HBT’s thermal impedance measurement

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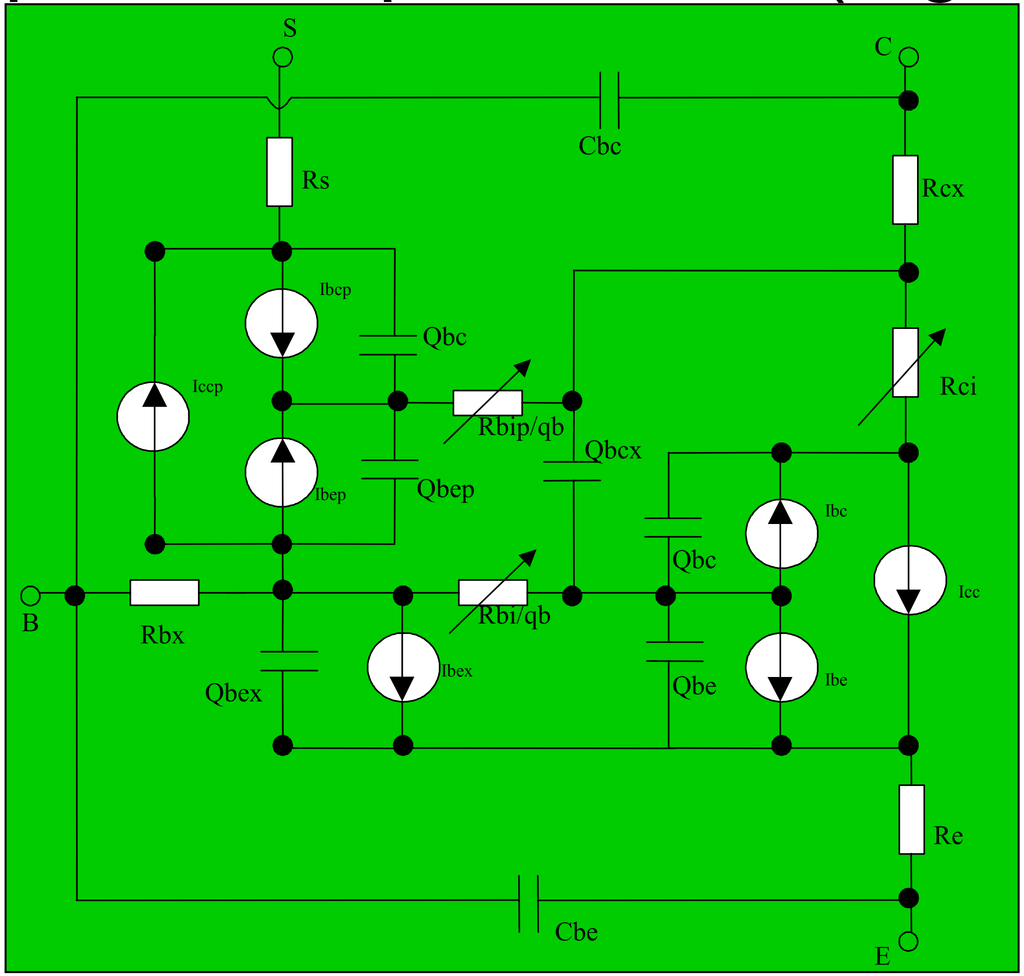
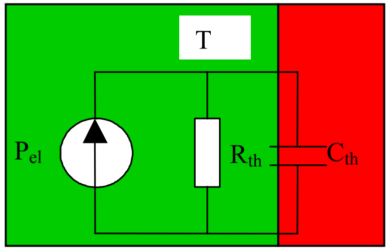
Motivation

