A Novel Method for Transit Time Parameter Extraction Taking into Account the Coupling Between DC and AC Characteristics

Dominique BERGER and Didier CELI

STMicroelectronics, Device Modelling
850, rue jean Monnet
F-38926 Crolles Cedex

HICUM user's meeting

September 30, 2001

Minneapolis, MN

Outline

- Introduction
- Extraction issues
  - Classic extraction strategy
  - DC-AC coupling through main characteristics
- A novel extraction strategy
  - Static parameters correction
  - Improvements on current gain and output characteristics
- Conclusion
- References

Introduction

The Aim of this presentation is

- To present a single device extraction strategy of the main HICUM model parameters.

  ➔ Main parameters are:
  - DC parameters used for the modelling of the transfer current
  - AC parameters like transit time parameters modelling both the DC and AC behaviour of the transistor

  ↳ proposed a new extraction strategy to solve this coupling between AC & DC parameters

- To present the results obtained using measurement on NPN transistor fabricated within a 0.25 μm SiGe BiCMOS technology of STMicroelectronics

- To present critical points we have encountered with this method

Classic Extraction Strategy [1]

Depletion capacitances & series resistances

$$\frac{1}{2\pi f_T} = f\left(\frac{1}{I_C}\right)$$ **Characteristic**

Transfer current parameters
c_{10}, Q_{p0}, h_{jci}
assuming h_{jei}=1

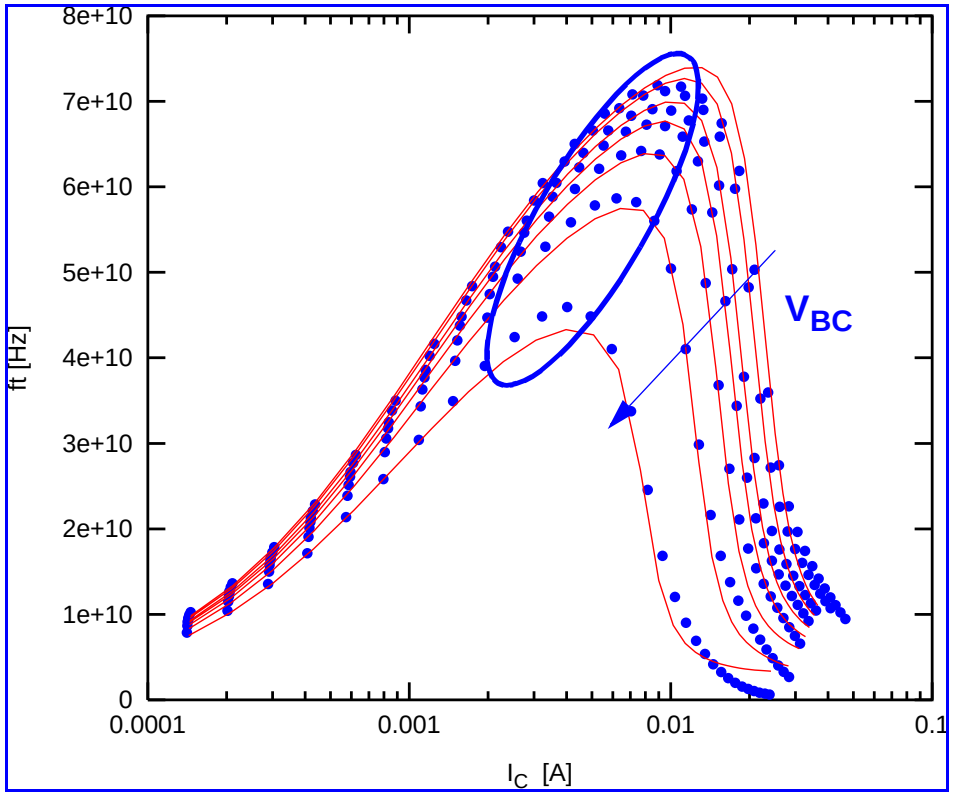
transit time at low bias
τ_0, $\Delta\tau_{0h}$, τ_{bvl}

