Co-simulation and Optimization Micro Electro Mechanical Systems by Using Method of Theoretical Investigation by V. Mkrttchian

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ABSTRACT

Before elaboration and designing of micro electromechanical systems (MEMS) it is very important to carry out an appropriate computer modeling for analyzing and optimizing. To describe adequately the physical phenomenon talking place in MEMS it is necessary to revise the emitting methods of theoretical investigation and choose a suitable one. For theoretical investigation of uniform MEMS several methods have been developed. One of the widely used methods is the well-known coupled-wave theory . For periodical structures transfer matrix method and Bloch wave analysis have been used successfully. Other less employed methods have been devoted for uniform MEMS analysis.

They are the Round's method, a discrete – time approach based on a digital signal processing formulation and a Hamiltonian formulation for coupled-wave equations. For nonuniform MEMS transitive and reflective properties investigation the extension of the methods described above has been used. They are the extensions of transfer matrix method, Bloch wave analysis generalization , coupled-wave theory and analysis methods extension. A variation technique and a Hamiltonian approach for non uniform MEMS analysis have been employed also.

The all generalized methods for non uniform MEMS investigation have a restriction on the amplitude of modulation. The reason is that for these methods it's significant that the wave equation solution is searched as a superposition of counter-propagating waves. The last condition badly complicates the problem solving in the case of non periodically and strongly modulated media.

The proposed non-traditional method of theoretical investigation is free from the above-mentioned drawbacks. It is based on the fact, that a solution of the wave equation in a modulated media is searched in the form of a single expression, but not in the form of generally accepted counter-propagating waves. Such a form of wave equation solution has been proposed by a number of authors and further has been extended, basically, to investigate different types of multilayer structures. This method allows to solve the correct boundary problem not only for linear but for nonlinear media as well. Furthermore, this approach permits to carry out the investigation for media with losses (or gain) and doesn't need any preliminary assumptions concerning the form of wave equation solution (i.e. the form of traveling waves, counter-propagating waves, exponentially increasing or decreasing waves or others in the case of non linearity). Such a representation of wave equation solution is also very effective to investigate electromagnetic wave interaction with arbitrary modulated media (including nonlinear) and permits to solve numerically diverse problems easily and comparatively rapidly by using of a well-known Runge-Kutta method of numerical integration.

For computer modeling of desired type of MEMS the non-traditional method of theoretical investigation is suggested.

Preliminary computer co-simulations and optimizations for uniform MEMS (taking into account losses and gain) have been carried out by using of the above-described non-traditional method of theoretical investigation.

Keywords: micro electromechanical systems (MEMS), indicator of sliding mode, observer, anticipatory compensation, Discontinuous Control and Setting Adjustment (DC&SA).

CO-SIMULATION AND OPTIMISATION METHODS DESCRIPTION

The suggested MEMS co-simulation and optimization procedure is based upon a synthesis of two independent concepts of control, the sliding mode [1] and optimal rating [2] and Fuzzy function for digital elements of MEMS. The currently accepted title of this technique is DISCONTINUOUS CONTROL AND SETTING ADJUSTMENT (DC & SA). It was introduced by Vardan Mkrttchian, in 1990 for the first time [2].

The sliding mode is a technique used for discontinuous control and setting adjustment for MEMS optimization. Non-linear systems of equations in mathematical solutions generate models intended to obtain the object-transitive functions of chips using the operator-type forms yielded through consecutive analysis of spatial variables. The models of MEMS optimization will include transport delays within the system. The delays prevent HF switching, necessitating improvements to be made to the sliding-mode techniques. Control within sliding mode enables us to decrease the sensitivity to variations of MEMS characteristics making them independent upon the environment. The mentioned problems can be overcome by using asymptotic observers of state and anticipatory devices eliminating delays. The physical properties of controlled flow does not allow to use the object parameter identification. Developed in this paper is a statistical method based upon the optimal rating. Our purpose is to generate an optimization model of a MEMS package wherein the discontinuity of control in control components would be formulated preceding the stages of selecting the specifications. Discontinuous control systems is an efficient tool for solving an entire family of control problems and optimization problems for dynamic groups of MEMS. Discontinuity of control results in a discontinuity of the right-hand parts of the differential equations describing the system dynamic properties. Deliberate introduction of MEMS into the sliding-mode operation will necessitate a continuous monitoring of the sliding-mode occurrence and stability. The dynamic component is determined on the basis of caring out the known condition.

THEORETICAL BASE OF DC & SA

The models of object optimization will include transport delays within the system. The delays prevent HF switching, necessitating improvements to be made to the sliding-mode techniques. Control within sliding mode enables us to decrease the sensitivity to variations of chip characteristics making them independent upon the environment. The mentioned problems can be overcome by using asymptotic observers of state and anticipatory devices eliminating delays. The physical properties of controlled flow do not allow using the object parameter identification. Developed in this paper is a statistical method based upon the optimal rating? Our purpose is to generate an optimum solution wherein the discontinuity of control in control components would be formulated preceding the stages of selecting the specifications. Discontinuous-control systems are an efficient tool for solving an entire family of control problems and optimization problems for dynamic solutions. Discontinuity of control results in a discontinuity of the right-hand parts of the differential equations describing the system dynamic properties. Deliberate introduction of objects into the sliding-mode operation will necessitate a continuous monitoring of the sliding-mode occurrence and stability.

