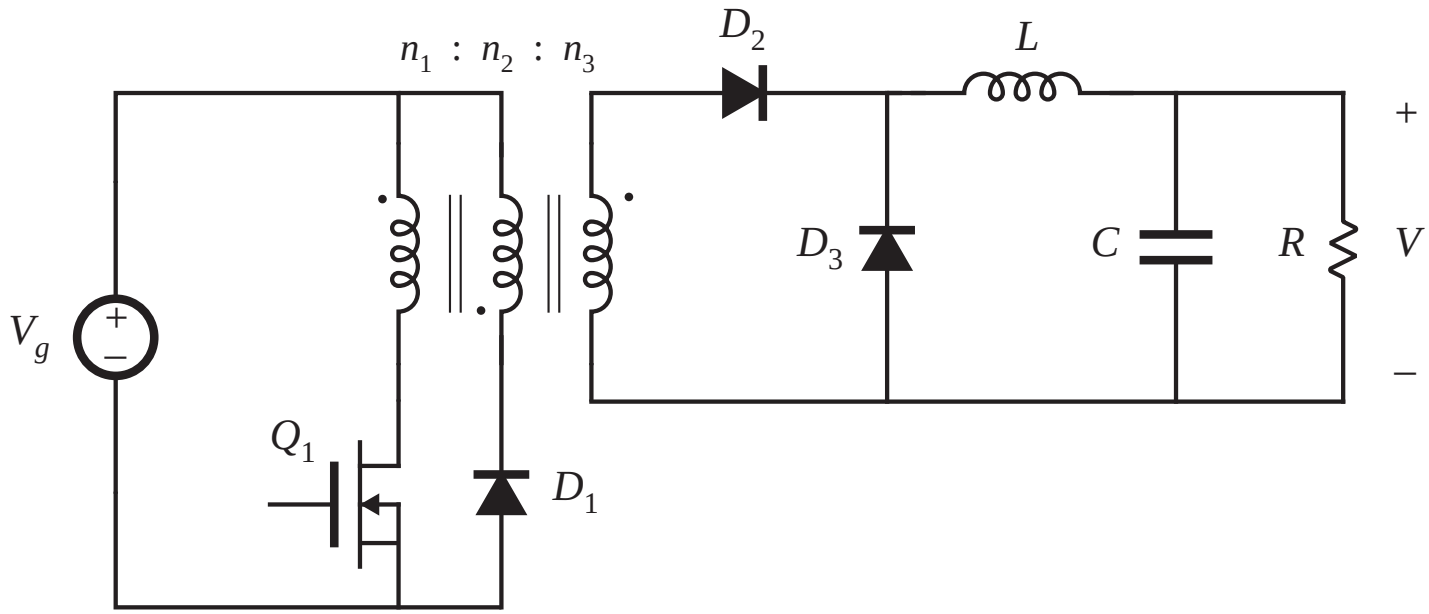
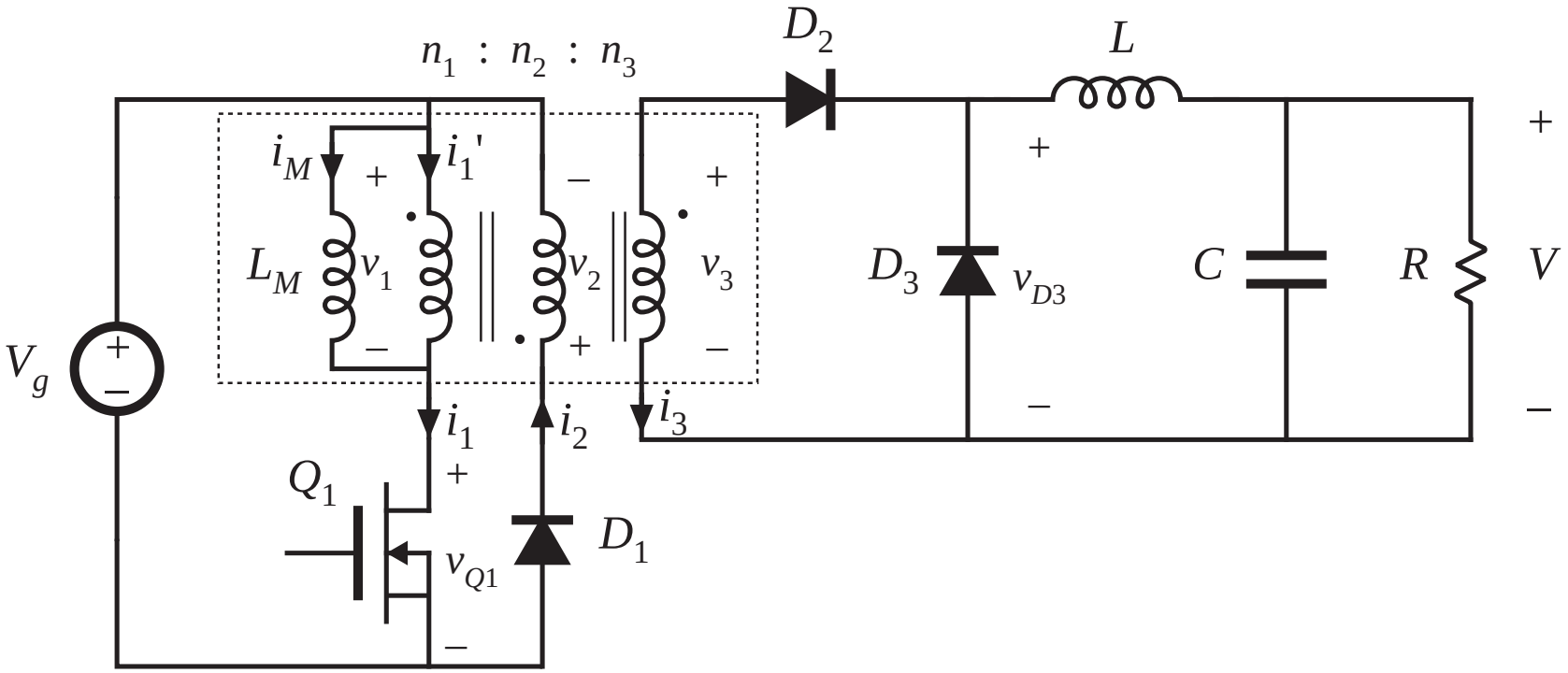
6.3.2. Forward converter

