# Resonant Converters

*Presented by*

*Xinbo Ruan*

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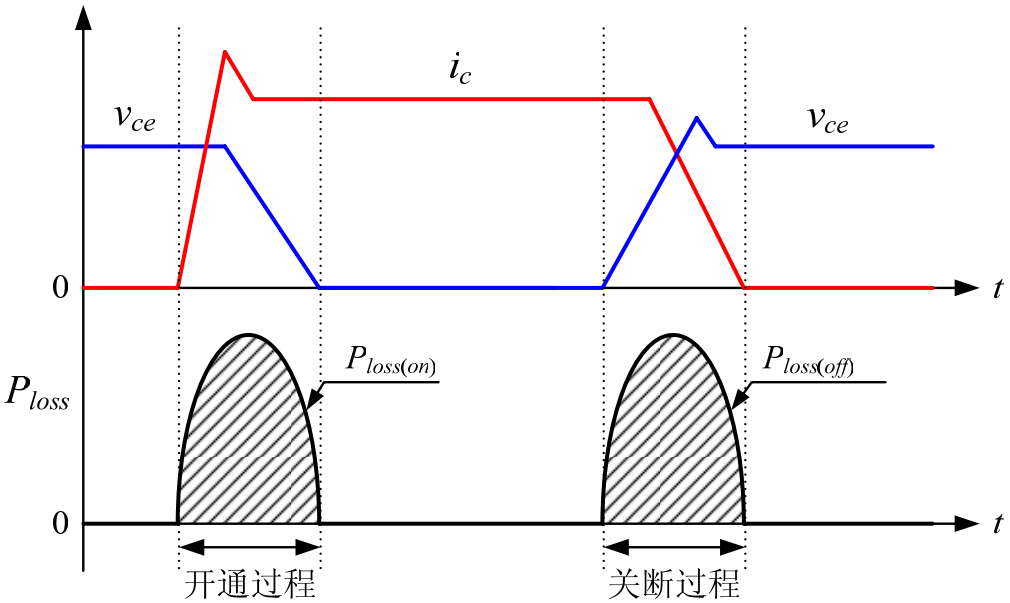
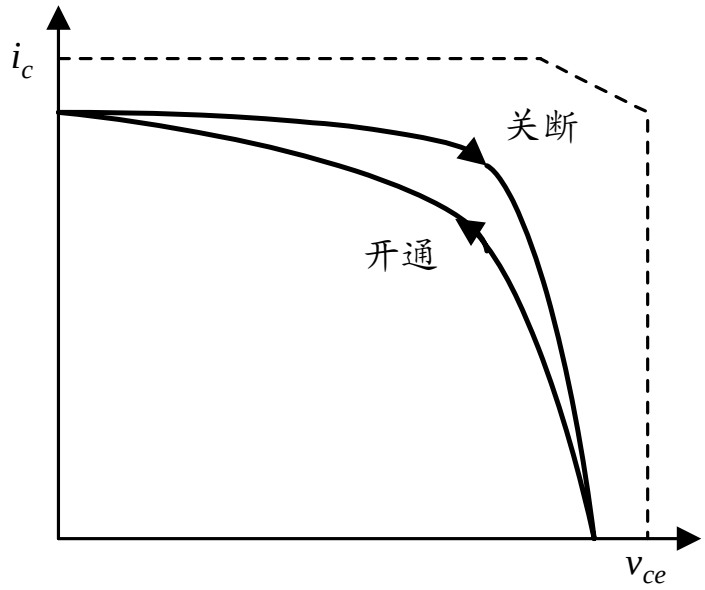
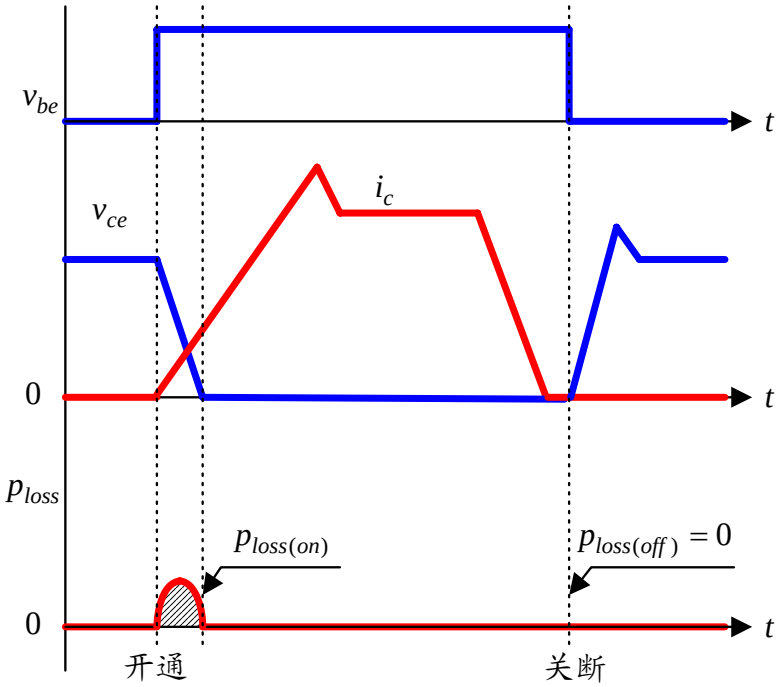
# Hard-Switching

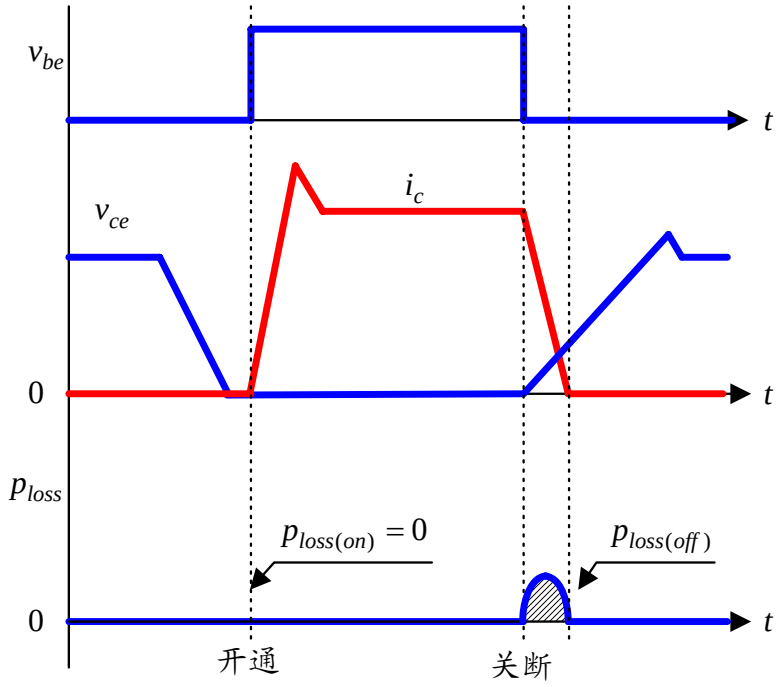


# Reduced Switching loss




Zero-Current-Switching




Zero-Voltage-Switching

# Method for reducing switching loss

减小开通损耗有以下几种方法:

① 在开关管开通时，使其电流保持在零，或者限制电流的上升率，从而减小电流与电压的交叠区，这就是所谓的零电流开通。

② 在开关管开通前，使其电压下降到零，这就是所谓的零电压开通。

③ 同时做到①和②，在这种情况下，开通损耗为零。

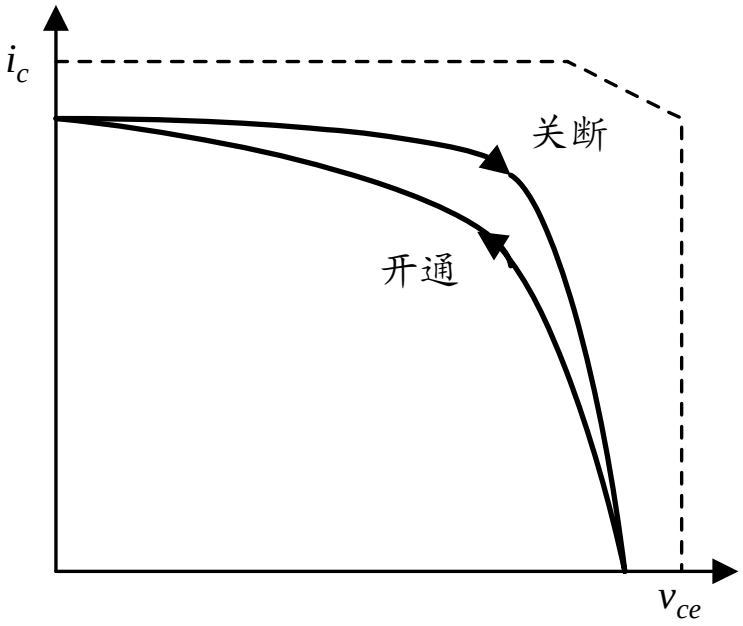
减小关断损耗有以下几种方法:

① 在开关管关断前，使其电流减小到零，这就是所谓的零电流关断。

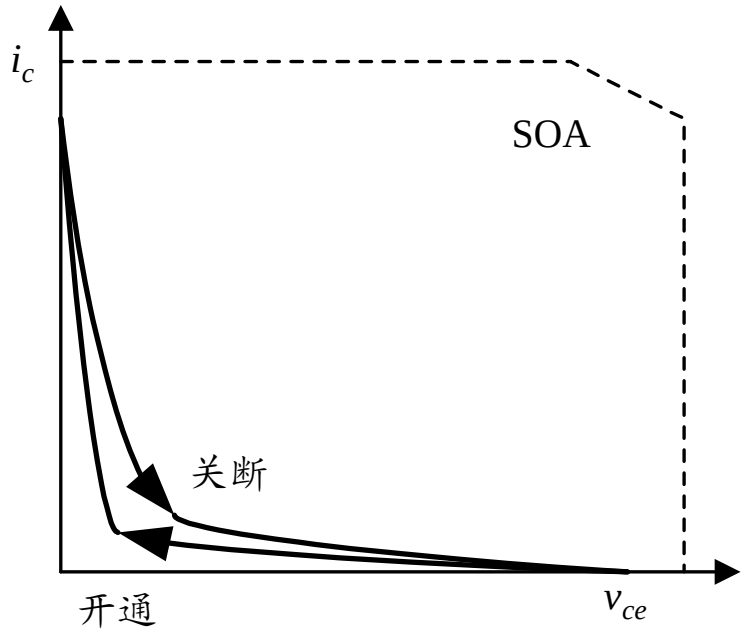
② 在开关管关断时，使其电压保持在零，或者限制电压的上升率，从而减小电流与电压的交叠区，这就是所谓的零电压关断。

