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(54) Title: METHOD AND APPARATUS FOR REDUCING THE SIZE OF THE INPUT BULK CAPACITOR IN AC TO DC CONVERTERS

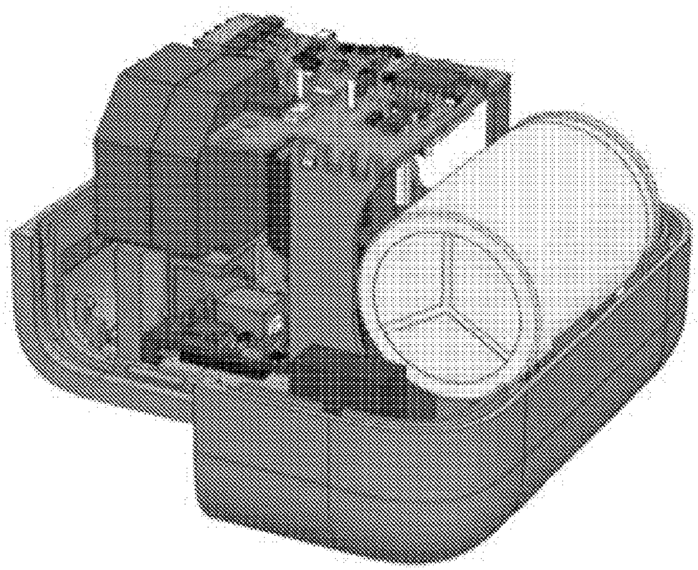

FIGURE 1

(57) Abstract: This patent applications describes several methodologies of decreasing the size of the input bulk capacitor, of increasing the power factor and reducing the RMS current through the input bulk capacitor. Some of these methodologies do not require any hardware change from the conventional AC -DC adapters and all is accomplished just through the modulation of the input current drawn by the isolated DC-DC converter. Others methodologies described in this patent application do require small changes in the hardware and that will amplify the effect of current modulation in reduction of the input bulk capacitor and will significantly improve the power factor.

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Method and Apparatus for Reducing the Size of the Input Bulk Capacitor in AC to DC Converters

Related Application/claim of priority

This application is related to and claims priority from US provisional application serial number 62/189,150, filed July 6, 2015, and which provisional application is incorporated by reference herein.

Background and summary of the present invention.

0001 In most of the power adapters under 75W there is an input stage as depicted in Figure2. It is composed of an EMI filter, a bridge rectifier formed by D1, D2, D3 and D4, and a bulk capacitor Bulk. After the bulk capacitor there is an isolated DC-DC Converter which transfers the energy form the bulk Capacitor to the secondary. In most of the applications the isolated DC-DC Converter uses a flyback topology due to its simplicity and its capability to operate over a large input voltage range. In most of the application the isolated DC-DC Converter operates from an input voltage range of 75V to 375V. To design the flyback to operate under 75V will compromise the performance of the converter. For that reason we place at the input a bulk capacitor of a certain size in order to reduce the voltage ripple and not allow the voltage across the bulk capacitor to decay under a certain level, such as 70V. In addition to this the designer has to ensure that the bulk capacitor is capable to handle the RMS current, caused by the ripple current with the line frequency and to a lower extend the high frequency currents produced by the isolated DC-DC Converter. In Figure 1 is presented the packaging of a 45W adapter. The bulk capacitor occupies approximately 30% of the volume of the adapter. In order to further decrease the size of the adapter and increase the power density the bulk capacitor reduction shall be one of the main priorities. In the patent application # 62/168,060 entitled "High Efficiency and High Power Density Power Adapter" (which is incorporated by reference herein) were presented several methods of eliminating the bulk capacitor with the purpose of increasing the power density. The bulk capacitor however has other important functions such as the line transient protection and EMI. Some of these functions can be addressed with other devices and circuity but that may add complexity and increase the cost. In Figure 3 are presented the key waveforms in the input stage of an AC to DC adapter. In Figure 3 is presented the line voltage, Vac, the voltage across the bulk capacitor, Vbk, the AC line current which is presented in absolute value, │Iac│, the current through the bulk capacitor Ibk, and the current going to the input of the isolated DC-DC Converter, Iin, which is considered to be constant.

0002 As is depicted in Figure 3 the voltage across the bulk capacitor Vbk is decaying prior t1, being discharged by the input current of the isolated DC-DC Converter, Iin. At t1, the rectified line voltage exceeds the level of the voltage across Cbk. Between t1 and t2 the line will charge the bulk capacitor and in the same time will provide the Iin for the DC-DC Converter. The line current, Iac and the current through the bulk capacitor discharge at the same rate until the current through the bulk capacitor becomes zero at t2. At that point the line current, Iac, is equal with the input current of the isolated DC-DC Converter. Further the current through the bulk capacitor becomes negative which means that the bulk capacitor is discharging. At t3 the line current becomes zero which represents the condition wherein the current coming out of the bulk capacitor it is equal with the current demanded by the isolated DC-DC Converter, Iin. After that point the current required by the isolated DC-DC Converter is provided fully by the bulk capacitor which is discharging linearly until t4, wherein the rectifier line voltage reaches the same level as the voltage across the bulk capacitor. In conclusion we have identified three intervals. Between t1 to t2, the current demanded by the isolated DC-DC Converter is provided by the line and the bulk capacitor is charged from the line. Between t2 to t3 the current required by the isolated DC-DC Converter is provided by the line and also by the bulk capacitor. The third interval in between t3 to t4 wherein the current required by the isolated DC-DC Converter is provided just by the bulk capacitor and the voltage across the bulk capacitor is discharged linearly until the line voltage reaches the same level as the voltage across the bulk capacitor. For example if we consider a 60W AC power adapter with an efficiency of the isolated DC-DC Converter at low line of 93% and the bulk capacitor has a value of 68uF, the voltage across the bulk capacitor has a ripple of 56V with a high voltage level of 123V and a low level of 66V. The RMS current through the bulk capacitor is 0.95A. If we set a minimum voltage across bulk, for example 70V, the ripple voltage across the bulk capacitor in this example is not acceptable. The present patent application will present several methods to reduce the ripple across the bulk capacitor.

0003 The present invention provides an AC to DC Converter containing an EMI filter, an input bridge rectifier, an input bulk capacitor, and an isolated DC-DC converter which transfers the power from primary to the secondary. The input current drawn by the isolated DC-DC Converter is synchronized with the line and modulated in a way to increase its amplitude when the current is delivered by the line, which occurs when the voltage of the ac line is the same with the voltage across the input bulk capacitor, and decrease its amplitude when the current is delivered by the input bulk capacitor.

0004 In an embodiment of the present invention, the modulation of the current amplitude during the time the current is delivered by the ac line is done in a sinusoidal like shape proportional to the input line voltage, by increasing the current amplitude when the input line voltage is increased and decrease the amplitude when the input line voltage is decreased.

0005 In addition, in an embodiment of the present invention, the average product of the voltage at the input of the isolated DC-DC converter and the current drawn by the isolated DC-DC converter remains constant regardless of the amplitude of the current modulation.

0006 In another version of the present invention, an AC to DC Converter contains an EMI filter, an input bridge rectifier, an input bulk capacitor, a controlled switch connected between the output of the bridge rectifier and the isolated DC-DC Converter. An additional two rectifiers are placed with the anode towards the each side of the input AC line and with the cathode to the input of the isolated DC-DC converter and an additional input capacitor is placed at the input of the isolated DC-DC Converter. The controlled switch is synchronized with the line and is turned off prior the line voltage reaches its peak and turned on again after a time interval, while the input current drawn by the isolated DC-DC Converter is synchronized with the line and is modulated in a such way that the current has a larger amplitude during the time, the current is delivered by the line and a lower amplitude when the current is delivered by the input bulk capacitor.

0007 In an embodiment of that version, the controlled switch is turned on after the peak of the ac line , when the voltage of the ac line is the same as the voltage of the ac line before the peak where the decaying voltage across the bulk capacitor reaches the same voltage as the ac line.

