2.12 Design a universal buck PWM converter to meet the following specifications: $V_{Imin} = 85\sqrt{2}$ V, $V_{Imax} = 264\sqrt{2}$ V, $V_O = 48$ V, $I_O = 0.2$ to 2 A, $V_r/V_O \leq 1\%$, $f_s = 200$ kHz, $r_L = 1\ \Omega$, $r_{DS} = 1\ \Omega$, $C_o = 100$ pF, $V_F = 0.7$ V, and $R_F = 25$ mΩ.

The maximum output power is

$P_{Omax} = V_O I_{Omax} = 48 \times 2 = 96 W$

$P_{Omin} = V_O I_{Omin} = 48 \times 0.2 = 9.6 W$

$R_{Lmin} = \frac{V_O}{I_{Omax}} = \frac{48}{2} = 24 \Omega$

$R_{Lmax} = \frac{V_O}{I_{Omin}} = 48/0.2 = 240 \Omega$

$V_{Imin} = 85\sqrt{2} = 120.21 V$

$V_{Imax} = 264\sqrt{2} = 373.35 V$

$M_{VDCmin} = V_O / V_{Imax} = 48/373.35 = 0.1286$

$D_{min} = M_{VDCmin} / \eta = 0.1286/0.9 = 0.143$

$D_{max} = M_{VDCmax} / \eta = 0.4/0.9 = 0.4444$

$L_{min} = R_{Lmax}(1 - D_{min}) / 2f_s = 0.5142 mH$

$\Delta i_{Lmax} = V_O(1-D) / f_s L = 0.3428 A$

$V_r = 0.01 V_O = 0.01 \times 48 = 0.48 V$

$r_{Cmax} = V_r / \Delta i_{Lmax} = 0.48/0.3428 = 1.4 \Omega$

$C_{min} = \max\left\{\frac{D_{max}}{2f_s r_C}, \frac{1-D_{min}}{2f_s r_C}\right\} = \frac{0.857}{2 \times 200 \times 10^3} = 2.1425 \mu F$

$V_{SMmax} = V_{DMmax} = V_{Imax} = 373.35 V$

$I_{SMmax} = I_{Omax} = 2.4714 A$

$P_{rDS} = r_{DS} D_{min} I_O^2{}_{max} = 1 \times 0.143 \times 2^2 = 0.572 W$

$P_{sw} = f_s C_o V_{Imax}^2 = 200 \times 10^3 \times 100 \times 10^{-12} \times 373.35^2 = 2.79 W$

$P_{VF} = V_F(1 - D_{min}) I_{Omax} = 1.2 W$

$P_{RF} = R_F(1 - D_{min}) I^2_{Omax} = 0.025 \times (1 - 0.143) \times 2^2 = 0.0857 W$

$P_D = P_{VF} + P_{RF} = 1.2 + 0.086 = 1.2857W$

$P_{rL} = r_L I_{Lmax}^2 = 1 \times 2^2 = 4W$

$P_{rC} = 1 \times 0.3428^2 / 12 = 0.0098W$

$P_{LS} = P_{rDS} + P_{VD} + P_{rL} + P_{rC} = 8.6578W$

$\eta = \frac{P_{Omax}}{P_{Omax} + P_{LS}} = 96/(96+8.657) = 91.728\%$

2.15 A buck PWM converter has $V_I = 5$ V $\pm$ 20%, $V_O = 1.8$ V, $I_O = 1$–10 A, $V_r/V_O \leq 3\%$, $r_{L(dc)} = 0.02\ \Omega$, $r_{DS} = 0.01\ \Omega$, $C_o = 150$ pF, $V_F = 0.3$ V, $R_F = 18$ mΩ, and $f_s = 500$ kHz. Find L, C, r_{Cmax}, I_{SMmax}, and V_{SMmax}. Estimate P_{LS} and η at I_{Omax} and V_{Imin}. Assume the initial efficiency $\eta = 80\%$ at full power.