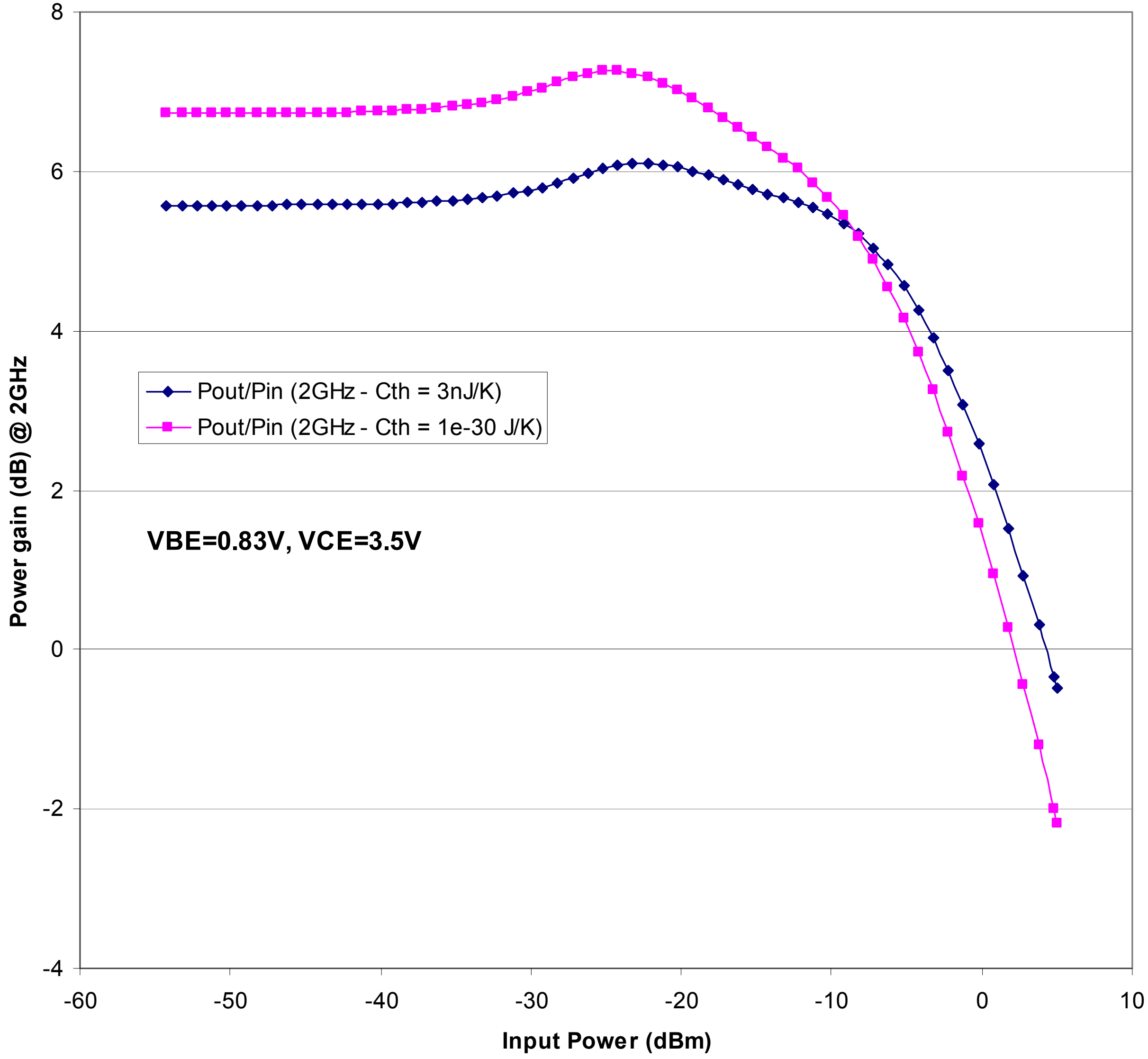
- Bipolar compact model (e.g. VBIC)





Thermal network

Do we really need C_{TH} ?



Harmonic balance simulation:

HICUM with ADS

RF power transistor

Power gain as a function of input power at 2GHz

We do really need C_{TH}.

- But, how to get it ?

Outline

- Motivation: done
- Presentation of two methods for:
  - Z_{TH} measurement
  - C_{TH} extraction
  - Z_{TH} modelling
- Scaling issues
- Questions

Z_{TH} measurement

1. Load Pull measurement

2. Small Signal measurement
   - frequency range
     - NWA
     - Z-parameters

3. Pulsed measurement

Load Pull measurement

- Measurement equipment
- De-embedding and calibration
- Indirect extraction
  - First, full compact model parameter extraction
  - Second, C_{TH} fitting
  - Third, C_{TH} is in general not very sensitive

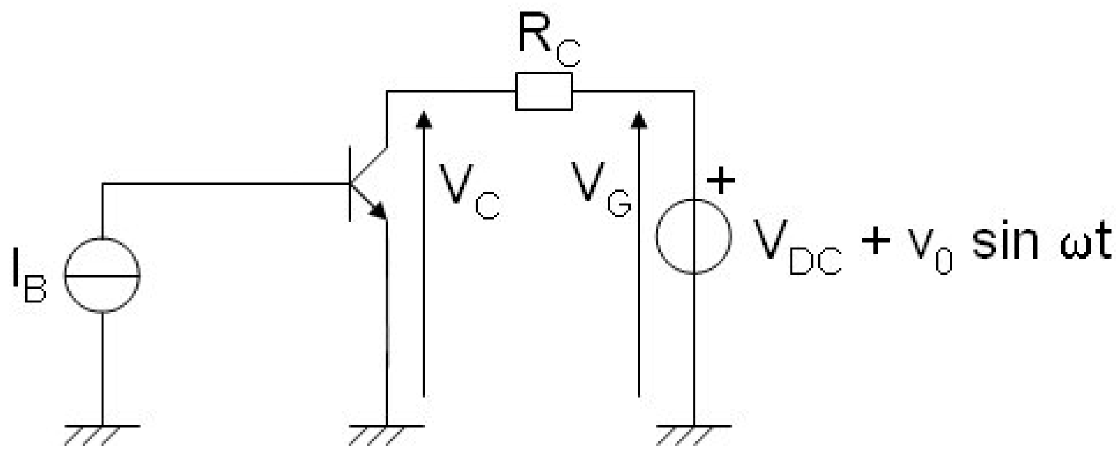
- => For instance, not the best choice

Small Signal measurement

- Frequency range: first order guess
  - Standard transistor:
    - Deep trench isolation
    - 0.25μm x 12.8μm
    - R_{TH} = 1000 K/W
    - C_{TH} = 0.5 nJ/K
    - $f_{TH} = 1/(2\pi\, R_{TH}\, C_{TH}) \approx 300$ kHz
  - Out of the range of standard NWA

