Geometric properties

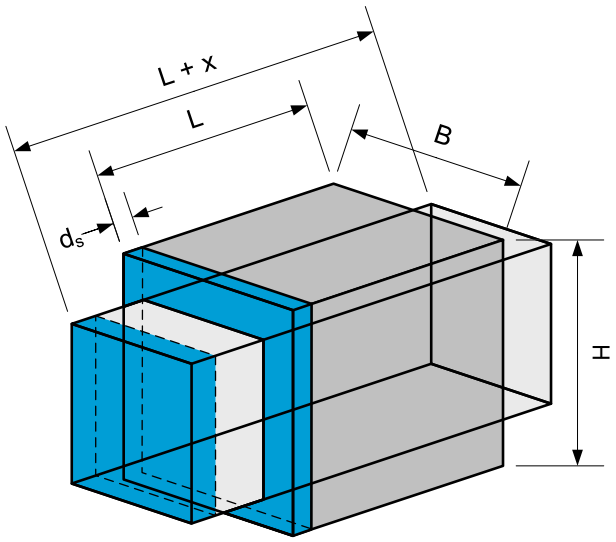
$A = H \cdot B\ [m^2]$	Cross section area
$d_s[m]$	Layer thickness (typical 60-500 µm)
$n = \frac{L}{d_s}[-]$	Number of layers

Material Properties

$\rho = 7.8e3\,\frac{kg}{m^3}$	Density
$E = 36e9\,\frac{N}{m^2}$	Young's modulus
$\nu = 0.34$	Poisson ratio
$\xi = 0.1$	Damping constant (estimate)
$-271^oC < T < 150^oC$	Operating temperature
$\varepsilon_{33} = 300 - 4000$	Dielectric constant (typical value = 1750)
$d_{33} = 4e-10\,\frac{m}{V}$	Charge constant
$HC = 350\,\frac{J}{kg \cdot K}$	Spec. heat capacity
$TC = 1.1\,\frac{W}{mK}$	Spec. thermal conductivity
$-20V < U < 120V$	Typical voltage

Mechanics

$\Delta L_{max} = \frac{L}{1000}$	Maximum displacement
$C_{axial} = \frac{EA}{L}$	Axial stiffness
$D = 2\xi\sqrt{C_{axial} m}$	Damping
$f_0 = \frac{1}{2\pi}\sqrt{\frac{C_{axial}}{m}}$	Resonance frequency
$t_{min} = \frac{1}{3f_0}$	Minimum rise time
$\varphi = 2\arctan\left(\frac{f}{f_0}\right)$	Phase lag
$F_{blocking} = \Delta l_{max} \cdot C_{axial}$	Blocking force
$\sigma_{dynamic} = 15\ MPa$	Preload for dynamic use
$\sigma_{static} = 30\ MPa$	Preload for static use
$4 - 20\ \%$	Hysteresis
$\Delta x_{creep}(t) = x \cdot 0.01 \cdot \log\left(\frac{t}{0.1}\right)$	Creep @ t [s]
$F_{pre\ tension} = \frac{1}{2}F_{blocking}$	Pre tension force (matching push-pull force)



Geometric characteristics of a Piezo stack.

Electronics

$x = d_{33} \cdot L \cdot \frac{U}{d_s}$	Displacement @ U [V]
$\varepsilon_0 = 8.9e-12\ \frac{F}{m}$	Permittivity of free space
$C_S = n \cdot \varepsilon_0 \cdot \varepsilon_{33} \cdot \frac{A}{d_s}$	Small signal capacitance (typical for U < 100 V)
$C_L = 1.7 \cdot C_S$	Large signal capacitance (typical for U > 100 V)
$P = \frac{1}{2} \cdot f \cdot C \cdot U^2$	Average Polarization Power
$E = \frac{1}{2} \cdot C \cdot U^2$	Polarization energy

Not generic for all frequency ranges, just for indication:

$\tan\delta_U = 0.015 + 0.016\sqrt{\frac{U}{[V]}}$	Loss factor @ U [V]
$\tan\delta_T = 0.28 + 0.17 \cdot \ln\left(\frac{T}{[K]}\right)$	Loss factor @ T [K]
$\tan\delta = \tan\delta_U + \tan\delta_T$	Loss factor
$P_{heat} = P \cdot \tan\delta$	Heat generation