.m	-	2000	2000	-	-	-
	N_s	Hz.m	1800	-	-	-	-	-
	Hoop or N_c	Hz.m	1030	1040	990	990	-	-
	N_t	Hz.m	2080	-	-	-	-	-
Compressive Strength		10^6 Pa	-	-	-	-	-	>600
Tensile Strength		10^6 Pa	-	-	-	-	-	80
Quality Factor	Q_m		600	500	600	600	-	750
MECHANICAL								
Compliances	S^E_{33}	x 10^{-12} m²/N	15.6	15.5	16.8	16.8	-	15
	S^E_{11}	x 10^{-12} m²/N	12.7	12.3	13.3	13.3	-	13
	S^E_{12}	x 10^{-12} m²/N	-3.86	-	-	-	-	-
	S^E_{13}	x 10^{-12} m²/N	5.76	-	-	-	-	-
	S^E_{55}	x 10^{-12} m²/N	39.2	-	-	-	-	-
	S^E_{66}	x 10^{-12} m²/N	-	-	-	-	-	-
	S^D_{33}	x 10^{-12} m²/N	7.76	7.9	-	-	-	-
	S^D_{11}	x 10^{-12} m²/N	11.1	10.9	11.8	11.8	-	-
	S^D_{12}	x 10^{-12} m²/N	-5.44	-	-	-	-	-
	S66	x 10^{-12} m²/N	-	-	-	-	-	-
	Y^E_{33}	x 10^{10} N/m²	-	6.6	5.9	5.9	-	-
	Y^E_{11}	x 10^{10} N/m²	-	8.2	7.5	7.5	-	-
	Y^D_{33}	x 10^{10} N/m²	-	12.6	-	-	-	-
	Y^D_{11}	x 10^{10} N/m²	-	9.9	8.5	8.5	-	-
Poisson's Ratio σ			-	0.31	0.31	0.31	-	0.3
Density	ρ	kg/m³	7600	7600	7600	7600	7500	7800
THERMAL DATA								
Curie Temperature	T_c	°C	330	320	320	325	300	325
Approx. Operating Temp.		°C	-	-	200	-	-	-
Specific Heat		J/kg K	-	-	-	-	-	420
Thermal Conductivity		W/m K	-	-	-	-	-	1.2
Young's Modulus	E	Gpa	-	-	-	-	-	-
Internal Friction	Q^{-1}	x 10^{-4}	-	-	-	-	-	-
TIME STABILITY		Relative change per						
Coupling Factor	k_p	time decade %	-1.70	-1.70	-2.10	-2.10		-2.50
Capacitance	C		-4.60	-	-	-	-	-
Permittivity	ε^T_{33}		-	-2.50	-4.60	-4.60	-	-6.00
Frequency	f		1.00	-	-	-	-	-
	d_{33}		-	-3.40	-3.40	-3.40	-	-
Time Constant		Seconds	-	-	-	-	-	-
	N_p		-	+0.8	+1.2	+1.2	-	+1.5

Typical Values measured at 20°C ±1°C are provided for design information only. Standard tolerances are approximately ±20% of these values.
Material properties are measured according to standard IEEE and DOD definitions and measuring techniques.

