Analytical E_{sw} for ideal Silicon Dmos

$$C_{ds} = \frac{C_{j0} A}{\sqrt{1+\frac{V_{ds}}{V_F}}}, \quad C_{j0} = \sqrt{\frac{\epsilon^2 E_{crit}^2}{4 V_{BV} V_F}}$$

on this week's HW → $V_F = 1$

$$\rightarrow \quad C_{ds} = \frac{C_{j0} A}{\sqrt{1+V_{ds}}}$$

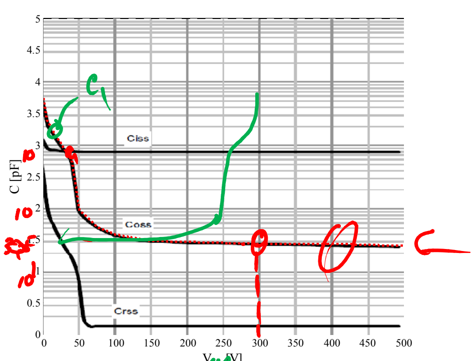
$$C_{eq,Q} = \frac{1}{V_g}\int_0^{V_g} C_{ds}\, dv = \frac{1}{V_g}\int_0^{V_g} \frac{C_{j0} A}{\sqrt{1+v}}\, dv$$

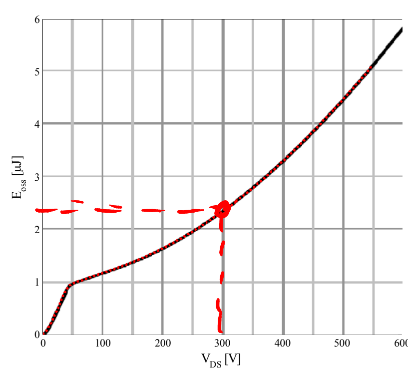
$$= \frac{C_{j0} A}{V_g}\, 2\sqrt{1+v}\Big|_{v=0}^{v=V_g} = \frac{2 C_{j0} A}{V_g}\left(\sqrt{1+V_g} - 1\right)$$

$$E_{sw} = 2 V_g C_{j0} A \left(\sqrt{1+V_g} - 1\right)$$

↳ Note: still linearly proportional to A (device area)

Energy Equivalent





M_1 $V_{DS} = V_{sw}$
M_2 $V_{DS} = V_g - V_{sw}$

<u>Matlab Code:</u>

```
Vdc = 550;

Vds = [0   5   10   40  50 75 100 150 200 300 400 500 600];
Coss = [5500 2500 1900 550 95 50 38  30  29  27  27  25  24]*1e-12;

vx = 0.01:.01:Vdc;
Cx = 10.^interp1(Vdc,log10(Coss),vx,'linear');

E = cumtrapz(vx, Cx.*vx);
Ceq_e = 2*(E)./vx.^2;
```

Example Buck Efficiency

			Min	Nom	Max
Drain-source on-state resistance	$R_{DS(on)}$	V_{GS}=10 V, I_D=5.2 A, T_j=25 °C	-	0.35	0.385
		V_{GS}=10 V, I_D=5.2 A, T_j=150 °C	-	0.94	-

$V_g = 300V$ - to - $150V$
$\eta \geq 95\%$
$P_{out} = 100W$

$$P_{sw} = V_g^2 C_{eq,Q} f_s$$

$$P_{cond} = i_{1rms}^2 R_{ds,on1} + i_{2rms}^2 R_{ds,on2}$$

$$= (\sqrt{D} I_L)^2 R_{ds,on} + (\sqrt{1-D} I_L)^2 R_{ds,on}$$

$$I_L = \frac{100W}{150V} \qquad = I_L^2 R_{ds,on}$$

$$C_{eq,Q} = 247pF \qquad \eta = \frac{P_{out}}{P_{out} + P_{cond} + P_{sw}} = \frac{100W}{100W + \left(\frac{100V}{150V}\right)^2 (.385\Omega) + (300)^2 (247pF) f_s}$$

$$f_s \leq \frac{\frac{100W}{.95} - 100W - \left(\frac{100V}{150V}\right)^2 (.385\Omega)}{(300V)^2 (247pF)} = 230kHz$$

$$P_{cond} = I_L^2 R_{on} = 0.171W$$

$$P_{sw} = V_g^2 C_{eq,Q} f_s = 5.1W$$

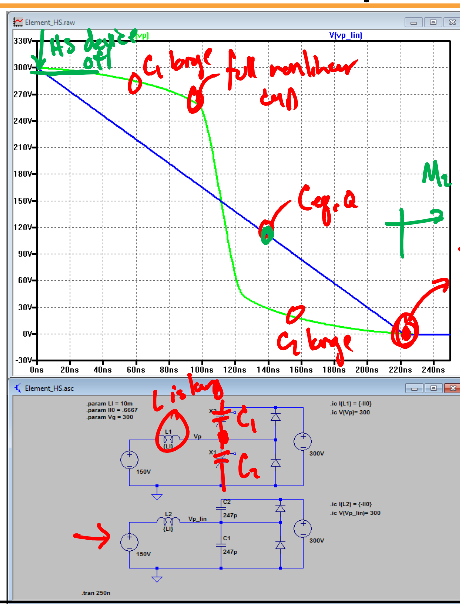
what if we could have a device half as big as IPB60R385, & it scaled proportionally?

$$P_{cond}' = 0.342W \qquad P_{sw}' = 2.55W$$

$P_{tot} = 2.892$
$\eta \simeq 97.3\%$

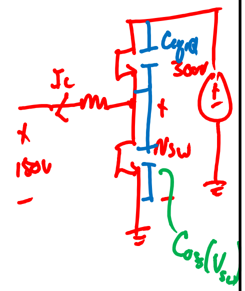
Cap	E_{sw}	
$C_{eq,Q}$	22µJ	
$C_{oss}(V_{ds}=300)$	2.6µJ	Wrong
$C_{eq,E}$	2.5µJ	Wrong
C_{oss} from table	3.4µJ	Wrong

Nonlinear Capacitance Waveforms



M2 turn on

Develops linear equivalent based on charge

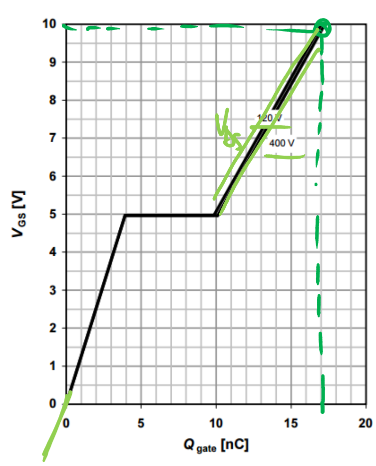


Gate Charge

9 Typ. gate charge

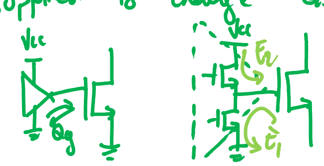
$V_{GS}=f(Q_{gate})$; I_D=5.2 A pulsed

parameter: V_{DD}



Until now, we have assumed we can switch MOSFET channel instantaneously

Some non-zero charge must be supplied to change V_{GS}



$$P_g = Q_g V_{cc} f_s$$