③ 同时做到①和②，在这种情况下，关断损耗为零。

# Switching Trajectory of Soft-Switching

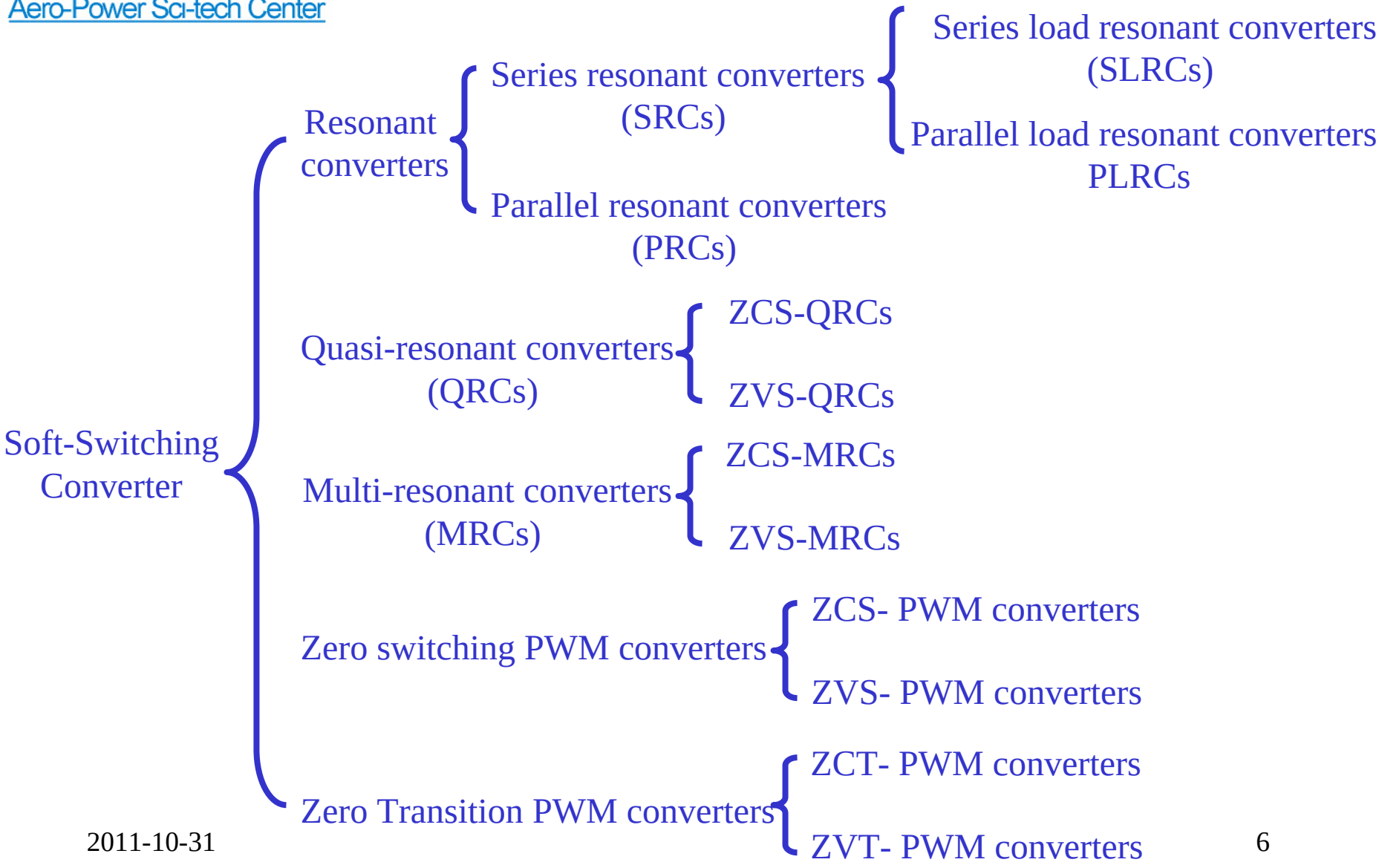



Hard-Switching

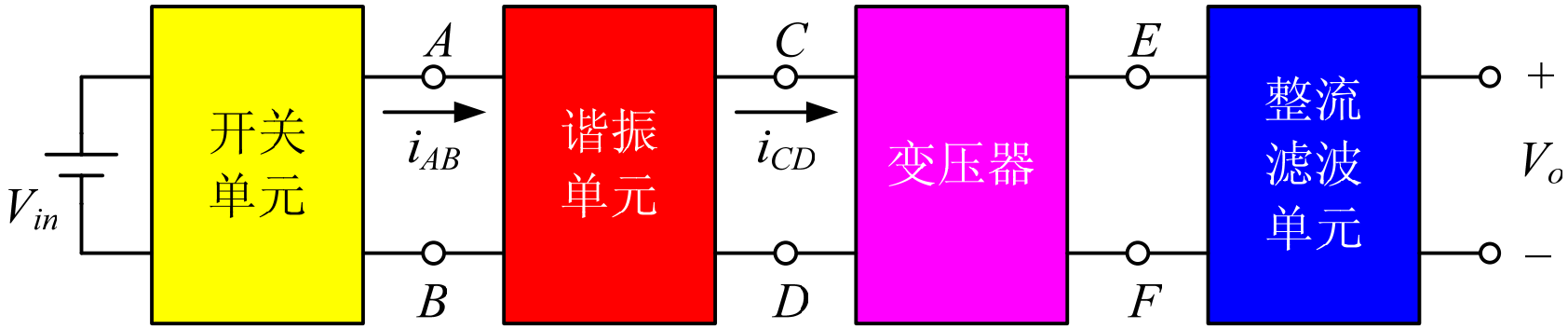


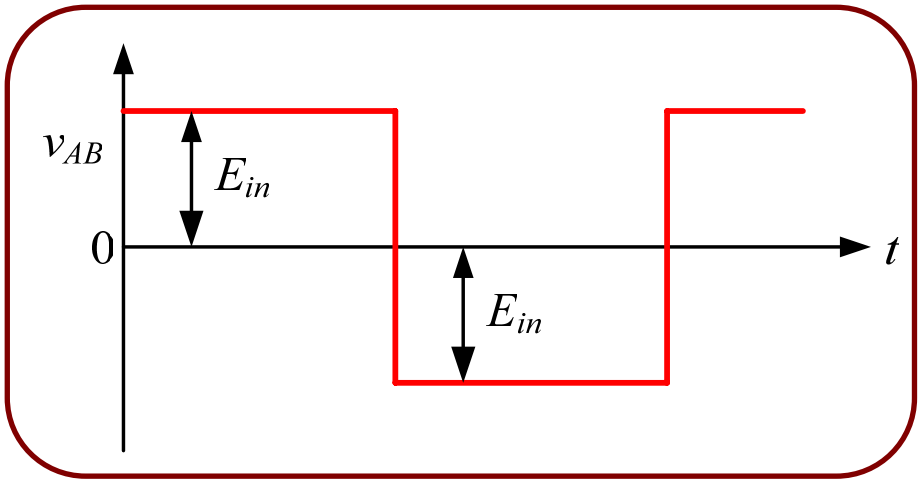

Soft-Switching

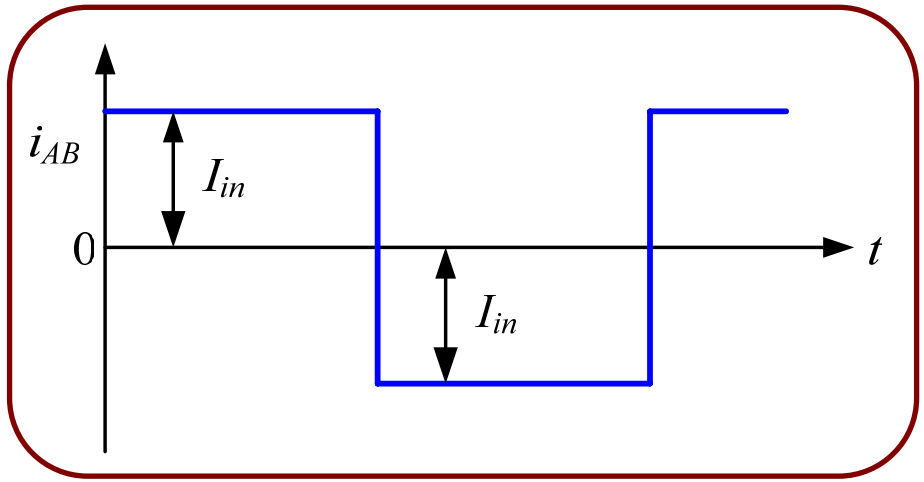
# Resonant Converters



# Unified Configuration of Resonant Converters



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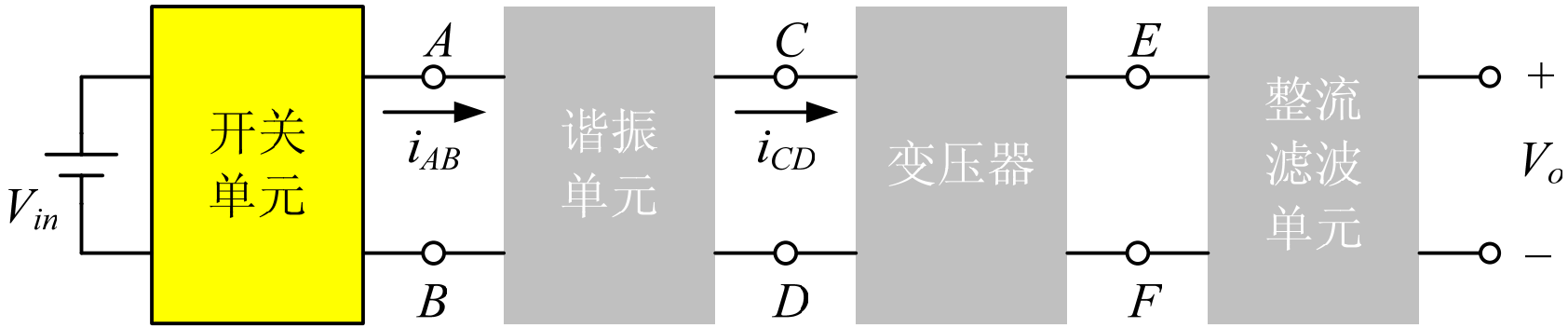
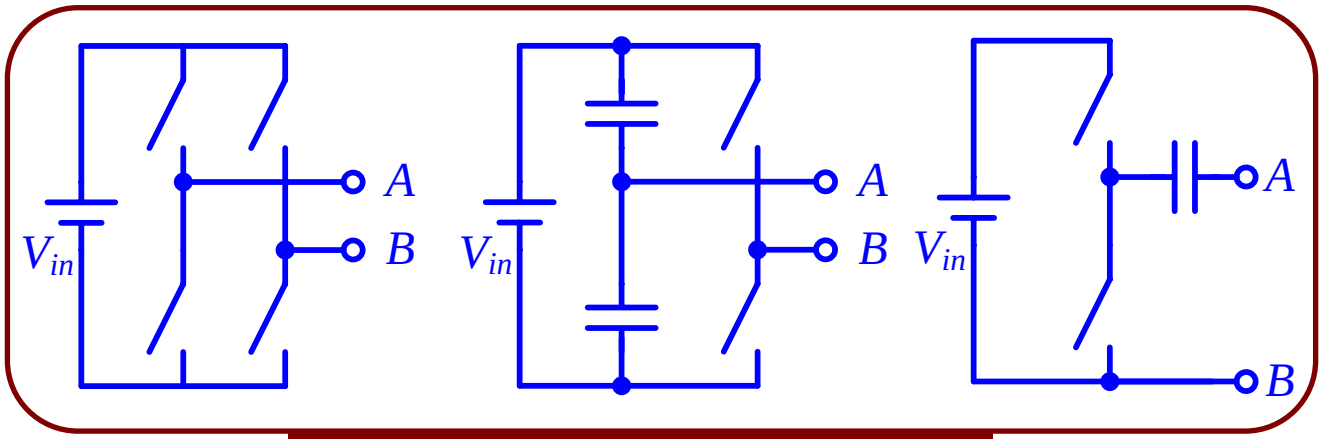
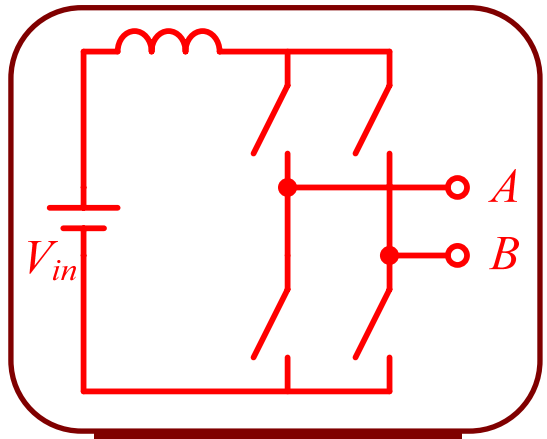
# Switching Cell



