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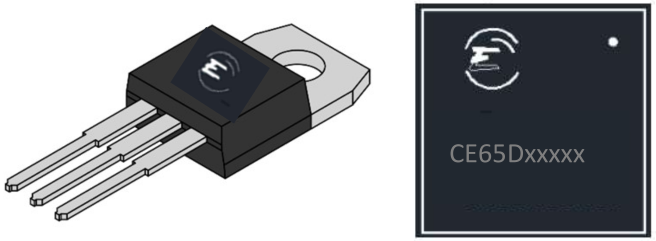
能华半导体

反激主开关损耗分析



江苏能华微电子科技发展有限公司

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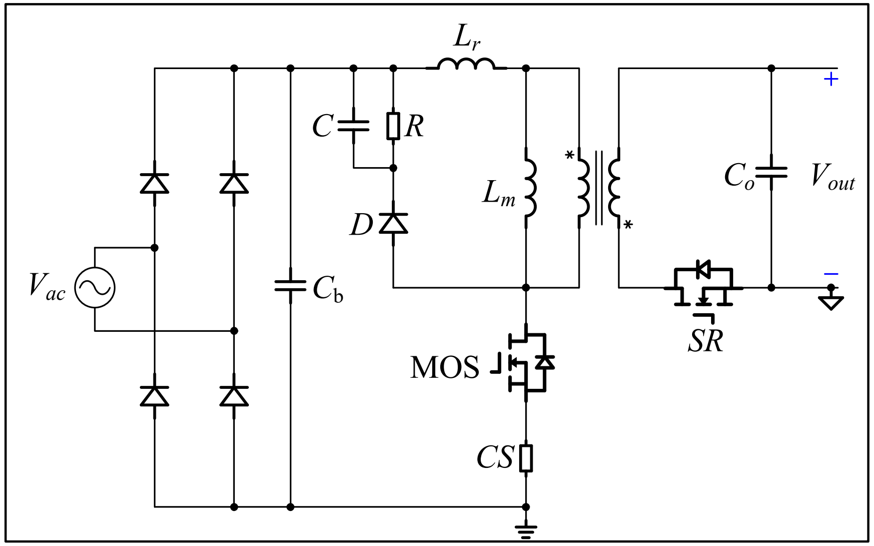
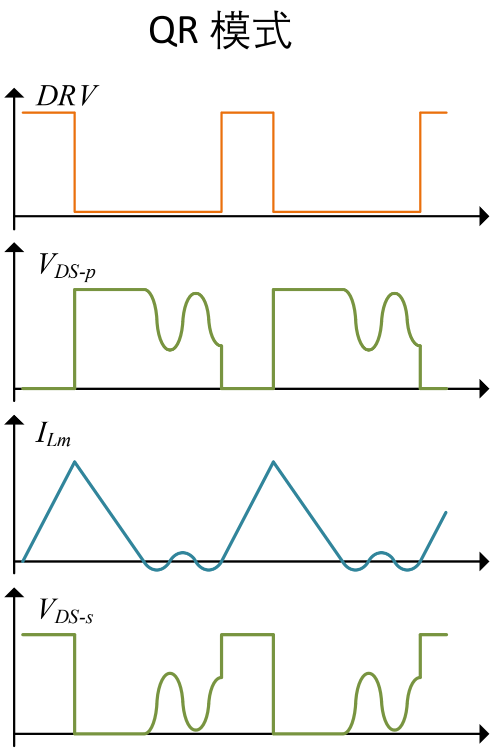
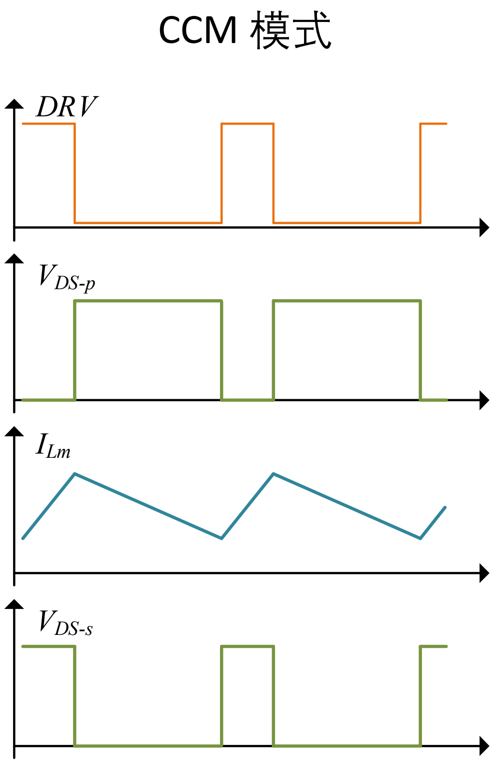
反激模态分类



