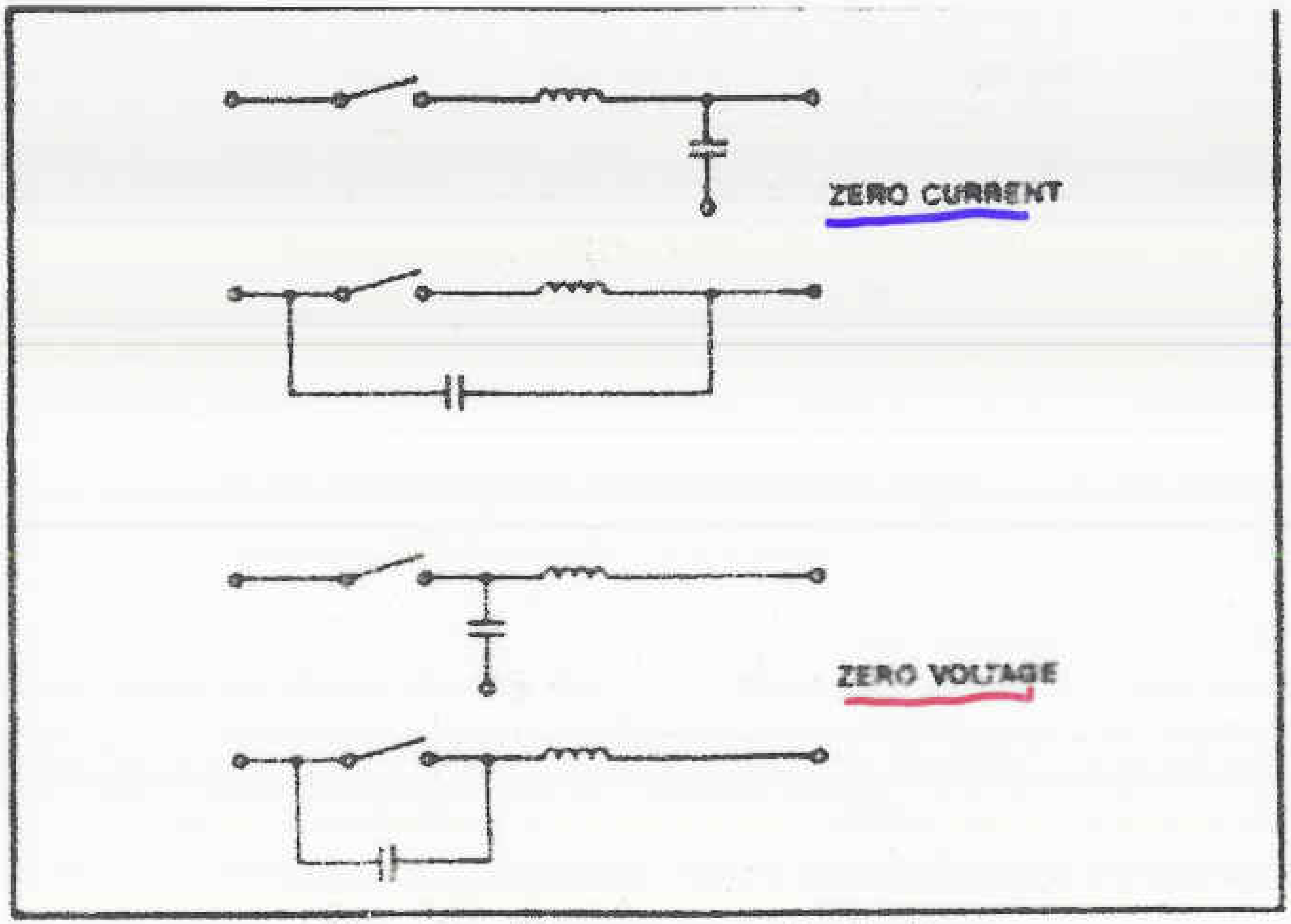