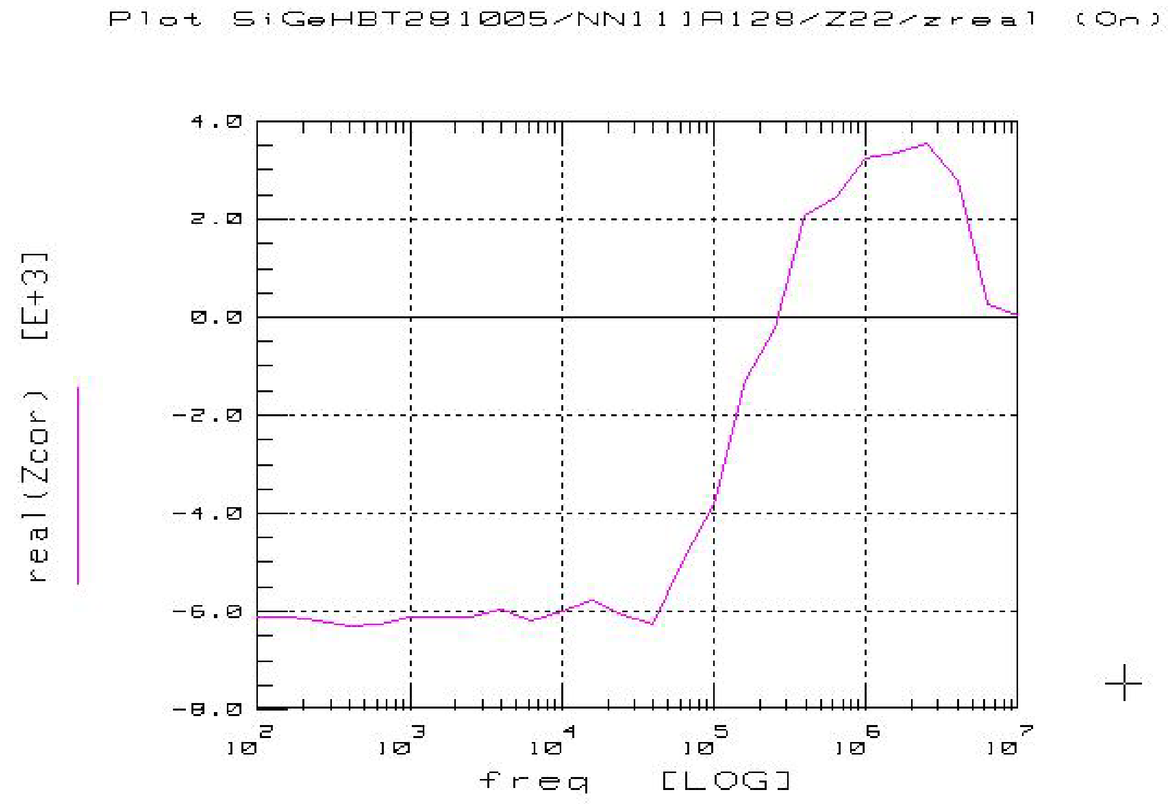
Measurement setup: AC

- Base: I_B constant
- Collector: $V_{DC} + V_{AC}$
- I_C through R_C
- $Z_{CE} = V_C/I_C$ (complex)
- frequency range
  - Theory: $0 \rightarrow \infty$
  - 0.1Hz→10 MHz



