

AN ELECTRICAL ISOLATION CIRCUIT FOR PREVENTING CURRENT FLOW FROM AN ELECTRICAL APPLICATION TO A DC POWER SOURCE

Field of the Invention

[0001] The present invention relates to electrical isolation of DC power sources. In particular, this invention relates to a method and apparatus for preventing current flow from an electrical application to a DC power source.

Background of the Invention

[0002] During operation of certain types of electrical applications, the voltages generated in these electrical applications may exceed the voltage of the DC power supply in use. This causes current to flow from the electrical application into the DC power supply. This may disadvantageously result in damage to the DC power supply. Typical examples of such electrical applications are inductive load systems such as DC motors.

[0003] In particular, this is encountered in brushless DC motors (BLDC) that require commutation for correct and efficient operation. Commutation is achieved in BLDC motors by the control of several switches configured to switch ON and OFF at predetermined intervals to control the commutation of the stator coils of the BLDC motor. The switches used in these BLDC motors may be semiconductor switches implemented on integrated circuits (ICs).

[0004] In most electrical applications, when the electrical application is turned OFF, the DC power supply will be isolated from the electrical application. However, in BLDC motors Back EMF is generated by the commutation of the stator coils. When the BLDC motor is turned OFF or when there is a loss of power, the Back EMF generated can disadvantageously induce current that is driven back into the DC power supply. The DC power supply may then be damaged by this induced current.

[0005] Such electrical applications thus require electrical isolation from the DC power supplies to prevent damage to the power supplies during normal operations.

[0006] Two of the more typical ways of isolation are by means of a Shottky diode or MOSFET between the power supply and the electrical application.

[0007] Referring to FIG. 1, a prior art implementation of electrical isolation for a BLDC motor 20 using a MOSFET 12 as shown. Using such an implementation provides for low voltage drop across the MOSFET 12 thus keeping the voltage supplied to the electrical application high. The power dissipation by the MOSFET 12 is also relatively low. However, this implementation does not fully prevent the back flow of induced current into the DC power source 10.

[0008] When the MOSFET 12 is switched OFF, electrical isolation occurs and no induced current can flow from the BLDC motor 20 back into the DC power source 10. However, when the MOSFET 12 is switched ON during normal operations, any induced current due to Back EMF in the BLDC motor 20 can still back flow into the DC power source 10.

[0009] Referring to FIG. 2, a prior art implementation of electrical isolation for a BLDC motor 20 using a Shottky diode 17 is shown. The Shottky diode 17 allows only uni-directional current flow, thus resulting in electrical isolation of the DC power source 10 from the electrical application, in the present case, the BLDC motor 20. However, using the Shottky diode 17 disadvantageously results in a high voltage drop across the Shottky diode 17 as well as high power dissipation.

[0010] Therefore, a need exists for an improved method and apparatus for providing electrical isolation for applications that may generate voltages in excess of the DC power supply.

Summary of the Invention

[0011] The present invention seeks to provide an electrical isolation circuit for preventing flow of current from an electrical application to a DC power source.

[0012] Accordingly, in one aspect, the present embodiment provides an electrical isolation circuit for preventing flow of current from an electrical application to a DC power source, the electrical isolation circuit comprising: a switch coupled between the DC power source and the electrical application and a comparator for controlling the switch by receiving inputs from the DC power source and the electrical application. The comparator causes the switch to switch ON when the DC power source has a higher voltage than the electrical application. The comparator causes the switch to switch OFF when the electrical application has a higher voltage than the DC power source, thereby preventing flow of current from the electrical application to the DC power source.

[0013] In a second aspect, the present embodiment provides, an electrical isolation circuit for preventing flow of current from an electrical application to a DC power source, the electrical isolation circuit comprising a MOSFET operating as a switch, coupled between the DC power source and the electrical application, and an op-amp operating as a comparator for controlling the MOSFET by receiving inputs from the DC power source and the electrical application. The op-amp causes the MOSFET to switch ON when the DC power source has a higher voltage than the electrical application. The op-amp causes the MOSFET to switch OFF when the electrical application has a higher voltage than the DC power source, thereby preventing flow of current from the electrical application to the DC power source.

[0014] In a third aspect, the present embodiment provides a method for electrical isolation to prevent flow of current from an electrical application to a DC power source, comprising the steps of (a) providing a switch coupled between the DC power source and the electrical application, (b) providing a comparator for controlling the switch by comparing inputs from the DC power source and the electrical application, and (c) switching the switch OFF when the electrical

application has a higher voltage than the DC power source, thereby preventing flow of current from the electrical application to the DC power source.