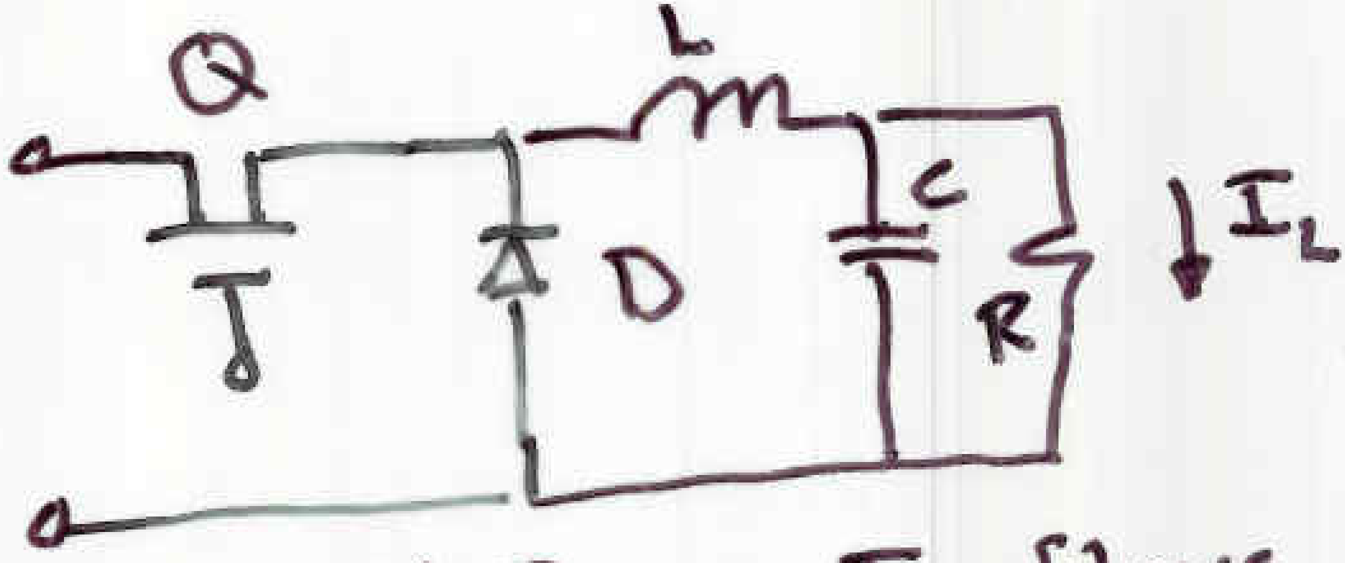


