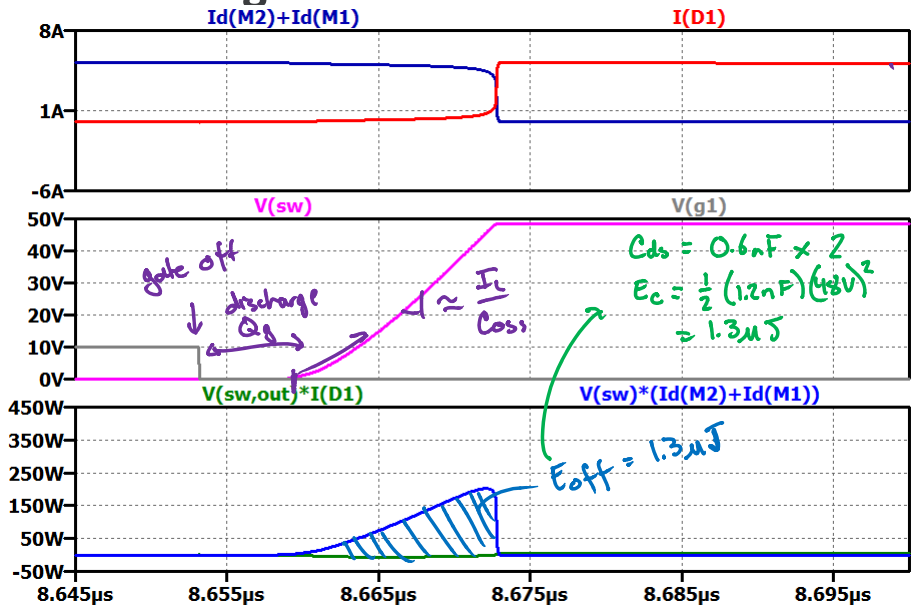
Switching Transition – FET turn OFF



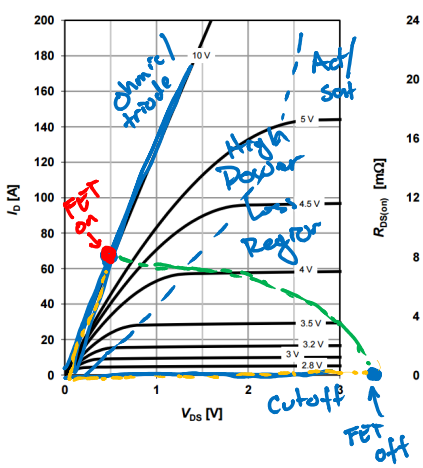
MOSFET Switching Behaviors

(1) static characteristics

5 Typ. output characteristics

I_D=f(V_{DS}); T_j=25 °C