0008 The modulation of the current drawn by the isolated DC-DC converter as per the embodiments of this invention will create a line frequency ripple across the capacitors at the output of the isolated DC-DC converter. In the event wherein there is a post regulator as the final stage after the isolated DC-DC converter, the post regulator will eliminate the line frequency ripple. The line frequency ripple can also be also steered into a ripple steering capacitor. In many applications the presence of the line frequency ripple may be within the acceptable levels. The current modulation drawn by the isolated DC-DC converter places the output capacitors at the output of the isolated DC-DC converter in a virtual parallel with the bulk capacitor and as a result we can decrease the value of the bulk capacitor and the ripple current through the bulk capacitor and the ripple across the bulk capacitor. This technology does lead to a better utilization of the capacitors at the input and the output of the isolated DC-DC converter. Another benefit of this technology is the improvement of the power factor by extending the time interval wherein the current is drawn for the AC line and shaping the current drawn by the isolated DC-DC converter proportional with the line voltage.

0009 These and other features of the present invention will be apparent from the following detailed description and the accompanying drawings

Brief Description of the Drawings

0010 Figure 1 schematically illustrates known packaging for a 45W adapter;

0011 Figure 2 shows a known input stage for a power adaptor under 75W;

0012 Figure 3 shows known waveforms in the input stage of an AC to DC adapter;

0013 Figure 4a shows an embodiment of a control methodology according to the present invention;

0014 Figure 4b shows how an increase in power extraction will be more efficient with current shaped according to the principles of the present invention;

0015 Figure 5 depicts the effect of power delivery on ripple across the bulk capacitor, in an embodiment according to the present invention;

0016 Figure 6 shows a prior art method of reducing the size of a bulk capacitor;

0017 Figure 7 shows the control signal that turns off a switch prior to the AC voltage reaching a peak, in an embodiment according to the present invention;

0018 Figure 8a shows the effect of using one of the embodiments of the present invention;

0019 Figure 8b shows another embodiment of the present invention; and

0020 Figures 9, 10, 11 and 12 show different methods of dealing with larger ripple across an output capacitor, described in provisional application serial numbers 62/154354 and 62/152722, which are incorporated by reference herein.

Detailed Description

0021 One of the embodiments of this invention consists into a control methodology of the isolated DC-DC Converter designed to increase the input current demanded by the isolated DC-DC Converter during the time wherein the energy is provided by the line, between t1 to t2 and decrease the current demanded by the isolated DC-DC Converter during the time wherein the energy is provided by the bulk capacitor, by maintaining the average current required by the isolated DC-DC Converter the same. This embodiment is described in Figure 4a. The availability of the digital control will allow us to implement such a concept in a cost effective way and without a complex circuity. For example if we will increase the input current of the isolated DC-DC Converter by 30% during the time interval t1 to t3, and accordingly decrease the current required by the isolated DC-DC converter by 17% during the time wherein the energy is provided by the bulk capacitor, between t3 to t4, the ripple across the bulk capacitor is reduced from 56V in the prior art example to 50V and the RMS current through the bulk capacitor is decreased to 0.86A from 0.95A in the prior art implementation. In the event we increase the current demanded by the isolated DC-DC Converter by 50% during the time the energy is provided by the line we can decrease the current demanded by the isolated DC-DC Converter from the bulk capacitor by 33.6% to maintain the same output power. That would mean a reduction of the ripple across the capacitor from 56V to 42V and a reduction of the RMS current through the bulk capacitor from 0.96A to 0.78A.

0022 Another way to look at it is that we can reduce the size of the bulk capacitor by 33% while maintaining the same voltage ripple in the event we increase by 50% the input current demanded by the isolated DC-DC Converter during the time wherein the energy is delivered by the line only.

0023 The advantage of this embodiment is that there is no hardware change and all is done through control and in the case of digital control the implementation of this concept it is done only in software. The basic concept of this invention is to increase in power delivered during the time when the energy is extracted from the line followed by a decrease of the power delivered during the time wherein the energy is delivered by the bulk capacitor in a such way that the average power delivery it is constant and equal with the power level for which the adapter is designed. The increase in power extraction from the line will be more efficient if the current demanded by the isolated DC-DC Converter is shaped as presented in Figure 4b. In this embodiment the power demanded by the isolated DC-DC Converter is increasing as the line increasing improving the power delivery efficiency and the power factor. In Figure 5 is depicted the effect of the increase of power delivery between t1 to t2 on the ripple across the bulk capacitor, on the line current, Iac, and on the current through the bulk capacitor, Ibk . The effect is described by the dotted line. An increase of the current demanded by the isolated DC-DC Converter during the time wherein the energy is delivered by the line will lead to a decrease of the current required from the bulk capacitor when the energy is delivered by the bulk capacitor and as a consequence a decrease in the ripple across the bulk capacitor. Operating in this mode the ripple across the output capacitor placed in the secondary will increase. That may be a problem in some of the applications but not a problem in the case wherein there are post regulators placed at the output or other means of steering the ripple towards other storage devices as described in the patent application # 62/154354 (Exhibit 1, also incorporated by reference) entitled “High Efficiency and High Power Density Power Adapter” and in the application # 62/152722 “Method and Apparatus for Controlled Voltage Levels for One or more Outputs” (which is incorporated by reference herein and a copy of which is Exhibit 2 hereto). In Figure 12 which corresponds to Figure 6 of the application # 62/152722 “Method and Apparatus for Controlled Voltage Levels for One or more Outputs” (Exhibit 2), is depicted such a case wherein there is a post regulator placed after the output of the isolated DC-DC Converter and a capacitor Cin at the input of the post regulator. The post regulator will be able to eliminate the ripple voltage if the proper headroom is respected in between the voltage at the input and the output of the post regulator.

0024 The Figures 9, Figure 10, Figure 11 correspond to Figures 12, Figure 13 and Figure 14 of the patent application # 62/154354 entitled “High Efficiency and High Power Density Power Adapter” (incorporated by reference herein) . These figures depict different methods of dealing with the larger ripple across the output capacitor. In Figure 10 and

Figure 11 is presented two methods of ripple steering wherein the ripple across the capacitor placed at the output of isolated DC-DC Converter is steered towards a storage capacitor placed on another secondary winding or in the secondary section using an active ripple steering circuit. In Figure 9 the ripple is handled by the storage capacitor placed in the front of the output post regulator. For example if we want to regulate an output voltage of 20V or below we can design that the output voltage of the isolated DC-DC Converter to be at an average voltage of 22V or even higher. That will allow us to handle a voltage ripple at the input of the post regulator of several volts. In addition of handling the low frequency ripple which is steered towards the output by implementing this invention, the placement of an electrolytic capacitor or similar type of storage capacitors will allow us to address other functions such as transient load, surge load and even hold up time. Traditionally these functions were addressed by the energy contained in the input bulk capacitor. By moving some of the energy storage into the secondary it will allow the converter to be able to react faster to any load transients and give more functions to the post regulator which will justify the cost associated with the post regulator.

0025 Another method of reducing the size of the bulk capacitor is described in the PCIM Europe 2012 paper entitled "DC Link Chpopper for AC-DC adapters". This concept is described in Figure 6. This implementation requires the addition of two rectifiers, D5 and D6, an additional switching device, such a Mosfet, a control signal McMo and a high frequency capacitor Co at the input of the isolated DC-DC Converter. The concept consists in increasing the time wherein the energy is delivered directly by the input line.

0026 As depicted in Figure 7, the control signal VcMo turns off the switch Mo prior the AC voltage reaches its peak at t2. Between t2 to t3 the isolated DC-DC Converter takes the energy directly from the line through the bridge rectifier formed by D6, D1, D5 and D2 as it did between t1 and t2 through D3, D1, D4 and D2. The time interval wherein the energy is taken directly from the line is increased from t1 to t2 as in the previous implementations to t1 to t3, doubling the time wherein the converter takes its energy directly from the line. During t2 to t3 the energy stored in the bulk capacitor which was charged from the line during the time interval t1 to t2 is stored. The voltage across the bulk capacitor does not change. At t3 the switch Mo is turned on and the bulk capacitor is connected in parallel with the input capacitor, Co, of the isolated DC-DC Converter. Between t3 to t4 the bulk capacitor will deliver the current required by the isolated DC-DC Converter. In conclusion this concept increases the energy delivery time from the line while decreasing the energy delivery time from the bulk capacitor. As a result the value of the bulk capacitor can be decreased. In the example presented at the PCIM Europe publication entitled “DC Link Chpopper for AC-DC adapters” the bulk capacitor is decreased from 110uF to 82uF by using this concept. In the same time at 90Vac the RMS line current is decreased by 17% and the RMS current through the bulk capacitor is decreased by 26%. In our calculation by using the “DC Link Chpopper for AC-DC adapters” methodology, for a 60W AC adapter with an efficiency of the DC-DC converter of 93% and using a 68uF capacitor the ripple is decreased to 41V , from 56V ,wherein the lowest voltage level across the bulk capacitor is 82V and the RMS current through the bulk capacitor is reduced to 0.85A from 0.95A.