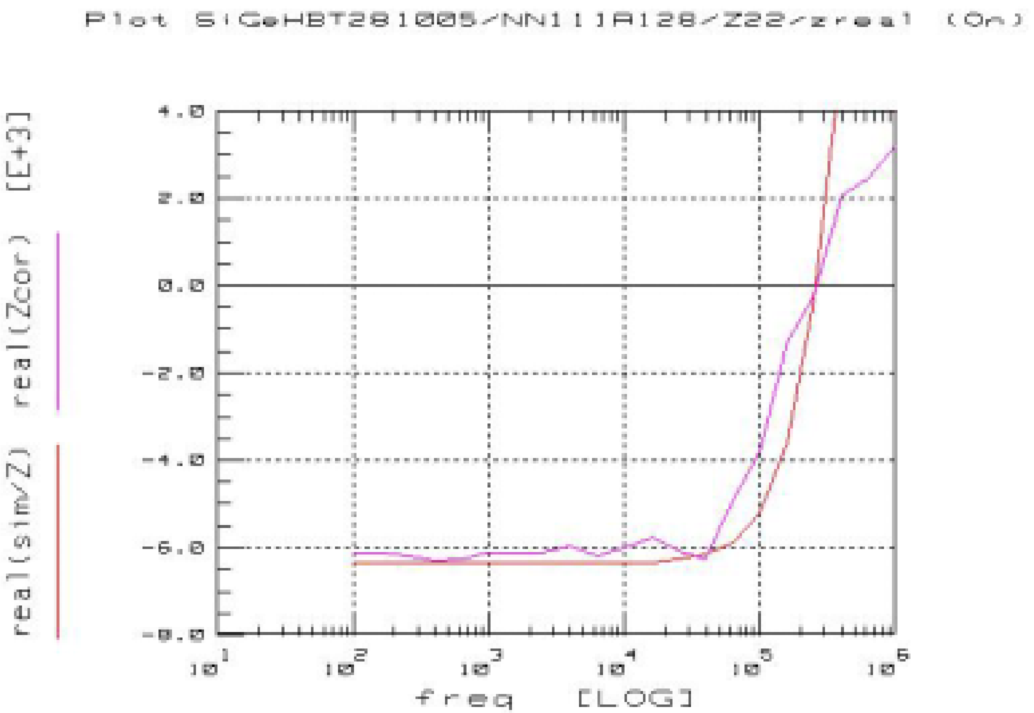
Measurement results: AC

- Real Part of Z_{CE}



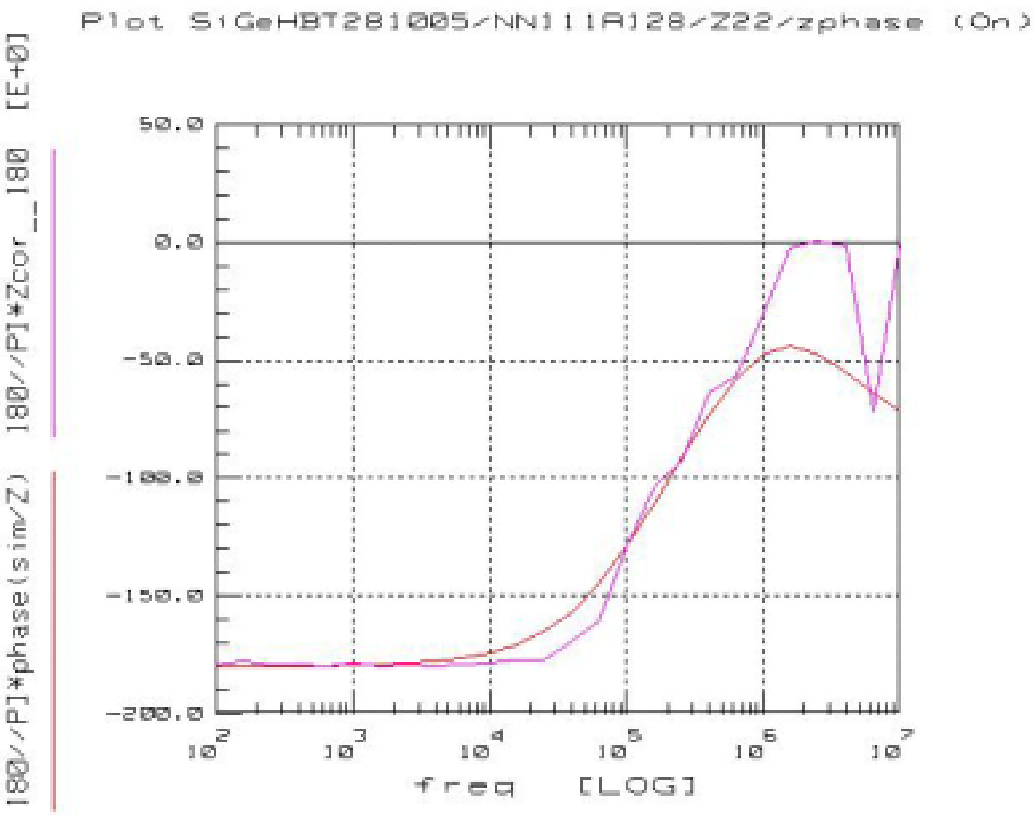
Modelling: AC

- Hicum compact model: R_{TH}
  - Real part of Z_{CE} at low frequencies



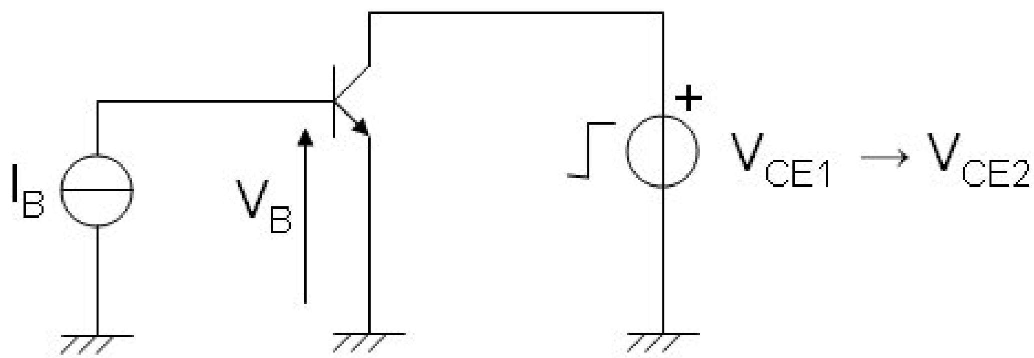
Modelling: AC

- Hicum compact model: C_{TH}
  - Phase of Z_{CE}



Measurement setup: pulse

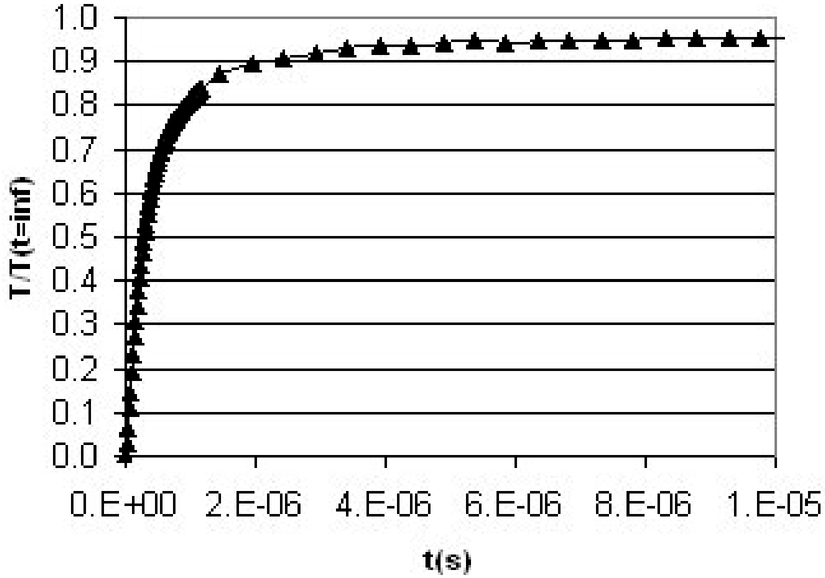
- Base: I_B constant
- Collector: $V_{CE1} \rightarrow V_{CE2}$
- Measure V_B
- Calibration $V_B \rightarrow T$
- time range
  - Theory: $0 \rightarrow \infty$
  - 10ns $\rightarrow$ 10s



