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— as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))

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(54) Title: HIGH CURRENT HIGH POWER SOLID STATE RELAY

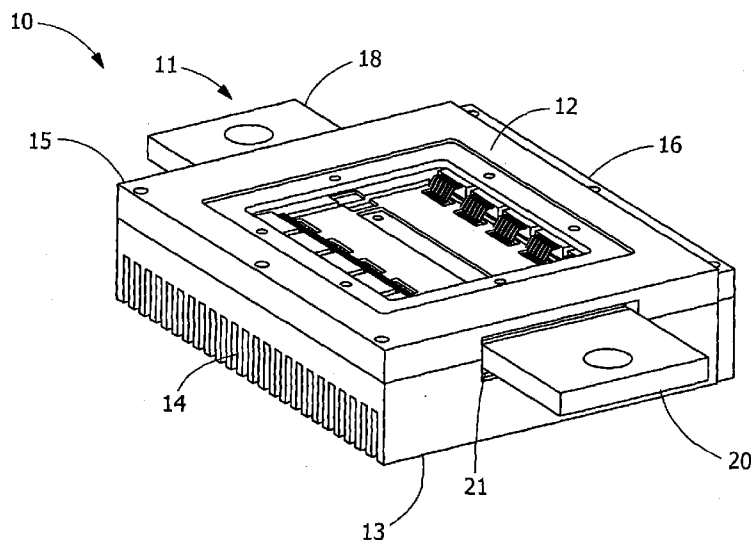


FIG. 1

(57) Abstract: A solid state relay includes a source bus and a drain bus. Solid state switches are arranged to switch power from the drain bus to the source bus. A control circuit controls a gate of the solid state switches. Each solid state switch includes a source terminal, a drain terminal and a gate terminal. The source terminals are conductively attached to the source bus and the drain terminals are conductively attached to the drain bus. The gate terminal opens and closes power through the solid state switches. The source bus is electrically isolated from the drain bus when the plurality of solid state switches is controlled by the gate terminal to an open state, the source bus is in electrical communication with the drain bus when the solid state switches is controlled by the gate terminal to a closed state.

HIGH CURRENT HIGH POWER SOLID STATE RELAY

BACKGROUND

[0001] The application generally relates to a high current high power solid state relay. The application relates more specifically to a high current high power solid state relay in a planar metal bus bar and heat dissipating enclosure.

[0002] Solid state relays (SSRs) may be based on a single MOSFET or multiple MOSFETs in a paralleled array. SSRs are generally limited in the amount of current, or the ampacity, that the device is capable of switching. Another limitation of SSRs is the lack of electrical isolation between the SSR actuating or gate circuits and the load circuits. However SSRs have an advantage over traditional mechanical relays as traditional relays have slower turn-on and turn-off times.

[0003] A MOSFET switch is a three terminal device including source, gate and drain terminals. SSRs in the past were limited by internal resistance present in the MOSFETs between the drain and the source when the device is gated on. Recent technology has reduced the dependency of the devices on the resistance from source to drain, but other physical limitations in the SSR package are still a concern. The relay package resistance due to the leadframe, wire bonds, etc., may limit the performance of the SSR. In high conductivity devices, the external resistances may offset improvements in the MOSFET, as the internal resistance between the drain and the source tends to increase significantly when the temperature of the SSR increases due to high currents. Other solid state devices may also be used to switch current in an SSR, such as SCRs or triacs.

[0004] To dissipate temperature increase in the MOSFET, large heat sinks are used for mounting the SSR to dissipate heat produced by the resistance and current. In some instances the heat sinks may permit the MOSFETs to become overheated due to temperature rise in the MOSFET, which can destroy the MOSFETs if the maximum

temperature rating is exceeded. One solution is to attempt to lower the resistance between the MOSFET, the source and the load by increasing package component parameters, e.g., connector size, trace width and thickness, and wire gauge, while decreasing other package component parameters, e.g., trace lengths, wire lengths, and connector resistance, within the design parameters of the heat sink.

