Direct Estimation of Bipolar Circuit Performance using a Two-Dimensional Device Simulator

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To improve the accuracy of the conventional circuit simulator and to get an optimized device structure easily, we developed and compared two types of circuit simulators. One uses numerical tables obtained from stationary solutions of a two-dimensional device simulator and the other uses the transient solutions of the device simulator directly. We called the former the "table method" and the latter the "direct method."

Figure 1 depicts the simulation flow for the table method. Before solving nodal equations, we must develop numerical tables for equivalent circuit elements. In this method, we adopted the equivalent circuit of a bipolar device shown in Fig. 2. Capacitances and current sources are obtained from the two-dimensional device simulator solutions.

Figure 3 shows the simulation flow for the direct method. Current and current derivatives are obtained from the transient solutions of the two-dimensional device simulator and are used to solve the nodal equations. First, the basic semiconductor equations are solved transiently for three terminal voltages for each transistor by increasing the time by Δt. The base and collector currents are then obtained. Using these currents, the derivatives of the currents with respect to the terminal voltages are obtained. The nodal equations are solved using these currents and current derivatives. This procedure is repeated until the solutions of the nodal equations converge. When nodal equations converge, time is increased by Δt, and the calculations are repeated.

Assuming that exact solutions are obtained by the direct method, we examined the accuracy of the table method. Difference between propagation delays of an ECL gate was investigated. Propagation delays were obtained from the simulation of the three-stage inverter chain shown in Fig. 4.

Figure 5 plots consumed power dependence of the propagation delay for the two methods. The table model gives smaller propagation delay than the direct method in the whole power region. The difference between the two methods is larger in the high power region than in the low power region. The reason is that, in the table method, the time delay in the extrinsic base region cannot be exactly estimated.

In summary, the table method gives exact solutions for DC analysis, however, it gives inaccurate results especially in the high power region because of both the incorrect equivalent circuit and the quasi-static approach. The direct method is considered to be the most accurate method to simulate circuit behaviors.

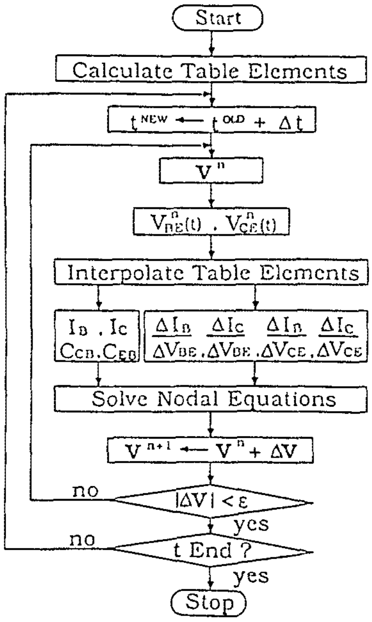

Fig. 1 Simulation flow of the table method.

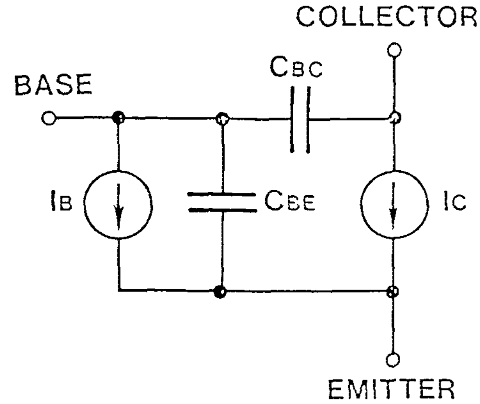

Fig. 2 Equivalent circuit of a bipolar transistor used in the tabel model.

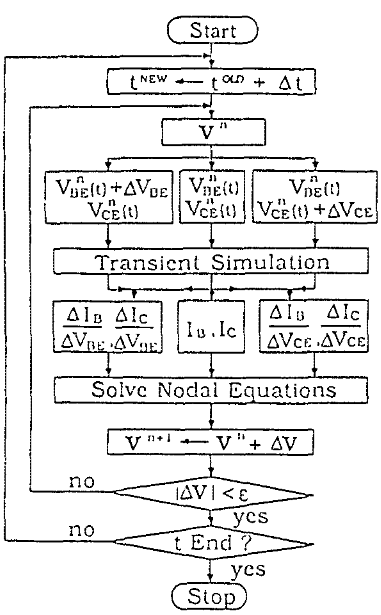

Fig. 3 Simulation flow of the direct method.

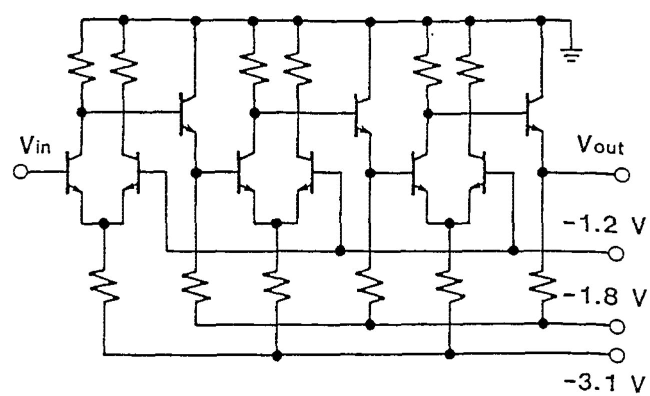

Fig. 4 Three-stage ECL gate inverter chain.

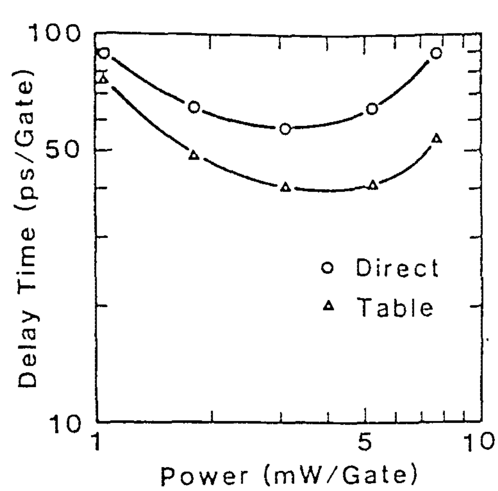

Fig 5. Comparison of the propagation delay for the table method and the direct method.