Flyback Converter Operated in QR
First valley turn on, includes deadtime

Christophe Basso - Switch Mode Power Supplies: SPICE Simulations and Practical Designs
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1) Input data

$V_{out} := 19\ V$ $V_{inLL} := 100\ V$ $N_{ps} := 0.25$ $P_{out} := 65\ W$

$C_{lump} := 200\ pF$ $L_p := 350\ \mu H$ $V_f := 0.6\ V$ $\eta_{LL} := 85\%$ $R_{load} := \frac{V_{out}^2}{P_{out}} = 5.554\ \Omega$

2) Calculations

Valley selection (1 first, 2 second, 3 third...): $N_v := 1$

$$I_{out} := \frac{V_{out}}{R_{load}} = 3.421\ A$$

First valley turn-on: $DT := \left(2 \cdot N_v - 1\right) \cdot \pi \cdot \sqrt{L_p \cdot C_{lump}} = 0.831\ \mu s$

Switching frequency:

$$F_{sw} := \frac{4}{\left(\sqrt{4 \cdot DT + \frac{2 \cdot L_p \cdot P_{out} \cdot \left(V_f + V_{out} + N_{ps} \cdot V_{inLL}\right)^2}{V_{inLL}^2 \cdot \eta_{LL} \cdot \left(V_f + V_{out}\right)^2}} + \frac{\sqrt{2} \cdot L_p \cdot \left(V_f + V_{out} + N_{ps} \cdot V_{inLL}\right) \cdot \sqrt{\frac{P_{out}}{L_p \cdot \eta_{LL}}}}{V_{inLL} \cdot \left(V_f + V_{out}\right)}\right)^2} = 34.064\ kHz$$

Switching period: $T_{sw} := \frac{1}{F_{sw}} = 29.356\ \mu s$

Peak current with nominal loading conditions: $I_{peak} := \sqrt{\frac{2 \cdot P_{out}}{L_p \cdot \eta_{LL} \cdot F_{sw}}} = 3.582\ A$

on time duration: $t_{on} := \frac{I_{peak} \cdot L_p}{V_{inLL}} = 12.536\ \mu s$

$P_{out2} := 0.5 \cdot L_p \cdot F_{sw} \cdot I_{peak}^2 = 76.471\ W$

corresponding duty ratio: $D := t_{on} \cdot F_{sw} = 0.427$

duty ratio D1: $D_{1flyQR} := \sqrt{\frac{2 \cdot L_p \cdot P_{out}}{\eta_{LL} \cdot T_{sw}}} \cdot \frac{1}{V_{inLL}} = 0.427$ then $t_{on} := D_{1flyQR} \cdot T_{sw} = 12.536\ \mu s$

duty ratio D2: $D_{2flyQR} := \sqrt{\frac{2 \cdot L_p \cdot P_{out}}{\eta_{LL} \cdot T_{sw}}} \cdot \frac{N_{ps}}{V_{out} + V_f} = 0.545$ then $t_{off} := D_{2flyQR} \cdot T_{sw} = 15.989\ \mu s$

duty ratio D3: $D_{3flyQR} := 1 - D_{1flyQR} - D_{2flyQR} = 0.028$ then $DT := D_{3flyQR} \cdot T_{sw} = 0.831\ \mu s$

2.1) Primary inductor rms current

$$I_{LflyQRrms} := I_{peak} \cdot \sqrt{\frac{1 - D_{3flyQR}}{3}} = 2.038\ A$$

$$I_{LflyQRrms2} := I_{peak} \cdot \sqrt{\frac{D_{1flyQR} \cdot \left\langle N_{ps} \cdot V_{inLL} + \left\langle V_{out} + V_f \right\rangle \right\rangle}{3 \cdot \left\langle V_{out} + V_f \right\rangle}} = 2.038\ A$$

2.2) Secondary diode rms current

$$I_{dflyQRrms} := \frac{I_{LflyQRrms}}{N_{ps}} \cdot \sqrt{\frac{D_{2flyQR}}{1 - D_{3flyQR}}} = 6.104\ A$$

$$I_{dflyQRrms2} := \frac{I_{peak}}{N_{ps}} \cdot \sqrt{\frac{D_{1flyQR} \cdot \left\langle N_{ps} \cdot V_{inLL} + \left\langle V_{out} + V_f \right\rangle \right\rangle}{3 \cdot \left\langle V_{out} + V_f \right\rangle} \cdot \frac{D_{2flyQR}}{1 - D_{3flyQR}}} = 6.104\ A$$

2.3) Primary switch rms current

$$I_{SWflyDCM} := I_{peak} \cdot \sqrt{\frac{D_{1flyQR}}{3}} = 1.351\ A$$

$$\frac{V_{inLL} \cdot D_{1flyQR}^{\ 2} \cdot T_{sw}}{L_p} \cdot \sqrt{\frac{\left\langle N_{ps} \cdot V_{inLL} + \left\langle V_{out} + V_f \right\rangle \right\rangle}{3 \cdot \left\langle V_{out} + V_f \right\rangle} \cdot \frac{1}{1 - D_{3flyQR}}} = 1.351\ A$$

$$I_{SWflyDCM2} := I_{LflyQRrms} \cdot \sqrt{\frac{D_{1flyQR}}{1 - D_{3flyQR}}} = 1.351\ A$$

$$I_{SWflyDCM3} := I_{peak} \cdot \sqrt{\frac{D_{1flyQR}}{3}} = 1.351\ A$$

2.4) Output capacitor rms current

$$I_{CoutflyDCM} := \sqrt{I_{dflyQRrms}^{\ 2} - I_{out}^{\ 2}} = 5.056\ A$$