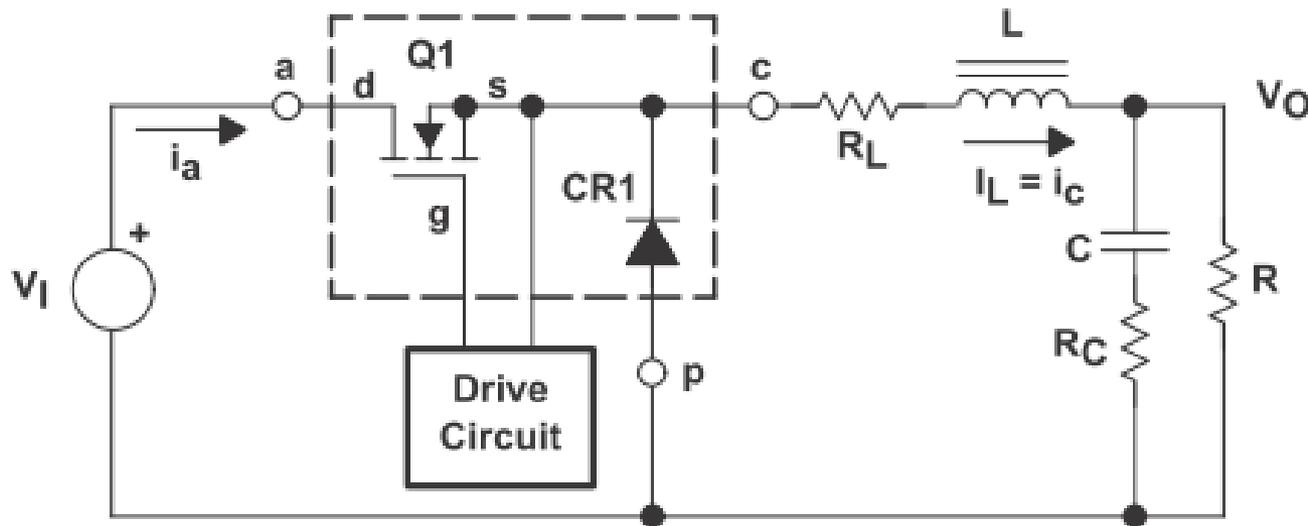# Buck SMPS fundamentals

[TI_slva057]

Introduction

■ Simplified schematic of the buck power stage with a drive circuit block included. The power switch, *Q1*, here is an n-channel MOSFET.

■ The diode, CR1, is usually called *catch diode*, or *freewheeling* diode

■ The inductor, *L*, and capacitor, *C*, make up the output filter

■ The capacitor ESR, R_C, (equivalent series resistance) and the inductor DC resistance, R_L, are included in the analysis

Buck Steady-State Mode Analysis

- A power stage can operate in continuous (CCM) or discontinuous (DCM) inductor current mode (see later)
  - ☐ continuous inductor current mode is characterized by current flowing continuously in the inductor
  - ☐ discontinuous inductor current mode is characterized by the inductor current being zero for a portion of the switching cycle
- Here, an n-channel power MOSFET is used
  - ☐ the advantage of using an n-channel FET is its lower $R_{DS(on)}$ but the drive circuit is more complicated because a floating drive is required
  - ☐ for the same die size, a p-channel FET has a higher $R_{DS(on)}$ but usually does not require a floating drive circuit
- Steady-state implies that the input voltage, output voltage, output load current, and duty-cycle are fixed and not varying
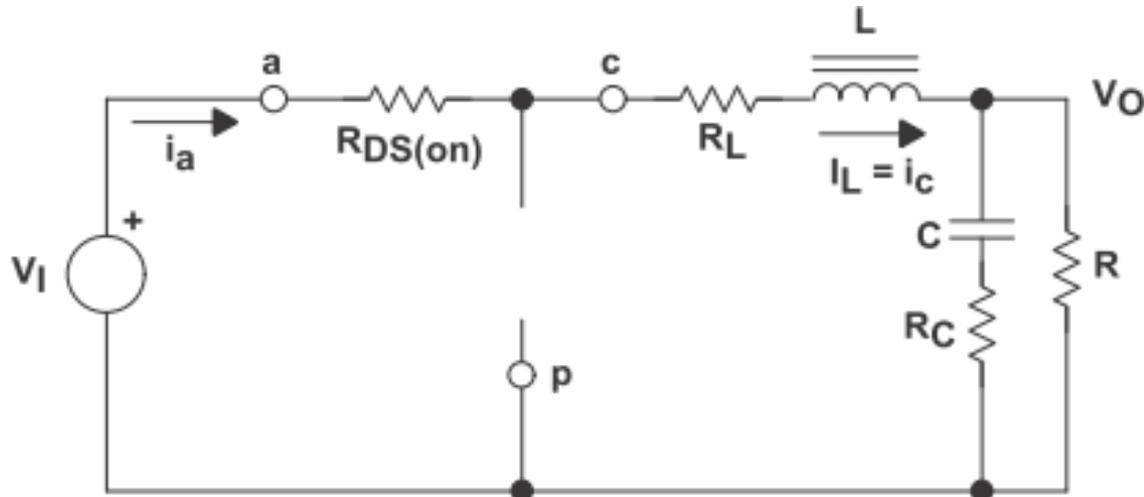
Buck Steady-State CCM Analysis

