Proposal for modeling the barrier effect in the bipolar compact model Hicum L0

Joerg Berkner

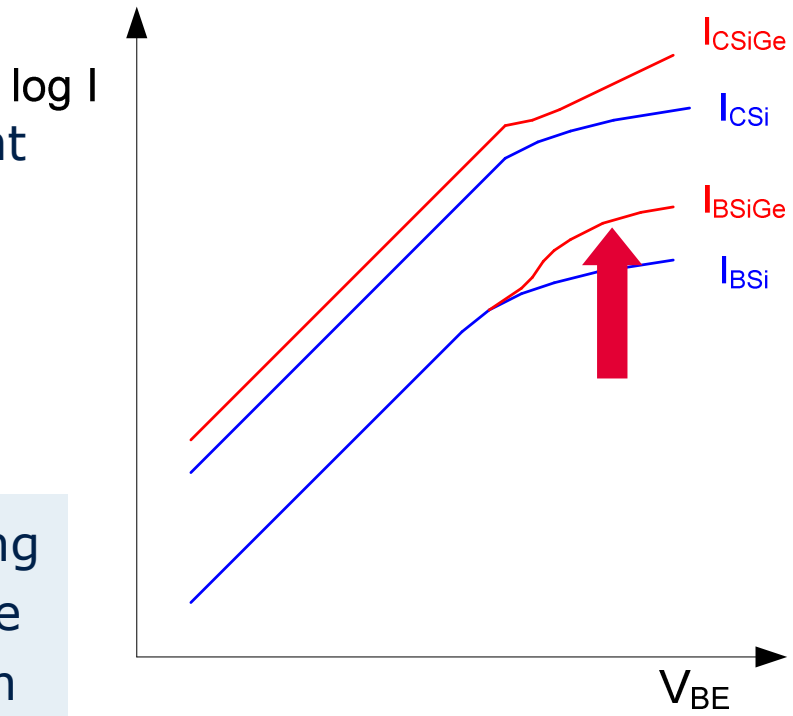
IFAG AIM AP T PFM EDA

Never stop thinking

Modeling the barrier effect in Hicum L0

- SiGe-Transistors show often a kink in the high base current region , called the “barrier effect”
- The effect was investigated by different authors, e.g. Tiwari [1], Peter et.al., [2], Sadovnikov et. al. [3]
- Cressler and Niu gave a nice summary about this effect, they wrote :

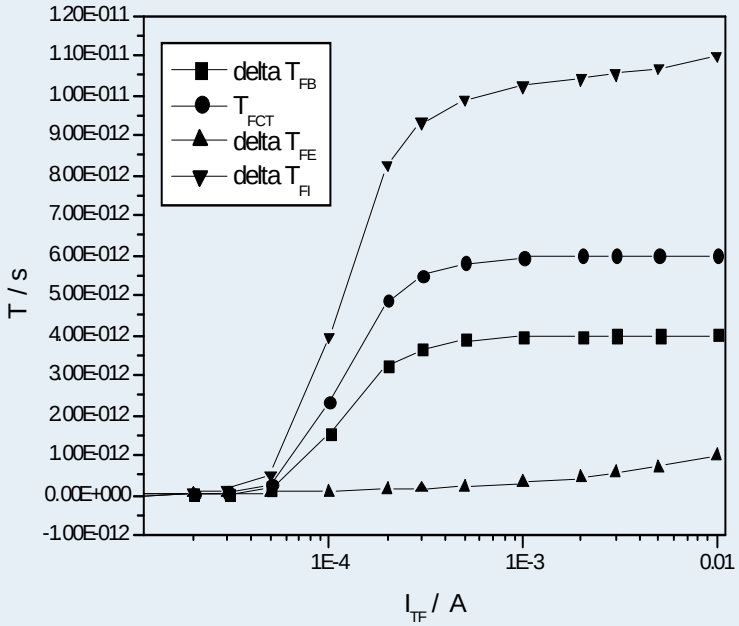
“The sudden increase in J_B accompanying the barrier onset in a SiGe HBT is the result of the accumulation of holes in the base region due to HBE (heterojunction barrier effect)” [4, p.241]



