Application
of
HICUM Level0 v1.2
to
Infineons B6CA Technologie

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Principal Bipolar/BiCMOS Modeling

Infineon Technologies

ATV PTP PFM EDA

Agenda

- Problems using VBIC
- Extraction procedure for HL0 QS related model parameters
- Results in comparison with VBIC v1.2
- Summary

Introduction

- The goal of this investigation was to answer the following two questions:

  Is the new bipolar compact model Hicum Level0 v1.2 able to model npn transistors of Infineon technologies with high breakdown voltages?

  Is Hicum Level0 v1.2 able to become the follower of VBIC?

- The investigation was made under the following conditions:

1. Simulator: Cadence Virtuoso Spectre version 7.1.1.239.isr15 16 Oct 2009
2. ICCAP: 2009 650.400 Oct 6 2009
3. Technology: B6CA, 0.5 µm Silicon BiCMOS, fT_peak= 5.5 GHz, Supply voltage 5 / 12 V *

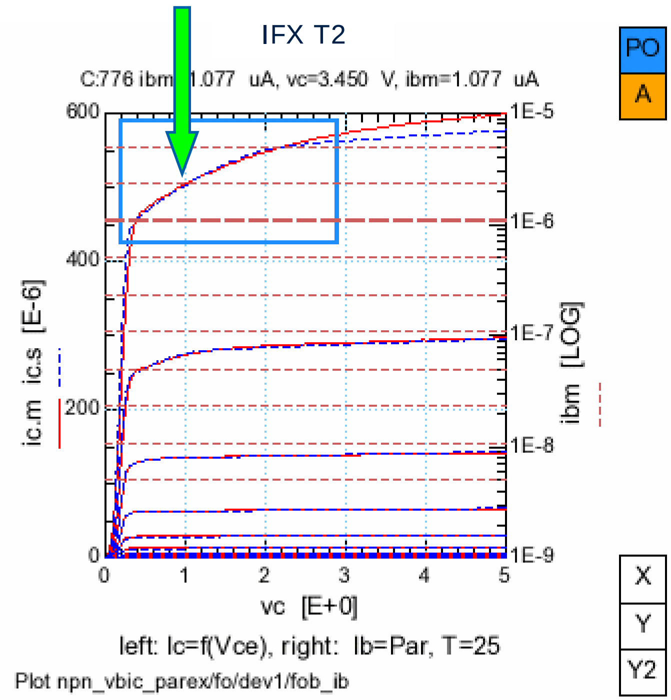
* Source: Infineon Technology Booklet 02.00

Problems using VBIC

We observed in the past the following problems using the VBIC 1.2 model:

- There is no model parameter combination RCI / GAMM, which is sufficient to model **both** the Ib and the Vb driven output characteristic
- If we use RCI>0, ft shows a very sharp ft roll off, which does not fit to reality
- The appropriate TF increase affects the switch behavior
- Using RCI>0 we observed a pole in CV simulations

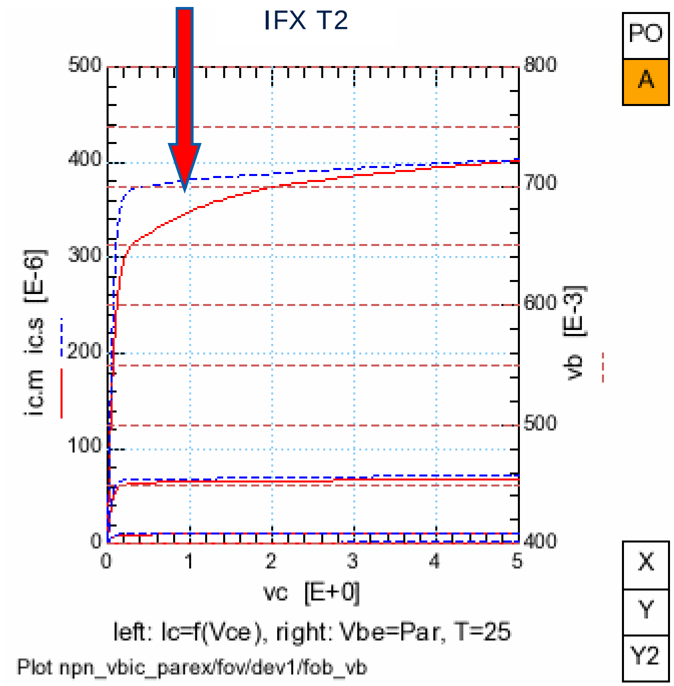
- Sufficient modeling of quasi saturation for Ib driven output characteristic



Ic=f(Vce), Ib=Par

RCI=3838, GAMM=3351p, V0=3, HRCF=1m

- Bad modeling of quasi saturation for Ib driven output characteristic



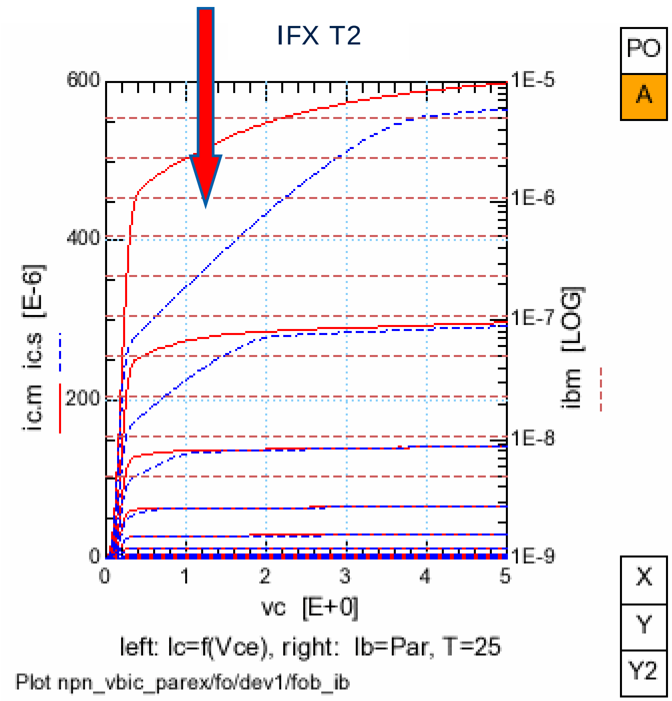
Ic=f(Vce), Vbe=Par

RCI=3838, GAMM=3351p, V0=3, HRCF=1m

- Problem: There is no combination RCI / GAMM, which is sufficient for both cases

Problems using VBIC

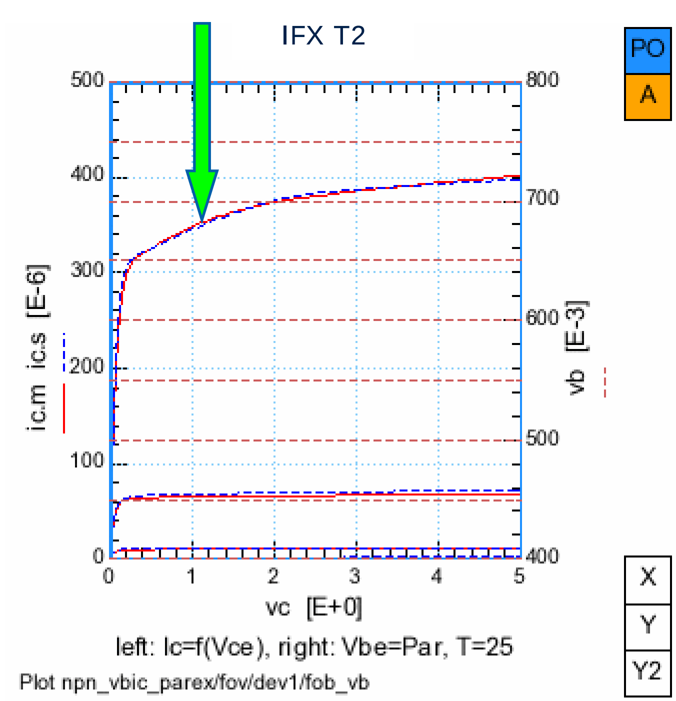
- Bad modeling of quasi saturation for Ib driven output characteristic



Ic=f(Vce), Ib=Par

RCI=6723, GAMM=1369p, V0=3, HRCF=1m

- Sufficient modeling of quasi saturation for Ib driven output characteristic



Ic=f(Vce), Vbe=Par

RCI=6723, GAMM=1369p, V0=3, HRCF=1m

- Problem: There is no combination RCI / GAMM, which is sufficient for both cases

