# 圧電材料定数値の取扱いについて
# Attention on using piezoelectric data

当圧電材料データ群は、（社）電子情報技術産業協会規格 JEITA：EM-4501（旧：EMAS-6100 ）あるいは、米国DOD-Standard：1376B / SH などの公的規格に規定された標準試験片の計測方法に基づき得られた静的・無負荷・1Vrms条件下のデータです。
従いまして必ずしも当データ群に基づくシミュレーション結果の正確性はもとより、実際の製品駆動条件等を含めたあらゆる動的状態を弊社として保証するものではありません。
有限要素解析法などのインプットパラメータとしてご使用になる際には、これらの点を十分ご考慮頂きますよう、 お願い致します。
なお、各特性値はあくまで規定の標準試験片形状における代表値であり、弊社保証値ではありません。
空欄は取得データがございませんのでご了承願います。
また、当データ群は予告なく変更することがありますので予めご了承願います。

The piezoelectric data are measured with based on the measurement procedure prescribed by official standards such as JEITA : EM-4501 (Japan) and / or DOD-Standard : 1376B / SH (US).
Following the official standards, provided data are basically the result of the standard shape specimen under the static measuring condition. ( ex. 1vrms, The specimen is non-loaded. )
Therefore, NTK do not guarantee " the accuracy of the simulation result " and also " every dynamic status including real product's driving situation" .
When you use them as input parameters for the finite element analytical methods, please consider these points enough. In addition, each datum is just a representative value of the standard shape specimen, so NTK do not guarantee each characteristic value.
We do not have the measuring data in the blank column. Thank you for your understanding.
Please note that NTK may change the data without a notification.

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# 圧電材料特性表①　Piezoelectric characteristics①

| 圧電特性 Piezoelectric Characteristics | 記号 Symbol | その他の代用記号 | Navy Type | I | | II | | | III | | VI | 無鉛 Lead Free | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 単位 Unit | MT-18 | MT-18K | MT-107 | MT-501 | E | MT-811 | MT-812A | MT-111H | LF02B | LF04A | LF05B |
| 比誘電率 Relative Dielectric Constants | $\varepsilon_{33}^{t}/\varepsilon_0$ | $K_{33}^{T}$, εr , ε | 無次元無単位 Dimensionless Unitless | 1400 | 1450 | 1800 | 1800 | 1920 | 1000 | 1100 | 3800 | 1400 | 2200 | 700 |
| | $\varepsilon_{11}^{t}/\varepsilon_0$ | $K_{11}^{T}$ | | 1250 | 1300 | 1630 | 1900 | 1900 | 1170 | 1220 | 2550 | 1300 | 1900 | 800 |
| | $\varepsilon_{33}^{s}/\varepsilon_0$ | $K_{33}^{s}$ | | | | 810 | | | 615 | | | 990 | 1300 | 500 |
| | $\varepsilon_{11}^{s}/\varepsilon_0$ | $K_{11}^{s}$ | | | | 960 | | | 760 | | | 1000 | 1400 | 450 |
| 誘電損失 Dielectric Loss (Dielectric Loss Tangent) | tan δ | D.F. | % (ex : 0.4%=0.004) | 0.4 | 0.35 | 2.0 | 1.7 | 2.0 | 0.18 | 0.18 | 2.5 | 1.3 | 1.9 | 0.4 |
| 結合係数 Coupling Factors | kp | kr | %表記する場合もある (ex : 0.60 = 60%) | 0.53 | 0.60 | 0.66 | 0.64 | 0.56 | 0.53 | 0.53 | 0.62 | 0.47 | 0.53 | 0.40 |
| | $k_{31}$ | - | | 0.30 | 0.34 | 0.34 | 0.38 | 0.31 | 0.31 | 0.30 | 0.33 | 0.27 | 0.3 | 0.24 |
| | $k_{33}$ | - | | 0.63 | 0.72 | 0.75 | 0.72 | 0.72 | 0.62 | 0.56 | | 0.50 | 0.59 | 0.46 |
| | kt | - | | 0.34 | 0.41 | 0.49 | 0.50 | 0.44 | 0.49 | 0.48 | | 0.39 | 0.47 | 0.38 |
| | $k_{15}$ | - | | 0.41 | 0.54 | 0.64 | 0.71 | 0.66 | 0.59 | 0.59 | | 0.46 | 0.52 | 0.66 |
| 圧電d定数 Piezoelectric Strain Constants | $d_{31}$ | - | pico Coulomb / Newton = pico meter / Volt (pC / N = pm / V) ($x10^{-12}$ C / N=$x10^{-12}$m / V) | -104 | -142 | -200 | -180 | -160 | -102 | -80 | -310 | -95 | -148 | -55 |
| | $d_{33}$ | - | | 270 | 340 | 450 | 410 | 425 | 225 | 230 | 620 | 180 | 300 | 110 |
| | $d_{15}$ | - | | 250 | 300 | 550 | 615 | 570 | 360 | 368 | | 260 | 370 | 300 |
| 圧電g定数 Piezoelectric Voltage Constants | $g_{31}$ | - | milli-Volt meter / Newton ( $x10^{-3}$ V･m / N ) | -9.2 | -10.5 | -11.5 | -11.0 | -9.4 | -10.4 | -11.5 | -8.0 | -8.1 | -7.7 | -9.4 |
| | $g_{33}$ | - | | 24.0 | 26.5 | 25.0 | 25.7 | 21.9 | 25.4 | 20.6 | 12.5 | 15.4 | 15.5 | 18.4 |
| | $g_{15}$ | - | | 23.0 | 26.9 | 26.1 | 34.5 | 34 | 35.1 | 34.1 | 15.0 | 22.9 | 21.6 | 43.1 |

