Contributions to HICUM Parameter Extraction

by

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Hicum Workshop at BCTM2001, Minneapolis

Outline

- Two point method for critical current I_{CK}
- Two point method for model parameter THCS
- Pitfall during extraction of QP0 and C10 from Gummel plot

Hicum Parameter Extraction
Two Point Method for Critical Current I_{CK} (1)

- Assuming ALHC=0 the normalized injection width w is given by:

$$i = 1 - \frac{I_{CK}}{I_{TF}} \quad \Rightarrow \quad w = \frac{w_I}{w_C} = \frac{i + \sqrt{i^2 + ALHC}}{1 + \sqrt{1 + ALHC}} \quad \Rightarrow \quad w = i$$

- Merging both base and collector transit time parts ΔT_{FB} and T_{FCT} results in:

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

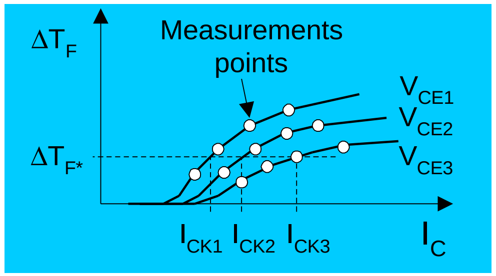
$$T_{FCT} = FTHC \cdot THCS \cdot w^2 \left[1 + \frac{2}{\frac{I_{TF}}{I_{CK}} \sqrt{i^2 + ALHC}} \right]$$

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

Hicum Parameter Extraction
Two Point Method for Critical Current I_{CK} (2)

- I_{TF} is given here by the measured I_C. There are two unknowns in second equ., the critical current I_{CK} and model parameter THCS.
- Using a plot sqrt((ΔT_{FB} /THCS)-1) vs. I_{CK} / I_{TF} we may vary THCS until the characteristic is a straight line and extract I_{CK} from slope.
- However, the better way is to use the two point equation.

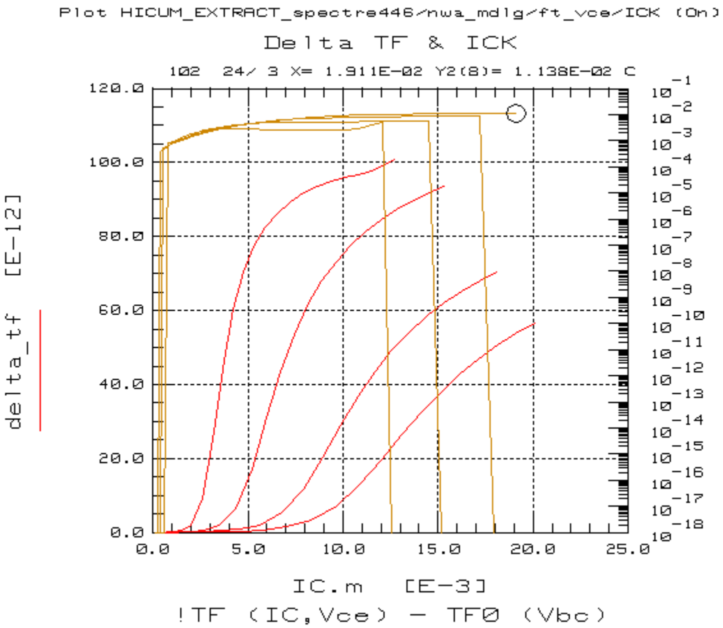
$$T_{FBC} = THCS \cdot w^2 \left[1 + \frac{2}{\frac{I_{TF}}{I_{CK}} \sqrt{i^2 + ALHC}} \right] \Rightarrow \frac{\Delta T_F}{THCS} = 1 - \left(\frac{I_{CK}}{I_{TF}} \right)^2$$

