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(54) Title: FREQUENCY CONTROLLED CAPACITIVE POWER CONVERTER

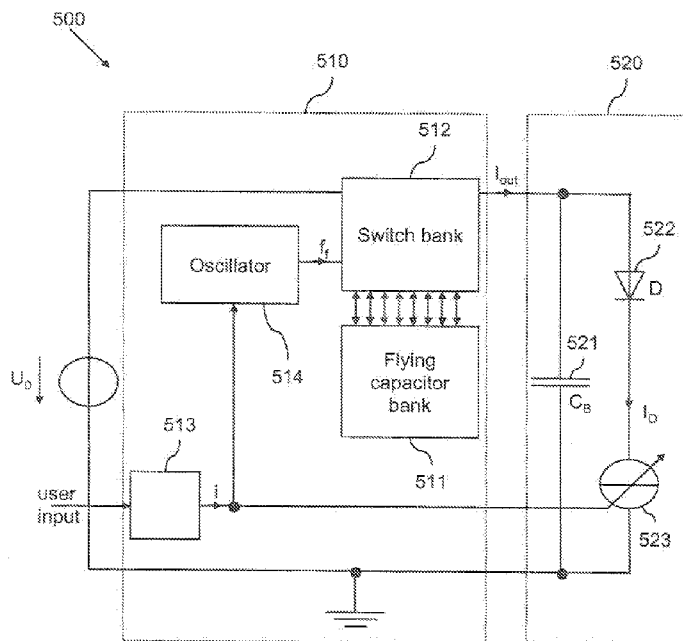


Fig.5

(57) Abstract: The present invention provides a capacitive power converter for transforming an electric input power (U_o) into an electric output power (I_{out}). The capacitive power converter (310) includes at least one flying capacitor (311), at least one switching element (312) for periodically charging and discharging the at least one flying capacitor (311) based on a switching frequency (f_f) and adjustment means (313, 314) for setting the switching frequency (f_f) based on the output power (I_{out}) of the capacitive power converter (310). Since the adjustment means (313, 314) always set the switching frequency (f_f) based on the output power (I_{out}) of the capacitive power converter (310), electric power losses occurred in the capacitive power converter (310) can be reduced. This leads to reduced heat generation and longer life time of an overall power source.



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Frequency controlled capacitive power converter

5 FIELD OF THE INVENTION

The present invention relates to a capacitive power converter and a method for driving a capacitive power converter, and in particular to a frequency controlled capacitive power converter and a method for controlling a switching frequency in a capacitive power converter. Moreover, the present invention relates to
10 a light emitting system implementing such a capacitive power converter.

BACKGROUND OF THE INVENTION

Electric power converters convert an electric input power into an arbitrary electric output power. In this technical field, one of the most important
15 requirements is the power loss during the power conversion.

A well known representative for electric power converters are capacitive power converters for supplying power to e.g. light emitting diodes (LEDs). Since LEDs become widely accepted for illumination due to their high efficiency, there is not only a need to improve LEDs itself but also the efficiency of their power
20 supply.

LEDs can be driven with different illumination degrees. As for example, high-brightness LEDs replacing the conventional Xenon flash in photographic applications can be driven in a flash mode and in a torch mode. The flash mode provides an extremely high illumination for a relatively short time, e.g.
25 several tenths of seconds. Therefore, in the flash mode, the LEDs require a high current over a relatively short period of time. In contrary thereto, in the torch mode, the LEDs only provide a moderate illumination but for a prolonged period of time, e.g. minutes or longer. Thus, in the torch mode, the LEDs require a low current over a relatively long period of time. These supply currents are provided by a capacitive
30 power converter.

In the capacitive power converter, one or more capacitors are repeatedly switched between the input to charge the capacitor taking electric power from source connected to the input and between the output to discharge the capacitor

and hence transferring electric power to the output. These capacitors are called flying capacitors. In between these two active states the flying capacitors are in a floating state for a very short period of time. This is known as the so-called break-before-make switching scheme. The transition from in between these two described active states is repeated many cycles per second representing the switching frequency. In prior art the switching frequency is chosen constant and optimized for just one load condition - either optimal for flash mode or optimal for torch mode. That is, in one of these two modes, there are unnecessary electric power losses because the switching frequency is not optimal.

However, in case of e.g. mobile applications, electric power losses lead to a faster discharge of the battery. Thus, batteries with higher electric capacities are necessary to provide a sufficient time of operation. Further, electric power losses warm up electric devices and can lead to malfunctions or even irreparable damages.

OBJECT AND SUMMARY OF THE INVENTION

Thus, it is an object of the present invention to reduce power losses in a capacitive power converter.

The inventor recognized, that power losses in a capacitive power converters depend not only on the output power and on the inner construction of the capacitive power converter but also on the switching frequency. The inventor further recognized, that the optimal switching frequency for the capacitive power converter depends on the application case. The application case itself can be determined based on the output power. Experiments show that a deviation between the applied switching frequency and the optimal switching frequency results in a disproportionate increase of the power losses. Therefore, the invention is based on the thought to provide a capacitive power converter having a variable switching frequency, wherein the switching frequency is set based on the output power.

