

SWITCHED CAPACITOR REGULATOR FOR DRIVING HIGH LOAD CURRENT AND METHOD THEREOF

Field of the Invention

[0001] The present invention relates to switched capacitor converters for providing stable voltage sources for sensitive applications. In particular, this invention relates to a switched capacitor regulator for driving high load current and method thereof.

Background of the Invention

[0002] Switched capacitor converters are often used as voltage regulators to provide stable voltage sources for low voltage applications. When used in electronic applications having physical size constraints, such switched capacitor converters are often implemented using integrated circuits together with external capacitors.

[0003] However, such switched capacitor converters are disadvantageously limited to providing low load currents for the low voltage applications. With emerging low voltage applications requiring higher load currents to drive more demanding applications, present day switched capacitor converters are simply unable to deliver the higher load currents required.

[0004] One such example of a low voltage application requiring higher load currents is in the field of miniature hard disk drives. An example of which is the IBM Microdrive. Such miniature hard disk drives are typically low voltage devices having controlling means such as processors powered by the switch capacitor converter provided. With such miniature hard disk drives, the switched capacitor converter on board is also necessarily smaller.

[0005] An example of one implementation of a prior art switched capacitor converter is shown in FIG. 1. The circuit architecture comprises a pumping capacitor 15, a load capacitor 17, two pairs of semiconductor switches (11, 14 & 12, 13) and a DC voltage source 22. The prior art switched capacitor converter 10 operates on the principle of charge balance transfer. The two pairs of semiconductor switches are configured to operate the prior art switched capacitor converter 10 continuously alternating between a charging stage and a discharging stage.

[0006] In the charging stage, the first pair of the semiconductor switches (11, 14) are closed, and the second pair (12, 13) are opened, coupling the DC voltage source 22 to the pumping capacitor 15. The pumping capacitor 15 is further coupled in series to the load capacitor 17. In this stage, both capacitors are charged.

[0007] In the discharging stage, the first pair of the semiconductor switches (11, 14) are opened, and the second pair of the semiconductor switches (12, 13) are closed, de-coupling the pumping capacitor 15 from the DC voltage source 22. The pumping capacitor 15 remains coupled to the load capacitor 17. In this stage, discharging occurs, with the pumping capacitor 15 discharging to the load capacitor 17, while the load capacitor 17 continues to provide current to the attached application. The continuous alternating charging and discharging stages of the prior art switched capacitor converter 10 regulates the desired voltage of the attached application.

[0008] However, the prior art switched capacitor converter disadvantageously allows for only low load currents to be drawn by the application. Increasing the ratings of the pumping and load capacitors to allow for higher load currents also disadvantageously results in the increase of the physical size of the capacitors and the overall architecture.

[0009] Other implementations of the prior art switched capacitor converter involves adding pumping capacitors and cascading them by having additional

semiconductor switches to couple them together during the charging and discharging phases. However, this implementation disadvantageously requires the use of more semiconductor switches and also increases the physical size of the overall architecture.

[0010] Therefore, a need exists for an improved switched capacitor converter architecture having size constraints for driving high load currents for low voltage applications.

Summary of the Invention

[0011] The present invention seeks to provide a switched capacitor regulator for driving high load currents.

[0012] Accordingly, in one aspect, the present invention provides a switched capacitor regulator for driving high load currents from a DC voltage source comprising a pumping capacitor, a load capacitor, and a plurality of switches. The plurality of switches are configured to place the regulator into a first charging stage and, alternately, a second charging stage. In the first charging stage, the DC voltage source is coupled in series to the pumping capacitor which is further coupled in series with the load capacitor such that current from the DC voltage source charges the pumping capacitor and the load capacitor in a first direction. In the second charging stage, the DC voltage source is coupled in series with the pumping capacitor which is further coupled in series with the load capacitor such that current from the DC voltage source charges the pumping capacitor in a second direction opposing the first direction and the load capacitor in the first direction.

