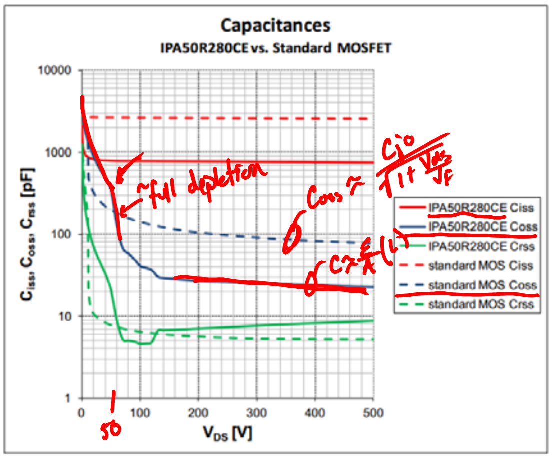
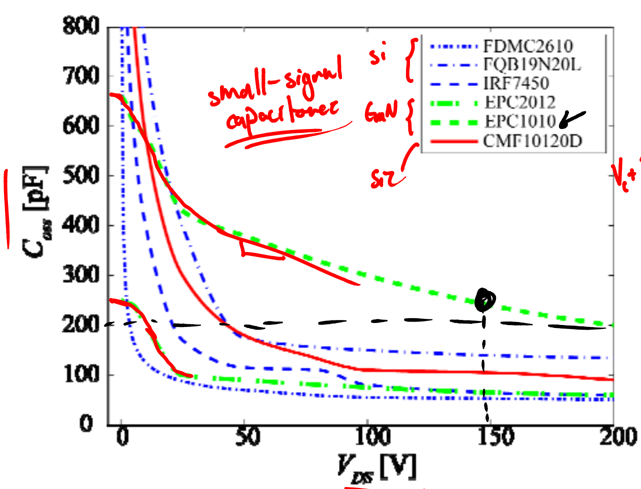
SJ Capacitance



WBG Material Capacitances



$C_{oss} = C(V_{ds})$

$\hat{i}_c = C(V_c)\frac{d\hat{v}_c}{dt}$

$V_c + \hat{v}_c$ $\hat{i}_c$ C_{oss}

$C = \frac{Q}{V}$ X

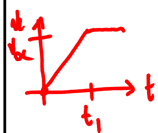
$C(V_c) = \frac{\Delta Q}{\Delta V}$

Modeling Nonlinear Capacitances

Energy

$$E_c = \int_0^{t_1} i_c v_c \, dt$$

$$E_c = \int_0^{t_1} C(v_c) \frac{dv_c}{\cancel{dt}} v_c \cancel{dt}$$



Apply chain rule

$$E_c = \int_{v_c(0)}^{v_c(t_1)} C(v_c) v_c \, dv_c$$

$$\boxed{E_c = \int_0^{V_{DC}} C(v_c) v_c \, dv_c}$$

Assume linear: $E_c = \int_0^{V_{DC}} C v_c \, dv_c$

$$\to E_c = C \frac{V_{DC}^2}{2}$$

Charge

$$Q_c = \int_0^{t_1} i_c \, dt$$

$$Q_c = \int_0^{t_1} C(v_c) \frac{dv_c}{\cancel{dt}} \cancel{dt}$$

$$\boxed{Q_c = \int_0^{V_{DC}} C(v_c) \, dv_c}$$

$$Q_c = \int_0^{V_{DC}} C \, dv_c$$

$$Q_c = C V_{DC}$$

Energy and Charge Equivalents

$$E_c = \int_0^{V_{DC}} C(v_c) v_c \, dv_c \qquad Q_c = \int_0^{V_{DC}} C(v_c) \, dv_c$$

If we want to know what linear capacitance would give the same energy stored at V_{DC}:

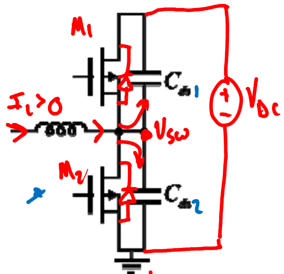
$$E_{c,lin} = \frac{1}{2} C_{eq,E} V_{DC}^2 = \int_0^{V_{DC}} C(v_c) v_c \, dv_c$$

$$\boxed{C_{eq,E} = \frac{2}{V_{DC}^2} \int_0^{V_{DC}} C(v_c) v_c \, dv_c}$$

$$Q_{c,lin} = C_{eq,Q} V_{DC} = \int_0^{V_{DC}} C(v_c) \, dv_c$$

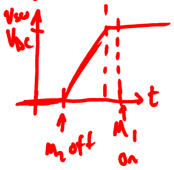
$$\boxed{C_{eq,Q} = \frac{1}{V_{DC}} \int_0^{V_{DC}} C(v_c) \, dv_c}$$

Switching Losses in a Half Bridge



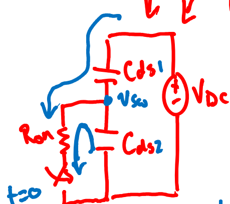
Two switching transitions:

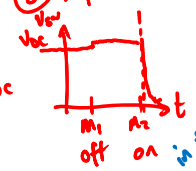
① M_2 turns off M_1 turns on



Possible to have no switching losses due to C_{ds}

② M_1 turns off, M_2 turns on





$V_{sw}(t=0) = V_{DC}$

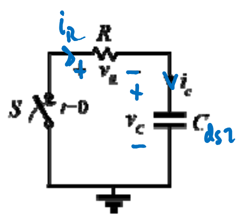
Hard-switched; $E_{sw} > \phi$

two components of $E_{sw} = E_1 + E_2$

in the linear case $E_2 = \frac{1}{2} C_{ds2} V_{DC}^2$ (due to discharging C_{ds2})

$E_1 = \frac{1}{2} C_{ds1} V_{DC}^2$ (due to charging C_{ds1})

M_2 Energy Loss



$V_c(0) = V_{DC}$

Energy dissipated is all of energy stored in C_{ds2} @ V_{DC}

$$E = E_{C_{ds2}}(t=0) = \boxed{\frac{1}{2} C_{eq,E} V_{DC}^2}$$

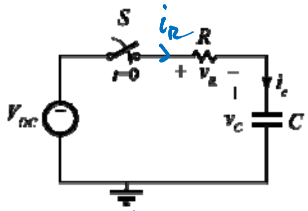
Verify:

$$E_R = \int_0^{t\to\infty} i_R v_R \, dt = \int_0^{\infty} i_c(-v_c)\,dt = \int_0^{\infty} C(v_c)\frac{dv_c}{dt}(-v_c)\,dt$$

$$E_R = \int_{V_{DC}}^{0} C(v_c)(-v_c)\,dv_c = \int_0^{V_{DC}} C(v_c)\,v_c\,dv_c = \frac{1}{2} C_{eq,E} V_{DC}^2$$

✓

M_1 Energy Loss



$$E_R = \int_0^\infty i_R v_R \, dt$$

$$= \int_0^\infty i_c (V_{DC} - v_c) \, dt$$

$$= \int_0^\infty C(v_c) \frac{dv_c}{dt} (V_{DC} - v_c) \, dt$$

$$E_R = \int_0^{V_{DC}} C(v_c)(V_{DC} - v_c) \, dv_c = -\int_0^{V_{DC}} C(v_c) v_c \, dv_c + \int_0^{V_{DC}} V_{DC} C(v_c) \, dv_c$$

$$\boxed{= V_{DC}^2 C_{eq,Q} - \frac{1}{2} C_{eq,E} V_{DC}^2}$$

$$E_{sw} = V_{DC}^2 C_{eq,Q}$$