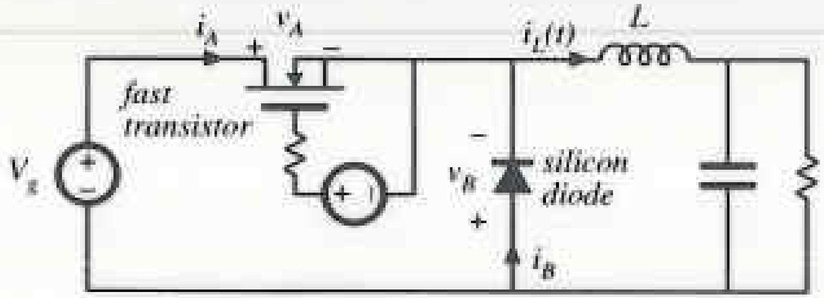
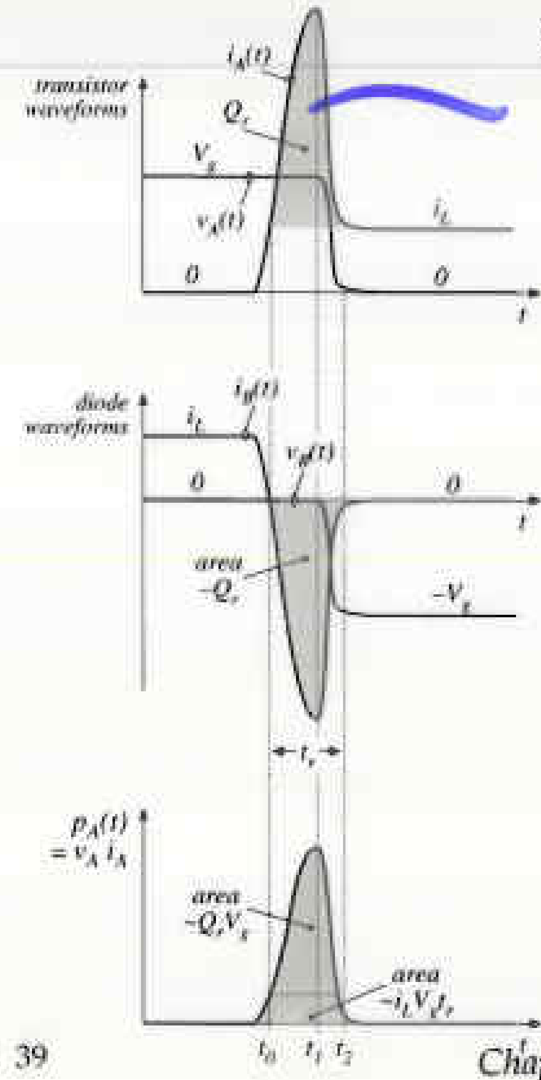
Diode Q_r increases Tr loss off-on