- In CCM, the Buck power stage assumes two states per switching cycle
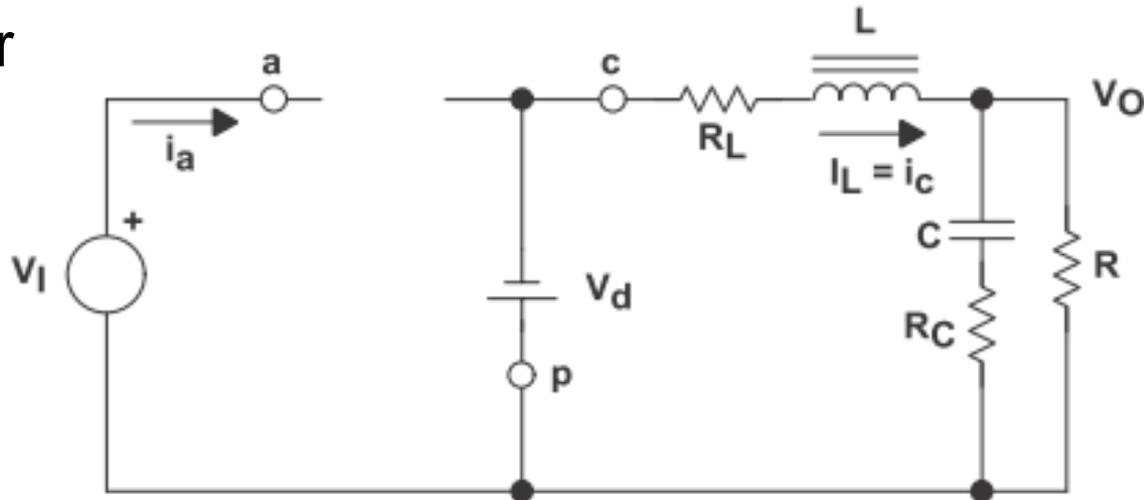
Note the
- active (a),
- passive (p), and
- common (c)