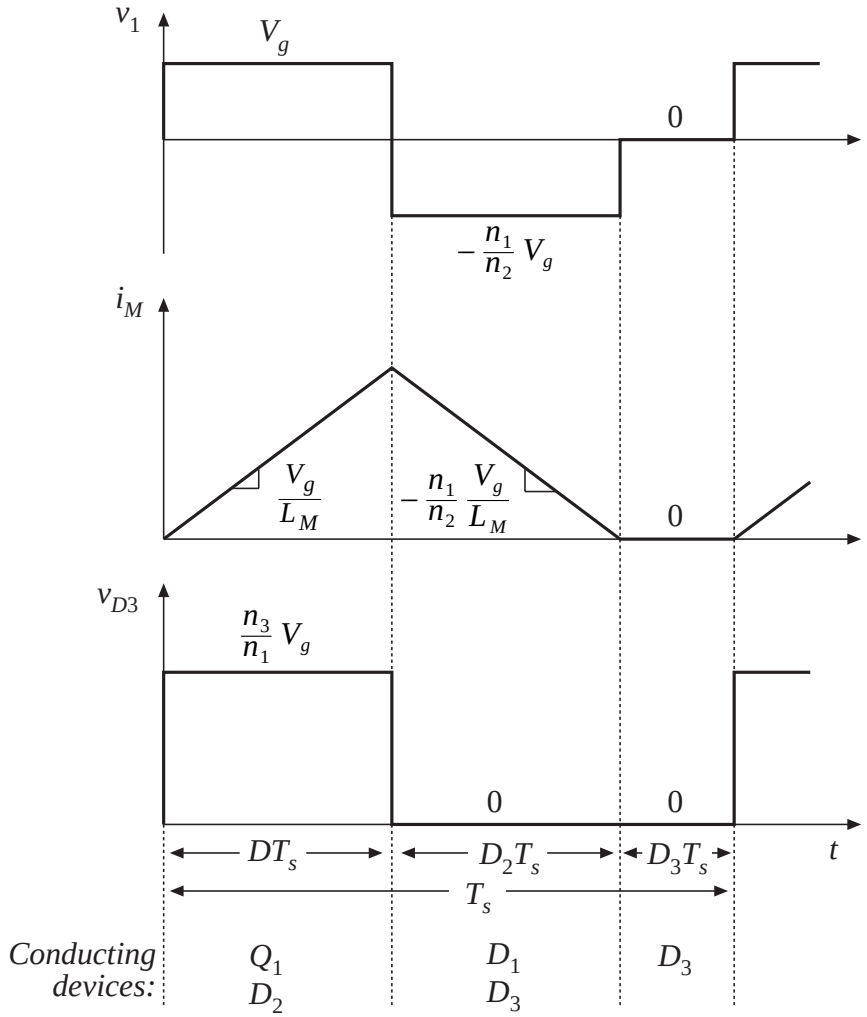


- Buck-derived transformer-isolated converter
- Single-transistor and two-transistor versions
- Maximum duty cycle is limited
- Transformer is reset while transistor is off