Therefore, the present invention proposes a frequency controlled capacitive power converter for transforming an electric input power into an electric output power. The capacitive power converter comprises at least one flying capacitor, at least one switching element and an adjustment means. The at least one switching element is adapted to periodically charge the at least one flying capacitor over an input of the capacitive power converter and to discharge the at least one flying

capacitor over an output of the capacitive power converter based on a variable switching frequency. The adjustment means are adapted to determine the required output power of the capacitive power converter and to set the variable switching frequency based on the determined output power. Since the adjustment means adjusts the variable switching frequency based on the output power, the electric power losses could be reduced dependent on the application. Since the electric power losses of the capacitive power controller are reduced, the overall power consumption is reduced such that especially for mobile devices the battery life is increased. Further, due to the reduced electric power losses, less heating of the capacitive power converter occurs such that the life time of the electronic elements is also increased. The determination of the output power can be implemented best by determining the output current and/or the output voltage of the capacitive power converter. Thus, the adjustment means may preferably be adapted to determine the output current and/or the output voltage of the capacitive power converter and to set the variable switching frequency based on the determined output current and/or output voltage. Since currents and/or voltages are simple to measure, the present embodiment could be easily integrated into conventional capacitive power converters with less technical efforts.

The inventor further recognized, that in a conventional capacitive power converter there are essentially two categories of losses – namely ripple losses and switching losses. Ripple losses occur in case of low switching frequencies and high load due to successive charging and discharging of the flying capacitor. In other words, in case of low switching frequencies, the output voltage and therewith the output power decreases, which increases the power losses. Switching losses occur in case of high switching frequencies due to non ideal electronic elements in the circuit of the capacitive power converter. In other words, in case of high frequencies, electric currents will be grounded leading to an increased power loss and therewith decreased output power. Thus, the adjustment means may preferably be further adapted to determine the ripple losses and the switching losses of the capacitive power converter and to set the variable switching frequency based on the determined ripple and switching losses. By determining the direct reason for the power losses in the capacitive power converter, the power losses could be determined more accurately and therewith reduced stronger.

The inventor further recognized, that switching losses proportionally dependent on the switching frequency and that the ripple losses depending indirectly proportionally on the switching frequency. Further, the total losses in the capacitive power converter can be approximated by the sum of switching and ripple losses.

5 Thus, there exists an optimal switching frequency generating an absolute minimum power loss. Choosing the applied switching frequency higher than this optimum switching frequency, the switching losses dominate. Choosing the applied switching frequency lower than this optimum switching frequency, the ripple losses dominate. Thus, the adjustment means may preferably be further adapted to determine and set an
10 optimal switching frequency, wherein ripple losses and switching losses of the capacitive power converter are equal. As already outlined, this would lead to absolute minimum power losses.

As already shown, the ripple losses occur due to the periodic charging and discharging of the flying capacitor. Therefore, the adjustment means may further
15 be adapted to set the variable switching frequency based on the capacitance of the at least one flying capacitor. Since the adjustment means now knows the required output power and the capacitance of the flying capacitor in detail, the power losses due to ripple losses and namely the self-discharge of the flying capacitor can be determined in more detail facilitating the determination of the variable switching frequency.

20 Further, the switching losses occur due to the non ideal electronic elements in the capacitive power converter. Thus, the adjustment means may further be adapted to set the variable charging frequency based on the value of non ideal electronic elements in the capacitive power converter. Preferably, these elements include a parasitic capacitance between at least one of the pin of the flying capacitor
25 and ground of the capacitive power converter. Since the adjustment means now knows the required output power and the parasitic elements in detail, the power losses due to switching losses and namely the current not passing the output of the capacitive power converter can be determined in more detail facilitating the determination of the variable switching frequency.

30 As known for skilled person, the output power need not necessarily to be measured but can also be provided based on an input signal provided e.g. by a user, who verifies by itself, whether the required output power (light intensity, motor speed, temperature, ...) is given. Thus, preferably, the output power of the capacitive power

converter is set by an input signal. Therein, the adjustment means set the variable switching frequency and the output power together. In doing so, there is no need to implement a complicated control loop reducing the overall complexity of the adjustment means and therewith of the capacitive power converter.

5 A very important application case for capacitive power converters is to drive light emitting diodes. The capacitive power converter may therefore be used in a light emitting diode driver for driving a light emitting diode. Since diodes are often used in varying illumination ranges, they require varying electric current settings. Thus, the present invention is very suitable for applications in light emitting diode
10 drivers.

 A preferred application of light emitting diodes is to illuminate a scenario for taking photos. Thus, the light emitting diode driver may be adapted to drive the light emitting diode in a flash mode and/or in a torch mode and all current settings in between these extremes. Since the electric energies for driving a diode in
15 these operational modes are extremely different, the efficiency in one of the operational modes is very poor. As already explained, electric power losses lead to heating and malfunction of electronic elements and reduced battery usage. This is especially problematical in the fields of semiconductor devices to which light emitting diodes belong. Thus, the present invention especially prevents unnecessary heating,
20 unnecessary battery discharge and malfunctions of light emitting diodes and their drivers in case of running in a torch mode and a flash mode.

