BUCK基础

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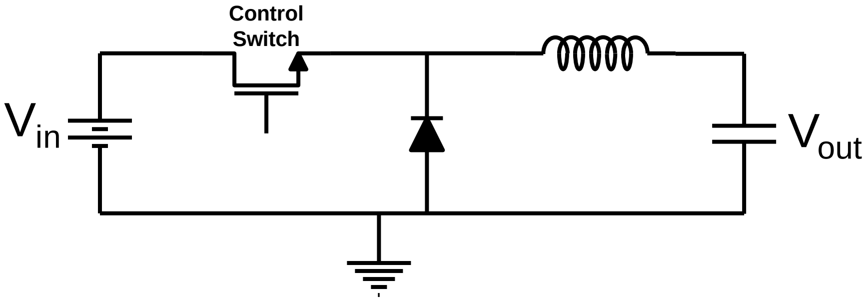
Buck Operation

- To generate a regulated output voltage, the control switch must begin switching
- When the control switch is *on*, the voltage across the inductor increases to the input voltage minus the output voltage, and energy is stored in the inductor
- When the control switch is *off*, energy continues to flow to the output through the inductor.
- The output capacitor filters the AC current, allowing DC current to flow into the load



Inductors

- Passive elements that stores energy in a magnetic field and resists changes in electric current

$$V = L * \frac{dI}{dT}$$

- Switch-mode power supplies rely on the **Steady-State Inductor Principle** for power conversion
- Common inductor considerations are
  - Inductance
  - DC Current Rating
  - Saturation Current Rating
  - DCR
  - Core loss
  - Saturation profile

Inductors

Examine the voltage across an inductor that is operating in periodic steady state. The governing equation is

$$v(t) = L\frac{di(t)}{dt} \quad \text{which leads to} \quad i(t) = i(t_o) + \frac{1}{L}\int_{t_o}^{t_{o+t}} v(t)dt$$

Since the inductor is in periodic steady state, then the current at time t_o is the same as the current one period T later, so

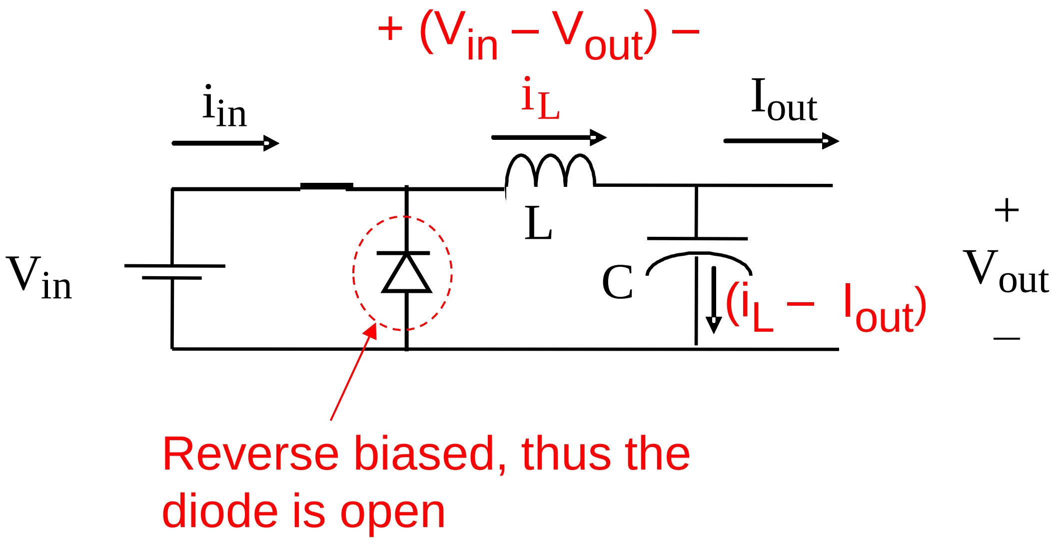
$$i(t_o + T) = i(t_o), \quad \text{or} \quad i(t_o + T) - i(t_o) = 0 = \frac{1}{L}\int_{t_o}^{t_{o+T}} v(t)dt$$

The conclusion is that $\int_{t_o}^{t_{o+T}} v(t)dt = 0$ **which means that**

the average voltage across an inductor operating in periodic steady state is zero