0027 In Figure 8a is depicted the effect of using one of the embodiments of this invention wherein the power extracted from the primary by the isolated DC-DC Converter is modulated by increasing the power extracted from the line during t1 to t3 while decreasing the power extracted from the bulk capacitor between t3 to t4. As previously mentioned the concept of modulating the power extraction works better if the conduction angle when the energy is extracted from the line increases. Implementing the embodiment of this invention in the implementation described in Figure 6 and Figure 7 the size of the bulk capacitor can be further reduced and the RMS current through the bulk capacitor further decreased. For example for a 60W AC adapter with an efficiency of the DC-DC converter of 93% using a 68uF capacitor and with a 30% increase of power extracted from the line during t1 to t3, the ripple is decreased to 33V, 20% lower by implementing this invention in comparison with the prior art. Further on, the lowest voltage level across the bulk capacitor is 90V ,11% higher than without implementing this invention. The RMS current through the bulk capacitor is reduced to 0.68A, which is a reduction of 20% by using this invention. All these comparisons are done against the prior art technology described in the “DC Link Chopper for AC-DC adapters” at PCIM Europe 2012.

0028 In Figure 8b is presented another embodiment of this invention wherein the energy extraction from the line is shaped in a half sinusoidal shape, synchronized with the AC line by increasing the amplitude of the input current demanded by the isolated DC-DC Converter as the line voltage increases. This current resembles to the input current in a power factor circuit and as in a power factor correction circuit this invention improves the power factor.

0029 This technology can be implemented at any input line though it has its strongest positive impact at low line. The fact that this embodiment does improve the power factor as well it can be used also for higher line operation.

0002 Though in this patent application is mentioning the flyback topology as suitable for the isolated DC-DC converter, there are other topologies which can be used for the isolated DC-DC converter, some of them with higher power conversion efficiency and capable of higher power densities.

Claims

1. An AC to DC Converter containing an EMI filter, an input bridge rectifier, an input bulk capacitor, an isolated DC-DC converter which transfers the power from primary to the secondary wherein the input current drawn by the isolated DC-DC Converter is synchronized with the line and modulated in a way to increase its amplitude when the current is delivered by the line, which occurs when the voltage of the ac line is the same with the voltage across the input bulk capacitor, and decrease its amplitude when the current is delivered by the input bulk capacitor.

2. The AC to DC Converter of claim 1 wherein the modulation of the current amplitude during the time the current is delivered by the ac line is done in a sinusoidal like shape proportional to the input line voltage, by increasing the current amplitude when the input line voltage is increased and decrease the amplitude when the input line voltage is decreased.

3. The AC to DC Converter of claim 1 wherein the average product of the voltage at the input of the isolated DC-DC converter and the current drawn by the isolated DC-DC converter remains constant regardless of the amplitude of the current modulation.

4. The AC to DC Converter of claim 2 wherein the average product of the voltage at the input of the isolated DC-DC converter and the current drawn by the isolated DC-DC converter remains constant regardless of the amplitude of the current modulation.

5. The AC-DC Converter of claims 1, wherein the line frequency ripple created by the modulation of the current drawn by the isolated DC-DC Converter is steered into a ripple steering capacitor.

6. The AC-DC Converter of claims 2, wherein the line frequency ripple created by the modulation of the current drawn by the isolated DC-DC Converter is steered into a ripple steering capacitor.

7. The AC-DC Converter of claims 3, wherein the line frequency ripple created by the modulation of the current drawn by the isolated DC-DC Converter is steered into a ripple steering capacitor.

8. The AC-DC Converter of claims 4, wherein the line frequency ripple created by the modulation of the current drawn by the isolated DC-DC Converter is steered into a ripple steering capacitor.

9. An AC to DC Converter containing an EMI filter, an input bridge rectifier, a input bulk capacitor, a controlled switch connected between the output of the bridge rectifier and the isolated DC-DC converter, an additional two rectifiers placed with the anode towards the each side of the input AC line and with the cathode to the input of the isolated DC-DC converter and an additional input capacitor placed at the input of the isolated DC-DC converter, wherein said controlled switch which is synchronized with the line is turned off prior the line voltage reaches its peak and turn on again after a time interval, while the input current drawn by the isolated DC-DC Converter is synchronized with the line and is modulated in a such way that the current has a larger amplitude during the time wherein the current is delivered by the line and a lower amplitude when the current is delivered by the input bulk capacitor.

10. The AC-DC Converter of claim 9 wherein said controlled switch is turned on after the peak of the ac line , when the voltage of the ac line is the same as the voltage of the ac line before the peak where the decaying voltage across the bulk capacitor reaches the same voltage as the ac line.

11. The AC-DC Converter of claim 9 wherein the input current drawn by the isolated DC-DC Converter when the current is delivered by the ac line is shaped in a sinusoidal like shape proportional to the input line voltage and synchronized with the AC line, by increasing its amplitude when the line voltage amplitude is higher and decreasing its amplitude when the line voltage is lower.

12. The AC-DC Converter of claim 10 wherein the input current drawn by the isolated DC-DC Converter when the current is delivered by the ac line is shaped in a sinusoidal like

shape proportional to the input line voltage and synchronized with the AC line, by increasing its amplitude when the line voltage amplitude is higher and decreasing its amplitude when the line voltage is lower.

13. The AC to DC Converter of claim 9 wherein the average product of the voltage at the input of the isolated DC-DC converter and the current drawn by the isolated DC-DC converter remains constant regardless of the amplitude of the current modulation.

14. The AC to DC Converter of claim 10 wherein the average product of the voltage at the input of the isolated DC-DC converter and the current drawn by the isolated DC-DC converter remains constant regardless of the amplitude of the current modulation.

15. The AC to DC Converter of claim 11 wherein the average product of the voltage at the input of the isolated DC-DC converter and the current drawn by the isolated DC-DC converter remains constant regardless of the amplitude of the current modulation.

16. The AC to DC Converter of claim 12 wherein the average product of the voltage at the input of the isolated DC-DC converter and the current drawn by the isolated DC-DC converter remains constant regardless of the amplitude of the current modulation.

17. The AC-DC Converter of claims 13 wherein the line frequency ripple created by the modulation of the current drawn by the isolated DC-DC Converter is steered into a ripple steering capacitor.

18. The AC-DC Converter of claims 15 wherein the line frequency ripple created by the modulation of the current drawn by the isolated DC-DC Converter is steered into a ripple steering capacitor.

19. The AC-DC Converter of claims 14 wherein the line frequency ripple created by the modulation of the current drawn by the isolated DC-DC Converter is steered into a ripple steering capacitor.

20. The AC-DC Converter of claims 16 wherein the line frequency ripple created by the modulation of the current drawn by the isolated DC-DC Converter is steered into a ripple steering capacitor.

21. The AC-DC Converter of claims 16 wherein the modulation amplitude of the current drawn by the isolated DC-DC converter is done in such a way to meet a certain power factor specification.

