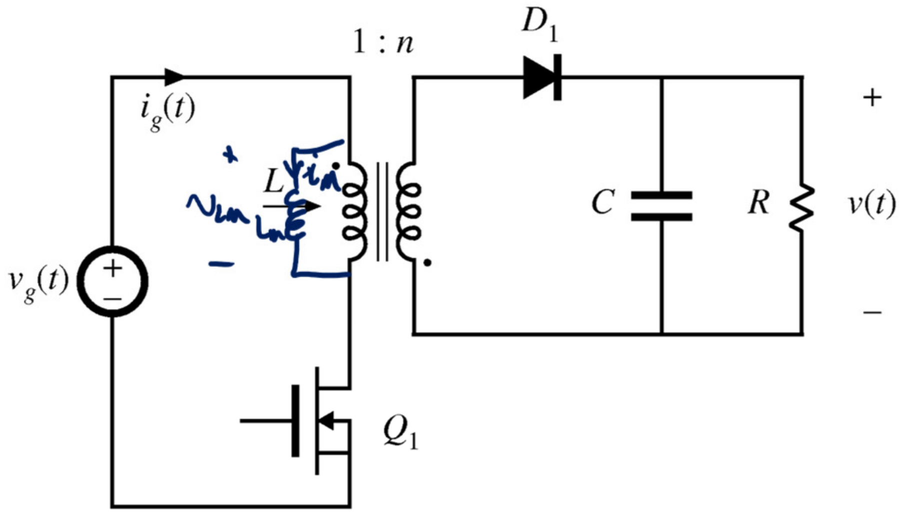
Nonideal Flyback



Flyback:

Has finite L_m

→ model R_{on} of Q_1

Averaging

$$\langle v_{Lm} \rangle = L \frac{d\langle i_m \rangle}{dt} = d(t)\left[\langle v_g \rangle - \langle i_m \rangle R_{on}\right] + d'(t)\left(-\frac{\langle v \rangle}{n}\right)$$

$$\langle i_c \rangle = C \frac{d\langle v \rangle}{dt} = -\frac{\langle v \rangle}{R} + d'(t)\frac{\langle i_m \rangle}{n}$$

$$\langle i_g \rangle = d(t)\langle i_m \rangle$$

Flyback Linearization

$i_m(t) = i(t)$

$$L \frac{d\langle i(t)\rangle_{T_s}}{dt} = d(t)\,\langle v_g(t)\rangle_{T_s} - d(t)\,\langle i_m(t)\rangle_{T_s} R_{on} - d'(t)\,\frac{\langle v(t)\rangle_{T_s}}{n}$$

$$L\frac{d\hat{i}}{dt} = \hat{d}\left(V_g - I_m R_{on} + \frac{V}{n}\right) + \hat{v}_g D + \hat{i}_m(-D R_{on}) + \hat{v}\left(-\frac{D'}{n}\right)$$

$$C \frac{d\langle v(t)\rangle_{T_s}}{dt} = d'(t)\,\frac{\langle i_m(t)\rangle_{T_s}}{n} - \frac{\langle v(t)\rangle_{T_s}}{R}$$

$$C\frac{d\hat{v}}{dt} = \hat{d}\frac{I_m}{n} + \hat{i}_m\frac{D'}{n} - \frac{\hat{v}}{R}$$

