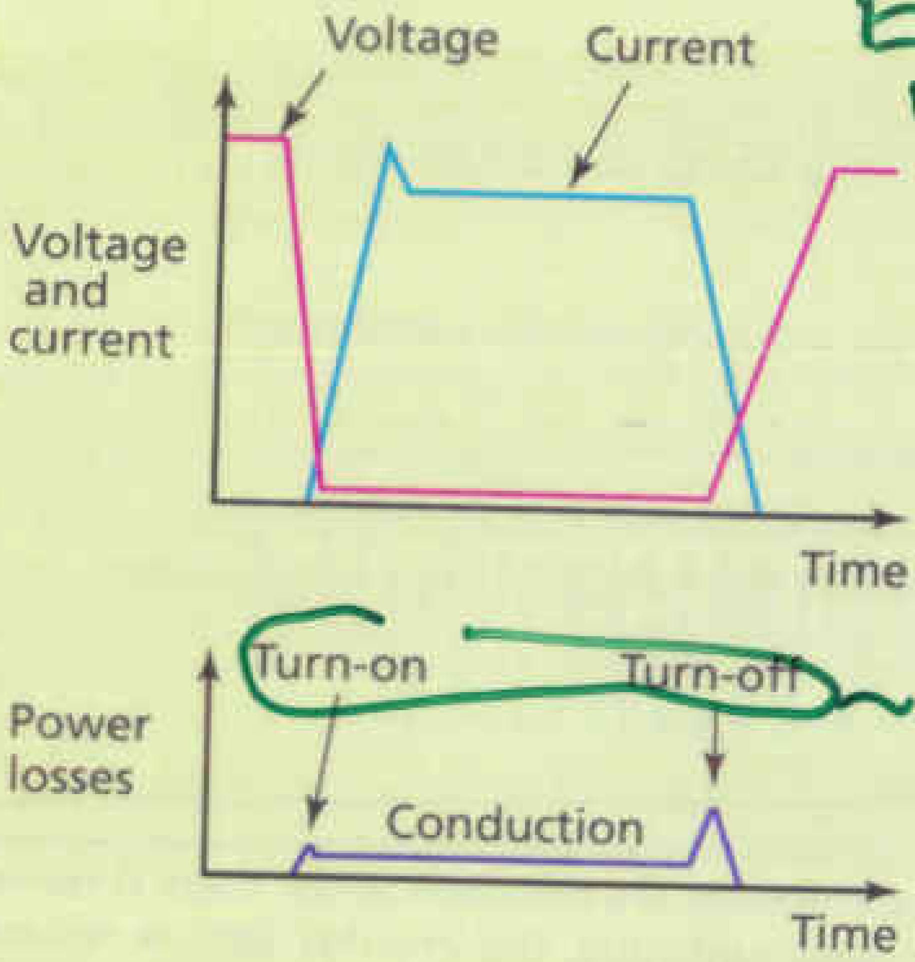
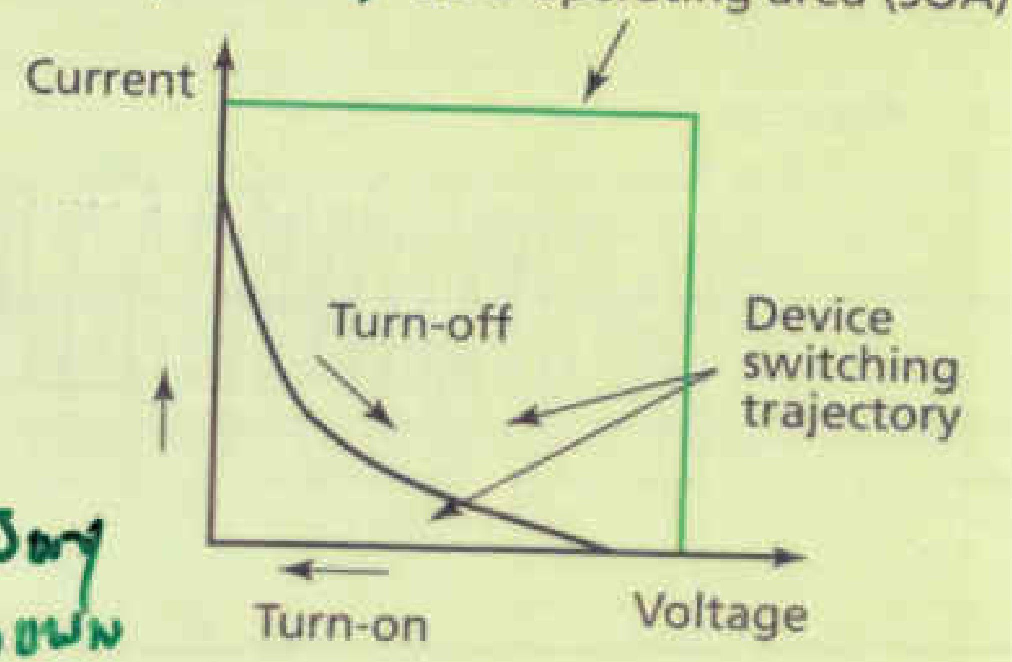
EE 564 Soft Switching