[0005] Intended advantages of the disclosed systems and/or methods satisfy one or more of these needs or provide other advantageous features. Other features and advantages will be made apparent from the present specification. The teachings disclosed extend to those embodiments that fall within the scope of the claims, regardless of whether they accomplish one or more of the aforementioned needs.

SUMMARY

[0006] One embodiment discloses a solid state relay including a source bus and a drain bus. A plurality of solid state switches is arranged to switch power from the drain bus to the source bus. A control circuit controls a gate terminal of the plurality of solid state switches. Each solid state switch of the plurality of solid state switches includes a source terminal, a drain terminal and a gate terminal. The source terminals are conductively attached to the source bus and the drain terminals are conductively attached to the drain bus. The gate bus is in electrical communication with the control circuit. The gate terminal is operable to open and close a power flow through the plurality of solid state switches in response to a signal from the control circuit. The source bus is electrically isolated from the drain bus when the plurality of solid state switches is controlled by the gate terminal to an open state; the source bus is in electrical communication with the drain bus when the plurality of solid state switches is controlled by the gate terminal to a closed state; and the source bus and the drain bus are co-planar.

[0007] In another embodiment, a solid state relay (SSR) package includes a cover portion and a bottom case portion defining a hollow interior for receiving a solid state relay. The cover portion and the bottom case portion are in thermal communication with

the solid state relay and arranged to dissipate heat generated by the operation of the solid state relay. The solid state relay includes a source bus and a drain bus. A plurality of solid state switches is arranged to switch power from the drain bus to the source bus. A control circuit controls a gate terminal of the plurality of solid state switches. Each solid state switch of the plurality of solid state switches includes a source terminal, a drain terminal and a gate terminal. The source terminals are conductively attached to the source bus and the drain terminals are conductively attached to the drain bus. The gate bus is in electrical communication with the control circuit. The gate terminal is operable to open and close a power flow through the plurality of solid state switches in response to a signal from the control circuit. The source bus is electrically isolated from the drain bus when the plurality of solid state switches is controlled by the gate terminal to an open state, the source bus is in electrical communication with the drain bus when the plurality of solid state switches is controlled by the gate terminal to a closed state; and the source bus and the drain bus are co-planar.

[0008] In still another embodiment, a solid state relay includes a source bus and a drain bus. A plurality of solid state switches are arranged to switch power from the drain bus to the source bus. A control circuit is provided to control a gate terminal of the plurality of solid state switches. Each solid state switch of the plurality of solid state switches includes a source terminal, a drain terminal and a gate terminal. The source terminals are conductively attached to the source bus and the drain terminals are conductively attached to the drain bus. The gate bus is in electrical communication with the control circuit. The gate terminal is operable to open and close a power flow through the plurality of solid state switches in response to a signal from the control circuit. The source bus is electrically isolated from the drain bus when the plurality of solid state switches is controlled by the gate terminal to an open state.

[0009] Certain advantages of the embodiments described herein include increased current capacity of solid state relays and effective isolation between the actuating circuits and the load circuits. This isolation is due to the implementation of Flyback converter (or

DC-to-DC converter) circuit in the control circuit. Further advantages of the disclosed embodiments are reduced turn-on/turn-off times and a low profile package.

[0010] Alternative exemplary embodiments relate to other features and combinations of features as may be generally recited in the claims.

BRIEF DESCRIPTION OF THE FIGURES

[0011] FIG. 1 is an isometric view of an exemplary SSR package with a planar metal bus bar in a metal enclosure.

[0012] FIG. 2 shows an isometric view of an exemplary SSR for use in the SSR package of FIG. 1.

[0013] FIG. 3 shows an exploded view of an exemplary drain bus arrangement.

