VBIC

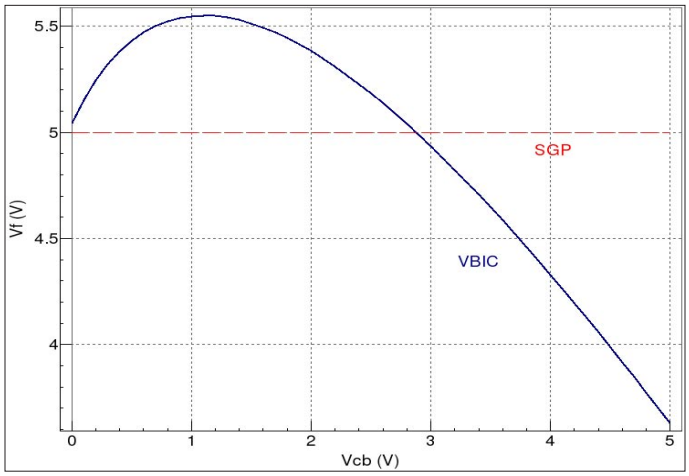
ADVANCED BJT AND HBT MODEL

The Origin and Goal of VBIC

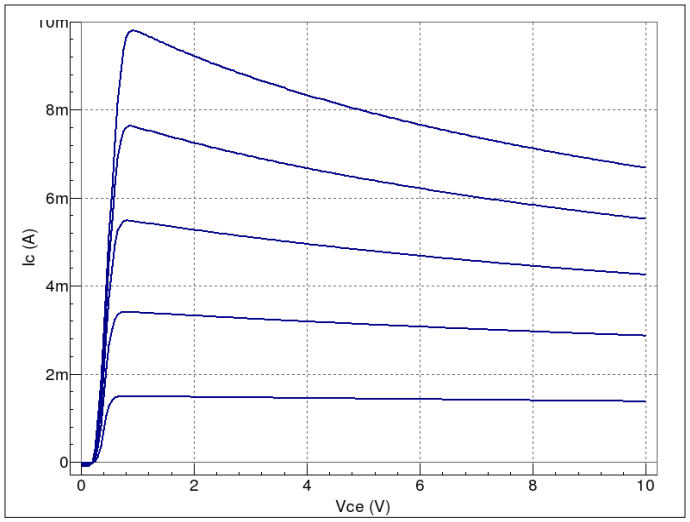
The Vertical Bipolar Inter-Company (VBIC) model results from the joint efforts of semiconductor and EDA companies to develop a successor of the 30-years-old industry standard SPICE Gummel-Poon (SPG) bipolar transistor model. VBIC follows the basic general concept of SGP but overcomes its major deficiencies and brings a variety of new advanced BJT and HBT modeling features. At the same time, VBIC is developed to provide the maximum backward compatibility with the SPG model in order to leverage the existing knowledge and training of characterization and IC design engineers. Today, VBIC the only model widely adopted by both BJT and HBT foundry and circuit design industries.

Fundamental VBIC Improvements Over SGP

- Early effect modeling based on depletion charges
- Separation of the collector and base current empirically linked by a current gain
- Improved HBT modeling capability
- Improved depletion capacitances and diffusion charges
- A model for parasitic PNP transistor
- Modified Kull quasi-saturation modeling to avoid negative conductance problem
- Weak base-collector avalanche model
- Base-emitter breakdown modeling
- Improved temperature mapping; physically, no negative built-in potentials at high temperatures)
- Self-heating
- Constant overlap capacitances



Early voltage modeling of VBIC and SGP.



HBT output characteristics of demonstrating VBIC electro-thermal modeling.

Silvaco Implementation

- The Silvaco model library (ModelLib) provides three versions of the VBIC model: the last two publicly available VBIC releases v1.1.5 (VBIC95) and VBIC v1.2 (VBIC99) as well as an enhanced VBIC version v1.3. The implementation of the VBIC versions v1.1.5 and v1.2 is fully compliant to publicly available VBIC Verilog-A code
- User-friendly parameter clipping, advanced internal model diagnostics, and extensive set of output variables
- Improved simulation speed based on VZERO and BYPASS SmartSpice options
- The excess phase network is defined in equivalent but simpler manner that eliminates unknown inductor current from the model state equations
- Linearization of the ideal diode currents greater then maximum current defined by option parameter EXPLI
- Hard limits on the local temperature to avoid numerical problems
- Extended numerical protection in the evaluation of the normalized base charge in the main and parasitic transistor as well the avalanche current for forward and low reverse bias

