

Description

Background of the Invention

Field of the Invention

This invention relates generally to switching circuits and, more particularly, to a thyristor which is optically triggerable near the zero-crossing point.

Background Art

Triac drivers are designed for use with a triac in the interface of logic systems to equipment powered from 220 Vac lines, such as solid state relays, industrial controls, motors, solenoids, and consumer appliances. A triac driver is itself a triac, or thyristors connected in inverse parallel, and may be triggered by either a single gate terminal or by the application of light.

Triggering of the triac at high values of main terminal voltages is generally undesirable because of the generation of noise and the possibility of premature device failure because of high localized current density. Therefore, it is desirable to trigger the triac as near as possible at the zero crossing point of the AC main terminal voltage. Many schemes have been designed for achieving zero point switching utilizing thyristors. LEDs are generally used to provide isolation between the logical input and the main terminal voltages and load.

When a thyristor is comprised of a vertical transistor in conjunction with a lateral transistor, the triggering at high main terminal voltages has been inhibited by means of a monolithic MOS field effect transistor coupled between the gate and the cathode of the thyristor. However, the breakdown voltage is limited by the thickness of the gate oxide of the MOS field effect transistor. Since thicker oxide of the gate increases the threshold voltage, a higher breakdown voltage device will decrease the zero-crossing effect.

The gate of the MOS field effect transistor of this previously known circuit was connected to the base of the thyristor. The high voltage appearing at the gate of the field effect transistor and the inability to run the gate metal across a PN junction forced the use of an additional bonding pad for each thyristor.

A triac driver in accordance with the precharacterising part of claim 1 is disclosed in US-A-4396932.

The invention seeks to provide a triac driver having an improved zero-crossing effect, a higher breakdown voltage, and fewer bonding pads than previously required.

Summary of the Invention

An LED triggered monolithic triac driver having a first terminal and second terminal coupled for receiving an AC voltage, said monolithic triac driver including first and second bipolar transistors; the emitter of said first bipolar transistor is coupled to said second terminal, the base and collector of said first bipolar transistor are respectively coupled to the collector and base of said second bipolar transistor; wherein the collector and base of said first bipolar transistor share common regions with the second bipolar transistor respectively; the emitter of said second bipolar transistor is coupled to said first terminal; said monolithic triac driver including third and fourth bipolar transistors, the emitter of said third bipolar transistor is coupled to said first terminal, the base and collector of said third bipolar transistor are respectively coupled to the collector and base of said fourth bipolar transistor wherein the collector and base of said third bipolar transistor share common regions with the base and collector of said fourth bipolar transistor respectively; the emitter of said fourth bipolar transistor being coupled to said second terminal; said monolithic triac driver having a first field effect transistor having a gate, and having current-carrying electrodes coupled between the base of said first bipolar transistor and said second terminal and having a second field effect transistor having a gate, and having current carrying electrodes coupled between the base of said third bipolar transistor and said first terminal; the driver being triggered by light actuation of the first and second and third and fourth transistors and characterised by a first photovoltaic diode having a cathode coupled to the collector of said first bipolar transistor and an anode coupled to the gate of said first field effect transistor and a second photovoltaic diode having a cathode coupled to the collector of said third bipolar transistor and an anode coupled to the gate of the second field effect transistor the first and second photovoltaic diodes being operative to control latch action of the triac driver.

Brief Description of the Drawing

The single FIGURE is a schematic of the preferred embodiment of the present invention.

Detailed Description of the Drawing

The single FIGURE is an equivalent schematic representation of the optically-activated zero crossing triac driver. Transistor 1 together with transistor 2 and transistor 1' together with transistor 2' re-

spectively form two thyristors in the so-called back-to-back or inverse parallel configuration. It is to be understood that the thyristors may each be a single PNP device, but are represented by two transistors for ease of description. Only the connections and operation for the thyristor including transistors 1,2 will be described herein; however, the other thyristor bearing the prime designations will be connected and operated in similar fashion. The collector and base of transistor 1 are connected to the base and collector of transistor 2, respectively. The emitter of transistor 2 is connected to main terminal 3 and the emitter of transistor 1 is connected to main terminal 4. Resistor 5 is coupled between the base of transistor 1 and main terminal 4 for shunting transistor 1 in order to reduce the sensitivity of the thyristor and preclude triggering by unwanted signals. Field effect transistor 6 has its drain connected to both the base of transistor 1 and the collector of transistor 2, and its source connected to main terminal 4 for shunting the base to emitter junction of transistor 1. Transistor 6 is preferably an enhancement-type field effect transistor which does not conduct when the voltage across main terminals 3,4 is zero, but which goes into conduction when the voltage between main terminals 3,4 is above the threshold voltage of transistor 6.