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# 圧電材料特性表②　Piezoelectric characteristics②

| 圧電特性 Piezoelectric Characteristics | 記号 Symbol | その他の代用記号 | Navy Type | I | | II | | | III | | VI | 無鉛 Lead Free | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 単位 Unit | MT-18 | MT-18K | MT-107 | MT-501 | E | MT-811 | MT-812A | MT-111H | LF02B | LF04A | LF05B |
| 周波数定数 Frequency Constants | Np | Nr | Hz・meter (Hz・m) | 2250 | 2200 | 1950 | 2050 | 2090 | 2320 | 2375 | 1950 | 3200 | 2990 | 3400 |
| | $N_{31}$ | - | | 1650 | 1650 | 1370 | 1460 | 1460 | 1720 | 1780 | 1400 | 2200 | 2130 | 2500 |
| | $N_{33}$ | - | | 1500 | 1500 | 1300 | 1410 | 1410 | 1610 | 1630 | 1400 | 2300 | 2120 | 2500 |
| | Nt | - | | 2200 | 2150 | 1900 | 1970 | 2040 | 2090 | 2080 | 2000 | 2900 | 2560 | 2900 |
| | $N_{15}$ | - | | 1000 | 1300 | 1050 | - | 890 | 1160 | 1170 | 900 | 1500 | 1430 | 1400 |
| 機械的品質係数 Mechanical Quality Factor | Qm | - | 無次元無単位 Dimensionless Unitless | 1300 | 1800 | 70 | 75 | 60 | 1200 | 1350 | 65 | 100 | 50 | 910 |
| ポアソン比 Poisson's Ratio | $\sigma_E$ | σ | | | 0.32 | - | | 0.39 | 0.30 | 0.28 | | 0.36 | 0.35 | 0.29 |
| 3点曲げ強度 Bending Strength (3 Points) | $\sigma b_3$ | - | $N / mm^2$ ($X 10^{-3}$ GPa) | 118 | 134 | - | | | 105 | 105 | | | | |
| 圧縮強度 Compression Strength | σc | - | $N / mm^2$ ($X 10^{-3}$ GPa) | | 630 | - | | | 420 | 420 | | | | |
| キュリー点温度 Curie Point Temperature | Tc | - | ℃ | 300 | 300 | 350 | 360 | 320 | 310 | 300 | 220 | 290 | 250 | 340 |
| 密度 (固体比重) Density (Specific Gravity) | ρ | D , SG | $g / cm^3$ | 7.60 | 7.65 | 7.86 | 7.90 | 7.65 | 7.69 | 7.63 | 7.70 | 4.55 | 4.45 | 4.50 |