$V_{Imin} = 5V - (\frac{20}{100} \times 5) = 4V$

$V_{max} = 5V + (20/100 \times 5) = 6V$

$V_r/V_O = 3\%$ $\quad V_F = 0.3V$ $\quad R_F = 18m\Omega$

$f_s = 500kHz$ $\quad C_o = 150pF$ $\quad r_{DS} = 0.01\Omega$

$r_L = r_C = 0.02\Omega$

Step 1 max minimum $= V_{out}/V_{in} = 1.8/6 \times 0.8$

$D_{min} = 0.375$

2. $L = R_{min}(1 - D_{min}) / 2f_s$

$L = \frac{1.8(1-0.375)}{2 \times 500 \times 10^3} = 1.125 \mu H$

3. $\Delta I_L = (6-1.8) \times 0.375 / (500 \times 10^3 \times 1.125 \times 10^{-6}) = 2.8$

4. $I_F = 10(1 - 0.375) = 62.5 Amp$

$P_D = I_F \cdot V_F = 62.5 \times 0.3 = 18.75$ Watt

$V_r = V_O \times 3\%$ $\quad V_r = 1.8 \times 3/100 = 0.054 V_{rms}$

$r_{Cmax} = V_r / \Delta I_L = 0.054 / 2.8$

$I_{sm\,max} = 11.4$ Ampere

$P_{SW} = f_s \times C_o \times V_{s\,max}^2 = 27 \times 10^{-4}$

$P_{rDS} = D \times r_{DS} \times I_{o\,max}^2 = 0.375 \times 0.01 \times 100 = 0.375$

$P_{rf} = (1-D) R_F\, I^2 = (1-0.375) \times 18 \times 10^{-3} \times 100 = 1.125$

$P_{rf} = (1-0.375) \times 0.3 \times 10 = 1.875$

$P_{FET} = P_{rDS} + P_{SW} = 0.37625$

$P_{LS} = P_{rDS} + P_{SW} + P_{D} + P_{rL} + P_{rC} = 3$

$P_{rL} = 0.02 \times 100 = 2$

$P_{rC} = 0.193 \times 2.8^2 / 12 = 0.0126$

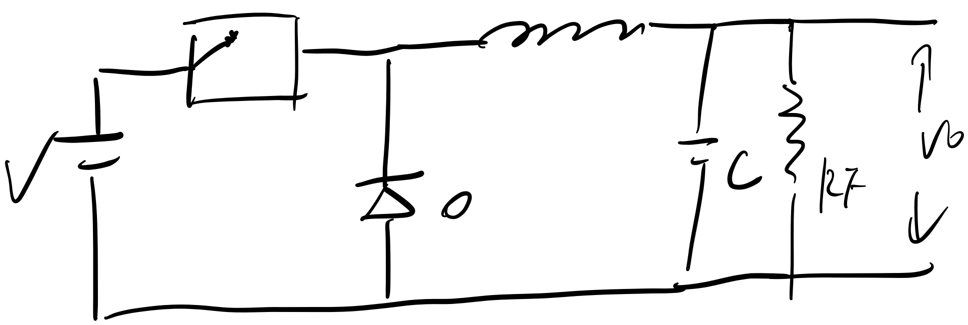
$P_{LS} = 0.375 + 0.0027 + 3 + 2 + 0.0126 = 5.3903$ Watt

$P_o = 1.8 \times 10 = 18$ Watt

$\eta = 18 / 18 + 5.3903 = 76.95\%$

$C = (1-D) / 16 f^2 LC = 138.67$ n farad

2.16 Design a buck converter to meet the following specifications: $V_I = 5 \pm 1$ V, $V_O = 3.3$ V, $I_O = 0$–5 A, $V_r/V_O \leq 1\%$, $f_s = 500$ kHz, $r_{DS} = 8$ mΩ, $R_F = 20$ mΩ, $V_F = 0.3$ V, $r_L = 50$ mΩ, and $Q_g = 50$ nC.



$V_S = 4$V $\quad V_o = 3.3$V

$I_o = 2$A $\quad f_s = 500$kHz

$Q_g = 50$nC $\quad R_F = 20$mΩ

$V_o = \delta V_s$

$\delta = \frac{V_o}{V_s} = \frac{3.3}{4} = 0.825$

$I_o = \frac{\Delta I}{2} \quad \frac{V_o}{R} = \left(\frac{V_o - V_s}{2L}\right) \delta / F \quad = 35 nH$

Tripple voltage and output voltage

$V_o = \frac{\Delta I}{L}$

$V_o = \frac{\Delta Q}{2C} \quad C = 50 \times 10^{-9} / 2 \times 3.3$

$= 7.57 nF$