Photovoltaic diode 7 has its cathode connected to both the collector of transistor 1 and the base of transistor 2. The anode of diode 7 is connected to the gate of transistor 6 and the drain and gate of field effect transistor 8. The source of transistor 8 is connected to main terminal 4.

One advantage of using MOS field effect transistors thusly is that they draw only minute amounts of current when the thyristor is in the off state. A conventional LED (not shown) may serve as the source of photons which couple with the bipolar transistors 1,2 thereby causing the thyristors to be switched on. The LED may be placed in the same encapsulation as the thyristor by known techniques.

When the main terminal 3 voltage is high, most of the voltage is applied to diode 7 in a reversed biased condition. By causing diode 7 to have the same junction depth and similar geometrical structure as the collector junction of transistor 1, the threshold voltage of transistor 6 may be controlled in order to maximize the zero-crossing effect.

When the LED is off and the AC voltage on main terminals 3,4 is high, the leakage current of diode 7 will charge the inherent gate capacitance of transistors 6,8. The threshold voltage of transistor 8 is designed to be greater than the threshold voltage of transistor 6. Once the voltage applied to the gates of transistors 6,8 is larger than the threshold voltage of transistor 8, transistor 8 will

conduct and discharge the gate charge on transistor 6.

When the LED is on and the AC voltage on main terminals 3,4 is high, photovoltaic diode 7 serves as a current source thereby charging the gate capacitance of transistor 6. Therefore, transistor 6 will conduct and the thyristor latch action is prohibited. As the AC voltage on main terminals 3,4 decreases, the voltage on the cathode of diode 7 will be lower than the voltage on its anode. Then transistor 6 will cease conducting and the triac will latch.

In general, the operation of the back-to-back thyristor is as follows. When the LED provides the triggering means, but the AC voltage on main terminals 3,4 is high, the thyristors will not latch due to the inhibiting action of transistors 6,8,6',8'. When the LED provides the triggering means and the AC voltage on main terminals 3,4 is low, i.e., substantially near the zero-crossing point, transistors 6,8,6',8' will not inhibit the thyristors and the latching action will occur. It may be readily seen that the thyristor including transistors 1,2 will function when the voltage on main terminal 3 is positive and the thyristor including transistors 1',2' will function when the voltage on main terminal 4 is positive.

By now it should be appreciated that there has been provided a triac driver having an improved zero-crossing effect, a higher breakdown voltage, and fewer bonding pads than previously required.

Claims

1. An LED triggered monolithic triac driver having a first terminal (3) and second terminal (4) coupled for receiving an AC voltage, said monolithic triac driver including first and second bipolar transistors (1,2); the emitter of said first bipolar transistor is coupled to said second terminal (4), the base and collector of said first bipolar transistor are respectively coupled to the collector and base of said second bipolar transistor (2); wherein the collector and base of said first bipolar transistor share common regions with the base and collector of said second bipolar transistor respectively; the emitter of said second bipolar transistor is coupled to said first terminal (3); said monolithic triac driver including third and fourth bipolar transistors (1',2'), the emitter of said third bipolar transistor (1') is coupled to said first terminal (3), the base and collector of said third bipolar transistor are respectively coupled to the collector and base of said fourth bipolar transistor (2') wherein the collector and base of said third bipolar transistor share common regions with



spectively form two thyristors in the so-called back-to-back or inverse parallel configuration. It is to be understood that the thyristors may each be a single PNP device, but are represented by two transistors for ease of description. Only the connections and operation for the thyristor including transistors 1,2 will be described herein; however, the other thyristor bearing the prime designations will be connected and operated in similar fashion. The collector and base of transistor 1 are connected to the base and collector of transistor 2, respectively. The emitter of transistor 2 is connected to main terminal 3 and the emitter of transistor 1 is connected to main terminal 4. Resistor 5 is coupled between the base of transistor 1 and main terminal 4 for shunting transistor 1 in order to reduce the sensitivity of the thyristor and preclude triggering by unwanted signals. Field effect transistor 6 has its drain connected to both the base of transistor 1 and the collector of transistor 2, and its source connected to main terminal 4 for shunting the base to emitter junction of transistor 1. Transistor 6 is preferably an enhancement-type field effect transistor which does not conduct when the voltage across main terminals 3,4 is zero, but which goes into conduction when the voltage between main terminals 3,4 is above the threshold voltage of transistor 6.

