TSTE19 Power Electronics

Lecture 13

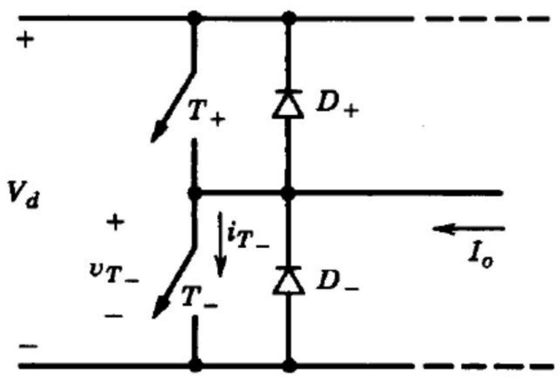
Tomas Jonsson
ISY/EKS

LINKÖPING UNIVERSITY

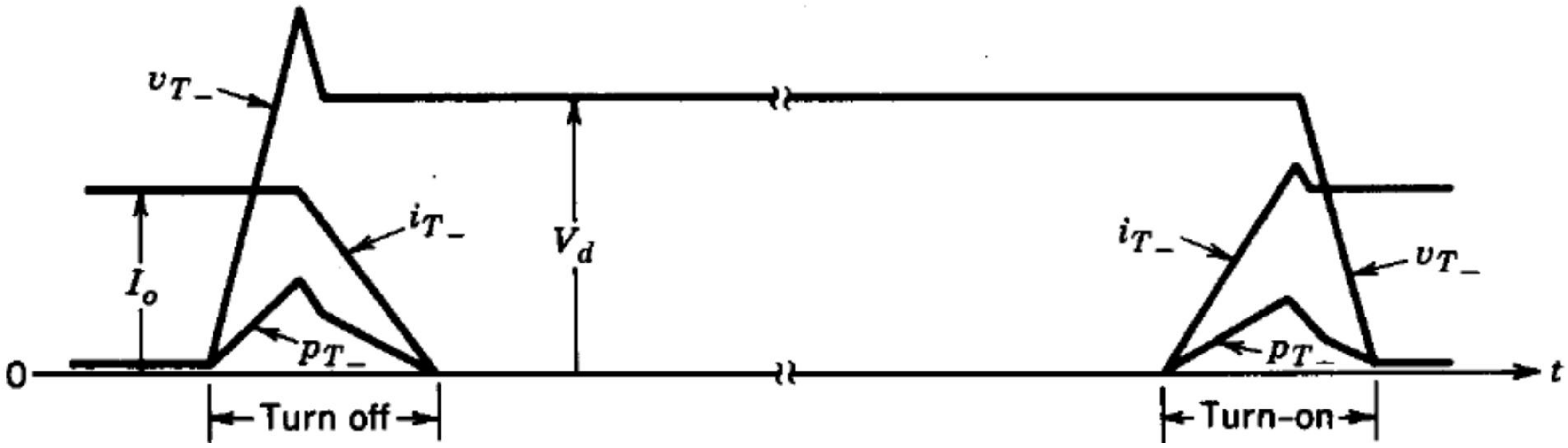
Outline

- Diagnostic Test
- Resonant load converters
- Exercises

Hard switching waveform

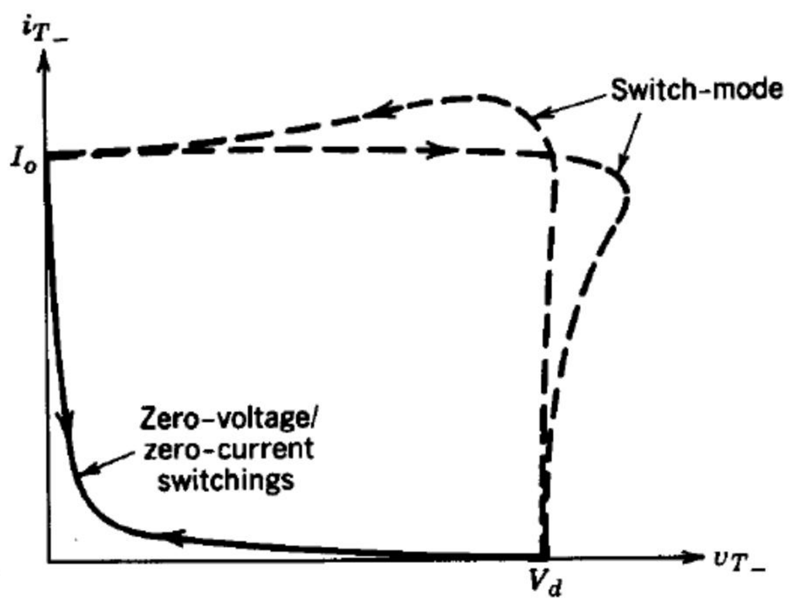


- Stray inductance gives voltage overshoot
- Stray capacitance gives current overshoot
- Parasitics limits di/dt and dv/dt
- $P_{T-} = v_{T-}\ i_{T-}$