[0013] In a second aspect, the present invention provides a method for operating a switched capacitor regulator having a pumping capacitor, a load capacitor, and a plurality of switches. The plurality of switches are configured to place the regulator into a first charging stage and, alternately, a second charging stage. The method comprises the steps of (a) placing the regulator into the first charging stage

by coupling a DC voltage source to the pumping capacitor which is further coupled in series to the load capacitor and (b) placing the regulator into the second charging stage by coupling the DC voltage source to the pumping capacitor which is further coupled in series to the load capacitor. In the first charging stage, current from the DC voltage source charges the pumping capacitor and the load capacitor in a first direction. In the second charging stage, current from the DC voltage source charges the pumping capacitor in an opposing second direction and the load capacitor in the first direction.

[0014] In a third aspect, the present invention provides a switched capacitor regulator for driving high load currents from a DC voltage source comprising a first switch, a second switch, a third switch, a fourth switch, a pumping capacitor, and a load capacitor. The DC voltage source is coupled to a first end of the pumping capacitor via the first switch. The DC voltage source is further coupled to a second end of the pumping capacitor via the second switch. The first end of the pumping capacitor is further coupled to a first end of the load capacitor via a third switch. The second end of the pumping capacitor is further coupled to the first end of the load capacitor via a fourth switch. The first switch and the fourth switch are closed and the second and third switch are opened to place the regulator into a first charging stage. The second and third switch are closed and the first and the fourth switch are opened to place the regulator into a second charging stage.

[0015] Accordingly, in a fourth aspect, the present invention provides a system for driving high load currents, a switched capacitor regulator, DC voltage source, and a low voltage application. the switched capacitor regulator comprises a pumping capacitor, a load capacitor, and a plurality of switches. The plurality of switches are configured to place the regulator into a first charging stage and, alternately, a second charging stage. In the first charging stage, the DC voltage source is coupled in series to the pumping capacitor which is further coupled in series with the load capacitor such that current from the DC voltage source charges the pumping capacitor and the load capacitor in a first direction. In the second charging stage, the DC voltage source is coupled in series with the pumping capacitor which is

further coupled in series with the load capacitor such that current from the DC voltage source charges the pumping capacitor in a second direction opposing the first direction and the load capacitor in the first direction.

Brief Description of the Drawings

[0016] Embodiments of the present invention will now be more fully described, by way of example, with reference to the drawings of which:

[0017] FIG. 1 illustrates a circuit diagram of a prior art switched capacitor converter;

[0018] FIG. 2 illustrates a circuit diagram of a switched capacitor regulator for driving higher load current in accordance to a preferred embodiment;

[0019] FIG. 3 illustrates a block diagram of a system having the switched capacitor regulator in accordance to the preferred embodiment.

Detailed Description

[0020] In the following description, details are provided to describe the preferred embodiments of the invention. It shall be apparent to one skilled in the art, however, that the embodiments may be practiced without such details. Some of these details may not be described at length so as not to obscure the preferred embodiments.

[0021] Switched capacitor regulators used particularly in miniature hard disk drives are often implemented using integrated circuits together with external capacitors. Such switched capacitor regulators are required to drive higher load currents and yet maintain a small physical size.

[0022] Referring to FIG. 2, a switched capacitor regulator 20 in accordance with the present invention comprises a DC voltage source 22, a plurality of switches 11, 12, 13, 14 a pumping capacitor 25, and a load capacitor 27.

[0023] The switched capacitor regulator 20 may be implemented in a variety of different low voltage applications. Referring to FIG. 3, a system is shown having the switched capacitor regulator 20 for a low voltage application, an example of the low voltage application being a controlling means 21 for a miniature hard disk drive 22.

[0024] The plurality of switches 11, 12, 13, 14 may comprise semiconductor switches implemented in an integrated circuit (IC). The plurality of switches 11, 12, 13, 14, are configured to operate the switched capacitor regulator 20 continuously alternating between a first charging stage and a second charging stage. The plurality of switches are controlled linearly when connecting to both the first charging stage and the second charging stage.

[0025] The switched capacitor regulator 20 essentially has an H bridge circuit configuration. The DC voltage source 22 is coupled to a first end of the pumping capacitor 25 via a first switch 11. The DC voltage source 22 is further coupled to a second end of the pumping capacitor 25 via the second switch 12.