NAVY II TYPE PIEZOELECTRIC CERAMICS

PROPERTY NO OF DAYS AFTER POLING	SYMBOL	UNIT	PZT5A1 I	PZT5A2 I	PZT5A3 I	PZT5A4 I
ELECTRICAL - LOW FIELD						
Relative Permittivity	$\varepsilon^T_{r\,33}$		1875	1700	1700	1850
Relative Permittivity	$\varepsilon^T_{r\,11}$		-	1730	1730	1650
Dielectric Loss	tan δ		0.02	0.02	0.02	0.017
Resistivity (at 25°C)	ρ el	Ωm	10^{12}	-	-	50^{10}
Resistivity (at 100°C)	ρ el	Ωm	-	-	-	-
Resistivity (at 200°C)	ρ el	Ωm	-	-	-	-
ELECTRICAL - HIGH FIELD						
Increase in $\varepsilon^T_{r\,33}$ @ 2KV/cm		%	-	-	-	-
Dielectric Loss @ 2KV/cm	tan δ		-	-	-	-
Increase in $\varepsilon^T_{r\,33}$ @ 4KV/cm		%	-	-	-	-
Dielectric Loss @ 4KV/cm	tan δ		-	-	-	-
ELECTRO-MECHANICAL						
Coupling Factors	k_p		0.62	0.60	0.60	0.66
	k_{15}		0.69	0.69	0.69	0.68
	k_{31}		-0.34	-0.34	-0.34	-0.37
	k_{33}		0.67	0.71	0.71	0.72
	k_t		0.45	-	-	-
Charge Constants	d_{33}	x 10^{-12} C/N	409	374	374	460
or Strain Constants	d_{31}	x 10^{-12} C/N or m/V	-176	-171	-171	-195
	d_h	x 10^{-12} C/N	58	32	32	-
	d_{15}	x 10^{-12} C/N or m/V	-	585	585	550
Voltage Constants	g_{33}	x 10^{-3} Vm/N	25.7	24.8	24.8	28
or Stress Constants	g_{31}	x 10^{-3} Vm/N	-11	-11.4	-11.4	-13
	g_h	x 10^{-3} Vm/N	3.6	2	2	-
	g_{15}	x 10^{-3} Vm/N	-	38.2	38.2	37
	$d_h g_h$	x 10^{-15}	-	64	64	-
Frequency Constants	N_p	Hz.m	2000	1960	1960	1970
	N_1	Hz.m	1370	1400	1400	1400
	N_3	Hz.m	1410	-	-	2060
	N_5	Hz.m	-	-	-	900
	N_a	Hz.m	-	1845	1845	-
	N_{3t} or N_{33}	Hz.m	-	1880	1880	-
	N_s	Hz.m	1465	-	-	-
	Hoop or N_c	Hz.m	930	890	890	-
	N_t	Hz.m	1940	-	-	-
Compressive Strength		10^6 Pa	-	-	-	>600
Tensile Strength		10^6 Pa	-	-	-	100
Quality Factor	Q_m		60	75	75	80
MECHANICAL						
Compliances	S^E_{33}	x 10^{-12} m²/N	17.2	18.8	18.8	18
	S^E_{11}	x 10^{-12} m²/N	16.7	16.4	16.4	16
	S^E_{12}	x 10^{-12} m²/N	-5.2	-	-	-
	S^E_{13}	x 10^{-12} m²/N	-	-	-	-
	S^E_{55}	x 10^{-12} m²/N	-	-	-	45
	S^E_{66}	x 10^{-12} m²/N	-	-	-	-
	S^D_{33}	x 10^{-12} m²/N	9.4	9.4	9.4	-
	S^D_{11}	x 10^{-12} m²/N	15	14.4	14.4	-
	S^D_{12}	x 10^{-12} m²/N	-7.1	-	-	-
	S_{66}	x 10^{-12} m²/N	43.7	-	-	-
	Y^E_{33}	x 10^{10} N/m²	-	5.3	5.3	-
	Y^E_{11}	x 10^{10} N/m²	-	6.1	6.1	-
	Y^D_{33}	x 10^{10} N/m²	-	10.6	10.6	-
	Y^D_{11}	x 10^{10} N/m²	-	6.9	6.9	-
Poisson's Ratio σ			-	-	-	0.35
Density	ρ	kg/m³	7750	-	7700	7900
THERMAL DATA						
Curie Temperature	T_c	°C	370	374	365	360
Approx. Operating Temp.		°C	-	250	250	-
Specific Heat		J/kg K	-	-	-	420
Thermal Conductivity		W/m K	-	-	-	1.2
Young's Modulus	E	Gpa	-	-	-	-
Internal Friction	Q^{-1}	x 10^{-4}	-	-	-	-
TIME STABILITY		Relative change per				
Coupling Factor	k_p	time decade %	-0.40	-0.10	0.00	-0.10
Capacitance	C		-1.60	-	-	-
Permittivity	ε^T_{33}			-0.90	-0.90	-2.00
Frequency	f		0.20	-		+0.1
	d_{33}		-	-2.90	-2.90	-
Time Constant	$_p\varepsilon T/33$ (25°C)	minutes	-	-	-	>100
	N_p		-	-	+0.1	-
Quality Factor	Q_m		-	-	-	+0.1
Dielectric Loss Factor	tan δ		-	-	-	-0.1

Typical Values measured at 20°C ± 1°C are provided for design information only. Standard tolerances are approximately ±20% of these values.
Material properties are measured according to standard IEEE and DOD definitions and measuring techniques.

