Design of Single Stage Power Factor Correction and on-Board Power Supply for Dental X-Ray Application

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Abstract- Expansion in the field of electrical engineering is rapid and admirableble. Even though the non linear power electronic equipments introduce some power quality issues, their use is unavoidable. Most of the medical equipments make use of power electronics devices. A serious issue includes Voltage stress. Low power factor and High current ripples. In order to overcome these, we are using Active PFC circuit, It can be implemented by PFC Boost topology to improved power factor, Generally power factor correction controller i.e.UCC28512 is used for many applications, But we have proposed in particular domain in the field of medical so that we are using for single stage PFC and Internal power supply for dental X-ray application, The IC operates in two stages 1.average current technique for PFC boost converter, 2.peak current technique for fly back converter, The application circuit is designed for 85 to 265 V universal Ac line 1 phase 47-63 Hz line frequency, A integrated controller for both the converter have been developed according to the designed values ,The PFC stage output 400V dc bus had been verified with hardware implementation and power factor have been achieved with PFC controller i.e. 0.9

Key words: AC to DC conversion, PFC Boost Converter output, Fly back converter, PFC controller is UCC28512

I. INTRODUCTION

The use of power electronics equipment single phase and three phase power system for conversion and controlling of electric power has led to increase harmonics in power system, In medical applications like RAD ,CT, MRI, A high voltage DC is required at the output, which necessities use of single phase bridge rectifier at the input side ,The non linear power electronic equipments generates current distortion (harmonics), Voltage stress at the input side, These voltage stress and current harmonics will results in poor power factor and THD is more , To overcome this drawback better to go for active power factor correction ,

According to our requirement we are using controlling device IC i.e. UCC28512 is a 20 pin IC, This is a standard IC it can be taken from Texas instruments, This IC can be used for some other applications but we are worked in particular domain in the field of medical, So it can be used for the application of Dental X-ray to improve the power factor, UCC 28512 is a control device it controls PFC stage as well has PWM stage.

In recent years there are two types of power factor correction i.e. active power factor correction and passive power factor correction. In passive power factor correction filters are placed at the input side to remove the unwanted frequencies from a signal and filter reduces the harmonic content of a current waveform, by using more number of passive power factor correction (filters),System may bulky It gives, Poor voltage regulation, Power factor depends on regulation, If regulation is less power factor also less, In order to minimize the filters better go for active power factor correction, In a active PFC consists of switching elements such has IGBT, MOSFET, BJT, etc, Active PFC can be implemented by Boost topology, This topology is the best method to improve the power factor by shaping the input current, It gives better THD. Smaller in size and lighter and also reduce cost, and fly back converter is used for onboard power supply, The two converter stage is controlled by a single controlling device i.e. is UCC 28512.

The single stage approach is the simple and convenient method for power factor correction taking in to consideration, The power stage consists of two converter i.e. combination of boost and fly back converter, These two converter are used for low power application less than 150watts, The objective of this project is to design a single stage PFC and on board power supply for dental x-ray application had been developed according to the designed values, The PFC stage output 400V dc bus had been verified with hardware implementation and power factor have been achieved with PFC controller i.e. 0.9

II. LITERATURE SURVEY

In literature, several studies have been presented regarding power factor correction by using different types of PFC Controller, In literature previously they are using different PFC controller to improve power factor in each stage , Actually we are doing single stage (PFC+PWM), Those stages are controlled By single controlling device IC i.e.UCC28512