 A light emitting system according to the present invention includes an electric power source, a capacitive power converter as described above, a buffer capacitor and a light emitting diode. The capacitive power converter receiving electric
25 power from the electric power source and, buffers it in the buffer capacitor. The light emitting diode is connected to the buffer capacitor and can use the electric power for generating illuminating light. Since the capacitive power converter according to the present invention reduces the electric power losses, the light emitting system will be protected against negative effects from power losses like overheating. Further, the
30 required electric power to drive the light emitting system is reduced.

 The present invention further provides a method for driving a capacitive power converter, which transforms an electric input power into an electric output power. The capacitive power converter includes at least one flying capacitor

and at least one switching element periodically connecting the flying capacitor to the input and output at a variable switching frequency. The method comprises the steps of: determining the electric output power of the capacitive power converter and setting the variable switching frequency of the capacitive power converter based on the determined electric output power. With the method as described above, the same advantageous effects as reached with the capacitive power converter according to the present invention can be achieved.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described in greater detail hereinafter, by way of non-limiting examples, with reference to the embodiments shown in the drawings.

Fig.1 is a capacitive power converter;

Fig.2 is a detailed illustration of a capacitive power converter; and

Fig.3 is a first embodiment for a frequency controlled capacitive power converter;

Fig.4 is a second embodiment for a frequency controlled capacitive power converter;

Fig.5 is an application of a frequency controlled capacitive power converter.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Fig.1 is capacitive power converter 100 including a switch bank 110 and a flying capacitor bank 120. The switch bank 110 comprises an input 130 for receiving an input power. In the present embodiment, the input power is shown as an input voltage V_{in} . The switch bank 110 further comprises an output 140 for providing an output power. In the present embodiment, the output power is shown as an output voltage V_{out} . The switch bank 110 and the flying capacitor bank 120 are connected via a plurality of connection lines.

The switch bank 110 includes at least one switch. The flying capacitor bank 120 at least includes at least one flying capacitor.

Each switch in the switch bank 120 is adapted to connect either one or more flying capacitors of the flying capacitor bank 120 between the input 130 and the output 140, or one or more flying capacitors of the flying capacitor bank 120 only to

the output 140 or the input 130. The state, when the capacitors of the bank 120 are either connected to the input 130, output 140 and ground is called the active state indicating that in this state the flying capacitors are either charged or discharged. The state, when the capacitors of the capacitor bank 120 are disconnected from input 130 and output 140 is called floating state. The floating state is a short intermediate state in between active states also referred to as break-before-make switching. In operation, the switch bank repeatedly changes the state of the capacitor bank between active state and ground state. The frequency of this state changing is the described switching frequency f_f at the beginning.

Next, the inner details of the capacitive power converter 100 should be shown in more detail.

Fig.2 is a detailed illustration of the capacitive power converter 100 shown in fig.1. Therein, the switch bank 110 includes four switches 210-240. The flying capacitor bank 120 includes one flying capacitor 253. A first switch 210 is connected between a first pin 251 of the flying capacitor 253 and the input 130. A second switch 220 is connected between a the first pin 251 of the flying capacitor 253 and the output 140. A third switch 240 is connected between the output 140 and the second pin 252 of the flying capacitor 253. A fourth switch 230 is connected between the second pin 252 of the flying capacitor 253 and ground.

In the present embodiment, the first to third switch 210-230 are PMOS-transistors P_1 - P_3 (p-channel metal oxide semiconductor transistor) and the fourth switch is a NMOS-transistor N_1 (p-channel metal oxide semiconductor transistor). All transistors P_1 - P_3 , N_1 include break-before-make measures to prevent excessive supply currents drawn from the buffer amplifiers which drive each separate switches 210-240. Further, all transistors P_1 - P_3 , N_1 are controlled by amplifiers, which are operated with the same voltage V_{in} as supplied to the input 130 of the capacitive power converter 100.

In the following, one complete switching cycle $T_f = 1/f_f$ should be explained in more detail. The complete switching cycle T_f is separated into two subsidiary cycles – a primary cycle T_1 and a secondary cycle T_2 . In the primary cycle T_1 , the first and fourth switch 210, 240 are closed and the second and third 220, 230 switch are open. Thus, the first pin 251 of the flying capacitor 253 is connected to the input 130 and the second pin 252 of the flying capacitor 253 is connected to to the

output 140. This effects, that positive charges accumulate at the first pin 251 and negative charges accumulate at the second pin 252. In the secondary cycle T_2 , the first and fourth switch 210, 240 are opened and the second and third switch 220, 230 will be closed. This effects, that the input 140 will be completely separated from the capacitive power converter 100. The first pin 251 is now connected to the output 140 and the second pin 252 is connected to ground. Therewith, the flying capacitor 253 will be discharged to the output 140. During the primary cycle in approximation the mathematical relation $V_{in} - V_{out} = V_C$ holds while during the secondary cycle the relation $V_{out} = V_C$ holds. Combining the two relations easily yields the input to output relation $V_{out} = V_{in}/2$ indicating the overall workings of this converter.