The diode switching transients induce switching loss in the transistor

see Section 4.3.2





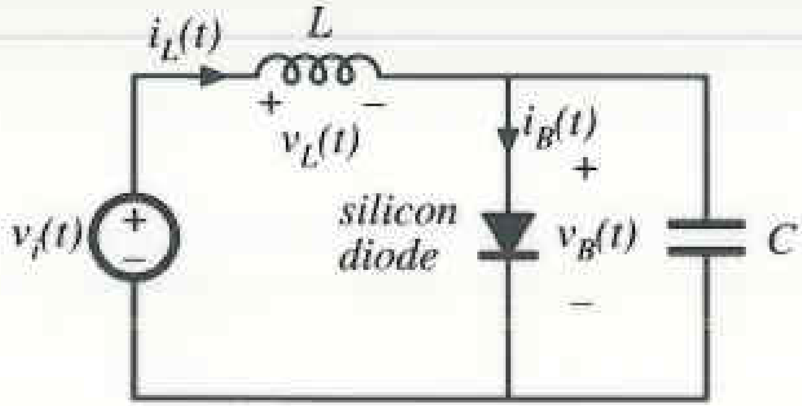
brief shoot through for I_{DS}

Peak I_D during V_{off}

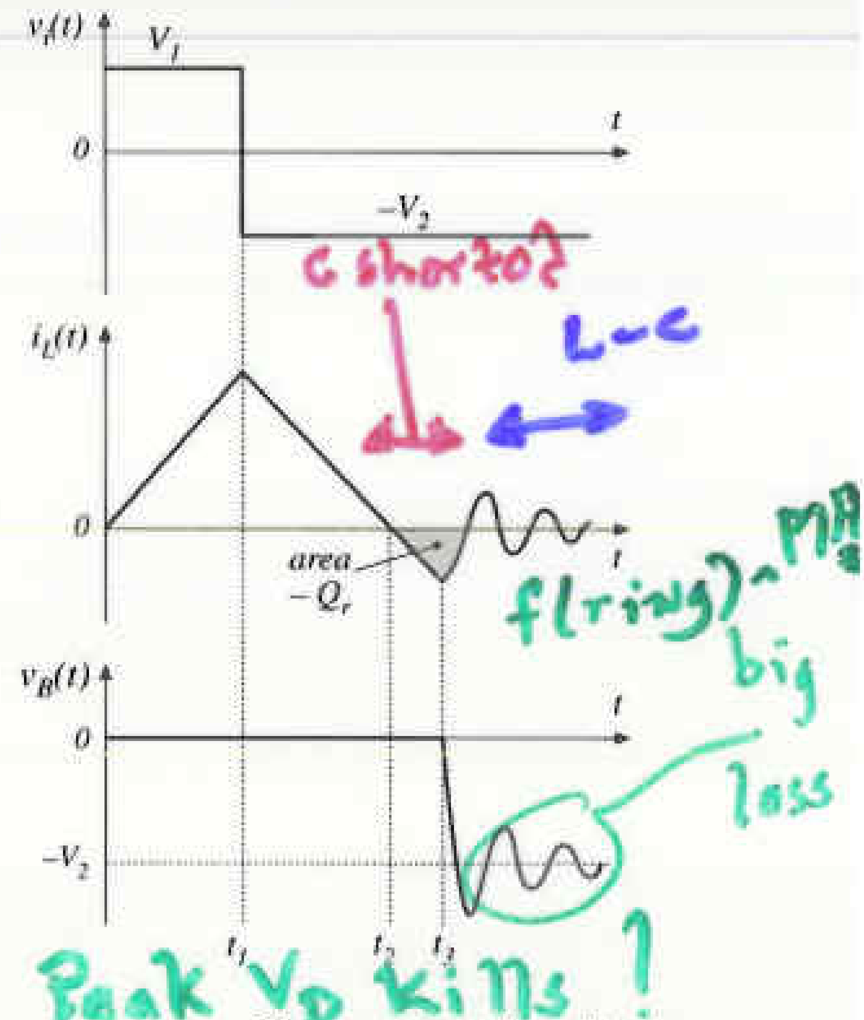
- Diode recovered stored charge Q_r flows through transistor during transistor turn-on transition, inducing switching loss
- Q_r depends on diode on-state forward current, and on the rate-of-change of diode current during diode turn-off transition

Ringing induced by diode stored charge

see Section 4.3.3



- Diode is forward-biased while $i_L(t) > 0$
- Negative inductor current removes diode stored charge Q_r
- When diode becomes reverse-biased, negative inductor current flows through capacitor C.
- Ringing of L-C network is damped by parasitic losses. Ringing energy is lost.



Energy associated with ringing

Recovered charge is $Q_r = -\int_{t_2}^{t_3} i_L(t)\, dt$

Energy stored in inductor during interval $t_2 \le t \le t_3$:

$$W_L = \int_{t_2}^{t_3} v_L(t)\, i_L(t)\, dt$$

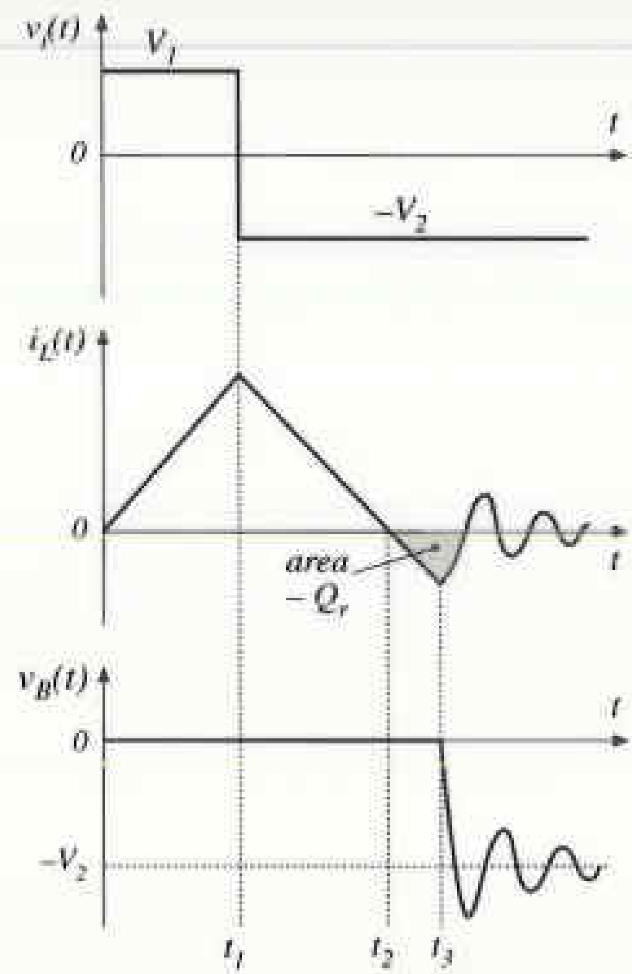
Applied inductor voltage during interval $t_2 \le t \le t_3$:

$$v_L(t) = L\,\frac{di_L(t)}{dt} = -V_2$$

Hence,

$$W_L = \int_{t_2}^{t_3} L\,\frac{di_L(t)}{dt}\, i_L(t)\, dt = \int_{t_2}^{t_3} (-V_2)\, i_L(t)\, dt$$

$$W_L = \tfrac{1}{2} L\, i_L^2(t_3) = V_2\, Q_r$$



Switching loss calculation

Energy lost in transistor:

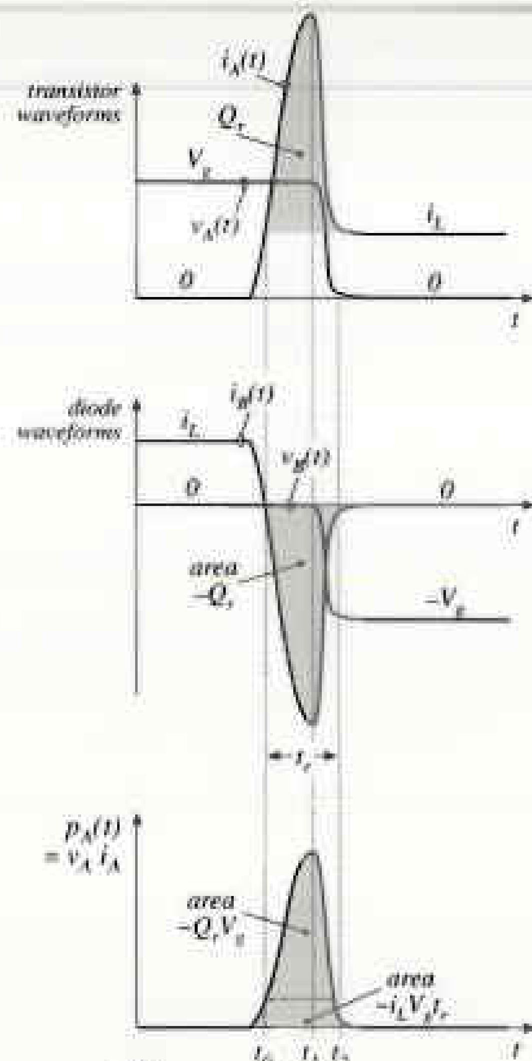
$$W_D = \int_{\substack{\text{switching} \\ \text{transition}}} v_A(t)\, i_A(t)\, dt$$

With abrupt-recovery diode:

$$W_D \approx \int_{\substack{\text{switching} \\ \text{transition}}} V_g\, (i_L - i_B(t))\, dt$$

$$= V_g\, i_L\, t_r + V_g\, Q_r$$

- *Often, this is the largest component of switching loss*



Soft-recovery diode:

$(t_2 - t_1) >> (t_1 - t_0)$

Abrupt-recovery diode:

$(t_2 - t_1) << (t_1 - t_0)$