



| Property | Symbol | Units | Hard Material Type | | | | | | |
|--------------------------------------|----------------|---------------------------------|--------------------|--------|--------|--------|--------|--------|--------|
| | | | K1000 | NCE81* | K1100 | K1300 | NCE40* | NCE41* | K1450 |
| Dielectric Constant (1 kHz) | K^T_3 | | 1000 | 1030 | 1100 | 1300 | 1250 | 1350 | 1450 |
| Dielectric Loss Factor (1 kHz) | $\tan\delta_e$ | | <0.004 | 0.0017 | <0.004 | <0.005 | 0.0025 | 0.004 | <0.012 |
| Dielectric Loss Factor (at 0.4kV/mm) | $\tan\delta_e$ | | | 0.006 | | | 0.011 | | 0.02 |
| Dielectric Constant (1 kHz) | K^T_1 | | | | | 1250 | | | |
| Clamped Dielectric Constant | K^S_3 | | 445 | | 550 | 600 | | | |
| Density | ρ | kg/m ³ | 7550 | 7750 | 7550 | 7550 | 7700 | 7930 | 7550 |
| Curie Point | T_c | °C | 325 | 300 | 325 | 325 | 318 | 318 | 320 |
| Mechanical Quality Factor | Q_m | | 1000 | 1300 | 550 | 500 | 700 | 1400 | 350 |
| Coupling Coefficients | k_p | | 0.56 | 0.56 | 0.57 | 0.58 | 0.58 | 0.57 | 0.57 |
| | k_{33} | | 0.64 | 0.69 | 0.66 | 0.7 | 0.68 | 0.68 | |
| | k_{31} | | 0.33 | 0.31 | 0.33 | 0.32 | 0.35 | 0.33 | 0.32 |
| | k_t | | 0.52 | 0.47 | 0.52 | 0.51 | 0.48 | 0.5 | |
| | k_{15} | | 0.58 | | | 0.65 | | | |
| Piezoelectric Charge | d_{31} | Coul/N x 10 ⁻¹² (or) | -110 | -98 | -120 | -125 | -133 | -130 | -130 |
| Displacement Coefficient | d_{33} | m/V x 10 ⁻¹² | 230 | 255 | 250 | 300 | 304 | 310 | 350 |
| | d_{15} | | | | | 500 | | | |
| Piezoelectric Voltage Coefficient | g_{31} | | -14 | -10.8 | -12.3 | -10.9 | -12 | -10.9 | -10.1 |
| Voltage Coefficient | g_{33} | V·m/N x 10 ⁻³ | 26 | 28 | 25.7 | 26.1 | 27.5 | 25.9 | 30.4 |
| | g_{15} | | | | | 45.2 | | | |
| Frequency Constants | N_p | | 2270 | 2300 | 2180 | 2200 | 2170 | 2280 | 2080 |
| | N_{tr} | | 2067 | 2130 | 2024 | 2100 | 2070 | 2000 | |
| | N_{ta} | Hz·m | 2361 | | 2310 | 2375 | | | |
| | N_{33} | | 1550 | | 1520 | 1500 | | | |
| | N_{31} | | 1630 | | 1620 | 1570 | | | |
| | N_H | | 1065 | | 1050 | 1040 | | | 1000 |
| Poisson's Ratio | ν | | 0.32 | | 0.32 | 0.34 | | | |