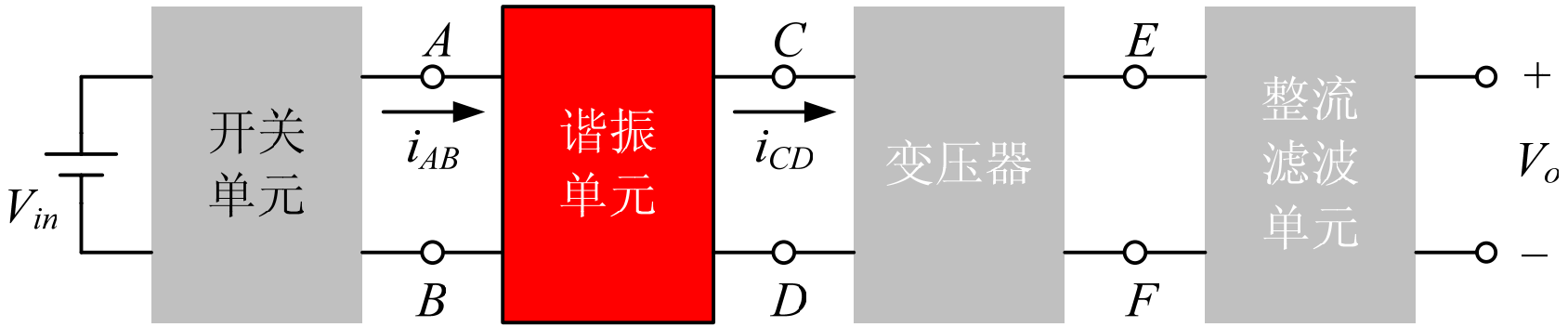



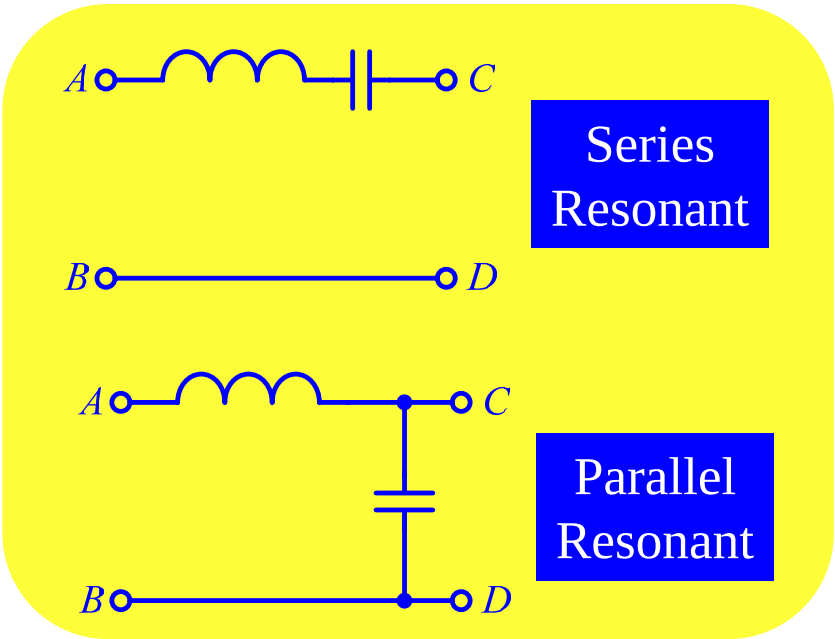

Voltage-Source Switching Cell

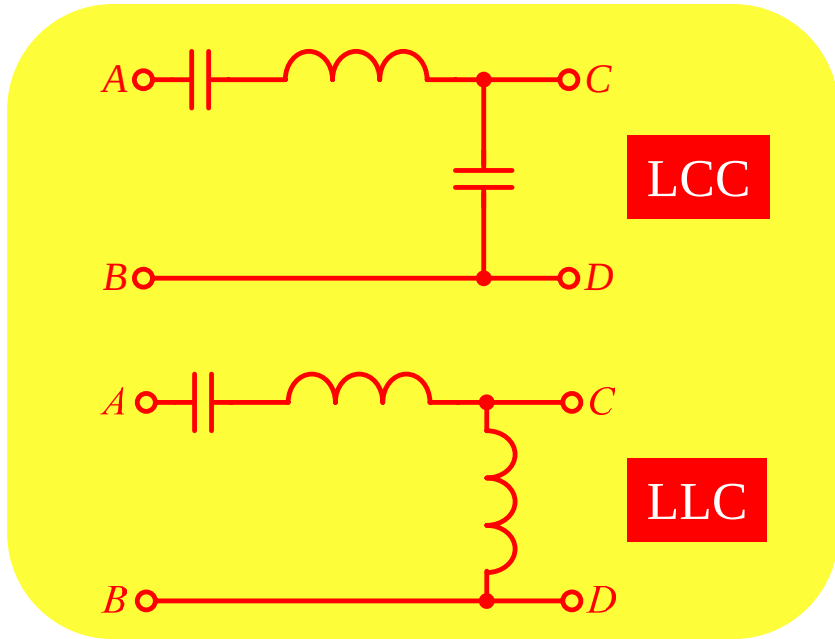



Current-Source Switching Cell

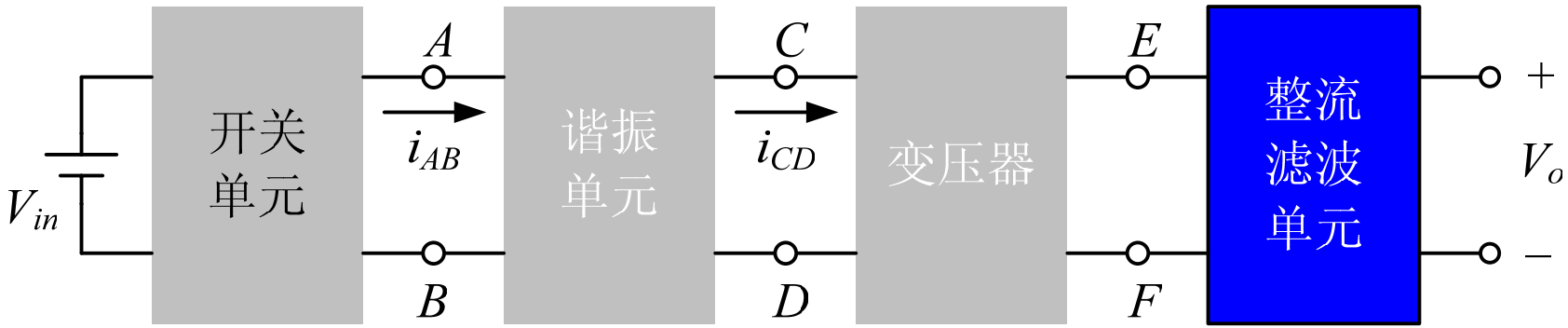
# Resonant Cell

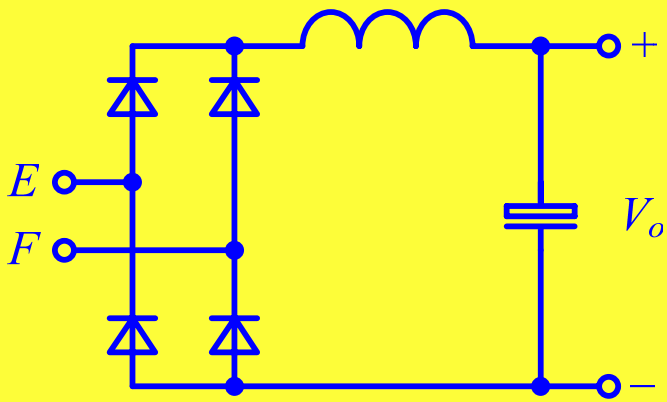


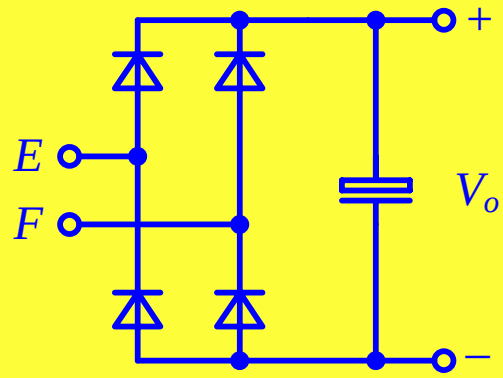



# Rectifier and Filter



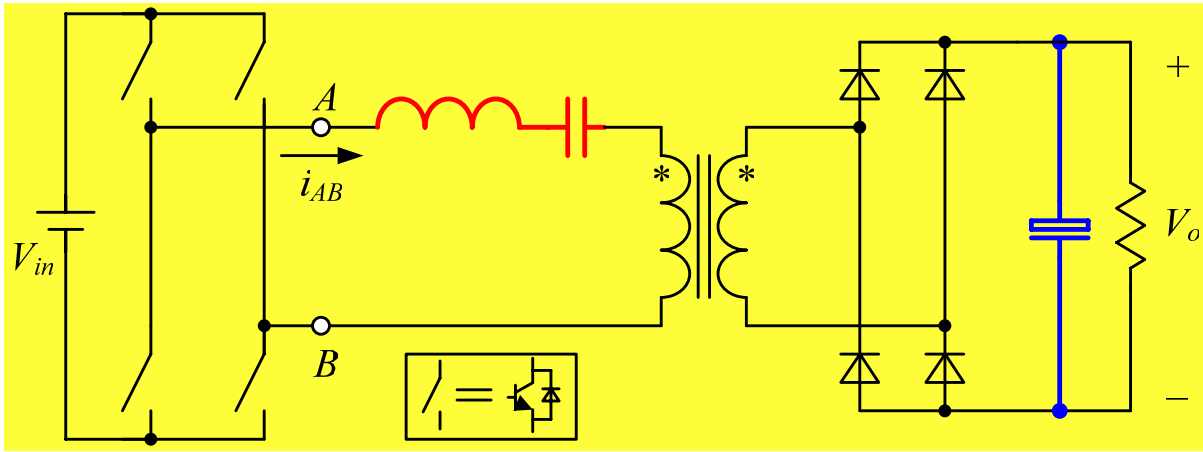




*LC* filter

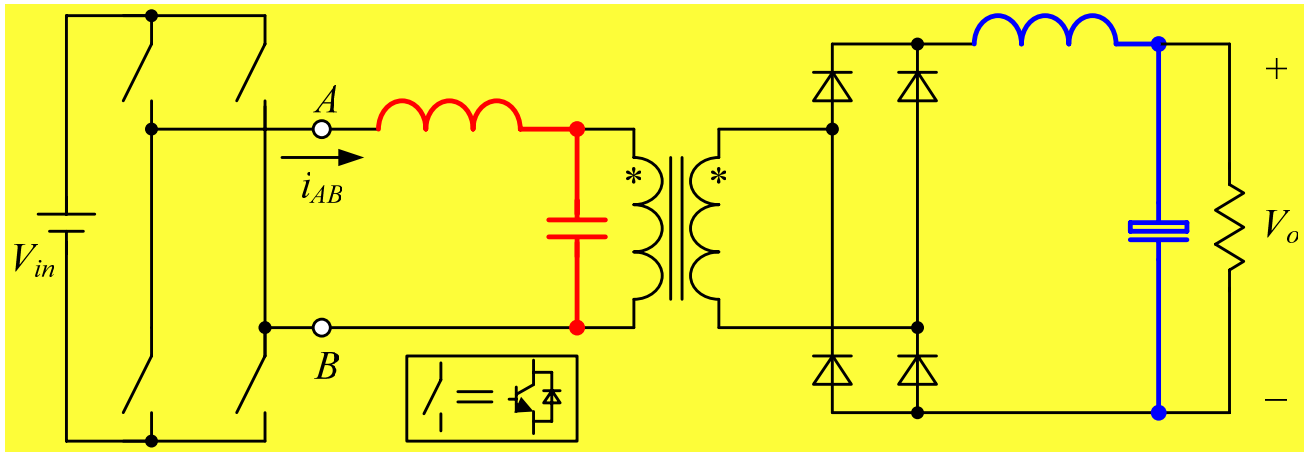



*C* filter

# Basic Resonant Converters: Two resonant components

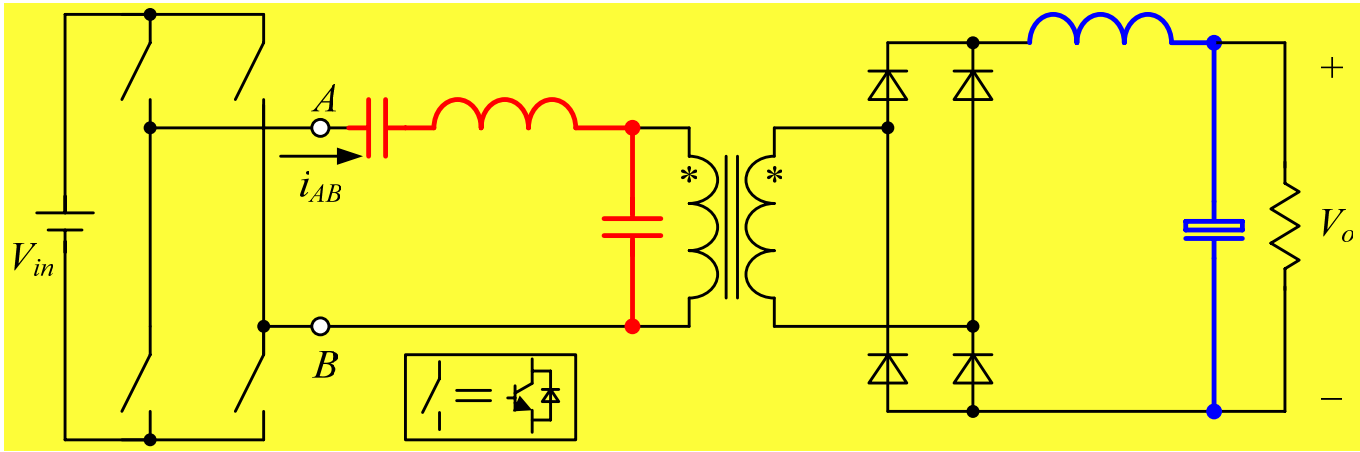