In the following, the losses occurring in the capacitive power converter 100 should be explained.

In a first step, the power losses occurring due to the power conversion in the capacitive power converter 100 should be considered. Power losses in the electric power converter occur as power losses $P_{loss, conv}$ due to the power conversion, as power losses $P_{loss, switch}$ due to the switches 210-240 and as power losses $P_{loss, par}$ due to non ideal network effects.

For calculating the power losses $P_{loss, conv}$ due to the power conversion, a special application case should be considered. In this application case, a load 260 including a buffer capacitor 261 and a light emitting diode (LED) 262 are connected to the output 140 indicating a practical load taking power from the converter. In effect, the load reduces the output voltage to a slightly lower value as calculated above making $V_{out} = V_{in}/2 - \Delta V$ just at the end of the secondary cycle. Thus, a constant voltage U_D occurred due to the LED 262 must be considered. Based thereon, the charge Q_1, Q_2 flowing through the flying capacitor 250 in the primary and secondary cycle T_1, T_2 can be expressed by:

$$Q_1 = Q_2 = 2C \Delta V \quad (1)$$

Therein, ΔV is generally known as ripple voltage ΔV depending on the diode voltage U_D . Considered, that this charge $Q_1 = Q_2$ flows in each, the primary and secondary cycle T_1, T_2 the ripple voltage ΔV becomes:

$$\Delta V = I_{out}/4f_t C \quad (2)$$

As can be seen from equation (2), the ripple voltage increases ΔV , if a higher output current I_{out} at the output 140 is required. Having the output current I_{out} and the output voltage V_{out} , which can be calculated via the power provided at the output 140, the total output power P_{out} and the power losses $P_{loss, conv}$ due to the power conversion results in:

$$P_{out} = 2f_t C \Delta V V_{in} - 4f_t C \Delta V^2 \quad (3)$$

$$P_{loss, conv} = 4f_t C \Delta V^2 \quad (4)$$

Next, the power losses $P_{loss, switch}$ due to the switches 210-240 should be calculated. Since the switches 210-240 are regarded as being CMOS-transistors in the present embodiment, they are controlled via a gate capacitance C_{gate} . To simplify matters, only the total capacitance $C_{gate, total}$ of all switches 210-240 together should be considered. Thus, the power loss due to switching results in:

$$P_{loss, switch} = f_t C_{gate, total} V_{in}^2 \quad (5)$$

Finally, the power losses $P_{loss, par}$ due to non ideal network effects should be calculated. These non ideal network effects occur due to wiring capacitances, drain-source capacitances and other non ideal effects in the capacitive power converter 100. All of these non ideal network effects can be approximately considered by two parasite capacitors C_{par} connected between the first and second pin 251, 252 of the flying capacitor 253 and ground. Thus, the power losses due to non ideal network effects can be determined by:

$$P_{loss, par} = 2f_t C_{par} (V_{in}/2)^2 = \frac{1}{2} f_t C_{par} V_{in}^2 \quad (6)$$

Thus, the complete power losses P_{loss} in the capacitive power converter 100 are the sum of equation (4), (5) and (6):

$$P_{loss} = P_{loss, conv} + P_{loss, par} + P_{loss, par} \quad (7)$$

The optimal effect of the present invention is given, when the power losses calculated by equation (7) is minimized. This is given, when the derivative of this equation as function of the frequency is zero: $dP_{\text{loss}}/df_f=0$. Thus, the switching frequency $f_{f, \text{opt}}$ is given, when this timely derived sum of equation (7) is zero and
 5 resolved to the switching frequency f_f :

$$f_{f, \text{opt}} = I_{\text{out}}/2V_{\text{in}}\sqrt{1/((C_{\text{par}}/2+C_{\text{gate, total}})C))} \quad (8)$$

Therewith, the optimal effect of the present invention can be achieved
 10 by setting the switching frequency f_f in the capacitive power converter 100 according to equation (8). In case the switching frequency f_f is exactly set at this optimum switching frequency $f_{f, \text{opt}}$ the total efficiency of the converter can readily be calculated using $\eta_{\text{opt}} = 1 - P_{\text{loss}}/P_{\text{in}} = 1 - 4/[1 + 2\sqrt{C/(C_{\text{par}}/2+C_{\text{gate, total}}))}]$.

However, to achieve noticeable effects in the power conversion, it is
 15 enough to vary the floating frequency f_f based on the required output power being the output current I_{out} in the present embodiment.

Fig.3 is a first embodiment for a frequency controlled capacitive power converter 300 based on the capacitive power converter 100 shown in fig.1 and further including a current sensor 310, a variable oscillator 320 and a buffer capacitor 330
 20 having the capacity C_B .

