$K \equiv \frac{2L}{RT_{sw}}$

Chapter 5. The Discontinuous Conduction Mode

for same D — New V_o/V_g

3 circuits, 3 intervals

L too small Δi too big

unidirectional switch blocks $-i$

R_L too large or I_{DC} too small

Open ckt load all DCM

"What if inductor runs dry" – $i_L = 0$

Chapter 5. The Discontinuous Conduction Mode

Go back to go and recalculate $M(D, R_L)$

Change is: $\overline{\text{DCM}}$ DC gain depends on load

5.1. Origin of the discontinuous conduction mode, and mode boundary

5.2. Analysis of the conversion ratio $M(D,K)$

Before $M(D)$ only

5.3. Boost converter example

$K \equiv \frac{2L}{R T_{sw}}$!

5.4. Summary of results and key points

Next $M(K,D)$!

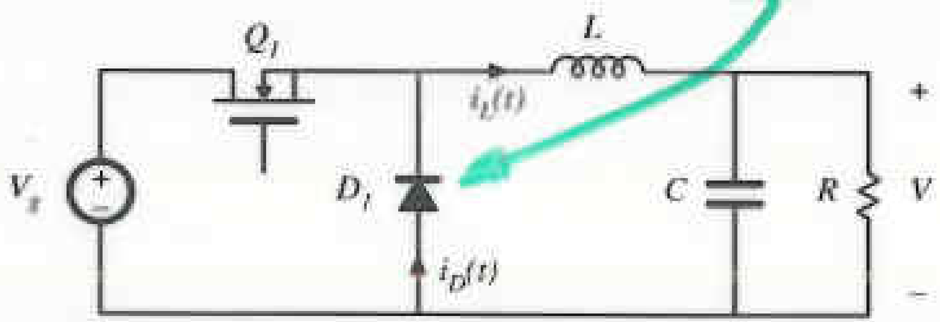
Web L 37 38 39

Ch5 HW Pg 19-22 HW Hints

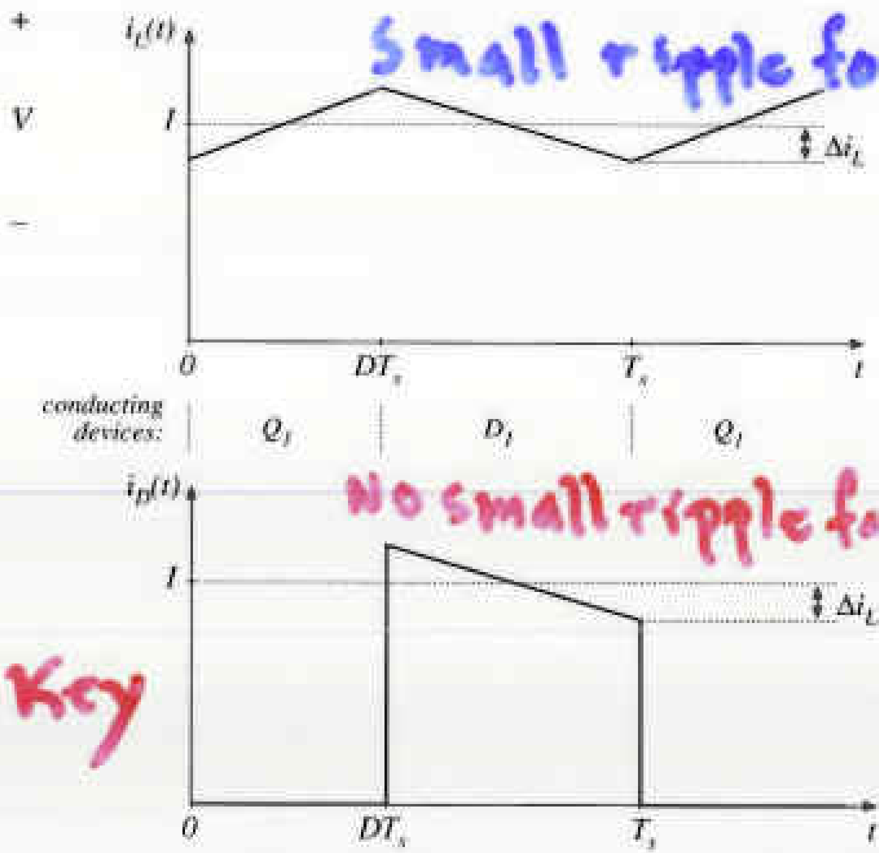
Web All foils

5.1. Origin of the discontinuous conduction mode, and mode boundary

Buck converter example, with single-quadrant switches



continuous conduction mode (CCM)