Photovoltaic diode 7 has its cathode connected to both the collector of transistor 1 and the base of transistor 2. The anode of diode 7 is connected to the gate of transistor 6 and the drain and gate of field effect transistor 8. The source of transistor 8 is connected to main terminal 4.

One advantage of using MOS field effect transistors thusly is that they draw only minute amounts of current when the thyristor is in the off state. A conventional LED (not shown) may serve as the source of photons which couple with the bipolar transistors 1,2 thereby causing the thyristors to be switched on. The LED may be placed in the same encapsulation as the thyristor by known techniques.

When the main terminal 3 voltage is high, most of the voltage is applied to diode 7 in a reversed biased condition. By causing diode 7 to have the same junction depth and similar geometrical structure as the collector junction of transistor 1, the threshold voltage of transistor 6 may be controlled in order to maximize the zero-crossing effect.

When the LED is off and the AC voltage on main terminals 3,4 is high, the leakage current of diode 7 will charge the inherent gate capacitance of transistors 6,8. The threshold voltage of transistor 8 is designed to be greater than the threshold voltage of transistor 6. Once the voltage applied to the gates of transistors 6,8 is larger than the threshold voltage of transistor 8, transistor 8 will

conduct and discharge the gate charge on transistor 6.

When the LED is on and the AC voltage on main terminals 3,4 is high, photovoltaic diode 7 serves as a current source thereby charging the gate capacitance of transistor 6. Therefore, transistor 6 will conduct and the thyristor latch action is prohibited. As the AC voltage on main terminals 3,4 decreases, the voltage on the cathode of diode 7 will be lower than the voltage on its anode. Then transistor 6 will cease conducting and the triac will latch.

In general, the operation of the back-to-back thyristor is as follows. When the LED provides the triggering means, but the AC voltage on main terminals 3,4 is high, the thyristors will not latch due to the inhibiting action of transistors 6,8,6',8'. When the LED provides the triggering means and the AC voltage on main terminals 3,4 is low, i.e., substantially near the zero-crossing point, transistors 6,8,6',8' will not inhibit the thyristors and the latching action will occur. It may be readily seen that the thyristor including transistors 1,2 will function when the voltage on main terminal 3 is positive and the thyristor including transistors 1',2' will function when the voltage on main terminal 4 is positive.

By now it should be appreciated that there has been provided a triac driver having an improved zero-crossing effect, a higher breakdown voltage, and fewer bonding pads than previously required.

Claims

1. An LED triggered monolithic triac driver having a first terminal (3) and second terminal (4) coupled for receiving an AC voltage, said monolithic triac driver including first and second bipolar transistors (1,2); the emitter of said first bipolar transistor is coupled to said second terminal (4), the base and collector of said first bipolar transistor are respectively coupled to the collector and base of said second bipolar transistor (2); wherein the collector and base of said first bipolar transistor share common regions with the base and collector of said second bipolar transistor respectively; the emitter of said second bipolar transistor is coupled to said first terminal (3); said monolithic triac driver including third and fourth bipolar transistors (1',2'), the emitter of said third bipolar transistor (1') is coupled to said first terminal (3), the base and collector of said third bipolar transistor are respectively coupled to the collector and base of said fourth bipolar transistor (2') wherein the collector and base of said third bipolar transistor share common regions with



the base and collector of said fourth bipolar transistor respectively; the emitter of said fourth bipolar transistor (2'') being coupled to said second terminal (4); said monolithic triac driver having a first field effect transistor (6) having a gate, and having current-carrying electrodes coupled between the base of said first bipolar transistor (1) and said second terminal (4) and having a second field effect transistor (6'') having a gate, and having current carrying electrodes coupled between the base of said third bipolar transistor (1') and said first terminal (3); the driver being triggered by light actuation of the first and second (1,2) and third and fourth (1',2') transistors and characterised by a first photovoltaic diode (7) having a cathode coupled to the collector of said first bipolar transistor (1) and an anode coupled to the gate of said first field effect transistor (6) and a second photovoltaic diode (7'') having a cathode coupled to the collector of said third bipolar transistor (1') and an anode coupled to the gate of the second field effect transistor (6'') the first and second photovoltaic diodes (7,7'') being operative to control latch action of the triac driver.