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|---------------------------------|------------|---------------------------------------|--------------------|--------|-------|-------|--------|--------|-------|
| | | | K1000 | NCE81* | K1100 | K1300 | NCE40* | NCE41* | K1450 |
| Elastic Constants Short Circuit | S_{11}^E | $\times 10^{-12} \text{m}^2/\text{N}$ | 12 | 11.1 | 12.1 | 11.1 | 12.4 | 12.5 | 12.5 |
| | S_{33}^E | | 14.6 | 15 | 14.7 | 16 | 14.6 | 16 | |
| | S_{12}^E | | -3.9 | -4.3 | -3 | -3.8 | -3.4 | -4.1 | |
| | S_{13}^E | | -5.2 | -5.4 | -5.3 | -4.5 | -5.4 | -5.7 | |
| | S_{55}^E | | | 34.5 | | 50.4 | 34.5 | 39.5 | |
| | S_{66}^E | | 31.8 | 30.8 | 30.2 | 29.8 | 31.5 | 33.2 | |
| Elastic Constants Open Circuit | S_{11}^D | $\times 10^{-12} \text{m}^2/\text{N}$ | 10.5 | 10 | 10.7 | 10 | 10.9 | 11.1 | 11.2 |
| | S_{33}^D | | 9.5 | 7.9 | 8.2 | 8.2 | 7.8 | 8.6 | |
| | S_{55}^D | | | 23.1 | | 29.1 | 23.1 | 20.8 | |
| Elastic Constants Short Circuit | Y_{11}^E | $\times 10^{10} \text{N}/\text{m}^2$ | 8.3 | 9.0 | 8.3 | 9 | 8.1 | 8.0 | 8 |
| | Y_{33}^E | | 6.8 | 6.7 | 6.8 | 6.3 | 6.8 | 6.3 | |
| Elastic Constants Open Circuit | Y_{11}^D | $\times 10^{10} \text{N}/\text{m}^2$ | 9.5 | 10 | 9.3 | 10 | 9.2 | 9.0 | 8.9 |
| | Y_{33}^D | | 10.5 | 12.7 | 12.3 | 12.2 | 12.7 | 11.6 | |

* For requests for wafer forms thinner than 0.40 mm, please contact us on piezosaes@ctscorp.com.

Data represent typical material values. Actual production values may vary $\pm 10\%$ for dielectric properties and $\pm 5\%$ for electromechanical and physical properties.