Comparison hard vs soft switching

- Small power loss with zero-voltage/zero-current switching
  - Avoid dissipative snubber circuit



Classification of resonant converters

- Converter topology and switching strategies
  - <u>Load-resonant converters</u>
  - Resonant switch converters
  - Resonant dc link converters
  - High frequency link integral half cycle converters

Load-resonant converter

- LC resonant circuit
  - Oscillating voltage and current applied to load
  - Switching done when V = 0 or I = 0
- Either serial or parallel resonant circuits
- Power flow controlled by resonant tank impedance
  - Impedance controlled by switching frequency vs resonant frequency
- Switching either on zero voltage or zero current

Undamped series-resonant circuit

- Initial conditions I_{L0} and V_{c0}
- Resonant frequency, ω_0
- Characteristic impedance, Z_0

$$L_r \frac{di_L}{dt} + v_c = V_d$$

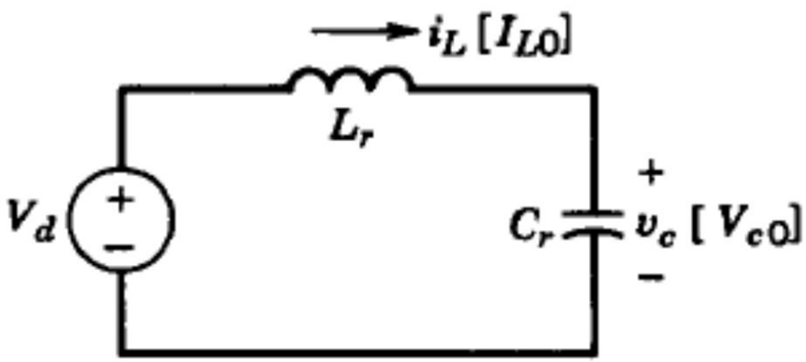
$$C_r \frac{dv_c}{dt} = i_L$$

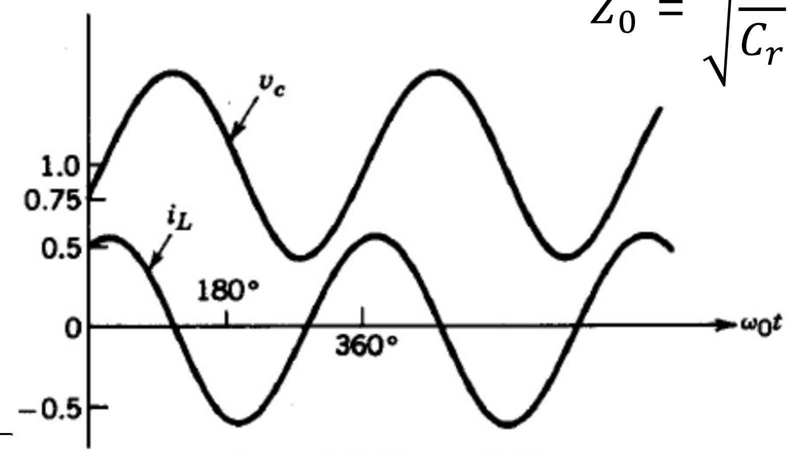
$$\omega_0 = 2\pi f_0 = \frac{1}{\sqrt{L_r C_r}}$$

$$i_L(t) = I_{L0}\cos\omega_0(t-t_0) + \frac{V_d - V_{c0}}{Z_0}\sin\omega_0(t-t_0)$$

$$v_c(t) = V_d - (V_d - V_{c0})\cos\omega_0(t-t_0) + Z_0 I_{L0}\sin\omega_0(t-t_0)$$

