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GENERATION INTERFERENCE DURING TRANSMISSION OF DIDGITAL SIGNALS IN HYBRID MICROCIRCUIT

Стаття присвячена аналізу міжелементних зв'язків в мікроелектронних гібридних мікросхемах з провідними каналами. Представлено як величина коефіцієнта взаємного впливу і максимальні значення індуктивних напруг в системі між структурами з провідними каналами можуть бути визначені на базі аналітичних співвідношень, ми базуємося на значеннях взаємних параметрів для моделі заміщення. Два паралельні канали у вигляді пасивно-активного каналу з постійною шириною і змінними відстанями описують модель системи. Змінне значення взаємних відстаней каналів встановило основний параметр дозволяючи керувати коефіцієнтом зв'язків. Вимірювання коефіцієнту зв'язків здійснювалося для різних значень відстаней між провідними каналами. Величини напруг, які вимірювалися на кінцях кожної активної і пасивної лінії, порівнювалися з величинами, отриманими в процесі аналізу.

This paper is devoted to the analysis of interelement couplings in a microelectronic hybrid circuit with reference to the structures of conducting paths. It presents how the value of the crosstalk coefficient and the maximum value of inductive voltages in the system, between the structures of conducting paths can be defined on the basis of analytic relations, we base on the values of mutually parameters for the replaced model. Two parallel paths in the configuration passive-active path with constant width and variable distance constitute the model of the system. The variable value of the mutual distance of the paths has constituted the main parameter allowing to control the coefficient of coupling. The measurements of the coefficient of couplings have been made for different values of the distance between the conducting paths. The values of voltages measured on the ends of each active and passive line have been compared to the values determined in the analysis.

1. Introduction

The analysis of electromagnetic couplings in a hybrid microcircuit is one of major problems of electromagnetic compatibility. Due to the knowledge of couplings mechanisms as well as methods allowing their calculation, their influence can be decreased in the design process.

The essential elements of the hybrid circuit are conducting paths made on the basis of Pd-Ag pastes. They are the main elements connecting single subassembly and elements. Unfortunately, non-zero values of their mutual capacity and inductance - especially critical in the near neighbourhood - become the main elements of the disturbances propagation. This effect is especially intensified during the transmission of signals with high frequency or signals with very short rise- and fall time of edges [1, 5]. The analysed model together with its corresponding equivalent elements is shown in fig. 1.

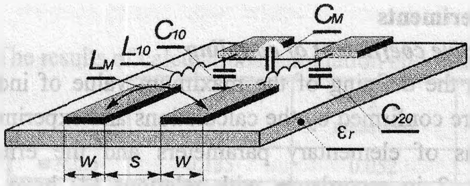

Fig. 1. The model system of coupled paths: w - path width, s - distance between paths.

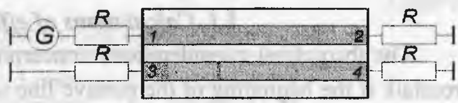

Fig. 2. The idea of measuring system.

2. Analysis of couplings coefficient in the parallel system of paths

The changeability of voltage and current for the optional system of mutual coupled conductive paths is possible to define through the solution of wave equations.

$$-\frac{\partial u}{\partial z} = \mathbf{R}\cdot i + \mathbf{L}\frac{\partial i}{\partial t} \qquad -\frac{\partial i}{\partial z} = \mathbf{G}\cdot u + \mathbf{C}\frac{\partial u}{\partial t} \tag{1}$$

In order to make it possible elementary parameters of the system of paths for the chosen configuration should be defined. In our case the wave method has been used to define the elementary parameters. The values of the elementary parameters for the examined configurations in accordance with the equivalent model presented in fig.1 have been determined from the expression:

$$C_{10} = C_{20} = \frac{\sqrt{\varepsilon_r}}{Z_{oe}\cdot c} \qquad C_M = \frac{\sqrt{\varepsilon_r}\left(1/Z_{oo} - 1/Z_{oe}\right)}{2\cdot c}\ [\mathrm{F/m}] \tag{2}$$

$$L'_{10} = L'_{20} = \frac{\sqrt{\varepsilon_r}\left(Z_{oe} - Z_{oo}\right)}{2\cdot c} \qquad L'_M = \frac{\sqrt{\varepsilon_r}\left(Z_{oe} - Z_{oo}\right)}{2\cdot c}\ [\mathrm{H/m}] \tag{3}$$

where: Z_{oe} - wave impedance of a line system for odd stimulation, Z_{oo} - wave impedance of line for even stimulation [2], c - velocity of light ($3\cdot10^8$m/s) , relative permittivity of the ceramic substrate (ε_r= 9.7).

Knowing these values it is possible to calculate voltage and current for a chosen parallel configuration of paths together with using simulation programmes, such as PSPICE or MICROCAP. However, in reality - especially for EMC aspects - the shape of the voltage or current course are not very often important but the maximum value of the induced disturbance in the disturbed circuit. The connecting quantity of the crosstalk quantity with equivalent parameters of the system of paths is the effective coefficient of coupling defined by the equation:

$$k_{eff} = \sqrt{\left(k_c^2 + k_m^2\right)/2} \tag{4}$$

where coefficient k_c - for the capacitive component and k_m - for the inductive component are defined by relations:

$$k_c = C'/C',\ \text{where}\ C' = C'_{10} = C'_{20} \quad k_m = L'_M/L',\ \text{where}\ L' = L'_{10} = L'_{20} \tag{5}$$

This coefficient (k_{eff}) allows to define the maximum value of crosstalk by impedance matching, in accordance with relations [4]:

$$U_{c\ \max} = \frac{U_o\left(1 - \sqrt{1 - k_{eff}^2}\right)}{2\cdot k_{eff}} \tag{6}$$

This value corresponds to the voltage value at the beginning of the passive line in point 3 (fig. 2).