Flyback Converter





QR反激-主开关MOS的损耗

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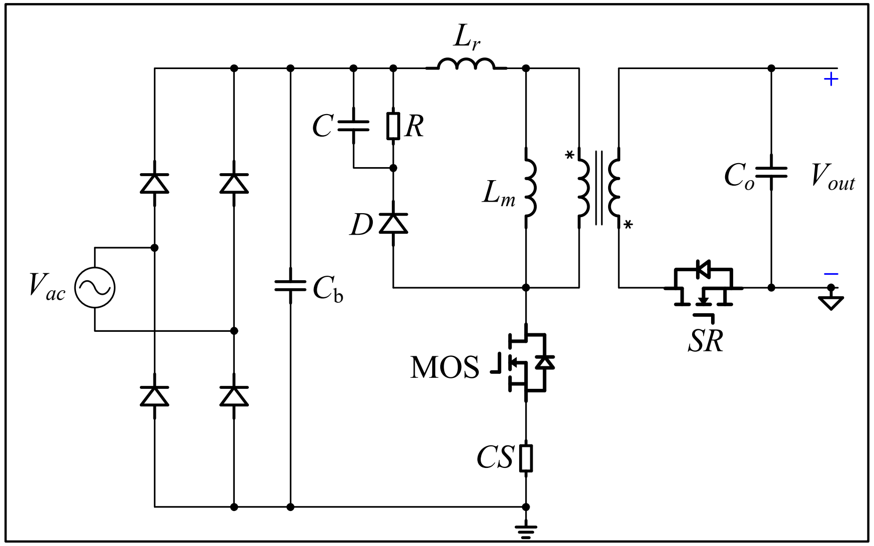
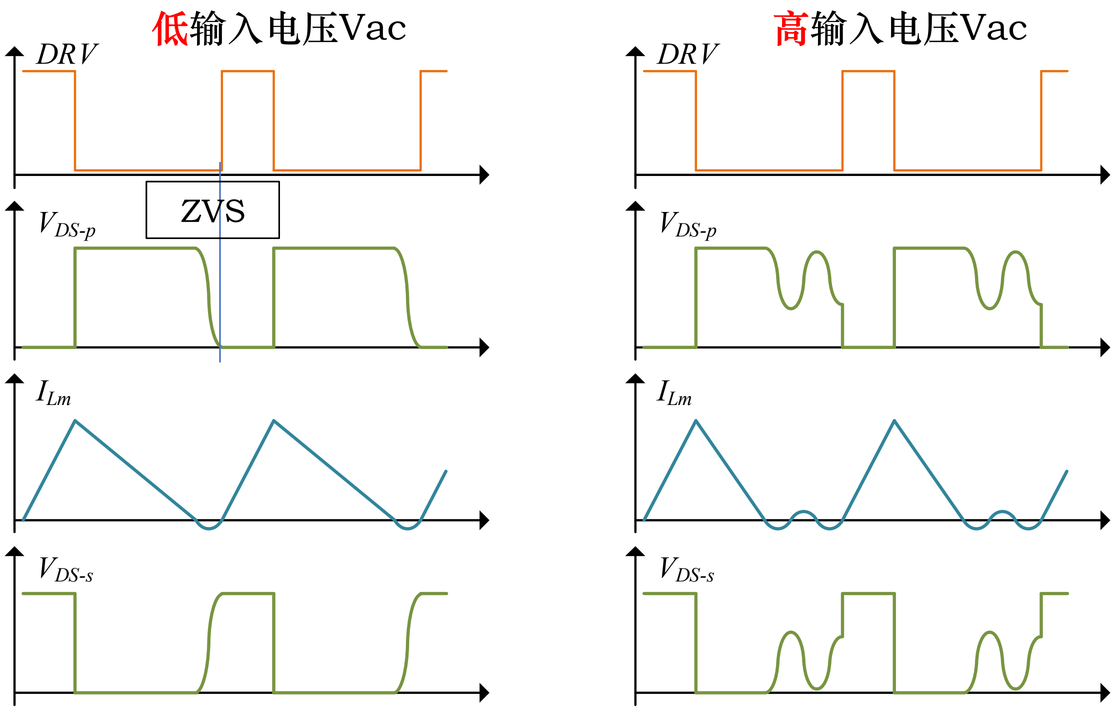