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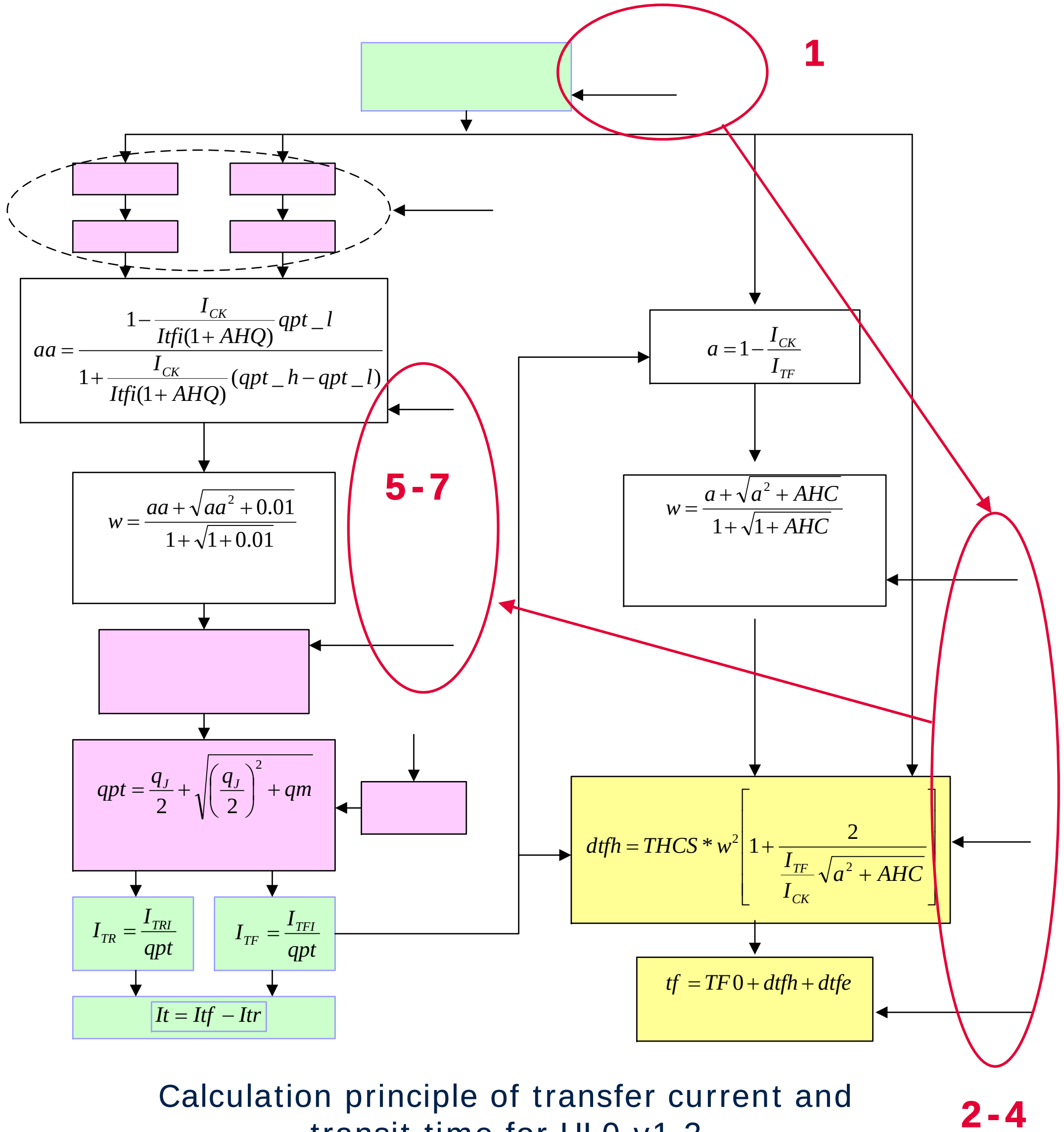
Extraction procedure for QS related model parameters

- The following extraction procedure was applied:

1. Calculate Ick vc. Vc and optimize RCI0, VLIM, VPT
2. Adjust AJE and THCS
3. Optimize T0, TBVL and DT0H on ft_peak(Vb)
4. Optimize AHC on ft roll off
5. Optimize AHCX (AHQ) below ft roll off inflection point
6. Optimize IQF and IQFH on forward output curves
7. Check Ic modeling on ft=f(Ic) and Ic=f(Vbe) curves

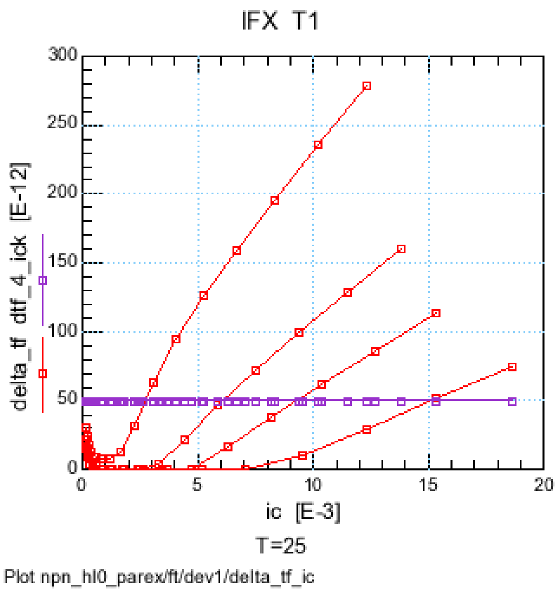
- Precondition: junction capacitance parameters, series resistances RE, RCX, Rbb, fwd early voltage, self heating (RTH) have been extracted or calculated before



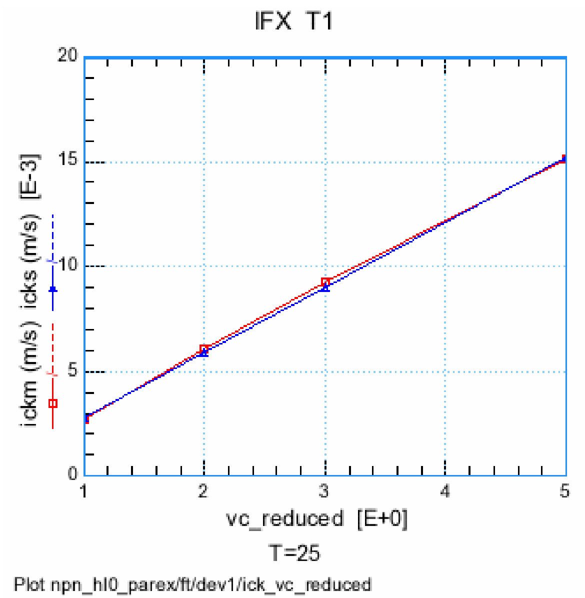
Calculation principle of transfer current and transit time for HL0 v1.2

Extraction step by step
Step1

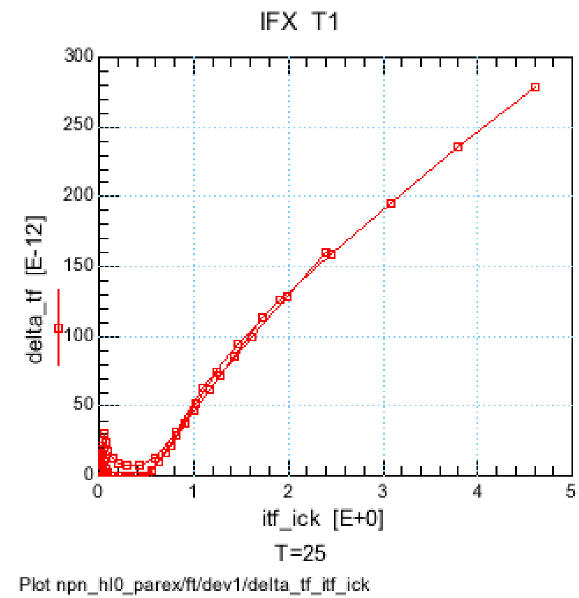
- Define a reasonable value for delta tf to calculate Ick(Vc)
- Extract RCI0, VLIM and VPT by optimization on Ick=f(Vc)
- The nearly linear Ick=f(Vc) indicates here, that the use of VPT for this technology is not necessary



delta tf=f(Ic, Vc)



Ick=f(Vc)