nodes: they'll be used later

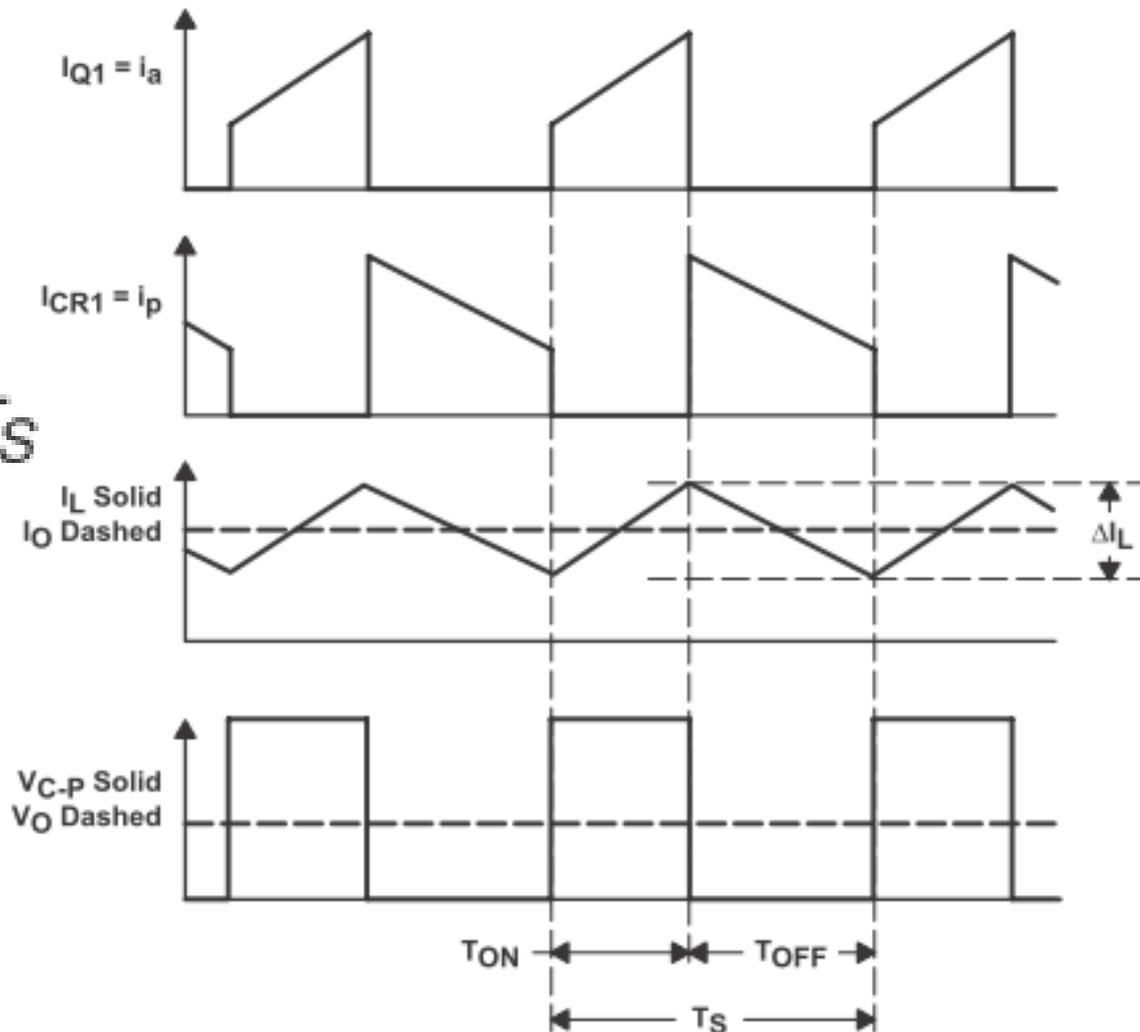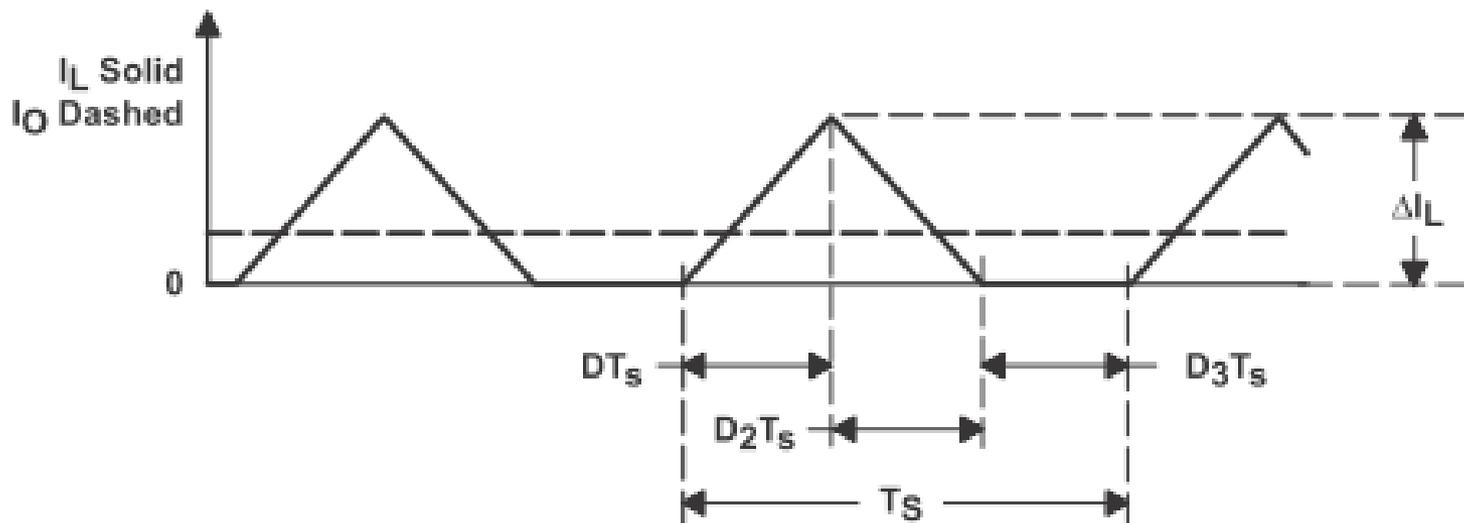# Buck Steady-State CCM Analysis