NAVY III TYPE PIEZOELECTRIC CERAMICS

PROPERTY NO OF DAYS AFTER POLING	SYMBOL	UNIT	PZT801 I	PZT802 I	PZT804 I	PZT805 I	PZT806 I	PZT807 I
ELECTRICAL - LOW FIELD								
Relative Permittivity	$\varepsilon^T_{r\,33}$		1000	1150	1050	1000	1250	1150
Relative Permittivity	$\varepsilon^T_{r\,11}$		-	1290	-	-	-	1190
Dielectric Loss	tan δ		0.004	0.003	0.001	0.002	0.003	0.0016
Resistivity (at 25°C)	ρ el	Ωm	10^{10}	10^{10}	-	10^{10}	10^{13}	10^{12}
Resistivity (at 100°C)	ρ el	Ωm	-	-	-	-	-	-
Resistivity (at 200°C)	ρ el	Ωm	-	-	-	-	-	-
ELECTRICAL - HIGH FIELD								
Increase in $\varepsilon^T_{r\,33}$ @ 2KV/cm		%	-	-	-	-	1.9	-
Dielectric Loss @ 2KV/cm	tan δ		-	-	-	-	0.004	-
Increase in $\varepsilon^T_{r\,33}$ @ 4KV/cm		%	-	-	-	-	4.7	3.6
Dielectric Loss @ 4KV/cm	tan δ		0.009	0.015	0.008		0.01	0.006
ELECTRO-MECHANICAL								
Coupling Factors	k_p		0.51	0.54	0.55	0.53	0.55	0.55
	k_{15}		0.55	0.55	-	-	-	-
	k_{31}		-0.30	-0.30	-	-0.30	-0.31	-0.29
	k_{33}		0.64	0.64	-	0.66	0.71	0.69
	k_t		-	-	-	-	0.45	0.47
Charge Constants	d_{33}	x 10^{-12} C/N	225	250	250	230	280	260
or Strain Constants	d_{31}	x 10^{-12} C/N or m/V	-97	-97	-	-100	-104	-92.75
	d_h	x 10^{-12} C/N	31	31	-	-	79	44.5
	d_{15}	x 10^{-12} C/N or m/V	330	300	-	-	-	294
Voltage Constants	g_{33}	x 10^{-3} Vm/N	25.4	24.6	26.9	27	26.4	25.08
or Stress Constants	g_{31}	x 10^{-3} Vm/N	-10.9	-10.9	-	-11	-10.9	-10.11
	g_h	x 10^{-3} Vm/N	3.6	3.6	-	-	8.3	4.86
	g_{15}	x 10^{-3} Vm/N	-28.9	-28.9	-	-	-	28.82
	$d_h g_h$	x 10^{-15}	112	112	-	-	-	-
Frequency Constants	N_p	Hz.m	2340	2285	2245	2350	2155	2320
	N_1	Hz.m	1700	1700	-	-	1660	-
	N_3	Hz.m	-	-	-	2050	1555	-
	N_a	Hz.m	2000	2000	-	-	-	-
	N_{3t} or N_{33}	Hz.m	2070	2070	-	-	-	-
	N_s	Hz.m	-	-	-	-	1780	-
	Hoop or N_c	Hz.m	1070	1070	-	-	1010	1080
	N_t	Hz.m	-	-	-	-	2060	2030
Compressive Strength		10^6 Pa	-	>517	-	>600	-	-
Tensile Strength		10^6 Pa	-	75.8	-	80	-	75
Quality Factor	Q_m		1000	1000	-	1000	1200	1200
MECHANICAL								
Compliances	S^E_{33}	x 10^{-12} m²/N	13.5	13.5	-	13	14.7	15.65
	S^E_{11}	x 10^{-12} m²/N	11.5	11.5	-	11	11.7	10.9
	S^E_{12}	x 10^{-12} m²/N	-	-	-	-	-3.6	-3.3
	S^E_{13}	x 10^{-12} m²/N	-	-	-	-	-	-4.8
	S^E_{55}	x 10^{-12} m²/N	-	-	-	-	-	31.4
	S^E_{66}	x 10^{-12} m²/N	-	-	-	-	-	28.3
	S^D_{33}	x 10^{-12} m²/N	8.5	8.5	-	-	7.4	8.2
	S^D_{11}	x 10^{-12} m²/N	10.1	10.1	-	-	10.8	9.9
	S^D_{12}	x 10^{-12} m²/N	-	-	-	-	-4.8	-4.2
	S_{66}	x 10^{-12} m²/N	-	-	-	-	30.7	-
	Y^E_{33}	x 10^{10} N/m²	7.4	7.4	-	-	-	-
	Y^E_{11}	x 10^{10} N/m²	8.7	8.7	-	-	-	-
	Y^D_{33}	x 10^{10} N/m²	11.8	11.8	-	-	-	-
	Y^D_{11}	x 10^{10} N/m²	9.9	9.9	-	-	-	-
Poisson's Ratio σ			-	-	-	0.3	-	-
Density	ρ	kg/m³	7600	7500	7450	7800	7600	7650
THERMAL DATA								
Curie Temperature	Tc	°C	300	300	300	300	300	300
Approx. Operating Temp.		°C	-	175	-	-	-	-
Specific Heat		J/kg K	-	-	-	420	-	-
Thermal Conductivity		W/m K	-	-	-	1.2	-	-
Young's Modulus	E	Gpa	-	-	-	-	-	88.6
Internal Friction	Q^{-1}	x 10^{-4}	-	-	-	-	-	8.6
TIME STABILITY		Relative change per						
Coupling Factor	k_p	time decade %	-2.10	-1.50	-	-2.00	-2.10	-1.50
Capacitance	C		-	-	-	-	-4.10	-3.50
Permittivity	ε^T_{33}		-4.00	-4.00	-	-4.50	-	-
Frequency	f		0.90	0.90	-	1.00	1.10	0.75
	d_{33}		-6.30	-6.30	-	-	-	-
Time Constant		Seconds	100 (at 25°C)	100 (at 25°C)	-	-	-	-

Typical Values measured at 20°C ±1°C are provided for design information only. Standard tolerances are approximately ±20% of these values.
Material properties are measured according to standard IEEE and DOD definitions and measuring techniques.