[0014] FIG. 4 shows a flow diagram of an exemplary control circuit for gating signals to MOSFETs in the SSR package.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0015] FIG. 1 shows an isometric view of an SSR package 10 with a planar metal bus bar 11 in a metal enclosure 15. SSR package 10 includes a cover 12 and a case bottom 13 defining a hollow interior for receiving an SSR 25 (FIG. 2). Cover 12 includes a removable lid 12a (FIG. 2). Case bottom 13 preferably includes fins 14 to increase heat dissipation from SSR package 10. Multiple fins 14 traverse the exterior surface of case bottom 13. In one embodiment fins 14 may be about 2.54 mm thick and separated by a gap of about 2.03 mm to 2.11 mm. Bus bar 11 includes a source bus 18 and a drain bus 20 at the output and input, respectively. Drain bus 20 conducts the supply electrical current to the input of SSR 25 and source bus 18 conducts the load electrical current from the output of SSR 25. A controller board 16 is attached to one side of metal enclosure 15. In one embodiment controller board 16 may be enclosed by aluminum or similar heat-conductive metals to extend the heatsink enclosure 15. Enclosure 15 may also be constructed of aluminum or similar heat-conductive metals. Busbar 11 extends into and from enclosure 15 through apertures 21. Busbar 11 is electrically isolated from contact with enclosure 15, e.g., via air gap around aperture 21, or dielectric spacers, or potting compounds, such as, thermal epoxies and the like (not shown).

[0016] Referring next to FIG. 2, an SSR 25 is shown having a plurality of switch elements, or MOSFETs 24. Each MOSFET 24 includes a source terminal 26 which is electrically connected directly to source bus 18, e.g., via solder or spot weld, or , electrically-conductive epoxy or compound. A drain terminal 28 of each MOSFET is connected to drain bus 20. In the embodiment of FIG. 2, SSR 25 is arranged with two rows 30 of six MOSFETs 24, and drain bus 20 has a pair of side bus members including a left drain bus member 32 and a right drain bus member 34. Drain bus members 32, 34 extend parallel to the left and right sides, respectively, of source bus 25 and are substantially coplanar with source bus 25 and drain bus 20. Drain bus members 32, 34 are connected with drain bus 20 main member 36 via cross member 38. Drain bus members 32, 34, 36 and 38 are all components of drain bus 20. Drain bus 20 may be unitary construction, e.g., cast, forged or machined, or multi-piece assembly in discrete sections. Drain bus 20 and source bus 18 are electrically isolated via air gap 40. Air gap 40 is maintained by the attachments of MOSFETs 24 between source bus 18 and left and right drain bus members 32, 34. MOSFETs 24 connect source bus 18 and drain bus 20 and are disposed on the output, or source terminal side adjacent source bus 18, and on the input or drain terminal side adjacent drain bus 20. The positioning of MOSFETs 24 adjacent both source and drain buses allows SSR to be a single layer with components such as MOSFETs 24 and buses 18, 20 exposed on either side to heat dissipation surfaces of SSR package 10 for improved heat dissipation and performance. In one embodiment the array of MOSFETs 24 have a total resistance no greater than 300 micro-ohm. In one embodiment the top surface of MOSFETs 24 may be in direct contact with the heat sink cover 15. The bottom of the bus members 32, 34 and the outer side of the drain bus 20 may have about 0.050" gap 43 separating drain bus 20 from the heat sink case bottom 13. Gap 43 may be maintained by clips 41 placed around the bus bar assembly drain bus members 32, 34 and by thermal epoxy 43a which may coat the entire bus bar assembly, as shown in FIG. 5. While the disclosed embodiment refers to MOSFETs 24 as the solid state switches it is understood that other solid state switches, e.g., Bipolar Junction Transistors (BJTs), Insulated-Gate Bipolar Transistors (IGBTs), SCRs or triacs may be used in place of MOSFETs.

[0017] Referring to FIG. 3, an exemplary drain bus arrangement is shown. Drain bus 20 includes left and right drain bus members 32, 34, a crossover member 42, and a drain bus connection member 44. Drain bus member 20 maintains substantially symmetrical current flow through drain bus 20. Connection member 44 provides a connection bus including an optional eyelet 46 for external cable or conductors to attach to SSR package 10.

