

## Bulk Capacitor Parameters Calculations

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

$$V_f := 1 \text{ V} \quad V_{in\_peak} := 120 \text{ V} \quad V_{peak} := V_{in\_peak} - 2 \cdot V_f = 118 \text{ V}$$

$$F_{line} := 50 \cdot \text{Hz} \quad P_{out} := 90 \cdot \text{W} \quad \eta := 86\%$$

**2) Calculations****2.1) Enter the Vmin voltage**

$$V_{min} := 50 \text{ V}$$

$$\text{Valeur de Cbulk: } C_{bulk} := \frac{2 \cdot P_{out} \cdot \left( \frac{1}{4 \cdot F_{line}} + \frac{\text{asin}\left(\frac{V_{min}}{V_{peak}}\right)}{2 \cdot \pi \cdot F_{line}} \right)}{\eta \cdot (V_{peak}^2 - V_{min}^2)} = 117.124 \text{ } \mu\text{F}$$

$$\text{Cbulk recharge time: } t_b := \frac{1}{4 \cdot F_{line}} - \frac{\text{asin}\left(\frac{V_{min}}{V_{peak}}\right)}{2 \cdot \pi \cdot F_{line}} = 3.607 \text{ ms}$$

$$\text{Time to go from 0 to Vmin: } t_1 := \frac{1}{2 \cdot \pi \cdot F_{line}} \cdot \text{asin}\left(\frac{V_{min}}{V_{peak}}\right) = 1.393 \text{ ms}$$

$$\text{Cbulk discharge time: } t_d := \frac{1}{4 \cdot F_{line}} + \frac{\text{asin}\left(\frac{V_{min}}{V_{peak}}\right)}{2 \cdot \pi \cdot F_{line}} = 6.393 \text{ ms}$$

$$I_{p2} = C \cdot \frac{d}{dt} \left( (V_{peak}) \cdot \sin(2 \cdot \pi \cdot F_{line} \cdot t) \right)$$

$$\text{Peak current in bulk cap: } I_{bulk\_peak} := 2 \cdot C_{bulk} \cdot V_{peak} \cdot \cos(2 \cdot \pi \cdot F_{line} \cdot t_1) \cdot \pi \cdot F_{line} = 3.933 \text{ A}$$

$$\text{Delivered average current: } I_{avg} := 2 \cdot F_{line} \cdot \frac{P_{out}}{\eta} \cdot \int_0^{\frac{1}{2 \cdot F_{line}}} \frac{1}{V_{min} + (V_{peak} - V_{min}) \cdot \sin(2 \cdot \pi \cdot F_{line} \cdot t)} dt = 1.193 \text{ A}$$

$$V_{bulk\_avg} := 2 \cdot F_{line} \cdot \int_0^{\frac{1}{2 \cdot F_{line}}} V_{min} + (V_{peak} - V_{min}) \cdot \sin(2 \cdot \pi \cdot F_{line} \cdot t) dt = 93.29 \text{ V}$$

$$V_{bulk\_avg2} := V_{min} - \frac{2 \cdot V_{min} - 2 \cdot V_{peak}}{\pi} = 93.29 \text{ V}$$

$$I_{load_{peak}} := \frac{P_{out}}{\eta \cdot V_{min}} = 2.093 \text{ A}$$

$$I_{diode_{peak}} := I_{load_{peak}} + I_{bulk_{peak}} = 6.026 \text{ A}$$

$$I_{diode_C} := \frac{P_{out}}{\eta \cdot V_{peak}} = 0.887 \text{ A}$$

$$S_{diode} := \frac{I_{diode_{peak}} - I_{diode_C}}{t_b} = 1.425 \frac{\text{A}}{\text{ms}}$$

$$t_{diode} := \frac{I_{diode_C}}{S_{diode}} = 622.525 \text{ } \mu\text{s}$$

$$t_{diode_{total}} := t_b + t_{diode} = 4.23 \text{ ms}$$

$$I_{avg2} := I_{diode_{peak}} \cdot t_{diode_{total}} \cdot F_{line} = 1.274 \text{ A}$$

$$\text{Rms current in bulk: } I_{bulk_{rms}} := I_{avg} \cdot \sqrt{\frac{2}{3 \cdot F_{line} \cdot t_{diode_{total}}} - 1} = 1.75 \text{ A}$$

