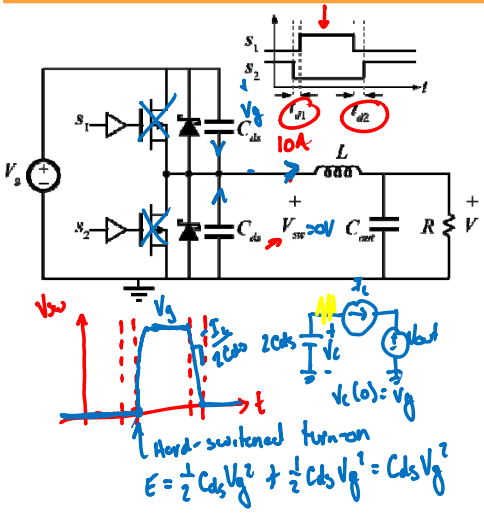
Buck Converter Example



$V_g = 100V$ $V_{out} = 50V$ $I_L = 10A$

$f_s = 1MHz$ MOSFETs are in Si

Assumptions:

(1) C_{ds} & r_{on} are the only parasitics

(2) C_{ds} is linear, constant-valued

(3) MOSFET C_{ds} & r_{on} are dominated by drift region

(4) $t_{dt} \ll T_s$

$P_{loss} = P_{sw} + P_{cond}$

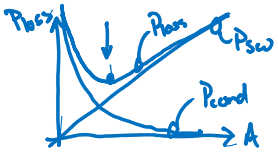
$P_{loss} = C_{ds} V_g^2 f_s + I_L^2 r_{on}$

$\eta \approx \frac{P_{out}}{P_{out} + P_{loss}}$

$E = \frac{1}{2} C_{ds} V_g^2 + \frac{1}{2} C_{ds} V_g^2 = C_{ds} V_g^2$

$P_{loss} = V_g^2 f_s C_{ds,sp} A + I_L^2 \frac{R_{on,sp}}{A}$

Find $\min(P_{loss})$ wrt Area



$\frac{\partial P_{loss}}{\partial A} = \phi = \frac{\partial}{\partial A}\left(V_g^2 f_s C_{ds,sp} A + I_L^2 \frac{R_{on,sp}}{A}\right)$

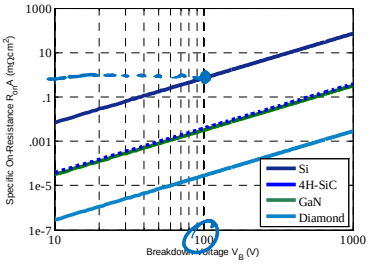
$\phi = \left(V_g^2 f_s C_{ds,sp} + I_L^2 R_{on,sp} \frac{-1}{A^2}\right)$

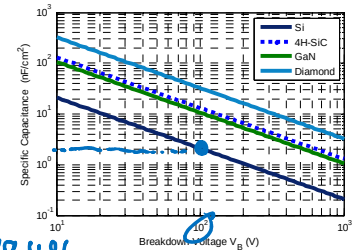
$A^2 = \frac{I_L^2 R_{on,sp}}{C_{ds,sp} V_g^2 f_s} = \frac{(10A)^2 (0.9\ m\Omega\ cm^2)}{\left(2\frac{nF}{cm^2}\right)(100V)^2 (1MHz)}$

$A = 0.067\ cm^2$

$P_{loss} = \underbrace{1.5W}_{P_{cond}} + \underbrace{1.34W}_{P_{sw}} = 2.84W$

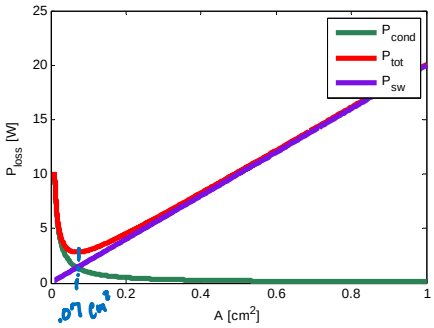
for Si $\begin{cases} C_{ds,sp} \approx 2\frac{nF}{cm^2} \\ R_{on,sp} \approx 0.9\ m\Omega cm^2 \end{cases}$

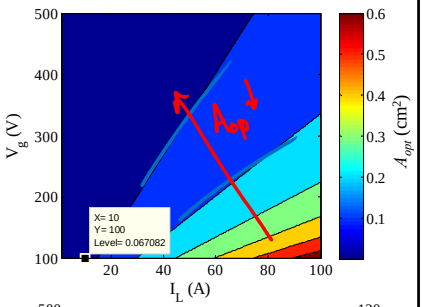


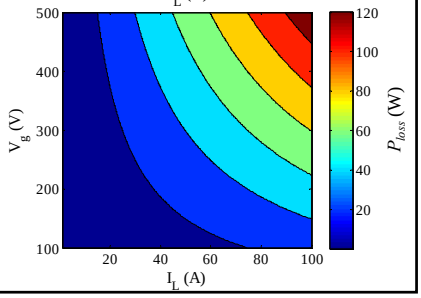


$\eta_{max} = 99.4\%$

Ideal Device Power Loss







Maximum Silicon Efficiency

$$P_{loss} = I_L^2 \frac{R_{on,sp}}{A} + V_g^2 f_s C_{oss,sp} A$$

$$= I_L^2 R_{on,sp} \sqrt{\frac{V_g^2 f_s C_{oss,sp}}{I_L^2 R_{on,sp}}} + V_g^2 f_s C_{oss,sp} \sqrt{\frac{I_L^2 R_{on,sp}}{V_g^2 f_s C_{oss,sp}}}$$

$$= \sqrt{I_L^2 R_{on,sp} V_g^2 f_s C_{oss,sp}} + \sqrt{V_g^2 f_s C_{oss,sp} I_L^2 R_{on,sp}}$$

$$= 2 I_L V_g \sqrt{f_s R_{on,sp} C_{oss,sp}}$$

$$\eta = \frac{V_{out} I_L}{V_{out} I_L + 2 I_L V_g \sqrt{f_s R_{on,sp} C_{oss,sp}}}$$

$$\eta_{max,si} = \frac{1}{1 + \frac{2}{M} \sqrt{f_s R_{on,sp} C_{oss,sp}}} \qquad M = \frac{V_{out}}{V_g}$$