Analysis result: switch conversion ratio $\mu$

Characteristics of the half-wave ZCS resonant switch
Buck converter containing half-wave ZCS quasi-resonant switch

\[ M = \frac{1}{1-M} \]

Boost converter example

\[ V_{out} = \frac{1}{1-M} V_{in} \]
20.1.3 The full-wave ZCS quasi-resonant switch cell

Analysis: full-wave ZCS
Full-wave cell: switch conversion ratio $\mu$

\[ \text{conversion like } \frac{M}{P} \]

If $M_{\text{cell}} \approx P$, then $\mu \approx \frac{2P}{F}$

\[ \langle i_1 \rangle \approx \frac{1}{T} \int I_1(t) \, dt \]

\[ M \cdot \frac{\langle i_1 \rangle}{I_1} \approx \frac{1}{T_0} t_2 \]

If $t_2$ is exactly one full period of resonance $T_0$

\[ t_2 > \frac{1}{f_0} \]

\[ M \approx \frac{t_2}{f_0} \approx F \]

\[ \mu = M \]

20.2 Resonant switch topologies

Basic ZCS switch cell: ZCS - QRL

SPST switch SW:

- Voltage-bidirectional two-quadrant switch for half-wave cell
- Current-bidirectional two-quadrant switch for full-wave cell

Connection of resonant elements:

Can be connected in other ways that preserve high-frequency components of tank waveforms
Connection of tank capacitor

Connection of tank capacitor to two other points at ac ground.

This simply changes the dc component of tank capacitor voltage.

The ac high-frequency components of the tank waveforms are unchanged.

PWM switch cell topology: HF (ac) view
A test to determine the topology of a resonant switch network

Replace converter elements by their high-frequency equivalents:
- Independent voltage source \( V_g \): short circuit
- Filter capacitors: short circuits
- Filter inductors: open circuits

The resonant switch network remains.

If the converter contains a ZCS quasi-resonant switch, then the result of these operations is

\[
L_s \quad SW \quad \quad L_r \quad D_2 \quad C_f \quad v_2(t) \quad -
\]
ZCS-QR

Converter examples

Buck

Boost

Buck-Boost

Cuk

High-frequency view of the switch network

Basic switch implementation options:
Q: single-quadrant (transistor)
D: single-quadrant (diode)
Q: current-bidirectional (e.g., MOSFET)
D: current-bidirectional synchronous rectifier (e.g., MOSFET)

ZCS quasi-resonant switch:
- Tank inductor is in series with switch; hence SW switches at zero current.
- Tank capacitor is in parallel with diode $D_2$; hence $D_2$ switches at zero voltage.

Discussion
- Zero voltage switching of $D_2$ eliminates switching loss arising from $D_2$ stored charge.
- Zero current switching of SW: device $Q_1$ and $D_1$ output capacitances lead to switching loss. In full-wave case, stored charge of diode $D_1$ leads to switching loss.
- Peak transistor current is $(1 + J_s) V_g/R_o$, or more than twice the PWM value.