[0026] The first end and the second end of the pumping capacitor 25 are further coupled to a first end of the load capacitor 27 via a third switch 13 and a fourth switch 14 respectively. The second end of the load capacitor 27 is grounded.

[0027] A method of operating the switched capacitor regulator 20 comprises the steps of alternately connecting between a first charging stage and a second charging stage. In the first charging stage, the first switch 11 and the fourth switch 14 are closed, while the second switch 12 and the third switch 13 are open. The DC voltage source 22 is thus coupled in series to the pumping capacitor 15 via the first switch 11. The pumping capacitor 25 is further coupled in series via the fourth

switch 14 to the load capacitor 27. In the first charging stage, current flows from the DC voltage source 22 and charges the pumping capacitor 25 and the load capacitor 27 in a first direction.

[0028] In the second charging state, the second switch 12 and the third switch 13 are closed, while the first switch 11 and the fourth switch 14 are closed. The DC voltage source 22 is now coupled in series to the pumping capacitor 25 via the second switch 12. The pumping capacitor 25 is further coupled in series via the third switch 13 to the load capacitor 27. The pumping capacitor 25 is however coupled to the DC voltage source 22 in an opposing direction from that of the first charging stage. The load capacitor 27 continues to receive current from the DC voltage source 22 in the same direction as in the first charging stage. In the second charging stage, current flows from the DC voltage source 22 and charges the pumping capacitor 25 and the load capacitor 27, albeit the pumping capacitor 25 is charged in an opposing second direction while the load capacitor 27 is charged in the first direction.

[0029] In the switched capacitor regulator 20 of the present invention, the switching between the first stage and the second stage results in the pumping capacitor 25 being charged in opposing directions, while the load capacitor 27 is always being charged in the same direction. The load capacitor 27 is thus being charged in both the first charging stage and the second charging stage. A higher load current can thus be advantageously drawn from the switched capacitor regulator 20 of the present invention, as the current can directly be drawn from the DC voltage source 22 and there is less reliance on the pumping capacitor 25. This advantageously allows the capacity of the pumping capacitor 25 to be greatly reduced as it acts mainly as a buffer in the present switched capacitor regulator 20.

[0030] It will be appreciated that although the embodiments have been described in detail, various modifications and improvements can be made by a person skilled in the art without departing from the scope of the present invention.

Claims

1. A switched capacitor regulator for driving high load currents from a DC voltage source comprising:

a pumping capacitor;

a load capacitor; and

a plurality of switches;

the plurality of switches being configured to place the regulator into a first charging stage and, alternately, a second charging stage;

wherein in the first charging stage, the DC voltage source is coupled in series with the pumping capacitor which is further coupled in series with the load capacitor such that current from the DC voltage source charges the pumping capacitor and the load capacitor in a first direction; and

wherein in the second charging stage, the DC voltage source is coupled in series with the pumping capacitor which is further coupled in series with the load capacitor such that current from the DC voltage source charges the pumping capacitor in a second direction opposing the first direction and the load capacitor in the first direction.

2. The switched capacitor regulator of claim 1, wherein the plurality of switches comprises a first switch, a second switch, a third switch and a fourth switch.

3. The switched capacitor regulator of claim 2, wherein the DC voltage source is coupled to a first end of the pumping capacitor via the first switch;

wherein the DC voltage source is further coupled to a second end of the pumping capacitor via the second switch;

wherein the first end of the pumping capacitor is further coupled to a first end of the load capacitor via a third switch; and

wherein the second end of the pumping capacitor is further coupled to the first end of the load capacitor via a fourth switch.

4. The switched capacitor regulator of claim 3, wherein the first switch and the fourth switch are closed and the second and third switch are opened to place the regulator into a first charging stage; and

wherein the second and third switch are closed and the first and the fourth switch are opened to place the regulator into a second charging stage.

