Frequently asked questions

Question:

How much energy can I extract from a piece of piezoceramic material?

Answer:
As an example of the energy generated by the piezoelectric effect, the following case is considered:

A force of 100 N compresses a cubic plate of Pz27 with dimensions L x W x Th = 10x10x10mm^3
The force is applied momentarily, and only once.

Relevant table values needed in calculation:		
$g_{33} = 27 \cdot 10^{-3}$ V·m/N	$k_{33} = 0{,}70$	$s^D_{33} = 12 \cdot 10^{-12}$ m²/N

First the stress level, X3, generated by the force is calculated:

$$X_3 = \frac{\text{Force}}{\text{Area}} = \frac{-100\ \text{N}}{1 \cdot 10^{-4}\ \text{m}^2} = -1 \cdot 10^{6}\ \text{Pa} = -1\ \text{MPa}$$

From the stress level we can calculate the generated electrical field (and generated voltage):

$$E_3 = -g_{33} \cdot X_3 = 27 \cdot 10^{-3}\ \text{V·m/N} \cdot 1 \cdot 10^{6}\ \text{Pa} = 27 \cdot 10^{3}\ \text{V/m}$$
$$U_3 = E_3 \cdot Th = 27 \cdot 10^{3}\ \text{V/m} \cdot 1 \cdot 10^{-2}\ \text{m} = 270\ \text{V}$$

As an assumption, we consider the cube to be compressed in open-circuit conditions. With a known elastic compliance for Pz27, combined with the applied stress, we can calculate the strain, S_3:

$$S_3 = s^D_{33} \cdot X_3 = -12 \cdot 10^{-12}\ \text{m}^2/\text{N} \cdot 1 \cdot 10^{6}\ \text{N/m}^2 = -12 \cdot 10^{-6}$$

From the strain we can calculate the change in thickness:

$$\Delta Th = Th_0 \cdot S_3^D = -1 \cdot 10^{-2}\ \text{m} \cdot 12 \cdot 10^{-6} = -1{,}2 \cdot 10^{-7}\ \text{m} = -120\ \text{nm}$$

With a known dimension change, we can calculate the mechanical work that has been performed:

$$W_{\text{mechanical}} = \tfrac{1}{2} \cdot F \cdot |\Delta Th| = \tfrac{1}{2} \cdot 100\ \text{N} \cdot 1{,}2 \cdot 10^{-7}\ \text{m} = 6 \cdot 10^{-6}\ \text{J} = 6\ \mu\text{J}$$

Finally we know that the coupling coefficient in a piezoelectric material is a measure of how much mechanical energy we can convert into electrical energy in one cycle (and vice versa). The conversion follows the following relationship:

$$\sqrt{\frac{\text{Electrical energy output}}{\text{Mechanical energy stored}}} = k = \sqrt{\frac{\text{Mechanical energy output}}{\text{Electrical energy stored}}}$$

Based on this, we can finally calculate the electrical energy that is generated by the compression of the Pz27 cube:

$$W_{\text{electrical}} = k_{33}^2 \cdot W_{\text{electrical}} = 0{,}70^2 \cdot 6 \cdot 10^{-6}\ \text{J} = 2{,}94\ \mu\text{J}$$

From this result we can clearly conclude that piezoelectric materials are extremely poorly suited as a medium for energy storage or generation.

The strength of piezoelectrics is however, that they work very efficiently at high frequencies, and can transform electrical energy into mechanical energy, or vice versa, with very low losses.
Even if the coupling coefficient is "only" 70%, it is not a problem to have a total conversion of more than 95%. This is due to the fact, that the coupling coefficient only expresses the conversion per cycle. A significant amount of energy can thus be cycled inside the transducer in operation.