Series Resonant Converter

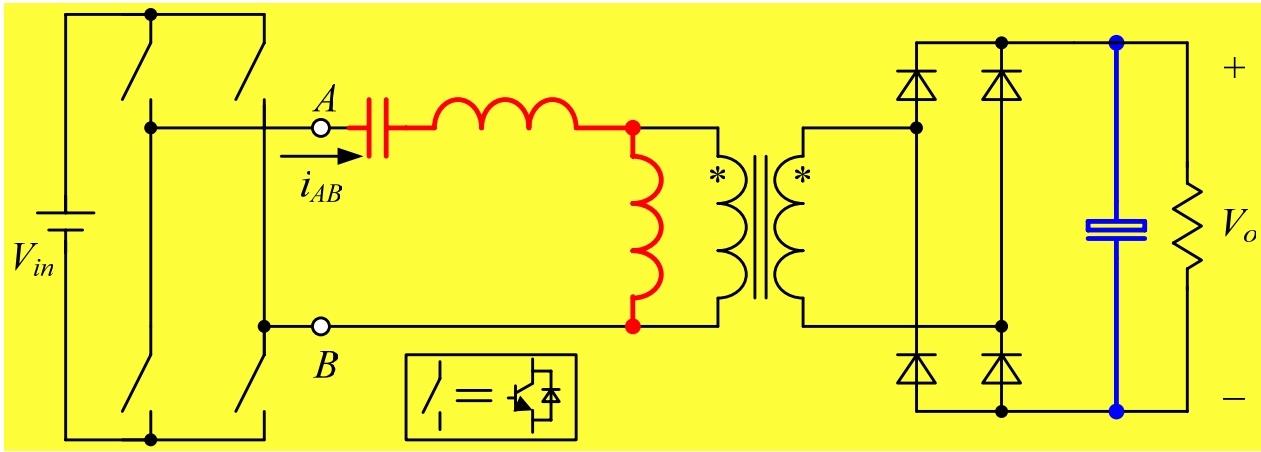



Parallel Resonant Converter

# Basic Resonant Converters: Three resonant components

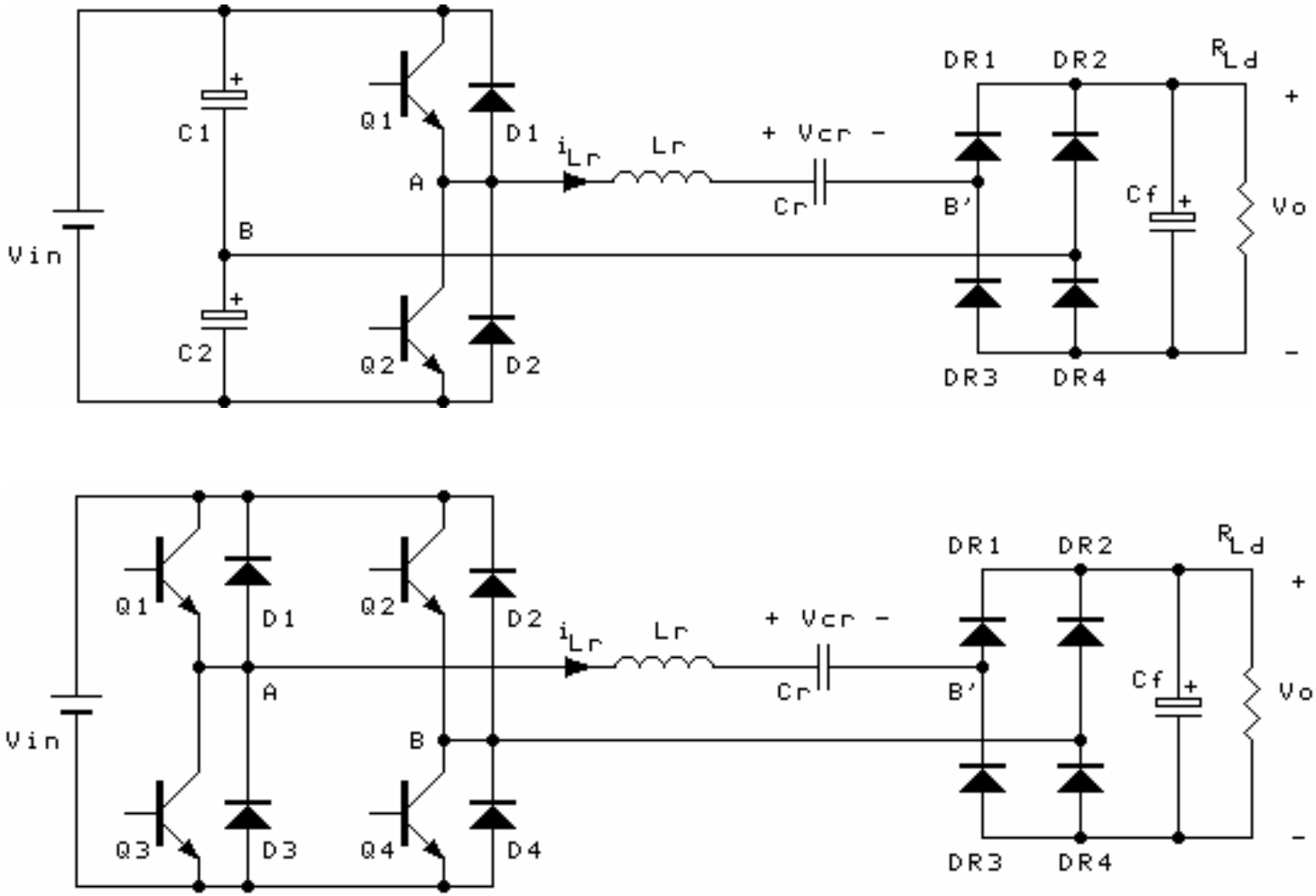



LCC Resonant Converter




LLC Resonant Converter

# Series Load Series Resonant Converters



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# Three kinds of operation modes

-Discontinuous Current Mode ($f_s < f_r/2$)

-Continuous Current Mode ( $f_r/2 < f_s < f_r$)

-Continuous Current Mode ($f_s > f_r$)

