

UCC3817/8A Design Procedure

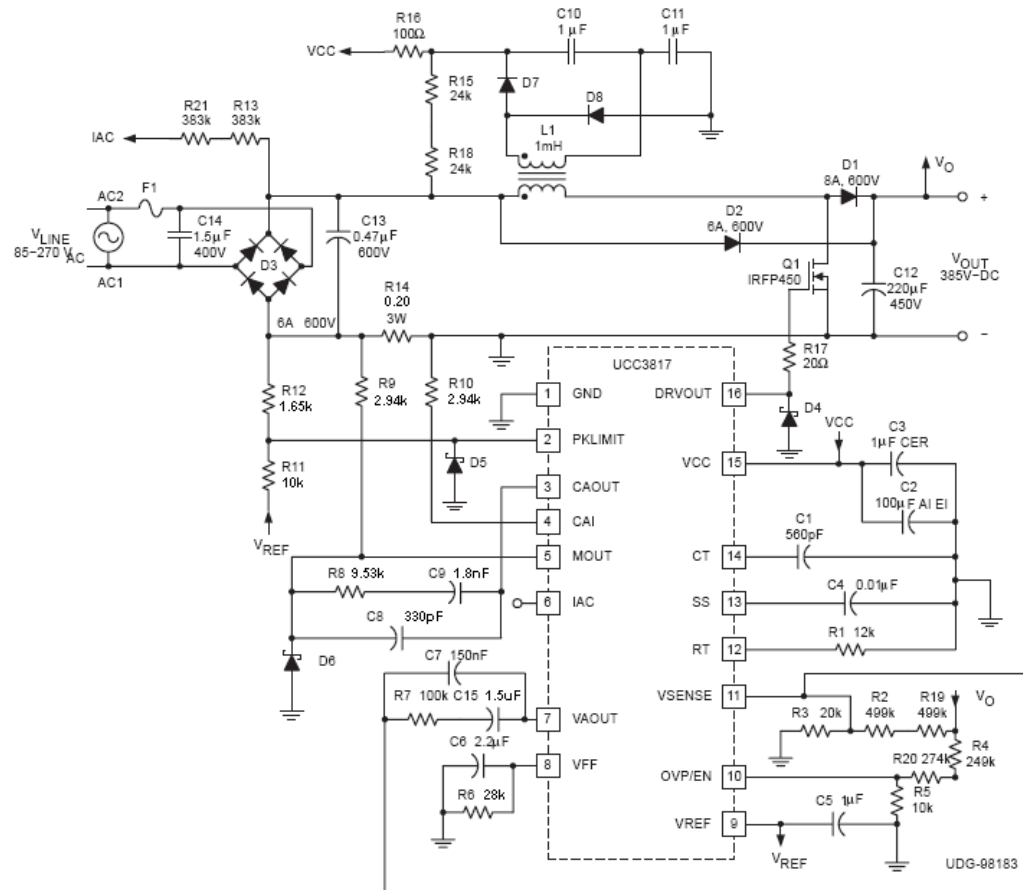


Figure 1. Typical Application Circuit

I. Power Factor Pre regulator Design:

1. PFC Design Goals:

$V_{inmin} := 85V$	V_{in} Minimum
$V_{inmax} := 265V$	V_{in} Maximum
$V_{out} := 385V$	Output Voltage
$P_{out} := 120W$	Output Power
$\eta_1 := 0.95$	Note η represents efficiency a.) η_1 is the estimated PFC efficiency
$f_s := 277 \cdot 10^3 Hz$	
$V_{ovp} := 425V$	Over Voltage Protection Trip Point

2. Device Parameters:

$$V_{rmsmin} := 1.4V \quad V_{rmsmax} := 5V \quad V_{ref} := 7.5V \quad V_{eamin} := .5V \quad V_{eamax} := 5.5V \quad V_p := 4V$$