$$\langle i_g(t)\rangle_{T_s} = d(t)\,\langle i_m(t)\rangle_{T_s}$$

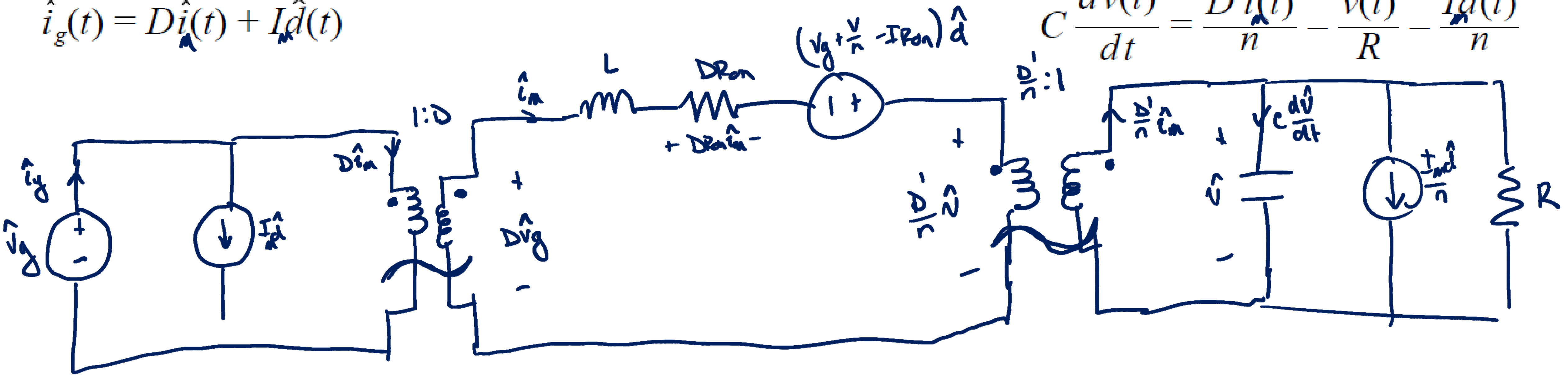
$$\hat{i}_g = I_m\hat{d} + D\hat{i}_m$$

Flyback Small Signal Model

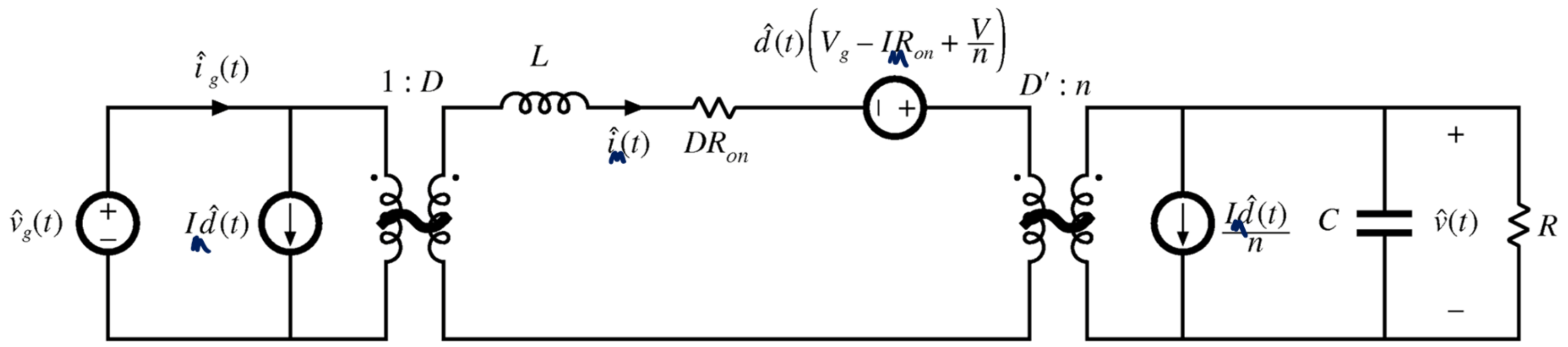
$$L\frac{d\hat{i}(t)}{dt} = D\hat{v}_g(t) - D'\frac{\hat{v}(t)}{n} + \left(V_g + \frac{V}{n} - I_m R_{on}\right)\hat{d}(t) - DR_{on}\hat{i}_m(t)$$

$$\hat{i}_g(t) = D\hat{i}_m(t) + I_m\hat{d}(t)$$

$$C\frac{d\hat{v}(t)}{dt} = \frac{D'\hat{i}_m(t)}{n} - \frac{\hat{v}(t)}{R} - \frac{I_m\hat{d}(t)}{n}$$