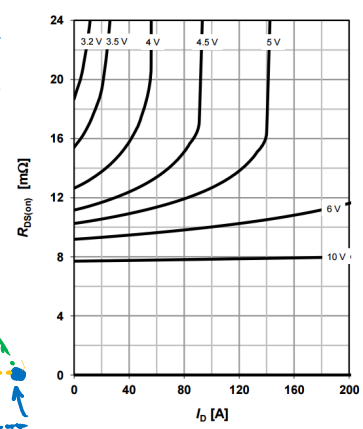
parameter: V_{GS}



6 Typ. drain-source on resistance

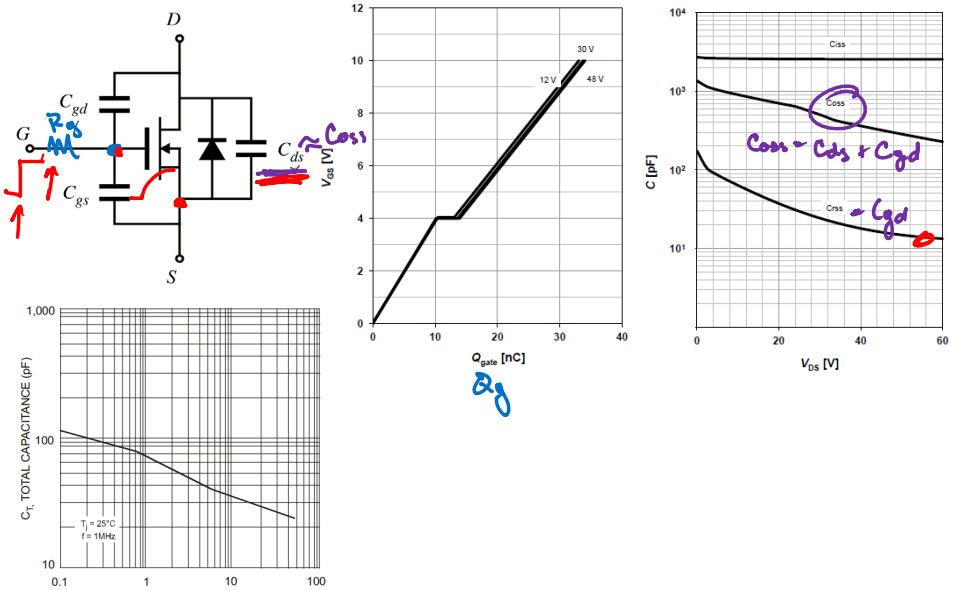
$R_{DS(on)}$=f(I_D); T_j=25 °C

parameter: V_{GS}



MOSFET Stored Charge

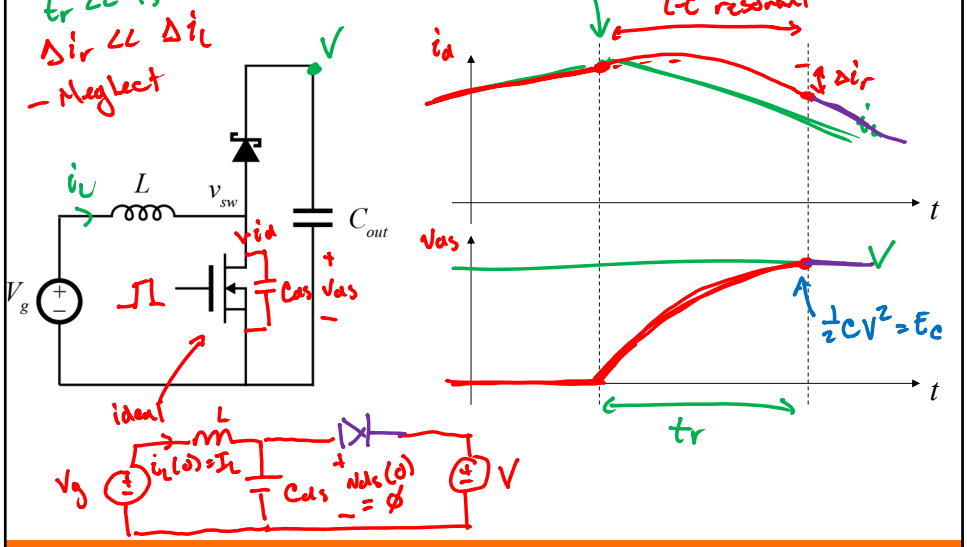
(2) Dynamic behavior