5. A method for operating a switched capacitor regulator having a pumping capacitor, a load capacitor, and a plurality of switches, the plurality of switches being configured to place the regulator into a first charging stage and, alternately, a second charging stage, the method comprising the steps:

a. placing the regulator into the first charging stage by coupling a DC voltage source to the pumping capacitor which is further coupled in series to the load capacitor;

b. placing the regulator into the second charging stage by coupling the DC voltage source to the pumping capacitor which is further coupled in series to the load capacitor;

wherein in the first charging stage, current from the DC voltage source charges the pumping capacitor and the load capacitor in a first direction; and

wherein in the second charging stage, current from the DC voltage source charges the pumping capacitor in a second direction opposing the first direction and the load capacitor in the first direction.

6. The method of claim 5, wherein the plurality of switches comprises a first switch, a second switch, a third switch and a fourth switch.

7. The method of claim 6, wherein the DC voltage source is coupled to a first end of the pumping capacitor via the first switch;

wherein the DC voltage source is further coupled to a second end of the pumping capacitor via the second switch;

wherein the first end of the pumping capacitor is further coupled to a first end of the load capacitor via a third switch; and

wherein the second end of the pumping capacitor is further coupled to the first end of the load capacitor via a fourth switch.

8. The method of claim 7, wherein the step a. further comprises the steps:

a1. closing the first switch and the fourth switch; and

a2. opening the second switch and the third switch.

9. The method of claim 7, wherein the step b. further comprises the steps:

b1. closing the second switch and the third switch; and

b2. opening the first switch and the fourth switch.

10. A switched capacitor regulator for driving high load currents from a DC voltage source comprising:

a first switch, a second switch, a third switch, a fourth switch;

a pumping capacitor; and

a load capacitor;

wherein the DC voltage source is coupled to a first end of the pumping capacitor via the first switch;

wherein the DC voltage source is further coupled to a second end of the pumping capacitor via the second switch;

wherein the first end of the pumping capacitor is further coupled to a first end of the load capacitor via a third switch; and

wherein the second end of the pumping capacitor is further coupled to the first end of the load capacitor via a fourth switch;

wherein further wherein the first switch and the fourth switch are closed and the second and third switch are opened to place the regulator into a first charging stage; and

wherein the second and third switch are closed and the first and the fourth switch are opened to place the regulator into a second charging stage.

11. The switched capacitor regulator of claim 10, wherein in the first charging stage, the DC voltage source is coupled to the pumping capacitor which is further coupled in series with the load capacitor such that current from the DC voltage source charges the pumping capacitor and the load capacitor in a first direction.

12. The switched capacitor regulator of claim 10, wherein in the second charging stage, the DC voltage source is coupled in series with the pumping capacitor which is further coupled in series with the load capacitor such that current from the DC voltage source charges the pumping capacitor in an opposing second direction and the load capacitor in the first direction.

13. A system for driving high load currents comprising:

- a switched capacitor regulator;
- a DC voltage source; and
- a low voltage application;

- wherein the switched capacitor regulator comprises: a pumping capacitor; a load capacitor; and a plurality of switches;
- the plurality of switches being configured to place the regulator into a first charging stage and, alternately, a second charging stage;

- wherein in the first charging stage, the DC voltage source is coupled in series with the pumping capacitor which is further coupled in series with the load capacitor such that current from the DC voltage source charges the pumping capacitor and the load capacitor in a first direction; and

- wherein in the second charging stage, the DC voltage source is coupled in series with the pumping capacitor which is further coupled in series with the load capacitor such that current from the DC voltage source charges the pumping capacitor in a second direction opposing the first direction and the load capacitor in the first direction.

14. The system of claim 13, wherein the plurality of switches comprises a first switch, a second switch, a third switch and a fourth switch.

15. The system of claim 14, wherein the DC voltage source is coupled to a first end of the pumping capacitor via the first switch;

wherein the DC voltage source is further coupled to a second end of the pumping capacitor via the second switch;

wherein the first end of the pumping capacitor is further coupled to a first end of the load capacitor via a third switch; and

wherein the second end of the pumping capacitor is further coupled to the first end of the load capacitor via a fourth switch.

16. The system of claim 15, wherein the first switch and the fourth switch are closed and the second and third switch are opened to place the regulator into a first charging stage; and

wherein the second and third switch are closed and the first and the fourth switch are opened to place the regulator into a second charging stage.

17. The system of claim 13 wherein the low voltage application comprises a controlling means for a miniature hard disk drive.