Fig. 7 - Resonant Switches

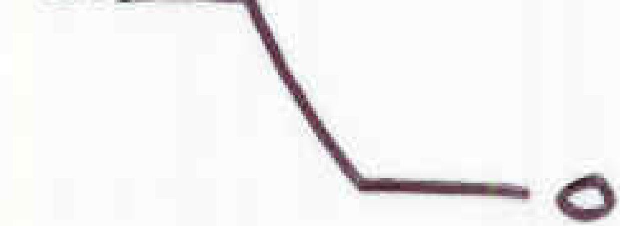


① if Q off D on, I_L flows through D

② i_D will continue to flow due to Q_{rr} for Δt_{rr} after Q on

③ When Q goes from off to on large $\mathcal{E}_{\substack{off \\ on}}$ occurs since V_{DS} large as

force i_Q to be zero as



ZCT switching

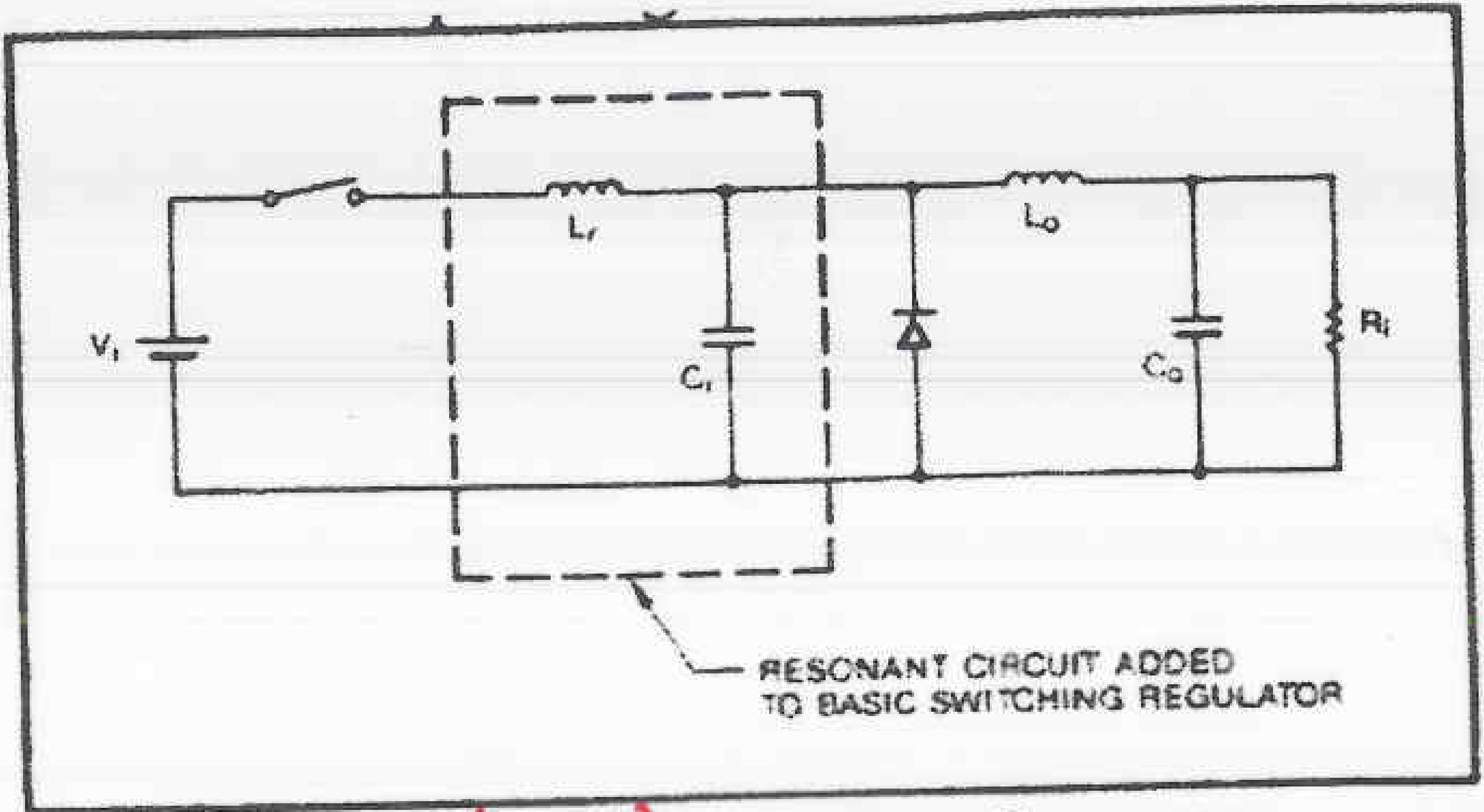


Fig. 3 - Basic (Buck) Resonant Converter