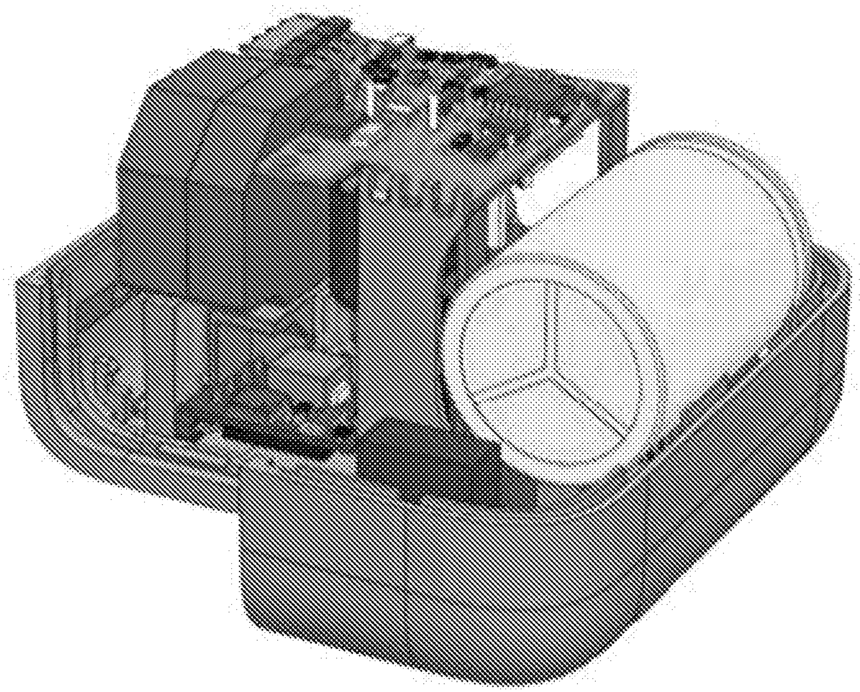
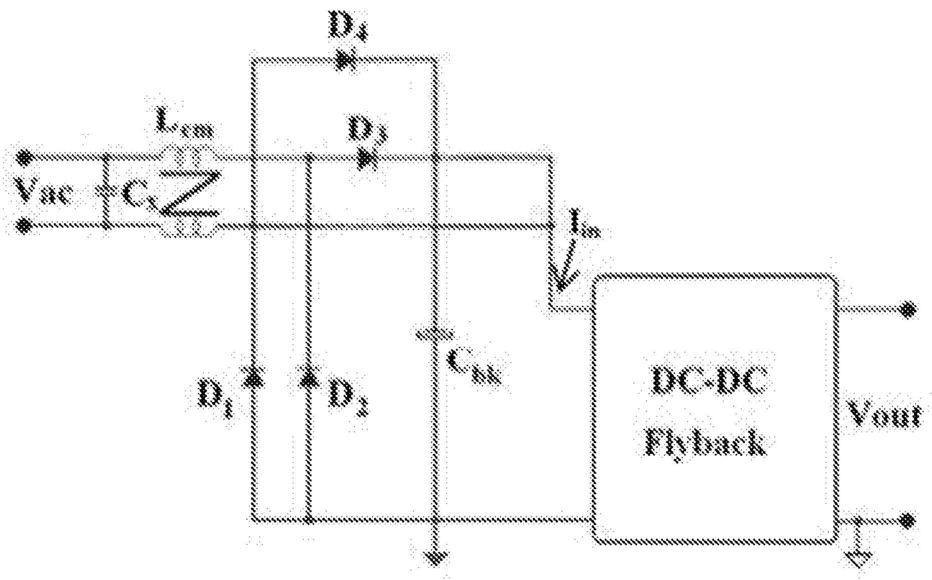
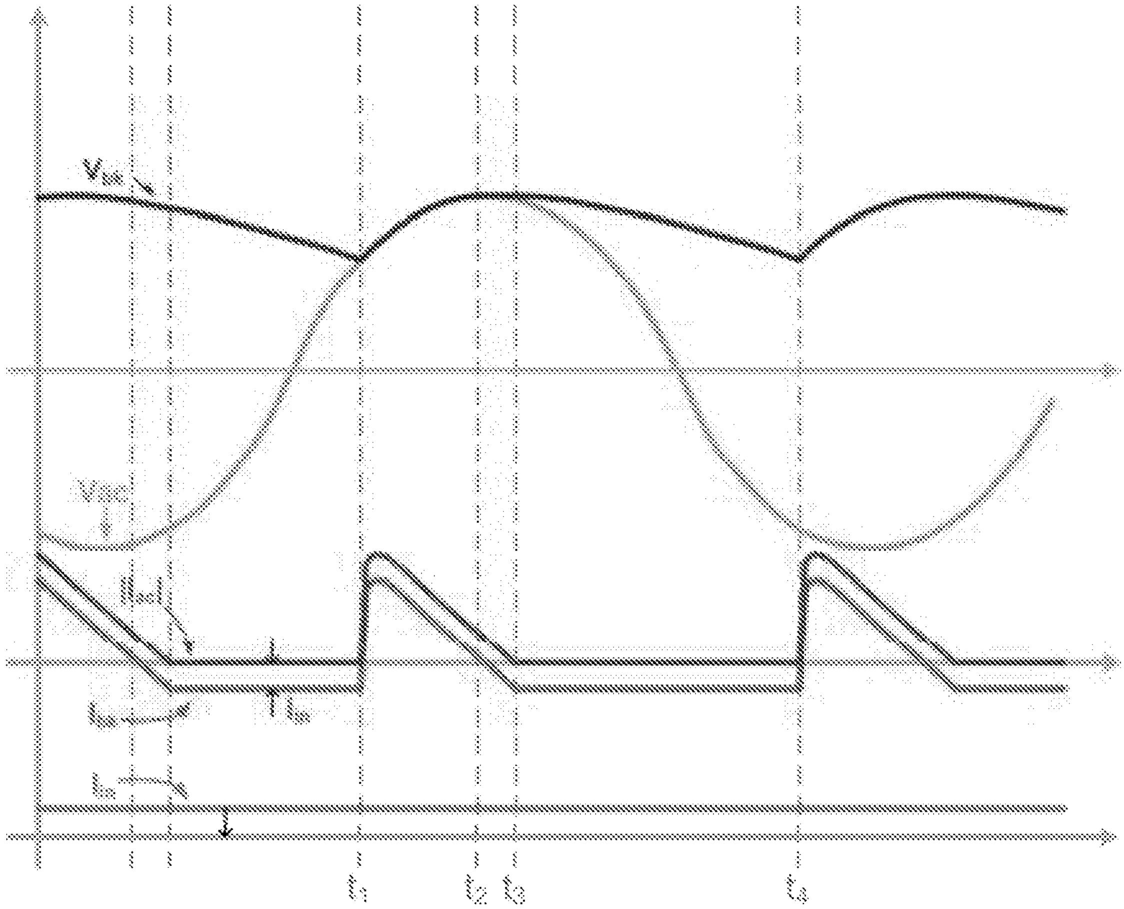