NAVY V & VI TYPE PIEZOELECTRIC CERAMICS

PROPERTY NO OF DAYS AFTER POLING	SYMBOL	UNIT	PZT5J1 1	PZT5H1 1	PZT5H2 1
ELECTRICAL - LOW FIELD					
Relative Permittivity	$\varepsilon^T_{r\,33}$		2600	3400	3400
Relative Permittivity	$\varepsilon^T_{r\,11}$		-	-	-
Dielectric Loss	tan δ		0.02	0.018	0.025
Resistivity (at 25°C)	ρ el	Ωm	-	-	$>10^{11}$
Resistivity (at 100°C)	ρ el	Ωm	-	-	10^{11}
Resistivity (at 200°C)	ρ el	Ωm	-	-	10^{10}
ELECTRICAL - HIGH FIELD					
Increase in $\varepsilon^T_{r\,33}$ @ 2KV/cm		%	-	-	-
Dielectric Loss @ 2KV/cm	tan δ		-	-	-
Increase in $\varepsilon^T_{r\,33}$ @ 4KV/cm		%	-	-	-
Dielectric Loss @ 4KV/cm	tan δ		-	-	-
ELECTRO-MECHANICAL					
Coupling Factors	k_p		0.60	0.60	0.65
	k_{15}		0.63	-	0.68
	k_{31}		-0.36	-0.35	-0.39
	k_{33}		0.69	0.72	0.75
	k_t		-	0.50	-
Charge Constants	d_{33}	x 10^{-12} C/N	500	620	593
or Strain Constants	d_{31}	x 10^{-12} C/N or m/V	-220	-250	-274
	d_h	x 10^{-12} C/N	60	125	45
	d_{15}	x 10^{-12} C/N or m/V	670	-	741
Voltage Constants	g_{33}	x 10^{-3} Vm/N	21.7	21.9	19.7
or Stress Constants	g_{31}	x 10^{-3} Vm/N	-9.6	-8.7	-9.1
	g_h	x 10^{-3} Vm/N	2.5	4.4	1.5
	g_{15}	x 10^{-3} Vm/N	35	-	26.8
	$d_h g_h$	x 10^{-15}	150	-	68
Frequency Constants	N_p	Hz.m	1980	1975	1965
	N_1	Hz.m	1450	1375	1420
	N_3	Hz.m	-	1785	-
	N_a	Hz.m	-	-	1930
	N_{3t} or N_{33}	Hz.m	-	-	2000
	N_s	Hz.m	-	1430	-
	Hoop or N_c	Hz.m	910	920	890
	N_t	Hz.m	-	1895	-
Compressive Strength		10^6 Pa	-	-	-
Tensile Strength		10^6 Pa	-	-	-
Quality Factor	Q_m		75	65	65
MECHANICAL					
Compliances	S^E_{33}	x 10^{-12} m²/N	22.7	21.9	20.8
	S^E_{11}	x 10^{-12} m²/N	16.2	17.7	16.4
	S^E_{12}	x 10^{-12} m²/N	-	-5.7	-
	S^E_{13}	x 10^{-12} m²/N	-	-	-
	S^E_{55}	x 10^{-12} m²/N	-	-	-
	S^E_{66}	x 10^{-12} m²/N	-	-	-
	S^D_{33}	x 10^{-12} m²/N	-	10.5	9
	S^D_{11}	x 10^{-12} m²/N	14.1	15.5	14.1
	S^D_{12}	x 10^{-12} m²/N	-	-7.6	-
	S_{66}	x 10^{-12} m²/N	-	48.5	-
	Y^E_{33}	x 10^{10} N/m²	4.4	-	4.8
	Y^E_{11}	x 10^{10} N/m²	6.2	-	6.2
	Y^D_{33}	x 10^{10} N/m²		-	11.1
	Y^D_{11}	x 10^{10} N/m²	7.1	-	7.1
Poisson's Ratio σ			0.31	-	-
Density	ρ	kg/m³	7400	7400	7450
THERMAL DATA					
Curie Temperature	T_c	°C	250	200	195
Approx. Operating Temp.		°C	140	-	110
Specific Heat		J/kg K	-	-	-
Thermal Conductivity		W/m K	-	-	-
Young's Modulus	E	Gpa	-	-	-
Internal Friction	Q^{-1}	x 10^{-4}	-	-	-
TIME STABILITY		Relative change per			
Coupling Factor	k_p	time decade %	-0.30	-0.20	-0.20
Capacitance	C		-	-1.50	-
Permittivity	ε^T_{33}		-1.10	-	-0.60
Frequency	f		-	0.30	-
	d_{33}		-4.00	-	-3.90
Time Constant		Seconds	-	-	-
	N_p		+0.2	-	+0.3

Typical Values measured at 20°C ± 1°C are provided for design information only. Standard tolerances are approximately ±20% of these values. Material properties are measured according to standard IEEE and DOD definitions and measuring techniques.