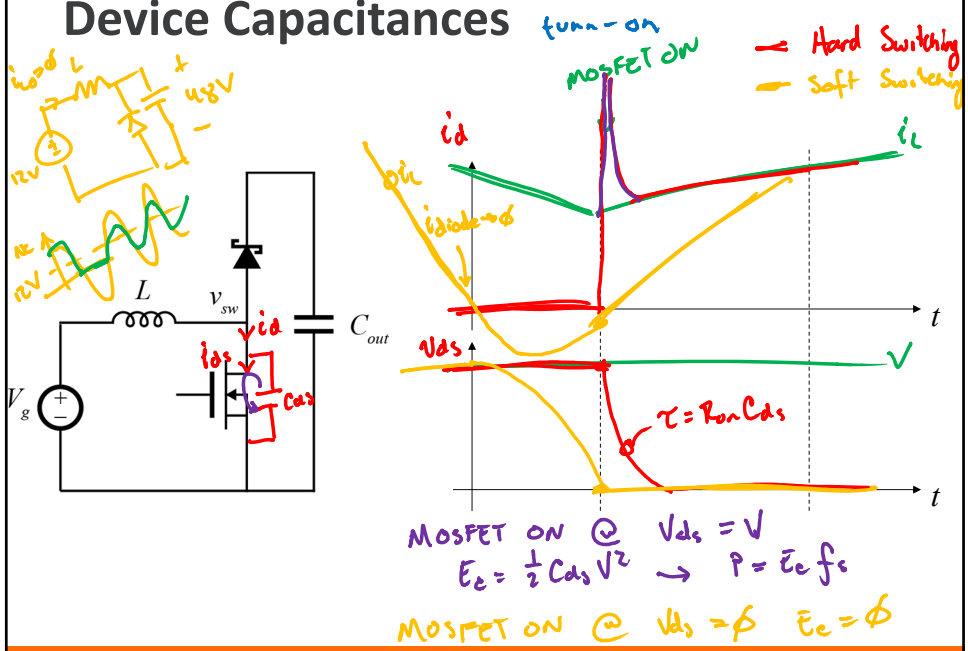
Device Capacitances

ECE 481:
$t_r \ll T_s$
$\Delta i_r \ll \Delta i_L$
– Neglect

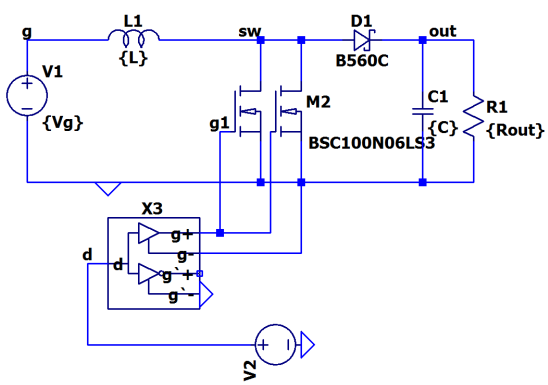
turn-off
MOSFET OFF
L-C resonant



Device Capacitances