use body diodes, control gate timing



Way down



use body diode

Soft switching

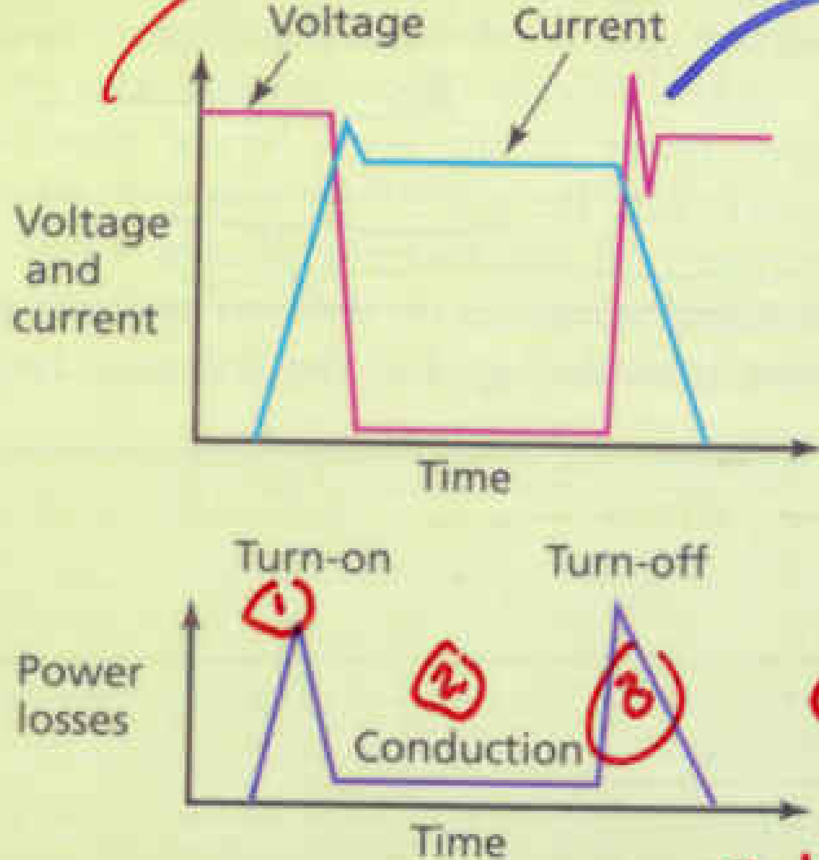
- Zero voltage across the device at both turn-on and turn-off keeps switching losses low.
- Neither diode recovery nor device capacitance causes undesirable effects during operation.
- Switching trajectory is well within the safe operating area.
- Electromagnetic interference is low because switching speeds approach at most 0.1–0.5 GV/s.
- Operation at high frequency is made possible by the low losses.