The buffer capacitor 330 is connected to the output 140 to stabilize the output voltage V_{out} . Further, the current sensor 310 measures the output current I_{out} and provides a signal to the variable oscillator 320. Based on that signal, the variable oscillator changes its own frequency and therewith the switching frequency f_f of the
 25 switch bank 110.

In the present embodiment the switching frequency f_f is set based on the output power measured based on the output current I_{out} by the current sensor 310. In this manner a feedback is established that ensures a fixed and defined relationship between the output current I_{out} and the variable frequency f_f .

30 Fig.4 is a second embodiment for a frequency controlled capacitive power converter 400 based on the capacitive power converter 100 shown in fig.1 and further including a current sensor 410, a variable oscillator 420 and a first buffer capacitor 430 and a second buffer capacitor 440 both having the capacity C_B .

The first buffer capacitor 430 is connected to the output 140 to stabilize the output voltage V_{out} and the second buffer capacitor 440 is connected to the input 130 to stabilize the input voltage V_{in} . In contrary to the first embodiment, the current sensor 310 measures the input current and provides a signal to the variable oscillator 420. Based on that signal, the variable oscillator 420 changes its own frequency and therewith the switching frequency f_f of the switch bank 110.

In the present embodiment, the switching frequency f_f is set based on the input power measured based on the input current by the current sensor 410. In this manner a feedback is established that ensures a fixed and defined relation between the input current and the switching frequency f_f . Since the input voltage source V_{in} is defined and independent of the power, the input current is directly representing the input power via the relation $I_{in} = P_{in}/U_0$. Thus no further calculations had therewith electronic hardware for setting the switching frequency is necessary.

Fig.5 is an LED illumination system 500 including a capacitive power converter 510 according to the present invention. The LED illumination system 500 further includes a source voltage U_0 connected to the input of the capacitive power converter 510 and a load 520 connected to the output of the capacitive power converter 510.

The capacitive power converter includes a flying capacitor bank 511, connected to a switch bank 512 via a plurality of connection lines. The switch bank 512 further receives a signal with a switching frequency f_f for driving the switch bank 512 in the same way as in the conventional capacitive power converter 100 described above. However, in the present invention, the signal with the switching frequency f_f is provided by a controllable oscillator 514, which can output a plurality of different signals with different switching frequencies f_f based on an instruction i . The instruction i is output by an adjustment unit 513, which is also adapted to provide the instruction i to the load 520 of the LED illumination system 500. The load 520 includes a buffer capacitance 521 connected in parallel to the capacitive power converter 510 and to a serial connection of a LED 522 and a current adjuster 523. The current adjuster 523 receives the instruction i from the capacitive power converter 510 and sets a specific current I_{out} based on the received instruction i . In this manner there is a fixed and optimal relationship between the output current setting and the variable frequency as described by equation 8).

Next numerical examples should be discussed for the present invention:

For that, the following network parameters should be assumed: $U_0=5V$, $C=1\mu F$ and $C_{loss}=C_{par}/2+C_{gate, total}=2nF$.

The first numerical example should be discussed based on the LED illumination system 500 according to fig.5. If the LED illumination system 300 is driven in flash mode, an output current of $I_{out}=500mA$ will be required. If the LED illumination system 300 is driven in torch mode, an output current of $I_{out}=100mA$ will be required.

As for the flash mode, according to equation (8), the optimum switching frequency f_f results into 1,1MHz. That is, the power efficiency ($\eta=1 - P_{loss}/P_{in}$) of the LED illumination system 300 driven in flash mode results into $\eta=91\%$.

As for the torch mode, the variable frequency adjust when the user sets to the smaller output current $I_{out} = 100 mA$. According to equation (8), the optimal frequency in torch mode becomes $f_f=220kHz$. Therewith, the power efficiency of the LED illumination system 500 driven in torch mode also results into around $\eta=91\%$. When driving a conventional illumination system in torch mode with $I_{out} = 100 mA$ at a switching frequency f_f of 1.1MHz (which is optimized for flash mode), the power losses will result into $P_{loss} = 55.6 mW$. Based on the given input voltage ($U_0=5V$), the input power will result into $P_{in} = 180 mW$. Thus, the power efficiency ($\eta=1 - P_{loss}/P_{in}$) results into $\eta=69\%$.

As can be seen from the foregoing numerical example, there is a wide scope for saving electric power, which can be fully used by the present invention.

The present invention proposes to amend the variable frequency of a capacitive power converter based on the required output power. This achieves, that the electric power converter will always be driven with the optimal power conversion efficiency and minimum power losses. Since the power losses are minimal, the capacitive power converter can be driven with reduced heating of the electric components and a longer life time. This is especially of interest for mobile applications enabling a longer operating time for batteries.