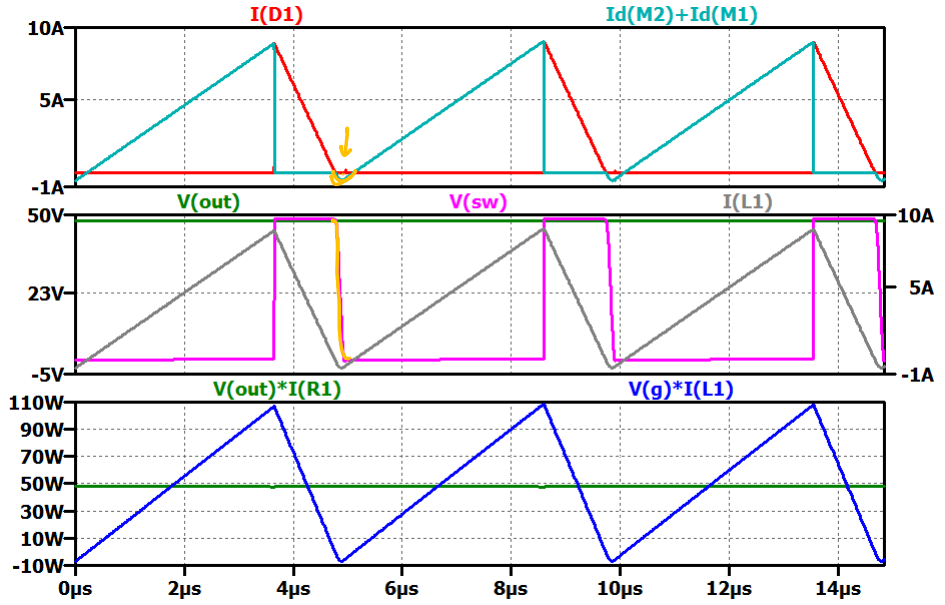


DCM: Soft Switching

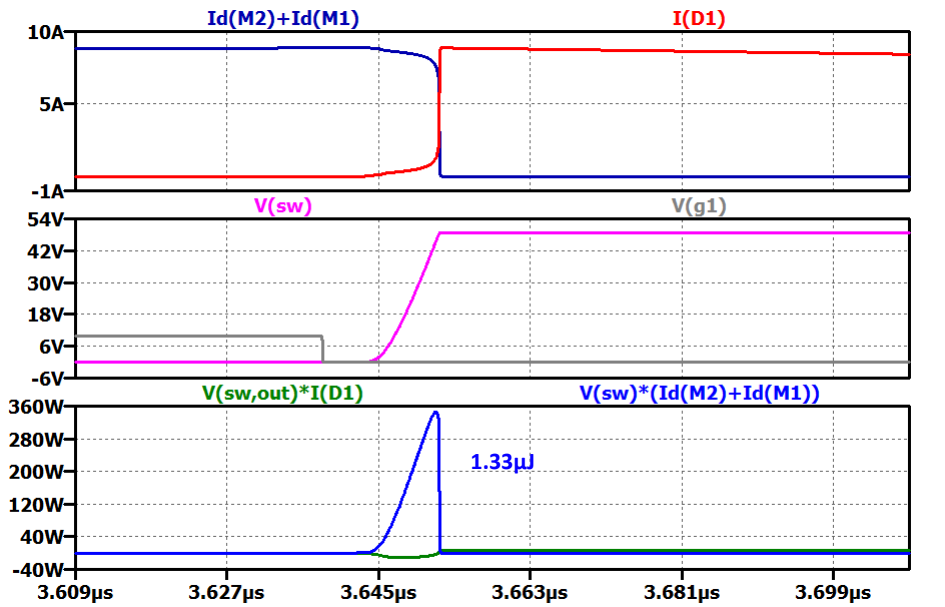


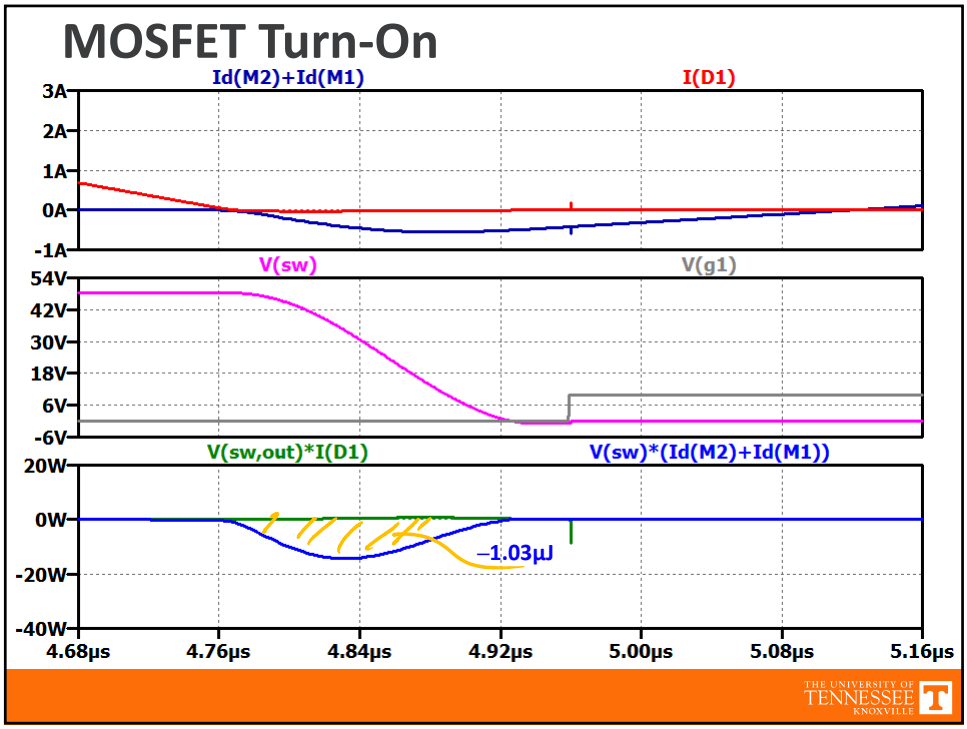
L	C_{out}	f_s	Diode	η (Sim)
22uH	22uF	202k	Si (FR)	93.9%
22uH	22uF	202k	Si Schottky	95.8%
4.6uH	22uF	202k	Si Schottky	98.2%

