Buck Maximum Duty Analysis in DCM Mode

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The Buck dropout voltage (the voltage difference between the input and output) is critical to some applications. Generally, the dropout voltage is determined by the maximum duty in CCM (Continuous Conduction Mode). However, if the Buck converter operates in DCM (Discontinuous Conduction Mode), the duty cycle needs to be reanalyzed. The paper addresses the buck maximum duty in DCM (Discontinuous Conduction Mode).

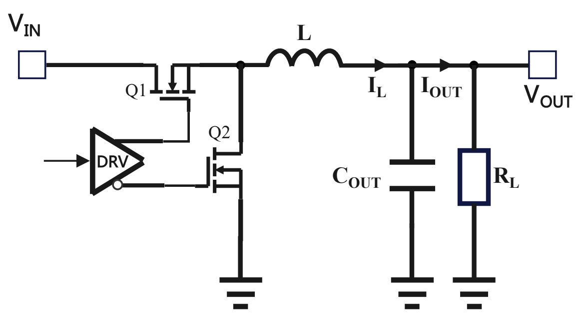

Figure 1-1 The Power Stage of Buck

1. The boundary conditions of DCM and CMM

The inductor ripple current at CCM:

$$\Delta I = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times L \times f_{SW}}$$

The output current at boundary conditions:

$$I_{OUT\_CR} = \frac{1}{2} \times \Delta I = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{2 \times V_{IN} \times L \times f_{SW}}$$

The boundary conditions :

$$I_{OUT} < \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{2 \times V_{IN} \times L \times f_{SW}}$$

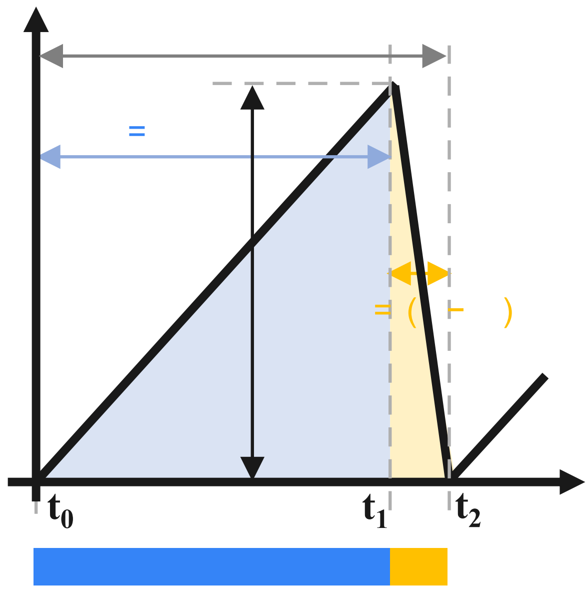

Figure 1-2 The Inductor Current at Boundary Conditions

2. Duty Analysis at DCM

The inductor current at DCM is illuminated in Figure1-3 . The duty requirement can be obtained via volt-second and power balance equations.

The volt-second balance equations:

$$(V_{IN} - V_{OUT}) \times D = V_{OUT} \times D_2$$

The peak current:

$$I_{PK} = \frac{(V_{IN} - V_{OUT}) \times D \times T_S}{L}$$

The output current (shaded area):

$$I_{OUT} = \frac{1}{2} \times I_{PK} \times \frac{t_{on} + t_{off}}{T_S} = \frac{1}{2} \times I_{PK} \times (D + D_2)$$

The duty at DCM:

$$D = \sqrt{\frac{2 \times L \times f_{SW} \times V_{OUT} \times I_{OUT}}{V_{IN} \times (V_{IN} - V_{OUT})}}$$

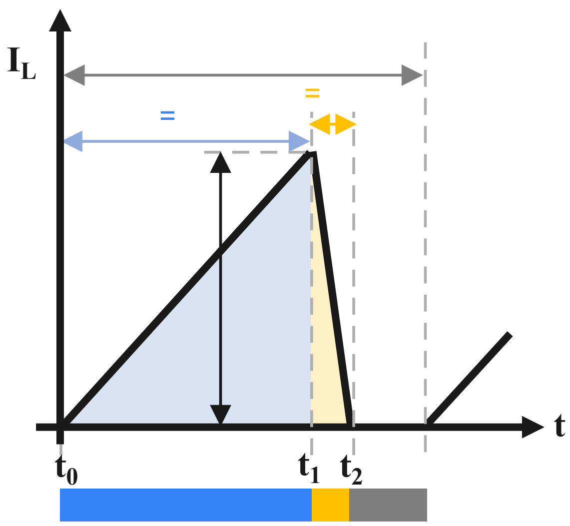

Figure 1-3 The Inductor Current at DCM

3. Example

A simulation is set up in Simplis to validate the mathematical analysis.

输入电压 V_{IN}	输出电压 V_{OUT}	电感 L	开关频率 f_{sw}	输出电流 I_{OUT}	临界电流 I_{OUT_CR}	模式	占空比 D(计算)	占空比 (仿真)
26V	24V	22uH	500kHz	50mA	84mA	DCM	0.71	0.71

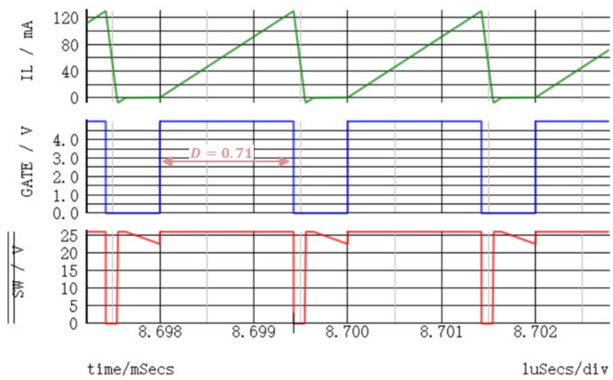

Figure 1-4 Simulation Results at Simplis

4. Conclusion

The paper quantifies the maximum duty of Buck DCM and validates the analysis result through simulation.