UCC3817/8A Design Procedure

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UCC3817 MathCAD Design Tool
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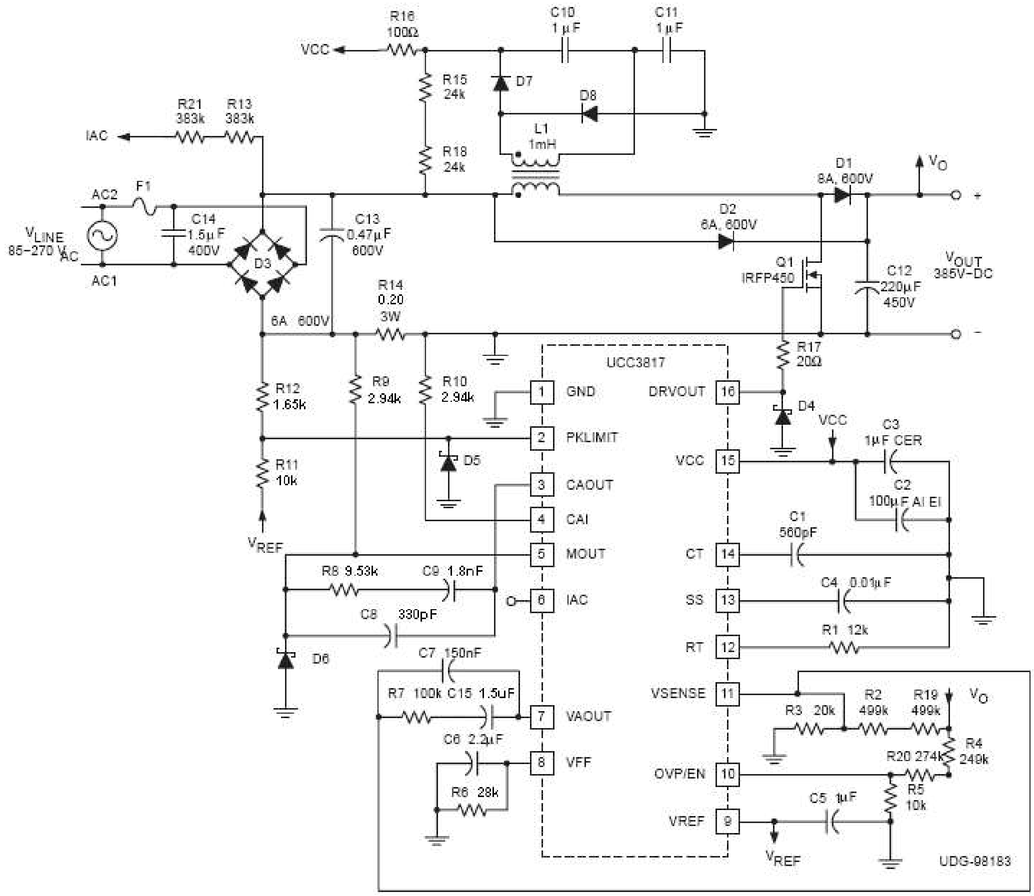

Figure 1. Typical Application Circuit

I. Power Factor Pre regulator Design:

1. PFC Design Goals:

$Vinmin := 85V$	Vin Minimum
$Vinmax := 265V$	Vin Maximum
$Vout := 385V$	Output Voltage
$Pout := 1000W$	Output Power
$\eta 1 := 0.95$	Note η represents efficiency a.) η1 is the estimated PFC efficiency
$fs := 120 \cdot 10^{3} Hz$	
$Vovp := 425V$	Over Voltage Protection Trip Point

2. Device Parameters:

$Vrmsmin := 1.4V \quad Vrmsmax := 5V \quad Vref := 7.5V \quad Veamin := .5V \quad Veamax := 5.5V \quad Vp := 4V$