DCM Simulation



MOSFET Turn-Off




MOSFET Turn-On
Id(M2)+Id(M1)
I(D1)
3A
2A
1A
0A
-1A
V(sw)
V(g1)
54V
42V
30V
18V
6V
-6V
V(sw,out)*I(D1)
V(sw)*(Id(M2)+Id(M1))
20W
0W
-20W
-40W
–1.03µJ
4.68µs
4.76µs
4.84µs
4.92µs
5.00µs
5.08µs
5.16µs
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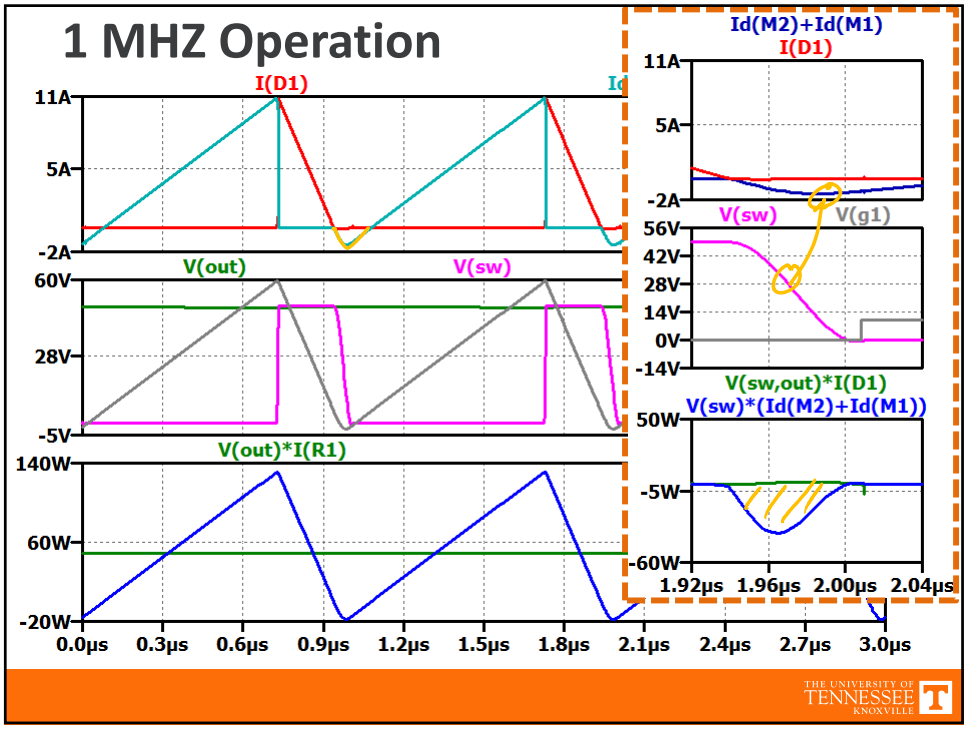
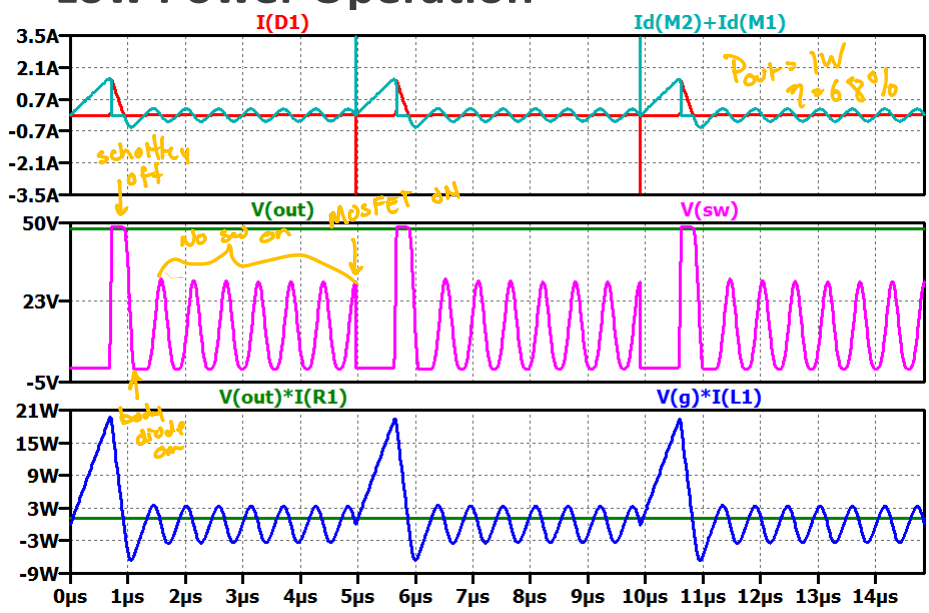
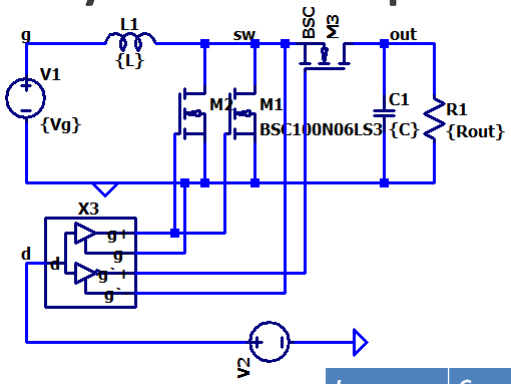