$$Z_0 = \sqrt{\frac{L_r}{C_r}}$$





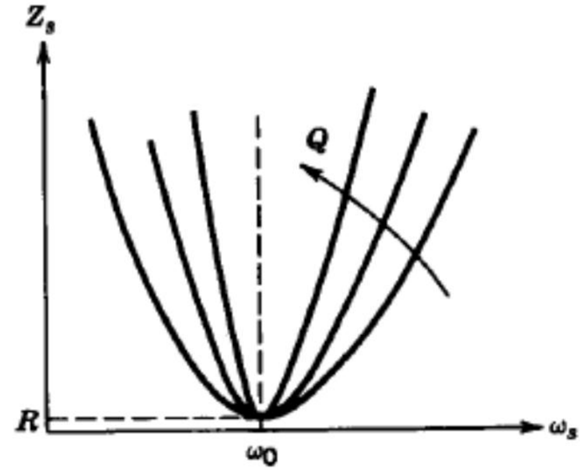
$I_{L0} = 0.5$, $V_{c0} = 0.75$

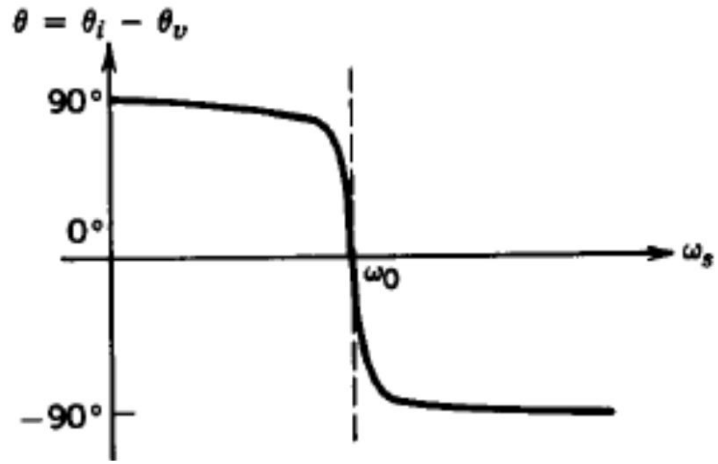
Impedance of series-resonant circuit

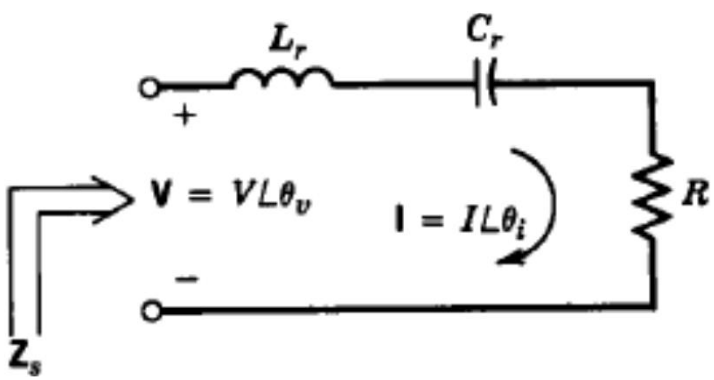
- Quality factor

$$Q = \frac{\omega_0 L_r}{R} = \frac{1}{\omega_0 C_r R} = \frac{Z_0}{R}$$

- Capacitive impedance at $\omega < \omega_0$
- Resistive at $\omega = \omega_0$
- Inductive impedance at $\omega > \omega_0$