2. The monolithic triac driver of claim 1 further including a third field effect transistor (8) having current carrying electrodes coupled between the gate of said first field effect transistor (6) and said second terminal (4), and a gate coupled to the anode of said first photovoltaic diode (7).
3. The monolithic triac driver of claim 1 or 2 wherein said first field effect transistor (6) is of an enhancement type.
4. The monolithic triac driver of claim 2 or 3 wherein said third field effect transistor (8) is of an enhancement type.
5. The monolithic triac driver of any preceding claim including a first resistive means (5) coupled between the base of said first bipolar transistor (1) and said second terminal (4).
6. The monolithic triac driver of any preceding claim including a fourth field effect transistor (8'') having current carrying electrodes coupled between the gate of said second effect transistor (6'') and said first terminal (3), and a gate coupled to the anode of said second photovoltaic diode (7'').
7. The monolithic triac driver of any preceding claim including a second resistive means (5')

coupled between the base of said third bipolar transistor (1') and said first terminal (3).

5 Revendications

1. Dispositif d'excitation de triac monolithique déclenché par DEL possédant une première borne (3) et une deuxième borne (4) couplées de façon à recevoir une tension alternative, ledit dispositif d'excitation de triac monolithique comportant des premier et deuxième transistors bipolaires (1,2) ; l'émetteur dudit premier transistor bipolaire est couplé à ladite deuxième borne (4), la base et le collecteur dudit premier transistor bipolaire sont respectivement couplés au collecteur et à la base dudit deuxième transistor bipolaire (2) ; où le collecteur et la base dudit premier transistor bipolaire partagent respectivement des régions communes avec la base et le collecteur dudit deuxième transistor bipolaire ; l'émetteur dudit deuxième transistor bipolaire est couplé à ladite première borne (3) ; et ledit dispositif d'excitation de triac monolithique comportant des troisième et quatrième transistors bipolaires (1', 2'), l'émetteur dudit troisième transistor bipolaire (1') est couplé à ladite première première borne (3), la base et le collecteur dudit troisième transistor bipolaire sont respectivement couplés au collecteur et à la base dudit quatrième transistor bipolaire (2'), où le collecteur et la base dudit troisième transistor bipolaire partagent respectivement des régions communes avec la base et le collecteur dudit quatrième transistor bipolaire ; l'émetteur dudit quatrième transistor bipolaire (2') étant couplé à ladite deuxième borne (4) ; ledit dispositif d'excitation de triac monolithique ayant un premier transistor à effet de champ (6) ayant une grille, et ayant des électrodes de transport de courant couplées entre la base dudit premier transistor bipolaire (1) et ladite deuxième borne (4) et ayant un deuxième transistor à effet de champ (6'') ayant une grille, et ayant des électrodes de transport de courant couplées entre la base dudit troisième transistor bipolaire (1') et ladite première borne (3) ; le dispositif d'excitation étant déclenché par activation lumineuse des premier et deuxième transistors (1, 2) et des troisième et quatrième transistors (1', 2'), et caractérisé par une première diode photovoltaïque (7) possédant une anode couplée au collecteur dudit premier transistor bipolaire (1) et une anode couplée à la grille dudit premier transistor à effet de champ (6), et une deuxième diode photovoltaïque (7'') ayant une cathode couplée au collecteur dudit troisième



transistor bipolaire (1') et une anode couplée à la grille du deuxième transistor à effet de champ (6'), les première et deuxième diodes photovoltaïques (7, 7') ayant pour fonction de commander l'action de verrouillage du dispositif d'excitation de triac.

2. Dispositif d'excitation de triac monolithique selon la revendication 1, comportant en outre un troisième transistor à effet de champ (8) ayant des électrodes de transport de courant couplées entre la grille dudit premier transistor à effet de champ (6) et ladite deuxième borne (4) et une grille couplée à l'anode de ladite première diode photovoltaïque (7).
3. Dispositif d'excitation de triac monolithique selon la revendication 1 ou 2, où ledit premier transistor à effet de champ (6) est du type enrichissement.
4. Dispositif d'excitation de triac monolithique selon la revendication 2 ou 3, où ledit troisième transistor à effet de champ (8) est du type enrichissement.
5. Dispositif d'excitation de triac monolithique selon l'une quelconque des revendications précédentes, comportant un premier moyen résistif (5) couplé entre la base dudit premier transistor bipolaire (1) et ladite deuxième borne (4).
6. Dispositif d'excitation de triac monolithique selon l'une quelconque des revendications précédentes, comportant un quatrième transistor à effet de champ (8') ayant des électrodes de transport de courant couplées entre la grille dudit deuxième transistor à effet de champ (6') et ladite première borne (3), et une grille couplée à l'anode de ladite deuxième diode photovoltaïque (7').
7. Dispositif d'excitation de triac monolithique selon l'une quelconque des revendications précédentes, comportant un deuxième moyen résistif (5') couplé entre la base dudit troisième transistor bipolaire (1') et ladite première borne (3).