CUSTOM PIEZOELECTRIC CERAMICS

PROPERTY NO OF DAYS AFTER POLING	SYMBOL	UNIT	PZT501 I	PZT502 I	PZT503 I	PZT504 I	PZT505 I	PZT506 I	PZT507 I	PZT508
ELECTRICAL - LOW FIELD										
Relative Permittivity	$\varepsilon^T_{r\,33}$		2000	1950	2100	2000	2600	2250	4400	3900
Relative Permittivity	$\varepsilon^T_{r\,11}$		-	-	1800	-	-	-	3300	-
Dielectric Loss	tan δ		0.02	0.02	0.02	0.015	0.019	0.02	0.016	0.02
Resistivity (at approx 25°C)	ρ el	Ωm	$>10^{11}$	-	50^{10}	50^{10}	50^{10}		1010	
Resistivity (at 100°C)	ρ el	Ωm	10^{11}	-	-	-	-	-	-	-
Resistivity (at 200°C)	ρ el	Ωm	10^{10}	-	-	-	-	-	-	-
ELECTRICAL - HIGH FIELD										
Increase in $\varepsilon^T_{r\,33}$ @ 2KV/cm		%	-	-	-	-	-	-	-	-
Dielectric Loss @ 2KV/cm	tan δ		-	-	-	-	-	-	-	-
Increase in $\varepsilon^T_{r\,33}$ @ 4KV/cm		%	-	-	-	-	-	-	-	-
Dielectric Loss @ 4KV/cm	tan δ		-	-	-	-	-	-	-	-
ELECTRO-MECHANICAL										
Coupling Factors	k_p		0.6	0.65	0.68	0.64	0.72	0.7	0.75	0.71
	k_{15}		0.63	-	0.66	-	-	-	-	0.72
	k_{31}		-0.34	-0.35	-0.38	-0.37	-	-	-0.39	0.41
	k_{33}		0.66	-	0.75	0.74	-	-	0.8	-0.75
	k_t		-	-	-	-	-	-	-	-
Charge Constants	d_{33}	x 10^{-12} C/N	405	450	500	450	610	545	820	720
or Strain Constants	d_{31}	x 10^{-12} C/N or m/V	-185	-195	-215	-200	-270	-225	-360	-315
	d_h	x 10^{-12} C/N	95	60	-	-	-	-	-	90
	d_{15}	x 10^{-12} C/N or m/V	564	-	515	-	-	-	-	750
Voltage Constants	g_{33}	x 10^{-3} Vm/N	22.9	25	24	25	-	-	20	18.5
or Stress Constants	g_{31}	x 10^{-3} Vm/N	-10.5	-11.5	-10	-12	-	-	-10	-9
	g_h	x 10^{-3} Vm/N	1.9	2	-	-	-	-	-	0.5
	g_{15}	x 10^{-3} Vm/N	36.4	-	33	-	-	-	-	-
	$d_h g_h$	x 10^{-15}	181	120	-	-	-	-	-	45
Frequency Constants	N_p	Hz.m	1950	1930	1975	2000	1900	1940	1925	1950
	N_1	Hz.m	1420	1400	1450	-	-	-	1400	1420
	N_3	Hz.m	-	-	1850	1900	-	-	1800	1880
	N_5	Hz.m	-	-	930	-	-	-	-	-
	N_a	Hz.m	-	-	-	-	-	-	-	-
	N_{3t} or N_{33}	Hz.m	-	-	-	-	-	-	-	-
	N_s	Hz.m	-	-	-	-	-	-	-	-
	Hoop or N_c	Hz.m	890	78	-	-	-	-	-	-
	N_t	Hz.m	-	-	-	-	-	-	-	-
Compressive Strength		10^6 Pa	-	-	>600	>600	-	-	>600	-
Tensile Strength		10^6 Pa	-	-	80	80	-	-	80	-
Quality Factor	Q_m		75	80	75	75	60	65	65	55
MECHANICAL										
Compliances	S^E_{33}	x 10^{-12} m²/N	-	-	18	19	-	-	20	22
	S^E_{11}	x 10^{-12} m²/N	16.4	16.1	15	15	16.5	15.5	16	16.4
	S^E_{12}	x 10^{-12} m²/N	-	-	-	-	-	-	-	-
	S^E_{13}	x 10^{-12} m²/N	-	-	-	-	-	-	-	-
	S^E_{55}	x 10^{-12} m²/N	-	-	39	-	-	-	-	-
	S^E_{66}	x 10^{-12} m²/N	-	-	-	-	-	-	-	-
	S^D_{33}	x 10^{-12} m²/N	-	-	-	-	-	-	-	8.8
	S^D_{11}	x 10^{-12} m²/N	14.4	14.1	-	-	-	-	-	13.9
	S^D_{12}	x 10^{-12} m²/N	-	-	-	-	-	-	-	-
	S_{66}	x 10^{-12} m²/N	-	-	-	-	-	-	-	-
	Y^E_{33}	x 10^{10} N/m²	-	-	-	-	-	-	-	4.9
	Y^E_{11}	x 10^{10} N/m²	6.1	6.2	-	-	-	-	-	6.1
	Y^D_{33}	x 10^{10} N/m²	-	-	-	-	-	-	-	11
	Y^D_{11}	x 10^{10} N/m²	6.9	7.1	-	-	-	-	-	7
Poisson's Ratio σ			0.31	0.31	0.3	0.3	-	-	-	-
Density	ρ	kg/m³	7600	7800	7800	7800	7830	8000	7800	7900
THERMAL DATA										
Curie Temperature	T_c	°C	330	350	285	270	285	300	165	208
Approx. Operating Temp.		°C	-	-	-	-	-	-	-	-
Specific Heat		J/kg K	-	-	420	420	-	-	420	-
Thermal Conductivity		W/m K	-	-	1.2	1.2	-	-	1.2	-
Young's Modulus	E	Gpa	-	-	-	-	-	-	-	-
Internal Friction	Q^{-1}	x 10^{-4}	-	-	-	-	-	-	-	-
TIME STABILITY		Relative change per								
Coupling Factor	k_p	time decade %	0.00	0.00	-0.50	-1.50	-	-	-0.60	-
Capacitance	C		-	-	-	-	-	-	-	-
Permittivity	ε^T_{33}		-0.90	-3.60	-1.00	-2.00	-	-	-1.00	-
Frequency	N_p		0.10	0.20	0.50	0.50	-	-	0.30	-
	d_{33}		-2.90	-3.10	-	-	-	-	-	-
Time Constant	$_p\varepsilon T/3$ (25°C)	minute	-	-	>300	>25	-	-	>500	-
Quality factor	Q_m		-	-	-	-	-	-	-3.00	-
Dielectric Loss factor	tan δ		-	-	-	-	-	-	-	-