3. Experiments

3.1. Calculations of effective coefficient of coupling

The theoretical considerations concerning the defining of the maximum value of induced crosstalk at the beginning of the passive line were confirmed by the calculations and experimental investigations. The results of the calculations of elementary parameters and the effective coefficient of couplings for the system in fig. 2 in accordance with relations (4) have been presented in table 1. The calculations were carried out for the system of two mutual parallel paths of the identical width w=1mm and mutual distance s = 0.5, 1.0 and 2.0 mm, respectively.

Table 1

Single parameters and values of coupling coefficient for the chosen systems of path.

	C, pF/m	C_M, pF/m	L, nH/m	L_M, nH/m	k_{eff}
w = 0.5	249	43.1	800	63.7	0.135
w = 1.0	256	24.2	804	36.3	0.074
w = 2.0	261	10.9	805	16.4	0.033

3.2. Measurements of values of effective coupling coefficient.

The tested circuit of conductive paths was made on the 96% Al_2O_3 ceramic substrate with geometrical dimensions 100×60×0.65 mm. The analysed samples had paths with constant width w = 1mm and mutual distance s = 0.5, 1, 2 mm, respectively. The full screen placed on the opposite side of the substrate was used as a reflexive conductor. The topology of the analysed system paths is presented in fig. 3.

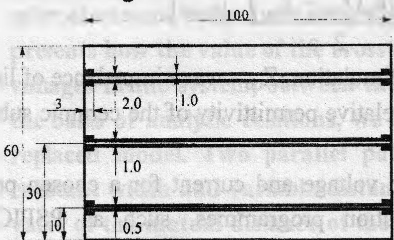

Fig. 3. Topology of conductive path system in test samples.

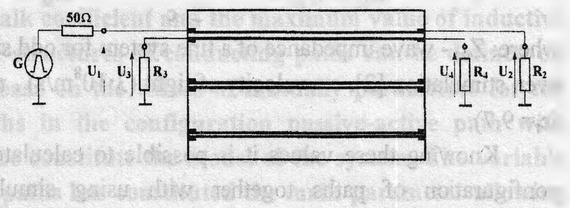

Fig. 4. Measuring diagram: R_1=R=R_3=R_4=50 Ω

During the measurements in accordance with the calculations, the influence of mutual distance between the paths on the value of crosstalk by impedance matching was analysed. The calculated value of wave impedance of the line is equal Z_o = 48 W. The measuring system is shown in fig. 4. The voltage pulse with U_o =10V amplitude, rise and fall time of edges $t_a = t_f$ = 2ns and the duration t_d=6ns was used as a testing pulse.

4. The results of calculations and measurements

Basing on the values presented in table 1, the value of crosstalk coefficient in accordance with relations (6) and on the basis of measurements and simulation was defined for the analysed system of paths in accordance with the equation:

$$\chi = U_3/U_1 \tag{7}$$

where: U_1 - voltage at the begining of active line, U_3 - voltage at the beginning of passive line

The obtained results have been presented in table 2.

Table 2

The results of calculations, simulation and measurements of crosstalk coefficient.

	K_{eff}	χ measured	χ_{PSPICE} calculated	$\chi_{RELATION\ 6}$ calculated
w = 0.5	0.135	0.052	0.058	0.067
w = 1.0	0.074	0.030	0.032	0.037
w = 2.0	0.033	0.013	0.014	0.016

Small divergences of results between the measurements, simulations and calculations confirm the correctness of relations describing the coefficient of the coupled line and the crosstalk coefficient.

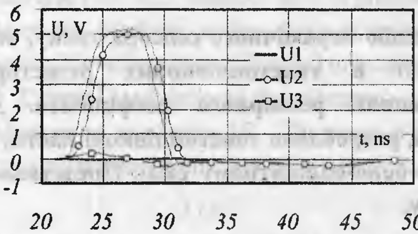

Fig. 5. The measured courses of voltage for chosen measuring points. (w=1mm,s=0.5mm $R_1 = R_2 = R_3 = R_4 = 50\ \Omega$).

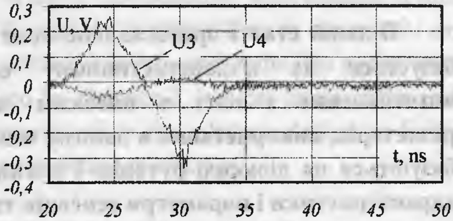

Fig. 6. The course of crosstalk voltage at the beginning and at the end of the passive line by impedance matching. (w=1mm, s=0.5mm $R_1 = R_2 = R_3 = R_4 = 50\ \Omega$)

The examples of voltage courses in passive and active line are presented in fig. 5 and fig. 6. These are the measurements for the impedance matching.

5. Conclusions

- ♦ The introduction of impedance matching in the system of parallel paths allows to eliminate only the crosstalk at the end of the passive line, instead of at its beginning; it depends on the mutual distance between paths.
- ♦ The increase of mutual distance between the paths makes possible the decreasing value of the coupling coefficient.
- ♦ The analysis of quantity of induced disturbances in the disturbed path is possible after defining L' and C' elementary parameters for the analysed system of paths.
- ♦ The high convergence of calculation results and measurements show the correctness of relations used to define the coupling coefficient of the line and the crosstalk coefficient.

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