QR Mode Flyback



通态损耗，关断损耗，驱动损耗

通态损耗，关断损耗，驱动损耗，开通损耗

QR反激-主开关MOS的损耗

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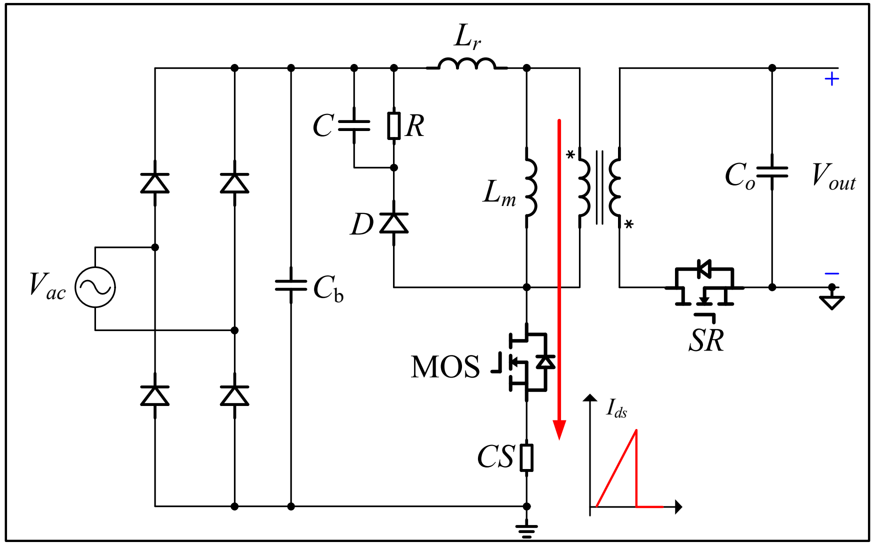
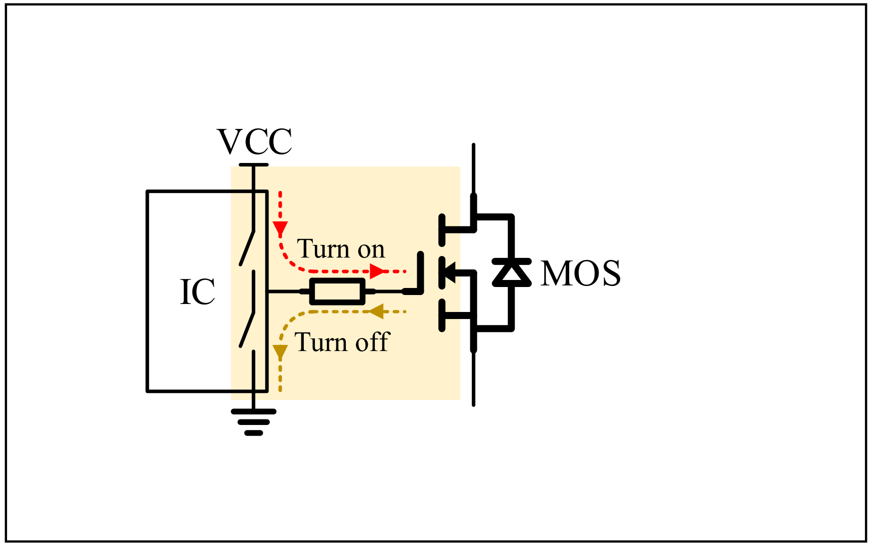