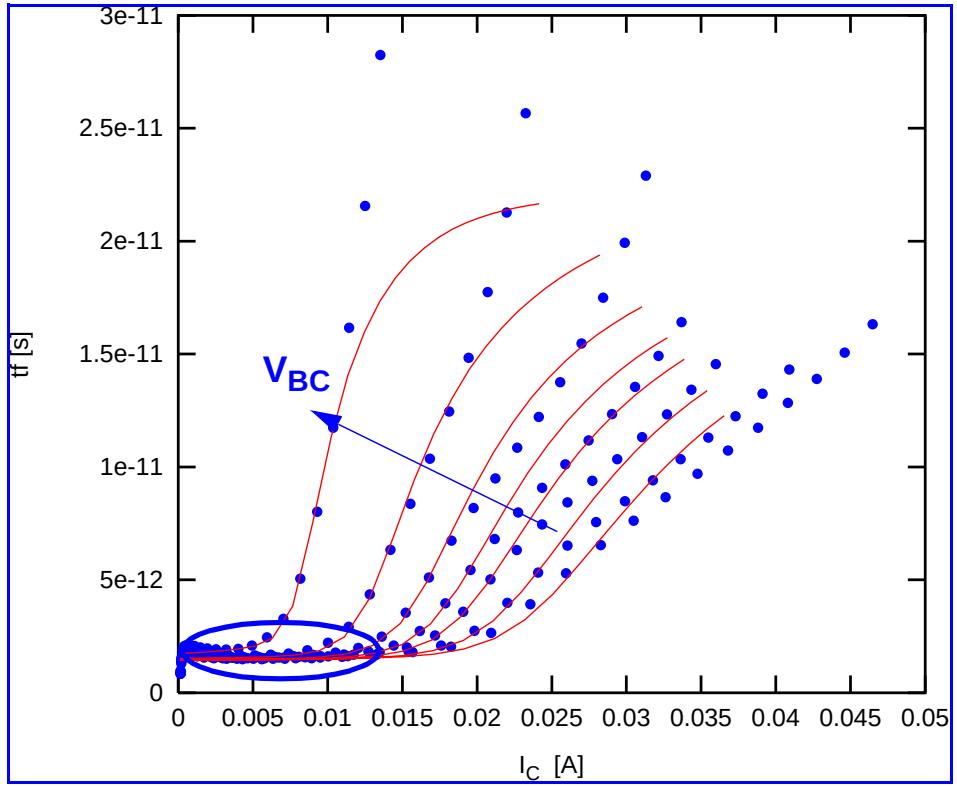
critical current ICK
Rci0, Vlim, Vces, Vpt