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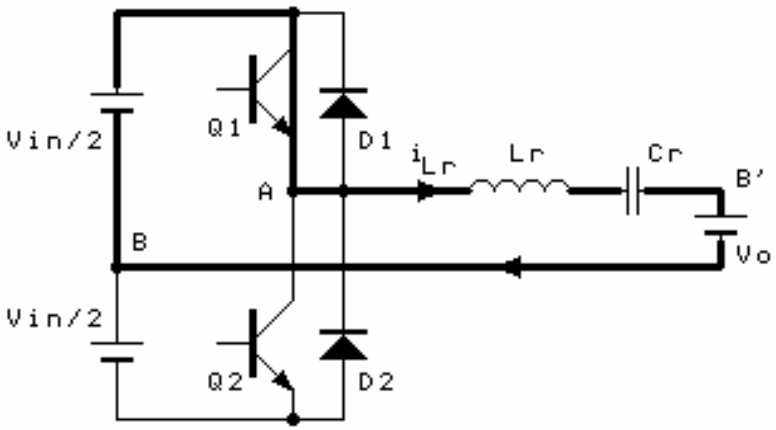
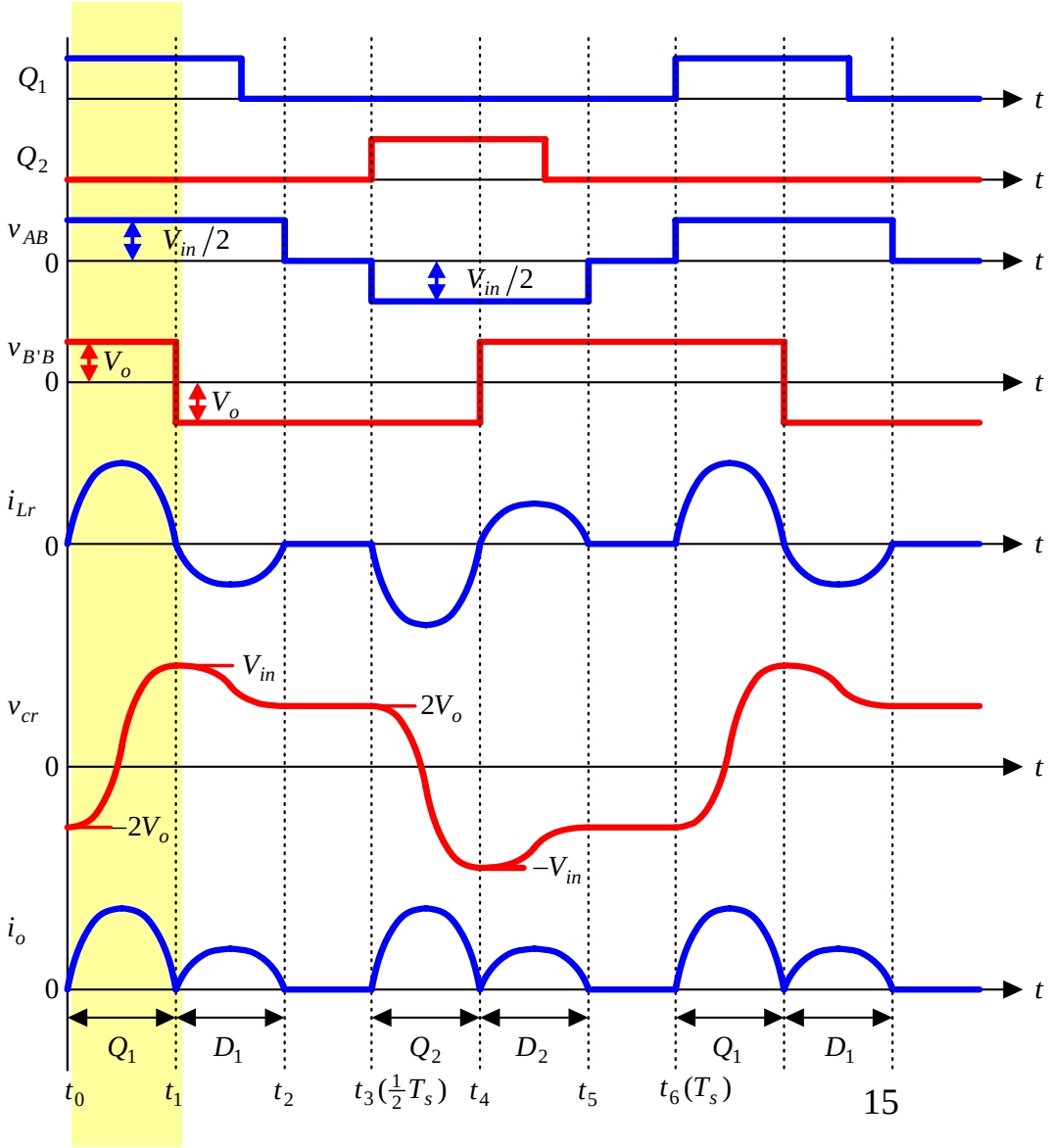
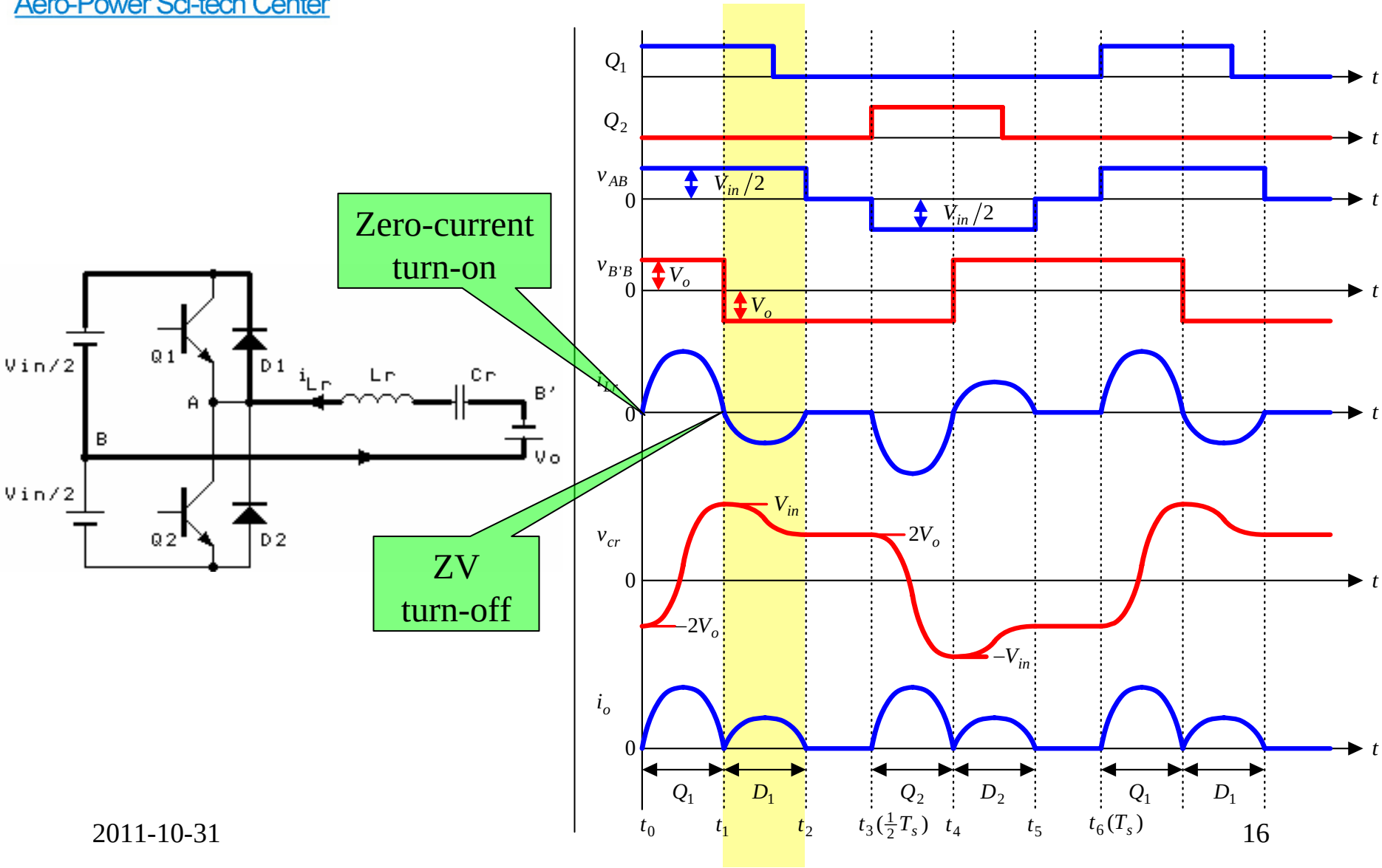
# DCM ($f_s < f_r/2$): $[t_0, t_1]$



# DCM ($f_s < f_r/2$) : [$t_1$ , $t_2$]



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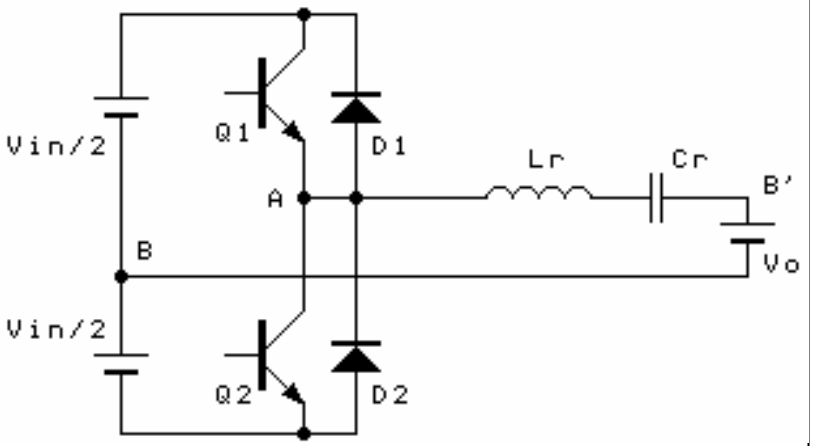
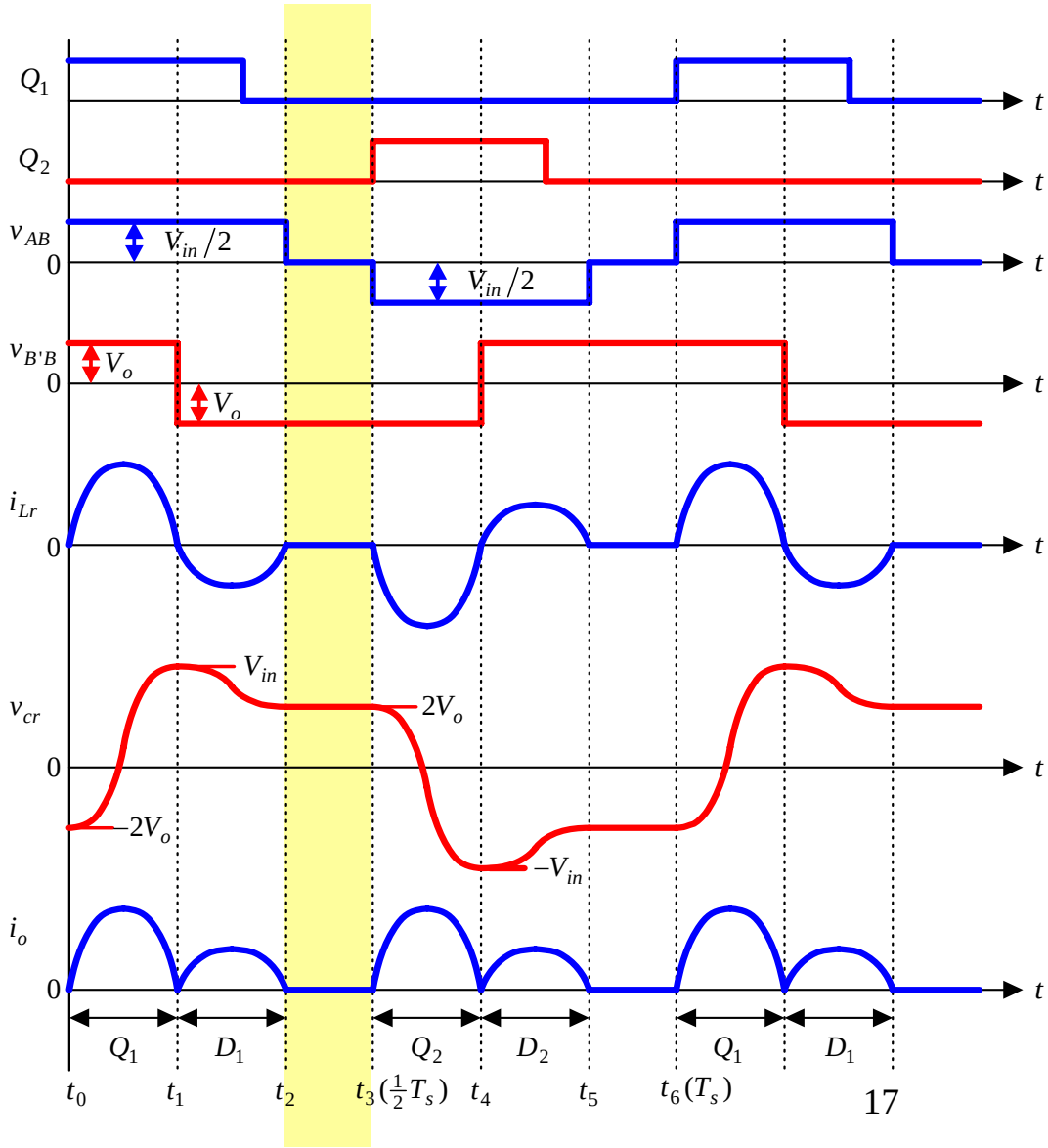
# DCM ($f_s < f_r/2$) : [$t_1$ , $t_2$]



