Buck Regulator Architectures

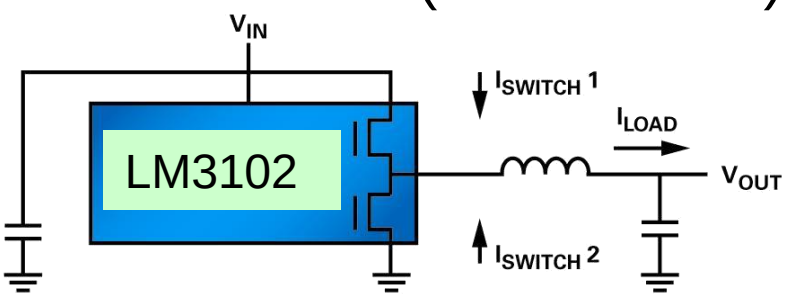
4.1 Overview

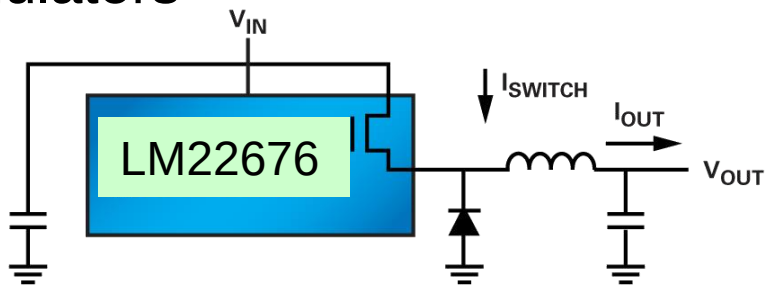
Buck-Switching Converters

Synchronous

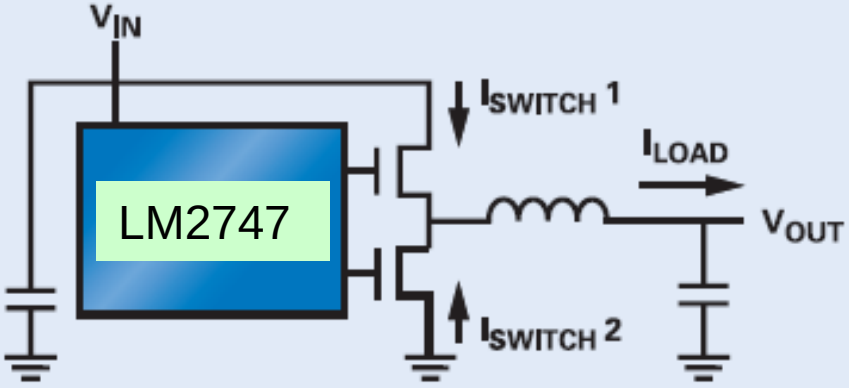
Non-Synchronous