Small ripple for i_L

No small ripple for i_D

Minimum diode current is $(I - \Delta i_L)$

Dc component $I = V/R$

Current ripple is

$$\Delta i_L = \frac{(V_g - V)}{2L} DT_s = \frac{V_g DD'T_s}{2L}$$

Note that I depends on load, but Δi_L does not.

Key

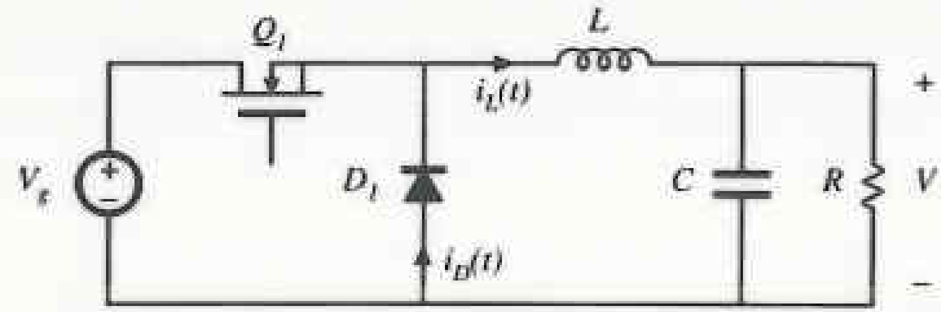
$R \to \infty \quad \Delta i > I$

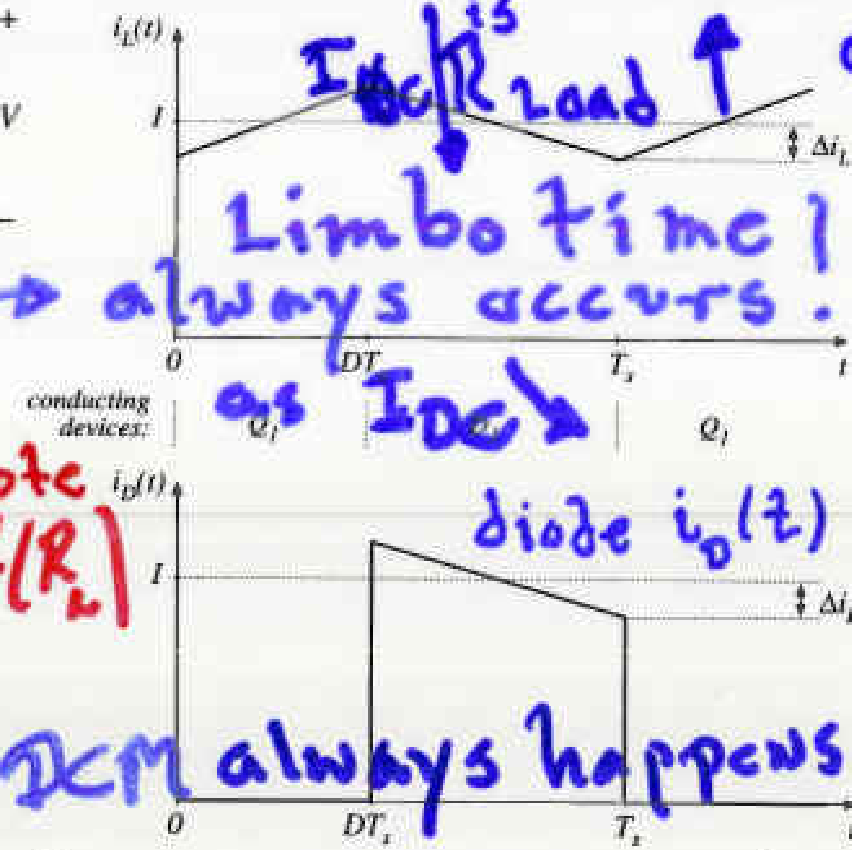
Use CCM Eqs v9 to DCM "event"