CLAIMS:

1 Capacitive power converter adapted to transform an electric input power (U_0) into an electric output power (I_{out}), the capacitive power converter (510) includes:

- at least one flying capacitor (511);
- 5 - at least one switching element (512) for periodically floating the at least one flying capacitor (511) based on a switching frequency (f_f); and
- adjustment means (513, 514) for setting the switching frequency (f_f) based on the output power (I_{out}) of the capacitive power converter (510).

10 2. Capacitive power converter according to claim 1, wherein the adjustment means (513, 514) is adapted to determine the output current (I_{out}) and/or the output voltage (V_{out}) of the capacitive power converter (510) and to set the switching frequency (f_f) based the determined output current (I_{out}) and/or output voltage (V_{out}).

15 3. Capacitive power converter according to claim 1 or 2, wherein the adjustment means (313, 314) is adapted to determine ripple losses and/or switching losses occurring in the capacitive power converter (510) and to set the switching frequency (f_f) based the determined ripple and/or switching losses.

20 4. Capacitive power converter according to claim 3, wherein the adjustment means (313, 314) is adapted to determine and to set the switching frequency (f_f) based on an optimal switching frequency ($f_{f,opt}$), which is given when the sum ripple losses and switching losses in the capacitive power converter (510) is

25 minimal.

5. Capacitive power converter according to one of the claims 1-4, wherein the adjustment means (313, 314) is adapted to set the switching frequency (f_f) based on the capacitance (C) of the at least one flying capacitor (510).

6. Capacitive power converter according to one of the claims 1-5, wherein the adjustment means (313, 314) is adapted to set the switching frequency (f_f) based on the value of non ideal electronic elements (C_{par} , C_{gate}) in the capacitive power
5 converter (510).

7. Capacitive power converter according to one of the claims 1-6, wherein the adjustment means (313, 314) are further adapted to set the output power (I_{out}) of the capacitive power converter (510) together with the switching frequency (f_f).
10

8. Capacitive power converter according to one of the claims 1-7, wherein the capacitive power converter (510) is a light emitting diode driver for driving a light emitting diode (522).

15 9. Capacitive power converter according to claim 8, wherein the light emitting diode driver is adapted to drive the light emitting diode (522) in a flash mode and in a torch mode.

10. Light emitting system including:
20 - an electric power source (U_0);
- a capacitive power converter (510) according to one of the claims 1-10 receiving electric power from the electric power source (U_0);
a buffer capacitor (521) for buffering output power (I_{out}) output by the capacitive power converter (510); and
25 a light emitting diode (522) receiving the electric power (I_{out}) buffered on the buffer capacitor (522) and generating light.

11. Method for driving a capacitive power converter (510) transforming an electric input power (U_0) into an electric output power (I_{out}), wherein the capacitive
30 power converter (510) includes at least one flying capacitor (511) and at least one switching element (512) periodically charging and discharging the flying capacitor (511) based on a switching frequency (f_f), the method comprises the steps:
- determining the electric output power (I_{out}) of the capacitive power

converter (510); and

- setting the switching frequency (f_f) of the capacitive power converter (510) based on the determined electric output power (I_{out}).

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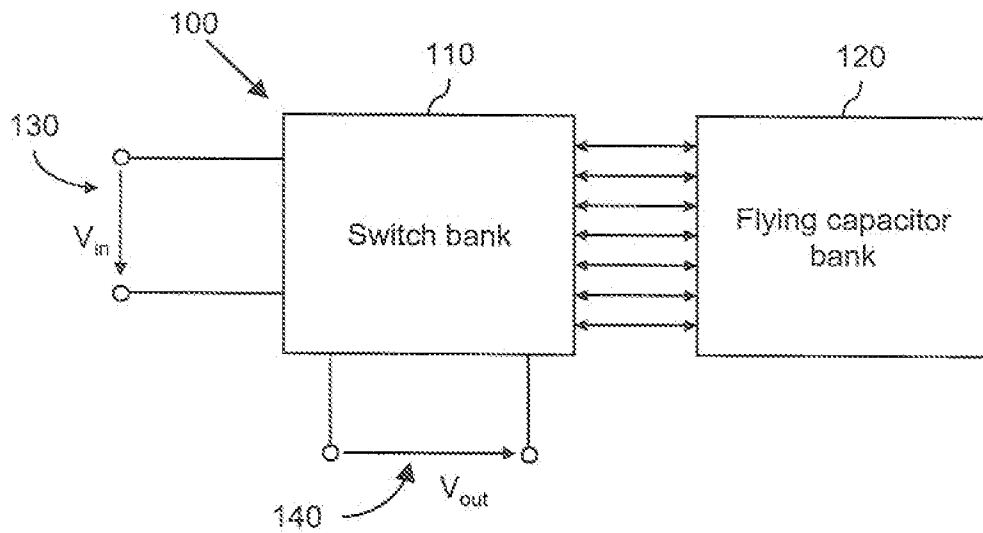