Base current parameters
I_{REIS}, I_{BEIS}
m_{REI}=2, m_{BEI}=1

transit time at high current
τ_{Ef0}, $g\tau e$, ahc, τ_{hcs}

f_T and Transit time

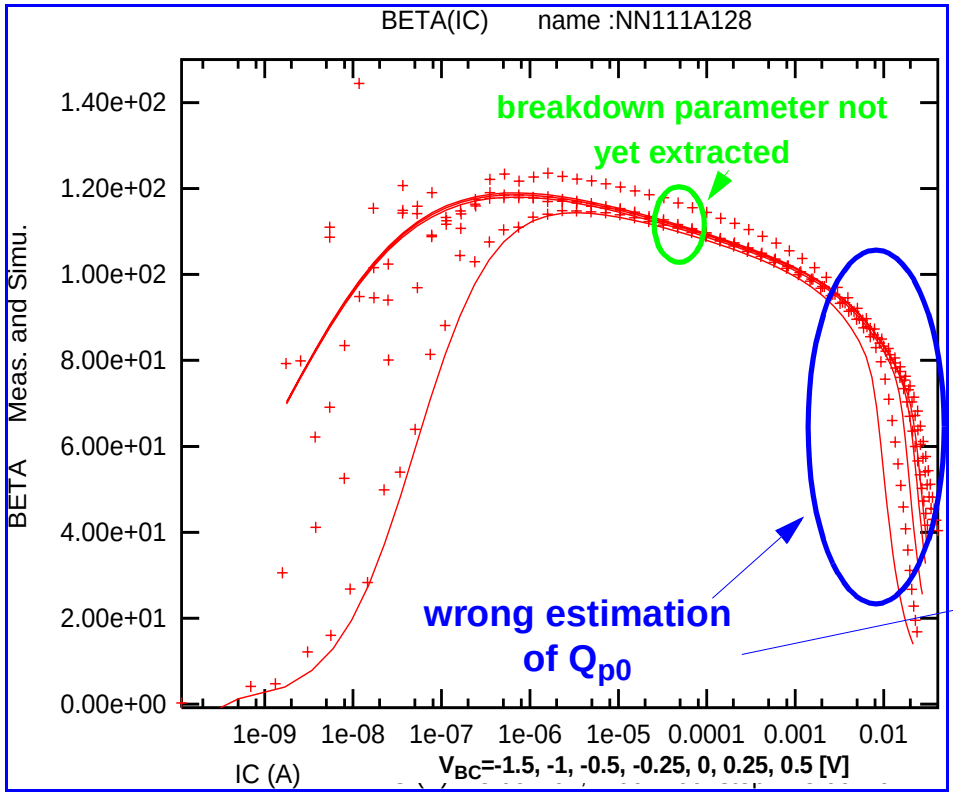


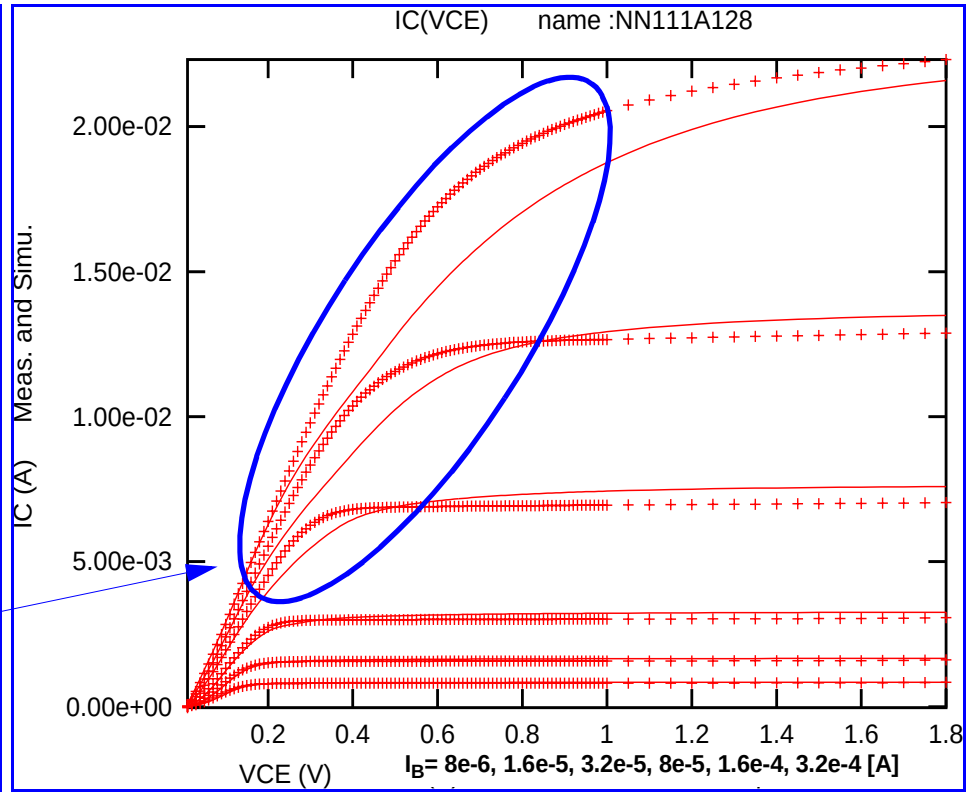


V_{BC} = -1.5, -1, -0.5, -0.25, 0, 0.25, 0.5 V

- The inaccuracy on Rcx and on the split of depletion capacitance, specially the Base-Emitter capacitance, affect strongly the fit of the f_T peak and its low injection behaviour.
- Transit time extraction method have been tested from simulated data, the extracted set of parameters corresponds with the initial one ➡ validation of the proposed method.

Gain and Output Characteristics





- The lack of accuracy on the onset of high injection effect comes from the inadequate evaluation of the effective knee current I_{Keff} which can be approximated in this region by the ratio:

$$I_{Keff} = \frac{Q_{p0}}{\tau_{f0}}$$

  - Inadequate Q_{p0} gives a wrong value for I_{Keff}, τ_{f0} coming from f_T curves.