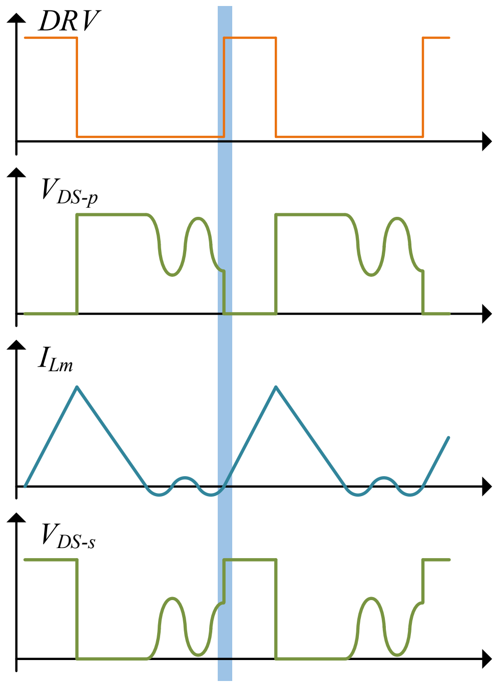
导通损耗

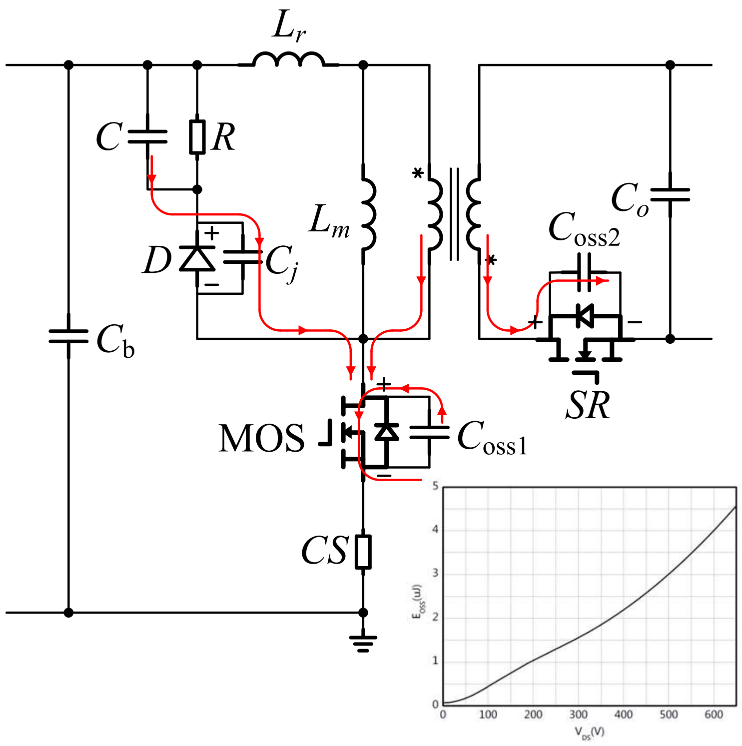
$$P_{\text{con}} = I_{\text{rms}}^2 * R_{\text{on}} \qquad I_{\text{rms}} = \frac{\sqrt{3}}{3} * I_p * Duty$$

驱动损耗

$$P_{drv} = Freq * VCC * Q_g$$

QR反激-主开关MOS的损耗





开通前:

主MOS的压降Vds=V_1

RCD支路压降为V_{bus}-V_1

SR的压降Vds=(V_{bus}-V_1)/n + Vo

开通后:

主MOS的压降Vds=0

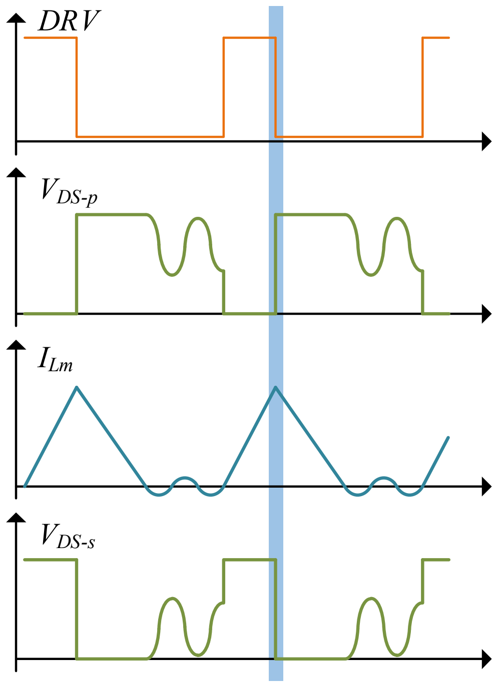
RCD支路压降为V_{bus}

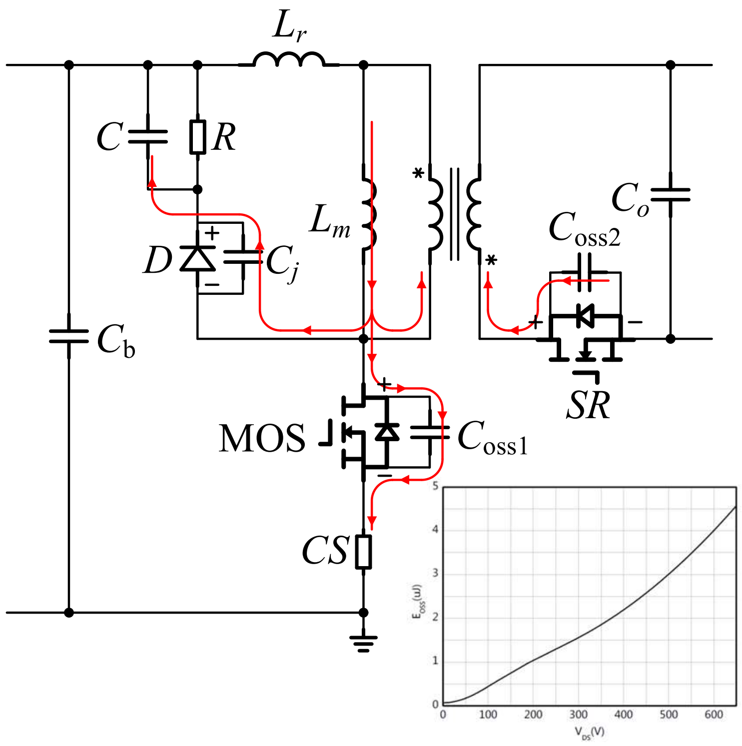
SR的压降Vds=V_{bus}/n + Vo

开通损耗 $$P_{on}=Freq*\left(\int V_{ds}*\boldsymbol{I_d}*dt+E_{oss}\right)$$

开通时，RCD和SR的寄生容(结电荷)的电流叠加到主MOS的Id，增加MOS的IV交叠损耗（零电流开通时的电流尖峰）

QR反激-主开关MOS的损耗





关断前:

主MOS的压降Vds=0

RCD支路压降为V_{bus}

SR的压降$Vds=V_{bus}/n + Vo$

关断后:

主MOS的压降$Vds= V_{bus}+nVo$

RCD支路压降为 - nVo

SR的压降Vds=0

关断时，励磁电流I_{Lm}给RCD、SR及主MOS的寄生容充电/放电，较大的寄生容会增加关断过程的时间

关断损耗 $P_{off} = Freq * \left(\int V_{ds} * I_d * \mathbf{dt} - E_{oss} \right)$

QR反激-主开关MOS的损耗

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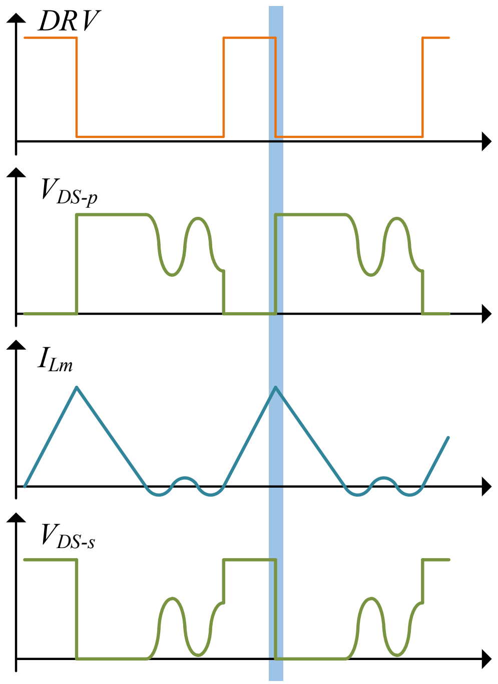
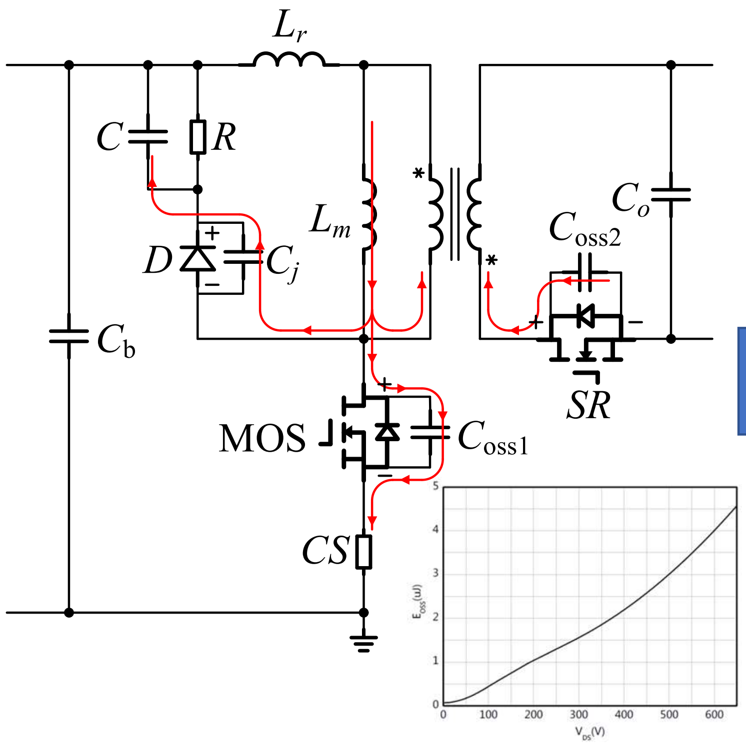
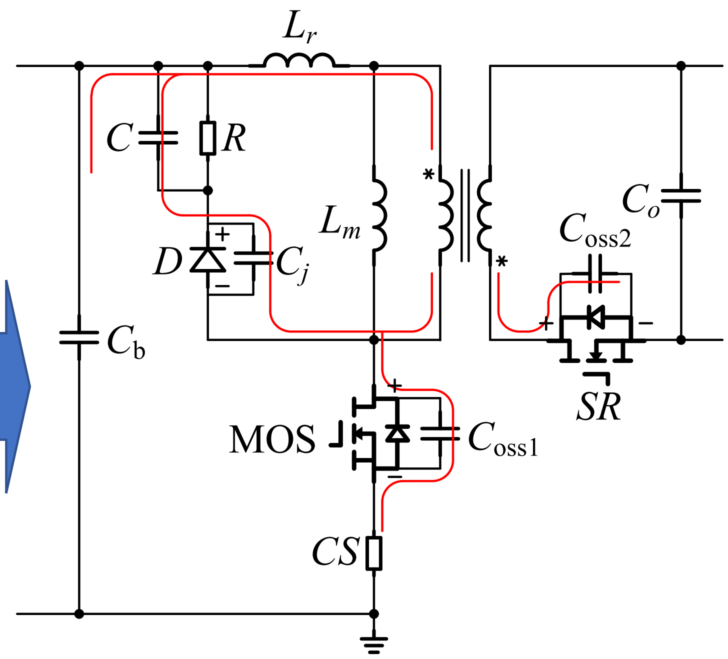