Fig.1

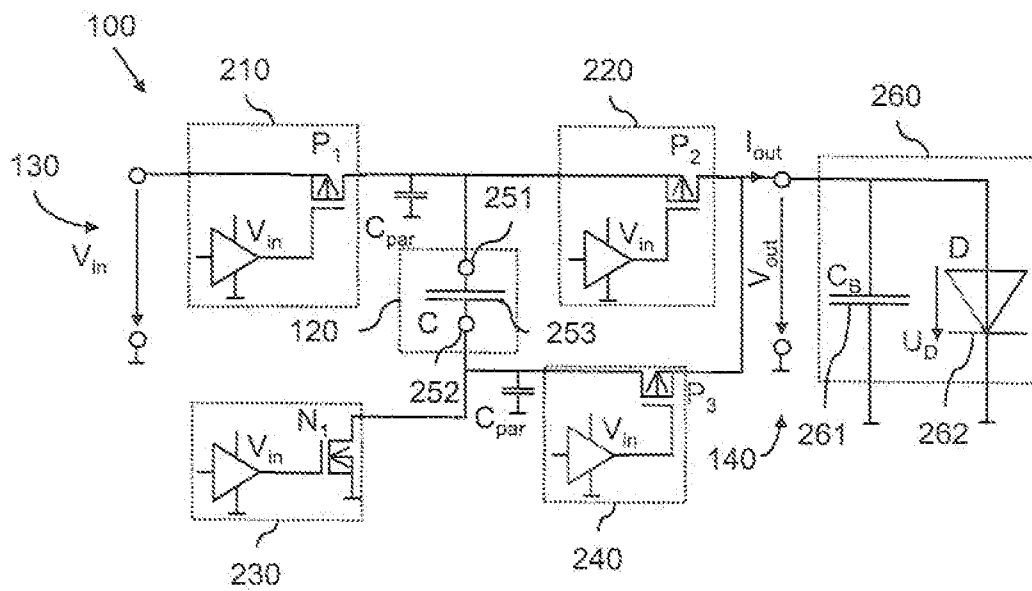


Fig.2

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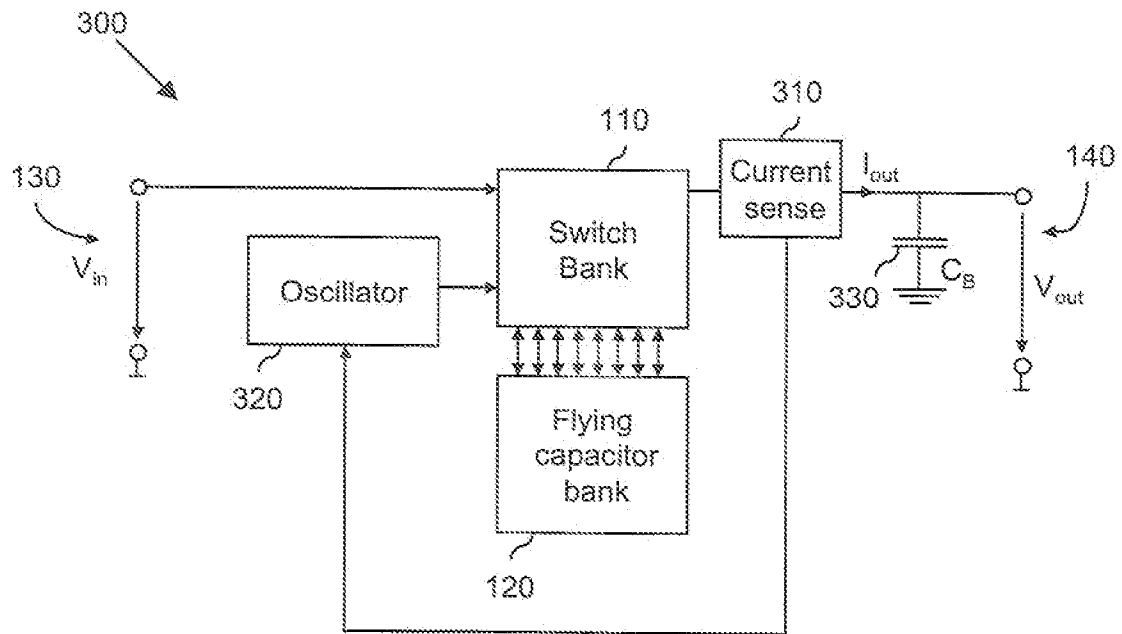


