Borderline PFC Small-Signal Parameters Calculations

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

$G_{PWM} := 6.8\ \frac{\mu s}{V}$ $V_{ac} := 100\ V$ $V_{err} := 1.647\ V$ $L_1 := 350\ \mu H$ $V_{out} := 400\ V$

$t_{on} := V_{err} \cdot G_{PWM} = 11.2\ \mu s$ $P_{out} := \frac{V_{ac}^2}{2 \cdot L_1} \cdot G_{PWM} \cdot V_{err} = 159.994\ W$ $C_{out} := 180\ \mu F$

$k_{div} := 0.0078$ $k_{mul} := 0.6\ \frac{1}{V}$ $R_i := 0.24\ \Omega$ $R_{load} := \frac{V_{out}^2}{P_{out}} = 1\ k\Omega$ $P_{in} := P_{out}$

From José Cappilla

$Start\_Freq_{log} := -2$ $Stop\_Freq_{log} := 3$ $Points\_per\_decade := 200$

$$Number\_of\_decades := Stop\_Freq_{log} - Start\_Freq_{log} = 5$$

$$Number\_of\_points := Number\_of\_decades \cdot Points\_per\_decade + 1 = 1001$$

$$k := 0 .. Number\_of\_points$$

$$f_k := 10^{Start\_Freq_{log} + k \cdot \frac{Number\_of\_decades}{Number\_of\_points}} \cdot Hz \qquad \omega_k := 2 \cdot \pi \cdot f_k$$

2) Voltage mode

$$\frac{d}{dV_{out}}\left(\frac{V_{ac}^2}{2 \cdot L_1} \cdot \frac{G_{PWM} \cdot V_{err}}{V_{out}}\right) \to -\frac{0.00099996428571428571431 \cdot \mu s}{\mu H} = -10 \cdot 10^{-4}\ \frac{1}{\Omega}$$

$$\frac{d}{dV_{err}}\left(\frac{V_{ac}^2}{2 \cdot L_1} \cdot \frac{G_{PWM} \cdot V_{err}}{V_{out}}\right) \to \frac{0.24285714285714285714 \cdot \mu s}{\mu H} = 0.243\ \frac{1}{\Omega}$$

Gain dc: $H_{0VM} := \frac{R_{load} \cdot G_{PWM} \cdot V_{ac}^2}{4 \cdot L_1 \cdot V_{out}} = 121.433$

Gain dc in dB: $H_{0VMdB} := 20 \cdot \log\left(\frac{R_{load} \cdot G_{PWM} \cdot V_{ac}^2}{4 \cdot L_1 \cdot V_{out}}\right) = 41.687$

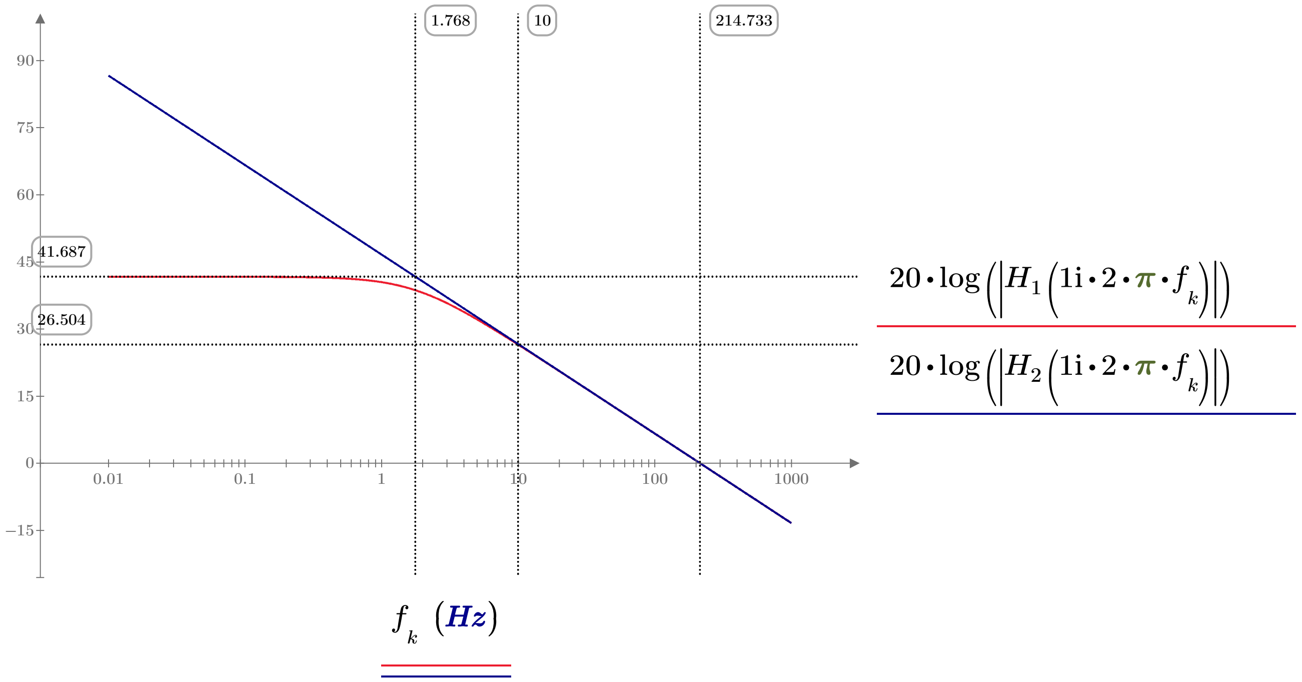
$$f_{p1} := \frac{1}{\pi \cdot R_{load} \cdot C_{out}} = 1.768\ Hz \qquad f_{po} := \frac{\frac{G_{PWM} \cdot V_{ac}^2}{2 \cdot L_1 \cdot V_{out}} \cdot \frac{1}{C_{out}}}{2 \cdot \pi} = 214.733\ Hz$$