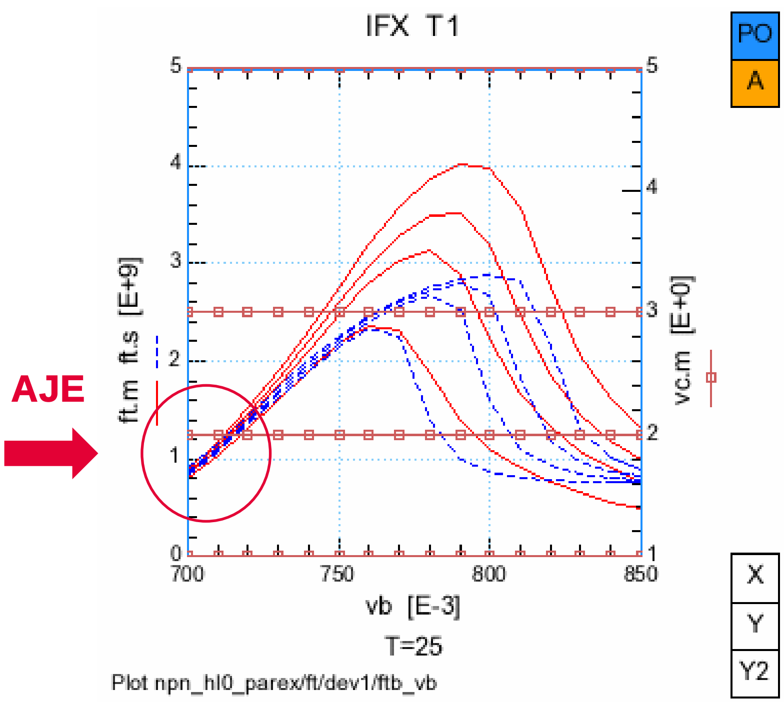


delta tf=f(Itf/Ick)

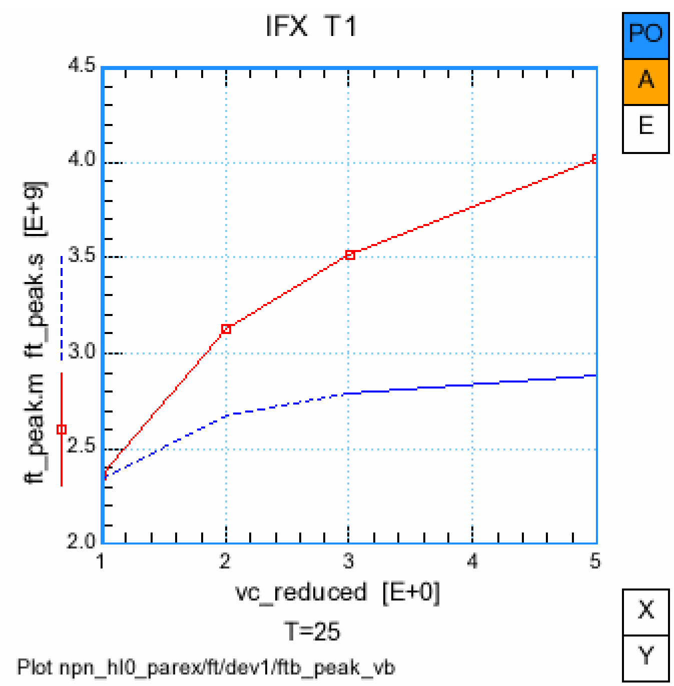
This extraction step is based on:
B.Ardouin et.al. “Transit time parameter extraction for the Hicum Bipolar Compact model”, BCTM2001

Extraction step by step
Step2

- Adjust now AJE in the Vbe range, if necessary
- The other parts of ft are still wrong



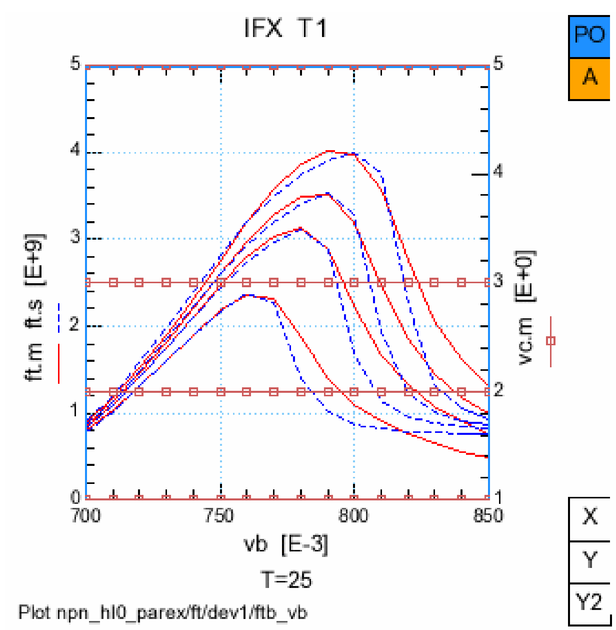
fT=f(Vb, Vc)



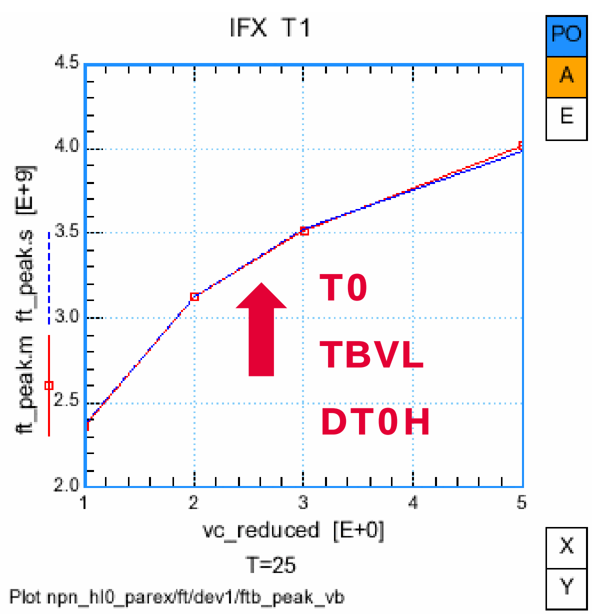
fT_peak=f(Vc)

Extraction step by step
Step3

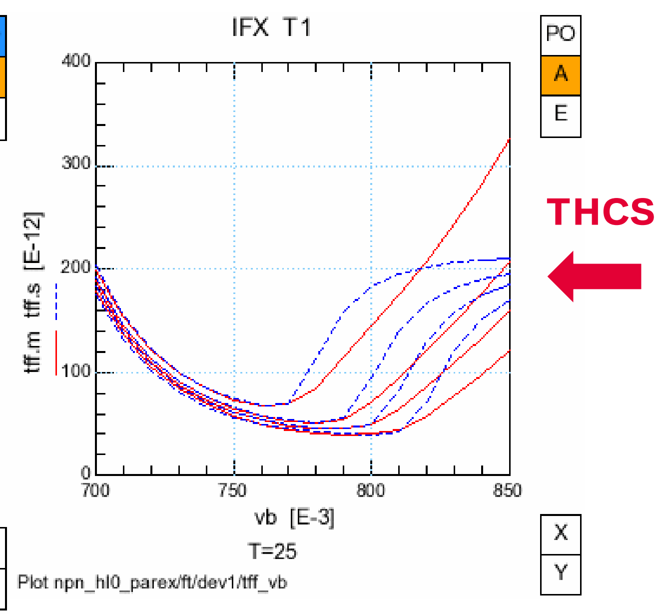
- Define a reasonable value for THCS (rule of thumb: 5 ...10 x tffmin)
- Optimize T0, TBVL and DT0H on fT_peak=f(Vc), if necessary, go back to step2 and adjust AJE again
- DT0H is very useful for SiGe technologies to model the reduction of ft increase for high Vc. For the given Si technology, however, DT0H was not used.



fT=f(Vb, Vc)



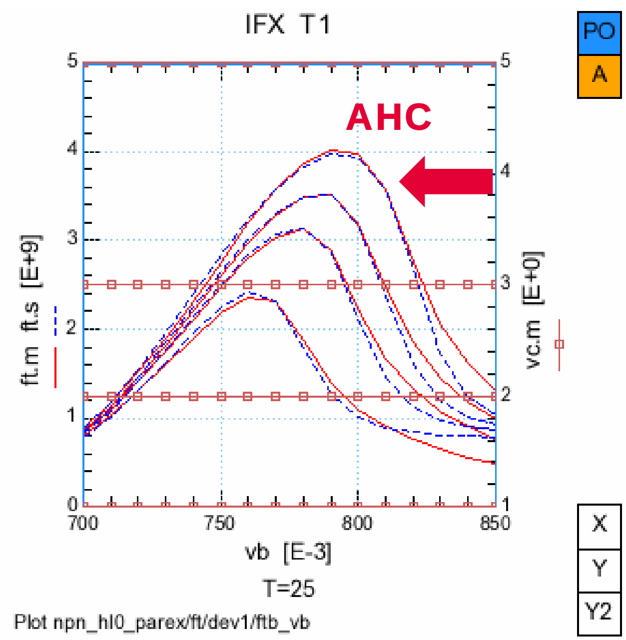
fT_peak=f(Vc)