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

a. Calculate Peak Input Current

$$Ipk := \sqrt{2} \cdot \frac{\frac{Pout}{\eta 1}}{Vinmin}$$

$$Ipk = 17.513\,A$$

$$dI := .20 \cdot Ipk$$

$$dI = 3.503\,A$$

b. Calculate Maximum Duty Cycle

$$D := \frac{Vout - \sqrt{2} \cdot Vinmin}{Vout}$$

$$D = 0.688$$

c. Calculate Inductance

$$L1 := \frac{Vinmin \cdot \sqrt{2} \cdot D}{dI \cdot fs}$$

$$L1 = 1.967 \times 10^{-4}\,H$$

d. Select an Inductance Close to the Calculated Value

$$L1 := 0.15 \cdot 10^{-3}\,H$$

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

a. Choose a Minimum Hold up Time for 60Hz

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

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

$$Vpfc\_Droop := 85V$$

c. Calculate PFC DC Current

$$Idc := \frac{Pout}{Vout}$$

$$Idc = 2.597\,A$$

d. Calculate Minimum Capacitance Needed

$$C12 := \frac{2 \cdot \frac{Pout}{\eta 1} \cdot tholdup}{Vout^2 - (Vout - Vpfc\_Droop)^2}$$

$$C12 = 5.785 \times 10^{-4} F$$

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

$$C12 := 220 \cdot 10^{-6} F$$

5. Select Timing Components (R_T and C_T) for 100 kHz switching frequency

Let C1 = 12 kohm

$$R1 := 12 \cdot 10^3 ohm$$

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

$$C1 = 4.167 \times 10^{-10} F$$

a. Choose a Capacitor Close to a Standard Value

$$C1 := 560 \cdot 10^{-12} F$$

6. Select Components for Vrms Filter:

$$Iacmax := 500 \cdot 10^{-6} A$$

$$Riac := Vinmax \cdot \frac{\sqrt{2}}{Iacmax}$$

$$Riac = 7.495 \times 10^5 ohm$$

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

Select Two Resistors to Meet Voltage Requirements

$$Riac = R21 + R13$$

DC current through Rvms is 1/2 Iac current (2:1 mirror) X 0.9 (dc factor) = 250uA X 0.9

$$Rvff := \frac{1.4V}{\frac{Vinmin}{Riac \cdot 2} \cdot 0.9}$$

$$Rvff = 2.804 \times 10^{4} ohm$$

$$Rvff = R6$$

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

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

$$R6 = Rvff$$

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.

$$fp := 2.6Hz$$

$$Cvff := \frac{1}{2 \cdot \pi \cdot Rvff \cdot fp}$$

$$Cvff = 2.186 \times 10^{-6} F$$

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

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

$$Cvff = C6$$

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

$$\text{Rsense} := \frac{1\text{V}}{\text{Ipk} + 0.5 \cdot \text{dI}}$$

$$\text{Rsense} = 0.052\,\text{ohm}$$

Choose a standard value

$$\text{Rsense} := 0.20\text{ohm}$$

$$\text{Rsense} = \text{R14}$$

8. Multiplier Set up

$$\text{Iac\_at\_Vinmin} := \text{Vinmin} \cdot \frac{\sqrt{2}}{\text{Riac}}$$

$$\text{Iac\_at\_Vinmin} = 1.569 \times 10^{-4}\,\text{A}$$

Imo at low line is determined by Iac_lowline, Veamax, and Vrmsmin.

$$\text{Km} := \frac{1}{\text{V}}$$

$$\text{Imomax} := \frac{\text{Iac\_at\_Vinmin} \cdot (\text{Veamax} - 1\text{V})}{\text{Km} \cdot \text{Vrmsmin}^2}$$

$$\text{Imomax} = 3.603 \times 10^{-4}\,\text{A}$$

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%.

$$\text{Plimit} := \frac{\text{Pout} \cdot (1.2)}{\eta 1}$$

$$\text{Plimit} = 1.263 \times 10^{3}\,\text{W}$$

$$\text{Vrs} := \frac{\text{Plimit} \cdot \sqrt{2}}{\text{Vinmin}} \cdot \text{Rsense}$$

$$\text{Rmout} := \frac{\text{Vrs}}{\text{Imomax}}$$

$$Rmout = 1.167 \times 10^{4}\,ohm$$

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

$$Rmout := 2.94 \cdot 10^{3}\,ohm$$

Rmout = 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.

$$Ilimit := \frac{Pout \cdot (1.3) \cdot \left(\sqrt{2}\right)}{Vinmin \cdot (\eta 1)} + 0.5 \cdot dI$$

$$Vrs := Ilimit \cdot Rsense$$

b. Calculate Ipeak Resistor Divider

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

$$R12 := \frac{Vrs \cdot R11}{Vref}$$

$$R12 = 6.538 \times 10^{3}\,ohm$$

Choose a standard resistor value

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

10. Current Loop Design

a. Gain of the PFC Power Stage is:

$$Gid(s) = \frac{Vout \cdot Rsense}{s \cdot Lboost \cdot Vp}$$

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

$$fc := 10 \cdot 10^{3}\,Hz$$

$$Gid := \frac{Vout \cdot Rsense}{2 \cdot \pi \cdot fc \cdot L1 \cdot Vp}$$

$$Gid = 2.042$$

c. In order to have a gain of 1 at the crossover frequency the current amp must have a gain of 1/Gps at the crossover frequency.