FIGURE 1



Prior Art

FIGURE 2



Prior Art

FIGURE 3

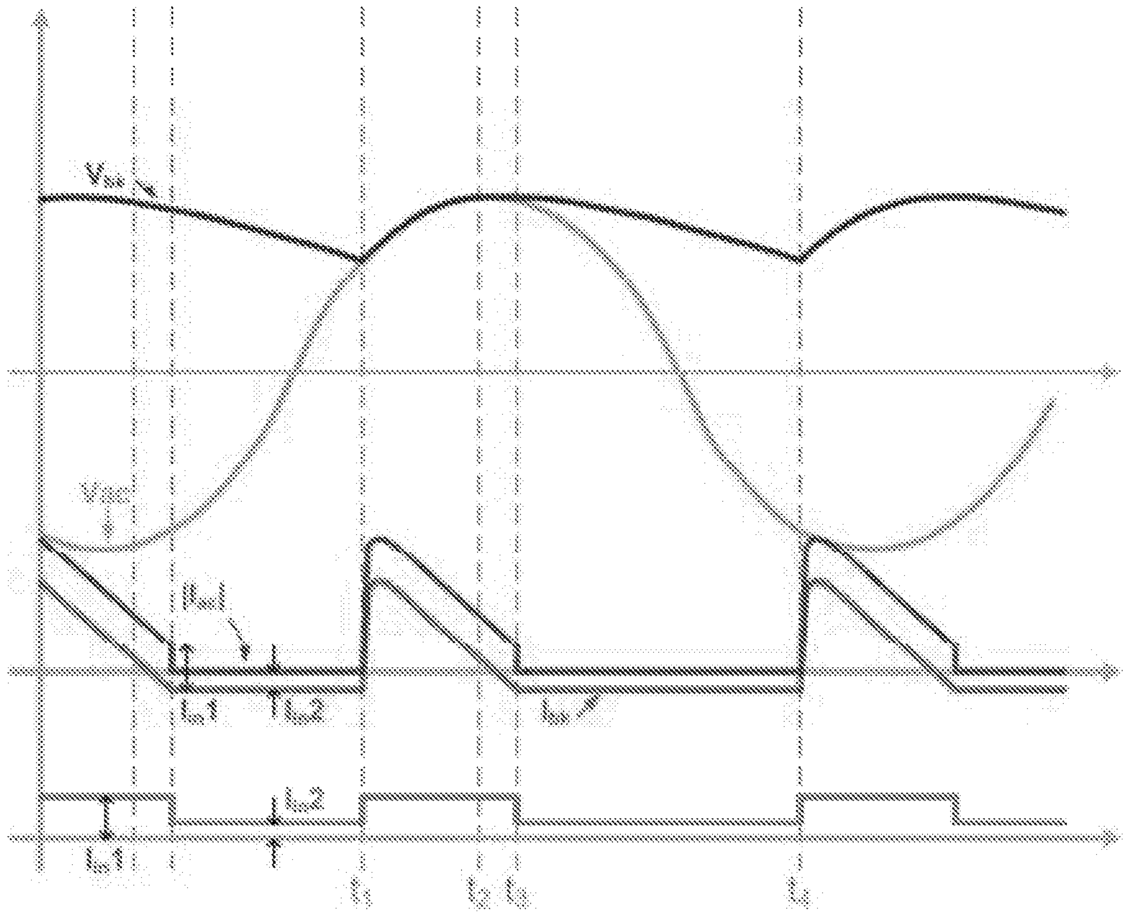


FIGURE 4a

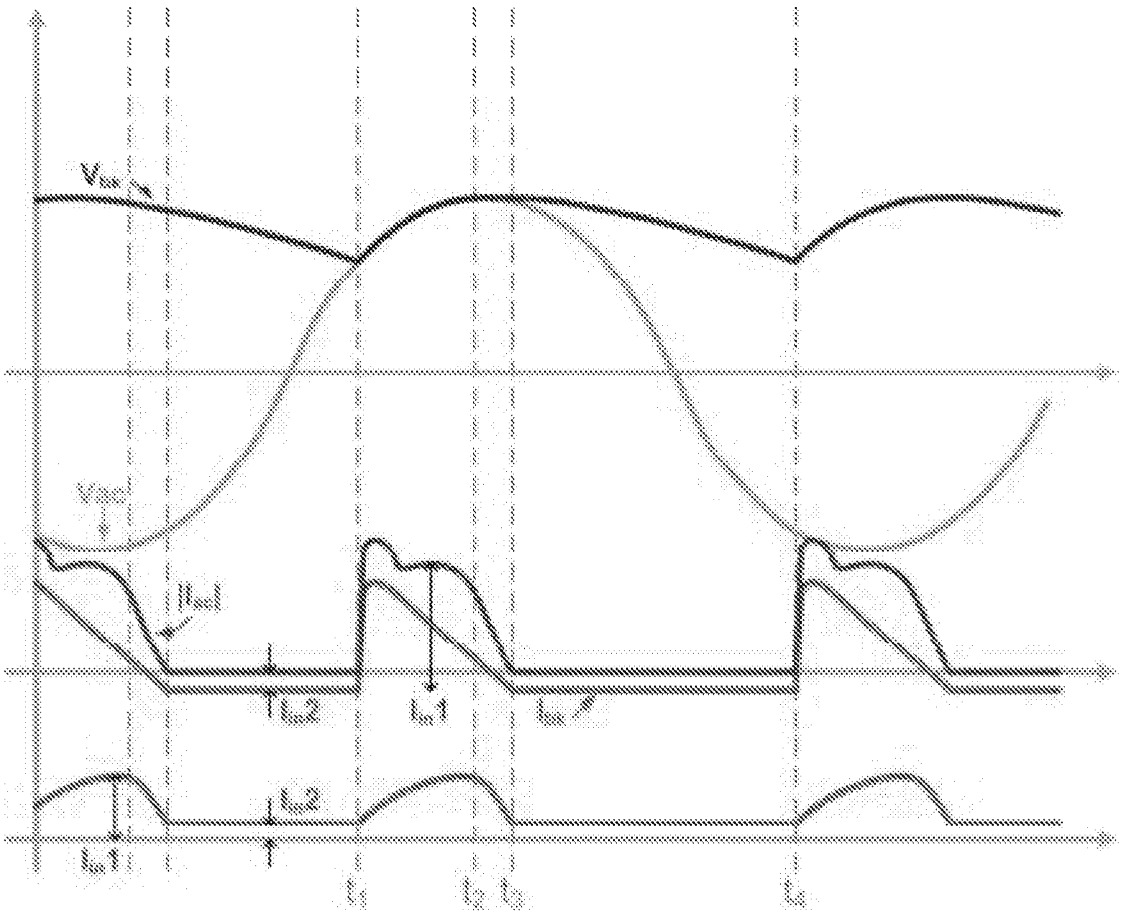