SiGe base current barrier effect

Modeling the barrier effect in Hicum L2

- In HICUM L2 the three current dependent T_{FT} parts and the appropriate charges are calculated separately



Base Part ΔT_{FB}

$$\Delta T_{FB} = (1 - FTHC) \cdot THCS \cdot w^2 \left[1 + \frac{2}{\frac{I_{TF}}{I_{CK}} \sqrt{i^2 + ALHC}} \right]$$

Collector Part T_{FCT}

$$T_{FCT} = FTHC \cdot THCS \cdot w^2 \left[1 + \frac{2}{\frac{I_{TF}}{I_{CK}} \sqrt{i^2 + ALHC}} \right]$$

Emitter Part ΔT_{FE}

$$\Delta T_{FE} = TEF0 \left(\frac{I_{TF}}{I_{CK}} \right)^{GTE}$$

Modeling the barrier effect in Hicum L2

- This allows to use the absolute base charge Q_bf for modeling the barrier effect

- The additional base current, created by the barrier effect, is calculated by the following approach [5]:

$$Ibh\_rec = \frac{Q\_bf}{TBHREC}$$

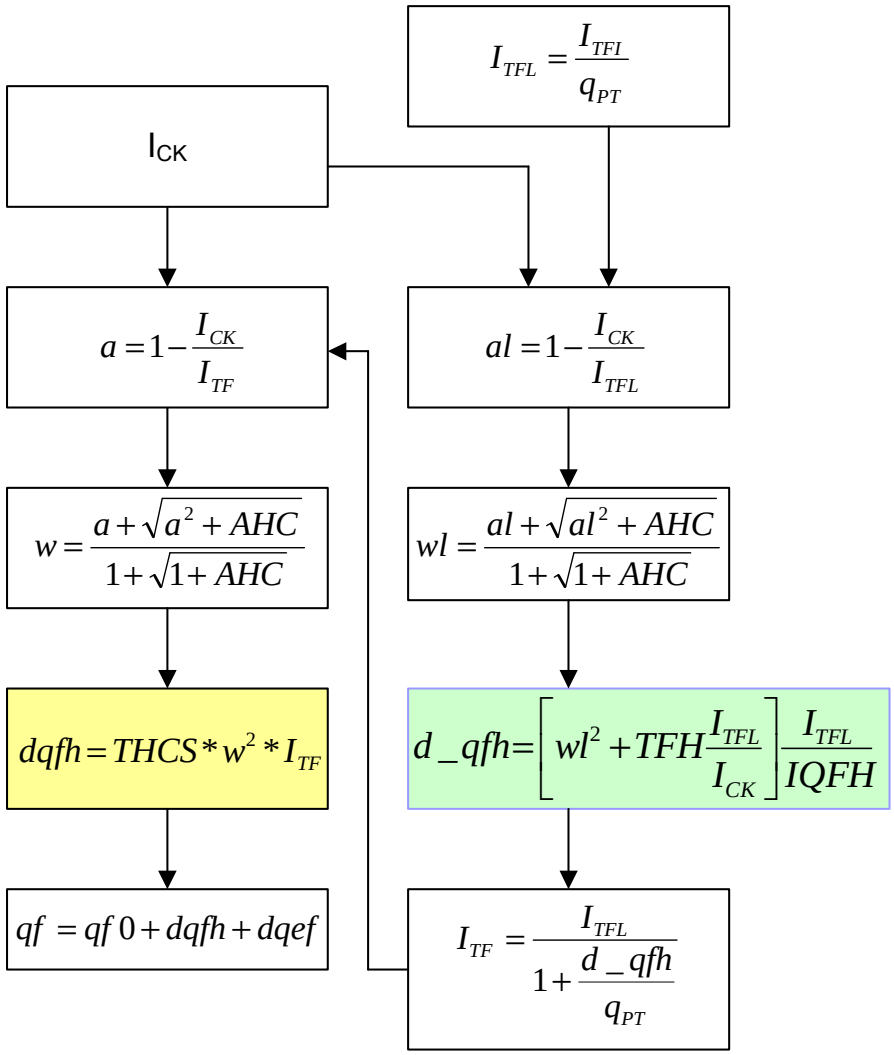
with the new model parameter TBHREC

Modeling the barrier effect in Hicum L0

- In Hicum L0 v1.12 , however, base and collector charge are merged into ONE current dependent charge component
- Additional, we have to decide between to different high current charge components:

  - d_qfh is used for the transfer current I_{TF}

  - dqfh is used for the total minority charge qf



Modeling the barrier effect in Hicum L0

- To model the barrier effect, we have to multiply the ideal BE current with a operating point dependent factor $f_{Barrier}$

$$I_{jbe} = I_{be} * f_{Barrier} + I_{re}$$

- If no barrier effect appears (low Vbe), we need $f_{Barrier}=1$
- If barrier effect appears (high Vbe), we need $f_{Barrier}>1$
- This could be realized normalizing the charge dqfh to qf0, like:

$$f_{Barrier} = 1 + \frac{dqfh}{qf0}$$

- However, this overestimates the increase of IB, because only the base component of dqfh is responsible for the IB increase

Modeling the barrier effect in Hicum L0

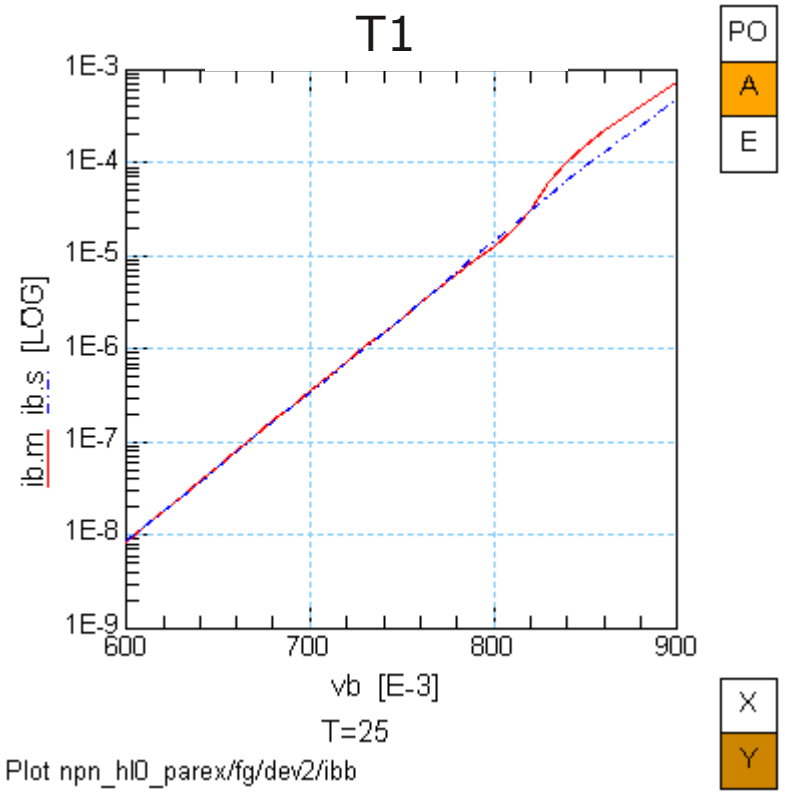
- That is why we have to split dqfh using a multiplier (1-FTHC). We end up with the following approach:

$$f_{Barrier} = 1 + \frac{(1 - FTHC) * dqfh}{qf0}$$

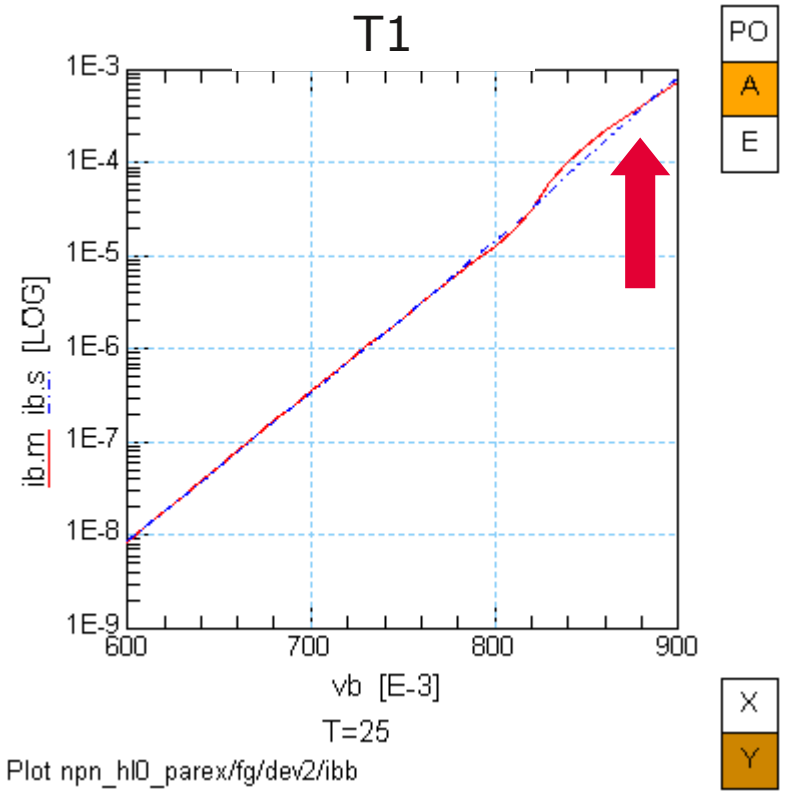
$$I_{jbe} = I_{be} * f_{Barrier} + I_{re}$$

Note: The model parameter FTHC is used here in the same meaning as in Hicum L2.