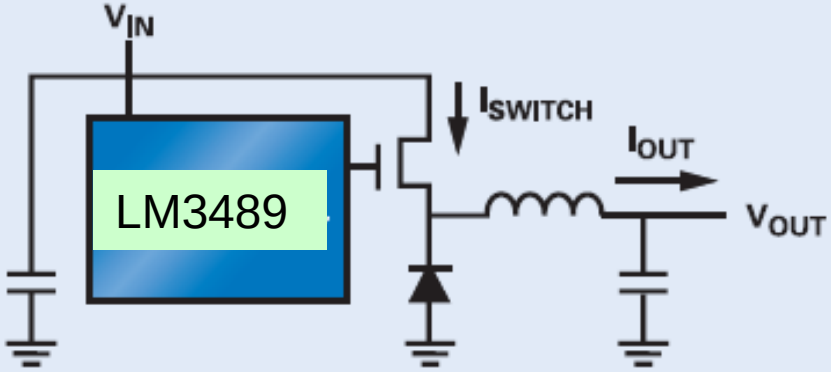
(Internal-FET) Regulators



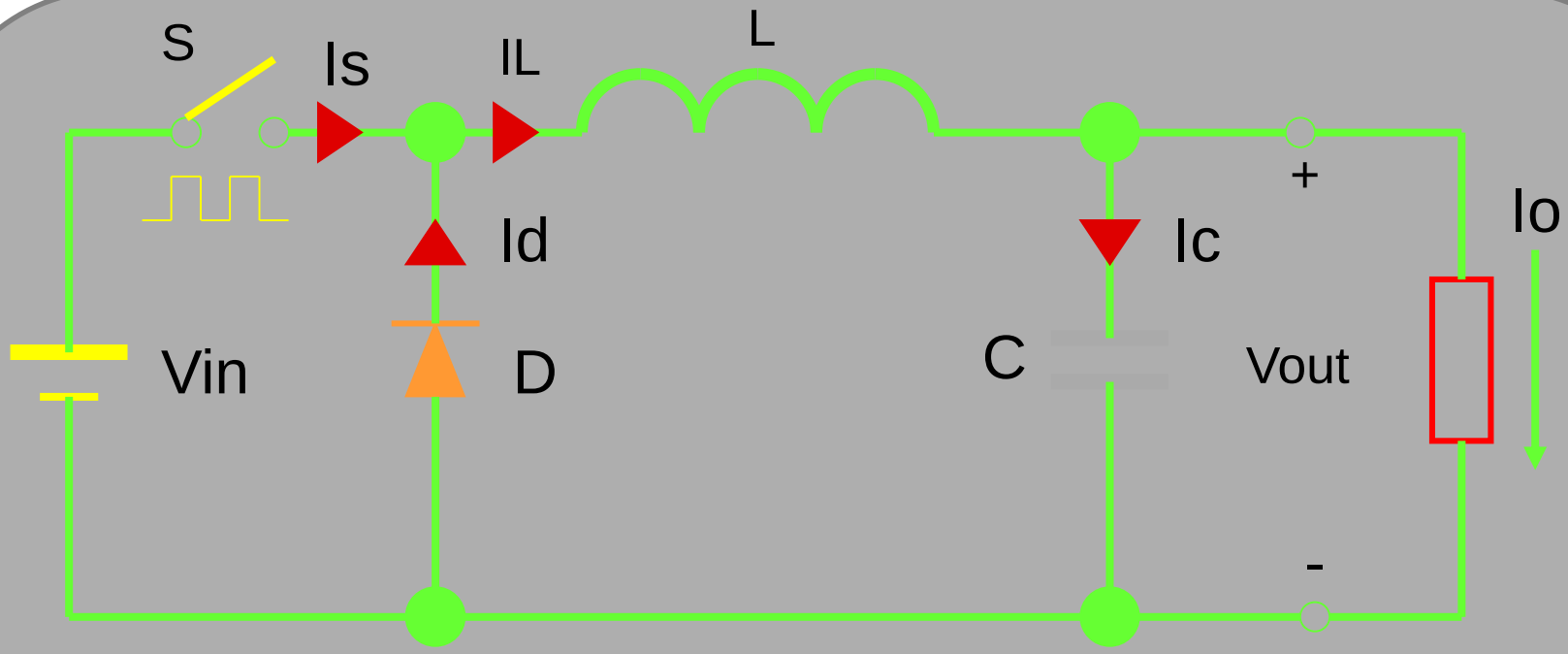


(External-FET) Controllers





Non-Synchronous Buck Converters



$\Delta I_{L,\,Ton} = \Delta I_{L,\,Toff}$