Typical Values measured at 20°C ± 1°C are provided for design information only. Standard tolerances are approximately ±20% of these values.
Material properties are measured according to standard IEEE and DOD definitions and measuring techniques.

PROPERTY NO OF DAYS AFTER POLING	SYMBOL	UNIT	PZT701 1	PZT702 1	PZT703 1	PZT407 1	PT1 1	PZT601 1
ELECTRICAL - LOW FIELD								
Relative Permittivity	$\varepsilon^T_{r\,33}$		425	1200	1100	1225	210	640
Relative Permittivity	$\varepsilon^T_{r\,11}$		-	1700	-	1400	240	750
Dielectric Loss	tan δ		0.01	0.005	0.029	0.0025	0.02	0.005
Resistivity (at approx 25°C)	ρ el	Ωm	$>10^{11}$	-	50^{10}	10^{10}	-	-
Resistivity (at 100°C)	ρ el	Ωm	10^{11}	-	-	-	-	-
Resistivity (at 200°C)	ρ el	Ωm	10^{10}	-	-	-	-	-
ELECTRICAL - HIGH FIELD								
Increase in $\varepsilon^T_{r\,33}$ @ 2KV/cm		%	-	-	-	-	-	
Dielectric Loss @ 2KV/cm	tan δ		-	-	-	-	-	
Increase in $\varepsilon^T_{r\,33}$ @ 4KV/cm		%	-	-	-	-	-	
Dielectric Loss @ 4KV/cm	tan δ		-	-	-	-	-	
ELECTRO-MECHANICAL								
Coupling Factors	k_p		0.52	0.48	0.63	0.64	<0.020	0.52
	k_{15}		0.68	-	0.68	0.70	0.36	0.69
	k_{31}		-0.3	-0.28	0.37	0.38	<0.020	0.30
	k_{33}		0.67	-	0.73	0.74	0.54	0.67
	k_t		-	-	-	-	-	0.48
Charge Constants	d_{33}	x 10^{-12} C/N	153	225	340	325	68	170
or Strain Constants	d_{31}	x 10^{-12} C/N or m/V	-60	-100	-150	-150	-3	-64
	d_h	x 10^{-12} C/N	33	25	-	-	62	-
	d_{15}	x 10^{-12} C/N or m/V	360	-	500	480	70	310
Voltage Constants	g_{33}	x 10^{-3} Vm/N	41	21	30	30	37	37
or Stress Constants	g_{31}	x 10^{-3} Vm/N	-16	-9.6	-10	-12	-2	-14
	g_h	x 10^{-3} Vm/N	9	-	-	-	33	-
	g_{15}	x 10^{-3} Vm/N	50	-	33	39	34	45
	$d_h g_h$	x 10^{-15}	297	-	-	-	2046	-
Frequency Constants	N_p	Hz.m	2340	2260	2100	2175	2870	2450
	N_1	Hz.m	1750	1625	1500	1620	n/a	-
	N_3	Hz.m	-	-	-	2000	-	-
	N_5	Hz.m	-	-	920	950	-	-
	N_a	Hz.m	2050	-	-	-	-	-
	N_{3t} or N_{33}	Hz.m	2100	-	-	-	2145	1750
	N_s	Hz.m	-	-	-	-	-	-
	Hoop or N_c	Hz.m	1070	1040	-	-	-	-
	N_t	Hz.m	-	-	-	-	-	2150
Compressive Strength		10^6 Pa	-	-	>600	>600	-	-
Tensile Strength		10^6 Pa	-	-	80	80	-	-
Quality Factor	Q_m		600	500	80	1200	1100	1000
MECHANICAL								
Compliances	S^E_{33}	x 10^{-12} m²/N	13.9	-	-	15	8.6	13.5
	S^E_{11}	x 10^{-12} m²/N	10.7	10.9	15	12	7.4	10
	S^E_{12}	x 10^{-12} m²/N	-	-	-	-	-	-3.1
	S^E_{13}	x 10^{-12} m²/N	-	-	-	-	-	-6.6
	S^E_{55}	x 10^{-12} m²/N	-	-	38	37	-	30.4
	S^E_{66}	x 10^{-12} m²/N	-	-	-	-	-	26
	S^D_{33}	x 10^{-12} m²/N	7.9	-	-	-	6.1	7.4
	S^D_{11}	x 10^{-12} m²/N	9.7	10	-	-	7.3	9
	S^D_{12}	x 10^{-12} m²/N	-	-	-	-	-	-4
	S_{66}	x 10^{-12} m²/N	-	-	-	-	-	26
	Y^E_{33}	x 10^{10} N/m²	7.2	-	-	-	11.6	7.4
	Y^E_{11}	x 10^{10} N/m²	9.3	9.2	-	-	13.5	9.8
	Y^D_{33}	x 10^{10} N/m²	10.3	-	-	-	16.4	13
	Y^D_{11}	x 10^{10} N/m²	12.7	10	-	-	13.7	11
Poisson's Ratio σ			0.31	0.31	0.3	0.3	-	0.31
Density	ρ	kg/m³	7700	7600	7800	7900	6900	7700
THERMAL DATA								
Curie Temperature	T_c	°C	350	325	270	315	255	300
Approx. Operating Temp.		°C	210	-	-	-	130	-
Specific Heat		J/kg K	-	-	420	420	-	-
Thermal Conductivity		W/m K	-	-	1.2	1.2	-	-
Young's Modulus	E	Gpa	-	-	-	-	-	-
Internal Friction	Q^{-1}	x 10^{-4}	-	-	-	-	-	-
TIME STABILITY		Relative change per						
Coupling Factor	k_p	time decade %	0.00	0.01	-0.50	-1.50	-	-
Capacitance	C		-	-	-	-	-	-
Permittivity	ε^T_{33}		0.06	0.03	-0.50	1.00	-	-
Frequency	N_p		-0.05	0.02	0.50	0.50	-	-
	d_{33}		-	-	-	-	-	-
Time Constant	$\rho\varepsilon T/3$ (25°C)	minute	-	-	>250	>7	-	-
Quality factor	Q_m		-	-	-	10	-	-
Dielectric Loss factor	tan δ		-	-	-	-10	-	-