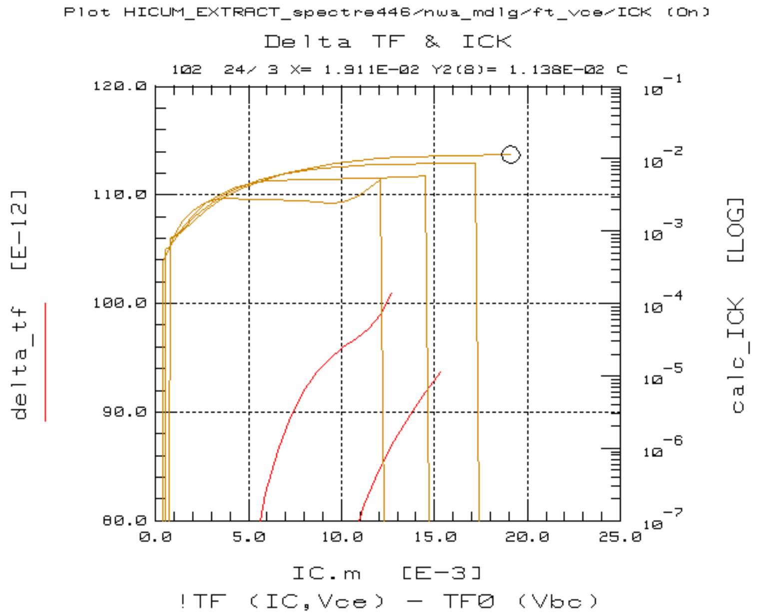


$$I_{CK} = \sqrt{\frac{\Delta T_{F2} - \Delta T_{F2}}{\frac{\Delta T_{F2}}{I_{C1}^2} - \frac{\Delta T_{F1}}{I_{C2}^2}}} = \sqrt{\frac{(\Delta T_{F2} - \Delta T_{F2}) I_{C1}^2 \cdot I_{C2}^2}{\Delta T_{F2} I_{C2}^2 - \Delta T_{F1} I_{C1}^2}}$$

Hicum Parameter Extraction
Two Point Method for Critical Current I_{CK} (3)

- Extracted I_{CK} values are lower than values by Ardouin's method





V_C /V	0.3	0.5	1	2
I_{CK} / mA (Ardouin)	4.1	7.75	13.6	20.1
I_{CK} / mA (Berkner)	2.65	5.79	8.77	11.38

Note: This example is based on the model file HICUM_EXTRACT (July 2001) from B.Arduin (UNI Bordeaux) and the appropriate (synthetic) data in the setup nwa_mdlg/ft_vce.

Hicum Parameter Extraction
Two Point Method for Model Parameter THCS (1)

- The same principle may be used for THCS

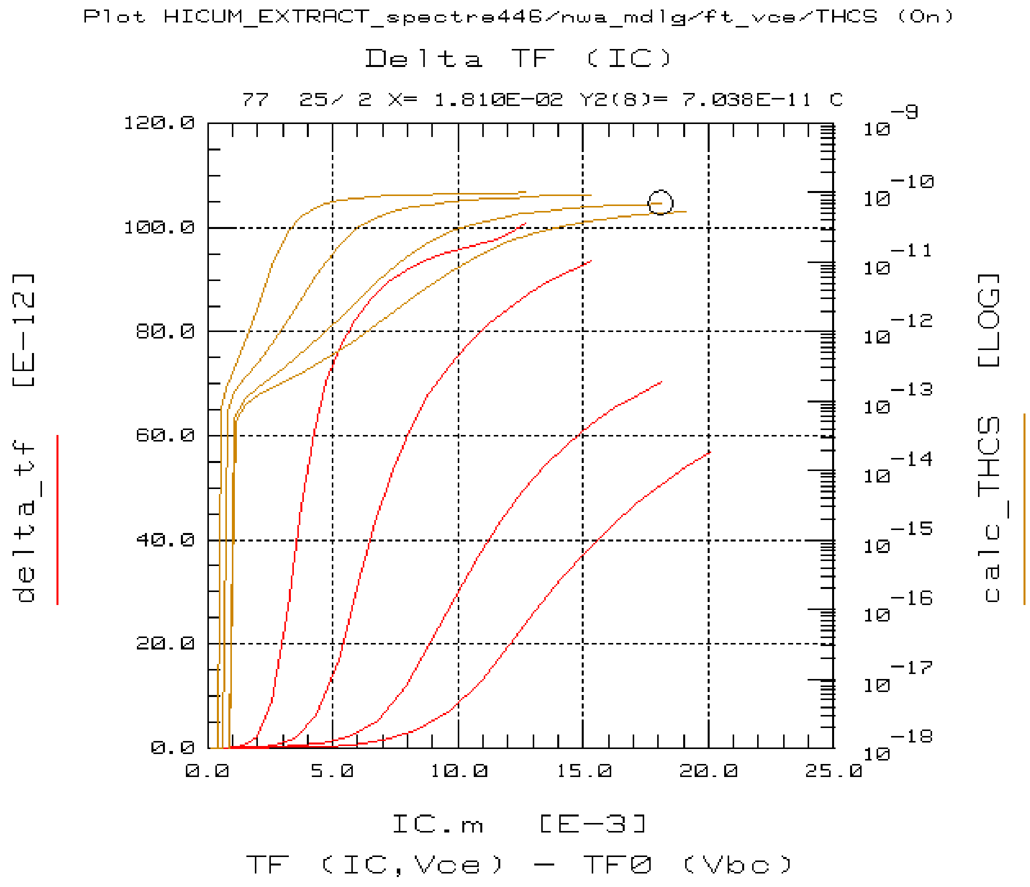
$$T_{FBC} = THCS \cdot w^2 \left[1 + \frac{2}{\frac{I_{TF}}{I_{CK}} \sqrt{i^2 + ALHC}} \right] \Rightarrow \frac{\Delta T_F}{THCS} = 1 - \left(\frac{I_{CK}}{I_{TF}} \right)^2$$

