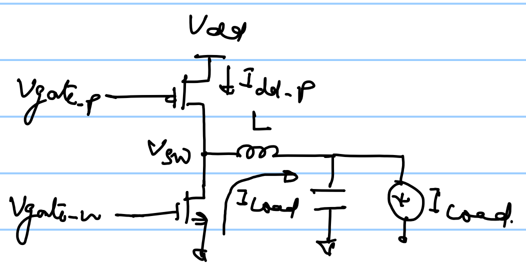
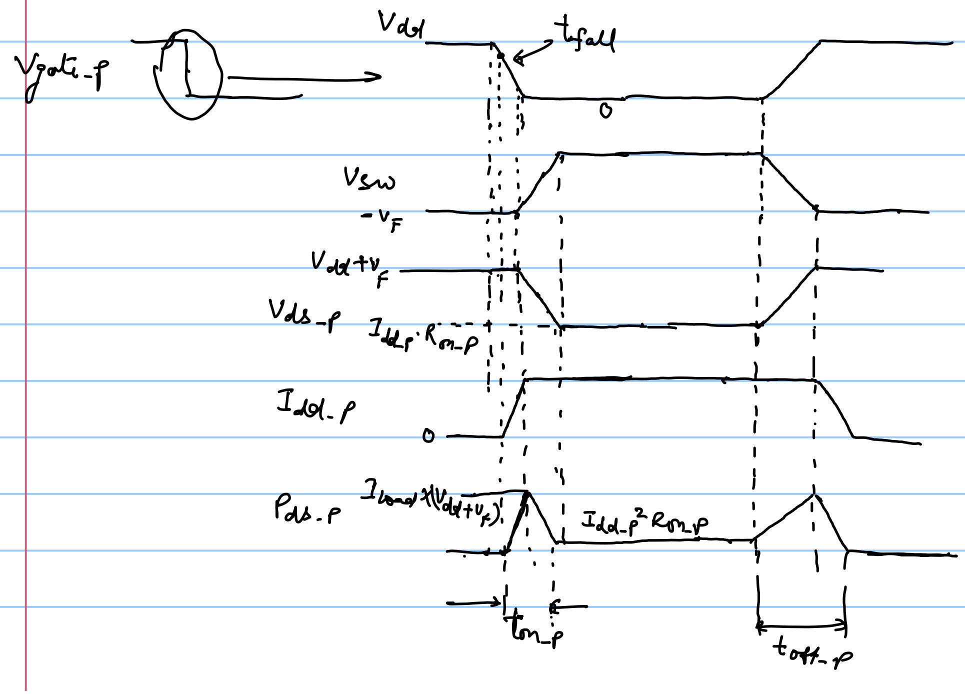
Hard Switching Losses





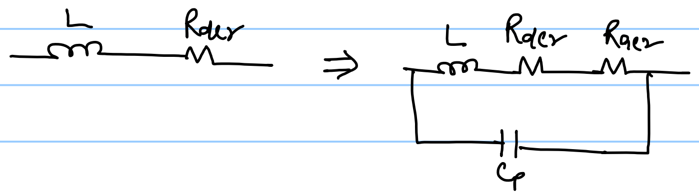
P_{sw} = average power during t_{on_p} & t_{off_p}

$$= \frac{\frac{1}{2} \times t_{on\_p} \times I_{dd}(V_{dd}+V_F) + \frac{1}{2} \times t_{off\_p} \times I_{dd}(V_{dd}+V_F)}{T_{sw}}$$

$V_{dd} >> V_F$

$$\approx \frac{\frac{1}{2}(t_{on\_p}+t_{off\_p})\, I_{dd}\, V_{dd}}{T_{sw}} = \boxed{\frac{1}{2}(t_{on\_p}+t_{off\_p})\, F_{sw}\, I_{load} \cdot V_{dd}}$$

<u>Magnetic Loss</u>



R_{acr} → magnetic losses (core loss, skin effect loss due to ac current)

R_{dcr} → resistive loss due to rms current (winding resistance) rms loss $= I_{L-rms}^2 \times R_{dcr}$

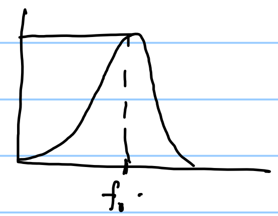
ac loss $= I_{L-ac}^2 \times R_{acr} = P_{ac}$

I_{L-ac} ↓ inductor ripple current (no dc current)

$$Q = \frac{\omega L}{R_{dcr} + R_{acr}}$$

R_{acr} ↓ measured data dominant at high freq.