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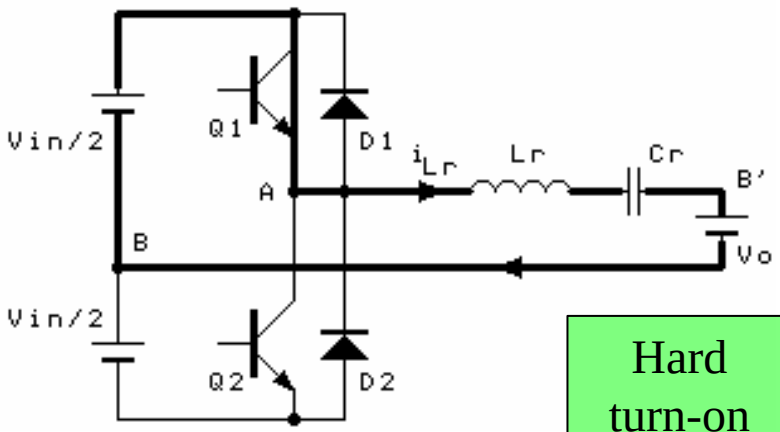
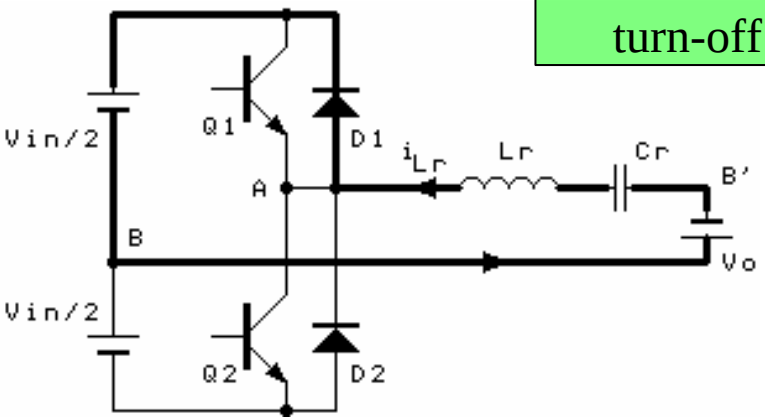
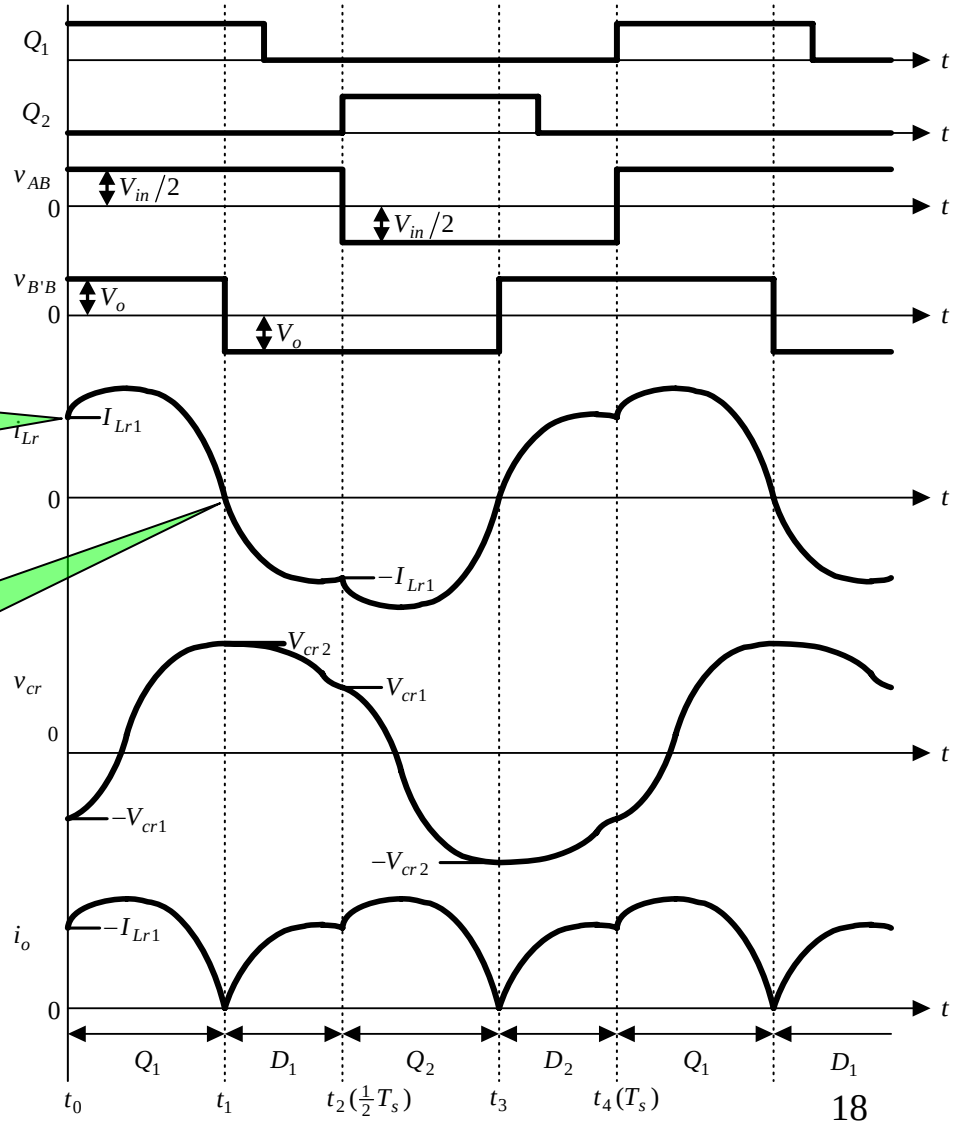
# Continuous Current Mode ( $f_r/2 < f_s < f_r$)




Hard turn-on

Zero-Voltage turn-off



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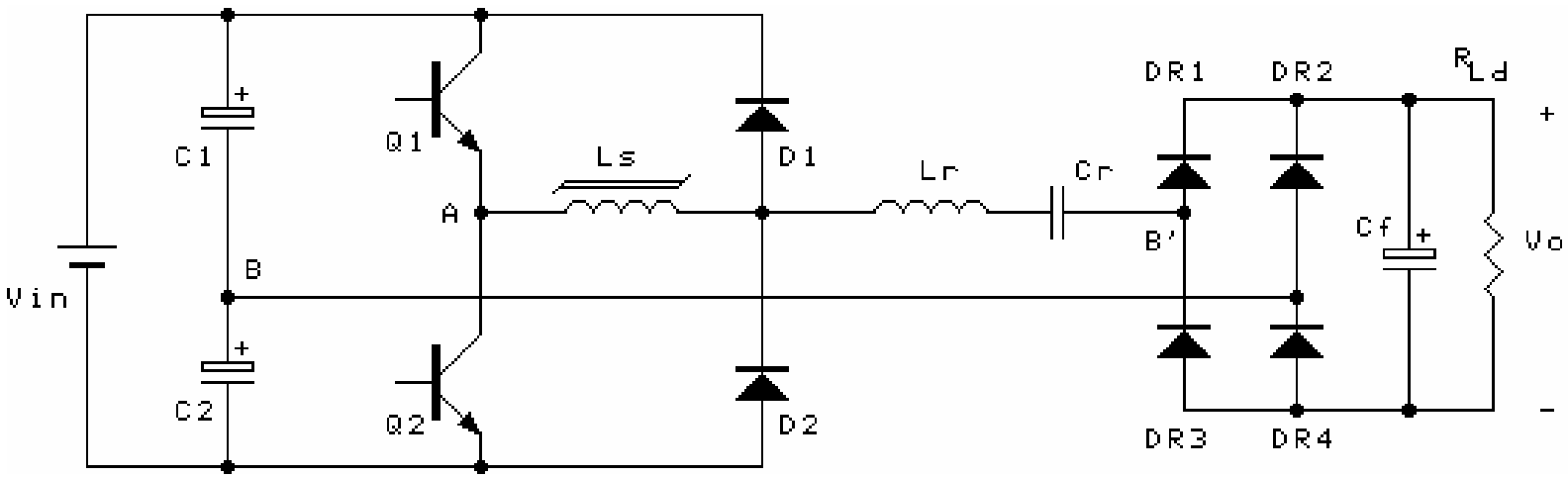
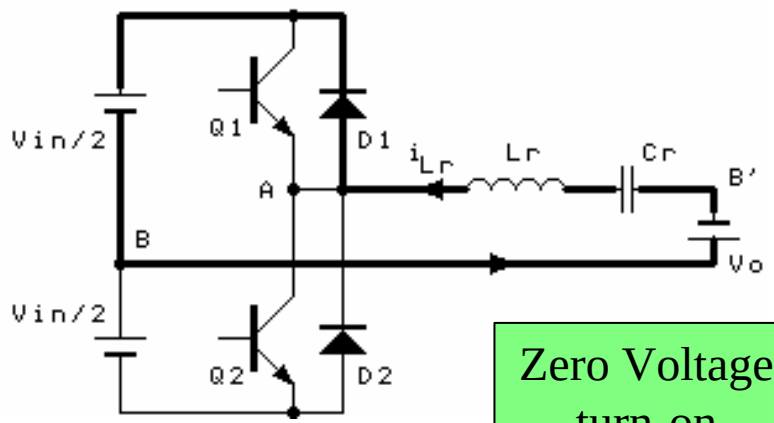
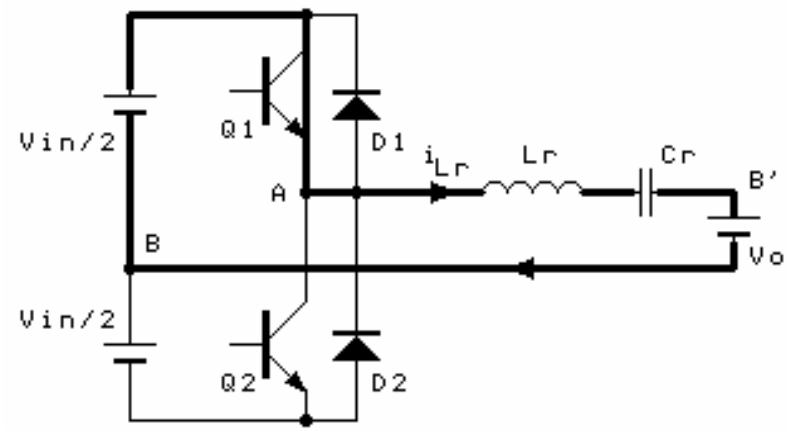
# Continuous Current Mode ( $f_r/2 < f_s < f_r$)



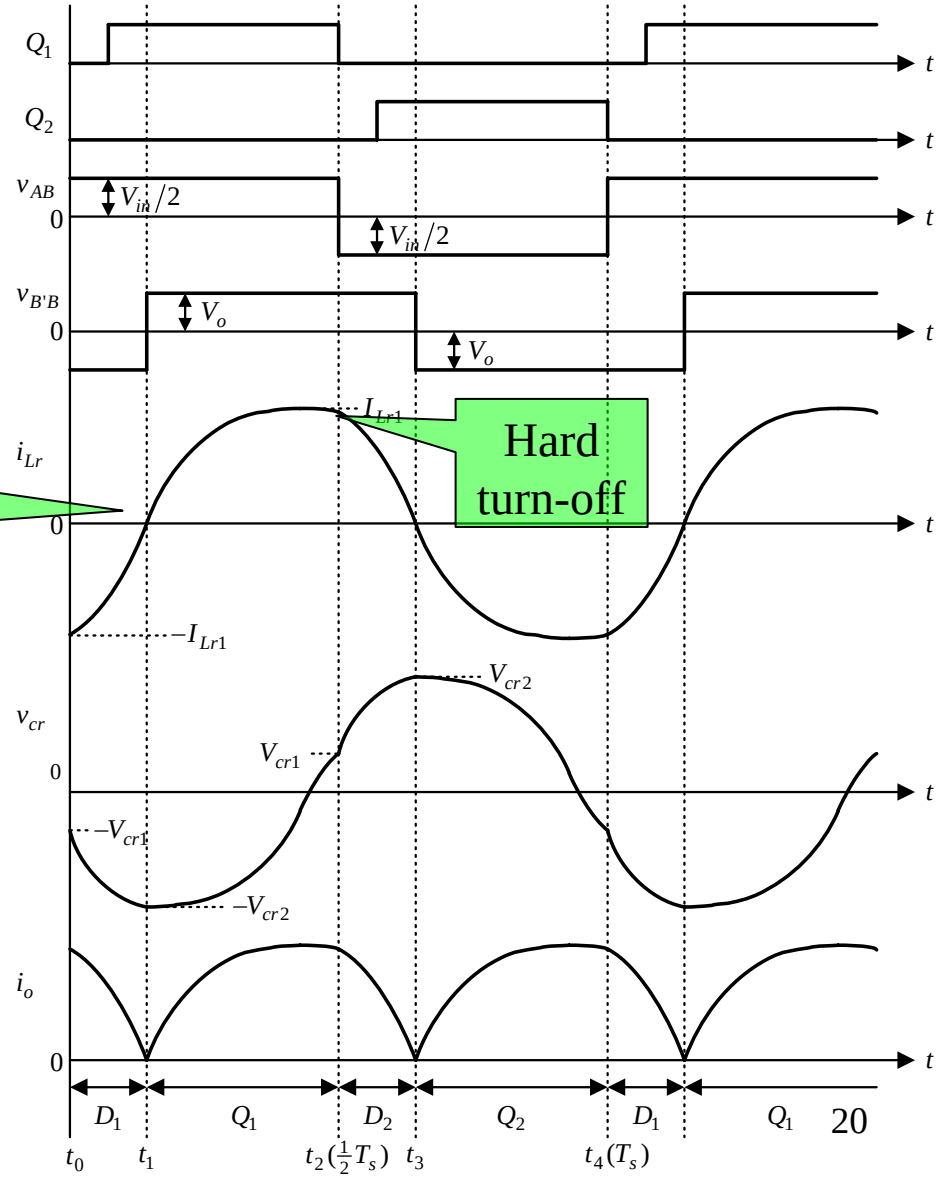
# Continuous Current Mode ($f_s > f_r$)