[0015] In a third aspect, the present embodiment provides a Brushless DC (BLDC) motor system having an electrical isolation circuit, the BLDC motor system comprising: a DC power source; a BLDC motor having a plurality of commutation switches configured to switch ON or OFF at predetermined intervals to control commutation of stator coils of the BLDC motor; an electrical isolation circuit comprising: a switch coupled between the DC power source and the BLDC motor; and a comparator for controlling the switch by receiving inputs from the DC power source and the BLDC motor; wherein the comparator causes the switch to switch ON when the DC power source has a higher voltage than the BLDC motor; and wherein the comparator causes the switch to switch OFF when the electrical application has a higher voltage than the DC power source, thereby preventing flow of current from the BLDC motor to the DC power source.

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 implementation of electrical isolation using a MOSFET between a power supply and an electrical application;

[0018] FIG. 2 illustrates a circuit diagram of a prior art implementation of electrical isolation using a Schottky diode between a power supply and an electrical application;

[0019] FIG. 3 illustrates a circuit diagram of an electrical isolation circuit in accordance with the present invention not providing electrical isolation; and

[0020] FIG. 4 illustrates a circuit diagram of an electrical isolation circuit in accordance with the present invention when providing electrical isolation.

Detailed Description

[0021] 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.

[0022] Referring to FIG. 3, an electrical isolation circuit 30 in accordance with the present embodiment is coupled to an electrical application. The present example of the electrical application is a BLDC motor 20. The electrical isolation circuit 30 comprises a MOSFET 50 operating as a switch and an op-amp 40 operating as a comparator.

[0023] The MOSFET 50 acts as a switch between the DC power source 10 and the electrical application, which in the present example is the BLDC motor 20. When the MOSFET 50 is switched OFF, the DC power source 10 is isolated from the electrical application. A drain 51 of the MOSFET 50 is coupled to the electrical application while a source 52 of the MOSFET 50 is coupled to the DC power source 10. A gate 53 of the MOSFET 50 is coupled to an output 43 of the op-amp 40. The op-amp 40 operating as a comparator provides the control for switching the MOSFET 50 ON or OFF.

[0024] A positive input 41 of the op-amp 40 is coupled to the DC power source 10 while a negative input 42 of the op-amp 40 is coupled to the electrical application. The op-amp 40 operating as a comparator thus receives voltage input from the DC 10 power source and the electrical application.

[0025] During operation of the BLDC motor 20, a plurality of commutation switches are utilized to control the commutation of the BLDC motors 20. The plurality of commutation switches are configured to switch ON or OFF at predetermined intervals to control the commutation of the stator coils of the BLDC motor 20. The commutation switches used in these BLDC motors 20 may be semiconductor switches implemented on integrated circuits (ICs).

[0026] Referring to FIG. 3, when starting the BLDC motor 20, the MOSFET 50 operating as a switch is OFF. Commutation switches 23 and 24 are then switched ON. This results in current 31 flowing from the DC power source 10 via an intrinsic diode or body diode of the MOSFET 50 through commutation switches 24 and 23 and then to ground. Voltage (V_{motor}) of the electrical application which in this case is the BLDC motor 20 is voltage (V_{dd}) of the DC power source 20 minus voltage drop across the body diode of the MOSFET 50. The op-amp 40 thus receives a higher voltage input at its positive input 41 compared to the negative input 42 which is V_{dd} minus voltage drop across the body diode of the MOSFET 50. The output of the op-amp returns a high output forcing the MOSFET 50 to switch ON. This allows the current 31 to be fully delivered from the DC power source 10 through the commutation switches 24 and 23 to the stator of the BLDC motor 20.

[0027] At a next interval, commutation switches 24 and 23 are initially ON but are now switched OFF. Referring to FIG. 4, as current in the BLDC motor 20 cannot decay instantly when switches 24 and 23 are switched OFF, back EMF is developed within the BLDC motor inducing current 33 to flow back into the DC power source 10. The induced current 33 will flow from ground to the DC power source 10 through body diode of commutation switch 25, body diode of commutation switch 22, and through the ON resistance of the MOSFET 50. This causes voltage (V_{motor}) of the BLDC motor to be higher than voltage (V_{dd}) of the DC power source 10. The op-amp 40 thus receives a higher voltage at the negative input 42 than the positive input 41. The output of the op-amp thus begins to return a low output as opposed to its earlier high output. As the output of the op-amp

decreases, the ON resistance of the MOSFET 50 increases until the MOSFET 50 switches OFF and completely isolates the DC power source 10 from the BLDC motor 20 which is the electrical application.

[0028] The electrical isolation circuit 30 of the present invention provides electrical isolation of the electrical application, preventing current flow from the electrical application back into the DC power source 10 thereby damaging it. By using the comparator 40 and a switch which in the present embodiment is the MOSFET 50, the present invention provides real time dynamic electrical isolation as and when there is a requirement for electrical isolation. The comparator compares the voltage of the DC power source 10 and the voltage of the electrical application.

[0029] During normal operations, the voltage of the DC voltage source 10 should always be higher than the voltage of the electrical application. The comparator would then provide an output to the switch to switch it ON. This then allows the DC power source 10 to provide current to the electrical application.