5.1. Origin of the discontinuous conduction mode, and mode boundary

Fig 5.1 | 5.2 pg 108

Buck converter example, with single-quadrant switches





Trend is I_{DC} ↓ R_{Load} ↑ ⊕ I_{DC}

Limbo time! always occurs as I_{DC} ↘

diode $i_D(t)$

Minimum diode current is $(I - \Delta i_L)$

Dc component $I = V/R$ = $f(R_L)$

Current ripple is

② Note $\neq f(R_L)$

CCM → $$\Delta i_L = \frac{(V_g - V)}{2L} DT_s = \frac{V_g DD' T_s}{2L}$$

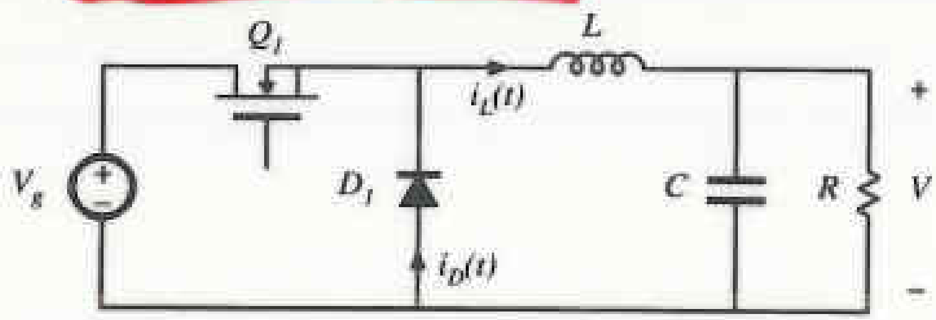
③ Note that I depends on load, but Δi_L does not.