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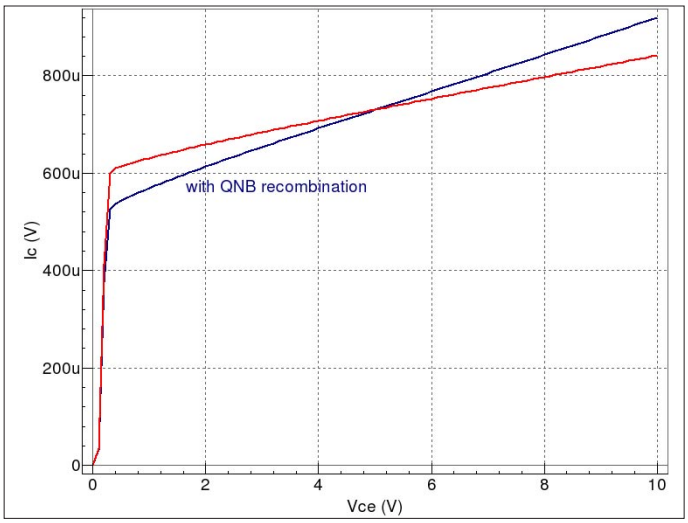
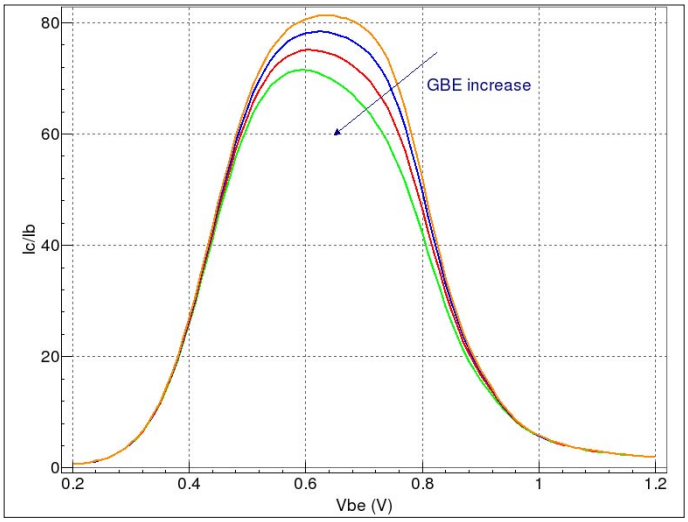
Silvaco Enhanced VBIC Model Features

To meet the growing circuit design requirements and to enlarge the range of the VBIC model applicability, Silvaco has introduced an enhanced VBIC model version v1.3. The enhanced VBIC modeling features include:

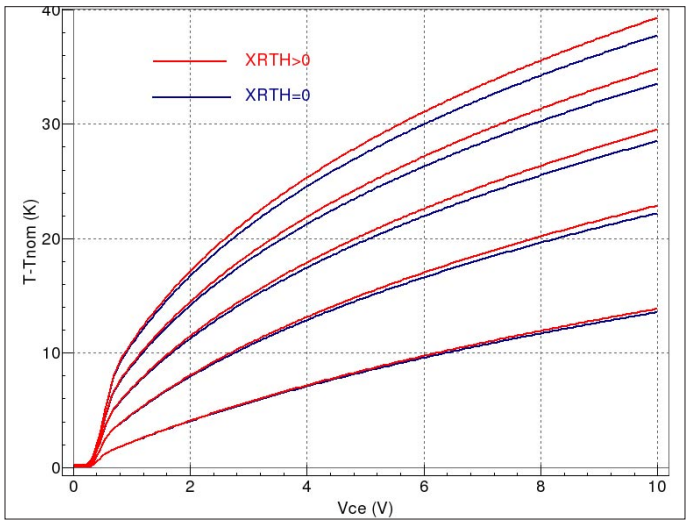
- A new base current component due to recombination in the quasi-neutral base. It is particularly useful for SiGe technologies with a box Ge profile and high doping in the quasi-neutral base or power devices having a wide base region. The model accounts for the base width modulation of the recombination current by junction depletion capacitances
- Generalized Early factor for accurate modeling of bipolar devices with non-uniform band gap in the base. The model effectively accounts for different contributions of the base-width modulation to the quasi-neutral base charge and the corresponding Gummel number. It is important for various applications of SiGe HBTs to precision analog circuits
- Modulation of the extrinsic collector resistance by the collector-substrate junction depletion region. It is implemented as an alternative to the Kull-Nagel quasi-saturation model. The most important applications are the vertical PNP transistors processed without buried layer in SmartPower type technologies.
- Extended temperature mapping of the electrical parameters. It includes temperature dependence of the Early voltage, thermal resistance as well as forward and reverse transit time parameters
- Nonlinear thermal resistance model that accounts for the non-uniform distribution of temperature. It is implemented in the form of the current (heat flow) source based on the Kirchhoff's transformation. The effect becomes increasingly important for modern SiGe and III-V HBTs as well as SOI processes



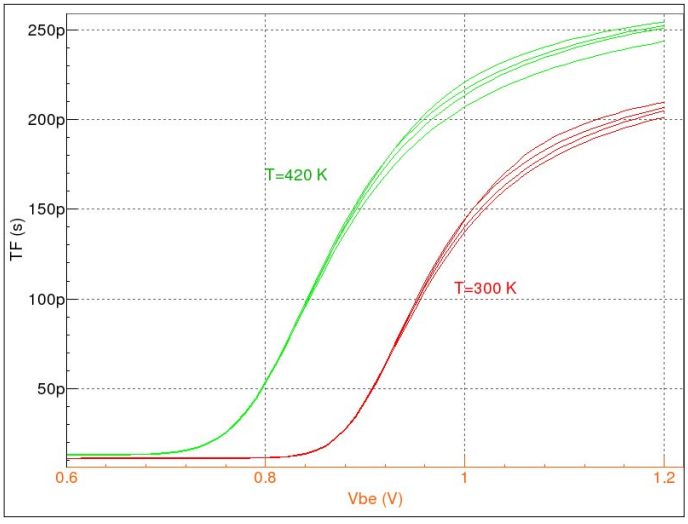
The effect of the recombination in quasi-neutral base on a transistor output characteristics.



The effect of non-uniform (graded) band-gap in the quasi-neutral base on a transistor current gain.



The effect of temperature dependent thermal resistance on the transistor temperature in output characteristics.



The temperature dependent forward transit times form different Vce.