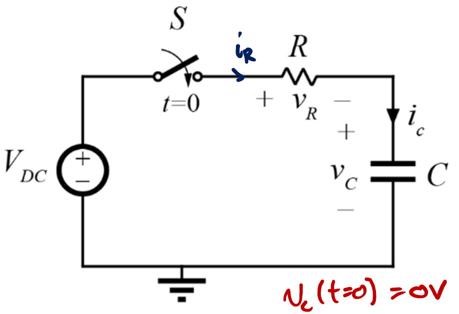
M_1 Energy Loss



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

$$v_R = V_{DC} - v_c$$

$$i_R = i_c = C \frac{dv_c}{dt}$$

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

$$E_R = \int_0^{V_{DC}} C V_{DC} \, dv_c - \int_0^{V_{DC}} C \cdot v_c \, dv_c$$

$$E_R = V_{DC} \underbrace{\int_0^{V_{DC}} C \, dv_c}_{Q_{tot}} - \underbrace{\int_0^{V_{DC}} C \cdot v_c \, dv_c}_{E_{tot}}$$

Insight

$$E_R = V_{DC}(V_{DC} C_{eq,0,Q}) - \frac{1}{2} C_{eq,0,E} V_{DC}^2$$

Total Half Bridge C_{oss} Loss

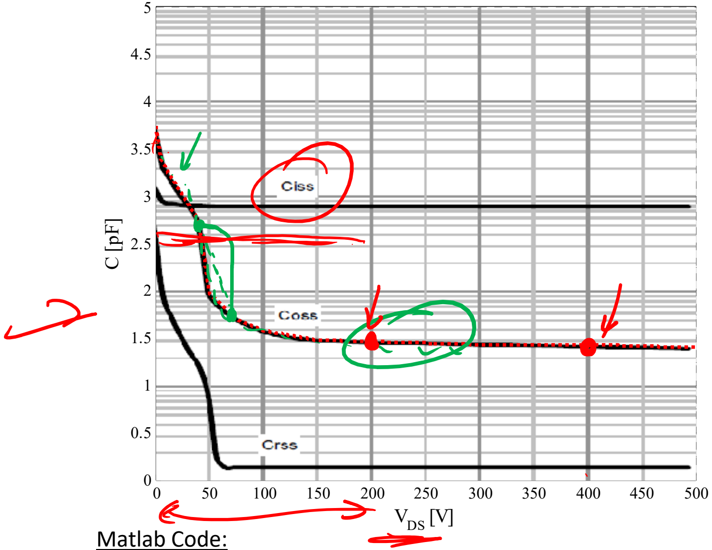
$$E_{total} = \frac{1}{2} C_{eq,E\_M2} V_{DC}^2 + V_{DC}^2 C_{eq,Q\_M1} - \frac{1}{2} C_{eq,E\_M1} V_{DC}^2$$