Transfer current parameters extraction issue

- The classic transfer current extraction must be review, specially the assumption $h_{jei}=1$.
- This direct extraction provides the ratios $\frac{c_{10}}{h_{jei}}$, $\frac{Q_{p0}}{h_{jei}}$ and $\frac{h_{jci}}{h_{jei}}$ which allow to define the saturation current $I_s = \frac{c_{10}}{h_{jei}} \times \frac{h_{jei}}{Q_{p0}} = \frac{c_{10}}{Q_{p0}}$ ➡ I_s is independent of h_{jei}.

$$I_T = \frac{c_{10}\left(\exp\left(\frac{V_{BEi}}{V_T}\right) - \exp\left(\frac{V_{BCi}}{V_T}\right)\right)}{Q_{p0} + h_{jei}Q_{JEi} + h_{jci}Q_{JCi} + Q_{FT}}$$

V_{BC}=0V
$I_C(V_{BE})$ characteristic

from $$Q_{JEi} = \frac{c_{10}}{h_{jei}} \times \frac{\exp\left(\frac{V_{BEi}}{V_T}\right)}{I_T} - \frac{Q_{p0}}{h_{jei}}$$

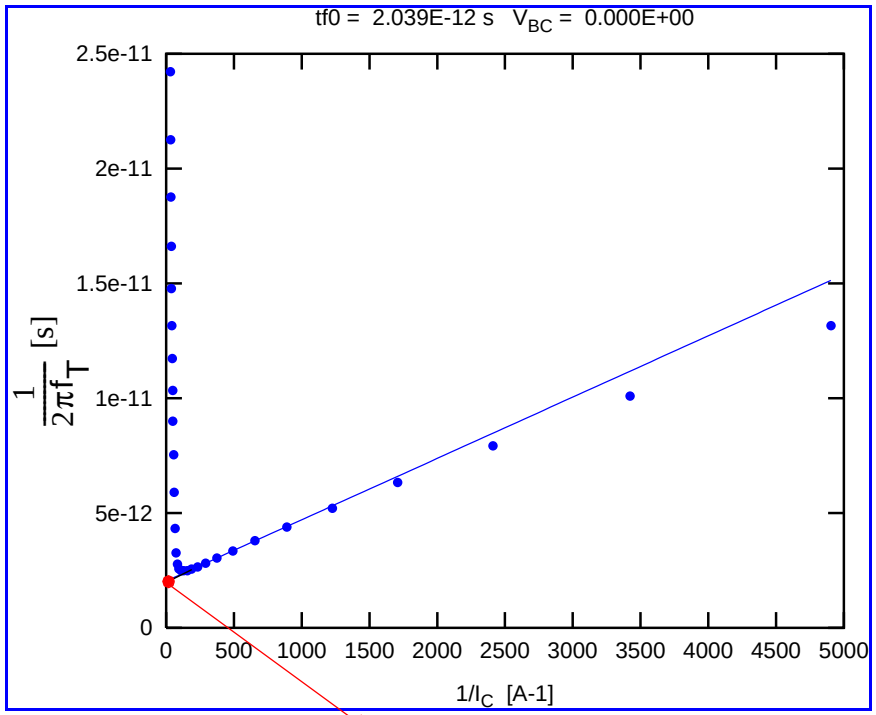
gives $$\frac{c_{10}}{h_{jei}} = r1 \quad \& \quad \frac{Q_{p0}}{h_{jei}} = r2$$

