

Flyback Converter Operated in CCM Fixed frequency

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

$$V_{outflyCCM} := 19 \text{ V} \quad V_{inflyCCM} := 100 \text{ V} \quad N_{fly} := 0.06 \quad L_p := 2 \text{ mH}$$

$$F_{sw} := 65 \text{ kHz} \quad P_{out} := 65 \text{ W}$$

2) Calculations

$$\text{switching period: } T_{sw} := \frac{1}{F_{sw}} = 15.385 \text{ } \mu\text{s}$$

$$\text{load resistance: } R_{load} := \frac{V_{outflyCCM}^2}{P_{out}} = 5.554 \text{ } \Omega$$

$$\text{normalized time constant: } \tau_L := \frac{L_p \cdot N_{fly}^2}{R_{load} \cdot T_{sw}} = 0.084$$

$$\text{critical load resistance beyond this value, DCM is entered: } R_{crit} := \frac{2 \cdot L_p \cdot F_{sw} \cdot N_{fly}^2}{\left(1 - \frac{V_{outflyCCM}}{V_{outflyCCM} + N_{fly} \cdot V_{inflyCCM}}\right)^2} = 16.25 \text{ } \Omega$$

$$\text{output current: } I_{outflyCCM} := \frac{P_{out}}{V_{outflyCCM}} = 3.421 \text{ A}$$

$$\text{duty ratio: } D_{flyCCM} := \frac{V_{outflyCCM}}{V_{outflyCCM} + N_{fly} \cdot V_{inflyCCM}} = 0.76$$

$$\text{primary inductor ripple current: } \Delta I_{LflyCCM} := D_{flyCCM} \cdot T_{sw} \cdot \frac{V_{inflyCCM}}{L_p} = 0.585 \text{ A}$$

$$\text{primary peak current: } I_{pflyCCM} := \frac{N_{fly} \cdot I_{outflyCCM}}{1 - D_{flyCCM}} + \frac{\Delta I_{LflyCCM}}{2} = 1.148 \text{ A}$$

$$\text{primary valley current: } I_{vflyCCM} := \frac{N_{fly} \cdot I_{outflyCCM}}{1 - D_{flyCCM}} - \frac{\Delta I_{LflyCCM}}{2} = 0.563 \text{ A}$$

$$\text{secondary peak current: } I_{pflyCCMsec} := \frac{I_{pflyCCM}}{N_{fly}} = 19.126 \text{ A}$$

$$\text{secondary valley current: } I_{vflyCCMsec} := \frac{I_{vflyCCM}}{N_{fly}} = 9.383 \text{ A}$$

$$\text{primary inductor rms current: } I_{LCCMflyrms} := \sqrt{\frac{(I_{vflyCCM}^2 + I_{pflyCCM}^2 + I_{pflyCCM} \cdot I_{vflyCCM})}{3}} = 0.872 \text{ A}$$

primary switch rms current: $I_{SWCCMfly} := I_{LCCMflyrms} \cdot \sqrt{D_{flyCCM}} = 0.76 \text{ A}$ or

$$I_{SWCCMgly2} := \sqrt{D_{flyCCM} \cdot \left(I_{pflyCCM}^2 - I_{pflyCCM} \cdot \Delta I_{LflyCCM} + \frac{\Delta I_{LflyCCM}^2}{3} \right)} = 0.76 \text{ A}$$

secondary inductor rms current:

$$I_{LCCMsecrms} := \sqrt{\frac{(I_{vflyCCMsec}^2 + I_{pflyCCMsec}^2 + I_{vflyCCMsec} \cdot I_{pflyCCMsec})}{3}} = 14.529 \text{ A}$$

secondary-side diode rms current: $I_{dCCMfly} := I_{LCCMsecrms} \cdot \sqrt{1 - D_{flyCCM}} = 7.118 \text{ A}$

output capacitor rms current: $I_{CoutflyCCM} := \sqrt{I_{dCCMfly}^2 - I_{outflyCCM}^2} = 6.242 \text{ A}$ or

$$I_{CoutflyCCM2} := I_{outflyCCM} \cdot \sqrt{\frac{D_{flyCCM}}{1 - D_{flyCCM}} + \frac{1}{3} \cdot \left(\frac{1}{2 \cdot \tau_L} \right)^2 \cdot (1 - D_{flyCCM})^3} = 6.242 \text{ A}$$