1 MHZ Operation
I(D1)
11A
5A
-2A
V(out)
V(sw)
60V
28V
-5V
V(out)*I(R1)
140W
60W
-20W
0.0µs
0.3µs
0.6µs
0.9µs
1.2µs
1.5µs
1.8µs
2.1µs
2.4µs
2.7µs
3.0µs
Id(M2)+Id(M1)
I(D1)
11A
5A
-2A
V(sw)
V(g1)
56V
42V
28V
14V
0V
-14V
V(sw,out)*I(D1)
V(sw)*(Id(M2)+Id(M1))
50W
-5W
-60W
1.92µs
1.96µs
2.00µs
2.04µs
THE UNIVERSITY OF TENNESSEE KNOXVILLE

Low Power Operation

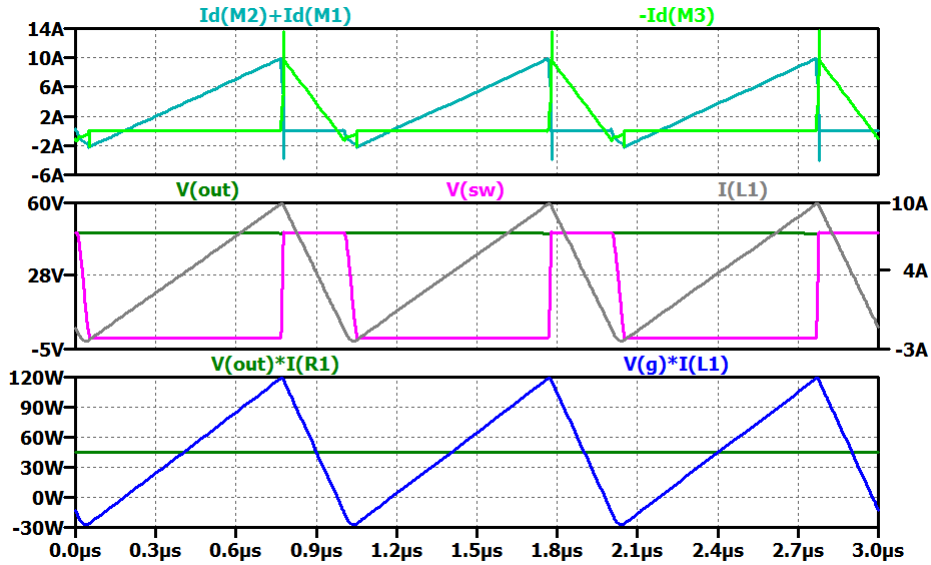


Synchronous Operation

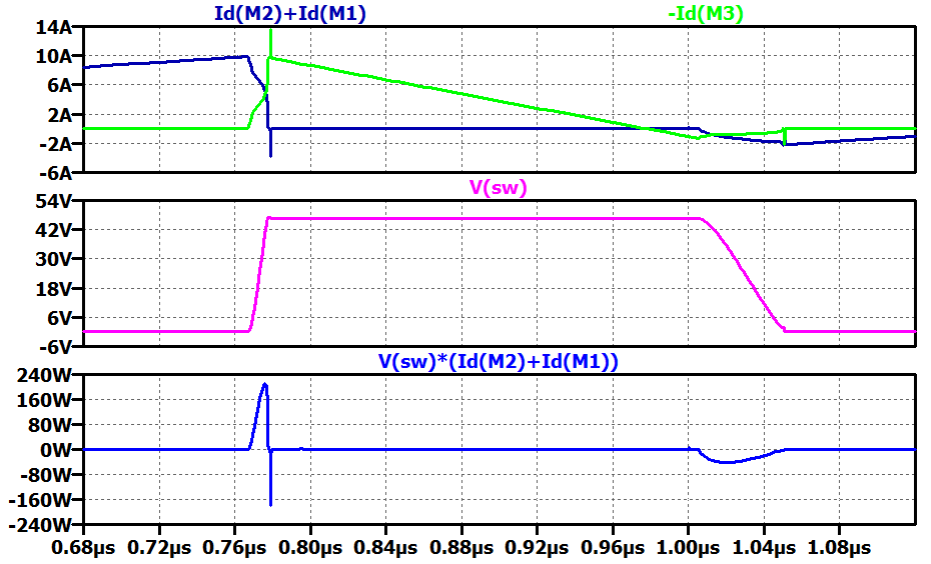


L	C_{out}	f_s	Diode	η (Sim)
22uH	22uF	202k	Si (FR)	93.9%
22uH	22uF	202k	Si Schottky	95.8%
4.65uH	22uF	202k	Si Schottky	98.4%
710nH	4.4uF	1 MHz	Si Schottky	98.2%
710nH	4.4uF	1 MHz	MOSFET	99.6%

