# EXAMINATION OF BOUNDARY LOCATION INFLUENCE ON PERIODIC WIRING CAPACITANCE SIMULATION

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The influence of the boundary location on periodic wiring capacitance simulation has been investigated. The wiring capacitances were calculated by solving Laplace's equation in the simulation. The Dirichlet type boundary conditions were set for the electrodes, and the Neumann type for the symmetric planes. The wiring patterns used in VLSI are periodic, hence simulation is usually performed using the calculation region shown in Fig. 1 (a), where the Neumann boundary plane is placed at the center of an *electrode* ($E_2$ type). However, we have found that the wiring capacitance depended strongly on the boundary location. When the Neumann boundary plane is placed at the center of an *insulator* ($I_2$ type), as shown in Fig. 1 (b), the simulated capacitance value results in a large difference compared with the one for the $E_2$ type.

Figure 2 (a) shows the calculation regions for an $I_n$ type, where the number of including electrodes $n$ is a parameter. The simulated capacitances for $I_n$ are shown in Fig. 2 (b). The capacitance values depend strongly on the calculation regions. Comparison of the simulated $C_{1,2}$ values for $I_2$ and $I_5$ resulted in a 15.2 percent difference. In addition, $C_{2,3}$ did not coincide with $C_{1,2}$ for $I_4$ and $I_5$.

The above dependency is explained as follows. Due to the Neumann boundary condition employed for the side planes, the equivalent applied bias for the $I_2$ type is as shown in Fig. 3. Hence, the simulated capacitance for the $I_2$ type is expressed by the following equation.

$$\begin{aligned} C_{1,2}^{I_2} &= C_{1,2}^* + C_{1,3}^* + C_{1,-2}^* + C_{1,-3}^* + C_{1,6}^* + C_{1,7}^* + \cdots \\ &= C_{1,2}^* + 2C_{1,3}^* + C_{1,4}^* + \sum_{j=1}^{+\infty} (C_{1,4j+2}^* + 2C_{1,4j+3}^* + C_{1,4j+4}^*) \end{aligned} \tag{1}$$

where the superscript * means the true capacitance. $C_{1,2}^{I_2}$ is not equal to $C_{1,2}^*$. This discrepancy originates from the additional charge induced by the electrodes except electrode 2 due to the Neumann boundary condition. The simulation always overestimated the capacitance value. The same explanation is applicable to the $E_2$ type, and the capacitance is given as

$$C_{1,2}^{E_2} = C_{1,2}^* + \sum_{j=1}^{+\infty} C_{1,2j+2}^* \tag{2}$$

The general expressions of $C_{1,2}$ for $I_n$ and $E_n$ ($n \geq 3$) are obtained as follows.

$$C_{1,2}^{I_n} = C_{1,2}^* + C_{1,3}^* + \sum_{j=1}^{+\infty} (C_{1,2nj-1}^* + C_{1,2nj}^* + C_{1,2nj+2}^* + C_{1,2nj+3}^*) \tag{3}$$

$$C_{1,2}^{E_n} = C_{1,2}^* + \sum_{j=1}^{+\infty} (C_{1,2(n-1)j}^* + C_{1,2(n-1)j+2}^*) \ . \tag{4}$$

In previous works [1]-[3], excellent agreements between measurements and simulations have been reported. The typical wiring pattern layout for the measurements has been periodic, as shown in Fig. 4. This measurement corresponds to an $E_2$ type simulation. Hence, the measured capacitance values agree well with the simulation of the $E_2$ type. However, this measured capacitance also involves the same error as (2).

In summary, the influence of the boundary location on periodic wiring capacitance simulation has been examined. The dependence of the capacitance values on the calculation region originates from the additional charge induced by the unexpectedly biased electrodes due to the Neumann boundary condition. It should be noted that measurements with a periodic wiring pattern also involve an error due to the periodic nature of the wiring.

References


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[3] T. Shibata, N. Shigyo, K. Kurosawa, R. Nakayama, R. Dang and H. Iizuka, "Capacitance Modeling and Measurements of Fine-Patterned Interconnects," Abstracts of ECS Spring Meeting, pp. 677-678, 1981.