When Switch Is Closed

Switch closed for DT seconds

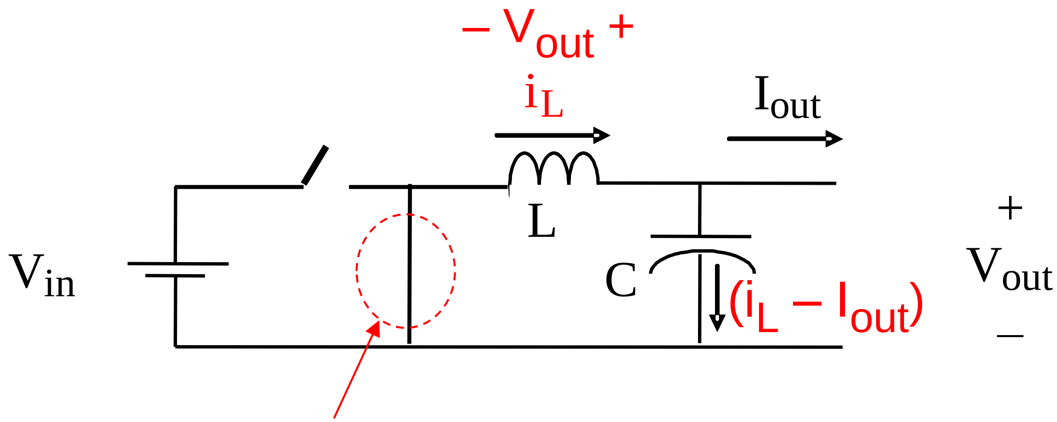


$$v_L = L\frac{di_L}{dt}, \quad \boxed{v_L = V_{in} - V_{out},} \quad V_{in} - V_{out} = L\frac{di_L}{dt}, \quad \frac{di_L}{dt} = \frac{V_{in} - V_{out}}{L}$$

for DT seconds

When Switch Is Open

Switch open for (1 − D)T seconds



i_L continues to flow, thus the diode is closed. This is the assumption of “continuous conduction” in the inductor which is the normal operating condition.

$$v_L = L\frac{di_L}{dt}, \quad \boxed{v_L = -V_{out},} \quad -V_{out} = L\frac{di_L}{dt}, \quad \frac{di_L}{dt} = \frac{-V_{out}}{L}$$

for (1−D)T seconds

Since the average voltage across L is zero

$$V_{Lavg} = D \bullet (V_{in} - V_{out}) + (1 - D) \bullet (-V_{out}) = 0$$

$$DV_{in} = \cancel{D \bullet V_{out}} + V_{out} - \cancel{D \bullet V_{out}}$$

The input/output equation becomes $\boxed{V_{out} = DV_{in}}$

From power balance, $V_{in} I_{in} = V_{out} I_{out}$ **, so**

$$\boxed{I_{out} = \frac{I_{in}}{D}}$$

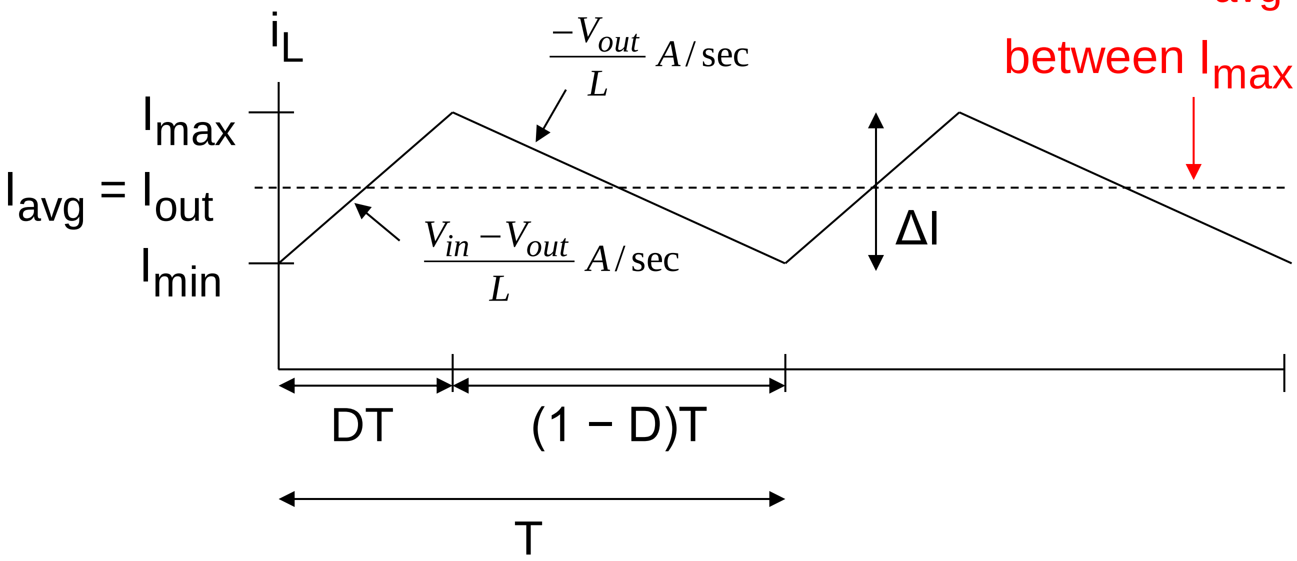
Note – even though i_{in} is not constant (i.e., i_{in} has harmonics), the input power is still simply $V_{in} \bullet I_{in}$ because V_{in} has no harmonics