| Property | Symbol | Units | Soft Material Type | | | | | | | | | | | |
|-----------------------------------|-----------------|--------------------------------------|--------------------|--------|--------|--------|--------|---------|--------|--------|--------|--------|--------|--------|
| | | | 3195STD | 3195HD | NCE51* | 3222HD | NCE56* | 3203STD | 3221HD | 3203HD | 3241HD | NCE55* | 3257HD | 3265HD |
| Dielectric Constant (1 kHz) | K^T_3 | | 1800 | 1900 | 1900 | 2650 | 2900 | 3250 | 3450 | 3800 | 4100 | 5000 | 5700 | 6500 |
| Dielectric Loss Factor (1 kHz) | $\tan \delta_e$ | | <0.02 | <0.02 | 0.015 | <0.02 | 0.014 | <0.02 | <0.02 | <0.02 | <0.02 | 0.022 | <0.03 | <0.03 |
| Dielectric Constant (1 kHz) | K^T_1 | | 1500 | 1600 | | 2948 | | 2800 | 3550 | 3200 | 3420 | | 5900 | 5400 |
| Clamped Dielectric Constant | K^S_3 | | 875 | 900 | | 800 | | 775 | 1000 | 1200 | 1300 | | 2050 | 2100 |
| Density | ρ | kg/m ³ | 7700 | 7950 | 7850 | 7900 | 7650 | 7700 | 7870 | 7870 | 7880 | 7920 | 8220 | 8220 |
| Curie Point | T_c | °C | 350 | 350 | 360 | 270 | 242 | 225 | 242 | 225 | 223 | 160 | 155 | >135 |
| Mechanical Quality Factor | Q_m | | 80 | 80 | 80 | 80 | 75 | 50 | 50 | 50 | 50 | 70 | 75 | 75 |
| Coercive Field (Measured < 1 Hz) | E_c | kV/cm | 14.9 | 12 | | | | 10.6 | 8.8 | 8 | 9 | | | |
| Remanent Polarization | P_r | μCoul/cm ² | 39.2 | 39 | | | | 37.2 | 38.5 | 39 | 38.5 | | | |
| Coupling Coefficients | k_p | | 0.63 | 0.68 | 0.65 | 0.72 | 0.64 | 0.69 | 0.74 | 0.75 | | 0.65 | 0.7 | 0.66 |
| | k_{33} | | 0.7 | 0.72 | 0.74 | 0.74 | 0.74 | 0.7 | 0.78 | 0.78 | 0.77 | 0.72 | 0.76 | 0.73 |
| | k_{31} | | 0.35 | 0.4 | 0.39 | 0.45 | 0.38 | 0.41 | 0.46 | 0.43 | 0.44 | 0.37 | 0.41 | 0.4 |
| | k_t | | 0.49 | 0.49 | 0.5 | 0.53 | 0.5 | 0.56 | 0.54 | 0.55 | 0.55 | 0.5 | 0.5 | 0.49 |
| | k_{15} | | 0.56 | 0.61 | | 0.77 | | 0.72 | 0.78 | 0.78 | 0.75 | | 0.65 | 0.68 |
| Piezoelectric Charge | d_{31} | Coul/N x 10 ⁻¹² (or) | -175 | -190 | -208 | -270 | -250 | -270 | -300 | -320 | -325 | -320 | -360 | -370 |
| Displacement Coefficient | d_{33} | m/V x 10 ⁻¹² | 350 | 390 | 443 | 485 | 580 | 530 | 600 | 650 | 640 | 694 | 730 | 750 |
| | d_{15} | | 360 | 460 | | 850 | | 790 | 1000 | 1000 | 880 | | 850 | 900 |
| Piezoelectric Voltage Coefficient | g_{31} | | -11 | -11.3 | -12.4 | -11.5 | -9.7 | -9.4 | -9.8 | -9.5 | -8.9 | -7.2 | -7.1 | -6.4 |
| Voltage Coefficient | g_{33} | V-m/N x 10 ⁻³ | 24.2 | 23.2 | 26.3 | 21.3 | 22.6 | 18.4 | 19.7 | 19 | 17.6 | 15.7 | 14.5 | 13 |
| | g_{15} | | 27.1 | 32.4 | | 32.6 | | 31.9 | 31.8 | 35.3 | 29.1 | | 16.3 | 18.8 |
| Frequency Constants | N_p | | 2020 | | 1925 | 1910 | 1950 | 1920 | 1830 | | | 1970 | 1940 | 2020 |
| | N_{tr} | | 2025 | 2110 | 2000 | 2050 | 2020 | 1870 | 2020 | 2000 | 2000 | 1990 | 2090 | 2095 |
| | N_{ta} | Hz·m | 2250 | 2360 | | 2350 | | 2220 | 2340 | 2350 | 2340 | | 2350 | 2340 |
| | N_{33} | | | | | | | | | | | | 1590 | 1550 |
| | N_{31} | | 1420 | 1440 | | 1420 | | 1400 | | | | | 1430 | 1440 |
| Poisson's Ratio | ν | | 0.32 | 0.34 | | 0.31 | | | | 0.31 | 0.31 | | 0.32 | 0.32 |
| Elastic Constants Short Circuit | S^E_{11} | x 10 ¹² m ² /N | 15.6 | 15.1 | 17 | 15.8 | 17.8 | 16.7 | 16 | 16.6 | 15.6 | 17 | 14.7 | 14.5 |
| | S^E_{33} | | 18.6 | 18.6 | 21.3 | 18.8 | 23.9 | 19.7 | 19.8 | 21 | 19.2 | 21 | 18.1 | 18 |
| | S^E_{12} | | -5.3 | -4.8 | -4.8 | -5 | -5.2 | -5.6 | -4.2 | -4.2 | -4.7 | -6 | -4.7 | -4.7 |
| | S^E_{13} | | -6.8 | -7.6 | -8.9 | -7.7 | -9.9 | -7.6 | -7.2 | -8.2 | -7.7 | -7.5 | -7.3 | -7.2 |
| | S^E_{55} | | 37 | 40 | 49.0 | 47 | 48.9 | 48.5 | 54 | 52.4 | 45.9 | 36.2 | 38.1 | 41.4 |
| | S^E_{66} | | 41.6 | 39.8 | 43.4 | | 46.1 | | | | | 46 | | |
| Elastic Constants Open Circuit | S^D_{11} | x 10 ¹² m ² /N | 13.7 | 12.7 | 14.4 | 12.6 | 15.2 | 13.9 | 12.6 | 13.5 | 12.5 | 14.7 | 12.2 | 12.2 |
| | S^D_{33} | | 9.4 | 9 | 9.6 | 8.5 | 10.8 | 10 | 7.8 | 8.2 | 7.8 | 10.1 | 7.6 | 8.4 |
| | S^D_{55} | | 25.4 | 25.1 | 22.9 | 19.1 | 22.9 | 23.4 | 21.1 | 20.5 | 20.1 | 16.4 | 22 | 22.3 |