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PROPERTY NO OF DAYS AFTER POLING	SYMBOL	UNIT	PZT5K1 1	PZT5K2 1	PZT5K4 1
ELECTRICAL - LOW FIELD					
Relative Permittivity	$\varepsilon^T_{r\,33}$		6200	6200	7100
Relative Permittivity	$\varepsilon^T_{r\,11}$		-	5200	-
Dielectric Loss	tan δ		0.02	0.02	0.02
Resistivity (at approx 25°C)	ρ el	Ωm	-	-	-
Resistivity (at 100°C)	ρ el	Ωm	-	-	-
Resistivity (at 200°C)	ρ el	Ωm	-	-	-
ELECTRICAL - HIGH FIELD					
Increase in $\varepsilon^T_{r\,33}$ @ 2KV/cm		%	-	-	-
Dielectric Loss @ 2KV/cm	tan δ		-	-	-
Increase in $\varepsilon^T_{r\,33}$ @ 4KV/cm		%	-	-	-
Dielectric Loss @ 4KV/cm	tan δ		-	-	-
ELECTRO-MECHANICAL					
Coupling Factors	k_p		0.68	0.70	0.70
	k_{15}		-	-	-
	k_{31}		-0.40	-0.42	-0.42
	k_{33}		0.75	0.78	0.78
	k_t		-	0.50	0.49
Charge Constants	d_{33}	x 10^{-12} C/N	870	880	950
or Strain Constants	d_{31}	x 10^{-12} C/N or m/V	-370	-401	-410
	d_h	x 10^{-12} C/N	130	78	130
	d_{15}	x 10^{-12} C/N or m/V	-	-	-
Voltage Constants	g_{33}	x 10^{-3} Vm/N	15.8	16	15.1
or Stress Constants	g_{31}	x 10^{-3} Vm/N	-6.8	-7.1	-6.5
	g_h	x 10^{-3} Vm/N	2.2	1.7	2.1
	g_{15}	x 10^{-3} Vm/N	-	-	-
	$d_h g_h$	x 10^{-15}	286	137	273
Frequency Constants	N_p	Hz.m	1920	1880	1880
	N_1	Hz.m	1380	-	-
	N_3	Hz.m	-	-	-
	N5	Hz.m	-	-	-
	N_a	Hz.m	-	-	-
	N_{3t} or N_{33}	Hz.m	-	-	-
	N_s	Hz.m	-	-	-
	Hoop or N_c	Hz.m	-	-	-
	N_t	Hz.m	-	-	-
Compressive Strength		10^6 Pa	-	-	-
Tensile Strength		10^5 Pa	-	-	-
Quality Factor	Q_m		65	68	60
MECHANICAL					
Compliances	S^E_{33}	x 10^{-12} m²/N	20.4	23.2	23.6
	S^E_{11}	x 10^{-12} m²/N	16.4	16.6	16.4
	S^E_{12}	x 10^{-12} m²/N	-	-	-
	S^E_{13}	x 10^{-12} m²/N	-	-	-
	S^E_{55}	x 10^{-12} m²/N	-	-	-
	S^E_{66}	x 10^{-12} m²/N	-	-	-
	S^D_{33}	x 10^{-12} m²/N	8.9	9.1	9.24
	S^D_{11}	x 10^{-12} m²/N	14.7	13.7	13.6
	S^D_{12}	x 10^{-12} m²/N	-	-	-
	S_{66}	x 10^{-12} m²/N	-	-	-
	Y^E_{33}	x 10^{10} N/m²	4.9	4.3	4.2
	Y^E_{11}	x 10^{10} N/m²	6.4	6	6.1
	Y^D_{33}	x 10^{10} N/m²	-	10.9	10.8
	Y^D_{11}	x 10^{10} N/m²	-	7.3	7.3
Poisson's Ratio σ			-	-	-
Density	ρ	kg/m³	8200	8200	8200
THERMAL DATA					
Curie Temperature	T_c	°C	160	150	137
Approx. Operating Temp.		°C	-	-	-
Specific Heat		J/kg K	-	-	-
Thermal Conductivity		W/m K	-	-	-
Young's Modulus	E	Gpa	-	-	-
Internal Friction	Q^{-1}	x 10^{-4}	-	-	-
TIME STABILITY		Relative change per			
Coupling Factor	k_p	time decade %	-0.50	-	-
Capacitance	C		-0.50	-	-
Permittivity	ε^T_{33}		-	-	-
Frequency	N_p		-	-	-
	d_{33}		-	-	-
Time Constant	$_p\varepsilon T/3$ (25°C)	minute	-	-	-
Quality factor	Q_m		-	-	-
Dielectric Loss factor	tan δ		-	-	-