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3) Input data

$$V_{outflyDCM} := 19 \text{ V} \quad V_{inflyDCM} := 100 \text{ V} \quad N_{fly} = 0.06 \quad L_p = 2 \text{ mH}$$

$$F_{sw} = 65 \text{ kHz} \quad P_{outflyDCM} := 10 \text{ W}$$

4) Calculations

switching period: $T_{sw} := \frac{1}{F_{sw}} = 15.385 \text{ } \mu\text{s}$

load resistance: $R_{load} := \frac{V_{outflyDCM}^2}{P_{outflyDCM}} = 36.1 \text{ } \Omega$

normalized time constant: $\tau_L := \frac{L_p \cdot N_{fly}^2}{R_{load} \cdot T_{sw}} = 0.013$

critical load resistance below this value, CCM is entered: $R_{crit} := \frac{2 \cdot L_p \cdot F_{sw} \cdot N_{fly}^2}{\left(1 - \frac{V_{outflyCCM}}{V_{outflyCCM} + N_{fly} \cdot V_{inflyCCM}} \right)^2} = 16.25 \text{ } \Omega$

dc output current: $I_{outflyDCM} := \frac{V_{outflyDCM}}{R_{load}} = 0.526 \text{ A}$

$$\text{peak primary current: } I_{pflyDCM} := \sqrt{\frac{2 \cdot P_{outflyDCM}}{L_p \cdot F_{sw}}} = 0.392 \text{ A}$$

$$\text{duty ratio D1: } D_{1flyDCM} := \sqrt{\frac{2 \cdot L_p \cdot P_{outflyDCM}}{T_{sw}}} \cdot \frac{1}{V_{inflyDCM}} = 0.51$$

$$\text{duty ratio D2: } D_{2flyDCM} := \sqrt{\frac{2 \cdot L_p \cdot P_{outflyDCM}}{T_{sw}}} \cdot \frac{N_{fly}}{V_{outflyDCM}} = 0.161$$

$$\text{duty ratio D3: } D_{3flyDCM} := 1 - D_{1flyDCM} - D_{2flyDCM} = 0.329$$

$$\text{Primary inductor rms current: } I_{LflyDCMrms} := I_{pflyDCM} \cdot \sqrt{\frac{1 - D_{3flyDCM}}{3}} = 0.185 \text{ A}$$

$$\text{or } I_{LflyDCMrms2} := I_{pflyDCM} \cdot \sqrt{\frac{D_{1flyDCM} \cdot (N_{fly} \cdot V_{inflyCCM} + V_{outflyDCM})}{3 \cdot V_{outflyDCM}}} = 0.185 \text{ A}$$

$$\text{Secondary diode rms current: } I_{dflyDCMrms} := \frac{I_{LflyDCMrms}}{N_{fly}} \cdot \sqrt{\frac{D_{2flyDCM}}{1 - D_{3flyDCM}}} = 1.515 \text{ A}$$

$$\text{or } I_{dflyDCMrms2} := \frac{I_{pflyDCM}}{N_{fly}} \cdot \sqrt{\frac{D_{1flyDCM} \cdot (N_{fly} \cdot V_{inflyCCM} + V_{outflyDCM})}{3 \cdot V_{outflyDCM}}} \cdot \frac{D_{2flyDCM}}{1 - D_{3flyDCM}} = 1.515 \text{ A}$$

$$\text{Primary switch rms current: } I_{SWflyDCM} := I_{pflyDCM} \cdot \sqrt{\frac{D_{1flyDCM}}{3}} = 0.162 \text{ A}$$

$$\text{or } \frac{V_{inflyCCM} \cdot D_{1flyDCM}^2 \cdot T_{sw}}{L_p} \cdot \sqrt{\frac{(N_{fly} \cdot V_{inflyCCM} + V_{outflyDCM})}{3 \cdot V_{outflyDCM}}} \cdot \frac{1}{1 - D_{3flyDCM}} = 0.162 \text{ A}$$

$$\text{or } I_{SWflyDCM2} := I_{LflyDCMrms} \cdot \sqrt{\frac{D_{1flyDCM}}{1 - D_{3flyDCM}}} = 0.162 \text{ A}$$

$$\text{or } I_{SWflyDCM3} := I_{pflyDCM} \cdot \sqrt{\frac{D_{1flyDCM}}{3}} = 0.162 \text{ A}$$

$$\text{Output capacitor rms current: } I_{CoutflyDCM} := \sqrt{I_{dflyDCMrms}^2 - I_{outflyDCM}^2} = 1.42 \text{ A}$$

$$\text{or } I_{CoutflyDCM2} := I_{outflyDCM} \cdot \sqrt{\sqrt{\frac{8}{9 \cdot \tau_L}} - 1} = 1.42 \text{ A}$$