[0030] However, when the voltage of the electrical application disadvantageously rises above the voltage of the DC voltage source 10 and causes current to flow back into the DC power source, the comparator would then provide an output to the switch to switch it OFF. This would then provide electrical isolation to prevent the flow of current back into the DC power source 10.

[0031] While the present description refers to the electrical application being a brushless DC motor. It will be appreciated by one skilled in the art that the present invention may be practiced with a variety of other electrical applications that require electrical isolation when excessive voltages are generated within the electrical application.

[0032] It will be further appreciated that although particular 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. An electrical isolation circuit for preventing flow of current from an electrical application to a DC power source, the electrical isolation circuit comprising:
 - a switch coupled between the DC power source and the electrical application; and
 - a comparator for controlling the switch by receiving inputs from the DC power source and the electrical application;wherein the comparator causes the switch to switch ON when the DC power source has a higher voltage than the electrical application; and
 - wherein the comparator causes the switch to switch OFF when the electrical application has a higher voltage than the DC power source, thereby preventing flow of current from the electrical application to the DC power source.
2. The electrical isolation circuit of claim 1, wherein the switch comprises a MOSFET having a gate, drain and source and wherein the comparator comprises an op-amp having a positive input, a negative input and an output.
3. The electrical isolation circuit of claim 2, wherein the output of the op-amp is coupled to the gate of the MOSFET, the positive input of the op-amp is coupled to the DC power source and the negative input of the op-amp is coupled to the electrical application.
4. The electrical isolation circuit of claim 3, wherein the drain of the MOSFET is coupled to the electrical application and the source of the MOSFET is coupled to the DC voltage source.
5. An electrical isolation circuit for preventing flow of current from an electrical application to a DC power source, the electrical isolation circuit comprising:
 - a MOSFET operating as a switch, is coupled between the DC power source and the electrical application; and
 - an op-amp operating as a comparator for controlling the MOSFET, by receiving inputs from the DC power source and the electrical application;

wherein the op-amp causes the MOSFET to switch ON when the DC power source has a higher voltage than the electrical application; and

wherein the op-amp causes the MOSFET to switch OFF when the electrical application has a higher voltage than the DC power source, thereby preventing flow of current from the electrical application to the DC power source.

6. The electrical isolation circuit of claim 5, wherein an output of the op-amp is coupled to a gate of the MOSFET, a positive input of the op-amp is coupled to the DC power source and a negative input of the op-amp is coupled to the electrical application.

7. The electrical isolation circuit of claim 5, wherein a drain of the MOSFET is coupled to the electrical application and a source of the MOSFET is coupled to the DC voltage source.

8. A method for electrical isolation to prevent flow of current from an electrical application to a DC power source, comprising the steps:

- a) providing a switch coupled between the DC power source and the electrical application;
- b) providing a comparator for controlling the switch by comparing inputs from the DC power source and the electrical application;
- c) switching the switch OFF when the electrical application has a higher voltage than the DC power source, thereby preventing flow of current from the electrical application to the DC power source.

9. The method of claim 8, further comprising the step:

- d) switching the switch ON when the DC power source has a higher voltage than the electrical application.

10. The method of claim 8, wherein the switch comprises a MOSFET having a gate, drain and source and wherein the comparator comprises an op-amp having a positive input, a negative input and an output.

11. The method of claim 10, wherein the output of the op-amp is coupled to the gate of the MOSFET, the positive input of the op-amp is coupled to the DC power source and the negative input of the op-amp is coupled to the electrical application.
12. The method of claim 11, wherein the drain of the MOSFET is coupled to the electrical application and the source of the MOSFET is coupled to the DC voltage source.
13. A Brushless DC (BLDC) motor system having an electrical isolation circuit, the BLDC motor system comprising:
 - a DC power source;
 - a BLDC motor having a plurality of commutation switches configured to switch ON or OFF at predetermined intervals to control commutation of stator coils of the BLDC motor;
 - an electrical isolation circuit comprising:
 - a switch coupled between the DC power source and the BLDC motor; and
 - a comparator for controlling the switch by receiving inputs from the DC power source and the BLDC motor;
 - wherein the comparator causes the switch to switch ON when the DC power source has a higher voltage than the BLDC motor; and
 - wherein the comparator causes the switch to switch OFF when the electrical application has a higher voltage than the DC power source, thereby preventing flow of current from the BLDC motor to the DC power source.
14. The BLDC motor system of claim 13, wherein the switch comprises a MOSFET having a gate, drain and source and wherein the comparator comprises an op-amp having a positive input, a negative input and an output.
15. The BLDC motor system of claim 14, wherein the output of the op-amp is coupled to the gate of the MOSFET, the positive input of the op-amp is coupled to the DC power source and the negative input of the op-amp is coupled to the electrical application.

16. The BLDC motor system of claim 15, wherein the drain of the MOSFET is coupled to the plurality of commutation switches of the BLDC motor and the source of the MOSFET is coupled to the DC voltage source.