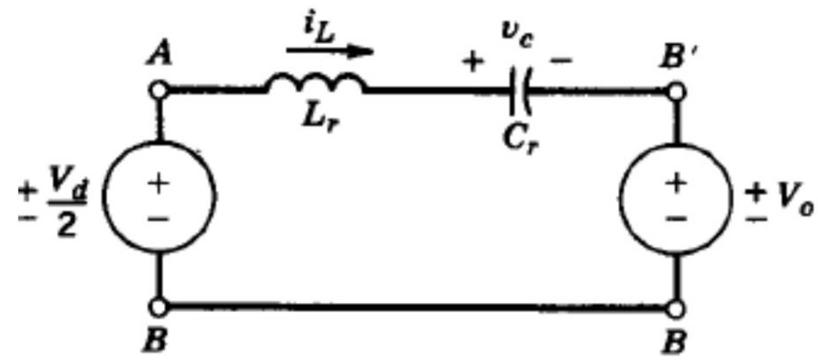


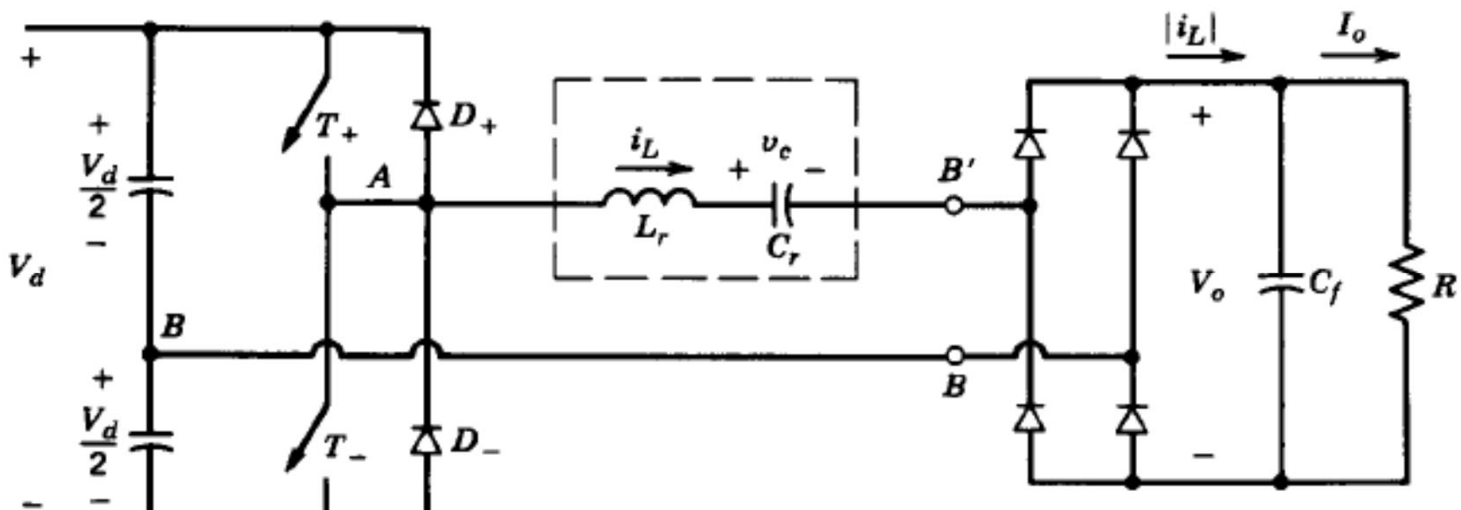




Series loaded resonant (SLR) dc-dc converter

- Transformer as L_r, could be used to give other output voltage and electrical isolation