Open Load: DCM always happens

Reduction of load current

Fig 5.3 Pg 105

Increase R, until $I = \Delta i_L$



Minimum diode current is $(I - \Delta i_L)$

Dc component $I = V/R$

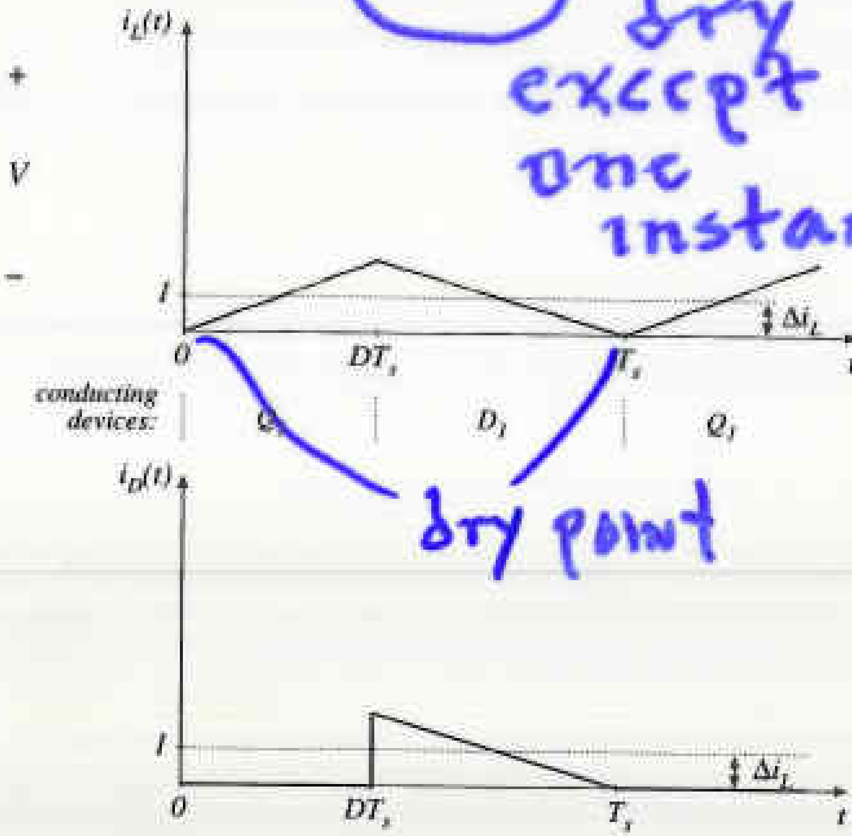
Current ripple is

$$\Delta i_L = \frac{(V_g - V)}{2L} DT_s = \frac{V_g DD'T_s}{2L}$$

Note that I depends on load, but Δi_L does not.

