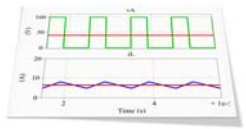
Basic principles of switch-mode power conversion (DC-DC): Concept of DC steady state

- Bi-positional switch
- PWM and duty ratio
- Cycle-by-cycle averaging
- **Concept of DC steady-state**
- Volt-sec balance
- Current-sec balance
- Power balance



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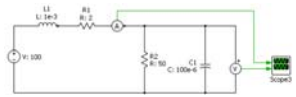
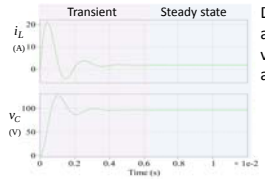
DC steady state in power converters

- DC steady state analysis is useful for
  - Thorough understanding of the operation, including various sub-intervals and modes of operation
  - Deriving input-output voltage and current relationships of various converter topologies
  - Design of various components such as inductors, capacitors, transformers
  - Selection of voltage and current ratings of semiconductor devices
  - Loss analysis

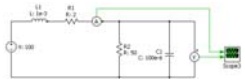
DC Steady state in non-switching circuits

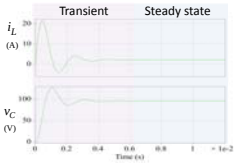




In non-switching circuits, DC steady state can be defined as a condition when all the variables (voltages, currents) are CONSTANT in time

DC Steady state in non-switching circuits

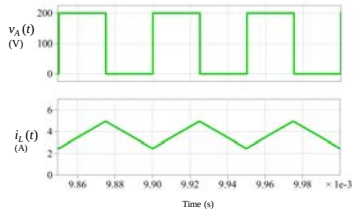




- Since, $v_L = L\frac{di_L}{dt}$ and i_L is constant, $v_L = 0$ and inductor is considered as a short circuit in dc steady state for non-switching circuits
- Since, $i_C = C\frac{dv_C}{dt}$ and v_C is constant, $i_C = 0$ and capacitor is considered as a open circuit in dc steady state

DC steady state in switching converters

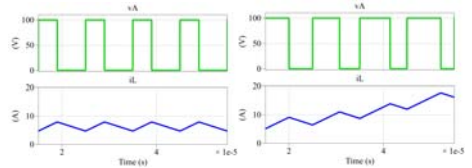
- In a switching converter, most of the voltages and currents are always switching or time varying
- Need for a different definition of DC steady state



Concept of DC steady state in switching converters

A switching converter is in DC steady state, if

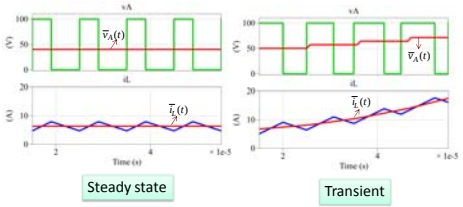
- ALL waveforms repeat exactly every switching period
  Example: $i_A(t) = i_A(t-T_S)$



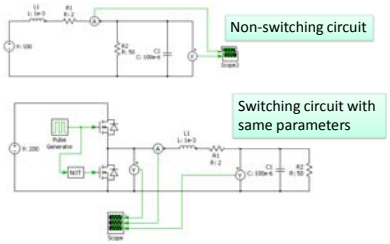
Concept of DC steady state in switching converters

A switching converter is in DC steady state, if

- CCA values of **ALL** variables remain constant

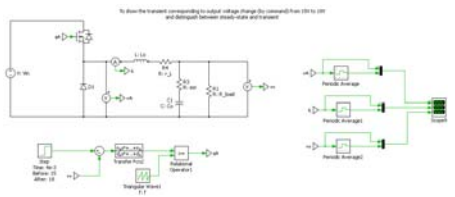


Simulation examples



Simulation examples

Closed-loop controlled step down converter showing steady-state operation and transient corresponding to a step change in command from 15V and 18V



DC steady state characteristics

Non-switching circuits	Switching circuits
All instantaneous quantities (voltages, currents) are constant	All CCA (cycle-by-cycle) quantities (voltages, currents) are constant
Instantaneous voltage across an inductor is zero; inductor can be considered a short for analysis and L value has no impact in steady state	CCA voltage across inductor is zero (volt-sec balance principle); inductance determines the switching frequency current ripple in steady state
Instantaneous current through a capacitor is zero; capacitor can be considered open for analysis and C value has no impact in steady state	CCA current through a capacitor is zero (current-sec balance principle); capacitance determines the switching frequency voltage ripple in steady state

AC steady state in power converters

- In AC steady state, even CCA quantities will not be constant
- CCA quantities can be constant, or at fundamental frequency (or possibly its multiples)
- Fundamental frequency significantly (an order or more) lower than switching frequency
- Fundamental frequency waveforms have constant amplitude and constant phase
- Useful when we analyze dc-ac and ac-dc converters later