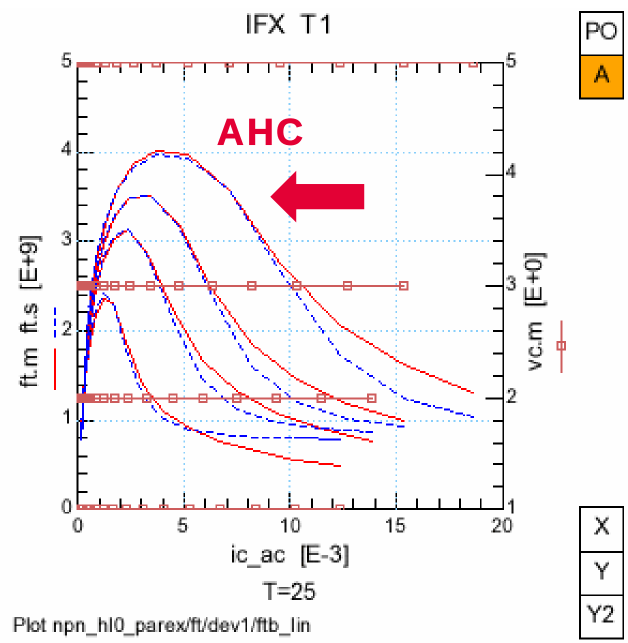
tff=f(Vb, Vc)

Extraction step by step
Step4

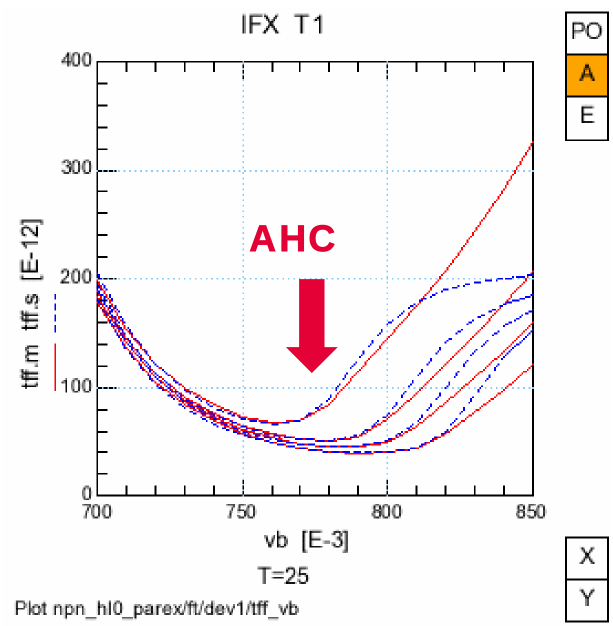
- Optimize the AC smoothing parameter AHC on the ft roll off before the inflection point



fT=f(Vb, Vc)



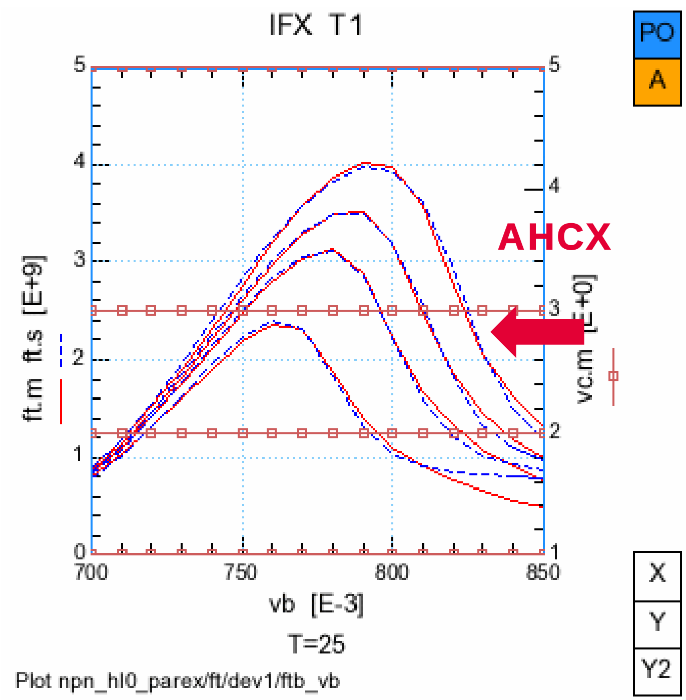
fT=f(Ic, Vc)



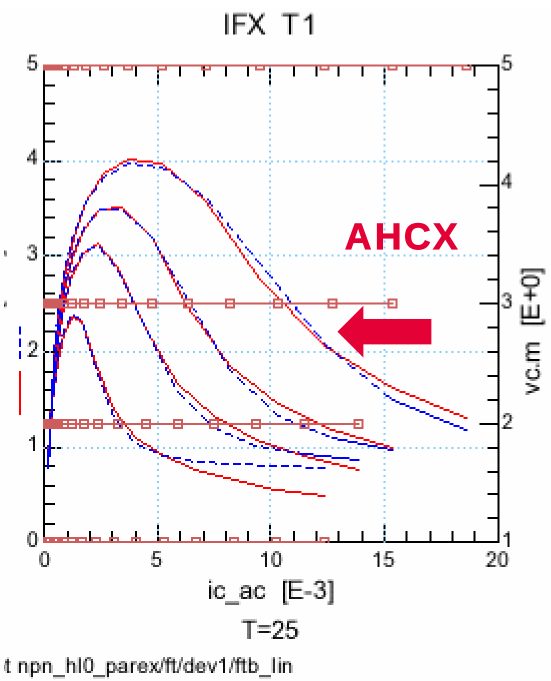
tff=f(Vb, Vc)

Extraction step by step
Step5

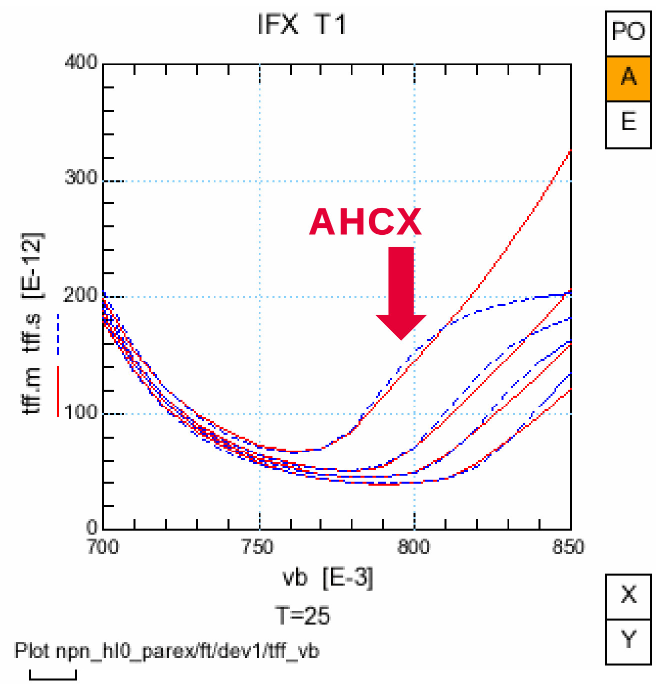
- Optimize the DC smoothing parameter AHCX (originally called AHQ) below ft roll off inflection point
- This give usually only a first guess for AHCX and must be further optimized on DC forward output and Gummel curves



fT=f(Vb, Vc)



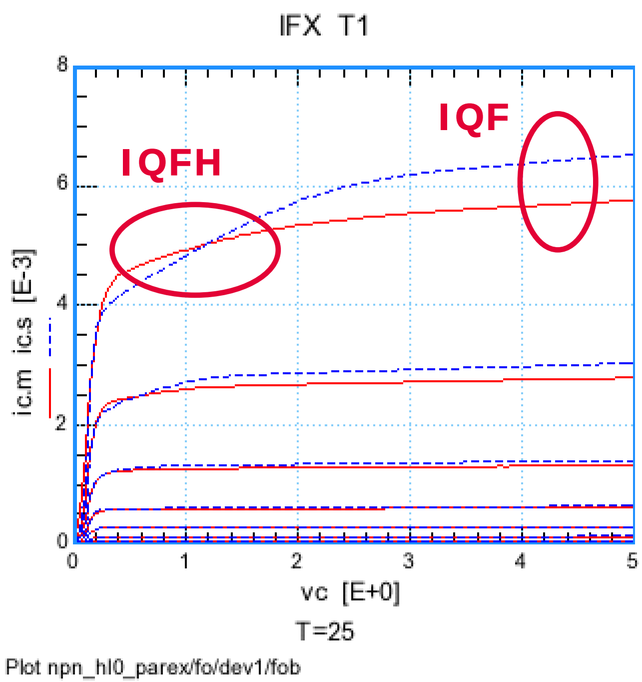
fT=f(Ic, Vc)