■ Waveforms in CCM

$$D = T_{ON}/T_S$$

Buck Steady-State DCM Analysis

- If the output load current is reduced below the critical current level, the inductor current will be zero for a portion of the switching cycle
  - in CCM, the peak to peak amplitude of the ripple current does not change with output load current
  - if the inductor current attempts to fall below zero, it just stops at zero because of the diode
- A power stage operating in DCM has three unique states during each switching cycle (ON, OFF and IDLE (D_3T_S))

# Buck Steady-State DCM Analysis

- Waveforms:
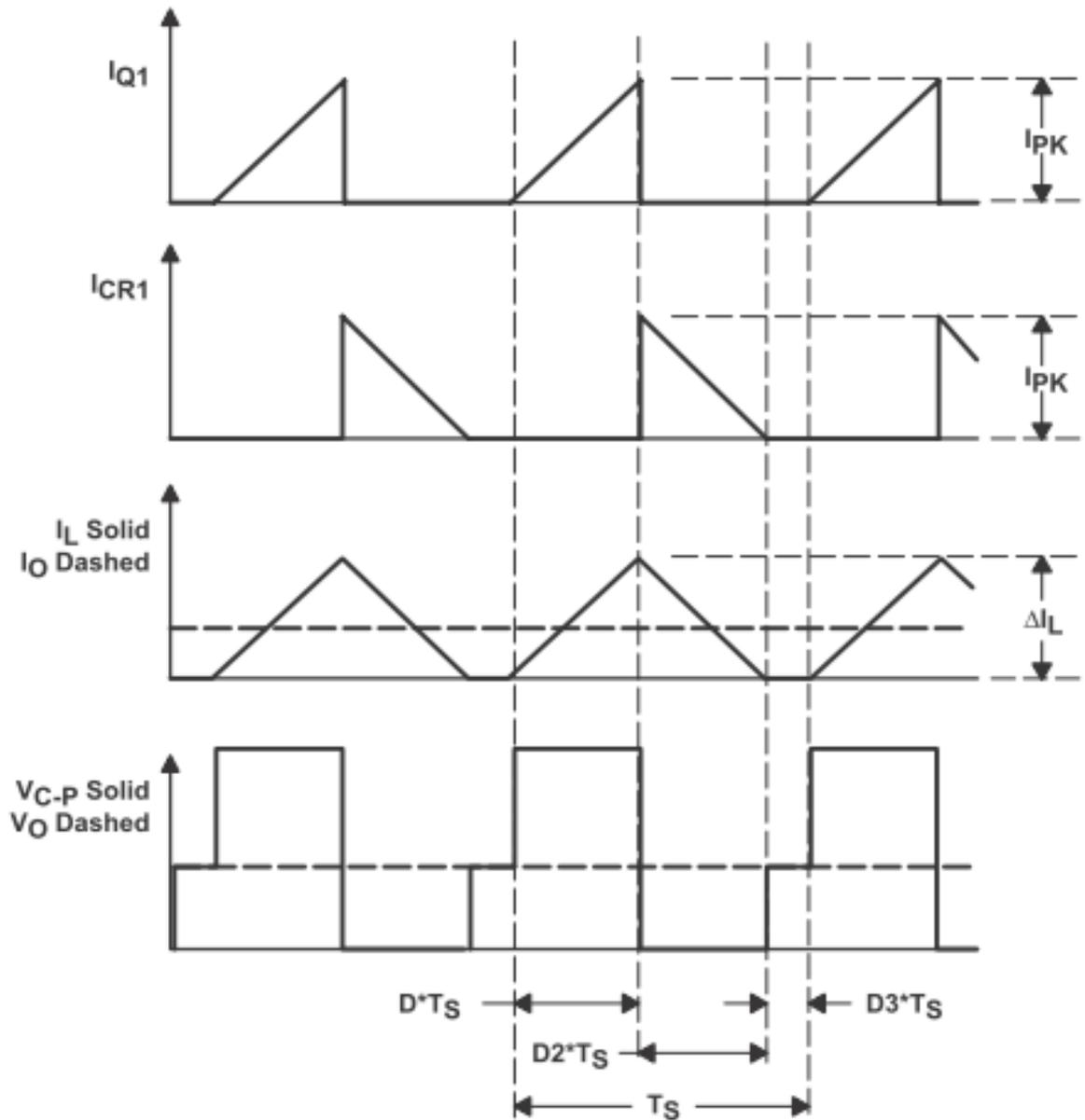
CCM and DCM

- Buck power stage are rarely operated in DCM in normal situations,
    - but DCM will occur anytime the load current is below the critical level
- A buck power stage can be designed to operate in CCM for load currents above a certain level
    - usually 5% to 10% of full load

Synchronous Buck Power Stage

- The buck converters seen up to now are *non-synchronous*