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PROPERTY NO OF DAYS AFTER POLING	SYMBOL	UNIT	PMN-PT28 I	PMN-PT30 I
ELECTRICAL - LOW FIELD				
Relative Permittivity	$\varepsilon^{T}_{r\,33}$		4500-5500	5500-7000
Coercive Field	E_C	kV/cm	3.0-3.3	2.5-2.8
ELECTRO-MECHANICAL				
Coupling Factors	k_{33}		0.88-0.90	0.90-0.94
	k_t		>0.55	>0.55
Charge Constants	d_{33}	x 10^{-12} C/N	1100-1700	1700-2200
or Strain Constants	d_{31}	x 10^{-12} C/N or m/V	-850	-950
Voltage Constants	g_{33}	x 10^{-3} Vm/N	>30	>40
or Stress Constants	g_{31}	x 10^{-3} Vm/N	>17	>15
Frequency Constants	N_t	Hz.m	0800-1900	1800-1900
MECHANICAL				
Compliances	S^{D}_{33}	x 10^{-12} m^2/N	10-14	10-14
	Y^{E}_{33}	x 10^{10} N/m^2	25-30	16-21
Poisson's Ratio σ				
Density	ρ	kg/m^3	> 8.0	> 8.0
THERMAL DATA				
Curie Temperature	T_c	°C	143	155
Trt Transition Temperature	T_{rt}	°C	95 ± 5	85 ± 5
Approx. Operating Temp.		°C	90	80
Acoustic Impedance	Z_A	10^6 kg/m^2sec	28	28

Typical Values measured at 20°C ±1°C are provided for design information only. Standard tolerances are approximately ±20% of these values. Material properties are measured according to standard IEEE and DOD definitions and measuring techniques.

MATERIAL CROSS REFERENCE TABLE

	PREVIOUS MATERIAL	CURRENT MATERIAL REFERENCE
NAVY I	PC4D	PZT401
	PZT4	PZT402
	PZT4D	PZT403
	PZT4D	PZT404
	PZT4E	PZT405
	PXE42	PZT406
NAVY II	PC5	PZT5A1
	PZT5A	PZT5A2
	PZT5A	PZT5A3
	PXE59	PZT5A4
NAVY III	PZT8	PZT801
	PZT8	PZT802
	PZT8L	PZT803
	PZT8S	PZT804
	PXE43	PZT805
	PC4	PZT806
	PC8	PZT807
NAVY V	PZT5J	PZT5J1
NAVY VI	PC5H	PZT5H1
	PZT5H	PZT5H2
CUSTOM	PZT5B	PZT501
	PZT5R	PZT502
	PXE5	PZT503
	PXE21	PZT504
	PXE50+	PZT505
	PXE55	PZT506
	PXE52	PZT507
	PZT5T	PZT508
	PC5K	PZT5K1
	n/a	PZT5K2
	n/a	PZT5K4
	PXE41	PZT407
	PT2	PT1
	PZT7A	PZT701
	PZT7D	PZT702
	PXE71	PZT703