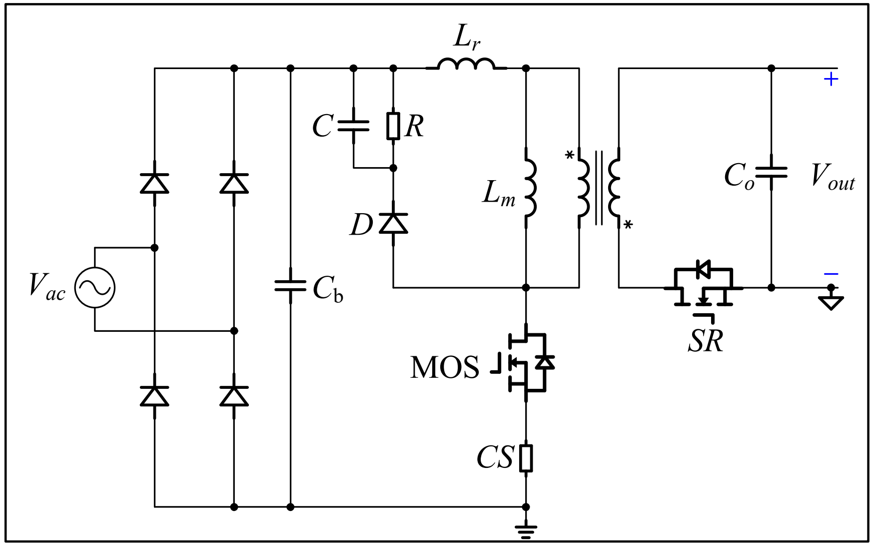




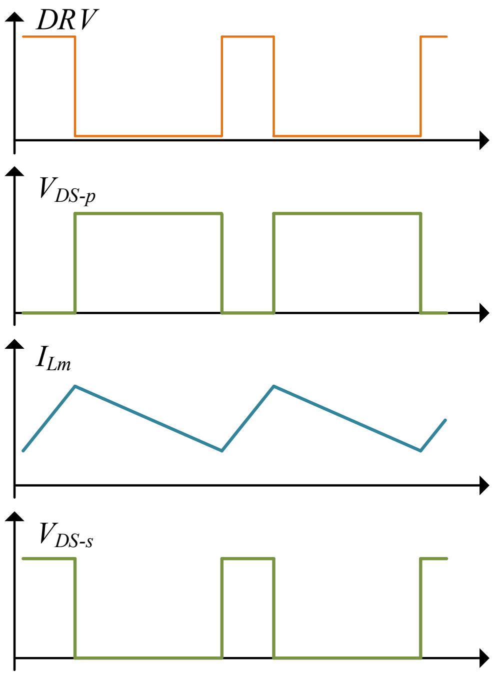
关断时，伴随着漏感Lr与RCD、SR及主MOS的寄生容高频振荡的过程，导致主MOS较大的尖峰电压

关断损耗 $$P_{off} = Freq * \left(\int V_{ds} * I_d * dt - E_{oss} \right)$$

CCM反激-主开关MOS的损耗



CCM Flyback



通态损耗，关断损耗，驱动损耗，开通损耗

通态损耗，关断损耗，驱动损耗，三者本质上和QR模式下的没有差别；
开通损耗略有不同；

CCM反激-主开关MOS的损耗

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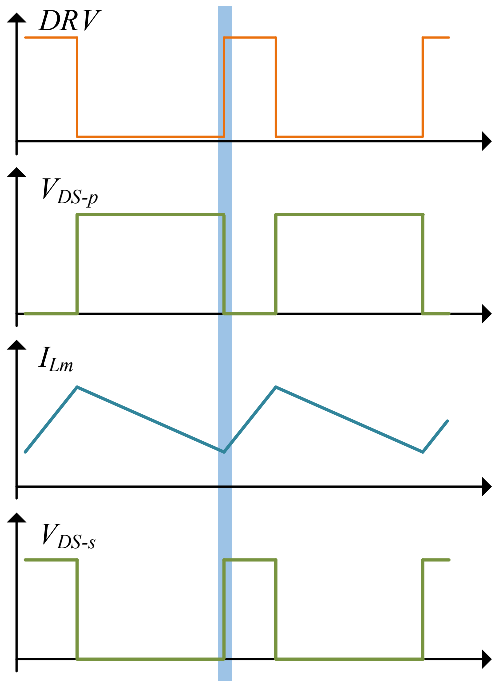
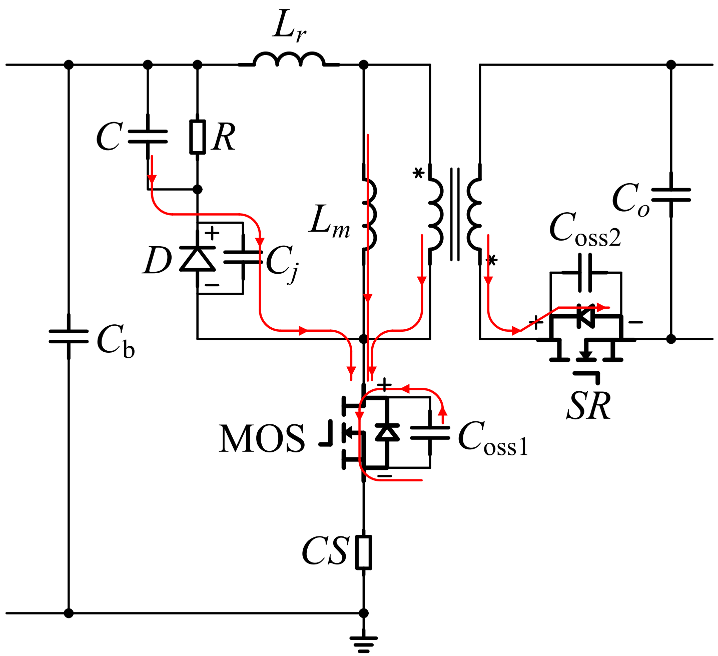