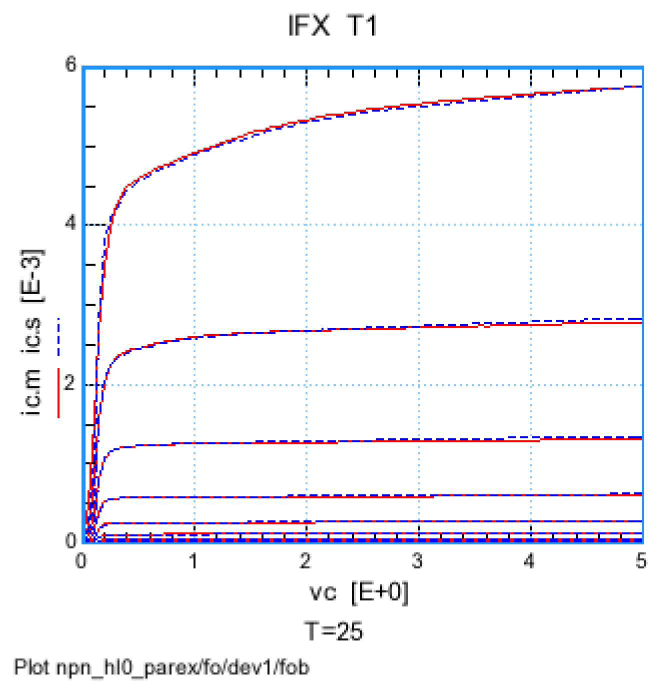
tff=f(Vb, Vc)

Extraction step by step
Step6

- Optimize IQF at FIQF=1 in the non-QS range of Ib driven forward output characteristic
- Optimize IQFH in the QS range Ib driven forward output characteristic



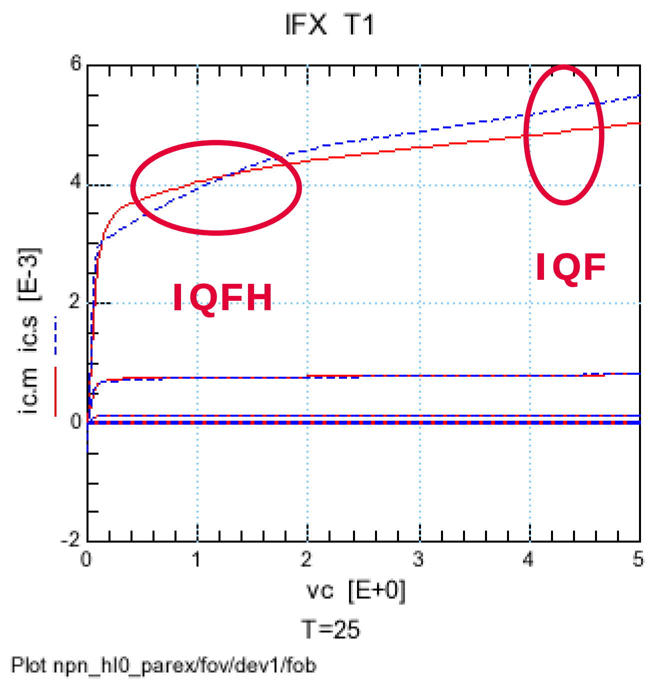
Ic=f(Vc), Ib=Par.



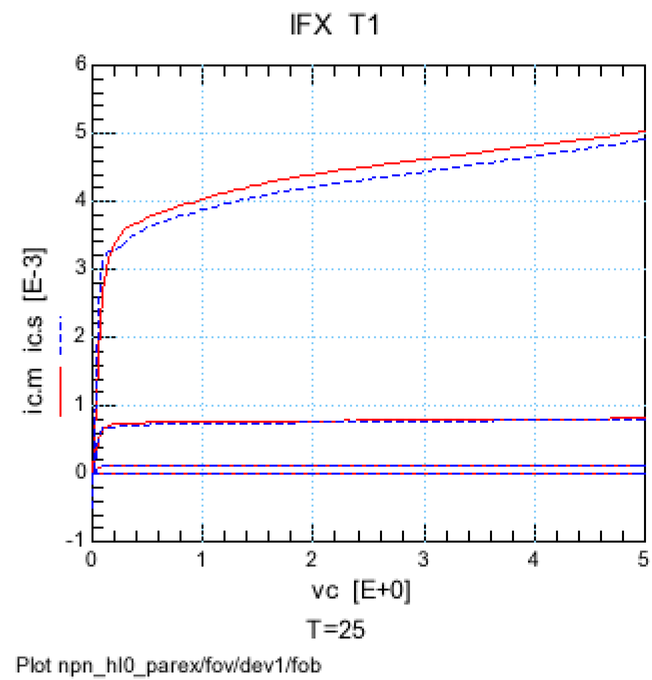
Ic=f(Vc), Ib=Par.

Extraction step by step
Step6

- Check IQF and IQFH on Vb driven forward output characteristic too, if necessary optimize together with Ib driven forward output characteristic

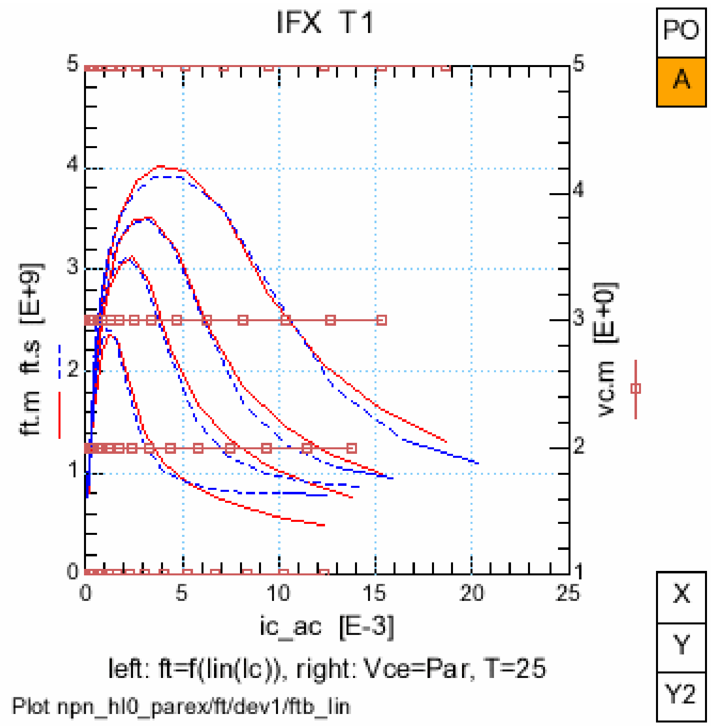


Ic=f(Vc), Vb=Par.

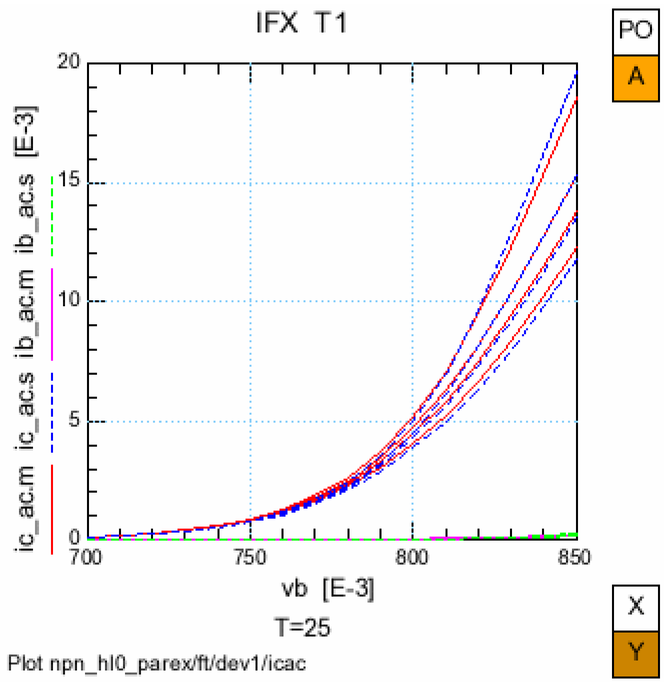


Ic=f(Vc), Vb=Par.

- Check again the collector current modeling using the AC plots ft = f(lin Ic, Vc) and Ic_ac=f(Vb, Vc)



fT=f(Ic, Vc)



Ic=f(Vb), Vc=Par.