CCM-DCM boundary

Not dry except at one instant

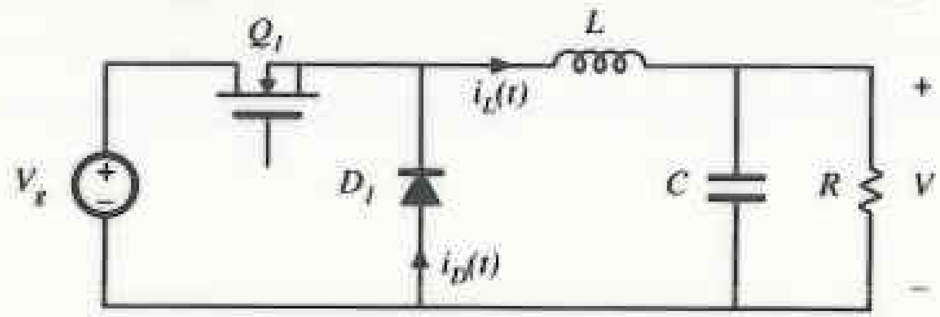


Get a third interval D_3

Further reduce load current

Fig 5.4 p116

Increase R some more, such that $I < \Delta i_L$



Minimum diode current is $(I - \Delta i_L)$

Dc component $I = V/R$

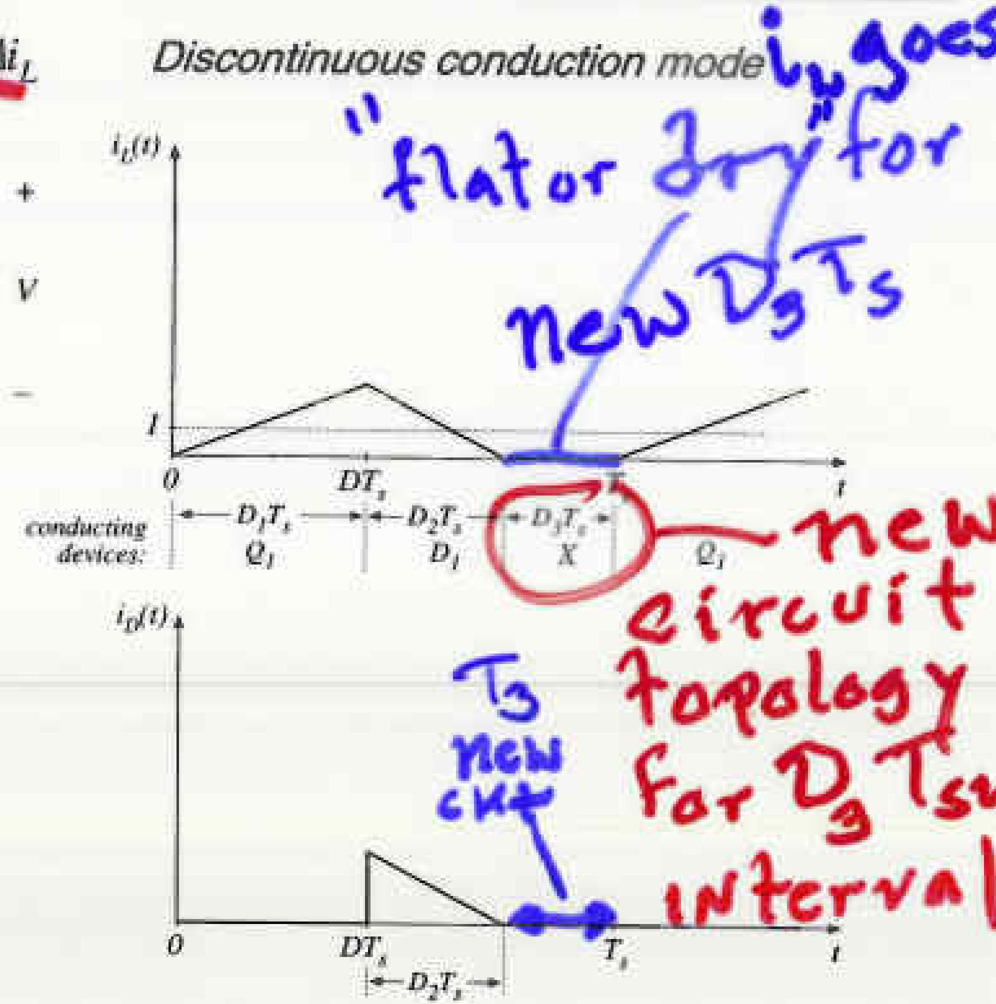
Current ripple is

$$\Delta i_L = \frac{(V_g - V)}{2L} DT_s = \frac{V_g DD'T_s}{2L}$$

Note that I depends on load, but Δi_L does not.

The load current continues to be positive and non-zero.

Discontinuous conduction mode



Mode boundary

$$I > \Delta i_L \quad for\ CCM$$
$$I < \Delta i_L \quad for\ DCM$$

Insert buck converter expressions for I and Δi_L :

$$\frac{DV_g}{R} < \frac{DD'T_sV_g}{2L}$$

CCM Eqs. still valid

Simplify:

Key "K"

$$\frac{2L}{RT_s} < D'$$

This expression is of the form

$$K < K_{crit}(D) \quad for\ DCM$$

where $K = \frac{2L}{RT_s}$ and $K_{crit}(D) = D'$

L too small

R too big

K ↓

K6 depends on converter

Mode boundary

CCM: bipolar disorder

~~thus~~ Kc ~~are~~ is circuit topology specific

$$I > \Delta i_L \quad \textit{for CCM}$$
$$I < \Delta i_L \quad \textit{for DCM}$$

DCM: The third personality emerges fun begins

Insert buck converter expressions for I and Δi_L:

$$\frac{DV_g}{R} < \frac{DD'T_sV_g}{2L}$$

Simplify:

$$\frac{2L}{RT_s} < D'$$

"K" Power of thinking

K ε Kcritical way of thinking

K = f(R, L, fsw)

Kc = f(D)

This expression is of the form

$$K < K_{crit}(D) \quad \textit{for DCM}$$

where $\underbrace{K = \frac{2L}{RT_s}}_{\text{choice of } L, R, f_{sw}}$ and $\underbrace{K_{crit}(D) = D'}_{\text{For Buck}}$

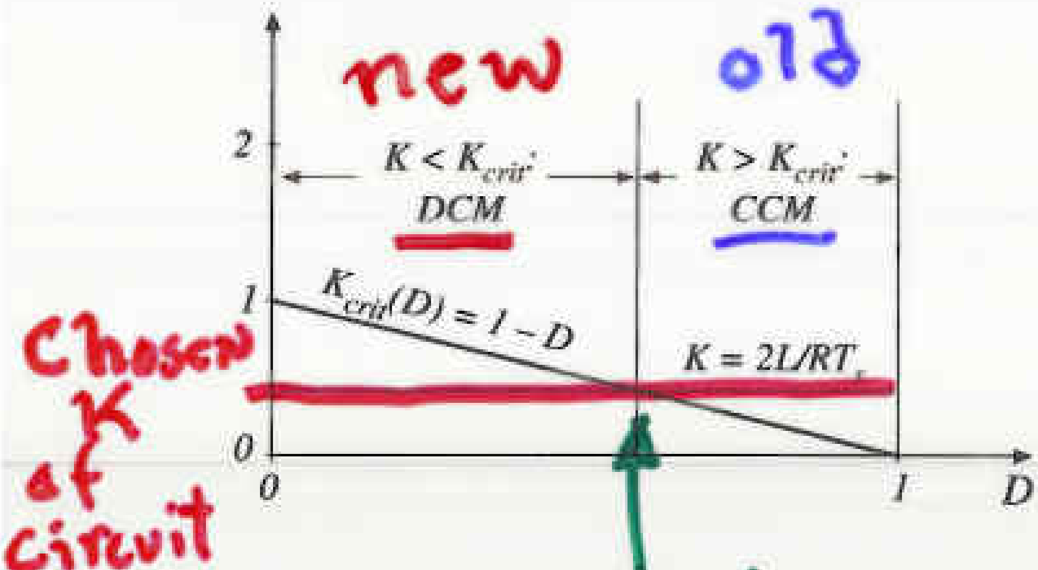
At CCM|DCM cross-over   Static: New m
Dynamic: P & Z must be same