FIGURE 4b

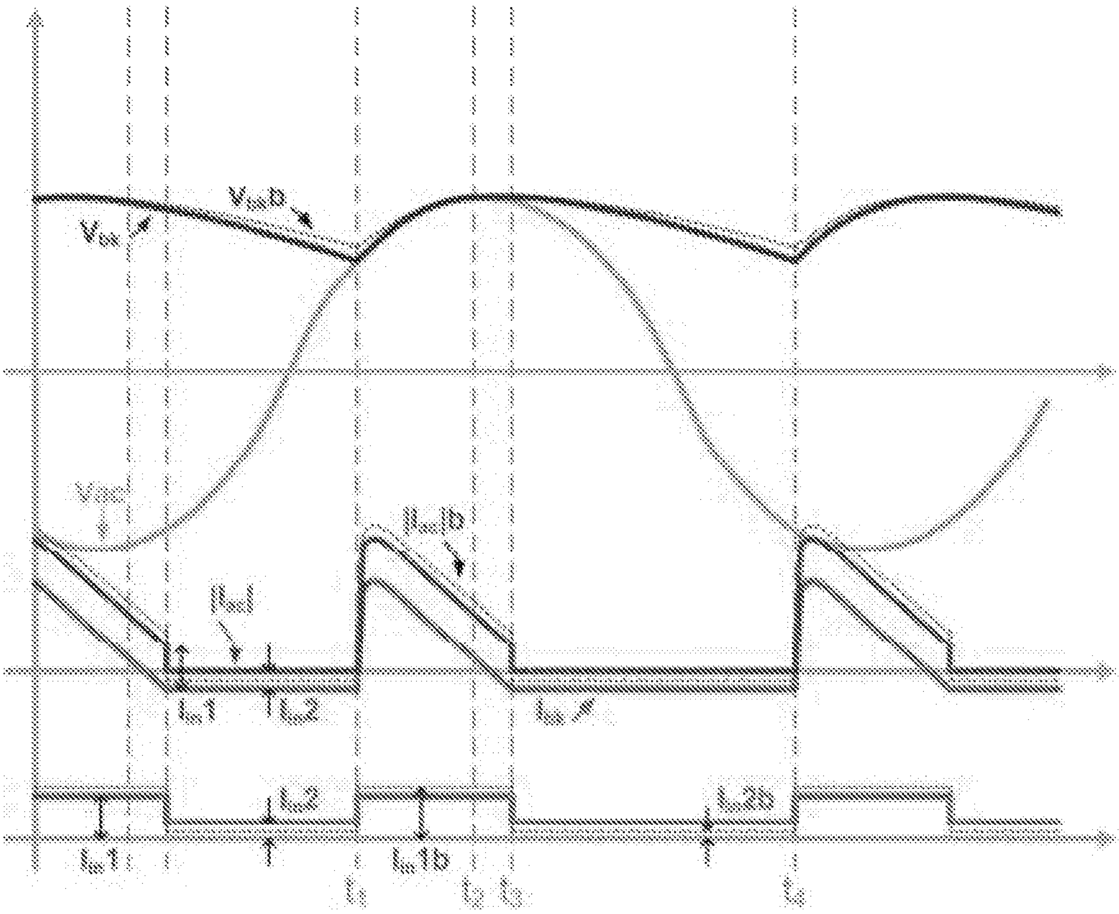


FIGURE 5

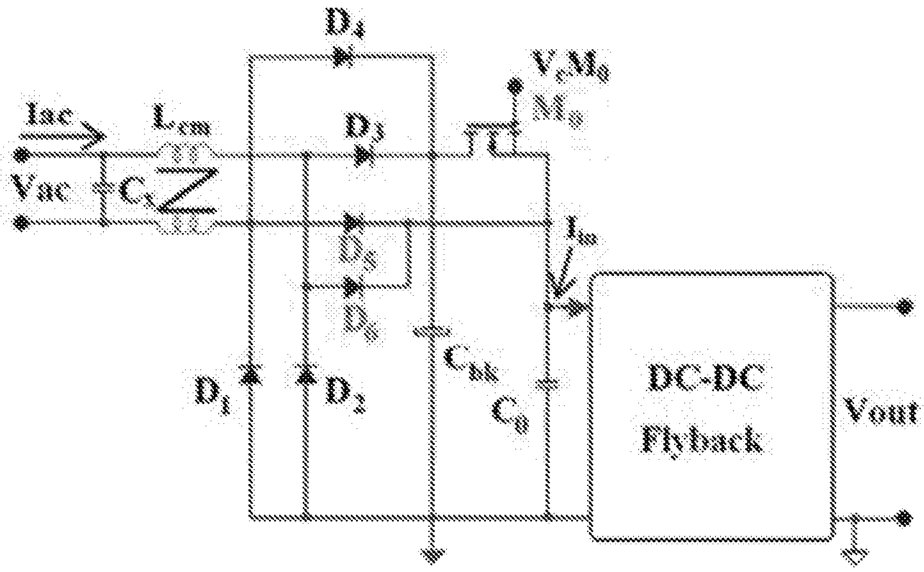
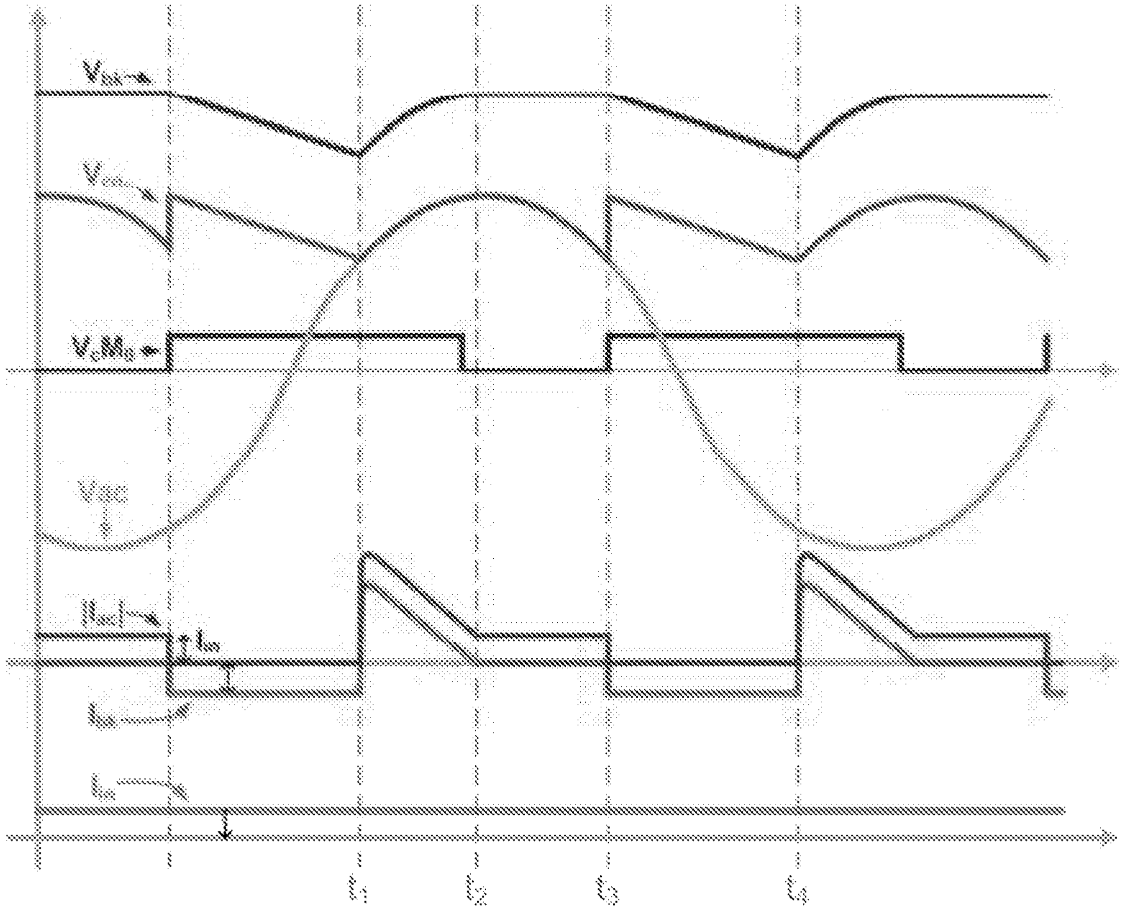