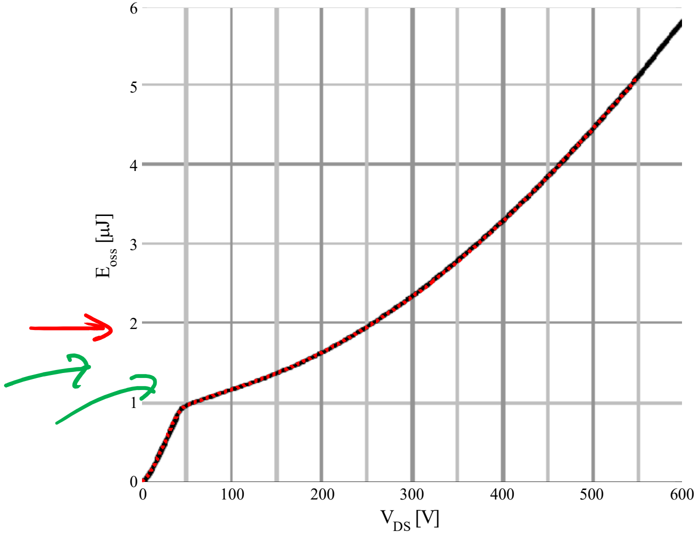
If M_1 & M_2 are identical

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

then energy loss depends only on Q-equiv capacitance

Energy Equivalent





Matlab Code:

```
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;
```

Nonlinear Capacitance Extraction

- http://web.eecs.utk.edu/~dcostine/personal/PowerDeviceLib/DigiTest/index.html

Datasheet Reported Capacitance

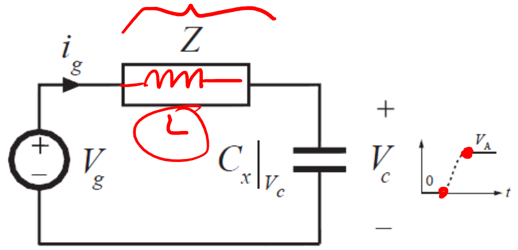
Dynamic characteristics

Input capacitance	C_{iss}	V_{GS}=0 V, V_{DS}=100 V, f=1 MHz	-	790	-	pF
Output capacitance	C_{oss}		-	38	-	
Effective output capacitance, energy related[6]	$C_{o(er)}$	V_{GS}=0 V, V_{DS}=0 V to 480 V	-	36	-	
Effective output capacitance, time related[7]	$C_{o(tr)}$		-	96	-	
Turn-on delay time	$t_{d(on)}$	V_{DD}=400 V, V_{GS}=10 V, I_D=5.2 A, R_G=3.3 Ω	-	10	-	ns
Rise time	t_r		-	5	-	
Turn-off delay time	$t_{d(off)}$		-	40	-	
Fall time	t_f		-	5	-	

6) $C_{o(er)}$ is a fixed capacitance that gives the same stored energy as C_{oss} while V_{DS} is rising from 0 to 80% V_{DSS}.

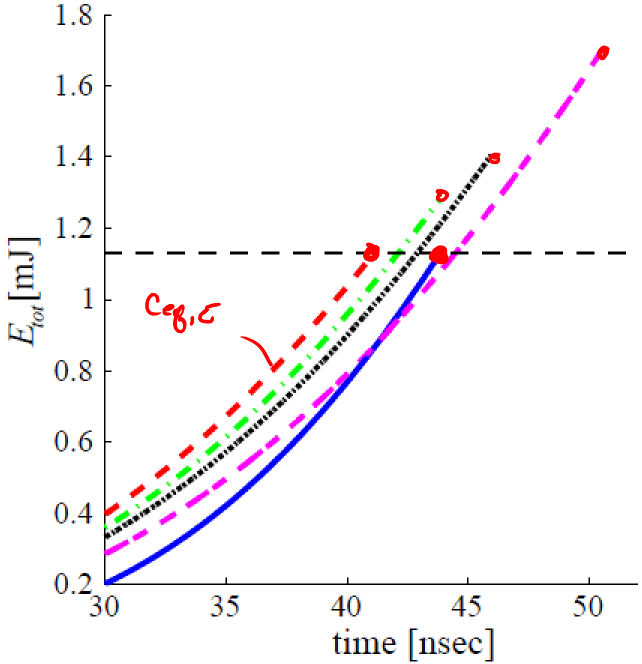
7) $C_{o(tr)}$ is a fixed capacitance that gives the same charging time as C_{oss} while V_{DS} is rising from 0 to 80% V_{DSS}.