L_r, C_r allow reduction of Sw loss
force ZCT

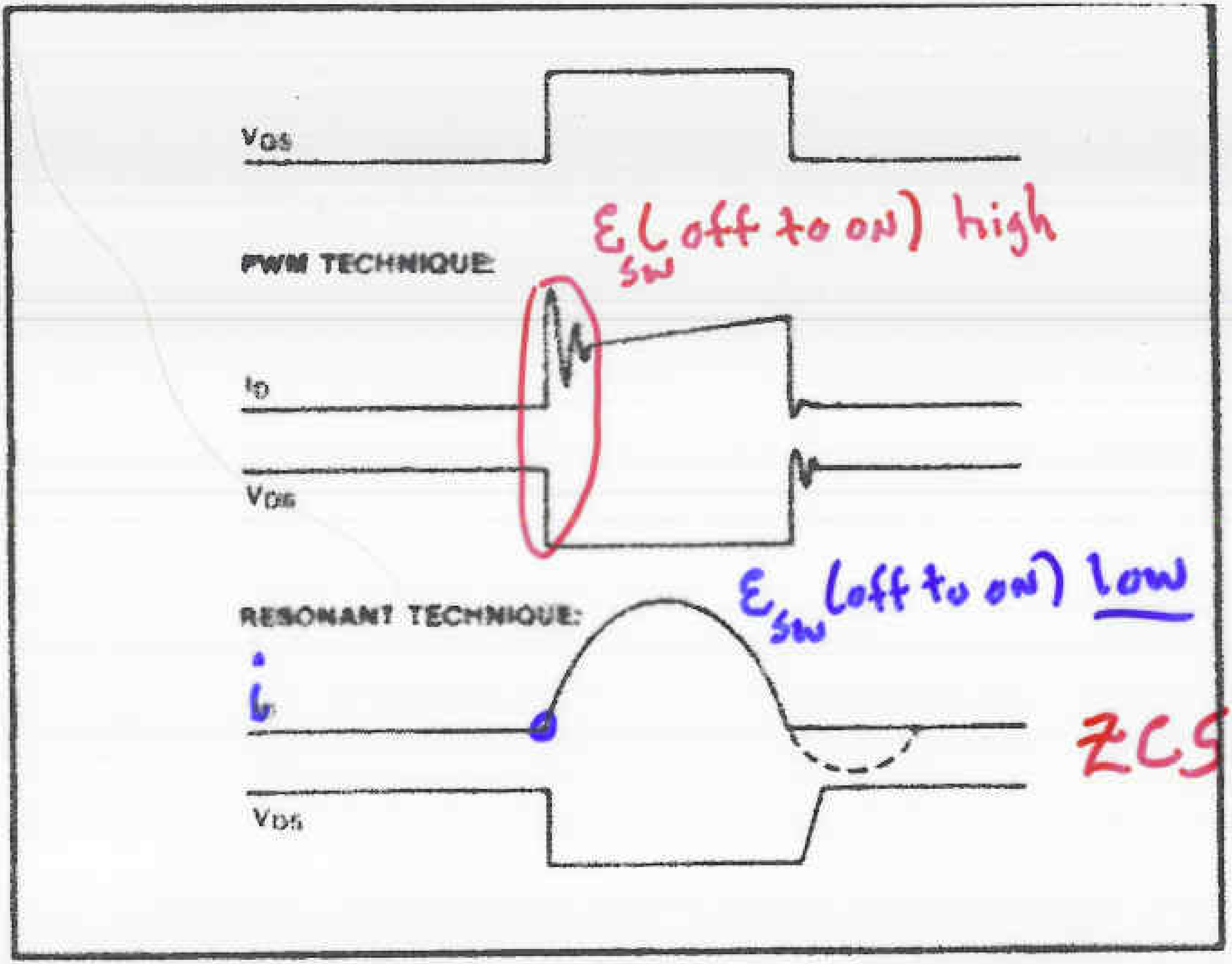


Fig. 5 - PWM vs. Resonant Switching

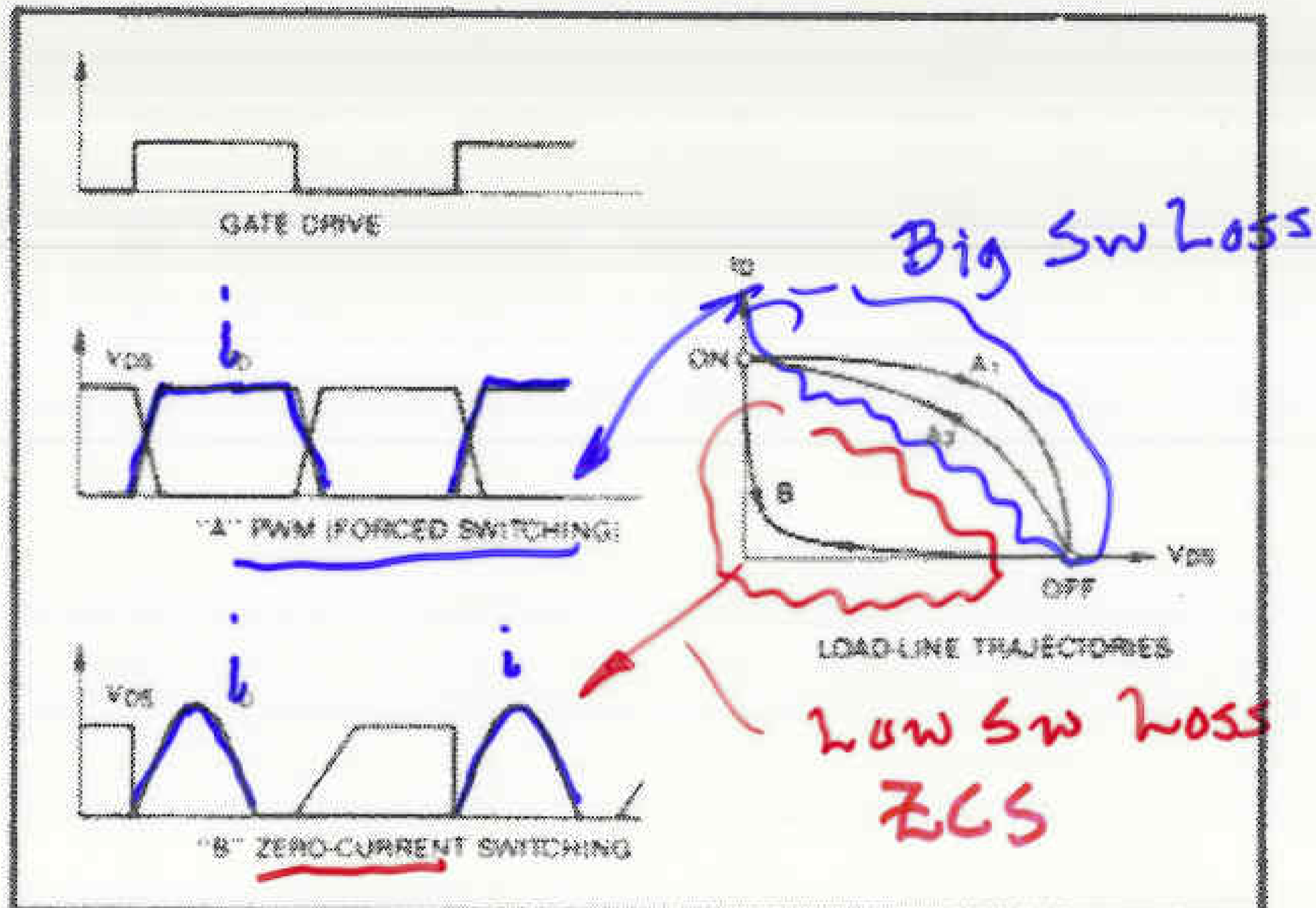
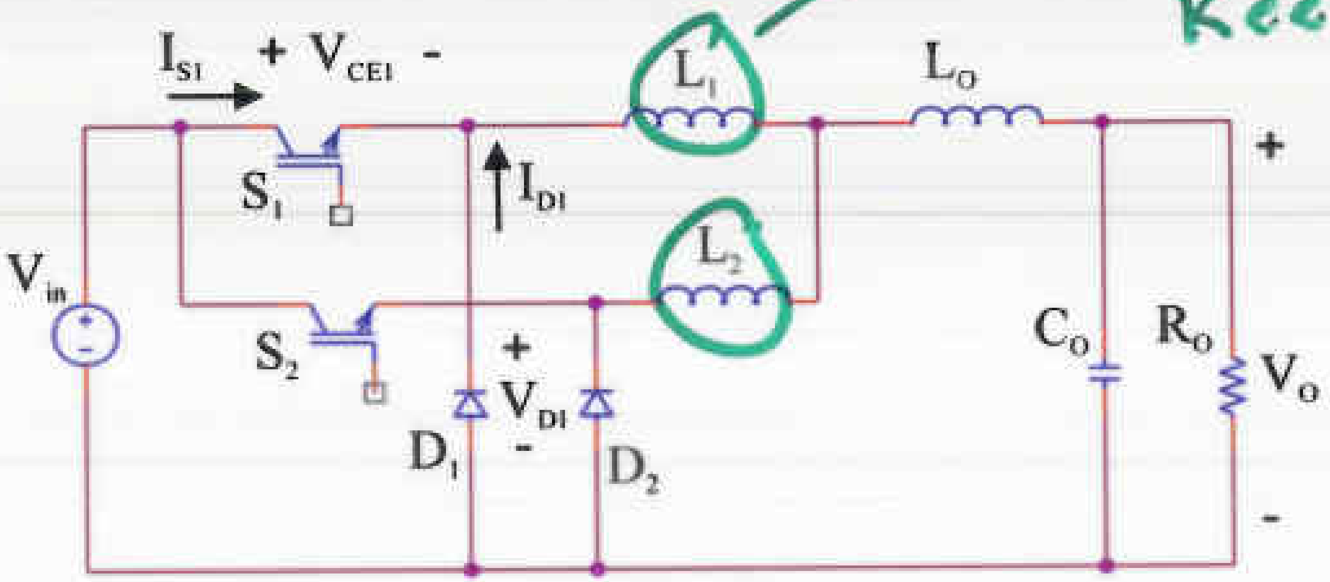