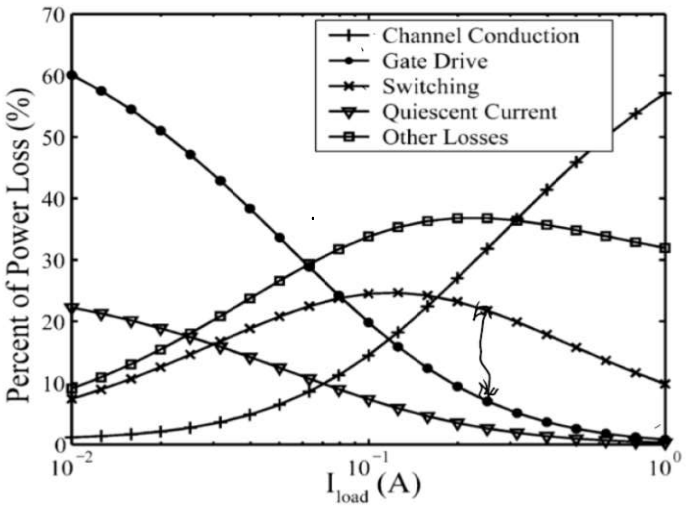
Q



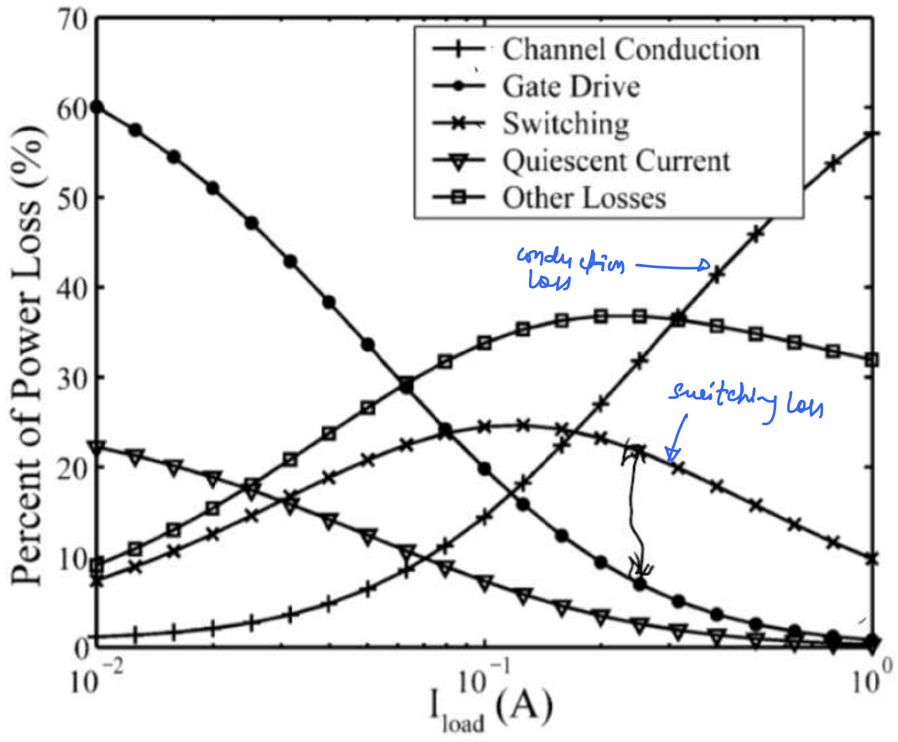
choose $F_{sw} \approx f_0$ for better efficiency.

$$P_{loss} = P_{cond} + P_{gate\text{-}sw} + P_{dead\_sw} + P_{sw} + P_{ac} + P_Q$$

- P_{cond} → $I_{rms}^2 R$ — conduction loss
- $P_{gate\text{-}sw}$ → $CV^2 f$ → gate drive loss
- P_{dead_sw} → $\frac{2 t_{dead}}{T_{sw}} \times V_F \times I$ → dead time loss
- P_{sw} → $\frac{1}{2}(t_{on} + t_{off}) V_{dd} \cdot I$ → hard switching loss
- P_{ac} → magnetic loss → $I_{ac}^2 R_{ac}$.
- P_Q → Quiescent loss → $V_{dd} \cdot I_Q$ (I_Q → current associated with controller)



Ref: M. D. Mulligan, et al "A constant-frequency method for improving light-load efficiency in synchronous buck converters,"IEEE Power Electron. Lett., vol. 3, no. 1, pp. 24–29, Mar. 2005.



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