

Modeling Techniques and Validation Methodologies in Closed-Loop Switched Mode Power Converter Products		
Total duration of 40 hours (each session of 10 hours)		
Sessions	Session theme	Major topics
S₁	Continuous-time (CT) large-signal and small-signal modelling of a buck converter	• State space modelling under CCM and DCM • State space averaging and small-signal modelling • PWM switch modelling under CCM • Derivation of equivalent circuit model • Large-signal and small-signal model under VMC and CMC • Derivation of various small-signal transfer functions • Characterization of steady-state parameter under CCM and DCM • Steady-state ripple parameters and loss formulations under CCM • Steady-state ripple parameters and loss formulations under DCM • Development of custom MATLAB model for model validation
S₂	Discrete-time (DT) large-signal and small-signal modelling of a buck converter	• Solutions of state space equations under CCM and DCM • Derivation of discrete-time (DT) large-signal model • Derivation of DT small-signal model • DT large-signal and small-signal models under CCM and DCM • DT large-signal and small-signal models of VMC buck converter • DT large-signal and small-signal models of CMC buck converter • Development of custom MATLAB model for model validation
S₃	Validation of Continuous Time Small-Signal Model of a Closed-Loop Buck Converter	• Setting up device under test (DUT) using buck evaluation boards • Identifying datasheet parameters and operating conditions • Working with test and measurements • Perform various time domain case studies • Performance frequency domain study using a loop-gain analyser • Validating small-signal model with transient test case studies • Validating frequency domain model with small-signal TF
S₄	Validation of Discrete Time (DT) Large-Signal Model of a Closed-Loop Buck Converter	• Validating DT large-signal models using test cases • Validating steady-state ripple parameters under CCM and DCM • Validating DT small-signal model using test frequency response • Verifying closed-loop fast-scale stability of CMC buck converters • Summarizing steps for validating large/small-signal models

Reference book and material:

- [1] R. W. Erickson and D. Maksimovic, Fundamentals of Power Electronics, 3rd Ed., Springer, 2020.
- [2] S. Kapat and P. T. Krein, "A Tutorial and Review Discussion of Modulation, Control and Tuning of High-Performance DC-DC Converters based on Small-Signal and Large-Signal Approaches" *IEEE Open Journal of Power Electronics*, vol. 1, pp. 339 - 371, Aug. 2020.