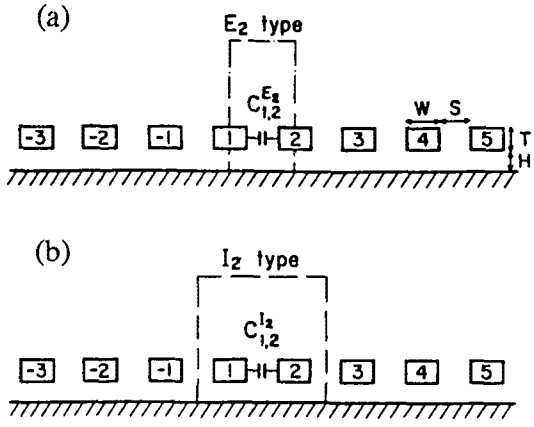


Fig. 1 Boundary conditions for periodic wirings.
(a) $E_2$ type : Neumann boundary plane is placed at the center of the electrode.
(b) $I_2$ type : Neumann boundary plane is placed at the center of the insulator between neighboring electrodes.

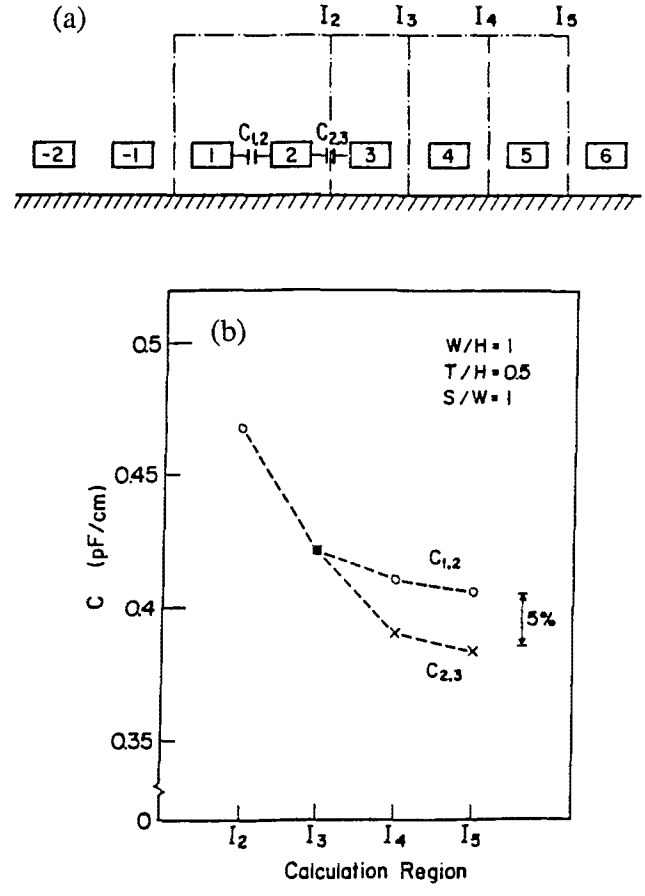


Fig. 2 (a) Calculation regions for $I_n$ type and (b) its influence on simulated capacitances.

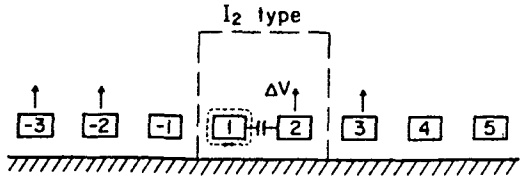


Fig. 3 Explanation of the dependency on $I_2$ type boundary condition. Induced charge $Q_1$ is calculated by integrating the electric field around electrode 1 as indicated by the dashed line.

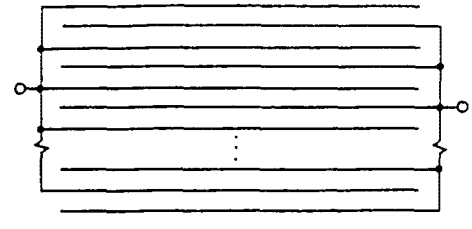

Fig. 4 Wiring pattern for measurement.