Sliding Mode

A distinguished feature of differential equations describing any control system is known to be the presence of a scalar of

$$\dot{x} = f(x,t,u), \quad u \in R^m .$$

vector parameter u referred to as *control:*

In early regulators, the controls have mostly been of relay type which was dictated by the need to make their implementation as simple as possible. As a result, the right-hand part of the differential equation of the system motion proved to be a discontinuous function of the system state vector. This has forced the control theory specialists think of an adequate description of the behavior of systems at discontinuity boundaries. For systems with isolated discontinuity points, some analysis and synthesis methods have been designed based on the classical theory of differential equations with the use of point-to-point transformations and averaging at the occurrence of high frequency switching.

Optimal Rating

One of the systems with discontinuous control is sliding modes adaptation to changing characteristics of the object and to processes existing in it. The accuracy of the existing methods of mode parameters correction in the class of self-optimizing systems and the systems with standard model to a great extent depend on the position of their working point because of transfer functions non-linear character. In this case the reaction of the system will be too slow and the control becomes unstable. That's why nominal optimum method has great perspectives. Here the new method of statistic and dynamic correction of mode parameters is suggested on the basis of the well-know method. It takes into consideration real and non-idealized characteristics of objects, variant and uncontrolled interference effecting on them. There the basic control parameters behind the variant values, have relay distribution and standard distribution. In both cases following the essence of the method of optimal rating of the controlling system is adjusted in the way to coincide the center of distribution of mode parameter with the center of the desired fanned-that is in admissible limits of the mistakes of system. The displacement of the points of the adjustment regulators, where the difference of hit probabilities of regulated values into the desired bands and out of them would be the greatest, is determined. In this case the system of regulation is adjusted in the way to coincide the desired value of the system with the center of distribution of mathematical waiting of the regulated value. The correction consists of two components: statistic one which is taking into consideration the variant character of input influences changes, and dynamic one which is taking into consideration the variant character of disturbances changes-parameters of object. Statistic component is determined in advanced and in the form of mass of data which is put into the memory of hosting computer. To define the statistic component, we use the continued or discrete model of the optimal rating, where the concept of some function is put in. This function characterizes the hit of the regulated parameter into the desired (admissible) band of mistakes of the control system. We call this function as " function of designees". It is defined for each concrete case on the basis deep analysis of technique-economic indices of control system.

THE MEMS SIMULATION RESULTS

It is our purpose to achieve a model suitable for use with all types of circuit simulations. Therefore it should be presented as a simple equivalent circuit. The circuit elements are derived from physical concepts which more often than not get lost whenever a complex model for a packaged device is extracted from an optimization model.

For the Finite Difference Time Domain computation of the package ports are defined on the coaxial lines as it is used in most simulators by observing wave ratios. The ports for chip connection are concentrated or internal ports defined by voltage and current. The resulting S-parameters of the ports are used to extract equivalent circuit elements leading to well defined values with physical sense.

The essential components of the MEMS simulation results are the sliding-mode indicator, observer and the anticipatory device.

Indicator of Sliding Mode

As was already noted, the approach used is oriented toward a deliberate introduction of sliding modes over the intersection of surfaces on which the control vector components undergo discontinuity. Realisation of such approach implies the knowledge of the conditions of the occurrence of sliding mode. Designed for this purpose was the indicator of sliding modes. From the point of view of mathematics, the problem may be reduced to that of finding the area of attraction to the manifold of the discontinuity surfaces intersection.

The sliding mode [4] is a technique used for discontinuous control and corrective devices[5] for chip-package optimization. Non-linear systems of equations in mathematical solutions generate models intended to obtain the object-transitive functions of chips using the operator-type forms yielded through consecutive analysis of spatial variables. The models of chip optimization will include transport delays within the system.

The delays prevent HF switching, necessitating improvements to be made to the sliding-mode techniques. Control within sliding mode enables us to decrease the sensitivity to variations of chip characteristics making them independent upon the environment.

The mentioned problems can be overcome by using asymptotic observers of state and anticipatory devices eliminating delays.

The physical properties of controlled flow does not allow to use the object parameter identification. Developed in this paper is a statistical method based upon the optimal rating.

Our purpose is to generate an optimization model of a transistor package wherein the discontinuity of control in control components would be formulated preceding the stages of selecting the specifications.

Discontinuous control systems is an efficient tool for solving an entire family of control problems and optimization problems for dynamic groups of bipolar transistor chips. Discontinuity of control results in a discontinuity of the right-hand parts of the differential equations describing the system dynamic properties. Deliberate introduction of transistor chips into the sliding-mode operation will necessitate a continuous monitoring of the sliding-mode occurrence and stability.

$$g = C_1 x + C_2 dx/dt$$

where: C_1, C_2 - constant of object of control;

x- is in parameter of system;

t- is time.