[0018] It should be noted that more or less MOSFETs 24 may be arranged in each row 30 as required to achieve the desired ampacity of the SSR 25. Preferably the rows 30 on either side of SSR 25 are symmetrical for balanced distribution of current.

[0019] In operation, controller board 16 controls signals to gate terminals (not shown) on MOSFETs 24 for controlling the switching of current between source terminals 26 to drain terminals 28. As discussed above, MOSFETs 24 may be connected in parallel between source conductor 18 and drain conductor 20. Gate terminals (not shown) for each MOSFET 24 are electrically connected together, and control MOSFETs to switch current from drain bus 20 to source bus 18 in the closed state and to block current flow from drain bus 20 to source bus 18 in the open state.

[0020] Referring next to FIG. 4 a flow diagram 50 illustrates an exemplary control circuit for gating signals to MOSFETs in the SSR package. In a control power path 51 a system power supply 52 provides an input power source for the control circuit 50. In one embodiment control power supply 52 may provide a 28 VDC nominal supply voltage. Control power is input to a circuit protection element 54. Circuit protection element 54 provides circuit protection for electrostatic discharge (ESD) and reverse polarity, lightning and Electromagnetic Interference (EMI). At the output of circuit element 54 voltage is regulated by a voltage regulation circuit 56. At the output of voltage regulation circuit 56 a flyback converter circuit 58, together with a flyback transformer 59 provides electrical isolation between the control power path 51 to an isolated DC voltage source 60 for powering an optocoupler device 62. A fault protection circuit 63 is connected between DC voltage source 63, optocoupler device 62 and MOSFETs 24. Optocoupler device 62

provides a gate signal 64 to control switching of MOSFETs 24 assembled in SSR package 10. A system ON/OFF signal 66 from an external control source (not shown) triggers optocoupler 62 for generating gate signal 64. SSR package 10 receives input power from a power source 68 and controls current flow to an external load 70 in response to gate signal 64.

[0021] SSR 25 may be capable of switching, rectifying or blocking high current in the range of 1 to 2880 amperes per SSR package 10, In one embodiment the SSR package fault protection circuit will begin a countdown-to-trip at 420A DC. Highly efficient switching by SSR 25 yields insignificant heat accumulation. Any heat that is built up is rapidly conducted away from MOSFETs 24 via metal surfaces of enclosure 15, including heat fins 14.

[0022] It should be understood that the application is not limited to the details or methodology set forth in the following description or illustrated in the figures. It should also be understood that the phraseology and terminology employed herein is for the purpose of description only and should not be regarded as limiting.

[0023] It is important to note that the construction and arrangement of the high current, high power SSR, as shown in the various exemplary embodiments is illustrative only. Although only a few embodiments have been described in detail in this disclosure, those who review this disclosure will readily appreciate that many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter recited in the claims. For example, elements shown as integrally formed may be constructed of multiple parts or elements, the position of elements may be reversed or otherwise varied, and the nature or number of discrete elements or positions may be altered or varied. Accordingly, all such modifications are intended to be included within the scope of the present application. The order or sequence of any process or method steps may be varied or re-sequenced according to alternative embodiments. In

the claims, any means-plus-function clause is intended to cover the structures described herein as performing the recited function and not only structural equivalents but also equivalent structures. Other substitutions, modifications, changes and omissions may be made in the design, operating conditions and arrangement of the exemplary embodiments without departing from the scope of the present application.

CLAIMS:

1. A solid state relay comprising:

a source bus and a drain bus; a plurality of solid state switches arranged to switch power from the drain bus to the source bus; and a control circuit for controlling a gate terminal of the plurality of solid state switches;

each solid state switch of the plurality of solid state switches comprising a source terminal, a drain terminal and a gate terminal;

wherein the source terminals are conductively attached to the source bus and the drain terminals are conductively attached to the drain bus; and the gate bus in electrical communication with the control circuit;

the gate terminal operable to open and close a power flow through the plurality of solid state switches in response to a signal from the control circuit;

the source bus electrically isolated from the drain bus when the plurality of solid state switches is controlled by the gate terminal to an open state;

the source bus in electrical communication with the drain bus when the plurality of solid state switches is controlled by the gate terminal to a closed state; and

the source bus and the drain bus at least partially co-planar.