$$\text{Rms current in diode: } I_{d_{rms}} := I_{avg} \cdot \frac{1}{\sqrt{3 \cdot F_{line} \cdot t_{diode_{total}}}} = 1.497 \text{ A}$$

$$\text{Input rms current: } I_{in_{rms}} := I_{avg} \cdot \sqrt{\frac{2}{3 \cdot F_{line} \cdot t_{diode_{total}}}} = 2.117 \text{ A}$$

$$\text{Rms current in bulk: } I_{bulk_{rms2}} := I_{avg2} \cdot \sqrt{\frac{2}{3 \cdot F_{line} \cdot t_{diode_{total}}} - 1} = 1.87 \text{ A}$$

$$\text{Rms current in diode: } I_{d_{rms2}} := I_{avg2} \cdot \frac{1}{\sqrt{3 \cdot F_{line} \cdot t_{diode_{total}}}} = 1.6 \text{ A}$$

$$I_{d_{avg}} := \frac{I_{avg2}}{2} = 0.637 \text{ A}$$

## **2.2) Enter the selected bulk capacitor**

$$C_b := 330 \text{ } \mu\text{F}$$

$$V_{min3} := \sqrt{\frac{\eta \cdot C_b \cdot V_{peak}^2 - 2 \cdot P_{out} \cdot t_d}{C_b \cdot \eta}} = 99.345 \text{ V}$$

$$f(V_{minX}) := -\frac{C_b \cdot (V_{minX}^2 - V_{peak}^2)}{2} - \frac{\pi \cdot \frac{P_{out}}{\eta} + 2 \cdot P_{out} \cdot \text{asin}\left(\frac{V_{minX}}{V_{peak}}\right)}{4 \cdot \pi \cdot F_{line}}$$

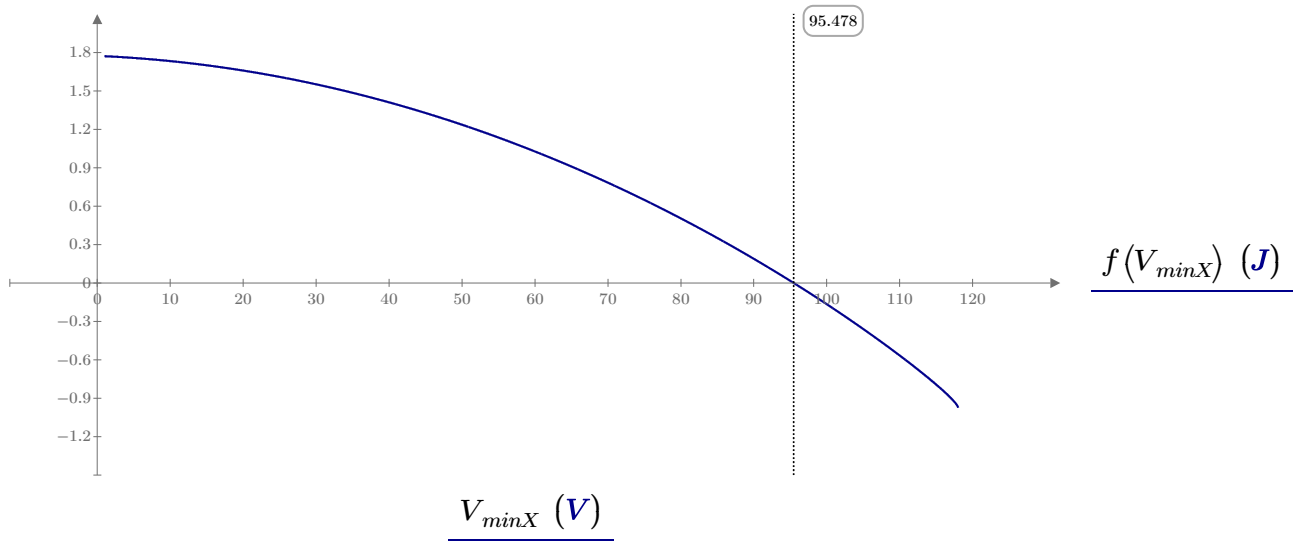
$$V_{minX} := \frac{V_{peak}}{2}$$

$$V_{min} := \text{root}\left(f(V_{minX}), V_{minX}\right) = 95.478 \text{ V}$$

$$\text{Ripple} := \frac{V_{min}}{V_{peak}} = 80.914\%$$

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$$V_{minX} := 1 \text{ V}, 1.01 \text{ V}.. V_{peak}$$



