Switching Losses in a Half Bridge

Target Switching Waveforms
Capacitive switching loss

ANALYSIS OF NONLINEAR CAPACITANCES

MOSFET Depletion Capacitance
Example Device $C_{oss}$

\[ C_{oss} = C_{ds} + C_{gd} \approx C_{ds} \]

- Analytical Model
  \[ C_{ds} = \frac{C_{sto}}{1 + \left( \frac{V_{DS}}{V_{gs0}} \right)^m} \quad n = \frac{1}{2} \]
- Numerical / Empirical Model

Datasheet Reported Capacitance

**Infineon**

**IPB60R385CP**

13 Typ. capacitances

\[ C = f(V_{ds}); \; V_{gs0} = 0 \text{ V; } f = 1 \text{ MHz} \]

14 Typ. Coss stored energy

\[ E_{oss} = f(V_{oss}) \]

**Linear**

\[ E_C = \frac{1}{2} C V_0^2 \]
Modeling Nonlinear Capacitances

\[ Q = \int_0^{V_{DC}} C(N_v) \, dV_c \]

\[ E = \int_0^{V_{DC}} C(N_v) \, V_c \, dV_c = C \left( \frac{V_c}{2} \right)^2 \]

Cannot simplify any further in the nonlinear case

Energy and Charge Equivalents

Linear capacitance can match any single characteristic of the full nonlinear capacitance

\[ Q = C_{eq,a} \cdot V_{DC} = \int_0^{V_{DC}} C(N_v) \, dV_c \]

\[ C_{eq,a} = \frac{1}{V_{DC}} \int_0^{V_{DC}} C(N_v) \, dV_c \]

Linear capacitance with the same change as nonlinear cap when biased to \( V_{DC} \) volts

Note: \( C_{eq,a} = \left< C(N_v) \right>_{V_{DC}} \)