| Property | Symbol | Units | Soft Material Type | | | | | | | | | | | |
|---|------------|-------------------------------|--------------------|--------|--------|---------|--------|---------|--------|--------|--------|--------|--------|--------|
| | | | 3195STD | 3195HD | NCE51* | 3222HD | NCE56* | 3203STD | 3221HD | 3203HD | 3241HD | NCE55* | 3257HD | 3265HD |
| Elastic Constants Short Circuit | Y_{11}^E | $\times 10^{10} \text{N/m}^2$ | 6.4 | 6.6 | 5.9 | 6.4 | 5.6 | 5.9 | 6.2 | 6 | 6.4 | 5.9 | 6.8 | 6.9 |
| | Y_{33}^E | | 5.4 | 5.4 | 4.7 | 5.3 | 4.2 | 5.1 | 5.1 | 4.8 | 5.2 | 4.8 | 5.5 | 5.6 |
| Elastic Constants Open Circuit | Y_{11}^D | $\times 10^{10} \text{N/m}^2$ | 7.3 | 7.9 | 7.0 | 7.9 | 6.6 | 7.2 | 7.6 | 7.5 | 8 | 6.8 | 8.1 | 8.2 |
| | Y_{33}^D | | 10.6 | 11.1 | 10.4 | 11.7 | 9.2 | 10 | 12.8 | 13.2 | 12.8 | 9.9 | 13.2 | 11.9 |
| Thermal Expansion (Perpendicular to poling) | α | ppm/°C | 3 | | | 3.5 | | | | | | | | |
| Specific Heat | C_p | J/kg·°C | 440 | | | 420 | | | | | | | | |
| | | J/mol·°C | 145 | | | 138 | | | | | | | | |
| Thermal Conductivity | | W/cm·°C | 1.9-2.3 | | | 1.9-2.3 | | | | | | | | |
| | | W/m·°K | 1.2 | | | 1.2 | | | | | | | | |
| Thermal Conductivity with Au Electrodes | K_d | W/m·°K | 1.45 | | | 1.45 | | | | | | | | |

* For requests for wafer forms thinner than 0.40 mm, please contact us on piezosales@ctscorp.com.

Data represent typical material values. Actual production values may vary $\pm 10\%$ for dielectric properties and $\pm 5\%$ for electromechanical and physical properties.