$\Delta I_{L,\,Ton} = (Vin - Vout) * Ton / L$

$\Delta I_{L,\,Toff} = -Vout * Toff / L$

$Vout = D*Vin$

$D = Ton / (Toff + Ton)$

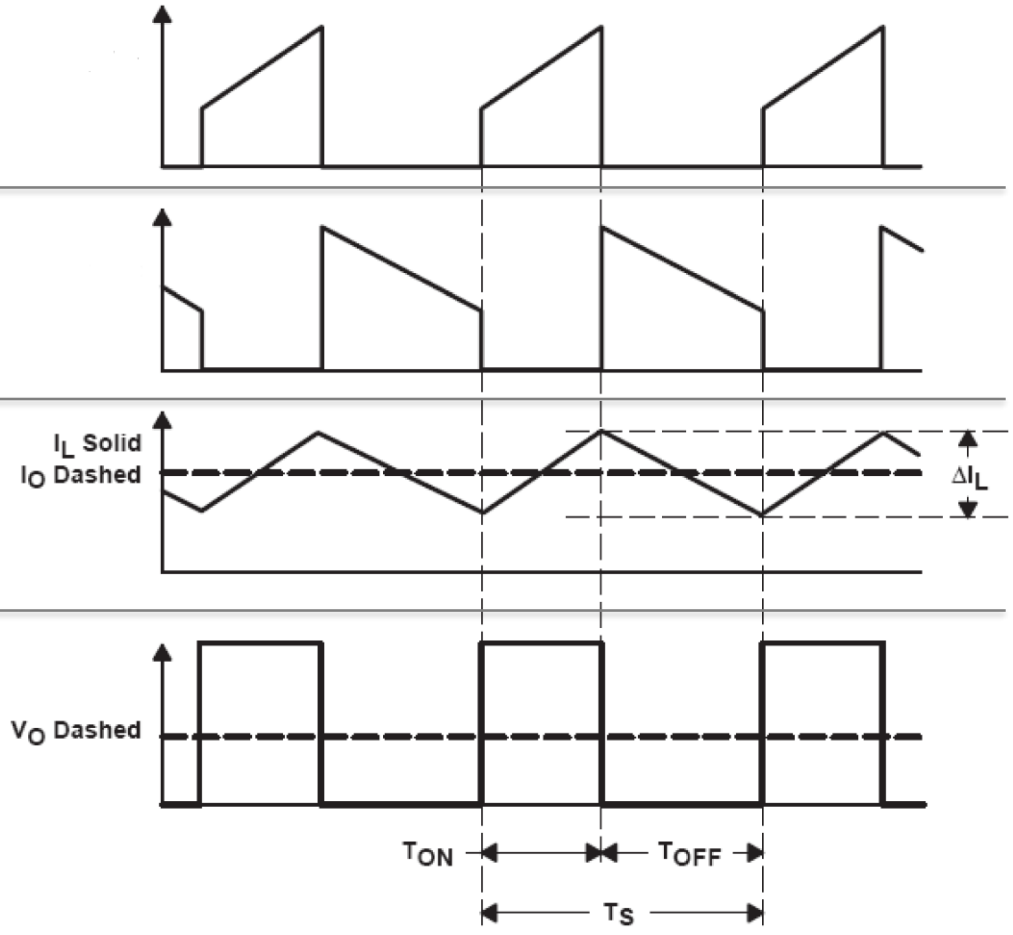
Buck Topology: Current and Voltage Waveforms