III. PROPOSED SYSTEM

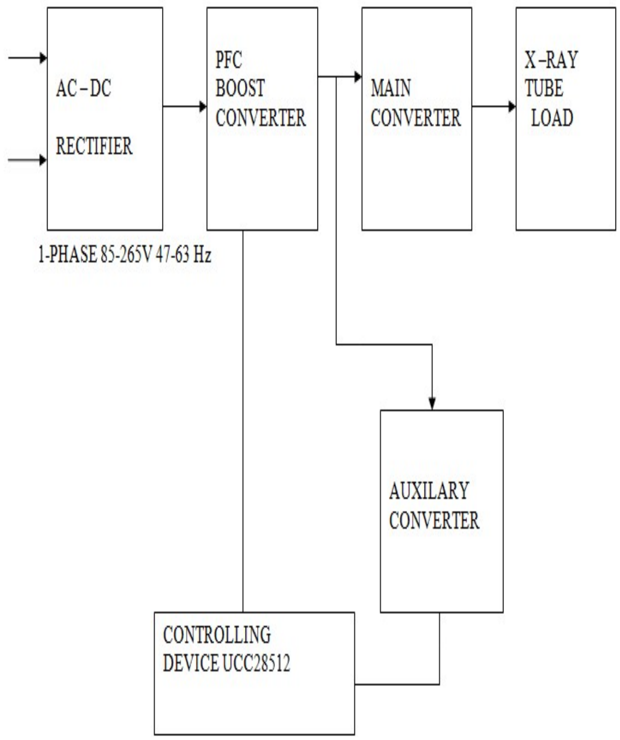


Fig-3.1: proposed block diagram.

Fig-3.1 shows circuit diagram of single stage PFC and Internal Power supply For Dental X – ray Application

In block diagram consists of AC-DC rectifier, The PFC Boost converter connected to the output of the full bridge rectifier , The PFC Boost converter output will provide an input to the auxiliary converter ,Those two stages are controlled by single controlling device i.e. IC UCC28512 and Load connected to the AC side of the full bridge inverter,

IV. Single Stage PFC and on-board Power Supply for a Dental X-ray Application Circuit

The proposed methodology of single stage PFC and On-board power supply for a dental X-ray application as shown, In the proposed methodology consists of PFC controller i.e.UCC28512,This is a standard IC taken from Texas instruments operated in same switching frequency in both the stages (PFC+PWM) i.e. 100kHz, The PFC controller will operates in two control stages i.e. Average current control technique for PFC Boost converter and Peak current control technique for Fly back converter, Those 2 stages are controlled by single controlling device IC UCC28512, In average current control PFC Boost converter operates ,The bridge rectifier conducts for short period of time in each cycle To withstand the RMS line current and maximum peak ac line voltage without saturation of the inductor L1,The current flowing from the supply side contains some current harmonics hence THD is more results in poor power factor, The PFC Boost inductor are connected in series with the rectifier, It observes the supply spiky current (harmonic current) and reduces the THD, If the load is Purely resistive the power factor achieve will be nearly unity, Because the voltage and current will be in phase, In peak current control technique auxiliary converter operates in maximum peak current (safe operating limit), If the auxiliary converter will operates for more than the peak level of current the transformer get saturate, If the high current flows through the transformer windings ,The windings may get damaged, Losses will be more , To avoid this issue the auxiliary converter operates with in a peak current (safe operating limit) and in our proposed system auxiliary converter is used for an on- board power supply, On- board power supply means In PFC controller consists of comparator, Differentiator, Integrator, amplifier etc providing a supply For those components by using auxiliary converter (fly back converter) And CNY 17-3 (opt-coupler) is a 6 pin IC connected to the output of the auxiliary converter, This IC is used to isolate the input and output feedback signal of the circuit ,