$$Gea := \frac{1}{Gid}$$

$$Gea = 0.49$$

$$Ri := Rmout$$

$$Rf := Ri \cdot Gea$$

$$Rf = 1.439 \times 10^{3}\ ohm$$

$$Cz := \frac{1}{2 \cdot \pi \cdot fc \cdot Rf}$$

$$Cz = 1.106 \times 10^{-8}\ F$$

$$Cp := \frac{1}{2 \cdot \pi \cdot Rf \cdot \left(\frac{fs}{2}\right)}$$

$$Cp = 1.843 \times 10^{-9}\ F$$

c. Choose values for Rf, Cz, and Cp closest to there calculated values

$Rf := 9.53 \cdot 10^{3} ohm$ $\quad Cz := 1.8 \cdot 10^{-9} F$ $\quad Cp := 330 \cdot 10^{-12} F$

$Rf = R8$ $\quad Cz = C9$ $\quad Cp = C8$

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.

$$vopk := \frac{Pout \cdot \frac{1}{\eta 1}}{2 \cdot \pi \cdot 120Hz \cdot C12 \cdot Vout}$$

$$vopk = 16.483\ V$$

$$vopp := vopk \cdot 2$$

$veapk := .015 \cdot (Veamax - Veamin)$

$veapk = 0.075\,V$

$Gvea := \frac{veapk}{vopp}$

$Gvea = 2.275 \times 10^{-3}$

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

$Rin := 2 \cdot 499 \cdot 10^{3} ohm$ Let the input resistor equal 1.12Mohm.

$Rin = R22 + R23$

$Rd := \frac{Vref \cdot Rin}{Vout - Vref}$

$Rd = 1.983 \times 10^{4}\,ohm$

$Rd := 20 \cdot 10^{3} ohm$

$Rd = R3$

$Cf := \frac{1}{2 \cdot \pi \cdot 120Hz \cdot Gvea \cdot Rin}$

$Cf = 5.841 \times 10^{-7}\,F$

Choose a standard value for the feedback capacitor

$Cf := 150 \cdot 10^{-9} F$

$Cf = C7$

$$Gps\_fc := \frac{Pout}{(Veamax - Veamin) \cdot Vout \cdot 2 \cdot \pi \cdot C12}$$

$$Gps\_fc = 375.809\ Hz$$

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.

$$Gvea1 := \frac{1}{2 \cdot \pi \cdot Rin \cdot Cp}$$

$$Gvea1 = 483.254\ Hz$$

$$Tv := Gps\_fc \cdot Gvea1$$

$$Tv = 1.816 \times 10^{5}\ Hz^{2}$$

$$fcrossover := \sqrt{Tv}$$

$$fcrossover = 426.159\ Hz$$

$$Rf := \frac{1}{2 \cdot \pi \cdot fcrossover \cdot Cp}$$

$$Rf = 1.132 \times 10^{6}\ ohm$$

Choose a standard resistor

$$Rf := 100 \cdot 10^{3} ohm$$

$$Rf = R7$$

Cz removes proportional gain caused by Op Amp loading

$$Cz := \frac{1}{2 \cdot \pi \cdot \frac{fcrossover}{10} \cdot Rf}$$

$$Cz = 3.735 \times 10^{-8} F$$

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

$$Cz = C15$$

12. Setting up OVP/PFC Enable Divider

$\mathrm{Rbot} := 10 \cdot 10^{3}\,\mathrm{ohm}$ Pick a resistor for R5

$\mathrm{Rbot} = \mathrm{R5}$

$\mathrm{R5} := \mathrm{Rbot}$

$\mathrm{Vovp} = 425\,\mathrm{V}$

The high side of the OVP divider (Rtop) should be formed by two resistors

$$\mathrm{Rtop} := \frac{(\mathrm{Vovp} - 8\mathrm{V}) \cdot \mathrm{Rbot}}{8\mathrm{V}}$$

$\mathrm{Rtop} = 5.213 \times 10^{5}\,\mathrm{ohm}$

Choose standard resistors that equal Rtop

$\mathrm{Rtop} = \mathrm{R20} + \mathrm{R4}$

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

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

Check OVP

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

Check PFC Enable

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