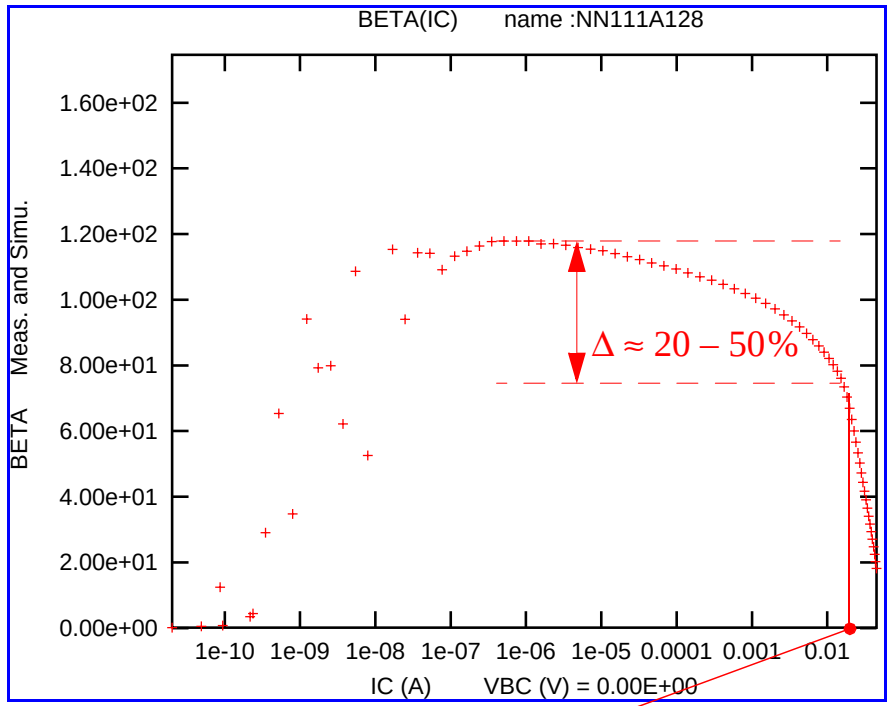
V_{BE}=0.7V
$I_C(V_{BC})$ characteristic

from $$\frac{Q_{p0}}{h_{jei}} + Q_{JEi} + \frac{h_{jci}}{h_{jei}} \times Q_{JCi} = \frac{c_{10}}{h_{jei}} \times \frac{e^{\frac{VBEi}{VT}} - e^{\frac{VBCi}{VT}}}{I_T}$$

gives $$\frac{h_{jci}}{h_{jei}} = r3$$

Static Correction from Transit time parameters





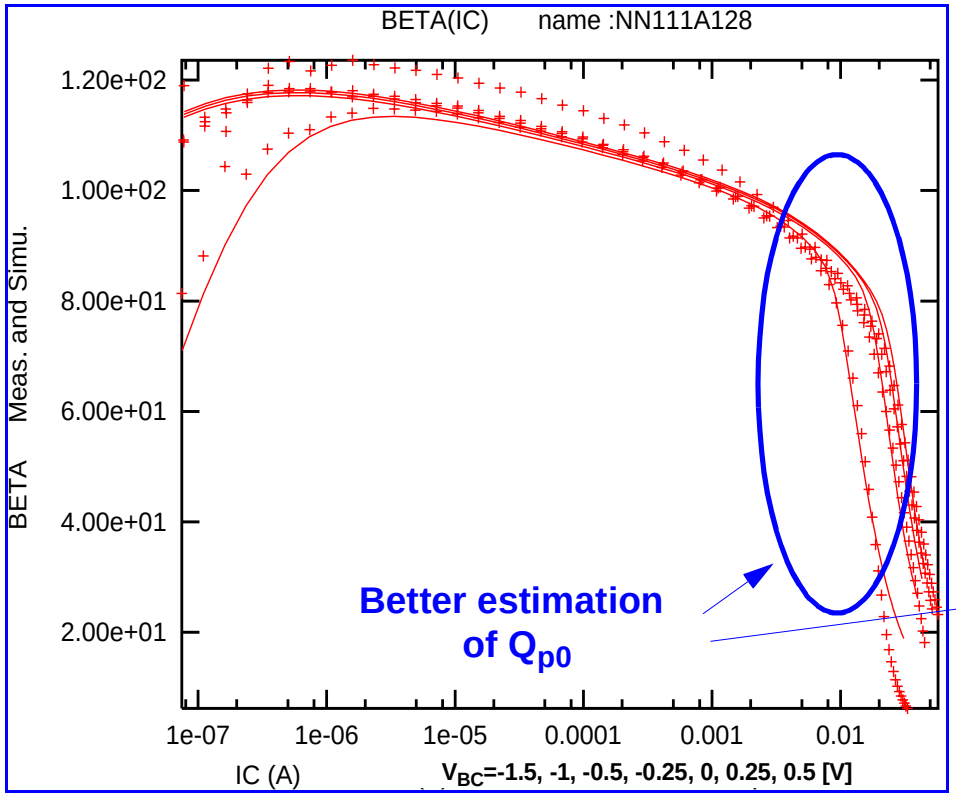
τ_0 → $Q_{p0} = I_{Keff} \times \tau_0$ ← I_{Keff}