Example Simulation

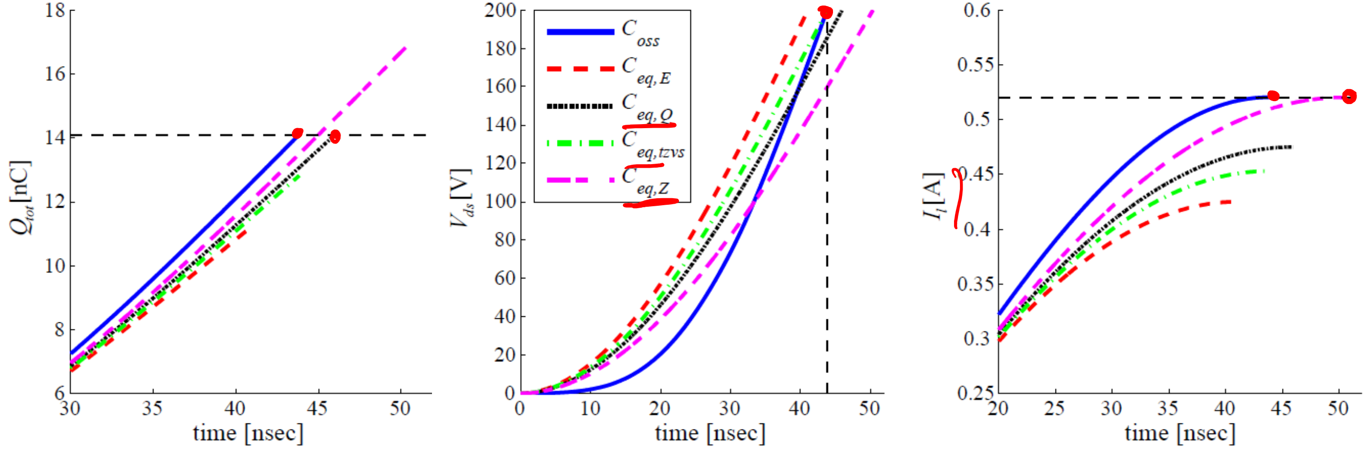


$C_{eq,Q} = 70.5$ pF, $C_{eq,E} = 56.4$ pF,

$C_{eq,tzvs} = 64.1$ pF $C_{eq,Z} = 84.5$ pF.



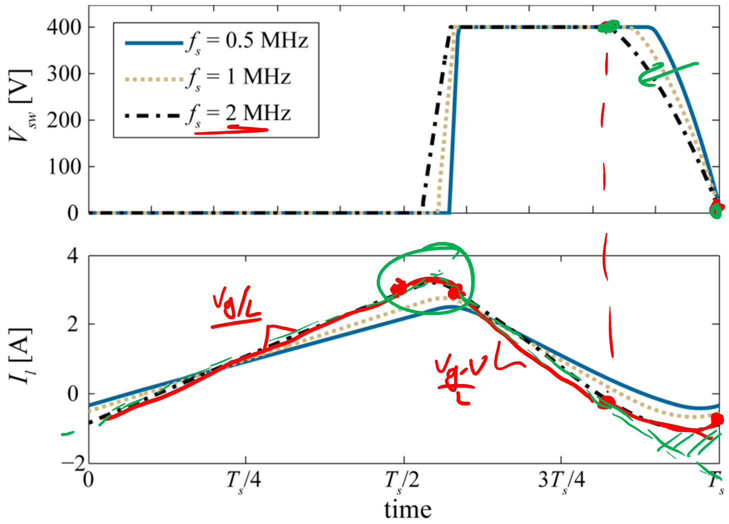
Further Simulation



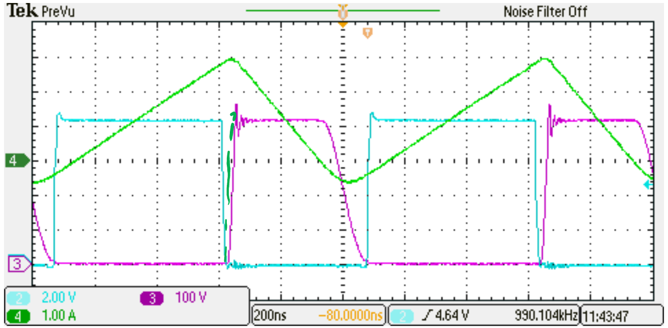
Solving resonance in power electronics

STATE PLANE ANALYSIS

Motivation



f_s = 0.5 MHz
f_s = 1 MHz
f_s = 2 MHz
V_{sw} [V]
400
300
200
100
0
I_l [A]
4
2
0
−2
0
$T_s/4$
$T_s/2$
$3T_s/4$
T_s
time

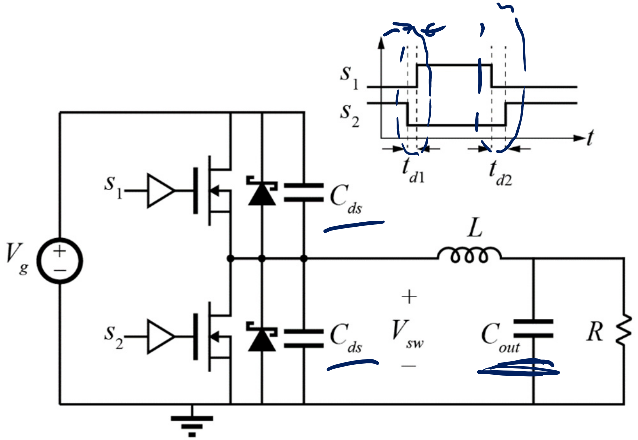


Tek PreVu
Noise Filter Off
4
3
2 2.00 V
3 100 V
4 1.00 A
200ns
−80.0000ns
2 ⁄ 4.64 V
990.104kHz
11:43:47

Time-Domain Analysis of Switching Transitions

(1) Assume Cout is a filter element with small ripple

(2) Assume Cds is linear



during dead time