Zero Voltage turn-on

Hard turn-off



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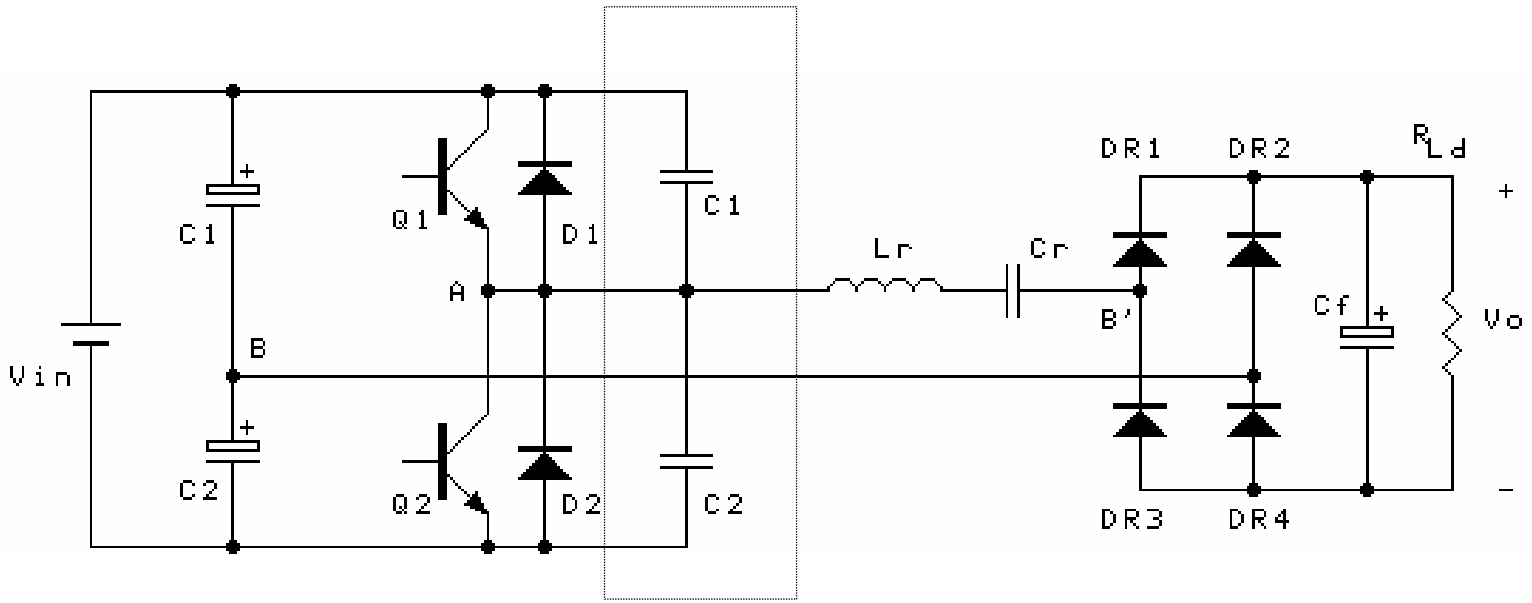
# Continuous Current Mode ($f_s > f_r$)