3. Select a Boost Inductor L1(L_{BOOST}):

a. Calculate Peak Input Current

$$I_{pk} := \sqrt{2} \cdot \frac{\frac{P_{out}}{\eta_1}}{V_{inmin}}$$

$$I_{pk} = 2.102 \text{ A}$$

$$dI := .20 \cdot I_{pk}$$

$$dI = 0.42 \text{ A}$$

b. Calculate Maximum Duty Cycle

$$D := \frac{V_{out} - \sqrt{2} \cdot V_{inmin}}{V_{out}}$$

$$D = 0.688$$

c. Calculate Inductance

$$L1 := \frac{V_{inmin} \cdot \sqrt{2} \cdot D}{dI \cdot f_s}$$

$$L1 = 7.101 \times 10^{-4} \text{ H}$$

d. Select an Inductance Close to the Calculated Value

$$\text{L1} := 7.101 \cdot 10^{-4} \text{ H}$$

4. Select a High Voltage Capacitor C12 (C_{OUT}):

a. Choose a Minimum Hold up Time for 60Hz

$$tholdup := 16 \cdot 10^{-3} \text{ s}$$

b. Select Amount of Voltage Droop that is Allowed During Hold up Time

$$V_{pfc_Droop} := 35V$$

c. Calculate PFC DC Current

$$I_{dc} := \frac{P_{out}}{V_{out}}$$

$$I_{dc} = 0.312 \text{ A}$$

d. Calculate Minimum Capacitance Needed

$$C12 := \frac{2 \cdot \frac{P_{out}}{\eta_1} \cdot tholdup}{V_{out}^2 - (V_{out} - V_{pfc_Droop})^2}$$

$$C12 = 1.571 \times 10^{-4} \text{ F}$$

d. Choose a Capacitor > or = the Minimum Capacitance For Your Design

$$\text{C12} := 165 \cdot 10^{-6} \text{ F}$$

5. Select Timing Components (R_T and C_T) for 277 kHz switching frequency

Let $R1 = 12 \text{ kohm}$

$$R1 := 12 \cdot 10^3 \text{ ohm}$$

$$C1 := \frac{.6}{R1 \cdot f_s}$$

$$C1 = 1.805 \times 10^{-10} \text{ F}$$

a. Choose a Capacitor Close to a Standard Value

$$\text{C1} := 180 \cdot 10^{-12} \text{ F}$$

6. Select Components for V_{rms} Filter:

$$I_{acmax} := 500 \cdot 10^{-6} \text{ A}$$

$$R_{iac} := V_{inmax} \cdot \frac{\sqrt{2}}{I_{acmax}}$$

$$R_{iac} = 7.495 \times 10^5 \text{ ohm}$$

$$\text{Riac} := 2 \cdot 383 \cdot 10^3 \text{ ohm}$$

Select Two Resistors to Meet Voltage Requirements

$$R_{iac} = R21 + R13$$

DC current through R_{rms} is 1/2 I_{ac} current (2:1 mirror) X 0.9 (dc factor) = 250uA X 0.9

$$R_{vff} := \frac{1.4V}{\frac{V_{inmin}}{R_{iac} \cdot 2} \cdot 0.9}$$

$$R_{vff} = 2.804 \times 10^4 \text{ ohm}$$

$$R_{vff} = R6$$

a. Choose an Rvff (R6) Resistor Close to a Standard Value

$$\text{Rvff} := 28.0 \cdot 10^3 \text{ ohm}$$

$$R6 = R_{vff}$$

b. Calculate the Needed Cvff Capacitance

The allowable contribution to THD from Vrms is 1.5%. The second harmonic is 66% of the fundamental, so to reduce the contribution to 1.5% the Vrms filter must have a gain of 1.5% / 66% or .022. Back-calculating the frequency of a pole which will give the necessary attenuation at 120Hz places the pole at 2.6Hz.

$$f_p := 2.6\text{Hz}$$

$$C_{vff} := \frac{1}{2 \cdot \pi \cdot R_{vff} \cdot f_p}$$

$$C_{vff} = 2.186 \times 10^{-6} \text{ F}$$

c. Choose an Rvff (C6) Resistor Close to a Standard Value

$$\text{Cvff} := 2.2 \cdot 10^{-6}$$

$$C_{vff} = C6$$

7. Size current sense resistor (R14) for a 1V dynamic range.

$$R_{\text{sense}} := \frac{1V}{I_{\text{pk}} + 0.5 \cdot dI}$$

$$R_{\text{sense}} = 0.433 \text{ ohm}$$

Choose a standard value

$$R_{\text{sense}} := 0.43 \text{ ohm}$$

$$R_{\text{sense}} = R14$$

8. Multiplier Set up

$$I_{\text{ac_at_Vinmin}} := V_{\text{inmin}} \cdot \frac{\sqrt{2}}{R_{\text{iac}}}$$

$$I_{\text{ac_at_Vinmin}} = 1.569 \times 10^{-4} \text{ A}$$

I_{mo} at low line is determined by $I_{\text{ac_lowline}}$, V_{eamax} , and V_{rmsmin} .