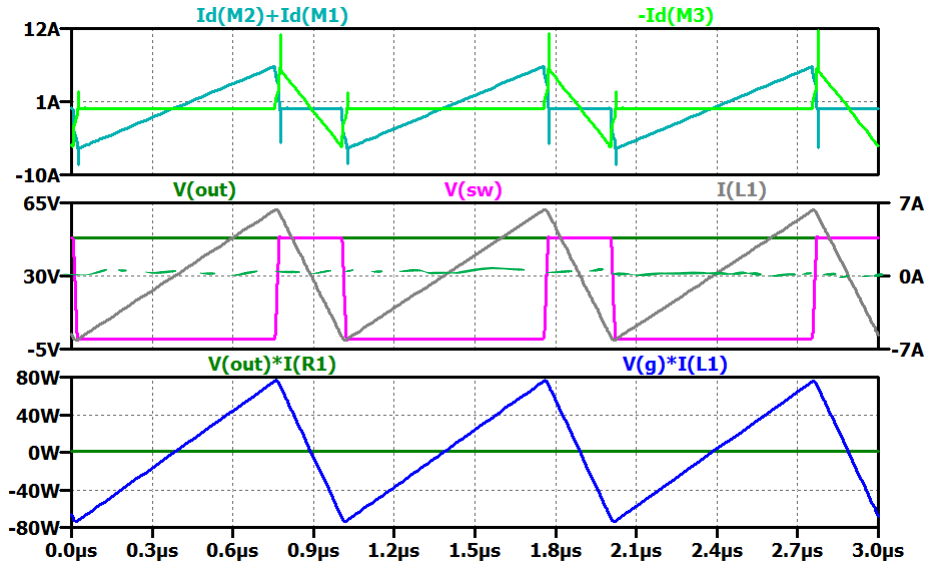
Synchronous Simulation



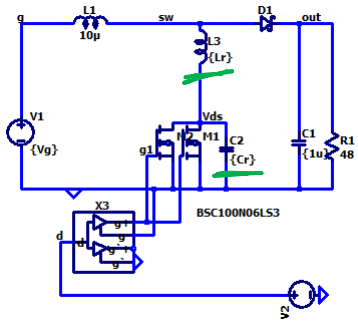
Switching Transitions



Low Power Operation

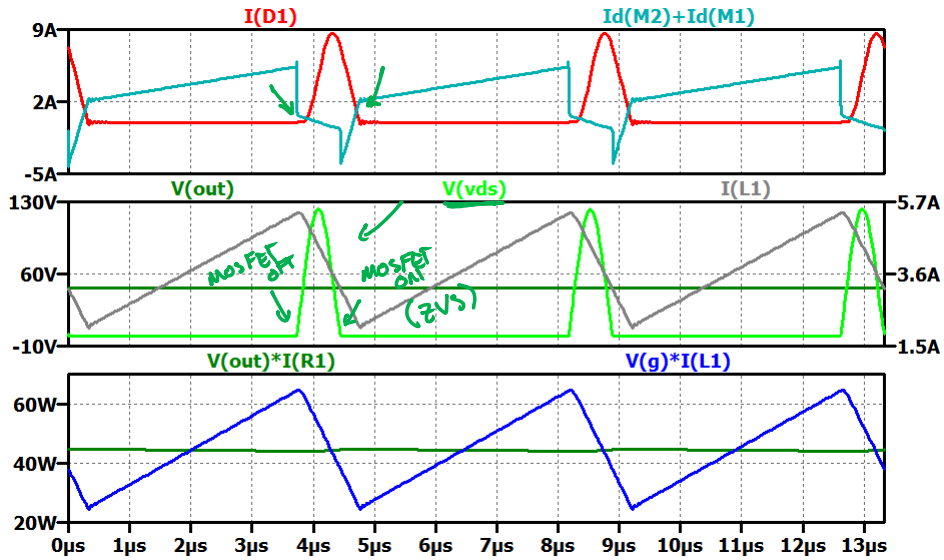


Resonant Operation

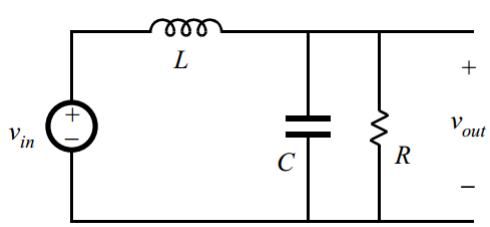


Switching	*L*	C_{out}	f_s	Diode	η (Sim)
Hard	22uH	22uF	202k	Si (FR)	93.9%
Hard	22uH	22uF	202k	Si Schottky	95.8%
Soft	4.65uH	22uF	202k	Si Schottky	98.4%
Soft	710nH	4.4uF	1 MHz	Si Schottky	98.2%
Soft	710nH	4.4uF	1 MHz	MOSFET	99.6%