Ansprüche

1. Geführt ausgelöster, monolithischer TRIAC-Treiber mit zwei zur Aufnahme einer Wechselspannung angeschlossenen Klemmen (3, 4), mit zwei bipolaren Transistoren (1, 2) wobei der Emitter des ersten bipolaren Transistors

mit der zweiten Klemme (4) und die Basis bzw. der Kollektor mit dem Kollektor bzw. der Basis des zweiten bipolaren Transistors (2) verbunden sind, und wobei der Kollektor und die Basis bzw. die Basis und der Kollektor des ersten bzw. zweiten bipolaren Transistors sich gemeinsame Bereiche teilen, sowie der Emitter des zweiten bipolaren Transistors mit der ersten Klemme (3) verbunden ist, ferner mit einem dritten und vierten bipolaren Transistor (1', 2'), wobei der Emitter des dritten bipolaren Transistors (1') mit der ersten Klemme (3) und die Basis und der Kollektor des dritten bipolaren Transistors jeweils mit dem Kollektor und der Basis des vierten bipolaren Transistors (2') verbunden sind, und wobei der Kollektor und die Basis des dritten bipolaren Transistors sich jeweils gemeinsame Bereiche mit der Basis und dem Kollektor des vierten bipolaren Transistors teilen, sowie der Emitter des vierten bipolaren Transistors (2') mit der zweiten Klemme (4) verbunden ist, weiterhin mit einem ersten Feldeffekt-Transistor (6) mit einer Torelektrode, dessen stromführende Elektroden zwischen der Basis des ersten bipolaren Transistors (1) und der zweiten Klemme (4) liegen, und mit einem zweiten Feldeffekt-Transistor (6'), der eine Torelektrode besitzt, und dessen stromführende Elektroden zwischen der Basis des dritten bipolaren Transistors (1') und der ersten Klemme (3) liegen, wobei der gesamte Treiber durch eine Lichtbetätigung des ersten und zweiten Transistors (1, 2) und des dritten und vierten Transistors (1', 2') ausgelöst wird, gekennzeichnet durch eine erste Photodiode (7), deren Kathode mit dem Kollektor des ersten bipolaren Transistors (1) und deren Anode mit der Torelektrode des ersten Feldeffekt-Transistors (6) verbunden ist, und durch eine zweite Photodiode (7'), deren Kathode mit dem Kollektor des dritten bipolaren Transistors (1') und deren Anode mit der Torelektrode des zweiten Feldeffekt-Transistors (6') verbunden ist, wobei die beiden Photodioden (7, 7') dazu dienen, den Haltevorgang des TRIAC-Treibers zu steuern.

2. Monolithischer TRIAC-Treiber des Anspruches 1 ferner mit einem dritten Feldeffekt-Transistor (8), dessen stromführende Elektroden zwischen der Torelektrode des ersten Feldeffekt-Transistors (6) und der zweiten Klemme (4) und dessen Torelektrode an der Anode der ersten Photodiode (7) angeschlossen sind.
3. Monolithischer TRIAC-Treiber des Anspruches 1 oder 2, bei dem der erste Feldeffekt-Transistor (6) als Verstärker ausgebildet ist.



4. Monolithischer TRIAC-Treiber des Anspruches 2 oder 3, bei dem der dritte Feldeffekt-Transistor (8) als Verstärker ausgebildet ist.

5. Monolithischer TRIAC-Treiber eines vorhergehenden Anspruches mit einem ersten ohmschen Widerstandselement (5), das zwischen der Basis des ersten bipolaren Transistors (1) und der zweiten Klemme (4) angeschlossen ist.

6. Monolithischer TRIAC-Treiber eines vorhergehenden Anspruches mit einem vierten Feldeffekt-Transistor (8'), dessen stromführende Elektroden zwischen der Torelektrode des zweiten Feldeffekt-Transistors (6') und der ersten Klemme (3) und dessen Torelektrode an der Anode der zweiten Photodiode (7') angeschlossen sind.

7. Monolithischer TRIAC-Treiber eines vorhergehenden Anspruches mit einem zweiten ohmschen Widerstandselement (5'), das zwischen der Basis des dritten bipolaren Transistors (1') und der ersten Klemme (3) angeschlossen ist.

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