Input current

Low side switch or diode

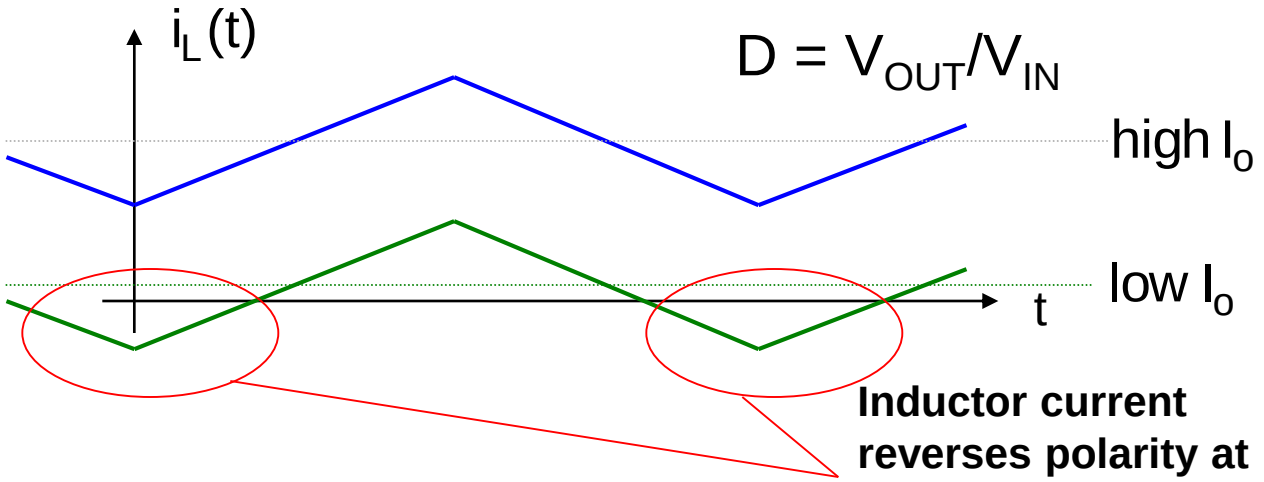
Output and Inductor

Switch

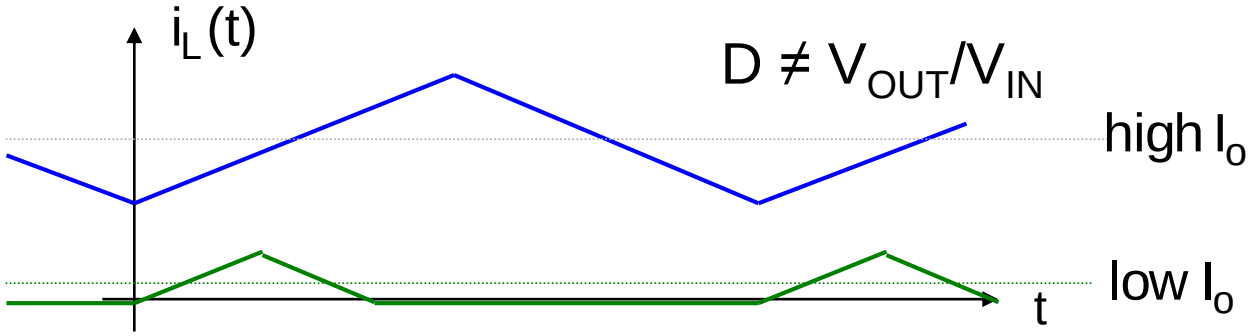


Light-Load Operation: CCM and DCM

Full Synchronous Mode. Stays in Continuous Conduction Mode (CCM)



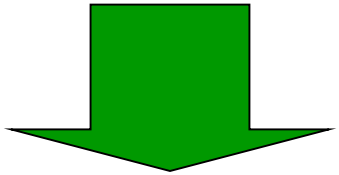
Diode or Diode Emulation



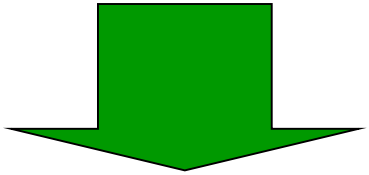
Inductor current drops to zero before the end of the cycle: "Discontinuous Conduction Mode" (DCM)

Cross Conduction with Synchronous Buck

- Direct Connection between V_{IN} and Ground



- High – Side and Low – Side must not be in ON state at the same time



- A time in which both MOSFET are Turned OFF is required:
  DEAD - TIME

DEAD – TIME

- FIXED DEAD – TIME
  - Fixed time between Turn-OFF and Turn-ON
  - No flexibility in MOSFET choice
- ADAPTATIVE DEAD – TIME
  - High-Side turns ON only if LS is OFF and vice versa
  - Full flexibility in MOSFET choice
- It is necessary to detect the Turn-OFF of both MOSFET

Control Mode

- Voltage Mode Control (VMC)
- Current Mode Control (CMC)
  - Peak Current Mode Control (PCMC)
  - Valley Current Mode Control (VCMC)
  - Average Current Mode Control (ACMC)
- Hysteretic Mode Control (HMC)

Voltage Mode Control Advantages and Disadvantages

- Advantages
  - Stable modulation/less sensitive to noise
  - Single feedback path
  - Can work over a wide range of duty cycles
- Disadvantages
  - Loop gain proportional to V_{IN}
  - LC double pole often drives Type III compensation
  - CCM and DCM differences - a compensation challenge
  - Slow response to input voltage changes
  - Current limiting must be done separately

Current Mode Control Advantages and Disadvantages

- Advantages
  - Power plant gain offers a single-pole roll-off
  - Line rejection
  - Cycle-by-cycle current limiting protection
  - Current sharing
- Disadvantages
  - Noise
  - Minimum ON-time
  - Sense resistor

Hysteretic Mode Control Advantages and Disadvantages

- Advantages
  - Ultra fast transient response (preferred to use in power hungry load)
  - No phase compensation required; In other words, Hysteretic Mode is a kind of large signal control
- Disadvantages
  - Noise Jitter susceptible
  - Very layout sensitive
  - Large switching frequency variation; Minimum ripple requirement

Thank you!