- Using two measurement points (ΔT_{FB1} ; I_{C1}) and (ΔT_{FB2} ; I_{C2}) we have:

$$THCS = \frac{\Delta T_{F1} - \Delta T_{F2} \left(\frac{I_{C2}}{I_{C1}} \right)^2}{1 - \left(\frac{I_{C2}}{I_{C1}} \right)^2}$$

Hicum Parameter Extraction
Two Point Method for Model Parameter THCS (2)

- The parameter THCS shows asymptotically behavior too.
- The value for the curve V_{CE} =1V is THCS=70.38pS.
- This is in accordance with the value THCS = 70 pS used for creating the synthetic data.



Hicum Parameter Extraction
Model Parameters QP0 and C10 (1)

- QP0 and C10 may be extracted from Gummel plot measured at V_{BC}=0 using an optimization

- The calculated quantity is given by:

$$\left(\frac{C10}{Q_{PT}}\right)_{meas} = \frac{I_{Cmeas}}{\exp\left(\frac{V_{BE}}{V_T}\right)}$$

Optimization

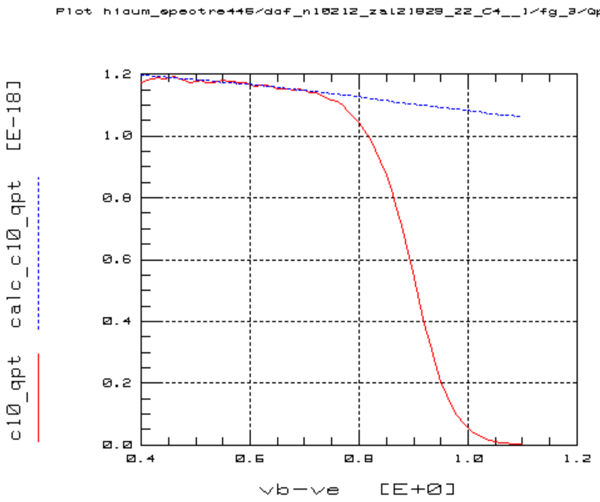
- The measured quantity is given by:

$$\left(\frac{C10}{Q_{PT}}\right)_{calc} = \frac{C10}{QP0 + Q_{JE}}$$

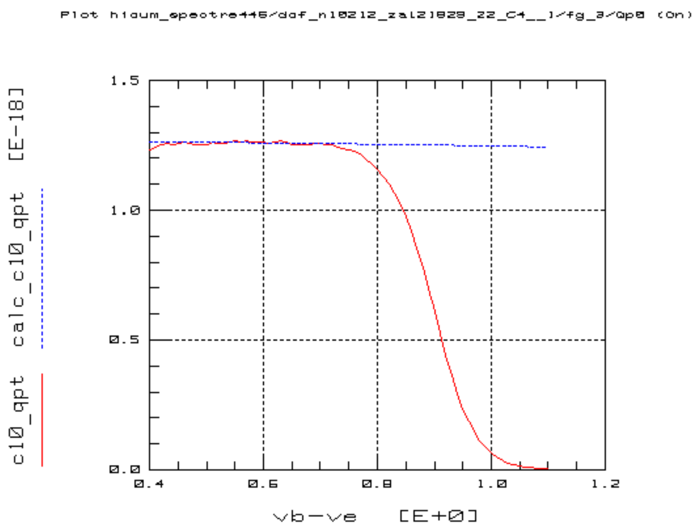
- However, the real device temperature effects via V_T very strong the QP0 and C10 values, extracted from Gummel plot

Hicum Parameter Extraction
Model Parameters QP0 and C10 (2)

- Pitfall: a small Δ T results in a large ΔQP0
- Conclusion: the actual device temperature must be known and used for V_T calculation as accurate as possible



T=25C



T=26C

T_celcius	T_kelvin	k	q	vt	c10	qp0
24	297.15	1.38E-23	1.602E-19	0.02559719	8.00E-32	6.60E-14
25	298.15	1.38E-23	1.602E-19	0.02568333	1.66E-31	1.34E-13
26	299.15	1.38E-23	1.602E-19	0.02576948	1.41E-30	1.13E-12