Overlap Time

9 Typ. gate charge

\[ q_{\text{typ}} = (Q_{\text{paras}} \cdot f) / 5.2 \text{ A} \text{ ms} \]

parameter: \( V_{\text{DD}} \)

\[ t_e = \frac{f_{\text{rise}}}{f_{\text{rise}} + f_{\text{fall}}} \]

\[ I_f = 5.2 \text{ A} \text{ ms} \]

Gate threshold voltage

\[ V_{\text{th}} \]

<table>
<thead>
<tr>
<th>( V_{\text{GS}} )</th>
<th>( V_{\text{DD}} )</th>
<th>( f )</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>3.5</td>
<td>1 MHz</td>
</tr>
</tbody>
</table>

Gate resistance

\[ f = 1 \text{ MHz}, \text{ open drain} \]

\[ R_{\text{g}} = 17 \Omega \]

\[ C_{\text{gs}} < C_{\text{gs}} \]

simplifying Assumption

\[ I_f = \text{ const during \text{on} cycle} \]

\[ I_f \]

\[ t_{\text{on}} \]

\[ t_{\text{off}} \]

\[ t_{\text{rise}} \]

\[ t_{\text{fall}} \]

\[ t_{\text{overlap}} \]

\[ P_{\text{on}} = \frac{1}{2} IV_{\text{DD}} t_{\text{on}} \]

\[ P_{\text{off}} = \frac{1}{2} IV_{\text{DD}} t_{\text{off}} \]

\[ P_{\text{loss}} = P_{\text{on}} + P_{\text{off}} \]

\[ t_{\text{overlap}} = \frac{Q_{\text{paras}}}{I_f} \]

\[ t_{\text{on}} = \frac{Q_{\text{paras}}}{I_f} \]

\[ t_{\text{off}} = \frac{Q_{\text{paras}}}{I_f} \]

\[ t_{\text{rise}} = \frac{Q_{\text{paras}}}{I_f} \]

\[ t_{\text{fall}} = \frac{Q_{\text{paras}}}{I_f} \]

\[ t_{\text{overlap}} = \frac{Q_{\text{paras}}}{I_f} \]

\[ I_f = \text{ const during \text{on} cycle} \]

\[ I_f \]

\[ t_{\text{on}} \]

\[ t_{\text{off}} \]

\[ t_{\text{overlap}} \]

\[ P_{\text{on}} = \frac{1}{2} IV_{\text{DD}} t_{\text{on}} \]

\[ P_{\text{off}} = \frac{1}{2} IV_{\text{DD}} t_{\text{off}} \]

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\[ t_{\text{off}} = \frac{Q_{\text{paras}}}{I_f} \]

\[ t_{\text{rise}} = \frac{Q_{\text{paras}}}{I_f} \]

\[ t_{\text{fall}} = \frac{Q_{\text{paras}}}{I_f} \]

\[ t_{\text{overlap}} = \frac{Q_{\text{paras}}}{I_f} \]
Synchronous MOSFET Overlap

- No Power in synchronous device
Example Calculation

Assume gate driver supplies $+I_g$ (or $\beta$)

$t_{on} = \frac{Q_g}{I_g} = \frac{300\mu A}{100\mu A} = 3\text{ ms}$

$t_{overlap} = \frac{Q_{sw}}{I_g} = \begin{cases} 7.5\text{ ms} \quad &I_g = 1\text{ A} \\ 75\text{ ms} \quad &I_g = 10\text{ A} \end{cases}$

Worst case:

$P_{on} = \frac{1}{2} V_g I_g t_{on}$

$P_{overlap} = \frac{1}{2} \frac{V_g I_g}{T_s} t_{overlap}$

$P_{on-off} = M_i \times \text{ turn-off}$

Therefore

$P_{total} = \frac{1}{2} V_g I_g t_{on} + \frac{1}{2} \frac{V_g I_g}{T_s} t_{overlap}$

$V_g = 7.5\text{ V}$

$P_{total} = 3.15\text{ mW}$

Example Buck Efficiency (L14)

\[ P_{out} = \frac{V_0^2}{2} \left( \frac{1}{R_{DS(on)}} \right) \]

\[ P_{out} = \frac{V_0^2}{2} \left( \frac{1}{R_{DS(on)}} \right) \]

\[ C_{Q2} = 2.7\text{ mF} \]

\[ f_s = \frac{100\text{ W}}{(30\text{ mF})(2.7\text{ mF})} = 235\text{ kHz} \]

\[ P_{wind} = I_c^2 R_{DS(on)} = 0.171\text{ W} \]

\[ P_{wind} = V_0^2 C_{Q2} f_s = 5.1\text{ W} \]
Switching Loss Summary

For a hard-switched device (MOSFET turns on/off $V_{ds}, V_{gs}$)

Switching losses:

$\text{Cons} \Rightarrow P = \left( C_{oss} V_{ds}^2 + C_{gss} V_{gs}^2 - \frac{1}{2} C_{pe} V_{pe}^2 \right) f_s$

$\text{Qg} \Rightarrow P_{qg} = V_{ds} Q_{g} f_s \rightarrow \text{losses occur in gate drive circuit (occur $1x$ for each MOSFET)}$

V-I overlap $\Rightarrow P_{overlap} = V_{ds} I_{overlap} \frac{f}{f_s} \rightarrow \text{hardy} = \frac{Q_{sw}}{f_s}$

reverse recovery (if present) $\Rightarrow P_{rr} = V_{ds} (Q_{rr} + I_{rr} f_s) f_s$
Switching Waveforms

- Add 1 \( \frac{1}{2} L \nu_0 \) -type bus
- Voltage/current overshoot
- Slowed down