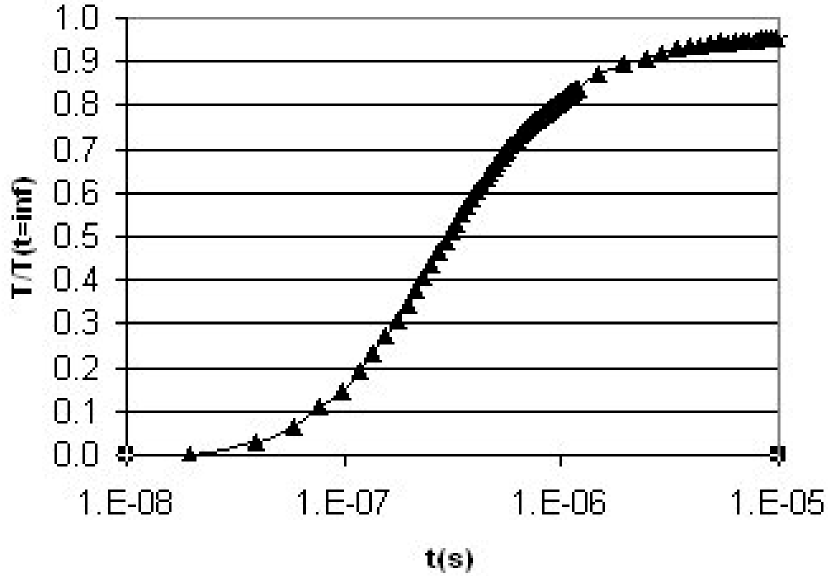
Measurement results: pulse

- $V_{BE}(t) \rightarrow T(t)$

Lin



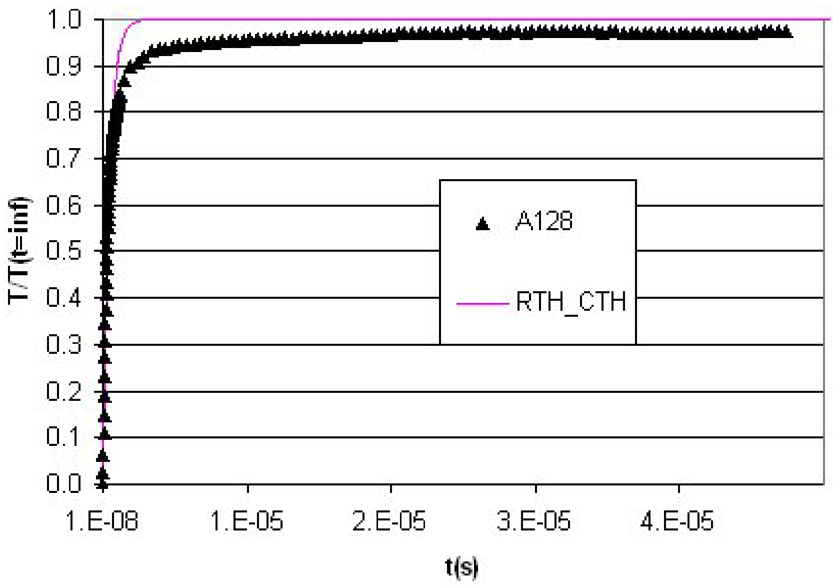
Log



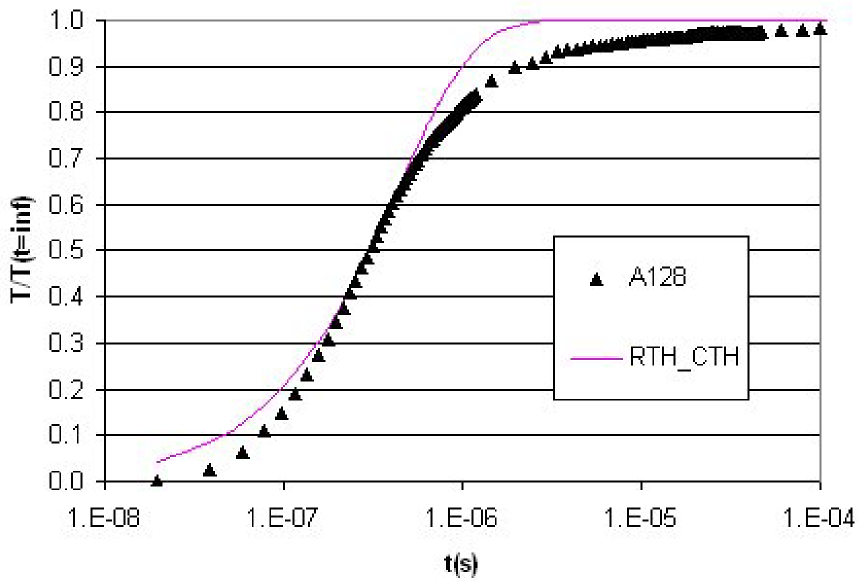
Modelling: pulse

- R_{TH}-C_{TH} cell:

