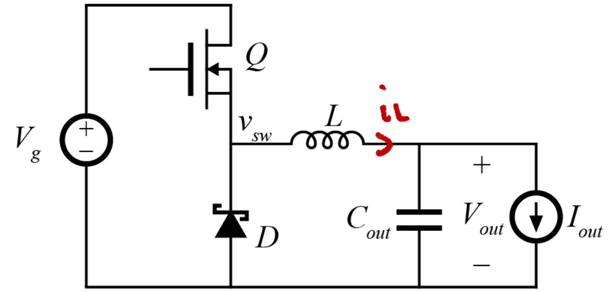
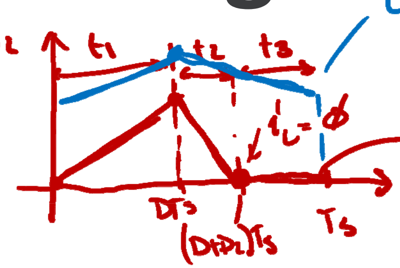
State-dependent Switching

DCM Buck





$t_1 \rightarrow$ defined by external modulation signal

CCM $t_2 = T_s - t_1$

$x(T_s) = e^{A_2 t_2} e^{A_1 t_1} x(0)$

DCM: $t_1 \rightarrow$ same

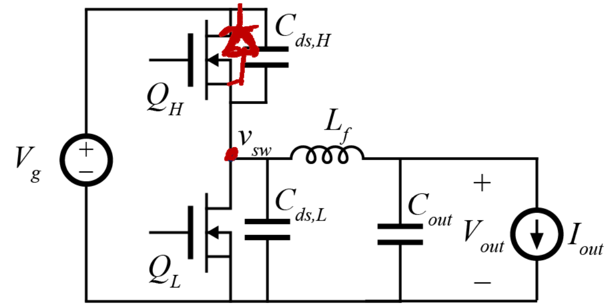
$t_2 \rightarrow$ defined by $i_L(t) > 0$

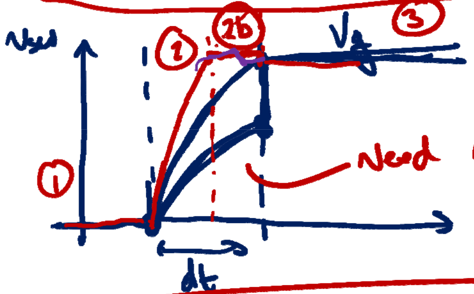
$t_3 \rightarrow T_s - t_1 - t_2$

$x(T_s) = e^{\tilde{A}_3 t_3} e^{\tilde{A}_2 t_2^*} e^{A_1 t_1} x(0)$

Neither / Diode ON / FET ON

ZVS Buck

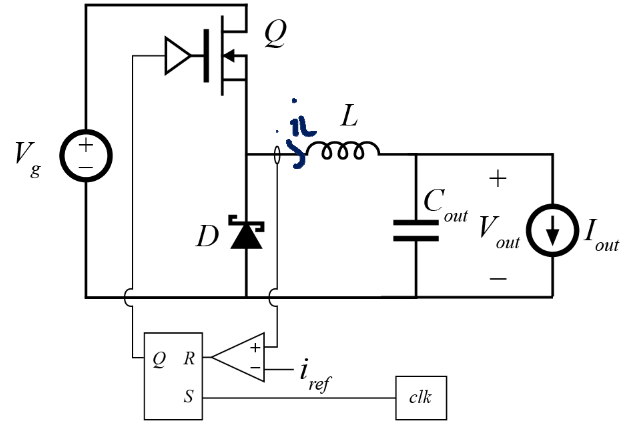


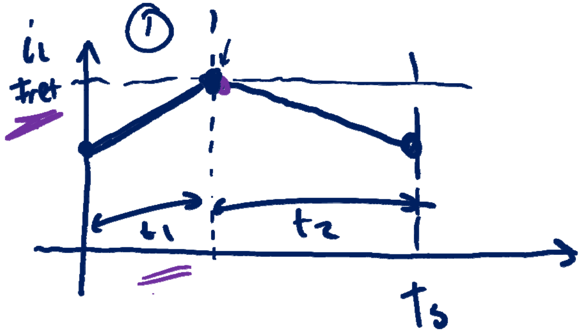


t_{2b}

Need Add'l interval if we overshoot ZVS

CPM Buck

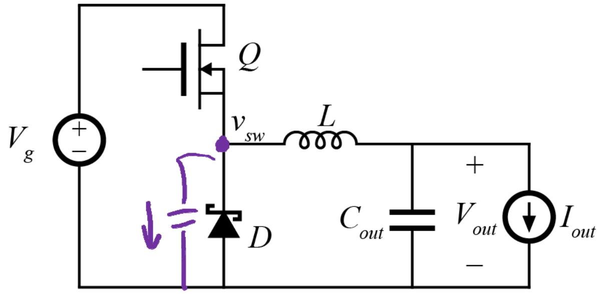


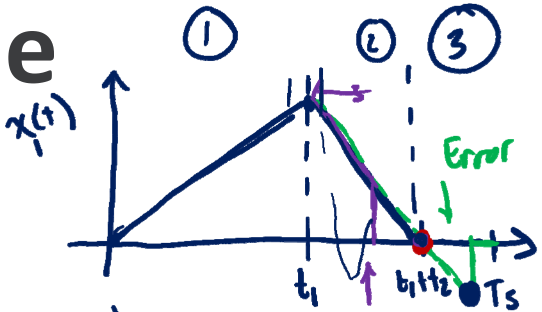


$t_1 \rightarrow$ whatever time it takes to get $i_L(t) = I_{ref}$

$t_2 \rightarrow T_s - t_1$

DCM Buck Example





Error from t_2 > actual

Assume Homogeneous system (Augmented state space, etc.)

$$\boxed{x(T_s) = e^{A_3 t_3} e^{A_2 t_2} e^{A_1 t_1} x(0)}$$

in steady-state $\boxed{X_{ss} = x(0) = x(T_s)}$

t_1 is known, T_s is known, $\underline{t_2}$ depends on waveform of $x_1(t)$

can solve steady-state solution for any t_2

Add a second equation

$$i_L(t_1+t_2) = \phi$$

$$x(t_1+t_2) = e^{A_2 t_2} e^{A_1 t_1} X_{ss}$$

$$i_L(t_1+t_2) = \boxed{C_L e^{A_2 t_2} e^{A_1 t_1} X_{ss} = \phi}$$

define $C_L = [\,0\,0 \cdots 1 \cdots 0\,0\,]$

corresponds to $i_L(t)$ in $x(t)$

Need to solve both equations together as a system

In general, this will require numerical iteration

Generalized State Space Modeling

General Case:

indep. inputs

$$\begin{cases} X_{ss} = f(t_i, u, v_i) \\ \phi = g(X_{ss}, t_i, u, v_i) \end{cases}$$

vector of times $t_i = [t_1, t_2 \ldots]$

vector of subinterval sequence $v_i = [1, 2, 3 \ldots]$

Not bad to iterate if v_i is known & any violation is at an interface between two switching states