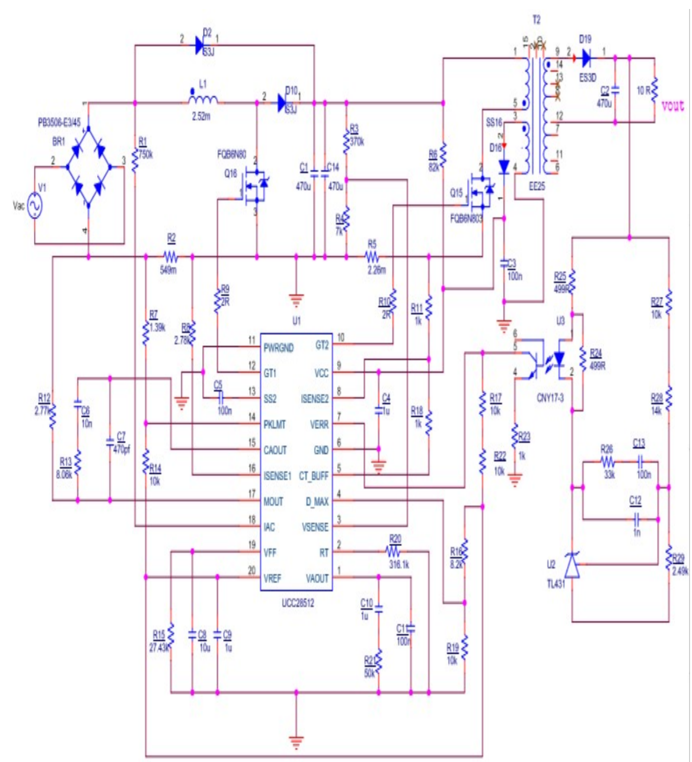


Fig-4.1: Proposed Methodology for Single stage PFC and on-board Power supply for Dental X-ray Application

Input Voltage	85V-265V
Input voltage	230V nominal
Input current	0.43A
Input Power	100W
Input switching frequency	50Hz

Table -4.2: input specifications

PFC output	400V DC bus
Fly back output	24 DC
Power factor with PFC controller	0.9lag
Switching frequency of the PFC stage and PWM stage	100KHz

Table -4.3: output specifications

V. DESIGN CALCULATION

Inductor L1 must be designed with minimum duty cycle to withstand the maximum RMS line current without saturation of the maximum peak ac line current

$$L_1 = \frac{V_{AC(min)}^{2} \times D_{1(min)} \times T_{s(pfc)}}{K_{RF} \times P_{IN}}$$

$$K_{RF} = \frac{\Delta i_{L1(p-p)}}{i_{L1(max)}}$$

$$T_{S(PFC)} = \frac{1}{\text{switching frequency of the pfc}}$$

$$\Delta i_{L1(p-p)} = K_{RF} \times I_{L1(max)} = 0.3326\ A$$

$$K_{RF} = 0.2$$

$$I_{L1(max)} = 1.6663A$$

$$T_{S(PFC)} = \frac{1}{100k} = 10\ \mu\ sec$$

$$L1 = \frac{85^2 \times 0.699 \times 10 \times 10^{-6}}{0.2 \times 100} = 2.52mH$$

R1 is designed to sense the rectified ac line voltage

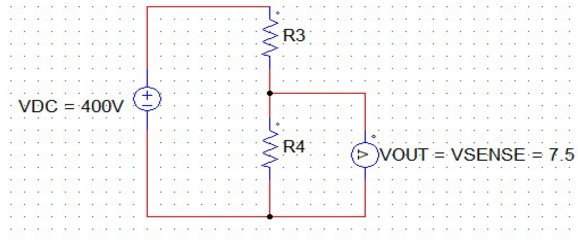
$$R_1 = \frac{\sqrt{2}VAC_{(max)}}{IAC_{(peak)}} \qquad R_1 = \frac{\sqrt{2} \times 265}{500\mu A} = 749.5K\Omega$$

$$R_2 = \frac{V_{DYNAMIC}}{i_{L1(max)} + 0.5 \times \Delta i_{L1(P-P)}}$$

$$R2 = \frac{1V}{1.663 + 0.5 \times 0.3326} = 546.6\ m\ \Omega$$

The voltage at the current sense resistor is called Dynamic voltage, Dynamic Voltage is selected for 1V for safe operation because R2 has current sense resistor it has enough power limit

To design R3 and R4 apply resistor divider between R3 and R4 such that the voltage V-Sense 7.5 V when VDC 400V



5.1: represents the Resistor devider circuit

$$V_{OUT} = \frac{V_1 \times R_4}{R_3 + R_4}$$

$$7.5 = \frac{400 \times R_4}{R_3 + R_4}$$

$$7.5R_3 + 7.5R_4 = 400R_4$$

7.5R3 = 392.5R4

The ratio R3 and R4 is given by R3/R4 =52.33Ωas per the recommendation and guidelines of the data sheet choose R4 has 7K

R3 = 52.33×R4

R3 = 52.33×7K

R3 = 366.1K

The current sense resistor for the PWM stage R5, is calculated so that at maximum current, its voltage is the threshold voltage comparator (nominally 1.3 V).