Flyback AC Model



This is an LTI equivalent

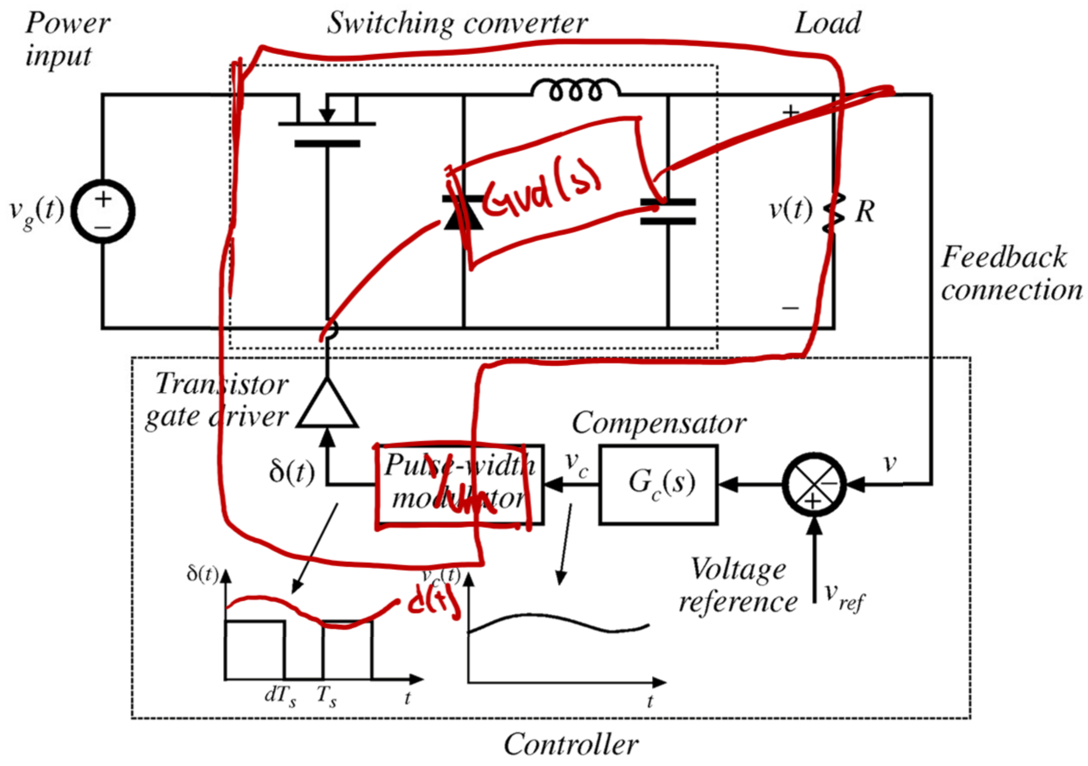
$\hat{v} = f(\hat{v}_g, \hat{d})$

↓ Laplace transform & apply superposition

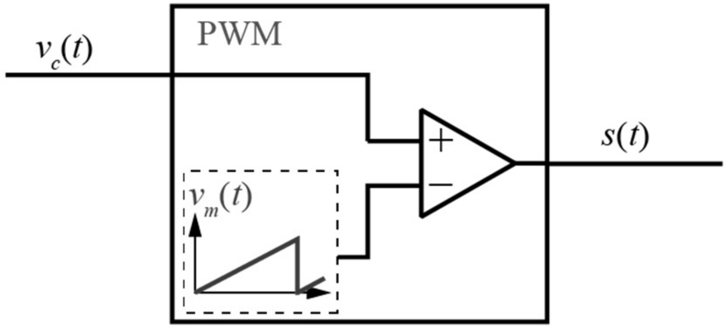
$$\hat{v}(s) = G_{vd}(s)\,\hat{d}(s) + G_{vg}(s)\,\hat{v}_g(s)$$

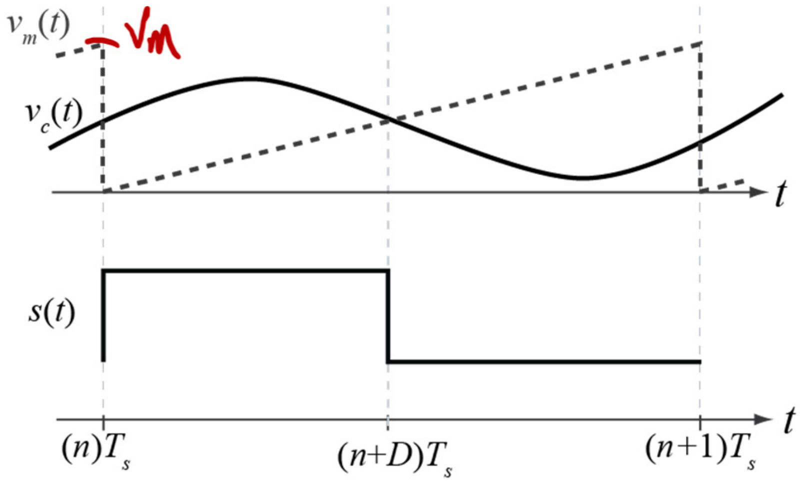
$$G_{vd}(s) = \left.\frac{\hat{v}(s)}{\hat{d}(s)}\right|_{\hat{v}_g(s)=0} \qquad G_{vg}(s) = \left.\frac{\hat{v}(s)}{\hat{v}_g(s)}\right|_{\hat{d}(s)=0}$$

7.3: Modeling Pulse Width Modulator



Functional PWM Model

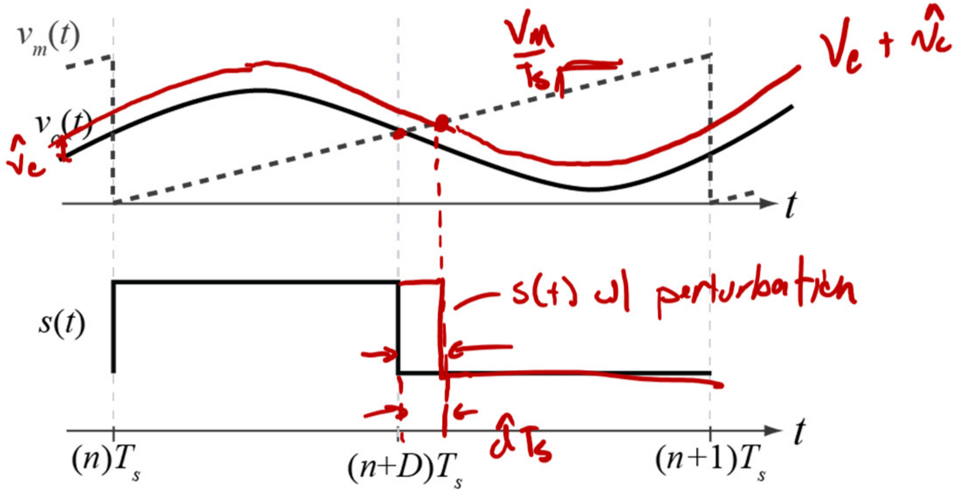




Small-signal model of PWM

$$\hat{d}\,T_s = \hat{v}_c \frac{T_s}{V_M}$$

$$\boxed{\hat{d} = \frac{1}{V_M}\hat{v}_c}$$



Sampling Behavior of PWM