Examine the inductor current

Switch closed, $v_L = V_{in} - V_{out}, \dfrac{di_L}{dt} = \dfrac{V_{in} - V_{out}}{L}$

Switch open, $v_L = -V_{out}, \dfrac{di_L}{dt} = \dfrac{-V_{out}}{L}$

From geometry, $I_{avg} = I_{out}$ is halfway between I_{max} and I_{min}



Periodic – finishes a period where it started

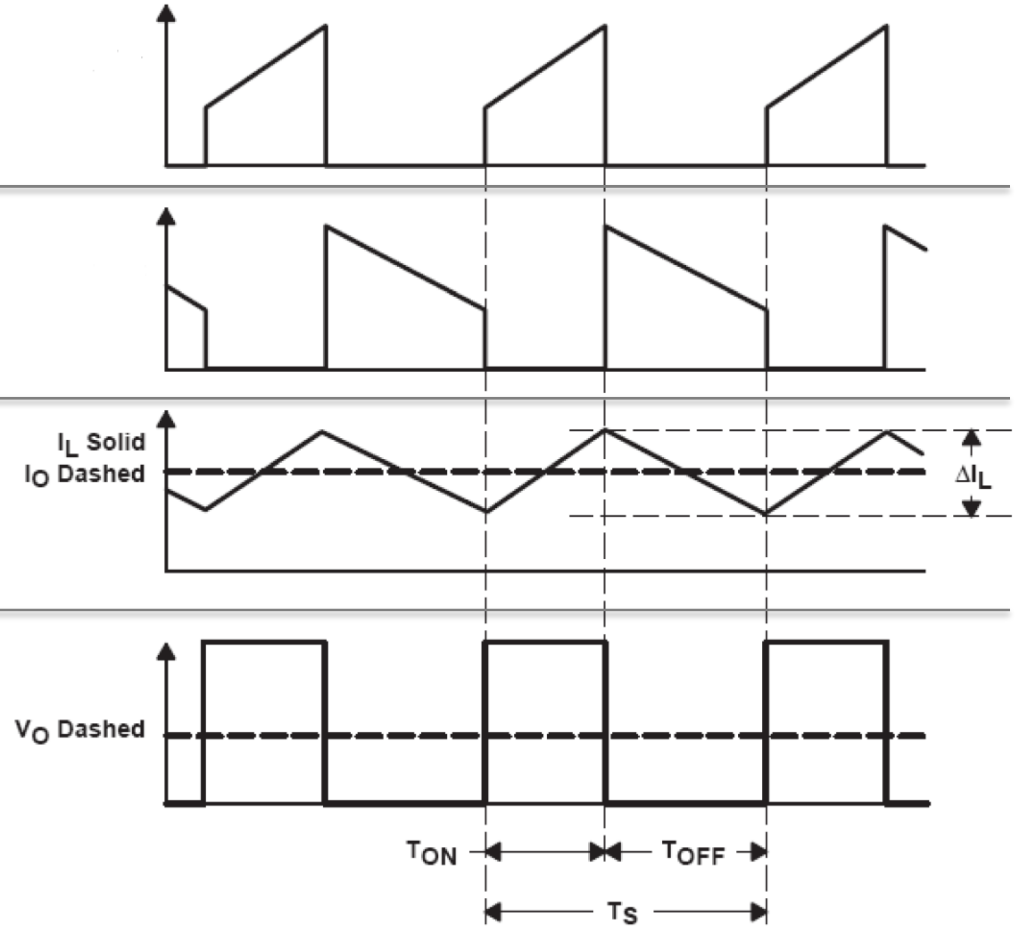
Buck Topology:
Current and Voltage Waveforms