Fig. 6 - Switching Stress and Switching Loss

Interleaved ZCT Buck

lags i_{L_1} wrt V_{L_1}
Keep $i_Q = 0$



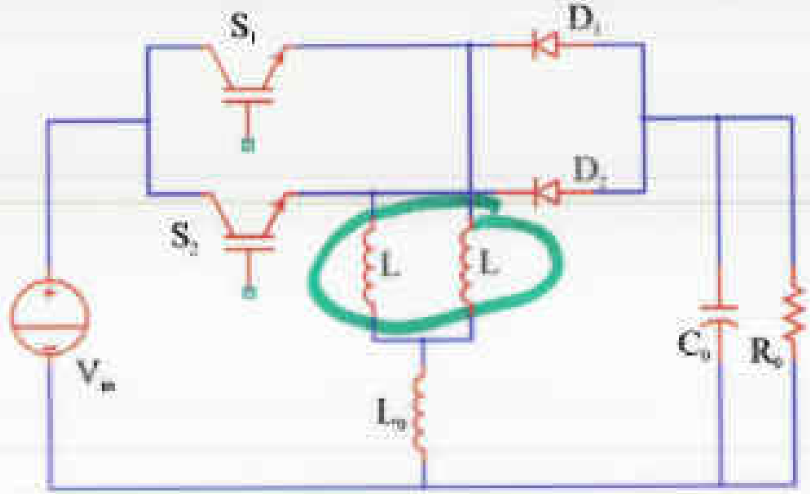
- Two small inductors (L_1, L_2) added to achieve zero-current-transition turn on of the switches S_1 and S_2
- Out-of-phase operation of S_1 and S_2, as in two-phase converters
- Significant reduction of losses associated with diode reverse recovery
- Simple operation, no resonant circuit

Comparison of Losses

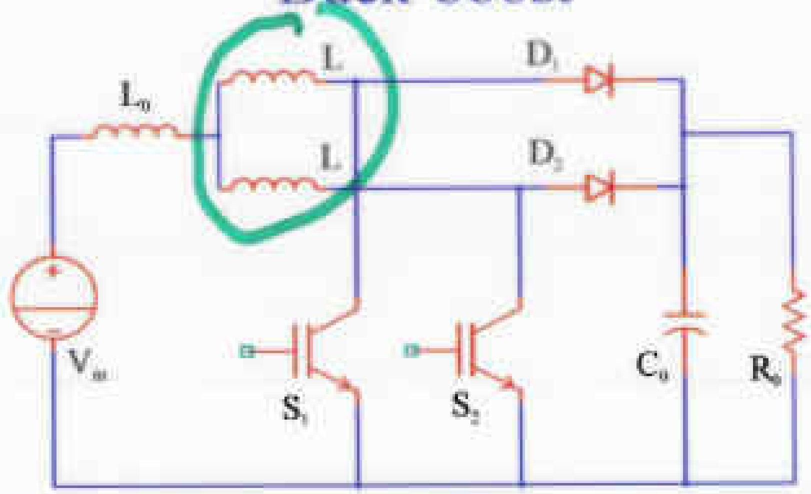
Powerex: CM150DU-24NFH		Hard switched	New circuit	
Turn-on loss	*(mJ)*	*4.0*	*0.4*	10x
Turn off loss	(mJ)	3.8	3.8	No advantage
Conduction loss (one sw. period)	(mJ)	6.1	6.1	
Loss per switch (32 kHz)	*(W)*	*444.2*	*164.5*	
Diode recovery loss	*(mJ)*	*12.0*	*2.0*	6x
Diode conduction loss (one sw. per.)	(mJ)	3.5	3.5	
Diode loss (32 kHz)	*(W)*	*496.6*	*88.3*	
Aux switch, eq (10)* in [2]	(mJ)			
Total loss (32 kHz)	*(W)*	*940.8*	*505.6*	2x better overall

*m=0.6, To=3 μs, k=2, Vc=10 V

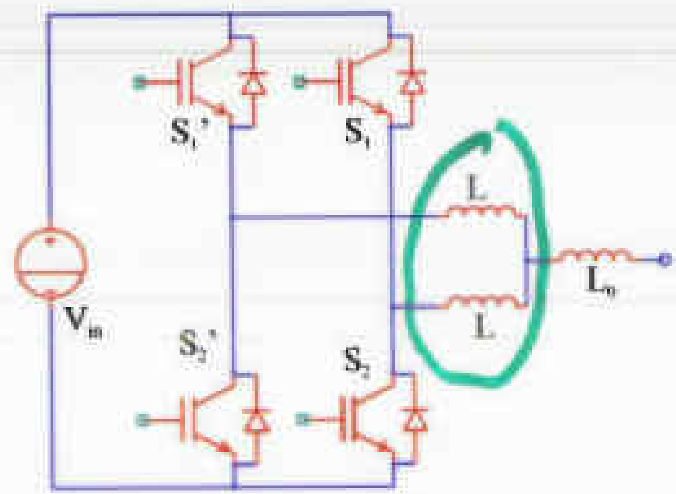
Examples of Other Interleaved ZCT Converters