# Output Characteristics

$$V_{base} = \frac{1}{2} V_{in}$$

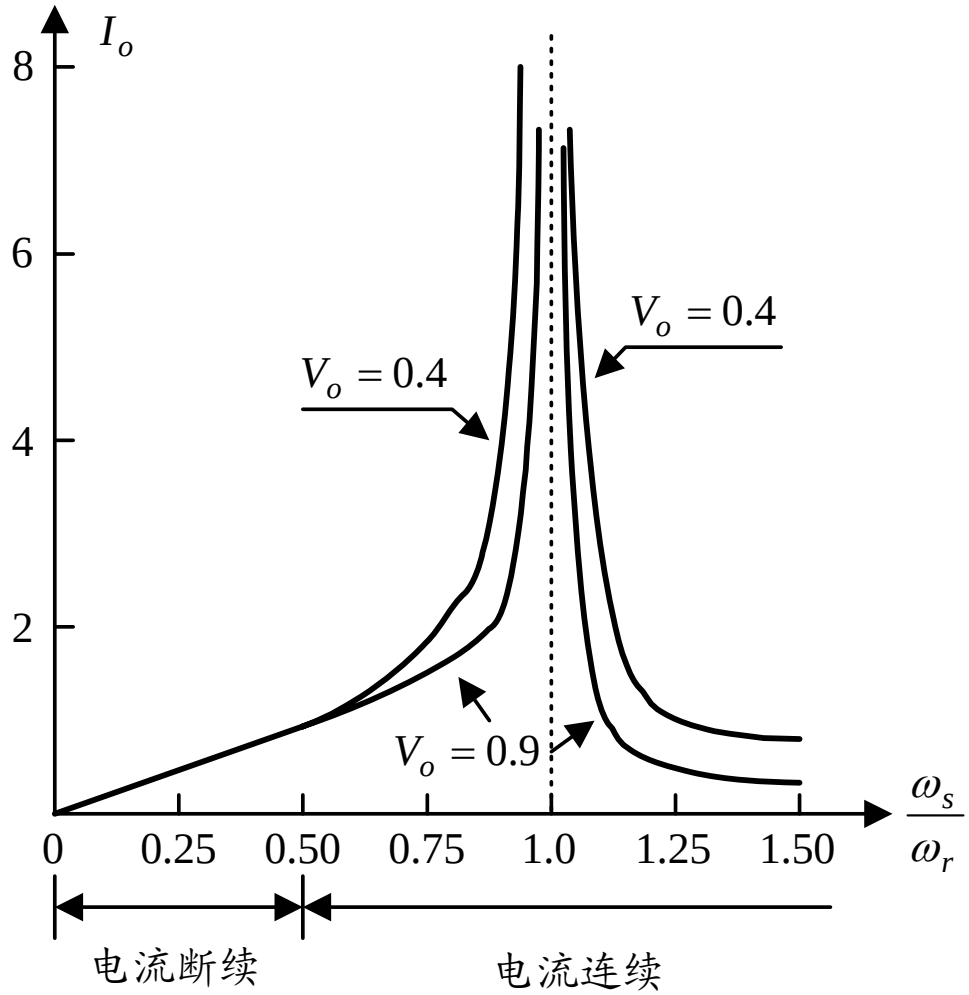
$$V_{base} = V_{in}$$

$$I_{base} = \frac{V_{in}}{2Z_r}$$

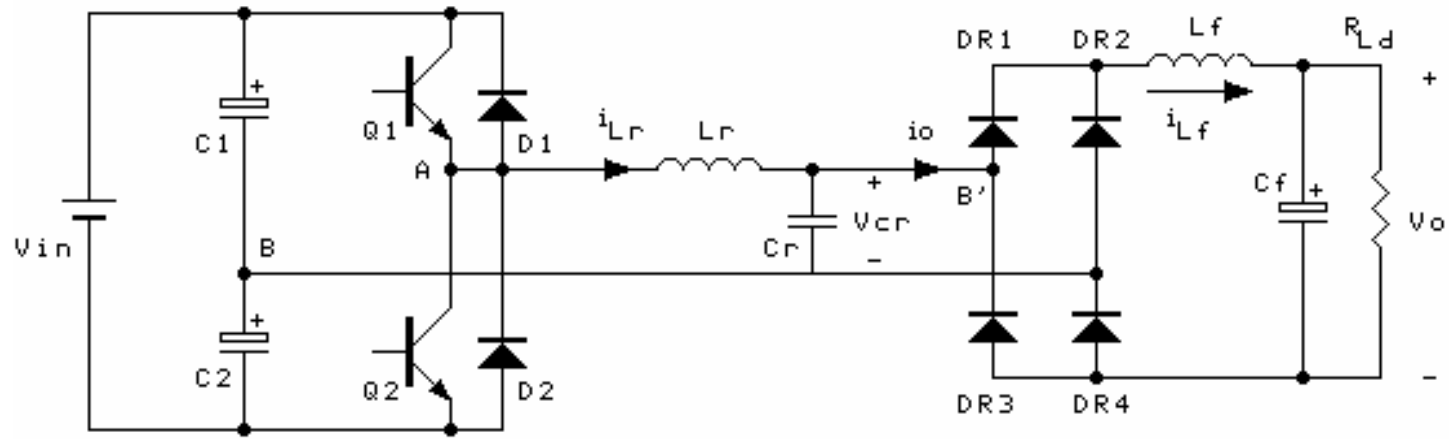
$$I_{base} = \frac{V_{in}}{Z_r}$$

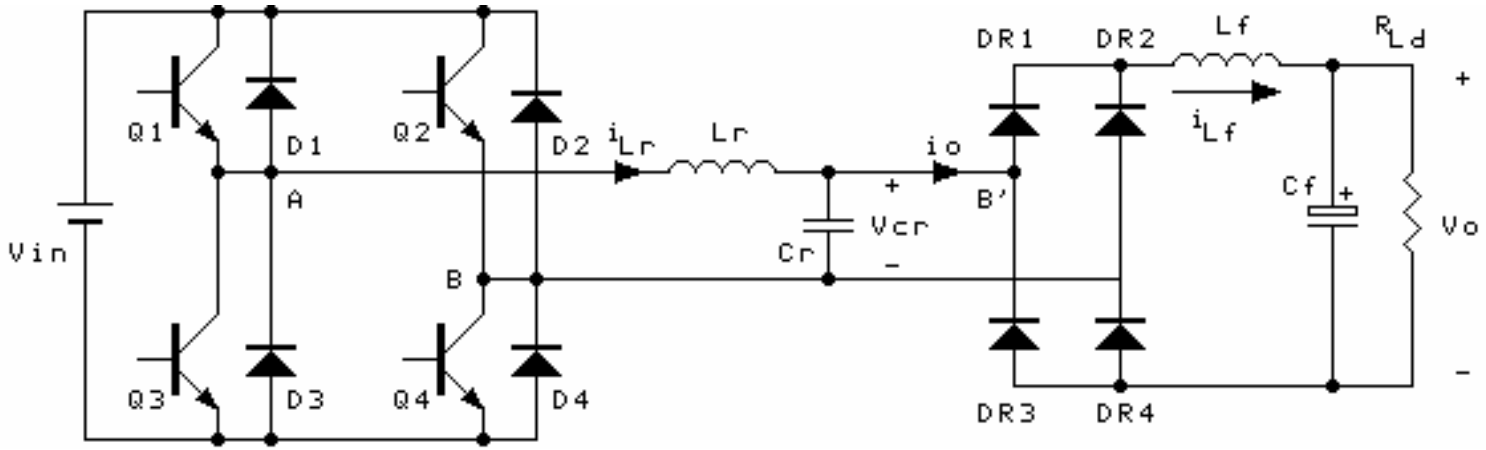
$$Z_r = \sqrt{L_r / C_r}$$

$$\omega_{base} = \omega_r = \frac{1}{\sqrt{L_r C_r}}$$



# Parallel Load Series Resonant Converters



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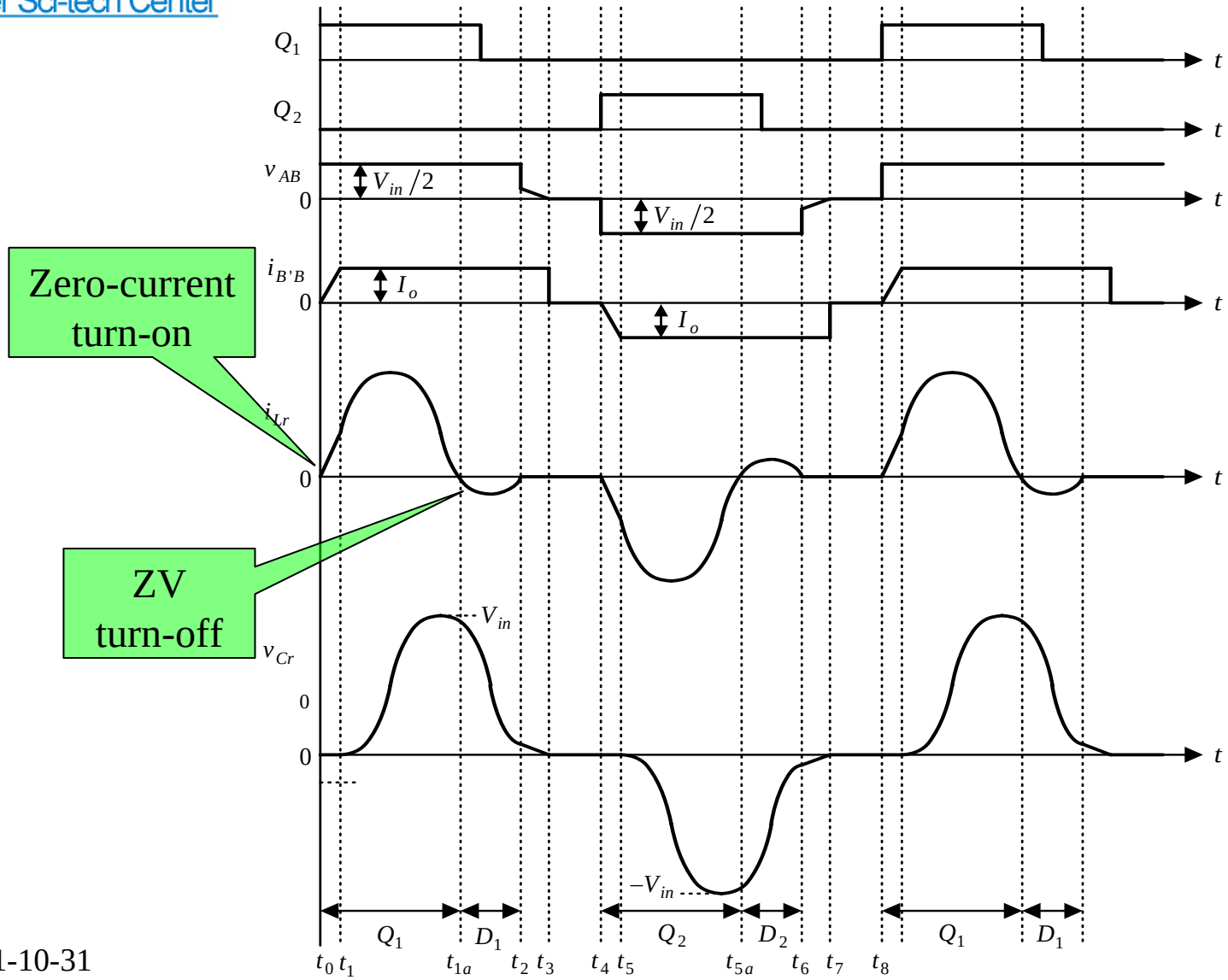
# DCM ($f_s < f_r/2$) : [$t_1$ , $t_2$]



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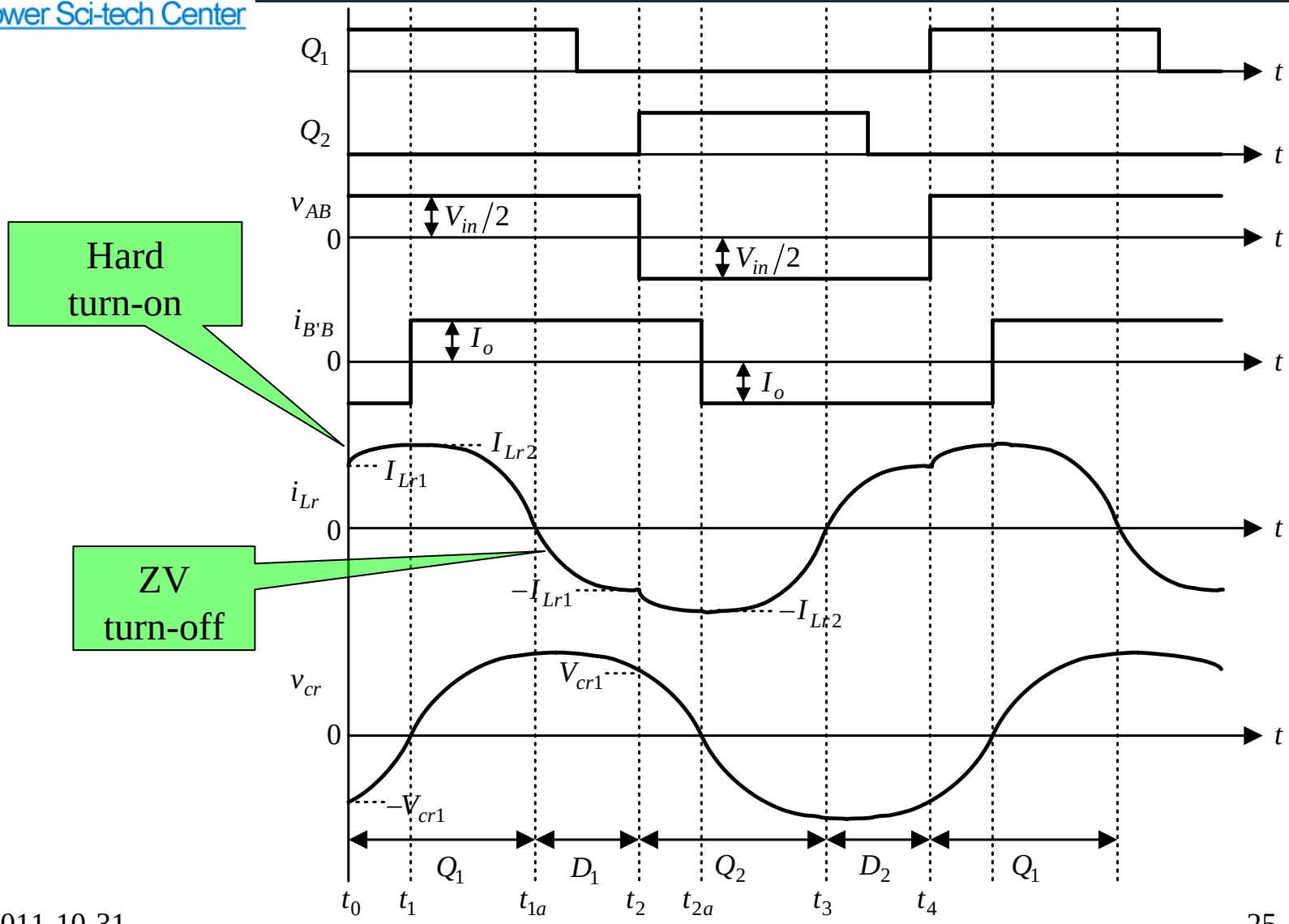
# Continuous Current Mode ( $f_r/2 < f_s < f_r$)



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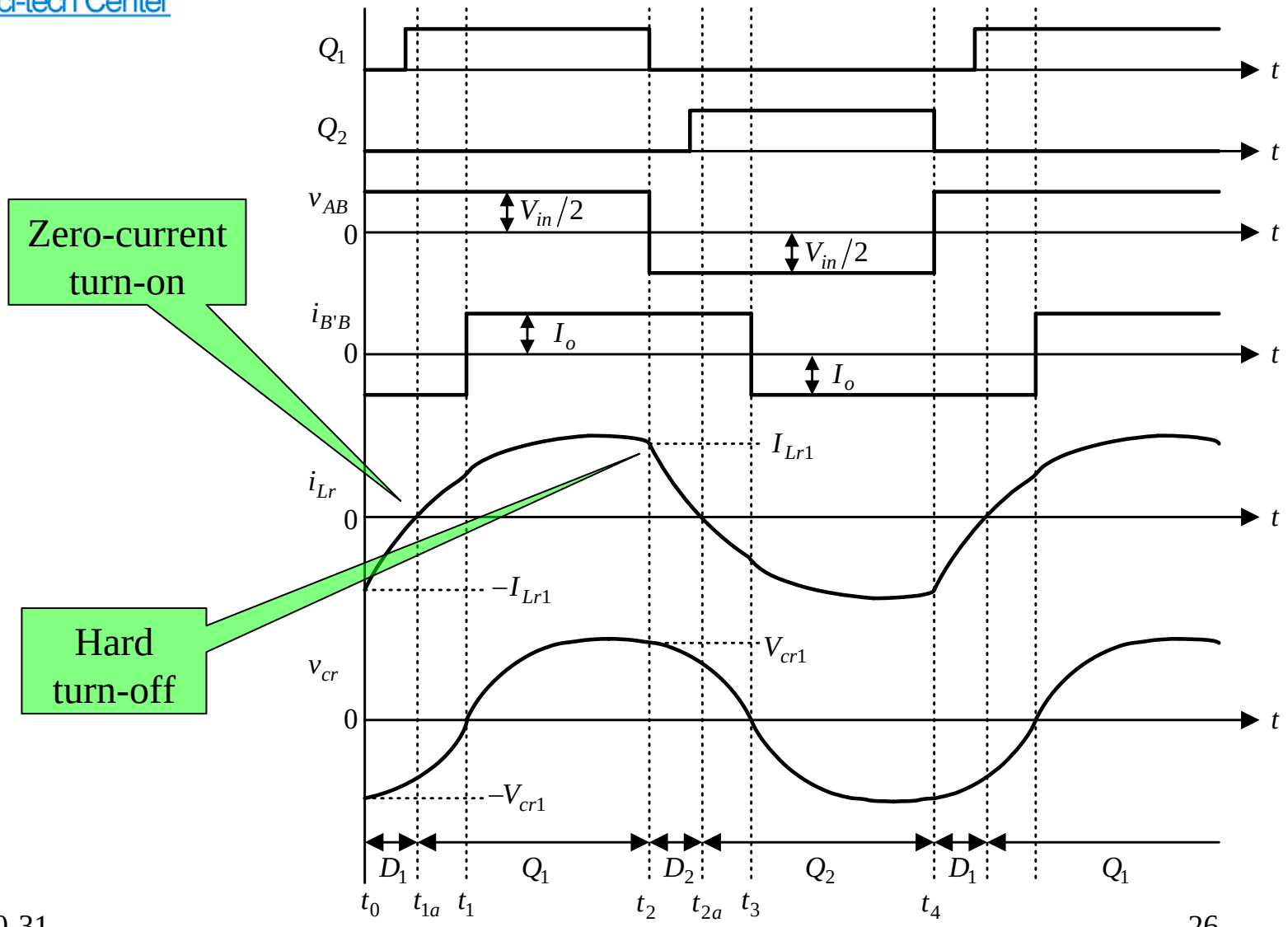
# Continuous Current Mode ($f_s > f_r$)



# Output Characteristics