Single Crystal Piezoelectric Materials

| Property | Symbol | Units | Material Type | | | | |
|--------------------------------------|----------------------|-------------------------------------|-------------------|-------------------|---------------|---------------|------|
| | | | PMN-28% PT Type A | PMN-32% PT Type B | PIN24%-PMN-PT | PIN33%-PMN-PT | |
| Density | r | kg/m ³ | 8100 | 8100 | 8122 | 8141 | |
| Phase Transition | T_{rt} | °C | 90-100 | 80-90 | 100-115 | 115-135 | |
| Curie Temperature | T_c | °C | 120-130 | 130-140 | 140-170 | 160-200 | |
| Coercive Field | E_c | kV/cm | 2.5 | 2.5 | 4.5-6 | 5.5-7 | |
| Piezoelectric Constants | d_{15} | pC/N | 135 | 192 | 122 | 147 | |
| | d_{31} | | -568 | -760 | -646 | -651 | |
| | d_{33} | | 1190 | 1620 | 1285 | 1338 | |
| | e_{15} | C/m ² | 8.69 | 8.69 | 8.52 | 9.48 | |
| | e_{31} | | -13.12 | -15.99 | -9.11 | -4.81 | |
| | e_{33} | | 21.72 | 19.42 | 17.60 | 19.31 | |
| | g_{15} | x10 ⁻³ Vm/N | 9.53 | 13.39 | 7.98 | 9.97 | |
| | g_{31} | | -11.67 | -12.29 | -15.36 | -16.23 | |
| | g_{33} | | 24.45 | 26.15 | 30.55 | 33.36 | |
| | h_{15} | x10 ⁸ V/m | 6.69 | 9.59 | 5.97 | 7.10 | |
| | h_{31} | | -16.55 | -25.81 | -11.86 | -6.00 | |
| | h_{33} | | 27.41 | 31.34 | 22.92 | 24.10 | |
| | Dielectric Constants | ϵ_{11}^S | (ϵ_0) | 1467 | 1368 | 1611 | 1509 |
| | | ϵ_{33}^S | | 895 | 700 | 868 | 905 |
| | | ϵ_{11}^T | | 1600 | 1620 | 1728 | 1666 |
| ϵ_{33}^T | | 5500 | | 7000 | 4753 | 4532 | |
| β_{11}^S | | x10 ⁻⁴ /(ϵ_0) | 6.82 | 7.31 | 6.21 | 6.63 | |
| β_{33}^S | | | 11.17 | 14.29 | 11.52 | 11.05 | |
| β_{11}^T | | | 6.25 | 6.17 | 5.79 | 6.00 | |
| β_{33}^T | | | 1.82 | 1.43 | 2.10 | 2.21 | |
| Electromechanical Coupling Constants | k_{15} | | 28% | 39% | 26% | 31% | |
| | k_{31} | | 43% | 44% | 46% | 47% | |
| | k_{33} | | 90% | 93% | 89% | 89% | |
| | k_t | | 60% | 62% | 50% | 54% | |
| Elastic Stiffness Constants | C_{11}^E | 10 ¹⁰ N/m ² | 11.58 | 11.21 | 12.43 | 11.57 | |
| | C_{12}^E | | 10.23 | 10.16 | 10.90 | 10.03 | |
| | C_{13}^E | | 9.31 | 9.04 | 11.02 | 10.15 | |
| | C_{33}^E | | 10.71 | 9.68 | 12.45 | 11.32 | |
| | C_{44}^E | | 6.44 | 6.05 | 6.98 | 6.45 | |
| | C_{66}^E | | 6.01 | 5.51 | 6.21 | 5.44 | |
| | C_{11}^D | | 13.75 | 15.34 | 13.51 | 11.86 | |
| | C_{12}^D | | 12.40 | 14.29 | 11.98 | 10.32 | |
| | C_{13}^D | | 5.71 | 4.03 | 8.93 | 8.99 | |
| | C_{33}^D | | 16.66 | 15.77 | 16.49 | 15.97 | |
| | C_{44}^D | | 7.02 | 7.16 | 7.49 | 7.12 | |
| | C_{66}^D | | 6.01 | 5.51 | 6.21 | 5.44 | |
| Elastic Compliance Constants | S_{11}^E | 10 ⁻¹² m ² /N | 45.86 | 58.85 | 45.76 | 47.18 | |
| | S_{12}^E | | -28.11 | -36.58 | -19.60 | -17.75 | |
| | S_{13}^E | | -15.43 | -20.80 | -23.16 | -26.39 | |
| | S_{33}^E | | 36.15 | 49.18 | 49.04 | 56.15 | |
| | S_{44}^E | | 15.53 | 16.53 | 14.33 | 15.50 | |
| | S_{66}^E | | 16.64 | 18.15 | 16.10 | 18.38 | |
| | S_{11}^D | | 39.23 | 49.53 | 35.84 | 36.62 | |
| | S_{12}^D | | -34.73 | -45.90 | -29.52 | -28.32 | |
| | S_{13}^D | | -1.54 | -0.93 | -3.43 | -4.67 | |
| | S_{33}^D | | 7.06 | 6.82 | 9.78 | 11.52 | |
| | S_{44}^D | | 14.24 | 13.96 | 13.35 | 14.04 | |
| | S_{66}^D | | 16.64 | 18.15 | 16.10 | 18.38 | |