The indicator compares those two signals recording the moment of changing the signs of function x and g. Similar signs of functions x and g at the output of the indicator show zero potential (sliding mode does not occur in the equivalent circuit), differing signs on the output show negative potential (sliding mode does occur).

Observer

The state vector of the equivalent circuit is not given. The given data include only certain dimensions of the vector. The problem of identifying the state vector is solved based on data provided by the observer

$$dy/dt = Ay + Bx - L(z - Ky)$$

where A, B, L, K are the know matrixes;

y- is out parameter of system.

z - is the vector composed in the form of linear combinations of the system and, in fact, is its estimation.

In the equation the state vector of the system can be directly measured, and the last member of the equation characterizes the gap between the intended and actual parameters of the state vector of the equivalent circuit. The value of the gap will be the solution of the homogeneous differential equation with any desired distribution of roots of the characteristic equation. We can receive components of matrix L for each case by solving the equation and transforming the differential integrating links. The link of delay in the equivalent circuit is disregarded in the observer diagram. The block diagrams are built according to the expressions obtained for the observer diagram [3]

The link of pure delay which exists in the system is disregarded in the block diagrams.

- The resulting model is invariable to outside disturbances;

- Eliminating the need for specialised testing packages embracing equivalent MEMS circuits;

- Simplified modelling yielding excellent characteristics of DC, RF and large-amplitude signals.

- A full-scale description of the package with simulated ports will provide a data base for extracting physical parameters of the package model.

- Modelling of several MEMS having identical sizes and topology will generate a range of device models, such as a sliding-mode indicator, sliding-mode observer, and an anticipating device.

The Anticipatory Devices

The technique of anticipatory compensation is based upon the preliminary supply of input signal with regard to the duration of delay. Considering the delay, the problem of controlling a multi-level equivalent circuit can be presented as follows:

$$dy/dt = Ay + Bx(t - t)$$

where τ. -is delay.

$$y(t) = \exp(At)y_0 + \int_0^t \exp\{A(t - g)\}Bx(g - t)dg$$

The integral in equation is replaced by the sum and γ is replaced by z+t yielding the expression

$$y(t+t) = \exp(Az)\{u(t) + B\sum_{i=0}^{N}\exp(-Az_i)u(z_i + t - t)t / N\}$$

where N - number of fragments of time [3].

THE MEMS OPTIMIZATION RESULTS

For example, if as base stationary meaning it is accepted "0" and Q1=0.5, Q2=0.5, it means, that at the given size of external influence of a condition of second unit differs from stationary more, than condition of first unit. It is clear, that the meaning variable Q can change in limits from 0 up to 1.As for definition Q it is necessary to know stationary meaning of unit of the circuit, that depends on logic of functioning of the circuit, and size of external influence, in logic function of each element, except usual variable (inputs and outputs and internal units), determining meanings of influence of external influence on a condition of given unit are entered and special variable and technique is unacceptable. Thus, technique of logic modeling of the digital circuits for the account of influence of external influence in a general kind following:

1. On inputs of whole digital circuit any combination of signals moves.

2. Size of external influence In the minimum meaning B=Bmin is appropriated.

3. At the given meaning B for all elements, on models for definition of external influence are calculated of variable vectors MU.

4. For all elements the equations are decided, therefore meanings of condition of all units (Q) turn out at the given meaning B. At function evaluation can be used of various algebra.

5. The external influence is increased by size of its step: B=B+dB. If In < Bmax, transition to a step 3 is made.

6. Here already dependence of a condition of each unit of the circuit from B in a range Bmin-Bmax is received; Q=J(B). As allowable limits of change Q: Qmin, Qmax are given, it is possible to find intervals of change B, at which meaning Q in norm, and meaning B, at which the circuit is not efficient.

7. If yet there were the sets of entrance signals of the circuit, at which work of the circuit is not investigated at change B, a new combination gets out and transition to item 2 is made.

For realization of this algorithm it is necessary, that the program of the analysis, as against the usual programs of logic modeling, had the following peculiarities:

1. Variable should have continuous character and to change in range from 0 up to 1.

2. Into the program of logic modeling models for the definition of external influence should be entered. Thus the program should be open in relation to these models. Without fail into structure of these models tabulated model, as the most universal should be entered.

3. Logic functions of separate elements except usual variable can enter special variable, external influence showing influence. Thus it is necessary to distinguish variable these two types.

4. The program should have an opportunity to work various algebra (logic bases), and it should be open in relation to them.

Besides a means of entrance language of the program should allow the task:

1. Parameters of models for definition of meanings of external influence. .

2. Combinations of entrance signals (every possible or any particular (specific) sets).

3. Interval of change B.

4. Parameters of the target information.

CONCLUSION

1. A non-traditional method of simulation is suggested to describe the physical phenomenon-taking place in MEMS.
2. The MEMS simulation described is based upon the concepts of control, sliding mode and optimal rating.
3. The MEMS simulation results have been developed of a sliding mode indicator, observer, and the anticipatory compensation.
4.The MEMS optimization results have been developed of a technique of logic modeling of the digital circuits for the account of influence of external influence in a general kind.

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