I_{LIMIT} is calculated taking 21% of I_{LMAX}

$$R_5 = \frac{V_{TH} \times I_{(LIMIT)}}{I_{(PEAK\ fly)}} \qquad R_5 = \frac{1.3 \times 0.349}{4.37} = 103.8\ m\ \Omega$$

As per the recommendation and guidelines of the data sheet R6= 86K

$$I_{(PEAK\ fly)} = Iavg + 5\ \%\ of\ Iavg$$

$$I_{(PEAK\ fly)} = 4.166 + 0.2083$$

$$I_{(PEAK\ fly)} = 4.374A$$

To Design R7 and R14 the ratio is given by

$$\frac{R_7}{R_{14}} = \frac{1}{\frac{vref}{IL1\ max \times R2} - 1}$$

R14 is chosen around 10KΩ and VREF is 7.4V

$$\frac{R_7}{10k\Omega} = \frac{1}{\frac{vref}{IL1max \times R2} - 1}$$

$$= \frac{R_7}{10k\Omega} = \frac{1}{\frac{7.4}{1.663 \times 0.546} - 1} = 1.39k$$

$$R_{12} = \frac{I_{Peak} \times R_1 \times R_2 \times K \times V_{FF(min)}^{2}}{\sqrt{2} \times V_{AC(min)} \times (V_{AOUT(max)} - 1)}$$

VAOUT (max)=5V VAC (min) = 85V

VFF (min) =1.4V K=1

$$R_{12}=\frac{1.663\times749.5K\times546.6m\times1\times1.4^2}{\sqrt{2}\times85\times(5-1)}=2.78K\Omega$$

As per the recommendation & guidelines of the data sheet R12 equation is same as the R13

$$R_{13}=R_{12}\times\frac{2\pi\times f_{CO(pfc)}\times L_1\times V_{CT\text{-}BUFF(P\text{-}P)}}{V_{C1}\times R_2}$$

$$R_{13}=2.78K\times\frac{2\Pi\times10\times10^3\times2.52\times10^{-3}\times4}{400\times546.6\times10^{-3}}$$

$$R_{13}=8.05K\Omega$$

Choose crossover frequency 10 kHz to achieve good results

The capacitance value of the energy storage capacitor. C1 is selected as per the recommendation and guidelines of the data sheet, to meet hold up time requirement at least a period of 1.5cycles

$$C_1=\frac{2\times P_{OUT}\times t_{HU}}{V_{C1}{}^2\times K_{R1}(2-K_{R1})}$$

$$C_6=\frac{1}{8.05\times10^3\times2\pi\times10\times10^3}=1.97\eta F$$

$$940uF=\frac{2\times100\times thu}{400\times0.29(2-0.29)}=372.2msec$$

$$C_6=\frac{1}{R_{13}\times2\pi\times f_{co(pfc)}}$$

$$C_7=\frac{1}{\pi\times f_{S(pfc)}\times R_{13}}$$

$$C_7=\frac{1}{\pi\times100\times10^3\times8.05\times10^3}=395.4\eta F$$

where $A_{FF(2)}=0.02\,for\ 3\%$ THD

$$C_8=\frac{1}{2\pi\times f_{AC}\times A_{FF(2)}\times R_{15}}$$

$$R_{15}=2\times R_1\times\frac{V_{VFF(avgmin)}}{V_{AC(min)}\times0.9}$$

$$R_{15}=749.5K\times\frac{1.4}{85\times0.9}=27.43K\Omega$$

$$C_8=\frac{1}{2\pi\times50Hz\times0.02\times27.43k}=5.27\mu F$$

To design R16 and R19 Apply resistor divider between R16 and R19 when input voltage VREF 7.5Vand VDX=VOUT=4.15V