- In *synchronous* converters, an active switch such as another power MOSFET, Q2 in this example, replaces the diode
  - this FET is then selected so that its ON-voltage drop is less than the forward drop of the diode
- either the drive circuit or the controller must insure that both FETs are not on simultaneously
  - a small amount of deadtime is necessary
- it always operates in CCM because current can reverse in Q2
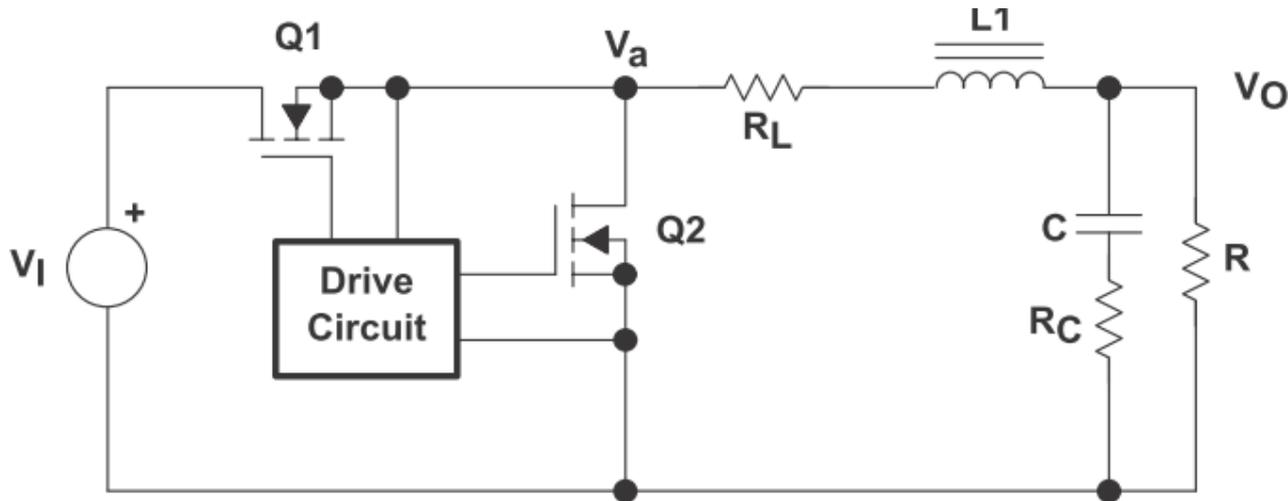
Buck Power Stages: other categories

- Buck switching solutions include
    - *power modules*: integrated FETs and inductor
    - *converters (regulators)*: integrated FET or FETs and external inductor
    - *controllers*: external FETs and inductors
- The compensation of the control loop may be
    - *internal*
    - *external*

Modules	Regulators	Controllers
· Ultimate Ease of Use with Integrated Inductor	· Balance between Ease of Use and flexibility	· Maximum Flexibility up to 100Vin, 12A Out
Power Modules & Nano Modules	Regulators	Controllers