Forward converter with transformer equivalent circuit

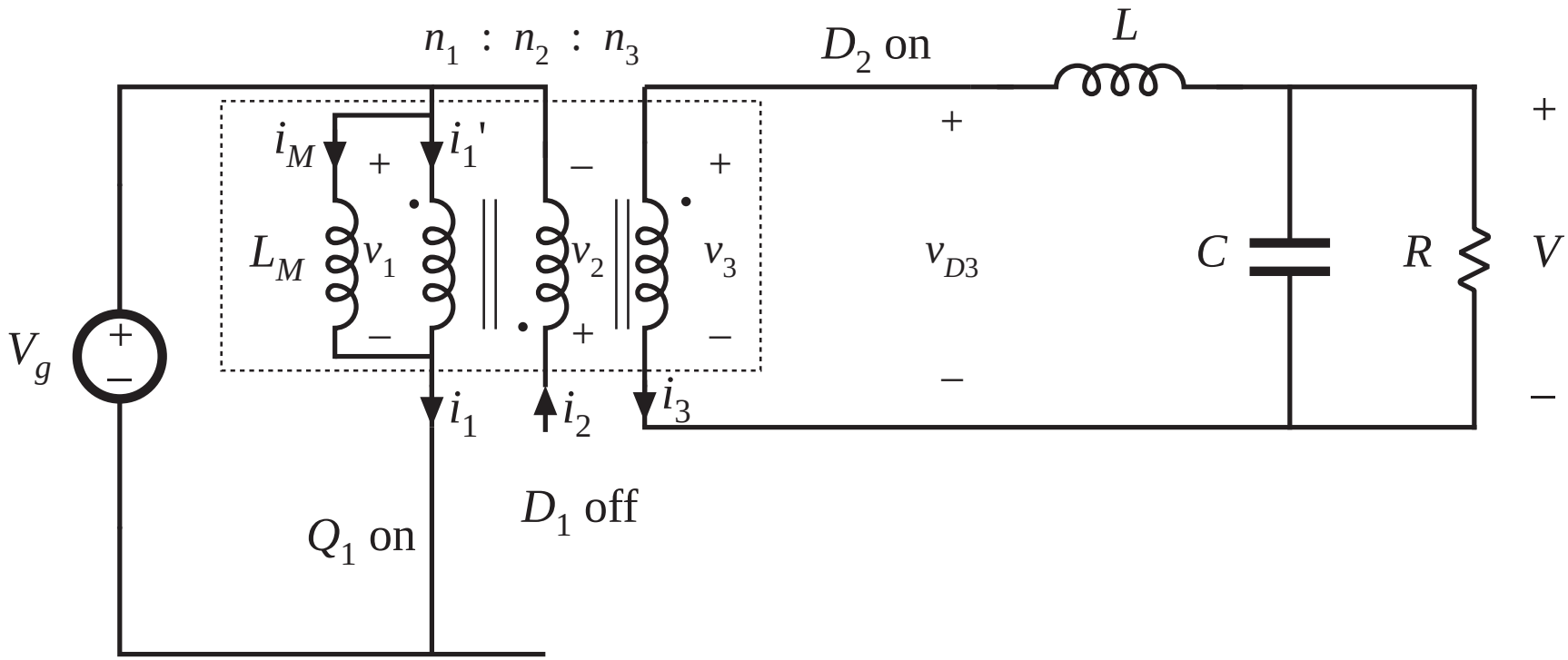


Forward converter: waveforms

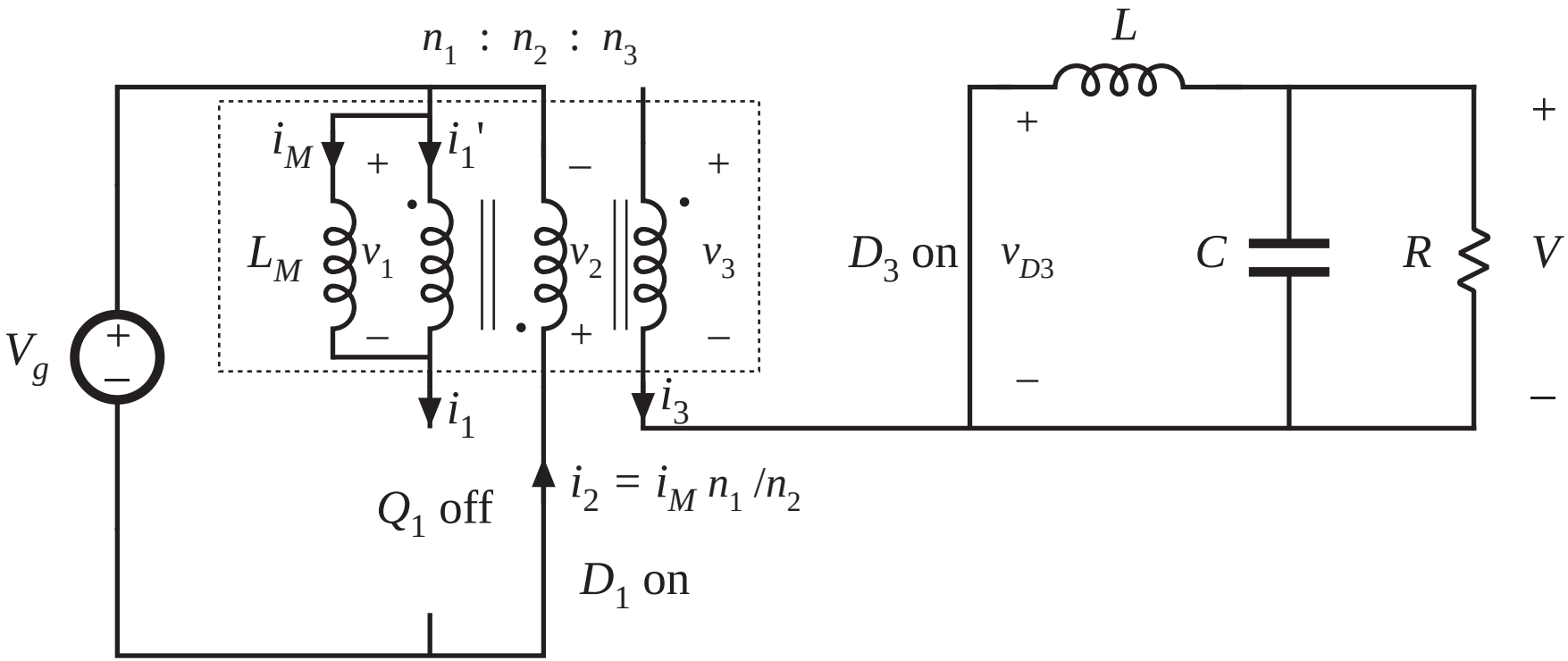


- Magnetizing current, in conjunction with diode D_1, operates in discontinuous conduction mode
- Output filter inductor, in conjunction with diode D_3, may operate in either CCM or DCM