K and K_{crit} vs. D

for Buck

Fig 5.5

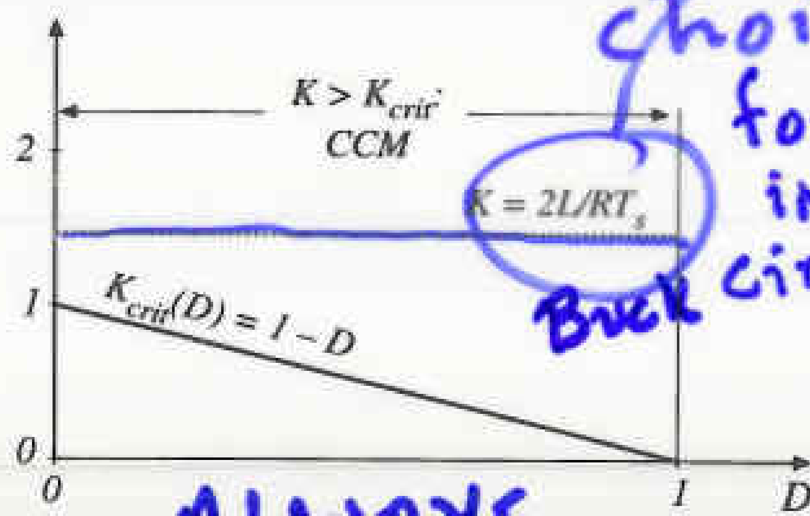
for $K < 1$:



What happens here?

Fig 5.6

for $K > 1$:



ALWAYS CCM

$\leq D \geq$ ← how to solve

<ext: $R \le R_c$

Critical load resistance R_{crit}

Too high $R \rightarrow$ DCM

Solve K_{crit} equation for load resistance R:

$$R < R_{crit}(D) \quad \textit{for CCM}$$
$$R > R_{crit}(D) \quad \textit{for DCM}$$

where $$R_{crit}(D) = \frac{2L}{D'T_s}$$

How to Guarantee CCM?
Simple way!
even for $R_L > R_{crit}$

Summary: mode boundary

Table 5.1 p 112

$$K > K_{crit}(D) \quad or \quad R < R_{crit}(D) \quad \text{for CCM}$$
$$K < K_{crit}(D) \quad or \quad R > R_{crit}(D) \quad \text{for DCM}$$

Way of K

intuitive

Parallel to R_{Load} to ~~to~~ insure?

Table 5.1. CCM-DCM mode boundaries for the buck, boost, and buck-boost converters

Converter	$K_{crit}(D)$	$\max_{0 \le D \le 1}(K_{crit})$	$R_{crit}(D)$	$\min_{0 \le D \le 1}(R_{crit})$
Buck	$(1-D)$	1	$\frac{2L}{(1-D)T_s}$	$2\frac{L}{T_s}$
Boost	$D(1-D)^2$	$\frac{4}{27}$	$\frac{2L}{D(1-D)^2 T_s}$	$\frac{27}{2}\frac{L}{T_s}$
Buck-boost	$(1-D)^2$	1	$\frac{2L}{(1-D)^2 T_s}$	$2\frac{L}{T_s}$

Depends on circuit

unique