FIGURE 6 **Prior Art**



Prior Art

FIGURE 7

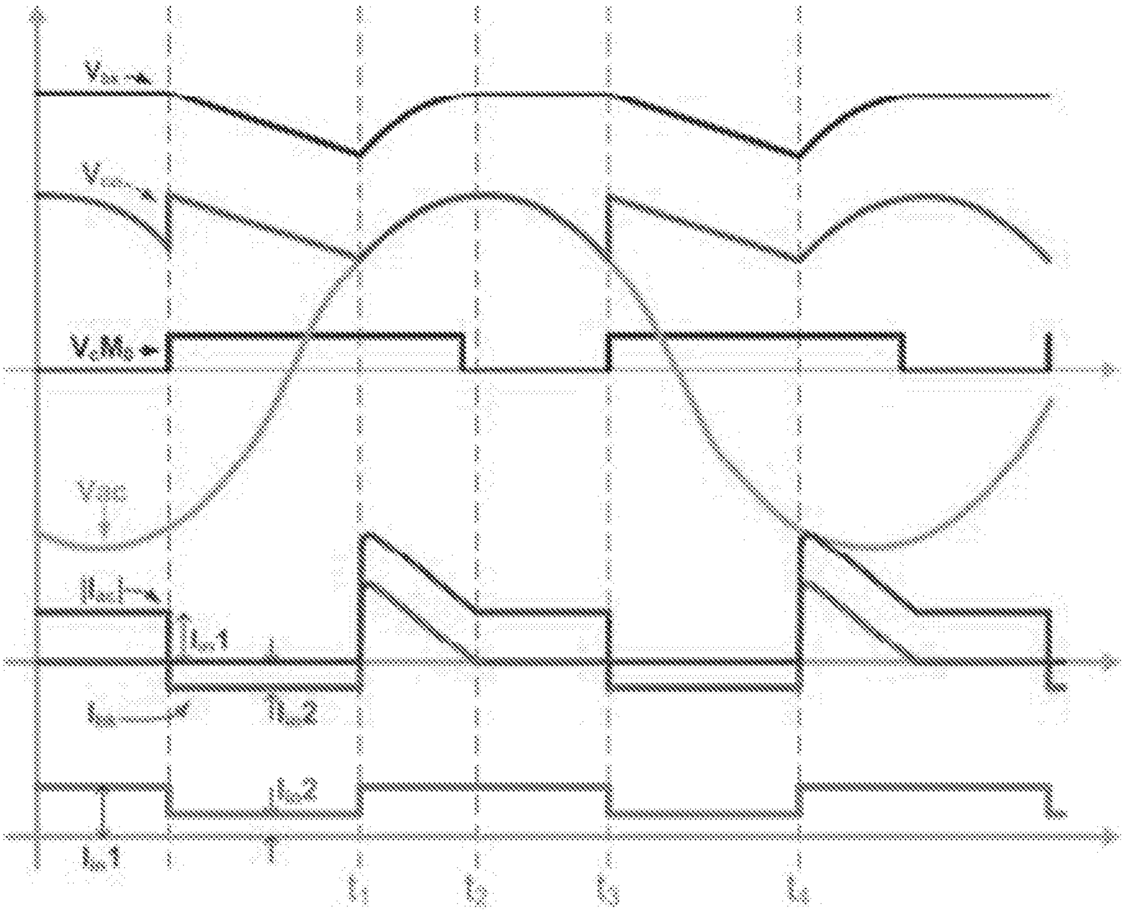


FIGURE 8a

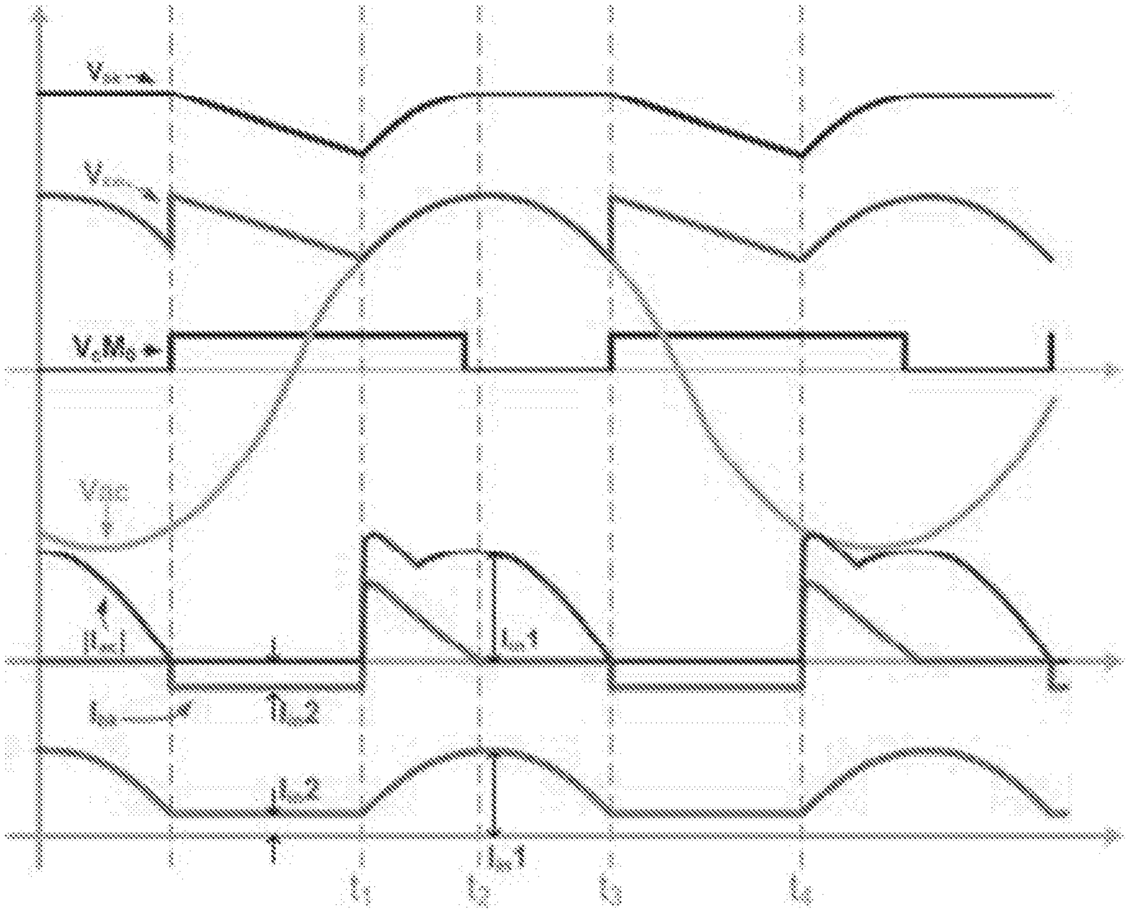
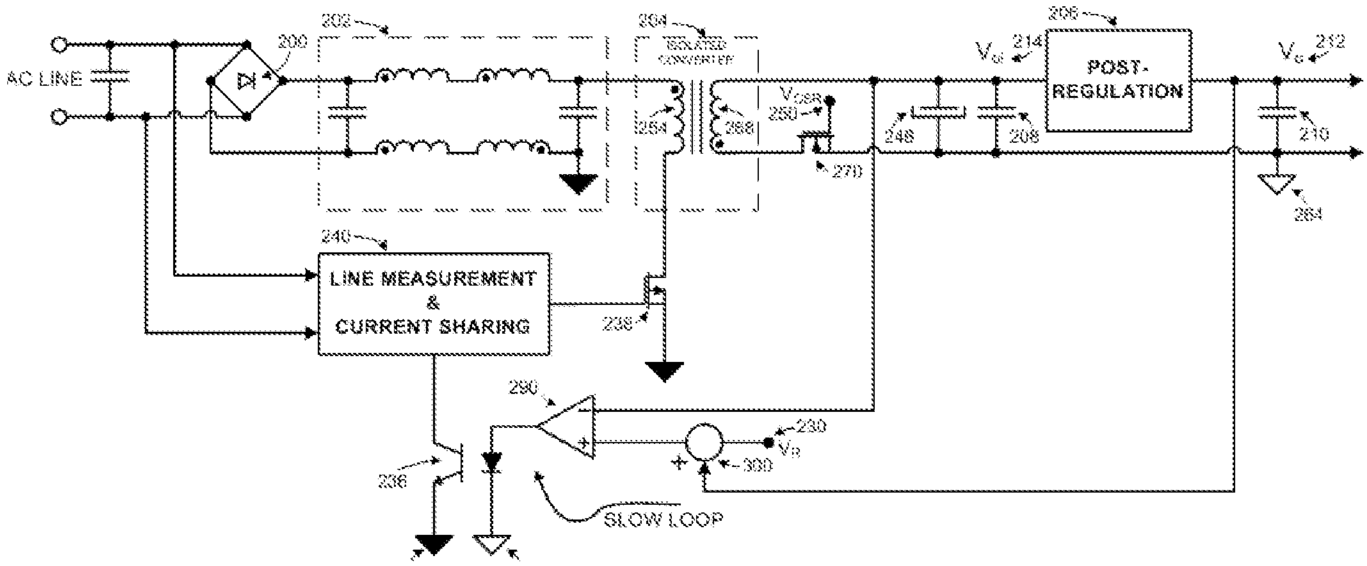


FIGURE 8b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POST-REGULATION
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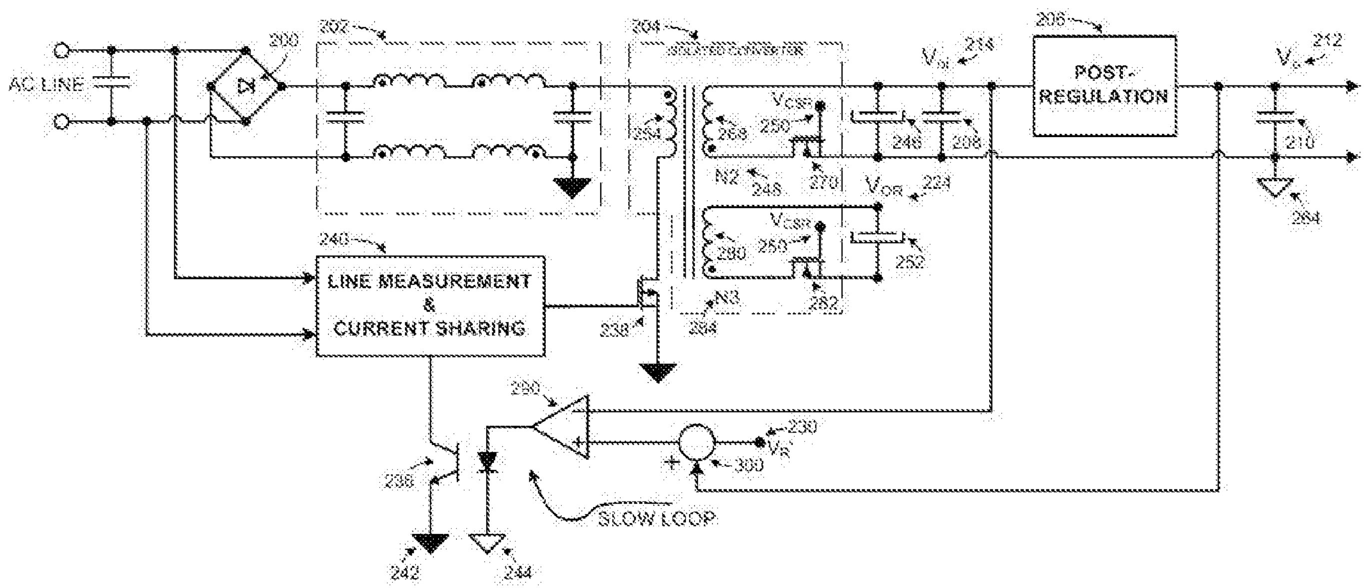
210
264
240
LINE MEASUREMENT & CURRENT SHARING
238
290
230
V_R
300
236
SLOW LOOP