开通前:

主MOS的压降Vds= V_{bus} + nVo

RCD支路压降为nVo

SR的压降Vds= -0.7V

二极管反向恢复**期间**:

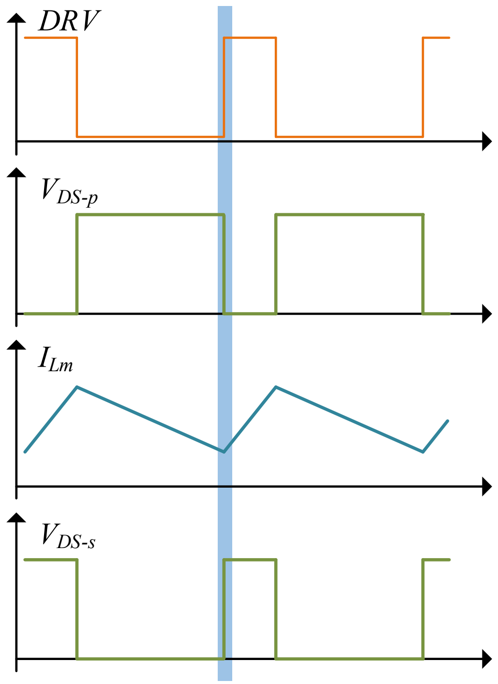
主MOS的压降Vds= V_{bus} + nVo

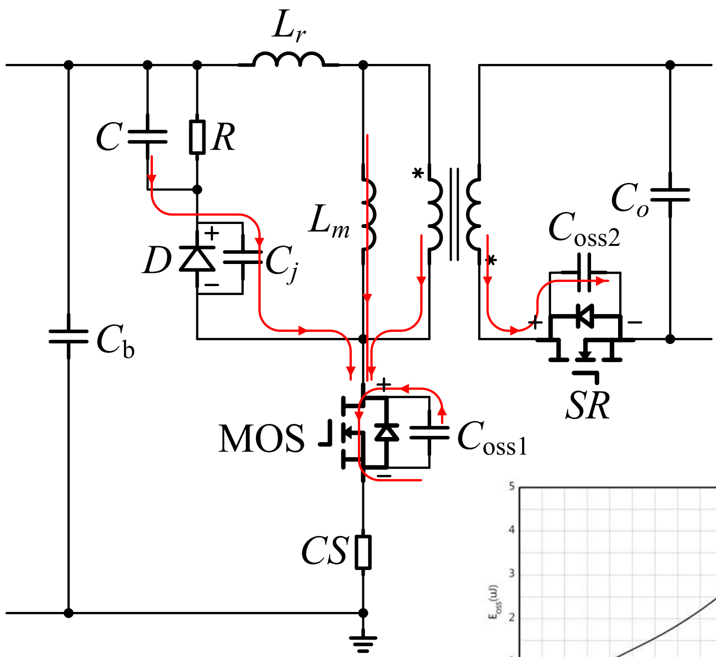
RCD支路压降为nVo

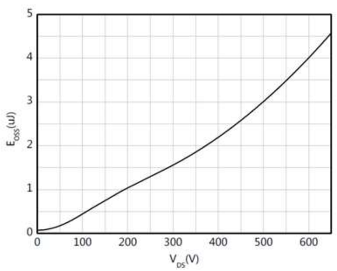
SR的压降Vds=0V

SR反向恢复造成主MOS开通损耗 $P_{on1} = Freq * (V_{bus} + nVo) * Q_{rr}$

CCM反激-主开关MOS的损耗







二极管反向后：

- 主MOS的压降Vds= V_{bus} + nVo
- RCD支路压降为nVo
- SR的压降Vds= 0V

开通过程结束：

- 主MOS的压降Vds=0
- RCD支路压降为V_{bus}
- SR的压降Vds=V_{bus}/n + Vo

总开通损耗 $$P_{on} = Freq * \left(\int V_{ds} * \boldsymbol{I_d} * dt + E_{oss} \right)$$

开通时，RCD和SR的寄生容(结电荷)的电流**以及SR的BD反向恢复电流**叠加到主MOS的Id，增加MOS的IV交叠损耗