Learning Outcomes in Compact Modeling of Devices for High-Speed IC Design

Please check if you learned the following items in this course. These are the minimum knowledge that you must gain through this course. If you feel any difficulty to understand any of the items below while attending the lectures, please ask questions and get clarified.

PART-I

1. How does a double-poly self-aligned bipolar transistor (BJT) structure with junction isolation look? Can you identify the internal and 1D intrinsic transistor within the structure? Do you understand the 1D static operation of a BJT? What are the emitter injection efficiency, base-transport factor, common base static current gain, common emitter static current gain, and how to obtain relations among them?
2. How to obtain a large-signal equivalent circuit (EC) for the 1D BJT? How to obtain the formulations for different circuit elements? How do the experimental I-V and C-V characteristics of BJTs at relatively low-to-medium current-densities look and how can they be interpreted using the model EC along with the element formulations?
3. What is integral charge control relation (ICCR)? What is the high current density related Kirk effect? What is the transient integral charge control (TICC) theory? What is charge partitioning? How to obtain a generalized charge partitioning scheme in transistor? How will the large-signal EC appear if the charge partitioning effect is included? What is the charge partitioning factor and how is it related to the TICC theory?
4. How to obtain the small-signal EC of a BJT from its large-signal counterpart? Can you figure out the expressions of the various y-parameters in terms of the small-signal circuit elements of the small-signal EC? How do the frequency-dependent y-parameters appear in various plots?
5. What is the transit frequency or unity gain cut-off frequency and how to measure it? What is the full regional approach (FRA) and how to estimate the transit frequency using FRA? How to obtain the expression for the transit frequency from the y-parameters? Can you express the transit frequency in terms of various circuit components of the small-signal EC of a BJT?
6. How is the FRA useful to estimate the charge partitioning factor?
7. What is a silicon germanium heterojunction bipolar transistors (SiGe HBT)? How does a SiGe HBT structure appear with deep trench isolation?
8. What is maximum oscillation frequency and how to obtain its expression? How is the maximum oscillation frequency of SiGe HBT compared to that of the Si BJT? Why did the SiGe HBTs come to replace the Si BJTs?
9. Why is ICCR not sufficient to model SiGe HBTs? What is generalized ICCR (GICCR) and how is it more suitable for SiGe HBTs? How does the TICC theory fit for SiGe HBTs in the light of GICCR?
10. How do the plots of frequency-dependent input and trans-admittance parameters deviate from their low-frequency counterparts and why? What are the quasi-static (QS) and non-quasi-static (NQS) effects? How does the time-dependent diffused minority charge appear within the transistor structure under large-transient inputs?
11. What is the classical theory to analytically formulate the NQS effect in the small-signal domain? How to approach for a large-signal NQS model?
12. What are the state-of-the-art NQS models? How to implement such a model in Verilog-A? How to extract the NQS related model parameters? Are they bias-dependent?

13. How does an oscillator circuit work? What is phase noise and how to estimate the phase noise of an oscillator circuit? How does the phase noise appear to be affected by the NQS effect?

PART-II

1. What is noise in devices and circuits? What are the noise currents, noise voltages, noise power spectral densities (PSDs) and what are their relations? Why are the PSDs so important?
2. What are the different kinds of noise present in the HBTs? What is shot noise and how does it affect the 1D HBT's noise property? How do the bias- and frequency dependent various noise PSDs appear?
3. How to implement noise in Verilog-A? What are the noise parameters, such as minimum noise figure, noise resistance and optimum source admittance and why are they important figures-of-merits (FoMs)? How to compute the noise parameters from a given set of noise PSDs for a 1D HBT? How do the bias- and frequency-dependent various noise parameters appear? What do they depend on other than the noise sources?
4. What is the classical formulation for noise PSDs in BJTs by Van-Vliet? What is noise correlation? How is it related to the charge partitioning and NQS effect? How to obtain the formulations for noise PSDs including the charge partitioning and NQS effects?
5. How to construct an implementation suitable noise model using the system theory? How to implement the model using Verilog-A? How will a better correlated noise model reflect in the various noise parameters?
6. What will be a total noise EC for an HBT? What will be the formulations for the noise PSDs considering the total noise EC? How to extract the noise-model specific parameters?
7. How does a low noise amplifier (LNA) work? Why is an accurate noise model so important for LNA design? How will an inaccurate noise model affect the LNA's behavior?

PART-III

1. What is electro-thermal heating or self-heating (SH) in connection with a semiconductor device? What is the heat source for HBT? How to represent the static self-heating using simple electrical network? How to determine the thermal resistance of the network?
2. What is dynamic SH and how to model it using electrical networks? How to determine the thermal capacitance(s)?
3. What is the distributed modeling of SH effect? For different kinds of BJT configurations (multi-emitter or single emitter), how to apply the distributed modeling technique?
4. What is thermal coupling effect? How to formulate the static thermal coupling problem? How to determine the static thermal coupling coefficients? How to construct a thermal network for both static SH and thermal coupling?
5. What is the dynamic thermal coupling and how to determine the coupling coefficients? How to construct a complete network including the static and dynamic SH and thermal coupling?
6. How does a power amplifier (PA) circuit operate? How can the self-heating affect the performance of a PA?