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Calculation of Self-Resonant Frequencies of Membrane Structures with Help of Schematic Design Program Package

A. I. Petrenko, V. V. Ladogubets, A. Yu. Beznosyk, A. D. Finogenov, and A. V. Tchkalov

Institute of Applied System Analysis of National Technical University of Ukraine "Kyiv Polytechnic Institute" (ESC IASA NTUU "KPI"), Kyiv, Ukraine

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Abstract—It is proposed an application of finite-element mathematical model for obtaining of equivalent electrical circuit by mechanical components substitution. To reduce dimension of obtained circuits we propose to use *RLC* reduction. It is considered an example of equivalent electrical circuit of micro accelerometer obtain. Mentioned approach is spread to equivalent circuits of MEMS components obtaining.

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Development of MEMS components requires calculation of electrical and non-electrical components parameters. With purpose of this problem solution it is frequently used an approach, based on developed objects characteristics according to their mathematical model, which is frequently obtained by finite element method. Essential drawback of this method is dimension of obtained mathematical model (10^4 and more equations). To eliminate this drawback methods, described in paper [1], allowing to reduce mathematical model dimension, are frequently used. But for joint calculation with schematic design program package, using united basis, it is necessary to include in these CADs bases, which are not typical for electrical components calculation.

Another method of the problem solution is electromechanical analogy method application. Basing on paper [2], it is possible to describe an object in form of equivalent electrical circuit on a basis of mathematical model. But application of obtained circuit as a basic one is restricted due to its dimension (elements count). But in this case reducing methods, based on Y-Δ transformation, are available, that makes possible obtaining of reduced object electrical circuit of required adequacy and allows to use schematic design package.

Now we consider this approach using example of natural frequencies obtain.

Among modern MEMS different converters, for example microelectromechanical capacity converters, are the most widespread. These converters consist of metalized membrane (upper electrode), which is pending over silicone plate (lower electrode). Its schematic circuit is shown in Fig. 1.

In case of voltage supplying electrodes are attracted by coulomb forces. From the other hand mechanical stresses in membrane material balance attractive forces. If electrodes are fed by correspondent frequency voltage, then membrane generates ultrasonic oscillations. Otherwise, if electrodes are fed by correspondent bias voltage, membrane oscillations result in correspondent alternating current generation, that can be used for oscillations parameters measuring.

To illustrate this now we consider following example. Membrane is made in form of silicone square plate *1* with a side of 50 μm. Plate sides lean on a surface, the other membrane surface is free and it can oscillate. Metallic weight in form of square plate *2* with a side of 10 μm is fixed at the center of the plate (Fig. 2).

If object, where membrane is placed, moves with acceleration **a**, then weight is influenced by force of inertia $\mathbf{\Phi} = -m\mathbf{a}$, which is applied in opposite direction that results in membrane deflection. Since this deformation is reversible, then there is a dependence of membrane deflection on inertia force, so object acceleration can be defined using deflection.

To construct mathematical model we use ANSYS Multiphysics v. 10.0, developed by ANSYS Inc. [3]. For beam discretization we use standard rectangular finite components of SHELL93 type with dimension 5×5 μm. Such elements were used to describe central part, but coefficient of elasticity and density were set