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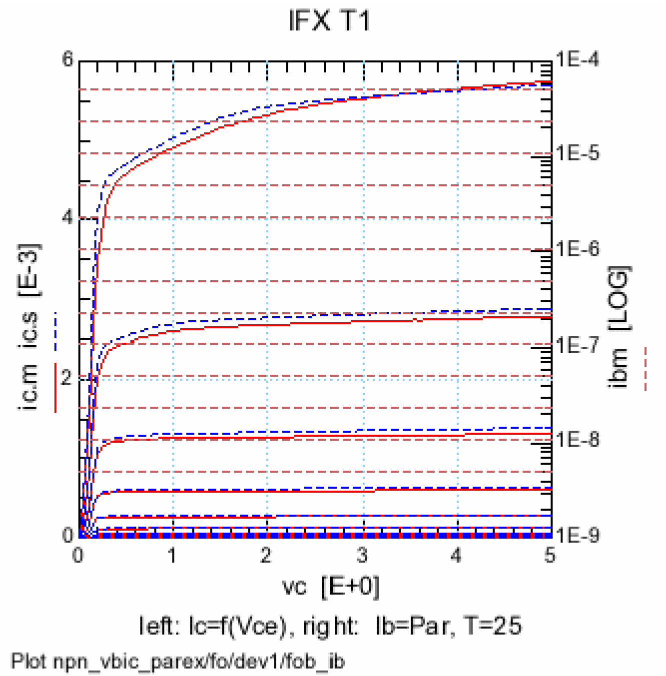
Comparison with VBIC 1.2

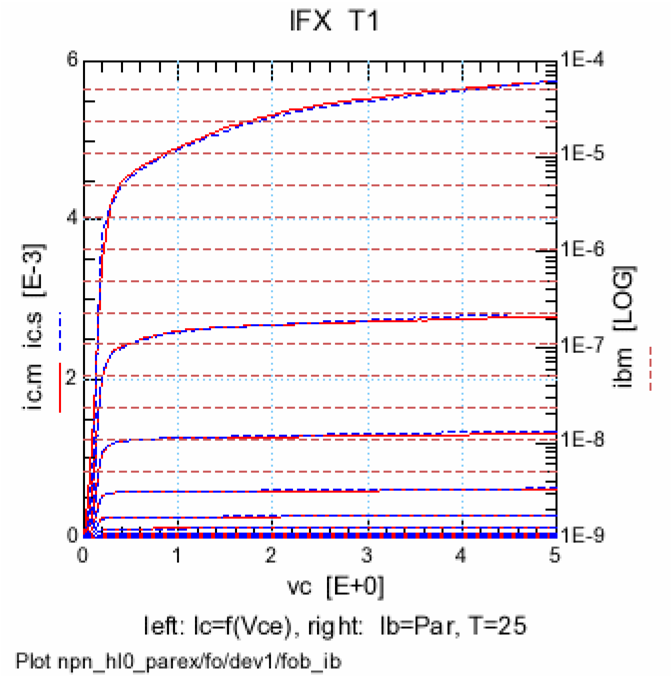
- Base current driven output characteristic: both models allow a sufficient fit

VBIC v1.2



Ic=f(Vc), Ib=Par.

HL0 v1.2

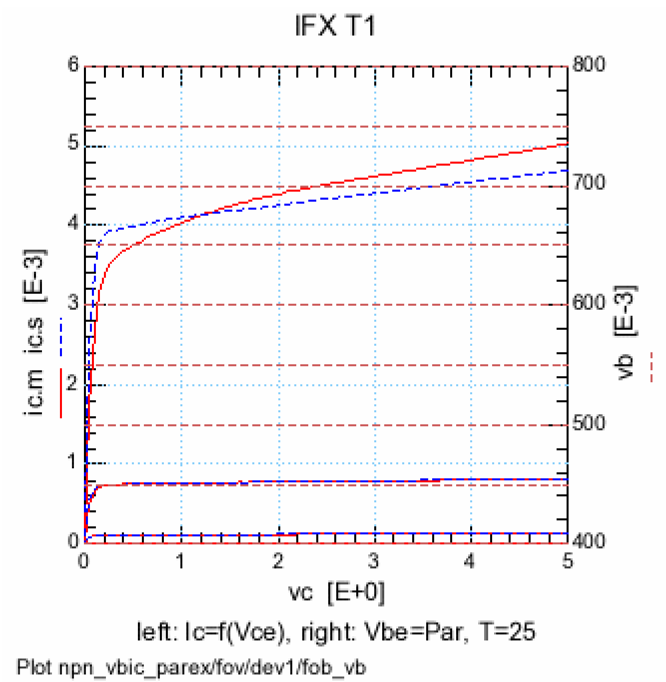


Ic=f(Vc), Ib=Par.

Comparison with VBIC 1.2

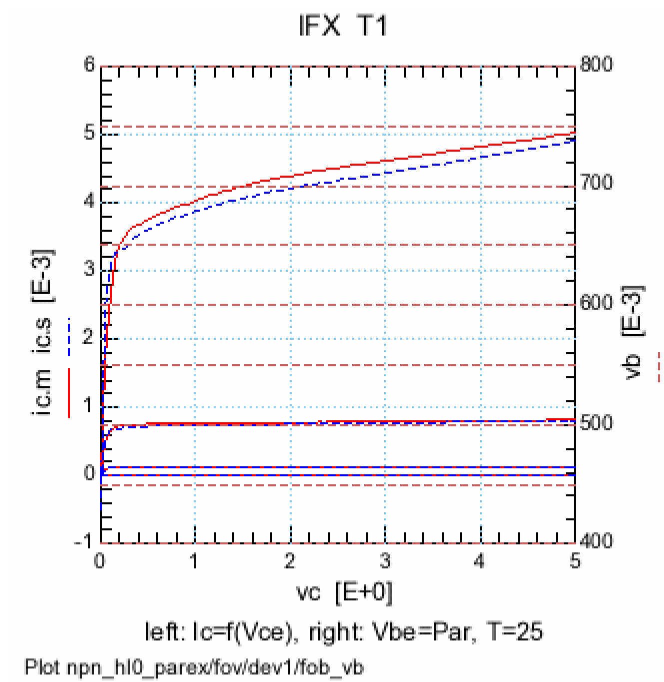
- Voltage driven output characteristic: Sufficient fit for HL0v1.2, VBIC 1.2, however, fails

VBIC v1.2



Ic=f(Vc), Vb=Par.

HL0 v1.2

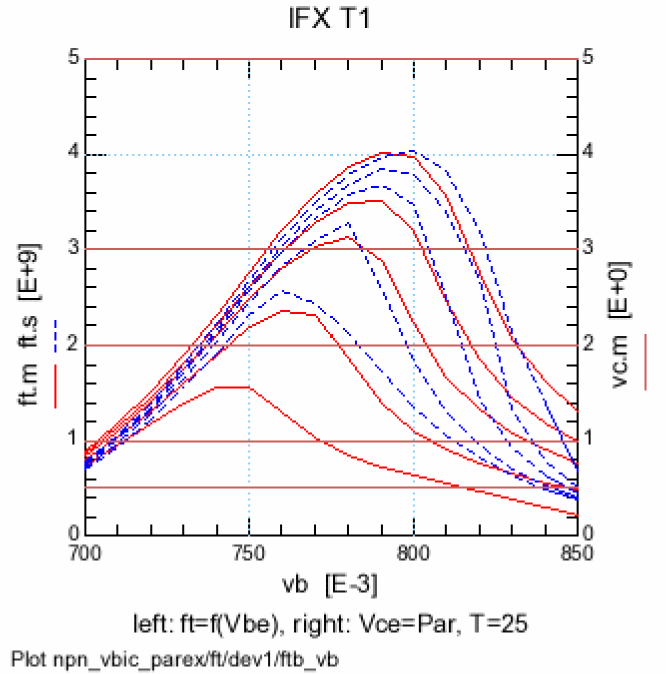


Ic=f(Vc), Vb=Par.

Comparison with VBIC 1.2

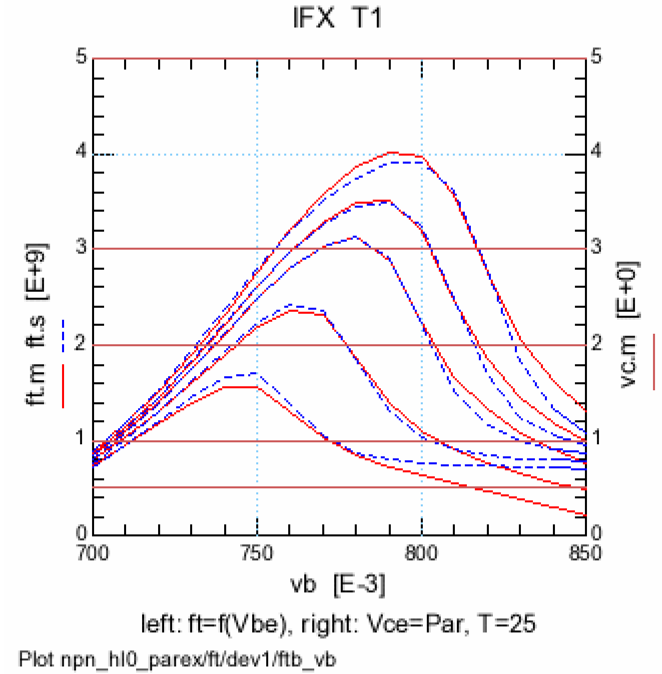
- ft vs. Vb: HL0 v1.2 fits the voltage dependence good, VBIC as bad as SGP and, especially for small devices, a sharp decrease created by RCI is observed, which was optimized on fwd output characteristic