Resonant	10uH + 2.4uH	1uF + 10nF	225 kHz	Si Schottky	98.6%

Resonant Boost Converter



Resonant Circuits



ECE 481:

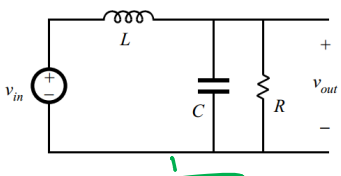
$i_L \approx I_L$

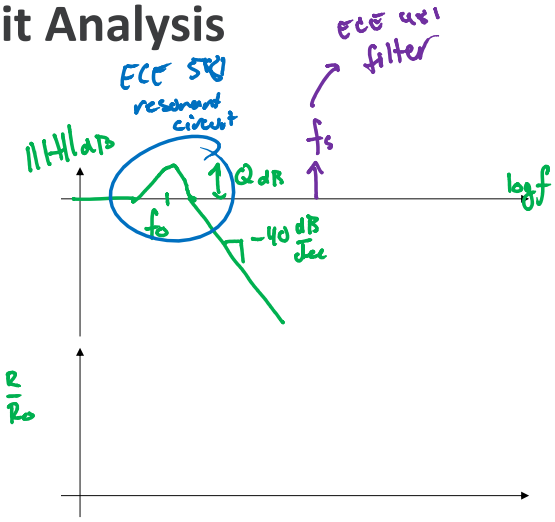
$v_{out} \approx V$

does not apply

$$LC\frac{d^2 v_{out}}{dt^2} + \frac{L}{R}\frac{dv_{out}}{dt} + (v_{out} - v_{in}) = \emptyset$$

Resonant Circuit Analysis



$$H(s) = \frac{1}{s^2 LC + \frac{L}{R}s + 1}$$

$$\omega_0 = \frac{1}{\sqrt{LC}} \quad R_0 = \sqrt{\frac{L}{C}} \quad Q = \frac{R}{R_0}$$