$$K_m := \frac{1}{V}$$

$$I_{\text{momax}} := \frac{I_{\text{ac_at_Vinmin}} \cdot (V_{\text{eamax}} - 1V)}{K_m \cdot V_{\text{rmsmin}}^2} = 3.603 \times 10^{-4} \text{ A}$$

$$I_{\text{momax}} = 3.603 \times 10^{-4} \text{ A}$$

The power limit for the forward converter is set to roughly 120% of the output power. To reduce instabilities the power limit needs to be set greater than 120%.

$$P_{\text{limit}} := \frac{P_{\text{out}} \cdot (1.2)}{\eta_1}$$

$$P_{\text{limit}} = 151.579 \text{ W}$$

$$V_{\text{rs}} := \frac{P_{\text{limit}} \cdot \sqrt{2}}{V_{\text{inmin}}} \cdot R_{\text{sense}}$$

$$R_{\text{mout}} := \frac{V_{\text{rs}}}{I_{\text{momax}}}$$

$$R_{mout} = 3.01 \times 10^3 \text{ ohm}$$

- a. Choose a standard value resistor resistor close to the calculated value.

$$\text{Rmout} := 3 \cdot 10^3 \text{ ohm}$$

$$R_{mout} = R9, R10$$

9. Select Components for Pulse by Pulse Current limiting:

- a. Choose a Peak Power Limit.

Remember this limit has to be higher than the power limit that the multiplier provides.

$$I_{limit} := \frac{P_{out} \cdot (1.3) \cdot (\sqrt{2})}{V_{inmin} \cdot (\eta_1)} + 0.5 \cdot dI$$

$$V_{rs} := I_{limit} \cdot R_{sense}$$

- b. Calculate Ipeak Resistor Divider

$$R11 := 10 \cdot 10^3 \text{ ohm}$$

$$R12 := \frac{V_{rs} \cdot R11}{V_{ref}}$$

$$R12 = 1.687 \times 10^3 \text{ ohm}$$

Choose a standard resistor value

$$\text{R12} := 1.65 \cdot 10^3 \text{ ohm}$$

10. Current Loop Design

- a. Gain of the PFC Power Stage is:

$$G_{id}(s) = \frac{V_{out} \cdot R_{sense}}{s \cdot L_{boost} \cdot V_p}$$

- b. Solving for the power stage gain at the desired crossover frequency of 10 kHz in the frequency domain yields:

$$f_c := 10 \cdot 10^3 \text{ Hz}$$

$$G_{id} := \frac{V_{out} \cdot R_{sense}}{2 \cdot \pi \cdot f_c \cdot L1 \cdot V_p}$$

$$G_{id} = 0.928$$

- c. In order to have a gain of 1 at the crossover frequency the current amp must have a gain of $1/G_{ps}$ at the crossover frequency.

$$G_{ea} := \frac{1}{G_{id}}$$

$$G_{ea} = 1.078$$

$$R_i := R_{mout}$$

$$R_f := R_i \cdot G_{ea}$$

$$R_f = 3.234 \times 10^3 \text{ ohm}$$

$$C_z := \frac{1}{2 \cdot \pi \cdot f_c \cdot R_f}$$

$$C_z = 4.921 \times 10^{-9} \text{ F}$$

$$C_p := \frac{1}{2 \cdot \pi \cdot R_f \cdot \left(\frac{f_s}{2}\right)}$$

$$C_p = 3.553 \times 10^{-10} \text{ F}$$

- c. Choose values for R_f , C_z , and C_p closest to there calculated values

$$\underline{R_f} := 3.23 \cdot 10^3 \text{ ohm} \quad \underline{C_z} := 4.9 \cdot 10^{-9} \text{ F} \quad \underline{C_p} := 355 \cdot 10^{-12} \text{ F}$$

$$R_f = R8$$

$$C_z = C9$$

$$C_p = C8$$

11. Voltage Amplifier Loop Design:

- a. We first determine how much ripple is on the output capacitor and then design the feedback to attenuate the ripple to .75% of THD.