VBIC v1.2



fT=f(Vb, Vc)

HL0 v1.2

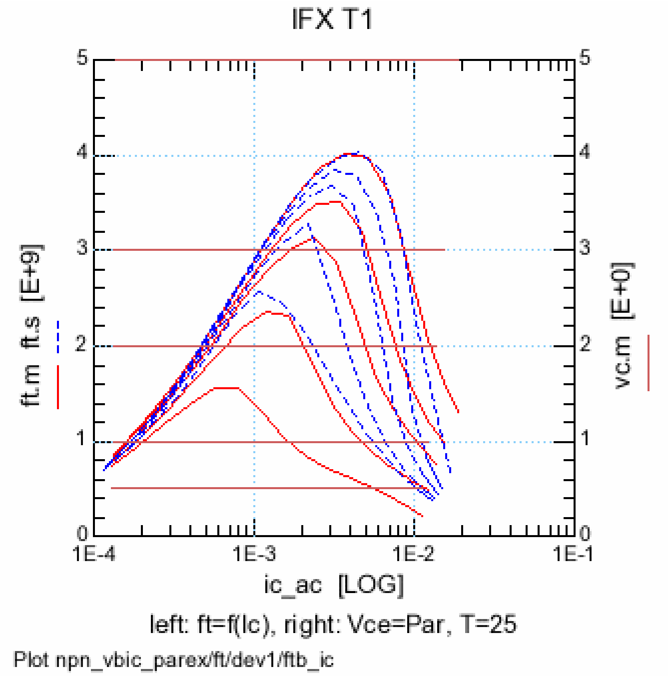


fT=f(Vb, Vc)

Comparison with VBIC 1.2

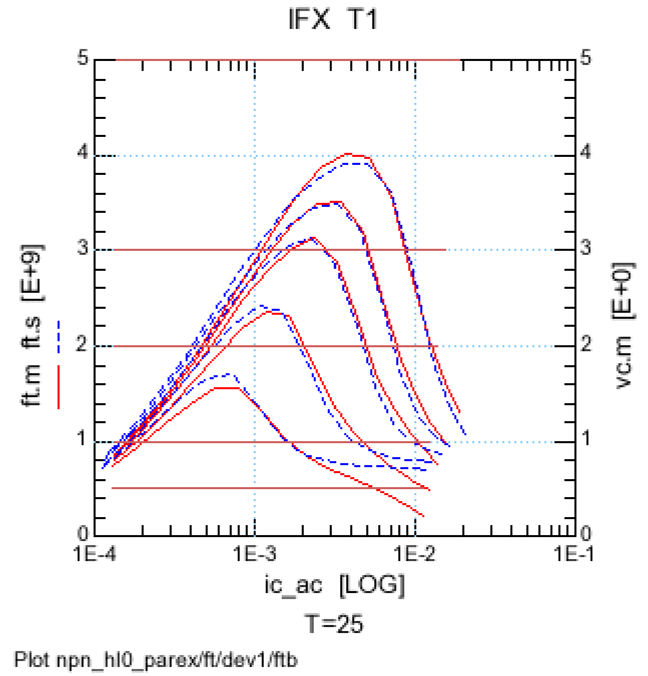
- ft vs. log(Ic): HL0 v1.2 fits Ic axis nearly sufficient, VBIC as bad as SGP

VBIC v1.2



fT=f(log Ic, Vc)

HL0 v1.2

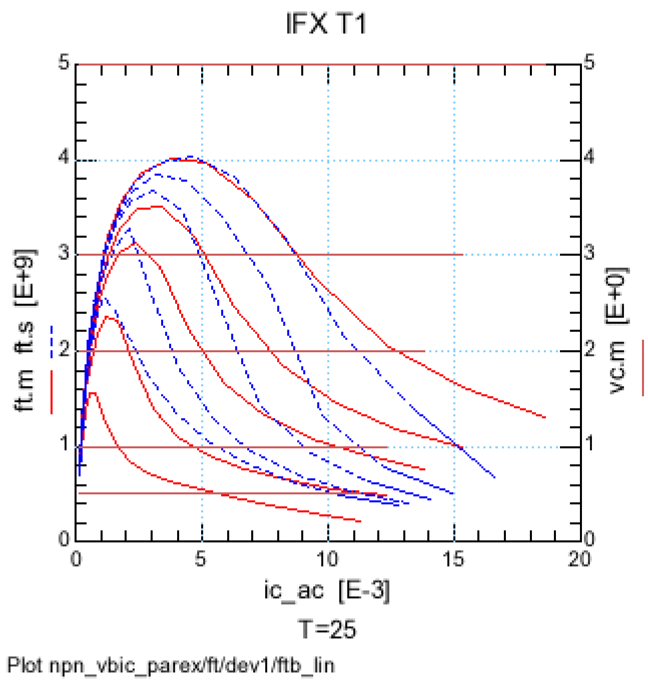


fT=f(log Ic, Vc)

Comparison with VBIC 1.2

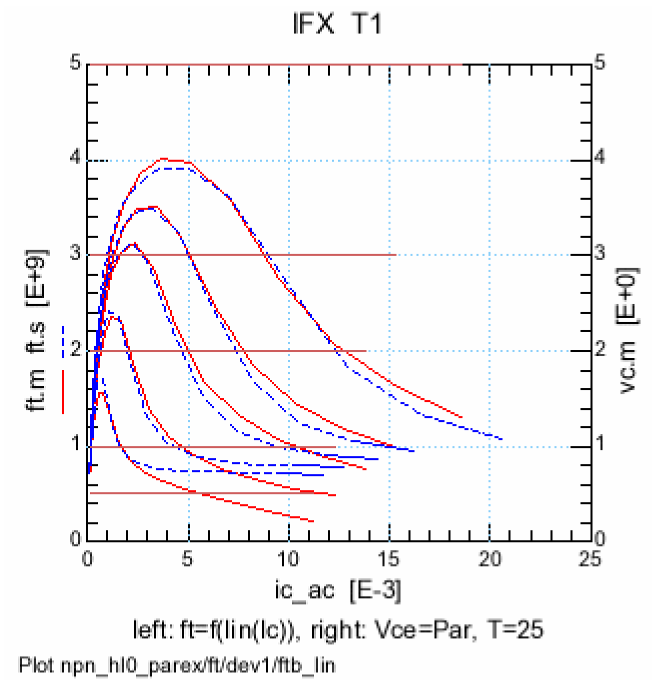
- ft vs. lin(Ic): HL0 v1.2 fits Ic axis nearly sufficient, VBIC as bad as SGP

VBIC v1.2



fT=f(lin Ic, Vc)

HL0 v1.2

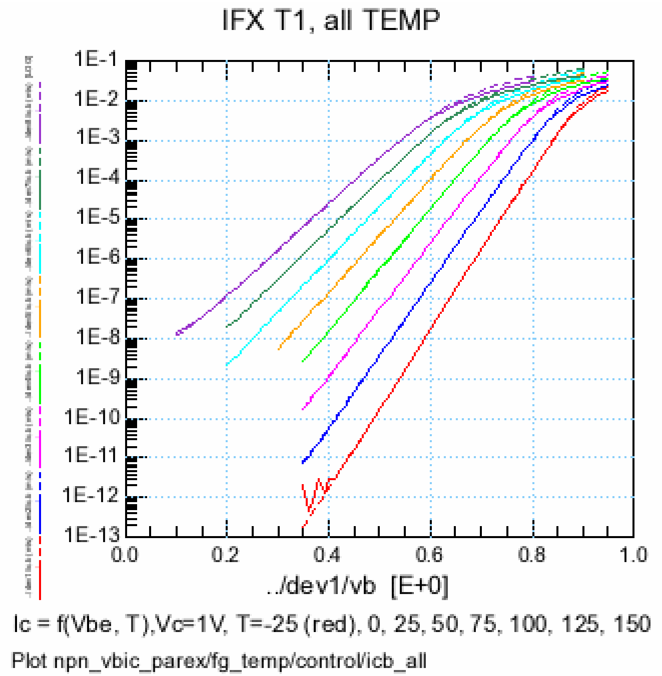


fT=f(lin Ic, Vc)