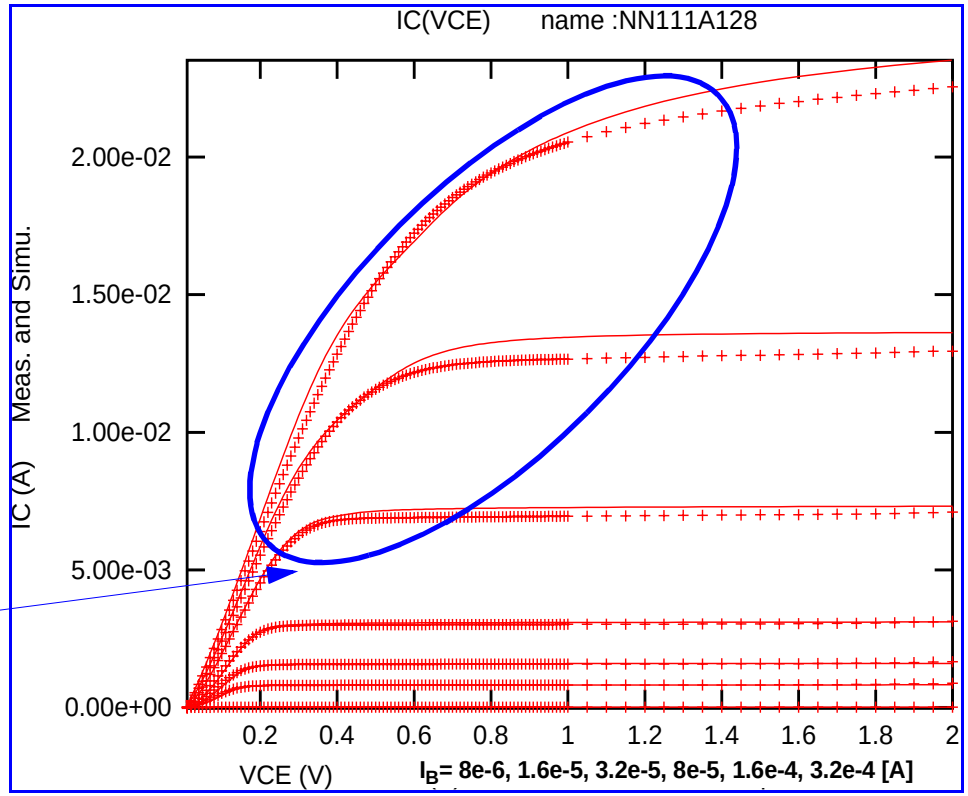
$$h_{jei}\ new = \frac{Q_{p0}}{r2}$$

$$c_{10}\ new = h_{jei}\ new \times r1$$

$$h_{jci}\ new = h_{jei}\ new \times r3$$

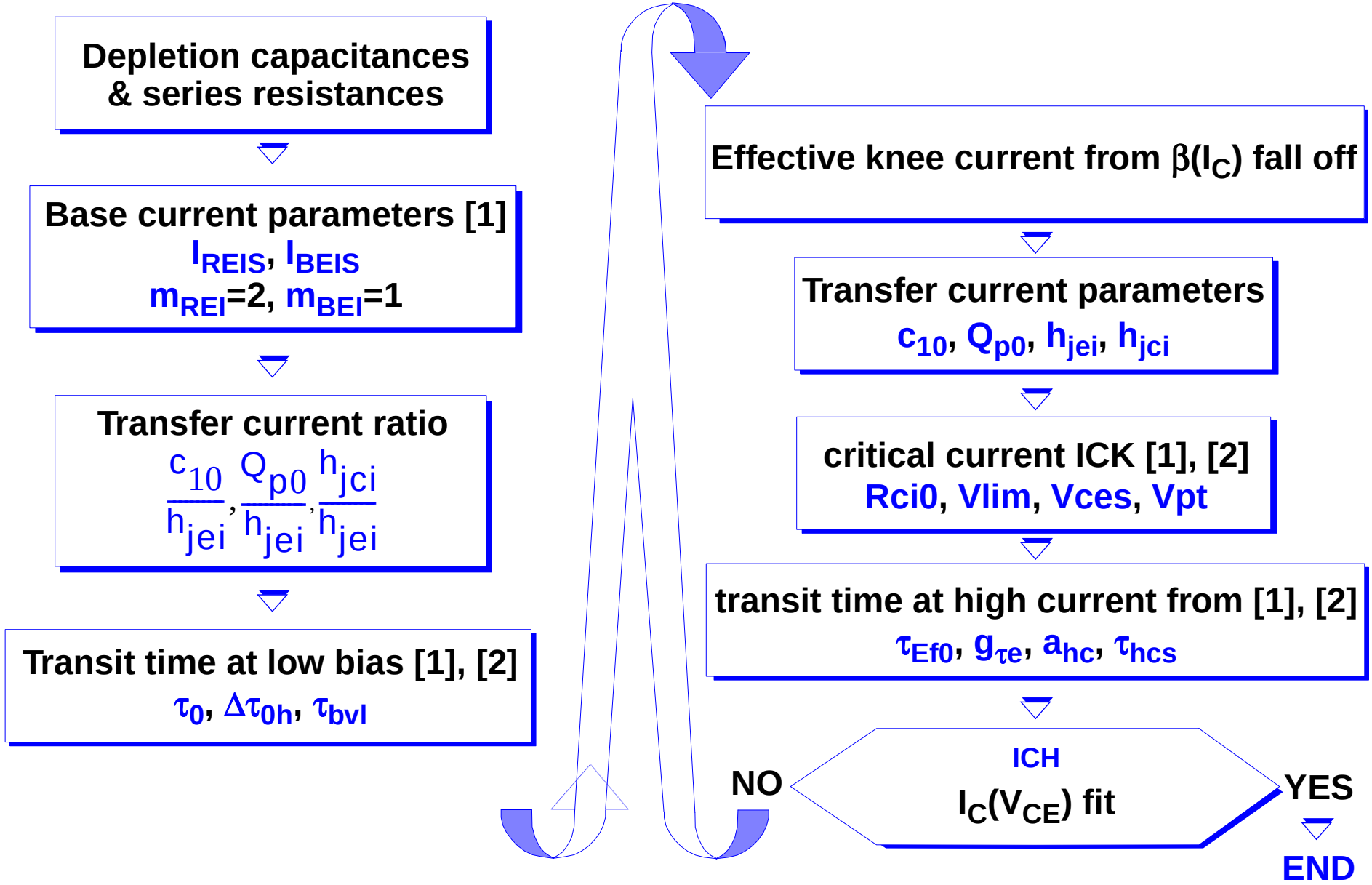
Forward current gain and output characteristics





- Avalanche breakdown parameters are not extracted.
- The fit in the circle range is better than the previous comparisons shown in slide 6
- The I_{Keff} current is arbitrary determined.
- The value of h_{jei} can be discussed (physical point of view : h_{jei}=3.5).

New proposed extraction strategy



Conclusion

- We propose an improved extraction strategy to solve the coupling between DC and AC parameters (c_{10}, Q_{p0}, h_{jei}, h_{jci},τ_0,...) by estimating Q_{p0} at high density of currents from the τ_0 value and defining an effective knee current I_{Keff}.

- A more accurate method to define the effective knee current must be developed. Criterium to be found in order to avoid extraction loops between f_T and output characteristics.

- The physical meaning of h_{jei} can be discussed but the following extraction strategy gives a suitable fit between theory and measurements for DC & AC characteristics.

- These comparisons could be certainly improved by a best evaluation of the serie resistance (Rcx) and of the split of the depletion capacitances.

- The scalability of the extracted parameters need to be verified.

REFERENCE

[1] D. Berger, D. Céli, N. Gambetta, T. Burdeau: "HICUM Parameters Extraction Methods", HICUM workshop, June 14/15 2001, Dresden.

[2] B. Ardouin, et al.: "Transit Time Parameters Extraction for the HICUM Bipolar Compact Model", Proceedings of the Bipolar Circuits and Technology Meeting, Minneapolis, 2001.