$$v_{opk} := \frac{P_{out} \cdot \frac{1}{\eta_1}}{2 \cdot \pi \cdot 120\text{Hz} \cdot C_{12} \cdot V_{out}}$$

$$v_{opk} = 2.637 \text{ V}$$

$$v_{opp} := v_{opk} \cdot 2$$

$$ve_{pk} := .015 \cdot (Ve_{max} - Ve_{min})$$

$$ve_{pk} = 0.075 \text{ V}$$

$$G_{vea} := \frac{ve_{pk}}{v_{opp}}$$

$$G_{vea} = 0.014$$

b. Select Standard Components for the Voltage Loop Closest to their Calculated Values

$$R_{in} := 511 \cdot 10^3 \text{ ohm} \quad \text{Let the input resistor equal 1.12Mohm.}$$

$$R_{in} = R_{22} + R_{23}$$

$$R_d := \frac{V_{ref} \cdot R_{in}}{V_{out} - V_{ref}}$$

$$R_d = 1.015 \times 10^4 \text{ ohm}$$

$$R_d := 10 \cdot 10^3 \text{ ohm}$$

$$R_d = R_3$$

$$C_f := \frac{1}{2 \cdot \pi \cdot 120\text{Hz} \cdot G_{vea} \cdot R_{in}}$$

$$C_f = 1.825 \times 10^{-7} \text{ F}$$

Choose a standard value for the feedback capacitor

$$C_f := 180 \cdot 10^{-9} \text{ F}$$

$$C_f = C_7$$

$$G_{ps_fc} := \frac{P_{out}}{(V_{eamax} - V_{eamin}) \cdot V_{out} \cdot 2 \cdot \pi \cdot C_{12}}$$

$$G_{ps_fc} = 60.129 \text{ Hz}$$

$$G_{vea1} := \frac{1}{2 \cdot \pi \cdot R_{in} \cdot C_f}$$

$$G_{vea1} = 1.73 \text{ Hz}$$

$$T_v := G_{ps_fc} \cdot G_{vea1}$$

$$T_v = 104.043 \text{ Hz}^2$$

$$f_{crossover} := \sqrt{T_v}$$

$$f_{crossover} = 10.2 \text{ Hz}$$

$$R_f := \frac{1}{2 \cdot \pi \cdot f_{crossover} \cdot C_f}$$

$$R_f = 8.668 \times 10^4 \text{ ohm}$$

Choose a standard resistor

$$R_f := 90 \cdot 10^3 \text{ ohm}$$

$$R_f = R7$$

$$C_z := \frac{1}{2 \cdot \pi \cdot \frac{f_{crossover}}{10} \cdot R_f}$$

Cz removes proportional gain caused by Op Amp loading

$$C_z = 1.734 \times 10^{-6} \text{ F}$$

$$C_z := 1.5 \cdot 10^{-6}$$

$$C_z = C15$$

Solving for the crossover frequency involves finding the product of the power stage gain and the e/a gain, setting that to one and solving for f. I've left out some symbolic calculations so that Mathcad can recalculate without intervention if other parameters change. An excellent explanation of this math can be found in Unitrode App Note U-153.

12. Setting up OVP/PFC Enable Divider

$$R_{bot} := 10 \cdot 10^3 \text{ ohm} \quad \text{Pick a resistor for R5}$$

$$R_{bot} = R5$$

$$R5 := R_{bot}$$

$$V_{ovp} = 425 \text{ V}$$

The high side of the OVP divider (R_{top}) should be formed by two resistors

$$R_{top} := \frac{(V_{ovp} - 8\text{V}) \cdot R_{bot}}{8\text{V}}$$

$$R_{top} = 5.213 \times 10^5 \text{ ohm}$$

Choose standard resistors that equal R_{top}

$$R_{top} = R20 + R4$$

$$R20 := 274 \cdot 10^3 \text{ ohm}$$

$$R4 := 249 \cdot 10^3 \text{ ohm}$$

Check OVP

$$\frac{8\text{V} \cdot (R5 + R4 + R20)}{R5} = 426.4 \text{ V}$$

Check PFC Enable

$$\frac{1.9\text{V} \cdot (R5 + R4 + R20)}{R5} = 101.27 \text{ V}$$