Buck-boost

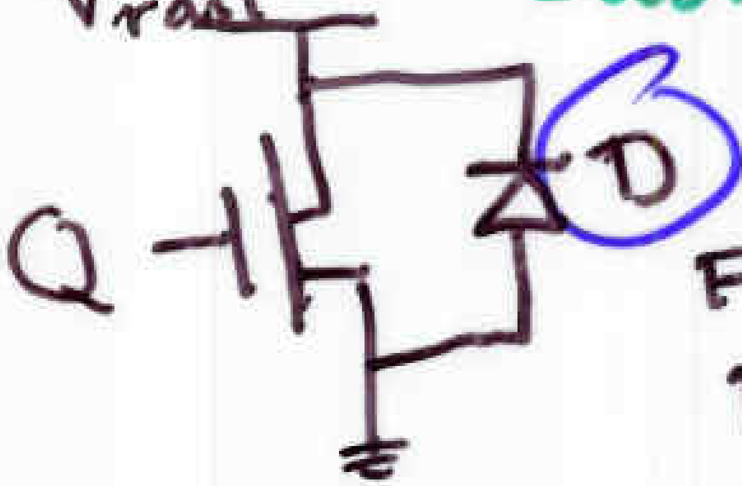


Boost



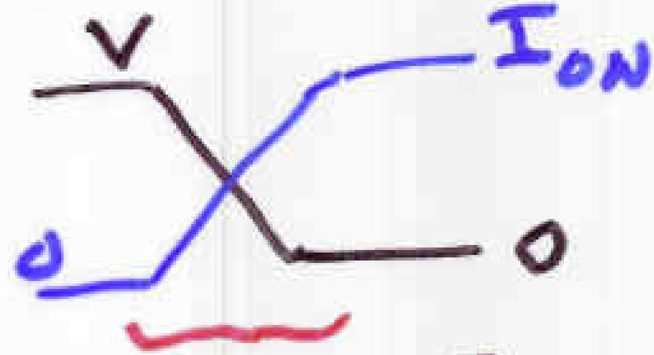
One leg of an interleaved ZCT bridge or three-phase inverter

Basic Concept ZVS



FET off

To go from FET off to FET on



$$[V I_{ON} \Delta t]$$

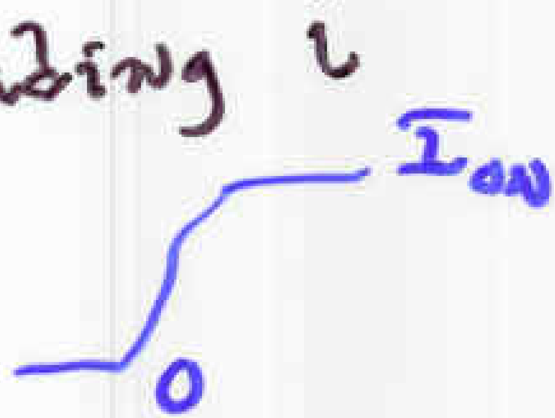
$\mathcal{E}_{\text{off to on}}$

$$P_{\substack{off\\on}} = f_{sw}\left[\mathcal{E}_{\substack{off\\on}}\right]$$

FET diode

<u>if</u> D is placed on ahead of Q by a leading i

$V_Q = 0$ during



$$\mathcal{E}_{\substack{off\\on}} \longrightarrow 0$$

IGBT MOSFET

ADVANTAGES:

1. ZERO CURRENT SWITCHING — ZVS too
2. LOW COMPONENT STRESS
3. LOW EMI
4. USEFUL PARASITIC ELEMENTS — Use L (parasitic)
5. IMPROVED DIODE RECOVERY — Losses ↓

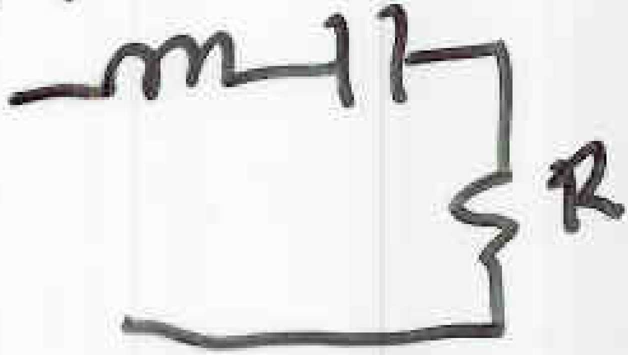
DISADVANTAGES:

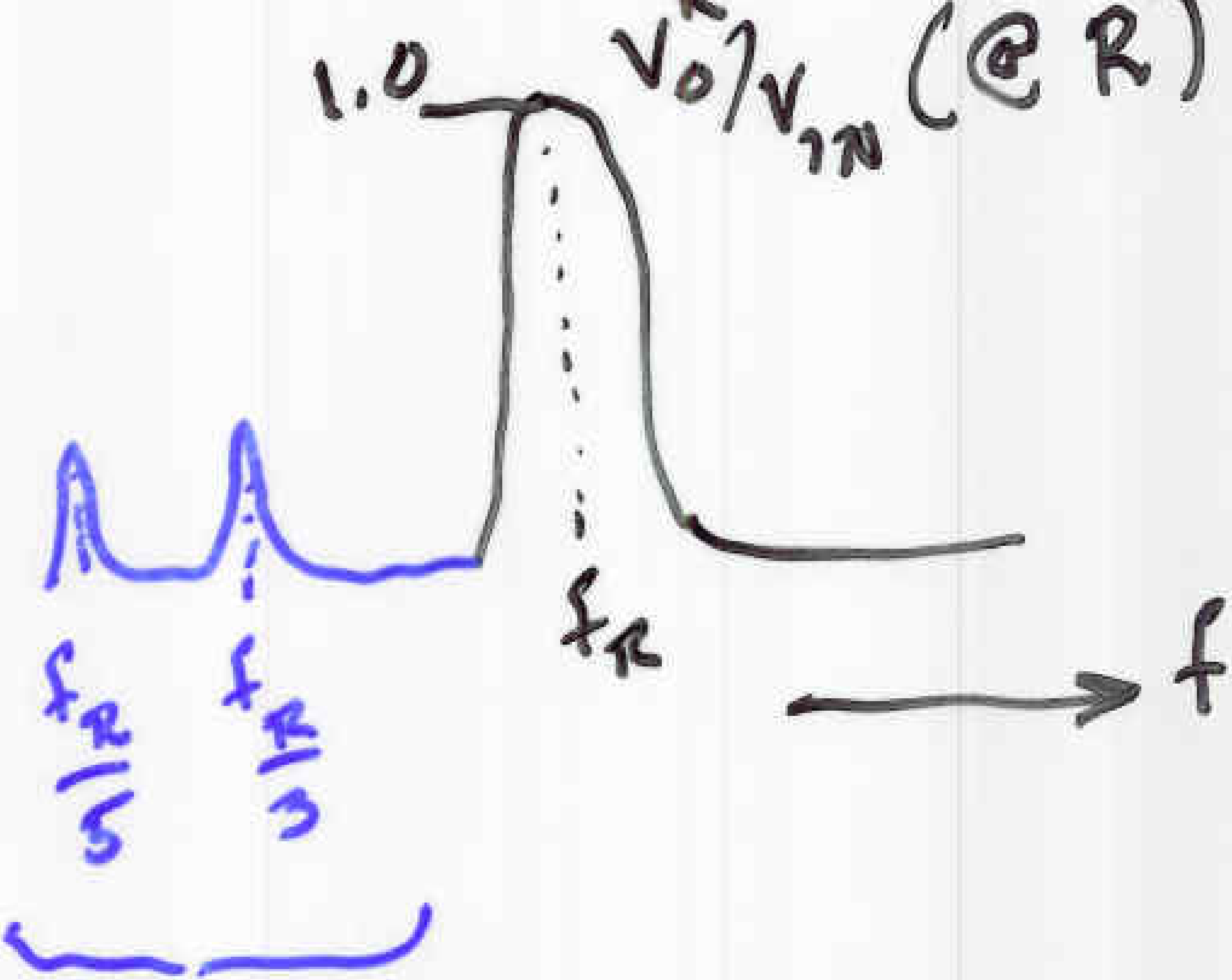
1. GREATER COMPLEXITY — Whoa!
2. HIGHER PEAK CURRENTS ← Sw Stress QI
3. NEW TECHNOLOGY LEARNING CURVE

Fig. 4 - Resonant Converter Advantages

$f_{sw} = \frac{f_R}{n}$ / 1, 3, ...

□-wave excitation





unique to □-wave excitation

V_o/V_{IN} across C $\frac{V_o^c}{V_{IN}} = ?$