FIGURE 9



AC LINE
200
202
204
206
POST-REGULATION
214
212
240
LINE MEASUREMENT & CURRENT SHARING
N2
N3
238
236
230
300
SLOW LOOP
242
244
246
208
210
252
224
264

FIGURE 10

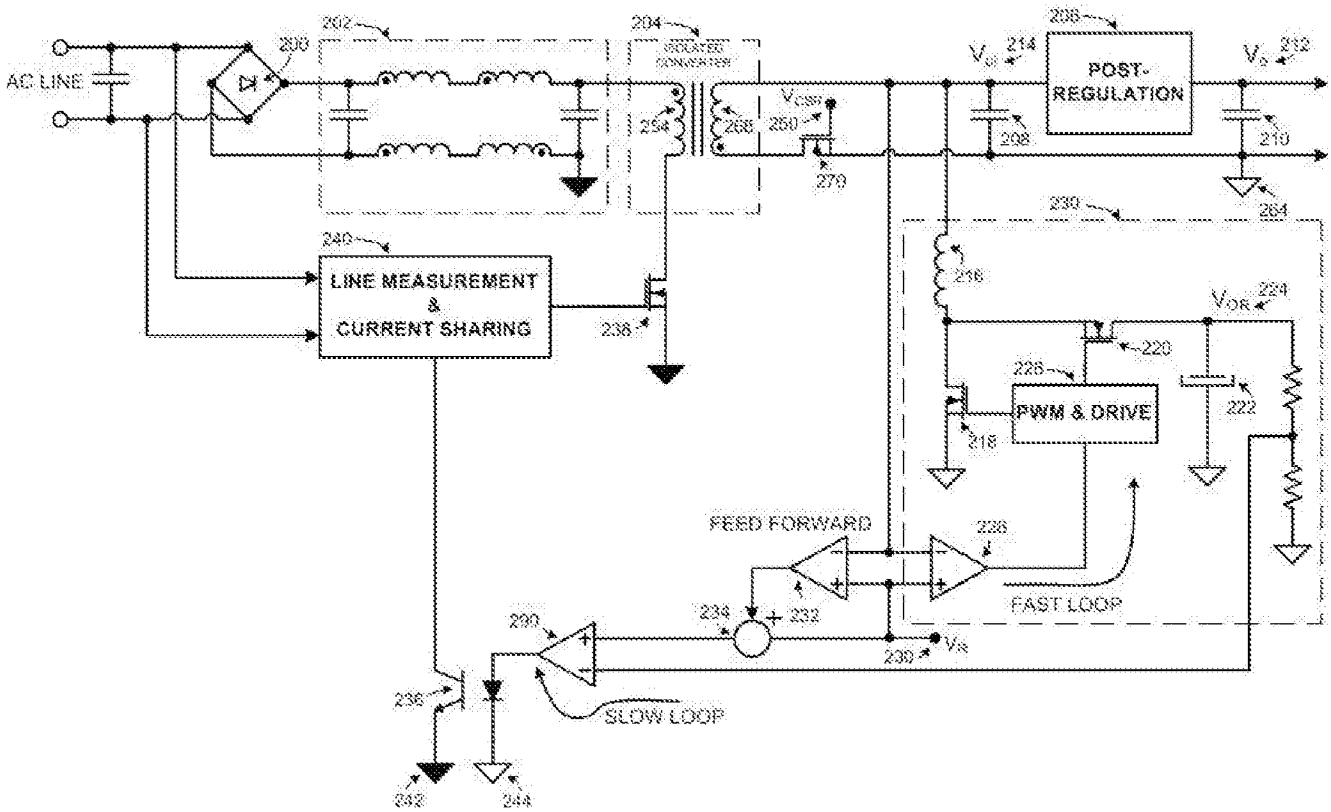

AC LINE
200
202
204
206
POST-REGULATION
214
212
254
268
260
270
208
210
264
230
240
LINE MEASUREMENT
&
CURRENT SHARING
238
216
224
220
226
PWM & DRIVE
222
218
FEED FORWARD
228
FAST LOOP
290
234
232
230
236
SLOW LOOP
242
244

FIGURE 11

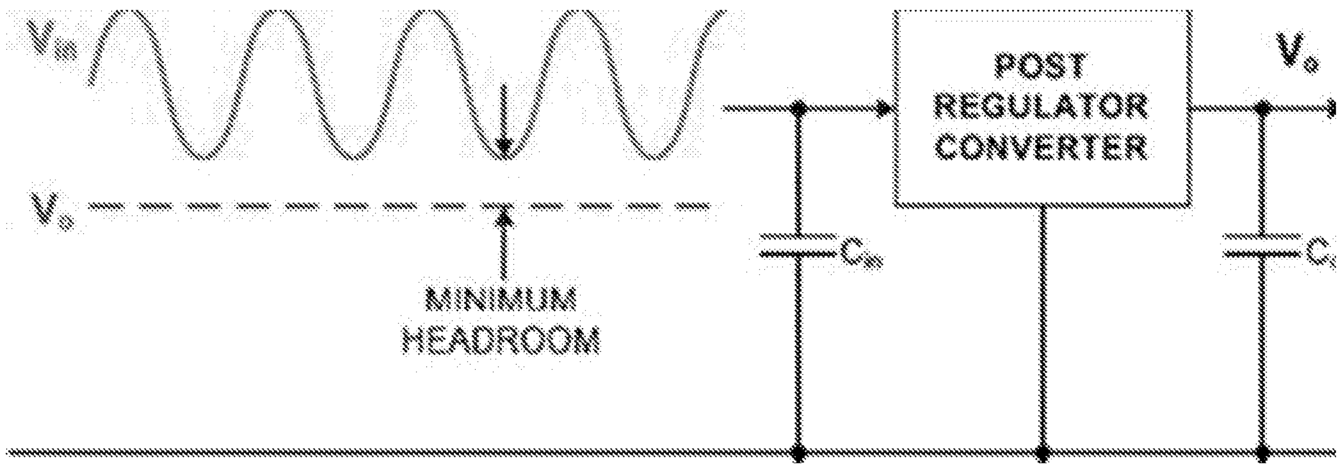


FIGURE 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/041010

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H02M 1/14; H02M 1/12; H02M 1/15; H02M 7/00; H02M 7/155; H02M 7/162; H02M 7/30 (2016.01)
CPC - H02M 1/14; H02J 1/02; H02J 2001/104; H02M 7/21; H02M 2001/004; H02M 2007/2195 (2016.08)
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC - H02M 1/12; H02M 1/14; H02M 1/15; H02M 7/00; H02M 7/155; H02M 7/162; H02M 7/30
CPC - H02J 1/02; H02J 2001/104; H02M 1/14; H02M 7/21; H02M 7/217; H02M 7/25; H02M 2001/0048; H02M 2007/2195

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
363/16; 363/17; 363/98; 363/126; 363/21.07; 363/21.02; 363/21.06; 363/21.01; 363/21.12; 363/98; 363/126 (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Orbit, Google Patents, IEEE, Google
Search terms used: adaptor, converter, AC, DC, AC-DC, alternating, direct, transformer, isolated, windings, capacitor, bulk capacitor, bridge, current, voltage, ripple

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 7,061,212 B2 (PHADKE) 13 June 2006 (13.06.2006) entire document	1-4, 9-16, 21 --- 5-8, 17-20
Y	US 5,038,263 A (MARRERO et al) 06 August 1991 (06.08.1991) entire document	5-8, 17-20
A	ON SEMICONDUCTOR. Power Factor Correction (PFC) Handbook. April 2014. [retrieved on 2016-08-24]. Retrieved from the Internet: <URL: http://www.onsemi.com/pub_link/Collateral/HBD853-D.PDF>. entire document	2, 4, 6, 8-21
A	US 2014/0268902 A1 (APPLE INC.) 18 September 2014 (18.09.2014) entire document	1-21
A	US 5,502,628 A (ARAKAWA) 26 March 1996 (26.03.1996) entire document	1-21
A	US 2008/0101099 A1 (JACOBS) 01 May 2008 (01.05.2008) entire document	1-21
A	US 6,108,222 A (LIANG) 22 August 2000 (22.08.2000) entire document	1-21

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search
24 August 2016

Date of mailing of the international search report
15 SEP 2016

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