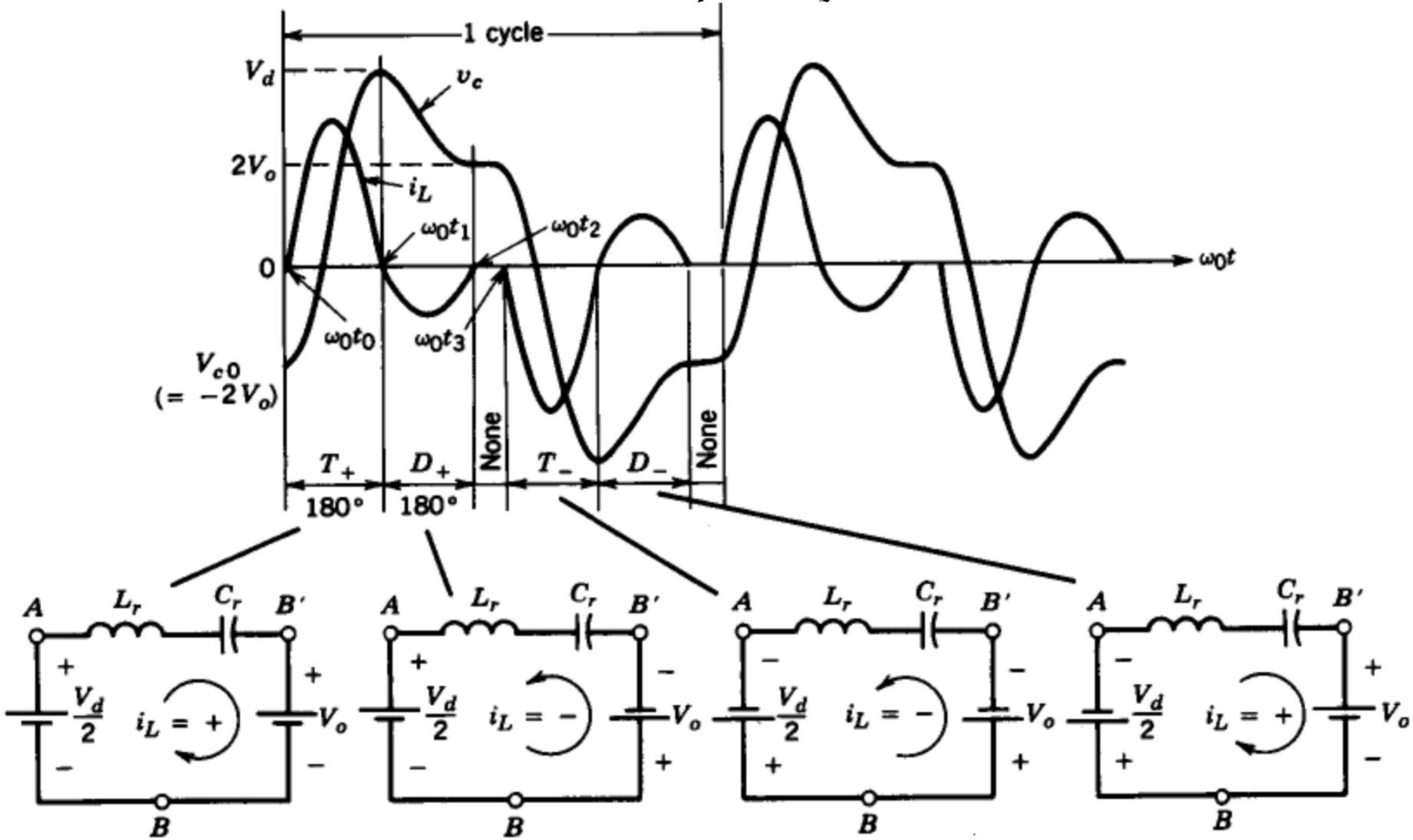




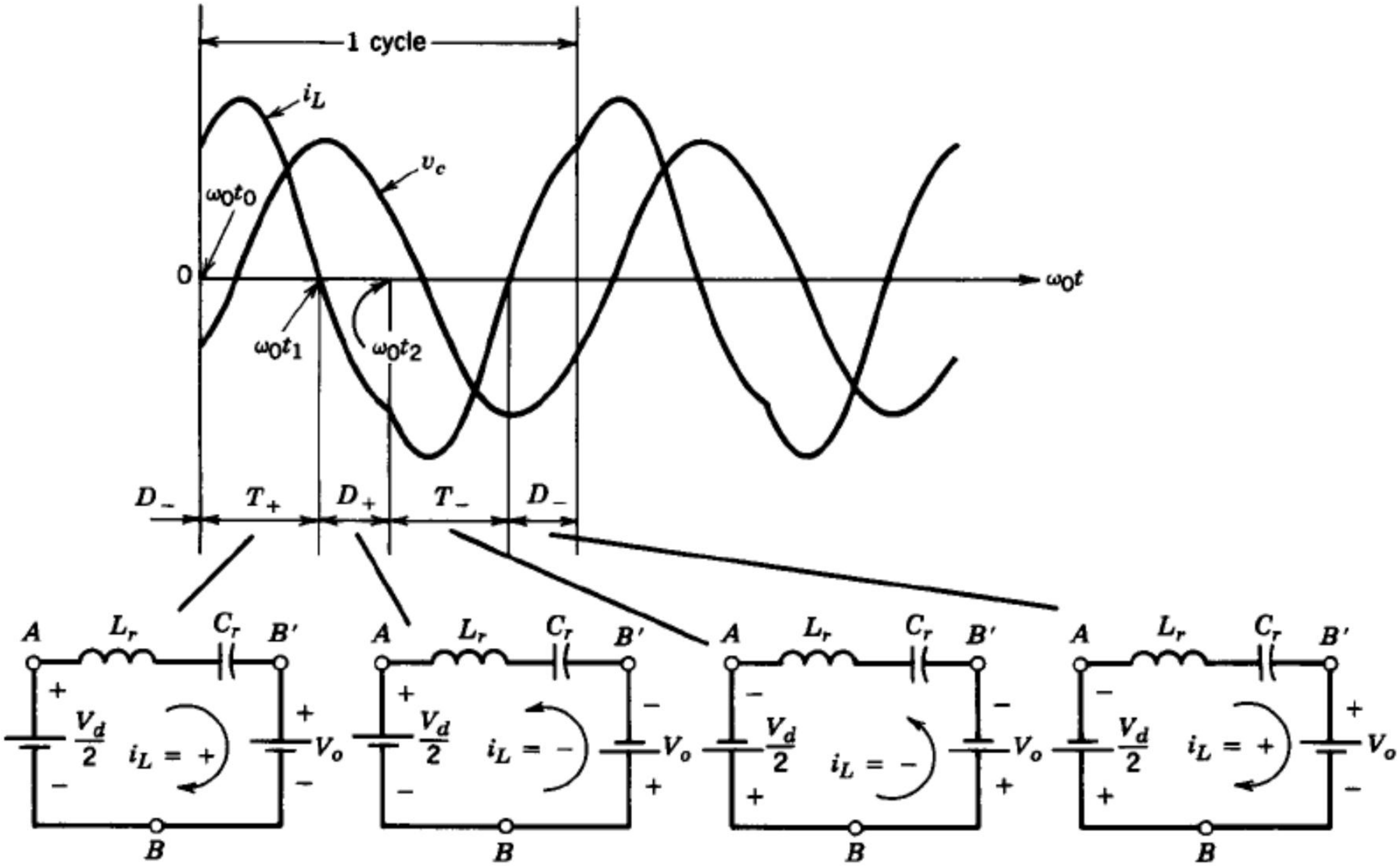
(a)