Fig.3

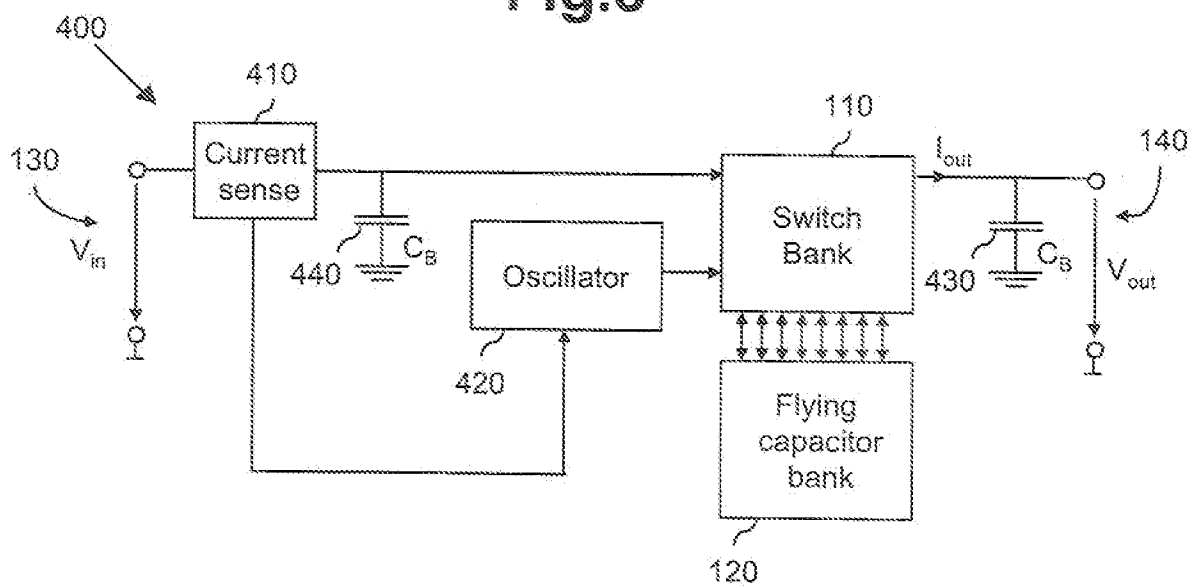


Fig.4

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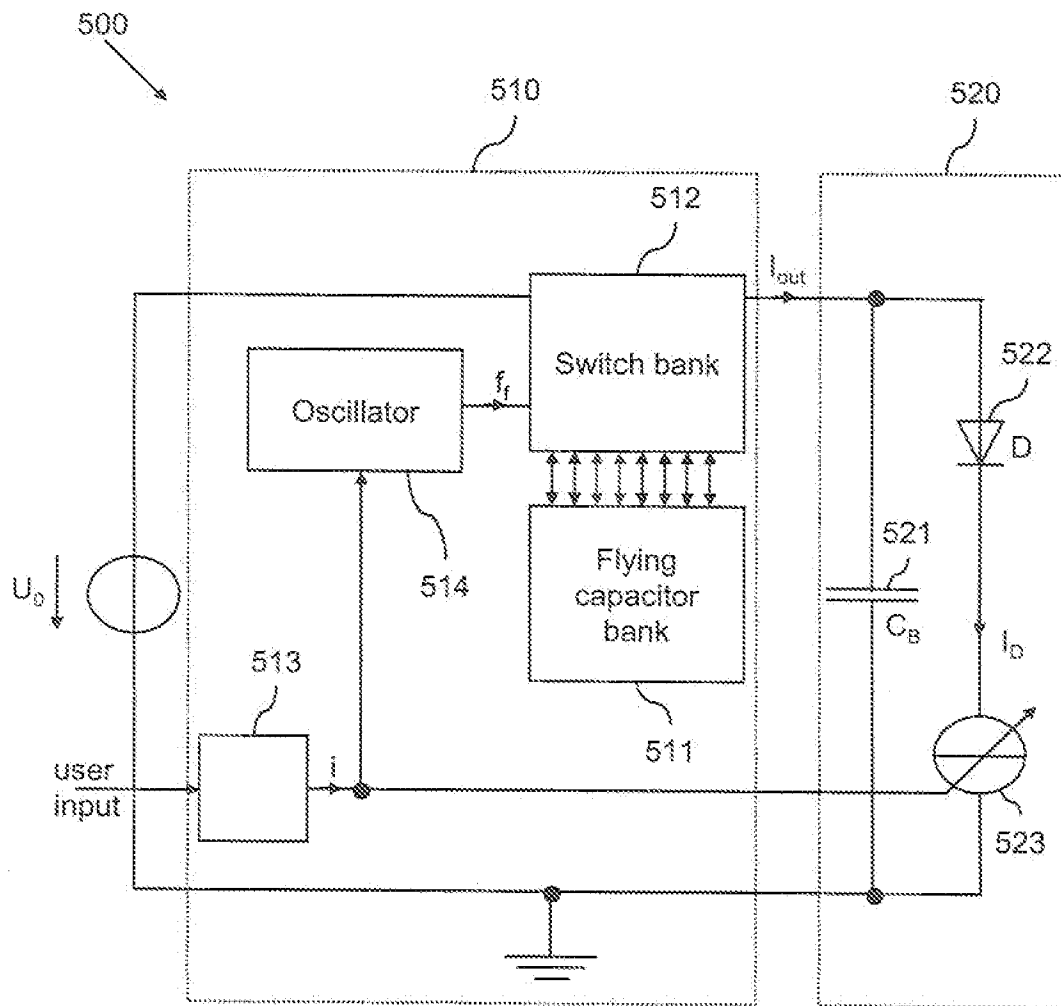


Fig.5