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# 圧電材料特性表③　Piezoelectric characteristics③

| 圧電特性 Piezoelectric Characteristics | 記号 Symbol | その他の代用記号 | Navy Type | I | | II | | | III | | VI | 無鉛 Lead Free | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 単位 Unit | MT-18 | MT-18K | MT-107 | MT-501 | E | MT-811 | MT-812A | MT-111H | LF02B | LF04A | LF05B |
| 弾性コンプライアンス定数 Elastic Compliance | $s_{11}^E$ | - | $x10^{-12}$ meter$^2$/ Newton ($x10^{-12}$ m$^2$/N) | 12.3 | 12.5 | 17.3 | 15.8 | 15.4 | 10.9 | 10.4 | 16.7 | 11.0 | 12.4 | 8.8 |
| | $s_{12}^E$ | - | | | -4.0 | | -5.4 | -6.0 | -3.3 | -2.9 | | -3.9 | -4.3 | -2.6 |
| | $s_{13}^E$ | - | | | -5.7 | | -8.3 | -4.4 | -4.7 | -4.4 | | -4.0 | -4.2 | -2.9 |
| | $s_{33}^E$ | - | | 15.8 | 16.0 | 22.0 | 21.0 | 18.1 | 13.5 | 13.0 | 17.6 | 11.2 | 13.3 | 9.4 |
| | $s_{44}^E$ | - | | | 41.8 | 50.8 | 41.5 | 44.6 | 36.8 | 36.2 | | 27.3 | 28.9 | 30.3 |
| | $s_{11}^D$ | - | | | 10.9 | | | | 9.8 | 9.3 | | 10.2 | 11.3 | 8.3 |
| | $s_{12}^D$ | - | | | -5.3 | | | | -4.3 | -3.7 | | -4.7 | -5.5 | -3.1 |
| | $s_{13}^D$ | - | | | -2.5 | | | | -2.1 | -2.4 | | -2.5 | -1.9 | -1.9 |
| | $s_{33}^D$ | - | | | 8.0 | | | | 8.4 | 9.0 | | 8.5 | 8.7 | 7.5 |
| | $s_{44}^D$ | - | | | 21.0 | 29.9 | | | 24.0 | | | 21.4 | 21 | 17.3 |
| | $s_{66}$ ($=s_{66}^D=s_{66}^E$) | | | | 32.4 | 47.4 | 42.7 | 42.8 | 28.2 | | | 29.8 | 33.5 | 22.8 |
| 弾性スティフネス定数 Elastic Stiffness | $c_{11}^E$ | - | $x10^{10}$ Newton / meter$^2$ ($x10^{10}$ N / m$^2$) | | 15.1 | 13.0 | | | 15.0 | | | 15.2 | 12.2 | 15.6 |
| | $c_{12}^E$ | - | | | | 8.8 | | | 7.9 | | | 8.5 | 6.3 | 6.9 |
| | $c_{13}^E$ | - | | | | 8.2 | | | 7.9 | | | 8.4 | 5.8 | 7.0 |
| | $c_{33}^E$ | - | | | 12.8 | 10.7 | 12.1 | | 12.9 | 12.7 | | 14.8 | 11.2 | 14.9 |
| | $c_{44}^E$ | - | | | 2.3 | 2.0 | 2.4 | | 2.7 | | | 3.7 | 3.5 | 3.3 |
| | $c_{11}^D$ | - | | | 15.3 | 13.4 | | | 14.7 | 15.4 | | 15.9 | 13.1 | 16.1 |
| | $c_{12}^D$ | - | | | | 9.2 | | | 7.6 | | | 9.2 | 7.1 | 7.4 |
| | $c_{13}^D$ | - | | | | 6.9 | | | 5.5 | | | 7.4 | 4.5 | 6.1 |
| | $c_{33}^D$ | - | | | 16.5 | 14.2 | 15.1 | | 14.7 | 16.3 | | 17.4 | 14.4 | 17.5 |
| | $c_{44}^D$ | - | | | 4.7 | 3.4 | 4.9 | | 4.2 | | | 4.7 | 4.8 | 5.8 |
| | $c_{66}$ ($=c_{66}^D=c_{66}^E$) | | | | 3.1 | 2.1 | 4.3 | | 3.5 | | | 3.4 | 3.0 | 4.4 |

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