SLR converter waveforms $\omega < \omega_0/2$

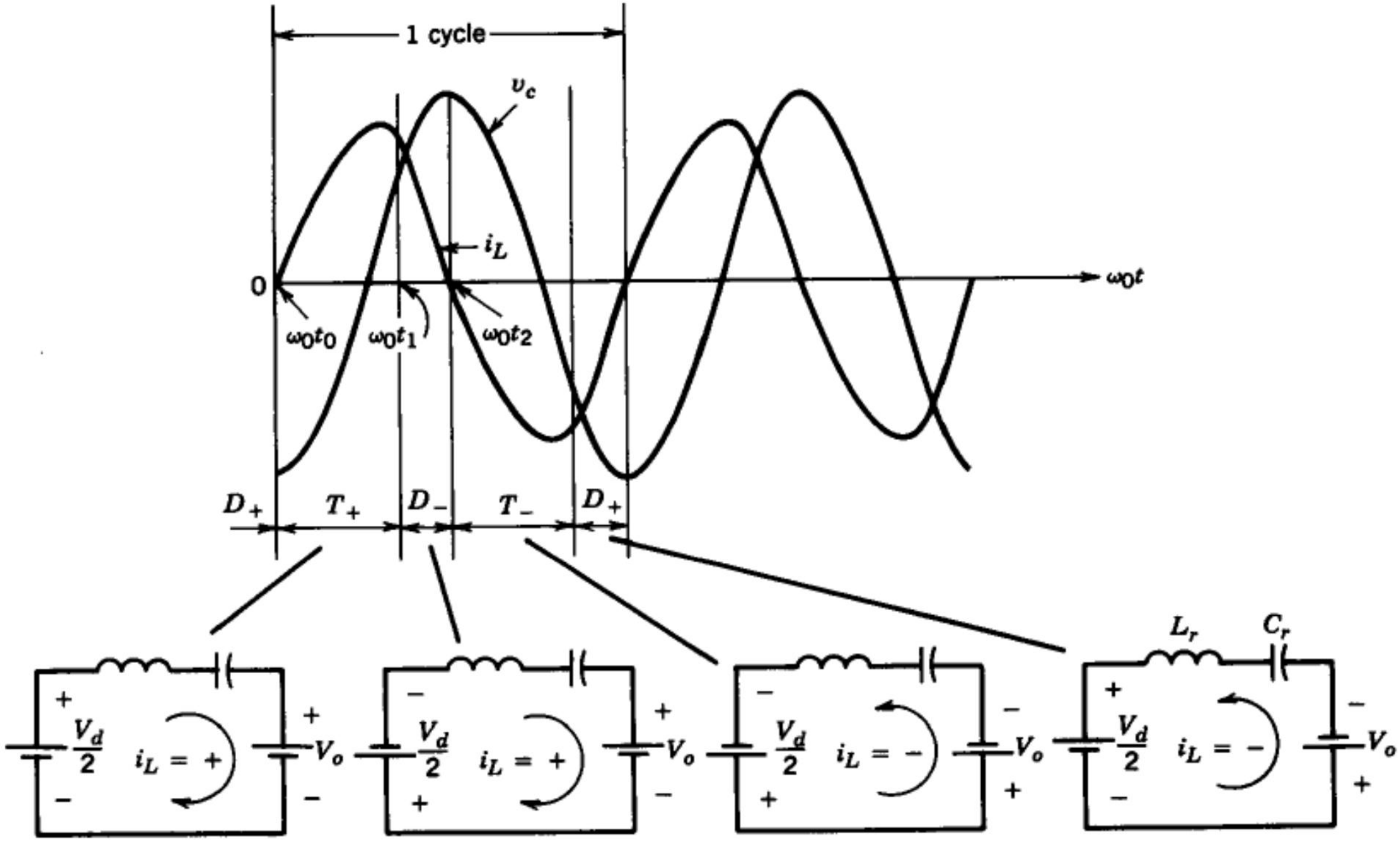
- Below half resonance frequency



SLR waveform $\omega_0/2 < \omega < \omega_0$

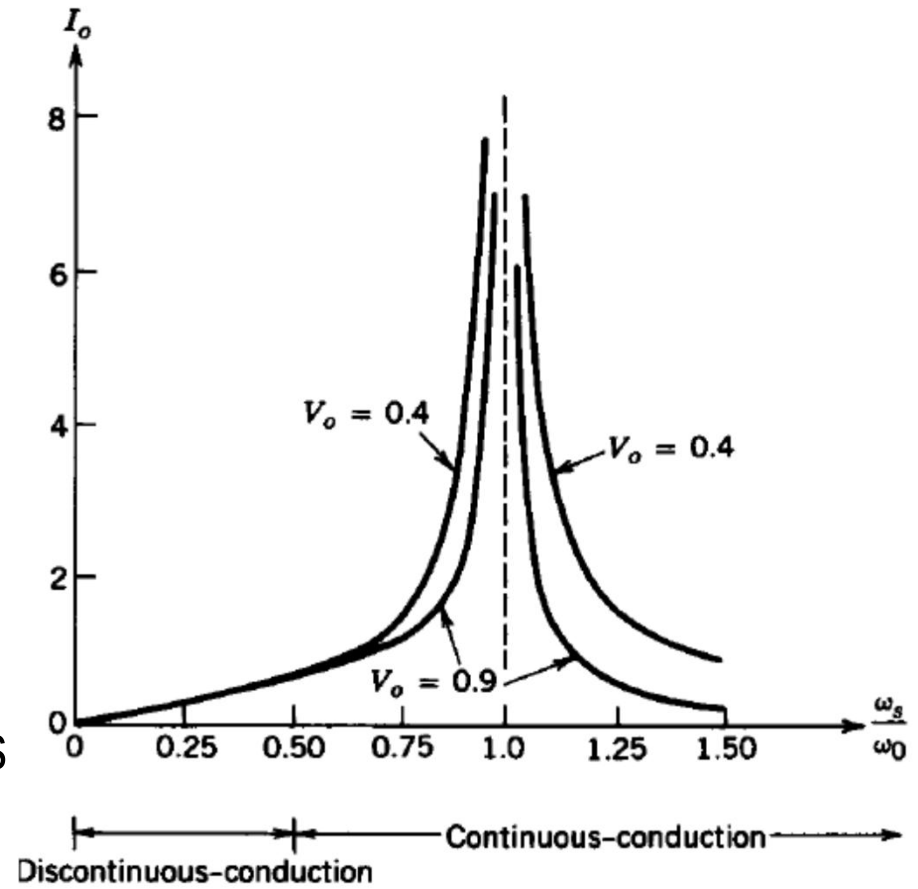


SLR waveform $\omega > \omega_0$



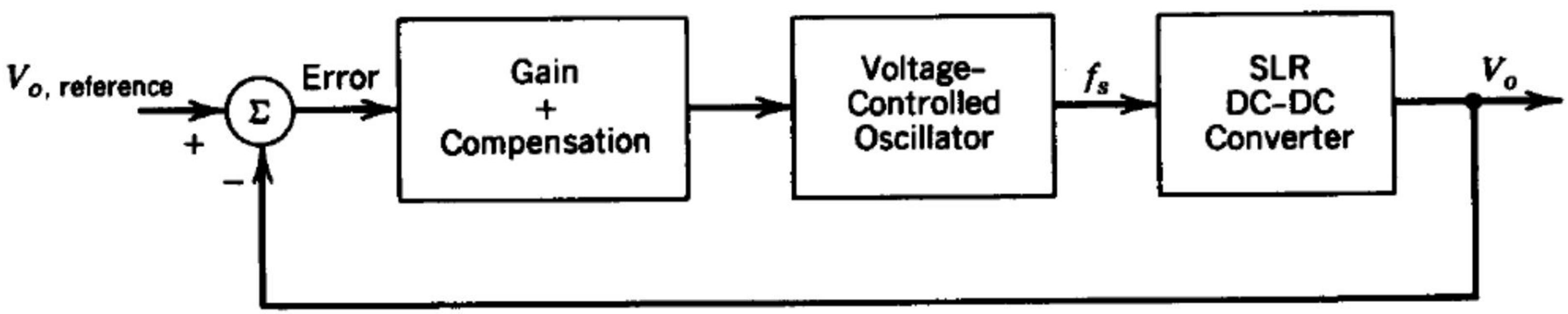
SLR Converter characteristics

- Plot for two different V_O values
  - Normalized values,
  $V_o = 1$ means $V_o = V_{base} = V_d/2$
  $I_o = 1$ means $I_o = I_{base} = V_{base}/Z_0$
- Current source at low ω_s
  - I_O output current
  - Inherent overload protection at low ω_s
- Control of power using the switch frequency
- High voltage and current peaks