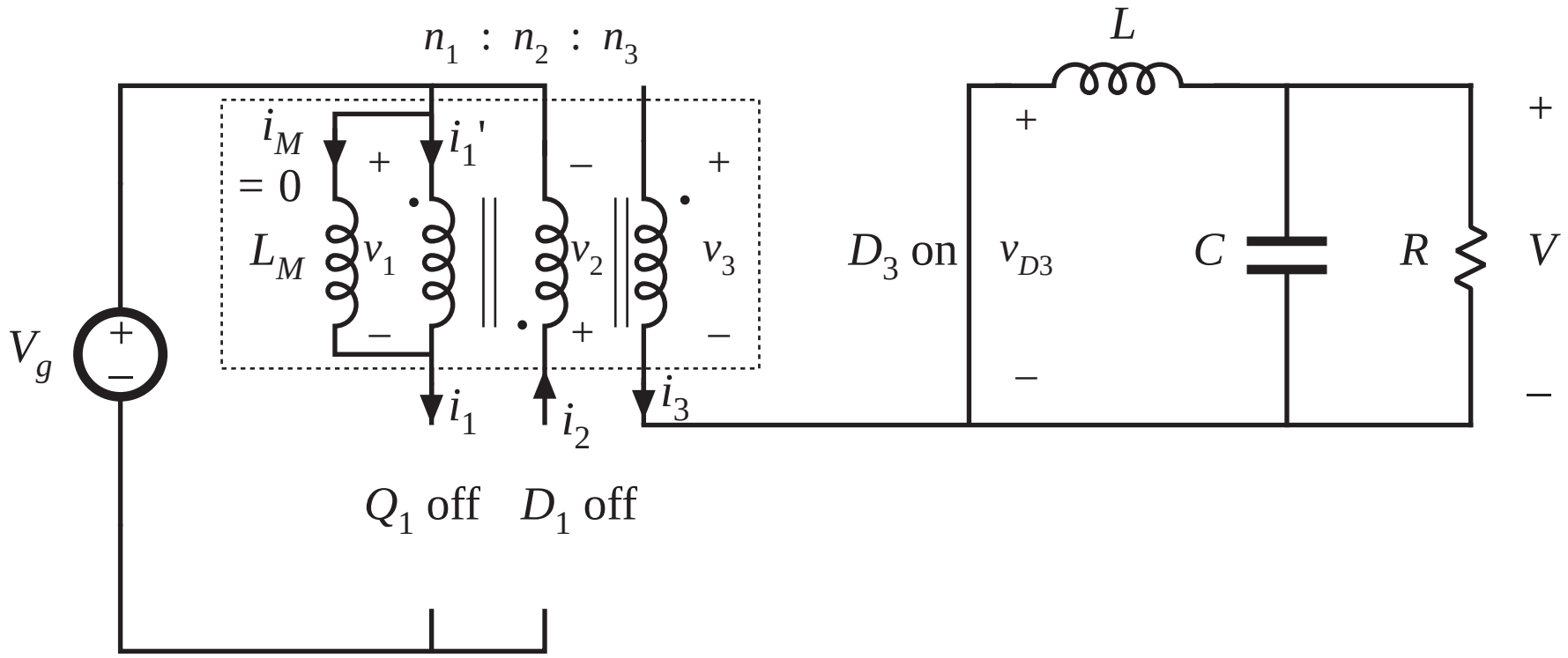
Subinterval 1: transistor conducts



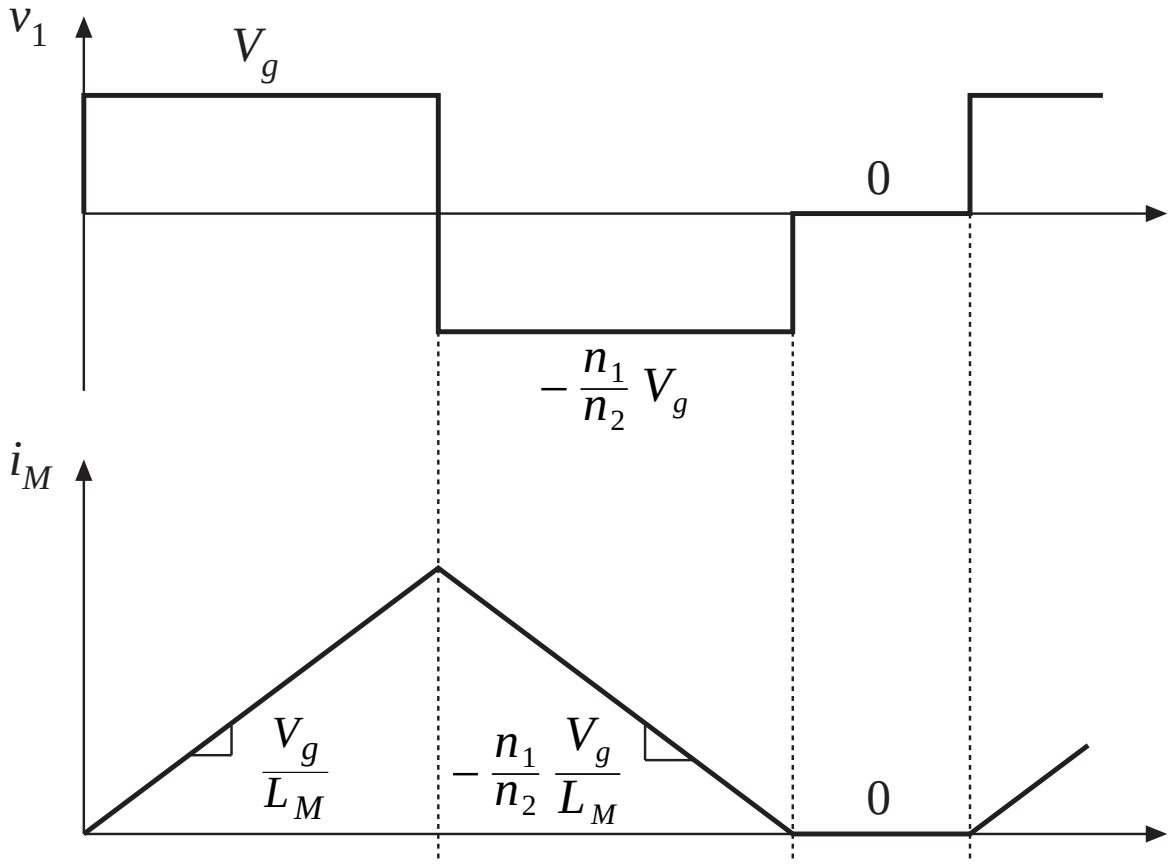
Subinterval 2: transformer reset



Subinterval 3



Magnetizing inductance volt-second balance



$$\langle v_1 \rangle = D\left(V_g\right) + D_2\left(-V_g n_1/n_2\right) + D_3\left(0\right) = 0$$

Transformer reset

From magnetizing current volt-second balance:

$$\langle v_1 \rangle = D\left(V_g\right) + D_2\left(-V_g n_1/n_2\right) + D_3\left(0\right) = 0$$

Solve for D_2:

$$D_2 = \frac{n_2}{n_1} D$$

D_3 cannot be negative. But $D_3 = 1 - D - D_2$. Hence

$$D_3 = 1 - D - D_2 \geq 0$$

$$D_3 = 1 - D\left(1 + \frac{n_2}{n_1}\right) \geq 0$$

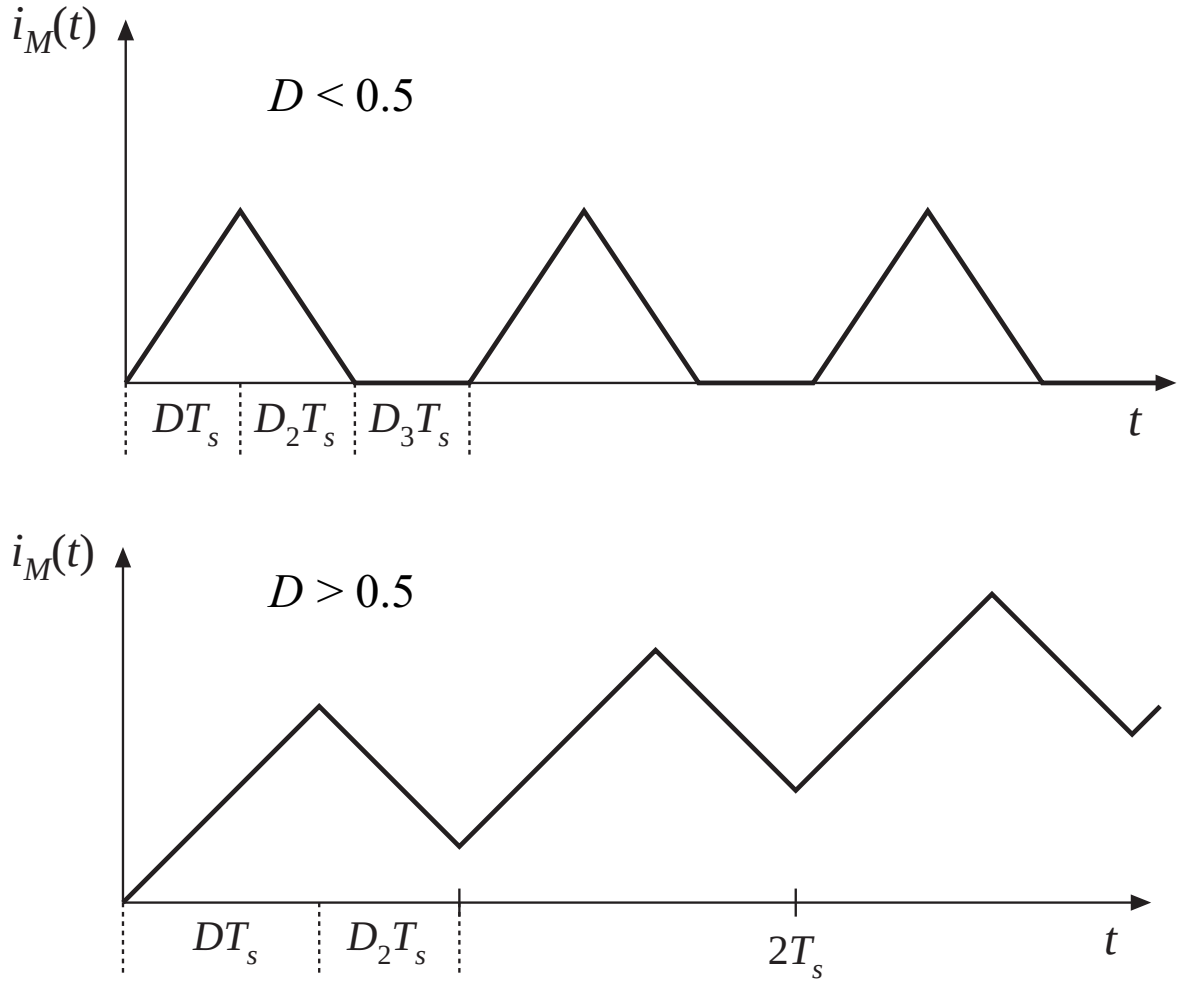
Solve for D

$$D \leq \frac{1}{1 + \frac{n_2}{n_1}}$$

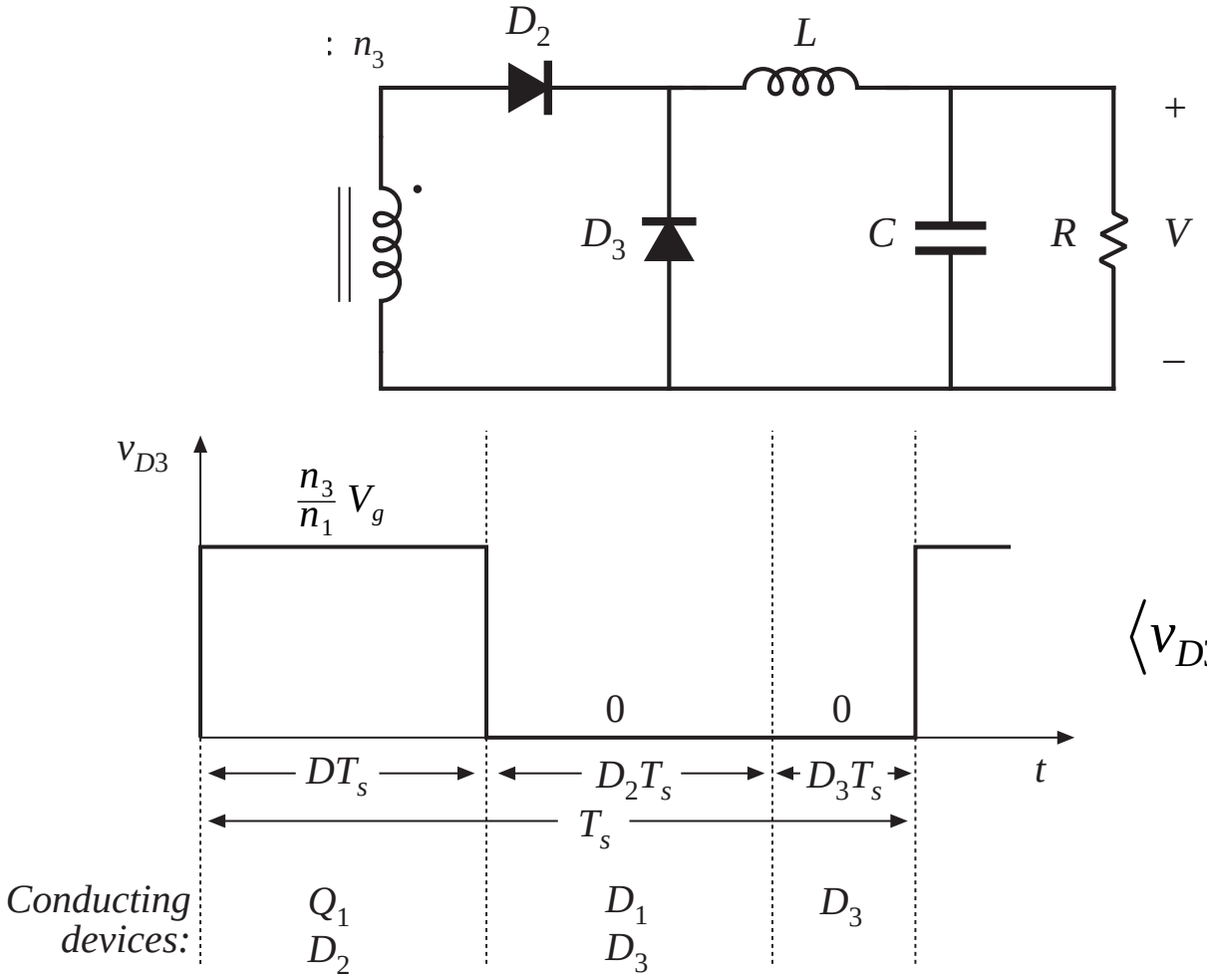
for $n_1 = n_2$: $D \leq \frac{1}{2}$