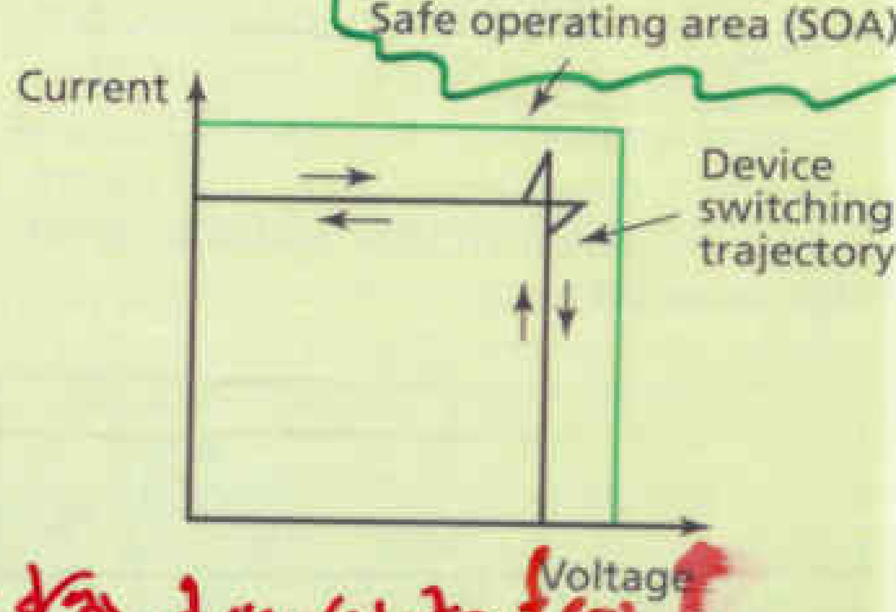
A hard look at hard and soft switching

Ch 4

which type

?





① & ③ dominate f_{sw} ?

562 – any cure?

① & ③ High limits what?

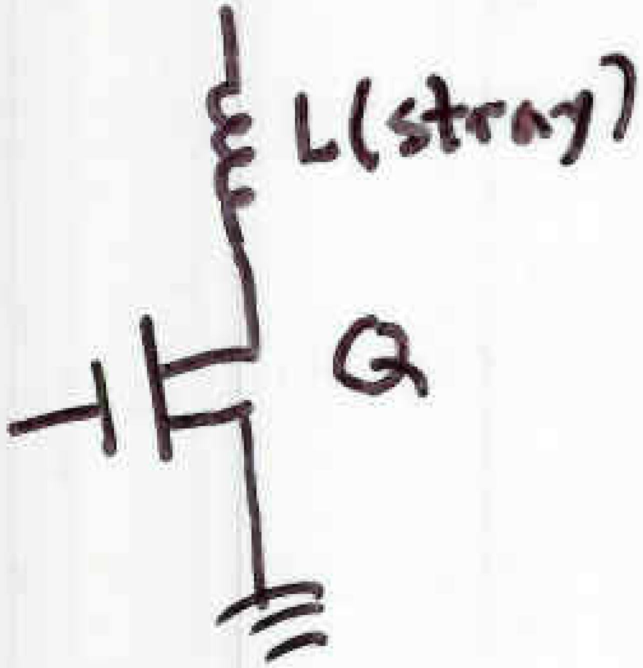
Hard switching

- Device carries a full load current and sustains full voltage at both turn-on and turn-off.
- Diode recovery effects and stray inductance increase stresses and device losses.
- Switching trajectory must be within the safe operating area.
- Electromagnetic interference is high because switching speeds are high, approaching 5–10 GV/s.
- Operation at high frequencies requires derating of the device to curb switching losses.

SOA curves

Type ½ $V_{off} I_{on}$

f_{max} limit

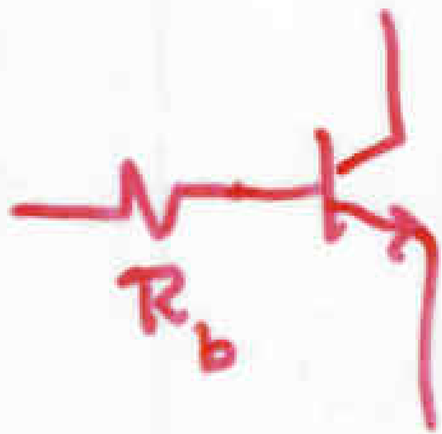


"on Q" goes to "off Q"

$\frac{di}{dt}$ is -

V_L $-$ $+$ spike

+V spike



Causes Avalanch!

Solution:

Slow $\frac{di}{dt}$, reduce L(stray)

Reduce $\frac{dv}{dt}$

more stable Ch 7/8/9 2nd semester

Introduction to Discontinuous Conduction Mode (DCM)

i_{diode} only one way

3rd circuit

- Occurs because switching ripple in inductor current or capacitor voltage causes polarity of applied switch current or voltage to reverse, such that the current- or voltage-unidirectional assumptions made in realizing the switch are violated.

if diodes used $i \to 0$

new circuit

- Commonly occurs in dc-dc converters and rectifiers, having single-quadrant switches. May also occur in converters having two-quadrant switches.

