A Transistor Parameter Extraction System--- TPARA

Susumu Inohira, Toshio Shinmi, Kyoichi Iida and Fumio Nakazawa+
(Hitachi Ltd., + Hitachi VLSI Engineering Corp.)

ABSTRACT

An interactive characterization system for scaled bipolar transistors has been developed. With this system, designers can extract accurate DC and AC model parameters for circuit simulation in a total time of 1-2 hours. The system is oriented to high frequency application of bipolar transistors.

1. Extraction method

A TPARA(Transistor PARAmeter) extraction system is composed of an HP9836 computer, a parameter analyzer, an LCR meter and a network analyzer. The software is written in BASIC in 11-k steps. Parameters for two models, the extended Gummel-Poon (GP3) model and the extended Ebers-Moll (EM5) model, are extracted from measured data of 5 DC characteristics, 3 C-V characteristics and several S parameters. Table.1 summarizes the extraction methods in the case of GP3 model. To obtain high accuracy, some original extraction methods have been developed. These are different from usual methods [1],[2]. The ideal current gain parameter BF and knee current IK are extracted simultaneously from the X/h_{FE}-$X*I_C$ plot , where h_{FE} is I_C/I_B and X is given by.

$$X = 1-V_{BC}/V_A-V_{BE}/V_B . \qquad (1)$$

The collector resistance RC value is obtained from $\delta V_{BC}/I_B$-βi plot calculated from high current I_E-V_{BC} data in inverse mode operation. After the parasitic effect caused by package and bonding pads has been excluded from measured f_T data, the forward transit time TF and the knee current IKA are extracted from the $1/w_T$-$1/I_C$ plot as usual.[1]. The parameter RATBC, which means the division ratio of collector-base capacitance, is calculated from the device dimensions as

$$RATBC = 1-A_E/A_C , \qquad (2)$$

where A_E and A_C are emitter area and collector-base junction area.

2. Results

Figure 1 shows an example of extraction of BF and IK. A highly accurate I_C, I_B-V_{BE} characteristics is obtained using the method shown in Fig. 2. Comparison between measured and simulated S parameters is illustrated in Fig. 3. The ECL ring oscillator is chosen to investigate the accuracy of the system. Figure. 4 shows simulated and measured delay time per gate of the ECL circuit. The lines were simulated by the GP3 model with parameters obtained from TPARA system. The parameter RATBC is essential to high frequency [3] and transient characteristics of integrated bipolar transistors.

References

[1] I. Getreu, Modeling the Bipolar Transistor, Tektronix, Inc., 1976.
[2] A. D. Hart & I. H. Leventhal, IEDM '86 Tech. Digest, pp.36-39,1986.
[3] P. J. van Wijner & L. C. Smith, Proc. of BCTM, pp.91-94,1988.

Table.1 Extraction method for GP3 model parameters

Parameters	Data	Method
BF, IK	hfe-Ic	X/hfe-X*Ic plot
RB, RE	high Ib-Vbe	Ning&Tang
RC	high Ib-Vbc	dVbc/Ib-Bi plot
VA, VB	Ic-Vce	Getreu
IS, NE1	Ic-Vbe	logIc-Vbe plot
C2, NE	low hfe-Ic	ln(X/hfe-1/BF)-Vbe plot
CJ, N, P	Cj-V	log Cj-log(V+p) plot
TF, IKA	ft-Ic	1/wt-1/Ic plot
RATBC	-	equation (2)

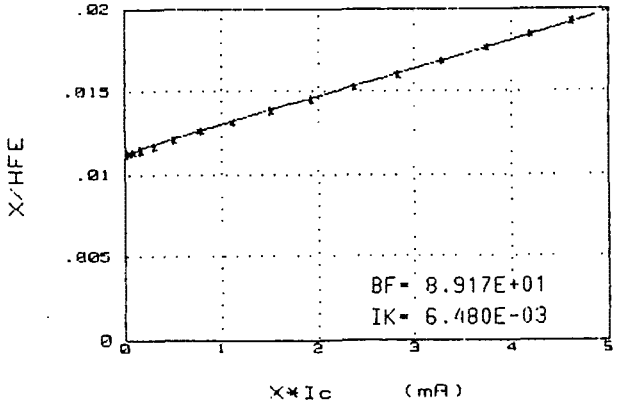

Fig.1 Extraction of BF and IK

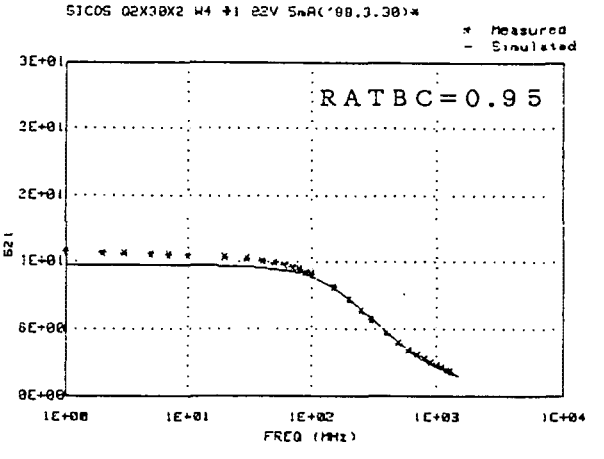

Fig.3 Frequency characteristics of S21 magnitude

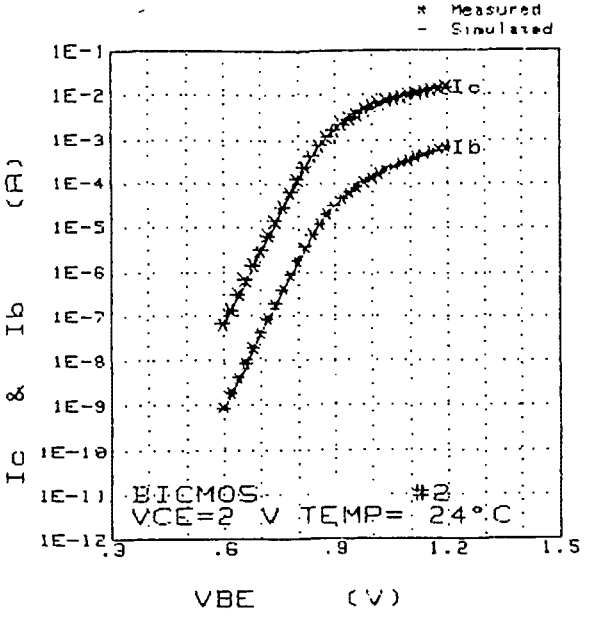

Fig.2 IC,IB-VBE characteristics

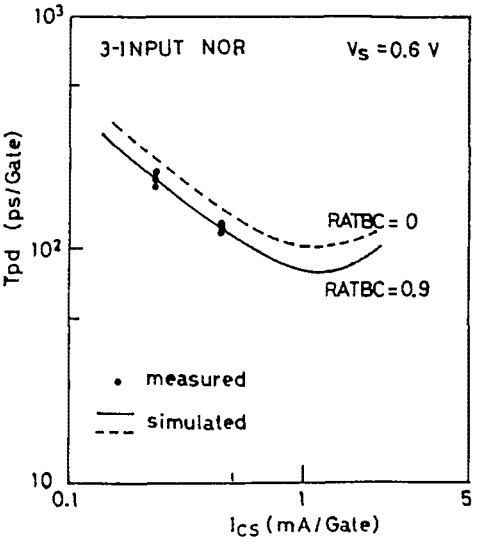

Fig.4 Comparison between simulated and measured delay time of ECL ring oscillator