2. The apparatus of claim 1, wherein the drain bus is connected to an electrical power source and configured to supply electrical current to an input of the plurality of solid state switches.
3. The SSR of claim 1, wherein the source bus is connected at the output of the plurality of solid state switches and to a load to supply electrical current from the plurality of solid state switches.
4. The SSR of claim 1, wherein each solid state switch of the plurality of solid state switches comprises a MOSFET.

5. The apparatus of Claim 1, wherein the drain bus further comprises a pair of side bus members extending adjacent to opposite sides of the source bus; each of the side bus members connected to the source bus by an equal number of the plurality of solid state switches; the solid state switches fixedly attached to the respective source bus and side bus member.
6. The solid state relay of claim 5, wherein the drain bus further comprises a crossover member, the crossover member connecting the pair of side bus members and a drain bus connector member; the drain bus connector member configured to connect the drain bus to an external conductor connected to an electrical supply source.
7. The solid state relay of claim 6, wherein the drain bus and the source bus are electrically isolated via an air gap, the air gap maintained by attachment of the solid state switches connected between the source bus and the pair of side bus members.
8. The solid state relay of claim 1, wherein the solid state switches adjacent the source and the drain bus being configured in a single layer, the solid state switches, the source and the drain bus exposed directly to a heat dissipation surface of an SSR package for heat dissipation and increased current carrying capacity.
9. The apparatus of claim 1, further comprising a plurality of fins traversing an exterior surface of the solid state relay, the plurality of fins adapted to dissipate heat from the solid state relay.
10. The solid state relay of claim 1, wherein the drain bus comprises a plurality of members, the plurality of members comprising at least a left drain bus member, a right drain bus members, a crossover member, and a drain bus connection member.
11. A solid state relay (SSR) package comprising:
 - a cover portion and a bottom case portion defining a hollow interior for receiving a solid state relay;
 - the cover portion and the bottom case portion in thermal conductive contact with the solid state relay and configured to dissipate heat generated in an operation of the solid state relay;

the solid state relay comprising:

a source bus and a drain bus; a plurality of solid state switches arranged to switch power to the source bus from the drain bus; and a control circuit for controlling a gate terminal of the plurality of solid state switches;

each solid state switch of the plurality of solid state switches comprising a source terminal, a drain terminal and a gate terminal;

wherein all of the source terminals are conductively attached to the source bus and all of the drain terminals conductively attached to the drain bus; and the gate bus in electrical communication with the control circuit;

the gate terminal operable to open and close a power flow through the plurality of solid state switches in response to a signal from the control circuit; and

the source bus electrically isolated from the drain bus when the plurality of solid state switches is controlled by the gate terminal to an open state;

the source bus in electrical communication with the drain bus when the plurality of solid state switches is controlled by the gate terminal to a closed; and

the source bus and the drain bus at least partially co-planar.

12. The SSR package of claim 11, wherein the control circuit comprises a controller board attached to one side of the case portion.
13. The SSR package of claim 11, wherein the drain bus is connected at the input of the plurality of solid state switches and to an electrical supply source.
14. The SSR package of claim 11, wherein each solid state switch of the plurality of solid state switches comprises a MOSFET.
15. The SSR package of claim 11, wherein the drain bus further a pair of side bus members extending adjacent to opposite sides of the source bus; each of the side bus members connected to the source bus by a half of the plurality of solid state switches;

the solid state switches fixedly attached to the respective source bus and side bus member.