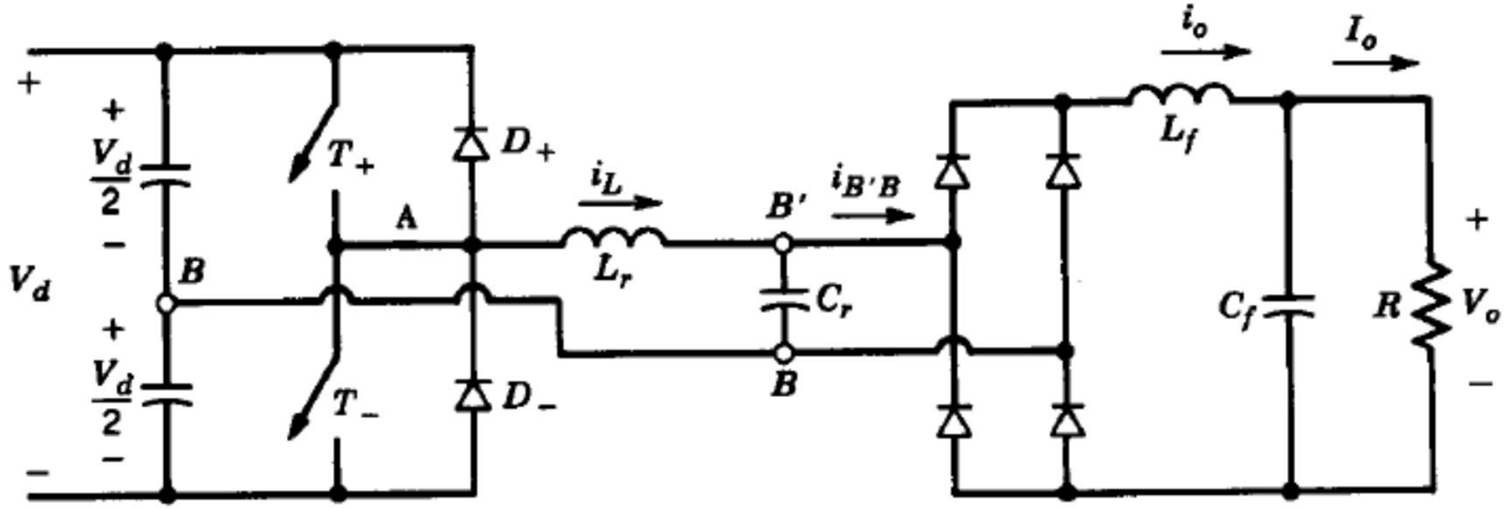


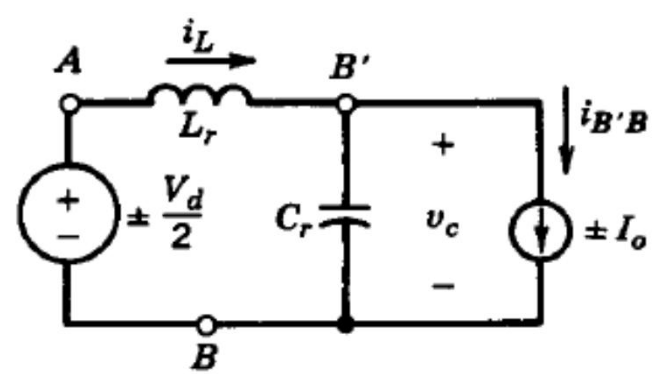
SLR Converter control

- Switch frequency controls output voltage
- EMI filter complicated due to varying f_s
- Modified control possible for full-bridge
  - Frequency not separately controlled, restricts load
- May use structure for other applications without rectifier
  - Induction heating (stove)



Parallel loaded resonant (PLR) converter





Comparison SLR vs PLR

- PLR behave as a voltage source
  - Better suited for multiple outlets
- PLR missing inherent short-circuit protection capability
- PLR converter can step up as well as step down
  - SLR only step down
  - Ignoring possible transformers
- PLR operates in many combinations of i_L and v_C states
  - SLR only have three modes

Lecture 13

Exercises

9-1

The SLR dc-dc converter of Fig. 9-lOa is operating in a discontinuous-conduction mode with $w_s < 0.5w_o$. In the waveforms of Fig. 9-11 (with t_o=0), the initial conditions in terms of normalized quantities are always as follows:

- $V_{c0} = -2V_o$ and $I_{Lo} = 0$.

Show that in terms of normalized quantities,

- $V_{c,peak} = 2$ and $I_{L,peak} = 1 + V_o$

9-2

Design an SLR dc-dc converter of Fig. 9-lOa with an isolation transformer of turns-ratio *n* : 1, where V_d = 155 V, and the operating frequency f_s = 100 kHz. The output is at 5 V and 20 A.

a) The foregoing converter is to operate in a discontinous-conduction mode with $w_s < 0.5 w_o$. The normalized output voltage V_o is chosen to be 0.9 and the normalized frequency to be 0.45. Using the curves of Fig. 9-15, obtain turns ratio *n*, L_r, and C_r.

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