$$\text{Cbulk recharge time: } t_b := \frac{1}{4 \cdot F_{line}} - \frac{\text{asin}\left(\frac{V_{min}}{V_{peak}}\right)}{2 \cdot \pi \cdot F_{line}} = 1.999 \text{ ms}$$

$$\text{Time to go from 0 to Vmin: } t_1 := \frac{1}{2 \cdot \pi \cdot F_{line}} \cdot \text{asin}\left(\frac{V_{min}}{V_{peak}}\right) = 3.001 \text{ ms}$$

$$\text{Cbulk discharge time: } t_d := \frac{1}{4 \cdot F_{line}} + \frac{\text{asin}\left(\frac{V_{min}}{V_{peak}}\right)}{2 \cdot \pi \cdot F_{line}} = 8.001 \text{ ms}$$

$$\text{Peak current in bulk cap: } I_{bulk_{peak}} := 2 \cdot C_b \cdot V_{peak} \cdot \cos(2 \cdot \pi \cdot F_{line} \cdot t_1) \cdot \pi \cdot F_{line} = 7.189 \text{ A}$$

$$V_{bulk_{avg}} := 2 \cdot F_{line} \cdot \int_0^{\frac{1}{2 \cdot F_{line}}} V_{min} + (V_{peak} - V_{min}) \cdot \sin(2 \cdot \pi \cdot F_{line} \cdot t) dt = 109.816 \text{ V}$$

$$\text{Approximated value: } V_{bulk_{avg}} := V_{min} - \frac{2 \cdot V_{min} - 2 \cdot V_{peak}}{\pi} = 109.816 \text{ V}$$

$$I_{load_{peak}} := \frac{P_{out}}{\eta \cdot V_{min}} = 1.096 \text{ A}$$

$$I_{diode_C} := \frac{P_{out}}{\eta \cdot V_{peak}} = 0.887 \text{ A}$$

$$I_{diode_{peak}} := I_{load_{peak}} + I_{bulk_{peak}} = 8.285 \text{ A}$$

$$S_{diode} := \frac{I_{diode_{peak}} - I_{diode_C}}{t_b} = 3.7 \frac{\text{A}}{\text{ms}}$$

$$t_{diode} := \frac{I_{diode_C}}{S_{diode}} = 239.69 \text{ } \mu\text{s}$$

$$t_{diode_{total}} := t_b + t_{diode} = 2.239 \text{ ms}$$

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$$I_{avg} := I_{diode_{peak}} \cdot t_{diode_{total}} \cdot F_{line} = 0.927 \text{ A}$$

$$\text{Rms current in bulk: } I_{bulk_{rms}} := I_{avg} \cdot \sqrt{\frac{2}{3 \cdot F_{line} \cdot t_{diode_{total}}} - 1} = 2.065 \text{ A}$$

$$\text{Rms current in diode: } I_{d_{rms}} := I_{avg} \cdot \frac{1}{\sqrt{3 \cdot F_{line} \cdot t_{diode_{total}}}} = 1.6 \text{ A}$$

$$\text{Input rms current: } I_{in_{rms}} := I_{avg} \cdot \frac{\sqrt{2}}{\sqrt{3 \cdot F_{line} \cdot t_{diode_{total}}}} = 2.263 \text{ A}$$

$$\text{Average current in a diode: } I_{d_{avg}} := \frac{I_{avg}}{2} = 0.464 \text{ A}$$

$$P_{bridge} := V_f \cdot I_{d_{avg}} \cdot 2 = 0.927 \text{ W} \qquad PF := \frac{P_{out}}{\eta \cdot I_{in_{rms}} \cdot \frac{V_{in_{peak}}}{\sqrt{2}}} = 0.545$$

$$\tan \delta := 0.15 \qquad R_{ESR} := \frac{\tan \delta}{4 \cdot \pi \cdot F_{line} \cdot C_b} = 0.723 \ \Omega$$

$$P_{bulk} := I_{bulk_{rms}}^2 \cdot R_{ESR} = 3.084 \text{ W}$$