Input current

Low side switch or diode

Output and Inductor

Switch

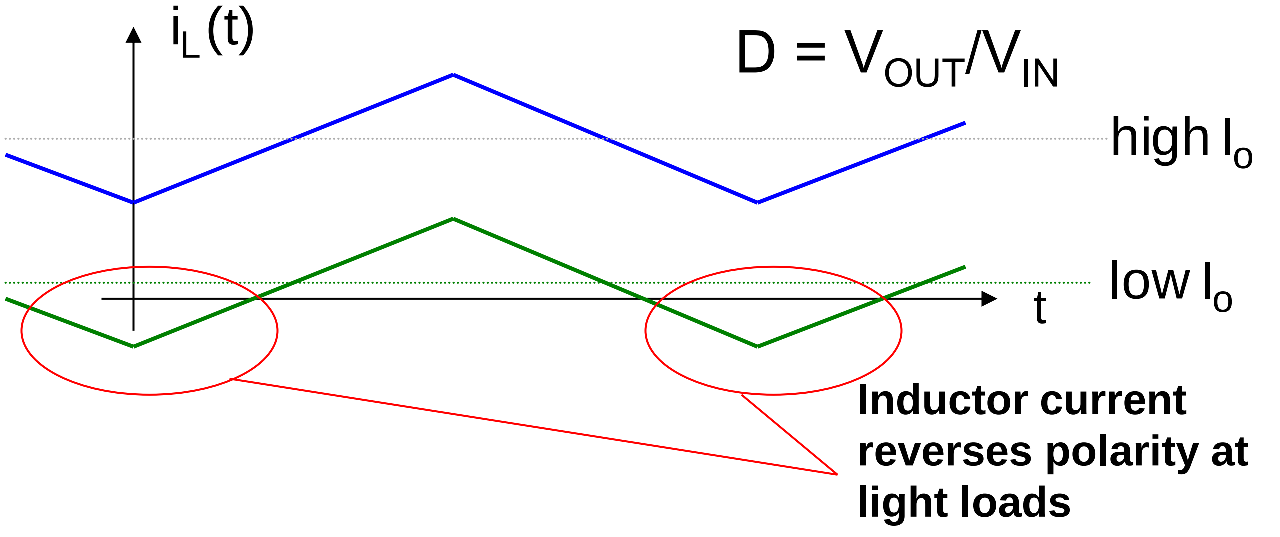


查看PMLKBUCKEVM的波形

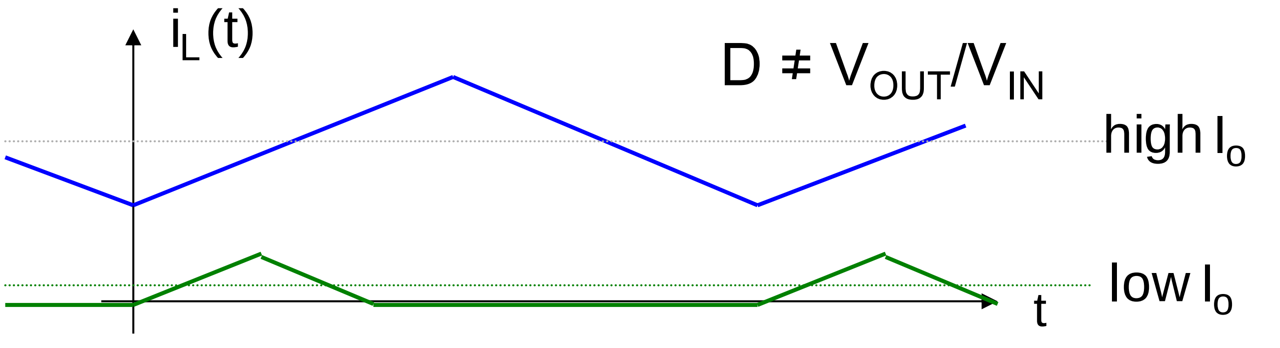
- 观察开关节点波形和输出电压波形
- 改变输入电压，观察开关节点波形占空比的变化
- 改变开关频率，观察开关节点波形的变化

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)

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)