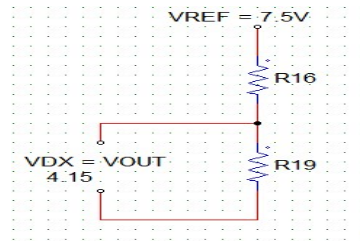


Fig 5.1: represents the Resistor divider circuit

D max is calculated by using the formula

$$Dmax=\frac{VDX-1.15}{4}$$

Dmax=0.75

$0.75\times4=VDX-1.15$

$$VOUT=\frac{VREF\times R19}{R16+R19}$$

VDX = 4.15v

$$4.15=\frac{7.5\times10K}{R16+10K}$$

R19 is choose around 10K

4.15×R16+4.15×10K = 7.5v×10k

4.15×R16 = 75k – 41.5k

4.15 R16 = 33.5k

R16 = 8.07kΩ and R19 = 10k

Choose has higher value i.e. R16 =8.2k

$$R_T=\frac{1}{31\times10^{-12}}\left(\frac{1}{fs_{PWM}}-2.0\times10^{-17}\right)$$

$$R_{20}=\frac{1}{31\times10^{-12}}\left(\frac{1}{100\times10^3}-2.0\times10^{-17}\right)=316.1k\Omega$$

As per the recommendation and guidelines of the data sheet the transformer turns i.e. choose N_1 = 254 turns and N_2 = 15 turns

R1	749.5k	R15	27.43k	R29	2.49k
R2	546.6m	R16	8.07k	C1	940uF
R3	366.1k	R17	10k	C2	1uF
R4	7k	R18	1k	C3	100nF
R5	103.8m	R19	10k	C4	1uF
R6	82k	R20	316.1k	C5	100nF
R7	1.398k	R21	50k	C6	1.97nF
R8	2.78k	R22	10k	C7	395.4nF
R9	2Ω	R23	1k	C8	5.8uF
R10	2Ω	R24	499 Ω	C9	1uF
R11	1k	R25	499 Ω	C10	1uF
R12	2.78k	R26	33k	C11	100nF
R13	8.05k	R27	10k	C12	1nF
R14	10k	R28	14k	C13	100nF