Why?

- Typical example: dc-dc converter operating at light load (small load current). Sometimes, dc-dc converters and rectifiers are purposely designed to operate in DCM at all loads.

open load always DCM

- Properties of converters change radically when DCM is entered:

  M becomes load-dependent

  Output impedance is increased

  Good!

  Dynamics are altered ← GOOD for stability – Ch 7/8/9

  Control of output voltage may be lost when load is removed

More Personalities!

PSpice simulations

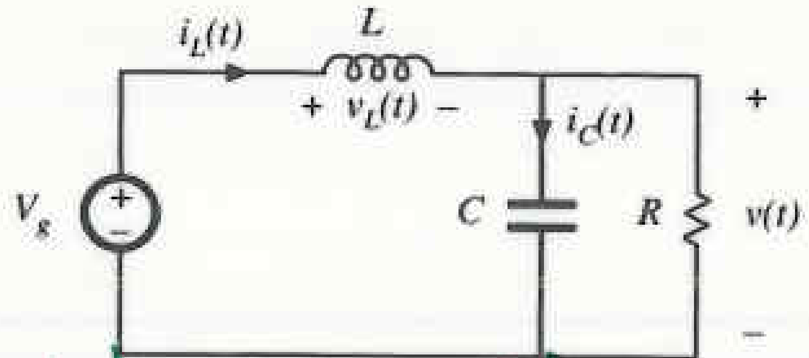
Subinterval 1

$v_L(t) = V_g - v(t)$
$i_C(t) = i_L(t) - v(t) / R$

Small ripple approximation
for $v(t)$ (but not for $i(t)$!):

Careful lazy one's "small ripple" as in DCM i varies from: i_{max} 0

$v_L(t) \approx V_g - V$
$i_C(t) \approx i_L(t) - V / R$



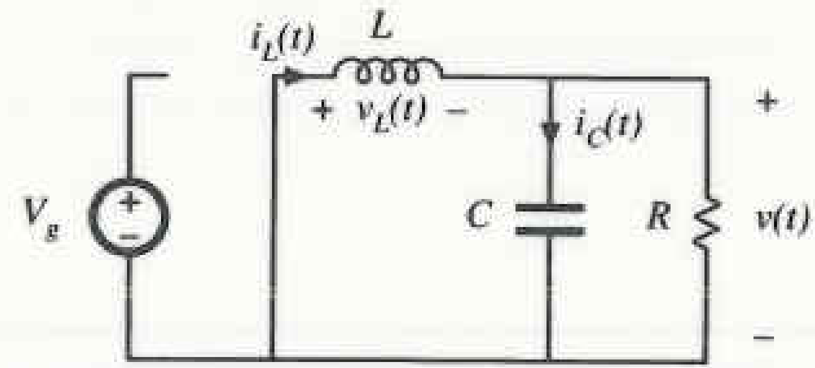
Subinterval 2

Useful

$$v_L(t) = -v(t)$$
$$i_C(t) = i_L(t) - v(t)/R$$

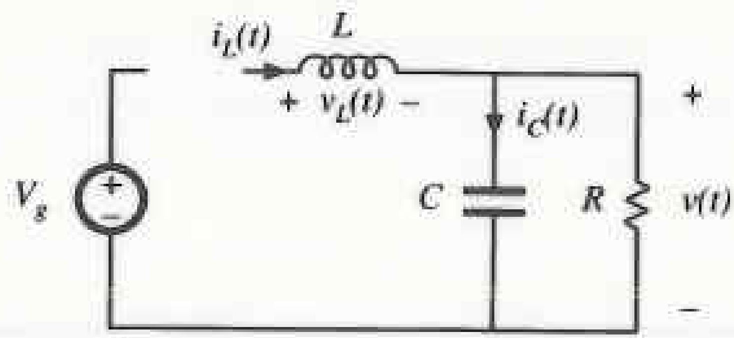
Small ripple approximation for $v(t)$ but not for $i(t)$:

$$v_L(t) \approx -V$$
$$i_C(t) \approx i_L(t) - V/R$$



Subinterval 3

$$v_L = 0, \quad i_L = 0$$
$$i_C(t) = i_L(t) - v(t)/R$$



Small ripple approximation:

$$v_L(t) = 0$$
$$i_C(t) = -V/R$$