What happens when $D > 0.5$

magnetizing current waveforms, for $n_1 = n_2$



Conversion ratio *M(D)*



$$\langle v_{D3} \rangle = V = \frac{n_3}{n_1} DV_g$$

Maximum duty cycle vs. transistor voltage stress

Maximum duty cycle limited to

$$D \leq \frac{1}{1 + \frac{n_2}{n_1}}$$

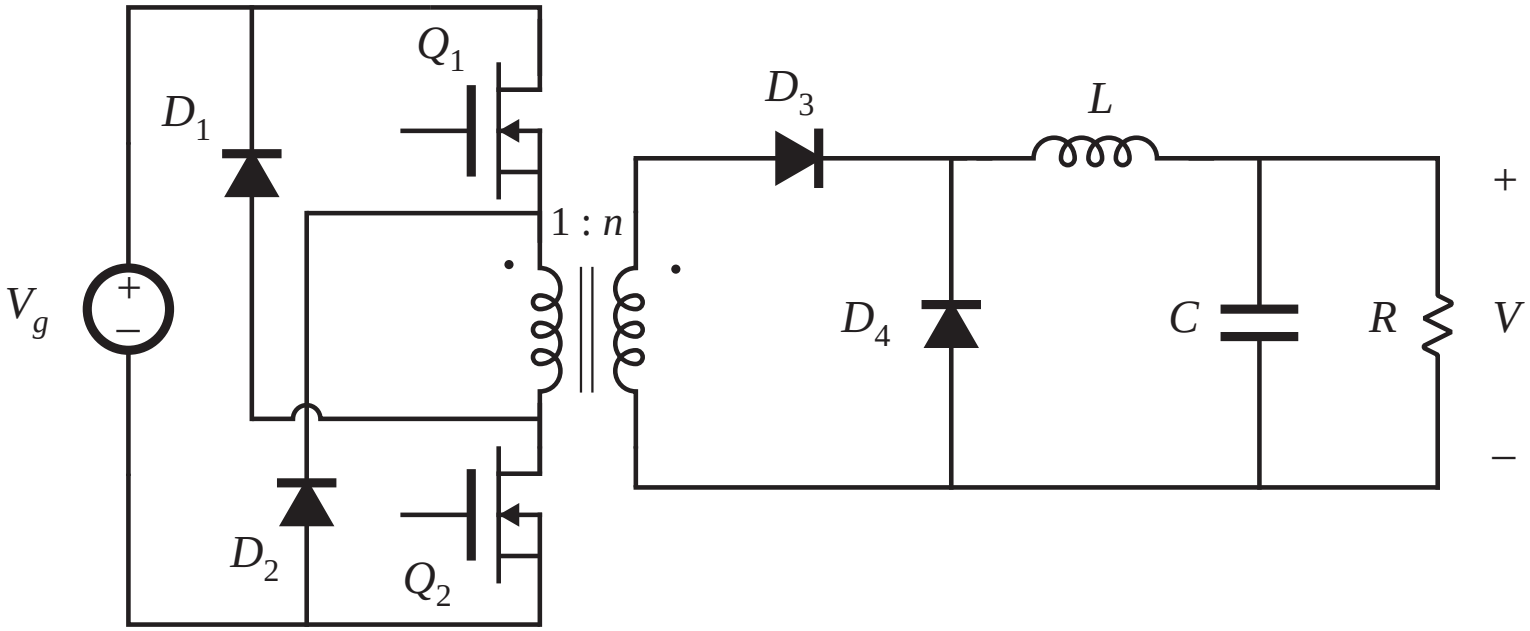
which can be increased by increasing the turns ratio n_2 / n_1. But this increases the peak transistor voltage:

$$\max\left(v_{Q1}\right) = V_g\left(1 + \frac{n_1}{n_2}\right)$$

For $n_1 = n_2$

$$D \leq \frac{1}{2} \qquad \text{and} \qquad \max(v_{Q1}) = 2V_g$$

The two-transistor forward converter



$$V = nDV_g \qquad D \le \frac{1}{2} \qquad \max(v_{Q1}) = \max(v_{Q2}) = V_g$$