Modeling the barrier effect in Hicum L0 Results

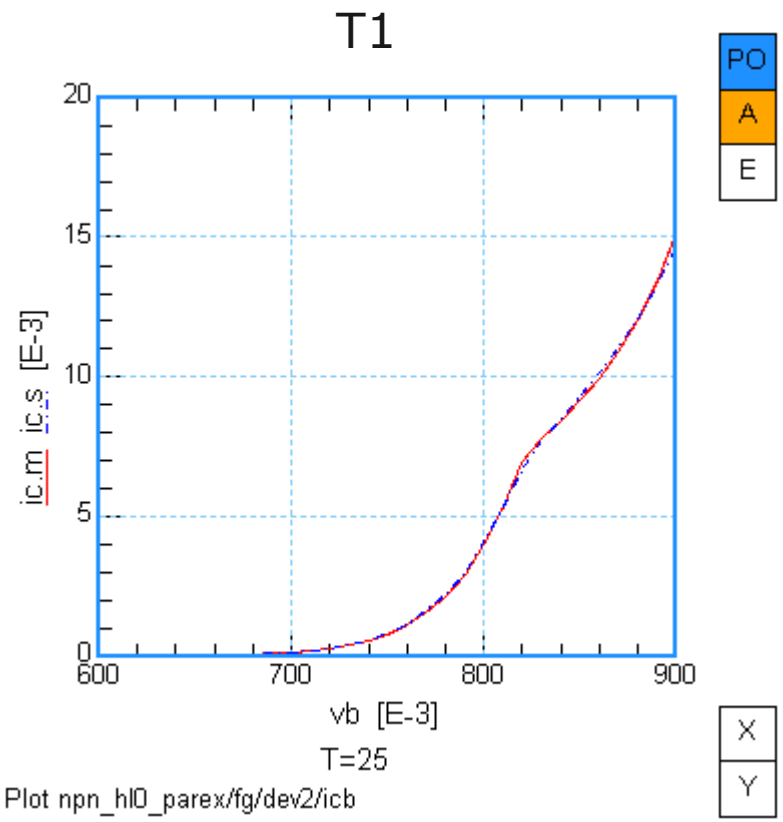


Ib=f(Vbe), Vc=1V
FTHC=1
no barrier effect

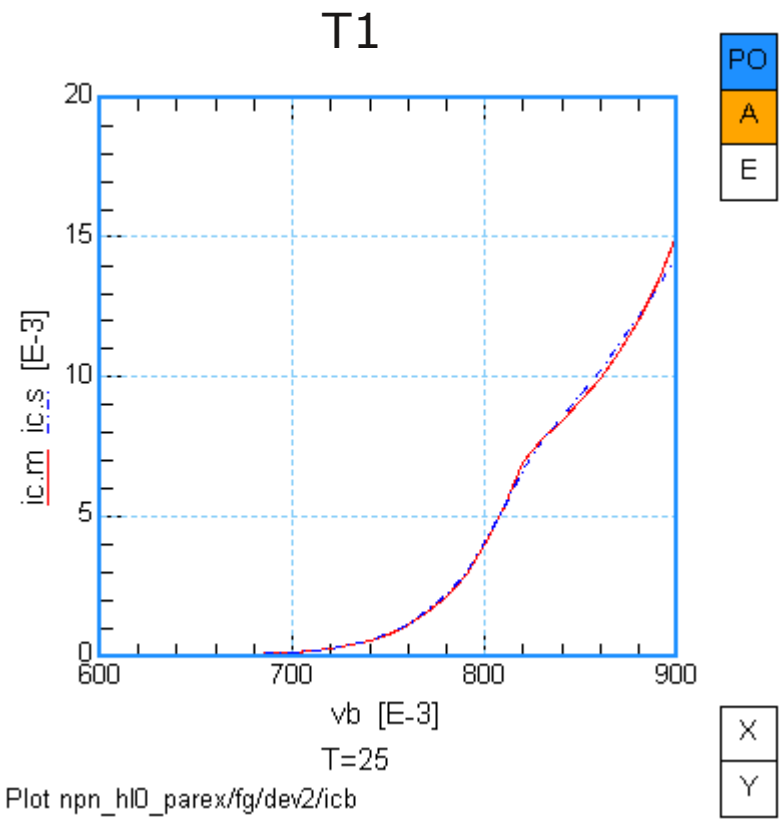


Ib=f(Vbe), Vc=1V
FTHC=0.95
with barrier effect

Modeling the barrier effect in Hicum L0 Results



Ic=f(Vbe), Vc=1V
FTHC=1, IQFH=357µA
no barrier effect



Ic=f(Vbe), Vc=1V
FTHC=0.95, IQFH=393µA
with barrier effect
IQFH is slightly adjusted

Modeling the barrier effect in Hicum L0 Summary

- SiGe-Transistors show often a kink in the high base current region, called the “barrier effect”
- This effect is modeled in HICUM L2 using the base minority charge Q_fb and the additional model parameter TBHREC
- In HICUM L0 this way is blocked, because base and collector part of the minority charge are merged in the charge dqfh
- A possible solution of the problem is to use a a multiplier $f_{Barrier}$ for the ideal base current. It is defined using a fraction of dqfh only.
- The model parameter FTHC, known already from HICUM L2, was introduced as the split factor. It may be extracted fitting the base current in the high Vbe range.

Modeling the barrier effect in Hicum L0 References

1. Tiwari, S.: “A New Effect at High Currents in Heterostructure Bipolar Transistors”, Electron Device Letters, vol.9, no.3, 1988, p.142 - 144

2. Peter, M.S.; Slotbom, J.W.; Terpstra, D.: “Impact Ionisation and Neutral Base Recombination in SiGe HBT’s”, BCTM 1999

3. Sadovnikov, A.; Krakowski, T.; El_Diwany: ”Influence of the Extrinisc Base on the Base Current Kink in SiGe BJTs”, ISTDM 2004

4. Cressler, John, Niu, Guofu: “Silicon-Germanium Heterojunction Bipolar Transistors”, Artech House, 2002

5. Schroeter, M.: “Hicum Level2 v2.2, Summary of extensions and changes”, March 2005