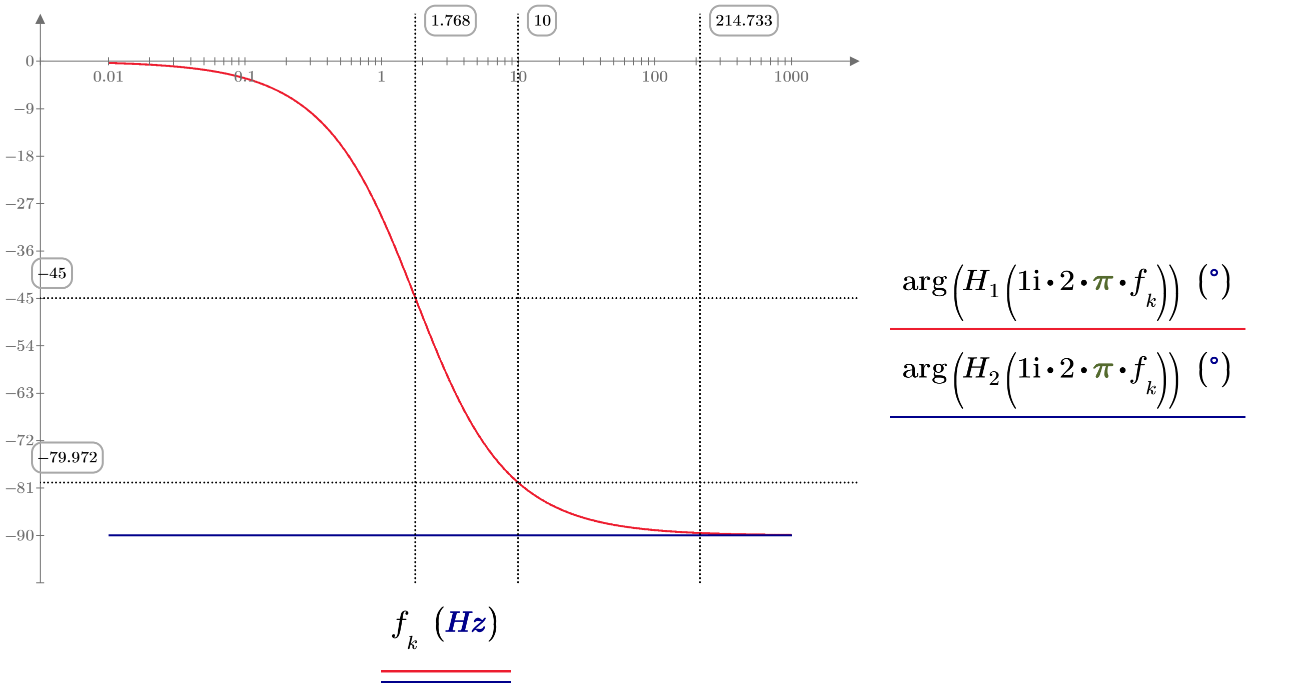
$t_{on} := \frac{P_{in}}{{V_{ac}}^2} \cdot 2 \cdot L_1 = 11.2\ \mu s$

