Resonant frequency and rise time calculations for NanoPositioning stages/actuators

In many applications, where piezo driven stages/actuators are used, it is important to know the resulting resonant frequency based on the load. It is also important to have an idea about the rise time for applications that require high dynamic response. The goal of this tech note is to show how these two important characteristics can be calculated:

Resonant frequency of the stage under given load conditions:

The resonant frequency is determined by the stiffness and the mass distribution within the stage/ actuator:

$$f^0_{res} = \frac{1}{2\pi}\sqrt{\frac{c_T}{m_{eff}}}$$

f^0_{res} - resonant frequency under no load

c_T - stiffness

m_{eff} - effective mass

From the above formula, it is easy to calculate the effective mass, since both the unloaded resonant frequency and stiffness are given.

If an additional mass (M) is added to the stage/actuator, the resonant frequency is reduced:

$$f^1_{res} = \frac{1}{2\pi}\sqrt{\frac{c_T}{m_{eff}+M}} = f^0_{res}\cdot\sqrt{\frac{m_{eff}}{m_{eff}+M}}$$

Rise time:

Because of their high resonant frequency piezo driven stages/actuators are well suited for fast response. The shortest rise time to expand the stage/actuator is determined by its resonant frequency:

$$t_{min} \approx \frac{1}{3\cdot f_{res}}$$

The rise time also depends on the maximum current of the driver electronics, which for a dynamic operation with a sinusoidal function is determined by

$$i_{max} = \pi\cdot f\cdot C\cdot U_{pp}$$

i_{max} - peak current (40 mA, when driven by NPC3 or NPC3-SG controllers)

U_{pp} - peak to peak drive voltage (max voltage corresponds to max travel)

f - frequency

C- capacitance of the actuator (provided by the manufacturer)

Example: Estimate the resonant frequency and the rise time for PSM2SG at 1N load.

Step 1: From PSM2SG specs

f^0_{res} - 5400 Hz

c_T = 65 N/µm

C = 1.8 µF

Step 2: From formulas discussed above:

5.4 = 1/2 * 3.14 √65 / m_{eff}

m_{eff} = 65 / 1149.6 = 0.06 kg

f^1_{res} - 5.4 √ 0.06/ (0.06+0.1) = 3.3 kHz

t_{min} = 1/ 3*3.3 = 0.1sec