Table 5.3: represents the designed values

VI. RESULTS

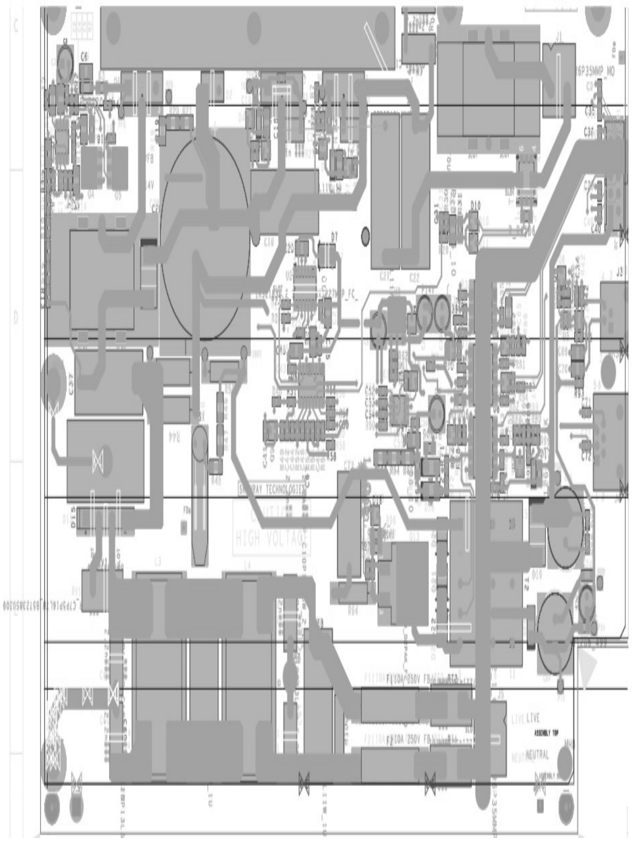


Fig 6.1: represents the top view of the PCB layout

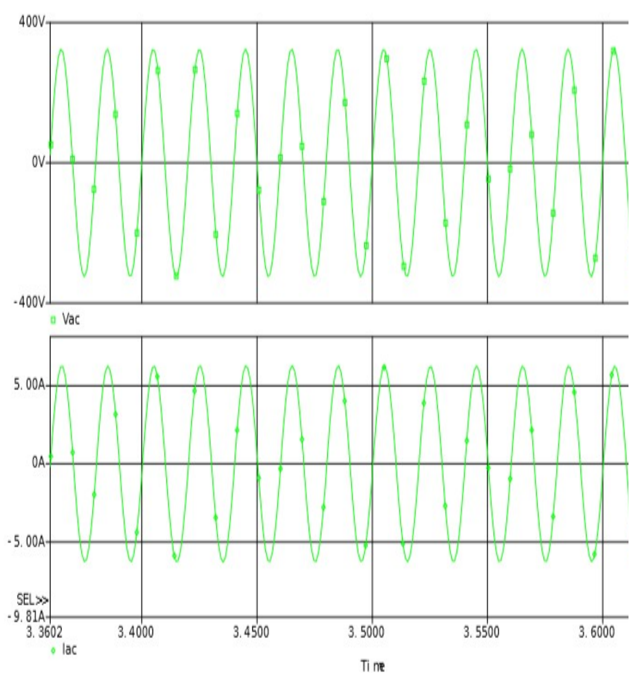


Fig 6.1: shows the Input voltage and Current waveforms

The above waveforms in figure 6.1 shows the input voltage and input current, the input voltage i.e.230V and the input current i.e. 0.43A, the above voltage and current waveforms are purely sinusoidal they do not contain any voltage and current distortion (harmonics) present at the input side to achieve power factor i.e. 0.9 lag with PFC controller

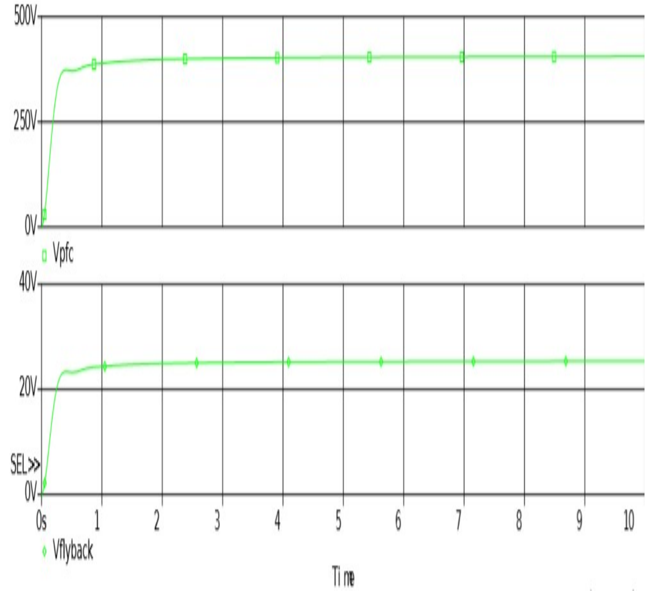


Fig 6.2: shows the Output voltage of the PFC stage and Fly back stage

By seeing the Fig 6.2 waveform, we are getting a ripple free PFC 400V dc bus voltage which is required for our system, The 400V dc voltage is given a input to the PWM stage fly back converter, In fly back stage stepping down the voltage to get 24V dc voltage the power factor had been achieved i.e. 0.9 lag in PFC stage

VII CONCLUSION

The conventional boost PFC and PWM has two stages that needs two separate ICs, This increase the complexity of the circuit and cost of the equipments is more, More components leads to reduce the working speed of the system, The intended result of the power factor correction stage and low voltage power supply or on- board power supply being controlled by a single controlling device i.e. UCC28512, by doing this ,complexity of the circuit is reduced , And power factor had been achieved with PFC controller i.e. 0.9 lag .

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