$I_{peak} := \frac{V_{ac} \cdot \sqrt{2}}{L_1} \cdot t_{on} = 4.525\ A$

Resistive loading: $H_1(s) := H_{0VM} \cdot \frac{1}{1 + \frac{s}{2 \cdot \pi \cdot f_{p1}}}$

SMPS loading: $H_2(s) := \frac{1}{\frac{s}{f_{po} \cdot 2 \cdot \pi}}$





selected crossover frequency: $f_c := 10\ Hz$

$20 \cdot \log\left(\left|H_1\left(1i \cdot 2 \cdot \pi \cdot f_c\right)\right|\right) = 26.504$ $\quad$ $\arg\left(H_1\left(1i \cdot 2 \cdot \pi \cdot f_c\right)\right) = -79.972\ °$

$$20 \cdot \log\left(\frac{H_{0VM}}{\sqrt{1 + \left(\frac{f_c}{f_{p1}}\right)^2}}\right) = 26.504 \qquad -\operatorname{atan}\left(\frac{f_c}{f_{p1}}\right) = -79.972\ °$$

$20 \cdot \log\left(\left|H_2\left(1i \cdot 2 \cdot \pi \cdot f_c\right)\right|\right) = 26.638$ $\quad$ $\arg\left(H_2\left(1i \cdot 2 \cdot \pi \cdot f_c\right)\right) = -90\ °$

$$20 \cdot \log\left(\frac{f_{po}}{f_c}\right) = 26.638$$

$$f_{poo} := f_{p1} \cdot \sqrt{H_{0VM} - 1} \cdot \sqrt{H_{0VM} + 1} = 214.726\ Hz$$

3) Current mode

$$\frac{d}{dV_{out}}\left(\frac{V_{ac}^{\ 2}}{2} \cdot \frac{k_{div} \cdot k_{mul} \cdot V_{err}}{R_i \cdot V_{out}}\right) \rightarrow -\frac{0.001003640625}{\Omega} = -0.001\ \frac{1}{\Omega}$$

$$\frac{d}{dV_{err}}\left(\frac{V_{ac}^{\ 2}}{2} \cdot \frac{k_{div} \cdot k_{mul} \cdot V_{err}}{R_i \cdot V_{out}}\right) \rightarrow \frac{0.24375}{\Omega} = 0.244\ \frac{1}{\Omega}$$

$$G_{0CM} := \frac{V_{ac}^{\ 2} \cdot k_{div} \cdot k_{mul} \cdot R_{load}}{4 \cdot R_i \cdot V_{out}} = 121.879$$

$$G_{0CMdb} := 20 \cdot \log\left(\frac{V_{ac}^{\ 2} \cdot k_{div} \cdot k_{mul} \cdot R_{load}}{4 \cdot R_i \cdot V_{out}}\right) = 41.719$$

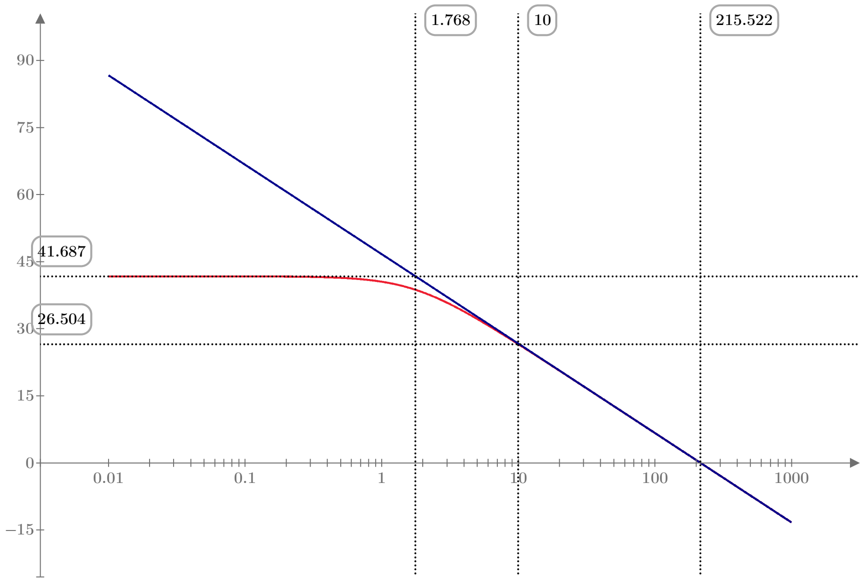
$$I_{peak} := \frac{k_{mul} \cdot k_{div} \cdot \sqrt{2} \cdot V_{ac} \cdot V_{err}}{R_i} = 4.542\ A \qquad \frac{L_1 \cdot k_{div} \cdot k_{mul}}{R_i} \cdot V_{err} = 11.241\ \mu s$$