lin

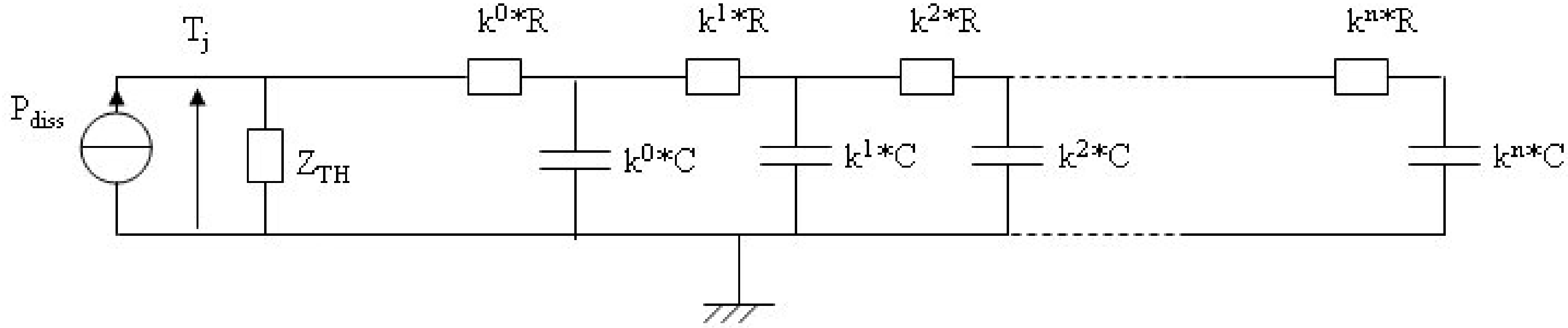


log

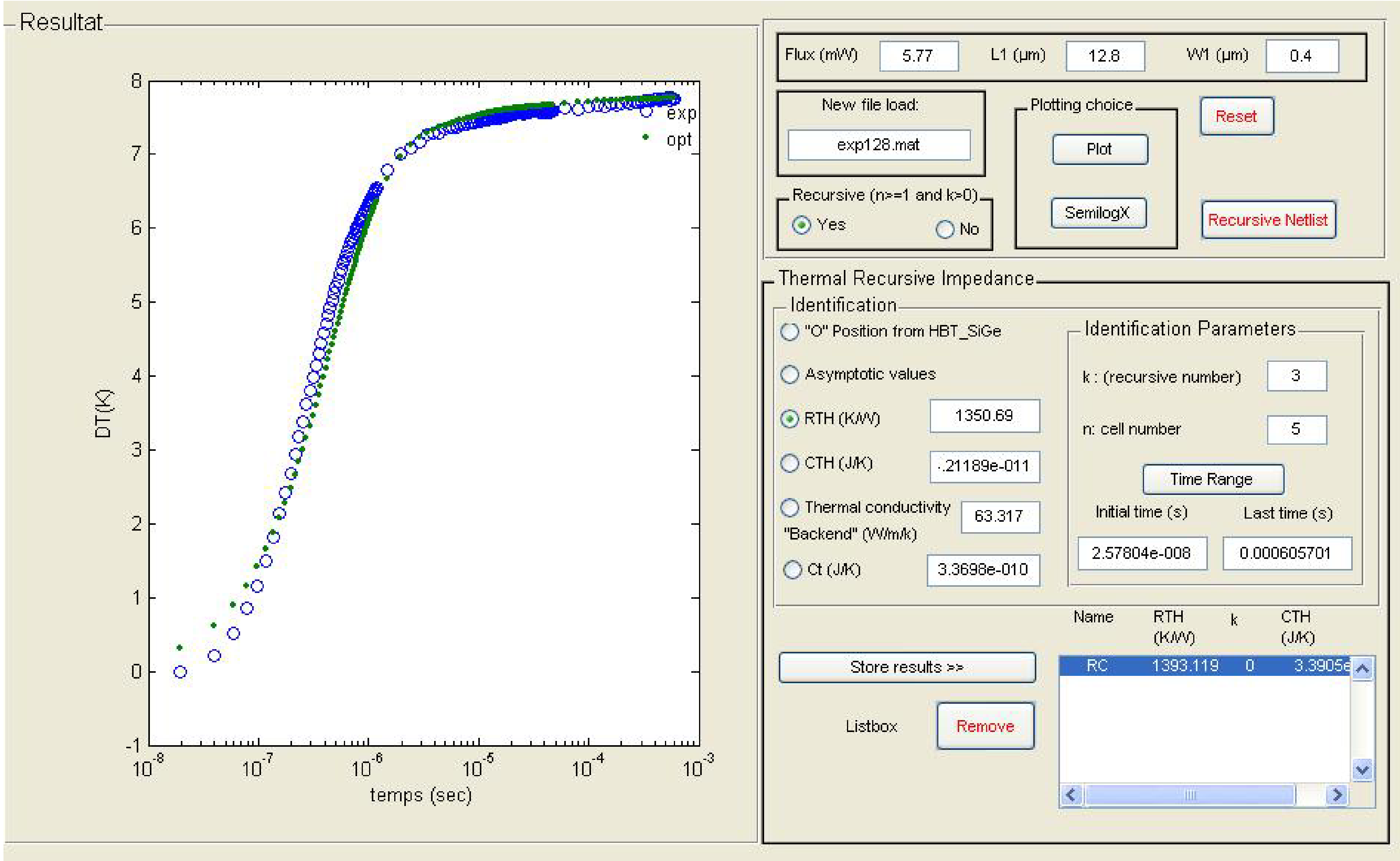


Modelling pulse: recursive network

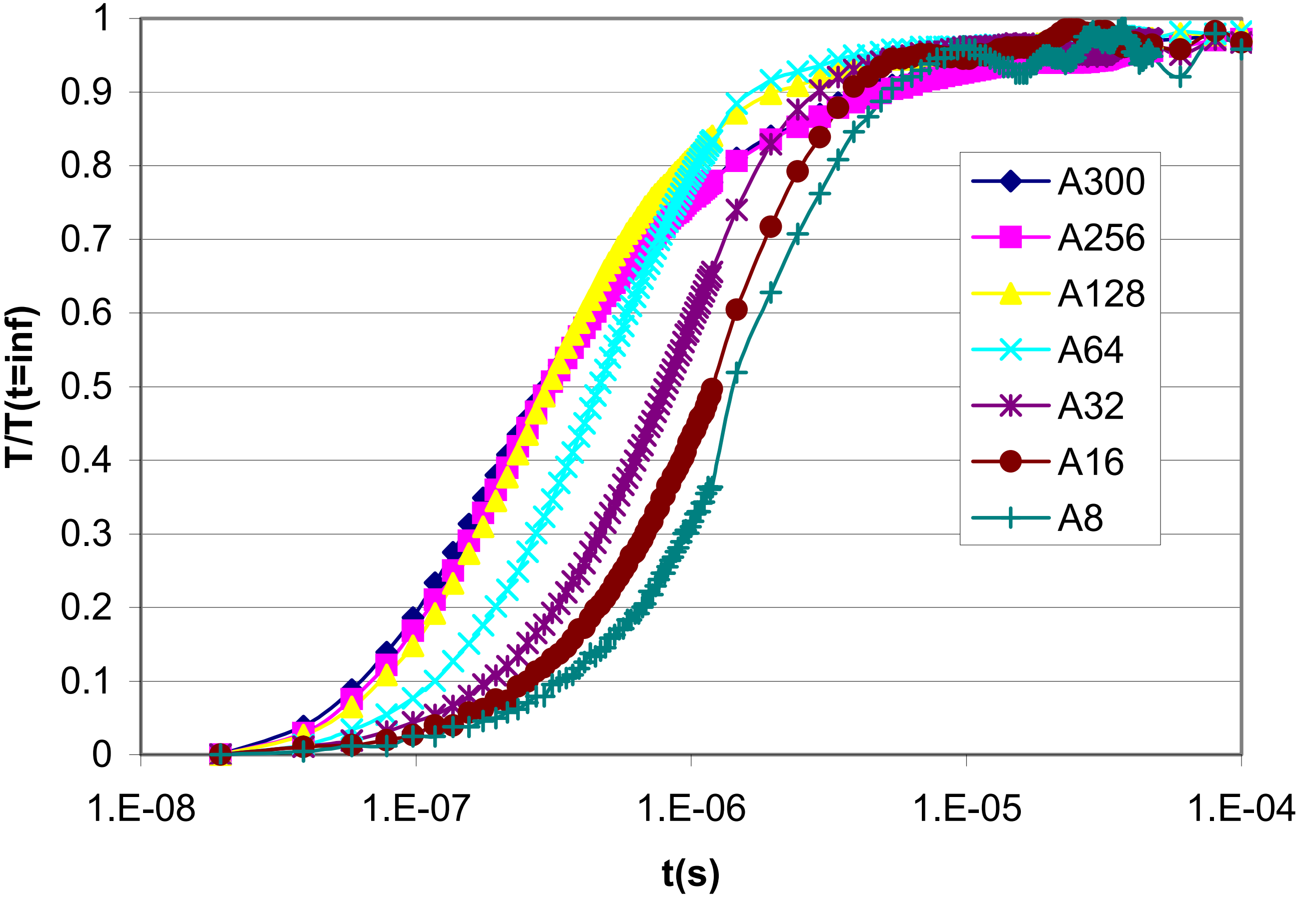
- Recursive network



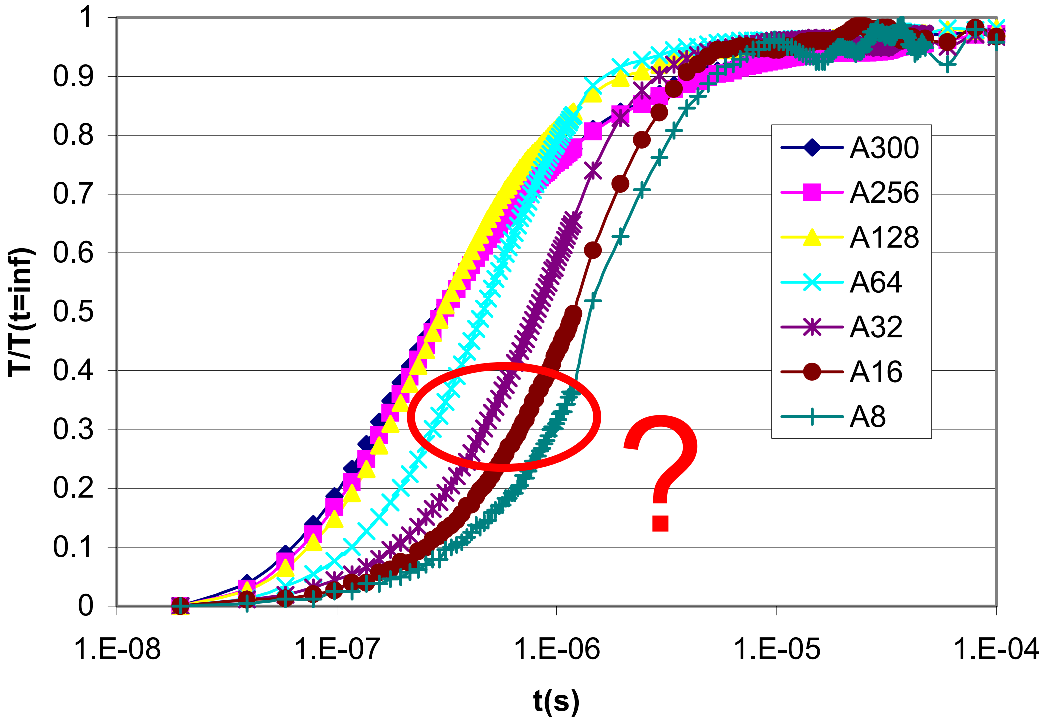
Recursive network: toolkit & results



Scaling issues

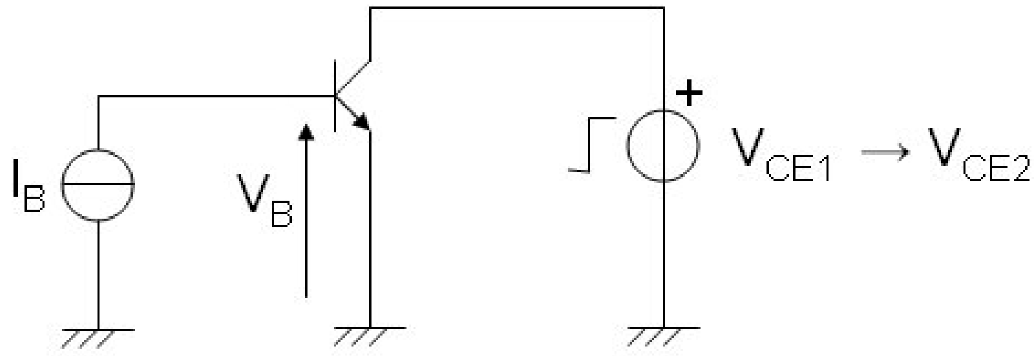


Why does the dynamic behaviour change for small devices?



Measurement problem

- Small transistors, small I_B, high Z_{in}
- New current source: new dynamic behaviour !!!



- Solution : ?

Discussion

- Pulse and AC method for C_{TH} determination
  - Both methods give similar results
  - Both methods need similar equipment
  - AC: a full parameter extraction has to be performed for R_{TH} and C_{TH} determination
  - Pulse: R_{TH} and C_{TH} can be directly determined, but a V_{BE}-T calibration is necessary
- Recursive network for accurate modelling
- Limits for small transistors

- Thanks for your attention