Comparison with VBIC 1.2

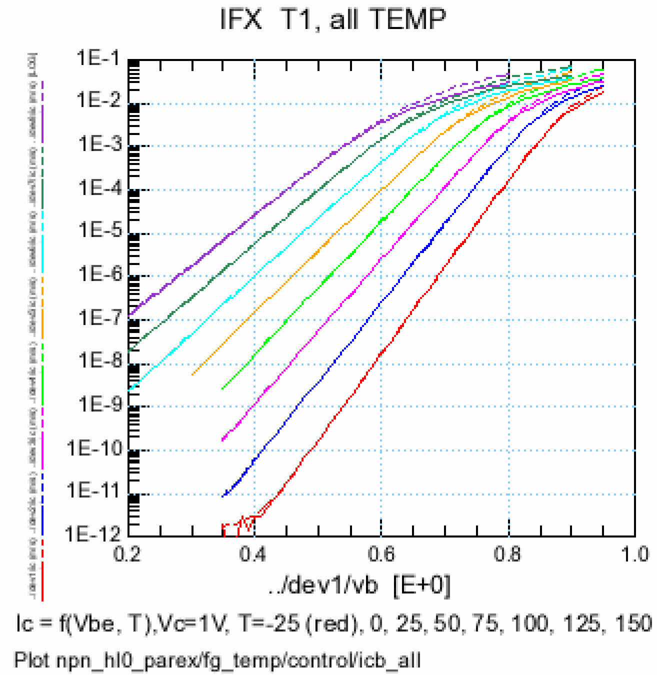
- Temperature behavior of Ic: both models allow sufficient fit

VBIC v1.2



Ic=f(Vb, T)

HL0 v1.2

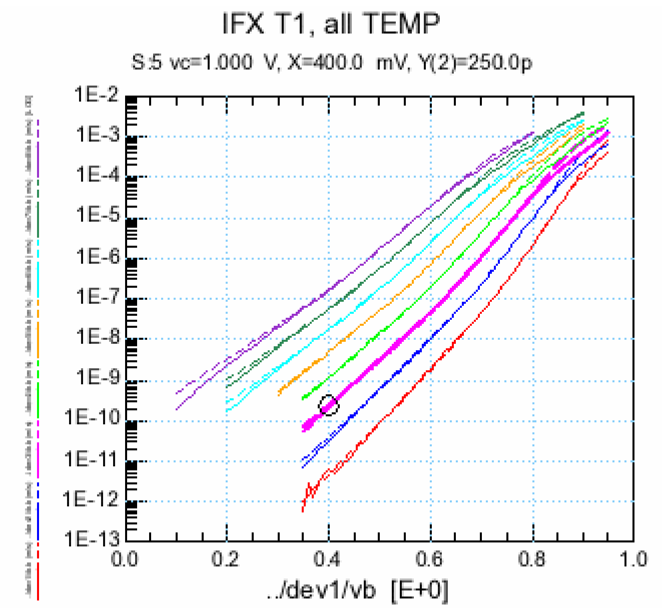


Ic=f(Vb, T)

Comparison with VBIC 1.2

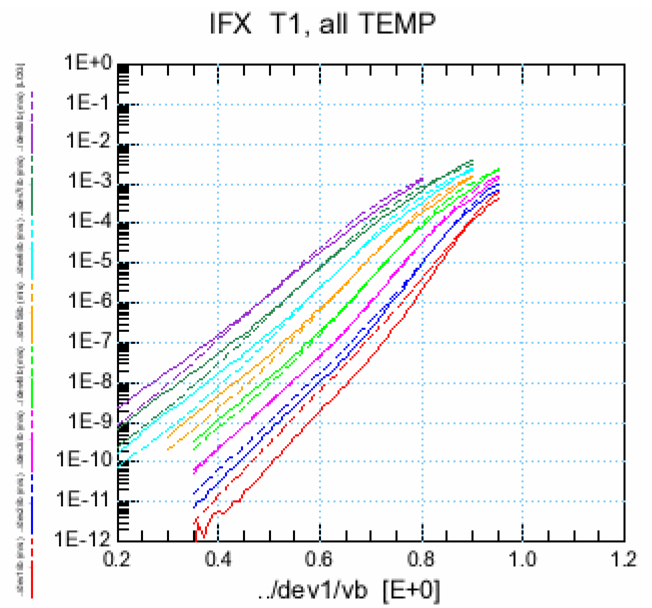
- Temperature behavior of Ib: VBIC allows to fit the non-ideal base current temperature dependence using XIN, HL0 v1.2 not, because instead of an extra parameter a value of mg=4.188 is used

VBIC v1.2 | Ib=f(Vb, T) | HL0 v1.2



Ib = f(Vbe, T), Vc=1V, T=-25 (red), 0, 25, 50, 75, 100, 125, 150

Plot npn_vbic_parex/fg_temp/control/ibb_all



Ib = f(Vbe, T), Vc=1V, T=-25 (red), 0, 25, 50, 75, 100, 125, 150

Plot npn_hl0_parex/fg_temp/control/ibb_all

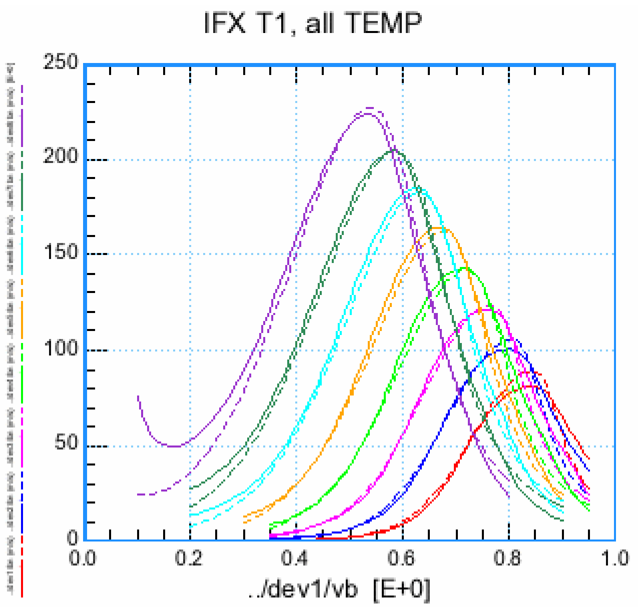
$$IBEN(T) = IBEN(TNOM)\left[rT^{XIN}\exp\left(\frac{EANE\cdot(rT-1)}{U_T}\right)\right]^{1/NEN}$$

$$IRES(T) = IRES(T_0)\left(\frac{T}{T_0}\right)^{\frac{1}{2}\left(3-\frac{q\cdot F1VG}{k}\right)}\exp\left(\frac{1}{2}\cdot\frac{VGBE}{V_T}\left(\frac{T}{T_0}-1\right)\right)$$

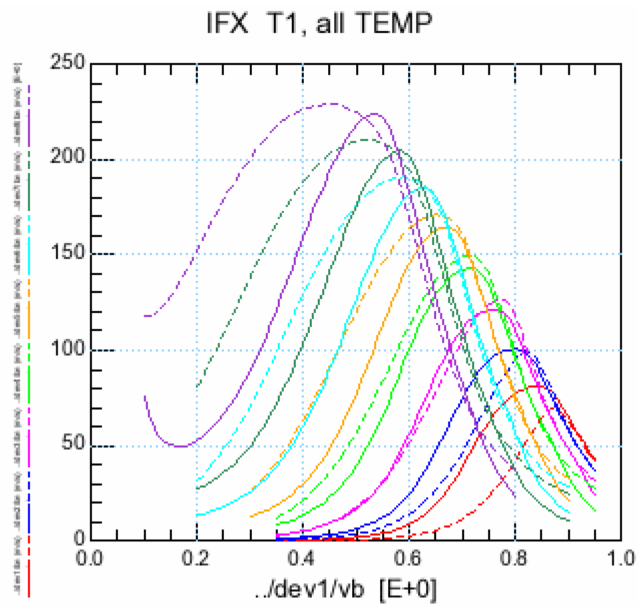
Comparison with VBIC 1.2

- Temperature behavior of Bn: VBIC allows to fit the beta increase temperature dependence sufficient, HL0 v1.2 not

VBIC v1.2 | Bn=f(Vb, T) | HL0 v1.2



Bn = f(Vbe, T), Vc=1V, T=-25 (red), 0, 25, 50, 75, 100, 125, 150
Plot npn_vbic_parex/fg_temp/control/bnb_all



Bn = f(Vbe, T), Vc=1V, T=-25 (red), 0, 25, 50, 75, 100, 125, 150
Plot npn_hl0_parex/fg_temp/control/bnb_all

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Summary

- Hicum L0 v1.2 is able to model sufficient the following effects:

1. QS of the voltage driven forward output characteristic
2. QS of the current driven forward output characteristic
3. ft voltage dependence and ft roll off

- This is an essential progress compared to HL0 v1.12 and an important advantage compared to VBIC 1.2
- Hicum L0 v1.2 is NOT able to model sufficient the temperature dependence of the non-ideal BE base current
- Request: An additional model parameter ZETARET must be introduced
- Two typing errors in the VHDL code must be corrected:

1. AHCX -> AHQ
2. ZETIQF -> ZETAIQF


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We innovate.
We partner.
We create value.

ENERGY EFFICIENCY
COMMUNICATIONS
SECURITY

Innovative semiconductor solutions for energy efficiency, communications and security.