$$P_{out} := \frac{V_{ac}^{\ 2}}{2 \cdot L_1} \cdot \frac{L_1 \cdot k_{div} \cdot k_{mul}}{R_i} \cdot V_{err} = 160.583\ W \qquad f_{p1} = 1.768\ Hz$$

$$f_{poCM} := \frac{V_{ac}^{\ 2} \cdot k_{div} \cdot k_{mul}}{4 \cdot \pi \cdot R_i \cdot V_{out}} \cdot \frac{1}{C_{out}} = 215.522\ Hz$$

Resistive loading: $H_3(s) := G_{0CM} \cdot \dfrac{1}{1 + \dfrac{s}{2 \cdot \pi \cdot f_{p1}}}$

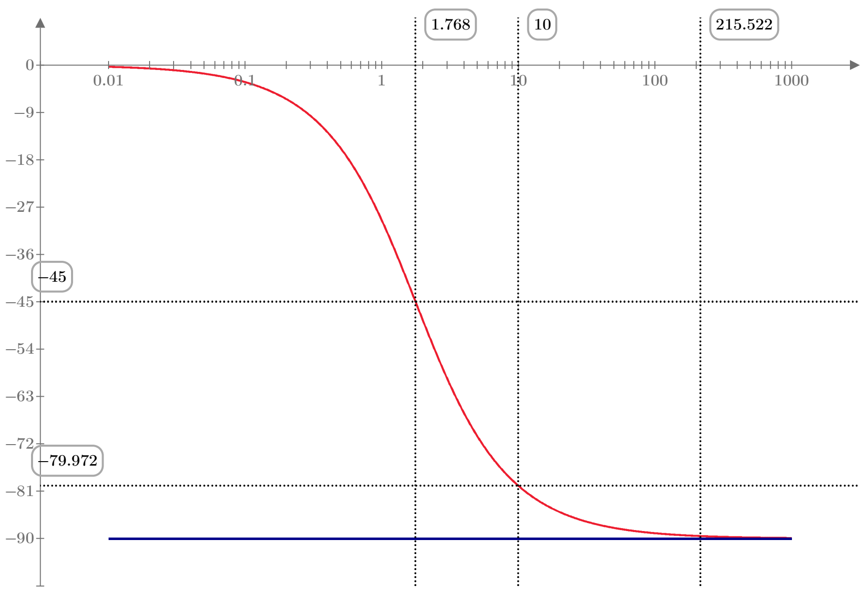
SMPS loading: $H_4(s) := \dfrac{1}{\dfrac{s}{f_{poCM} \cdot 2 \cdot \pi}}$



$20 \cdot \log\left(\left|H_3\left(1i \cdot 2 \cdot \pi \cdot f_k\right)\right|\right)$

$20 \cdot \log\left(\left|H_4\left(1i \cdot 2 \cdot \pi \cdot f_k\right)\right|\right)$

$f_k \ (Hz)$



$\arg\left(H_3\left(1i \cdot 2 \cdot \pi \cdot f_k\right)\right) \ (°)$

$\arg\left(H_4\left(1i \cdot 2 \cdot \pi \cdot f_k\right)\right) \ (°)$

$f_k \ (Hz)$

$20 \cdot \log\left(\left|H_4\left(1i \cdot 2 \cdot \pi \cdot f_c\right)\right|\right) = 26.67$

$\arg\left(H_4\left(1i \cdot 2 \cdot \pi \cdot f_c\right)\right) = -90 \ °$