16. The SSR package of claim 11, wherein the drain bus further comprises a crossover member, the crossover member connected between the pair of side bus members and a drain bus connector member; the drain bus connector member configured to connect the drain bus to an external conductor connected to the electrical supply source.
17. The SSR package of claim 11, wherein the drain bus and the source bus are electrically isolated via an air gap, the air gap maintained by attachment of the solid state switches connected between the source bus and the pair of side bus members.
18. The SSR package of claim 11, wherein the solid state switches adjacent the source and the drain bus being configured in a single layer, the solid state switches, the source and the drain bus exposed directly to a heat dissipation surface of an SSR package for heat dissipation and increased current carrying capacity.
19. The SSR package of claim 11, wherein the case bottom comprises a plurality of fins traversing an exterior surface of the case bottom, the plurality of configured to dissipate heat from SSR package.
20. A solid state relay comprising:
 - a source bus and a drain bus; a plurality of solid state switches arranged to switch power from the drain bus to the source bus; and a control circuit for controlling a gate terminal of the plurality of solid state switches;
 - each solid state switch of the plurality of solid state switches comprising a source terminal, a drain terminal and a gate terminal;
 - wherein the source terminals are conductively attached to the source bus and the drain terminals are conductively attached to the drain bus; and the gate bus in electrical communication with the control circuit;
 - the gate terminal operable to open and close a power flow through the plurality of solid state switches in response to a signal from the control circuit; and

the source bus electrically isolated from the drain bus when the plurality of solid state switches is controlled by the gate terminal to an open state.

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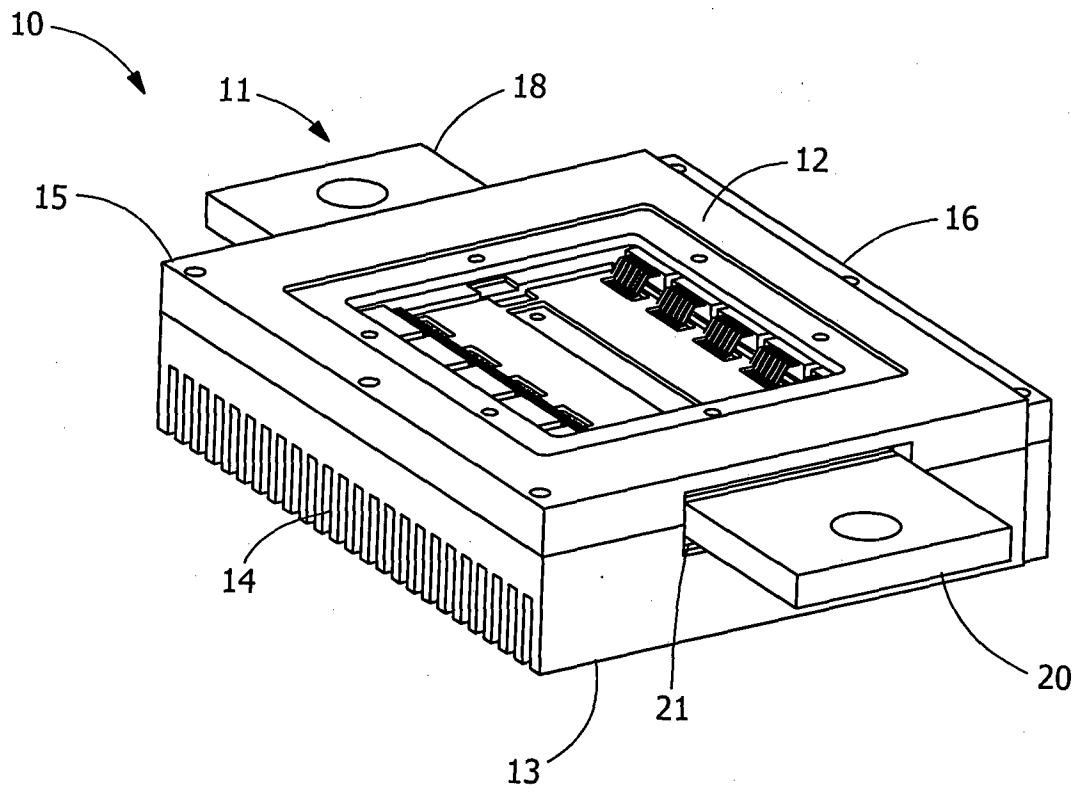


FIG. 1

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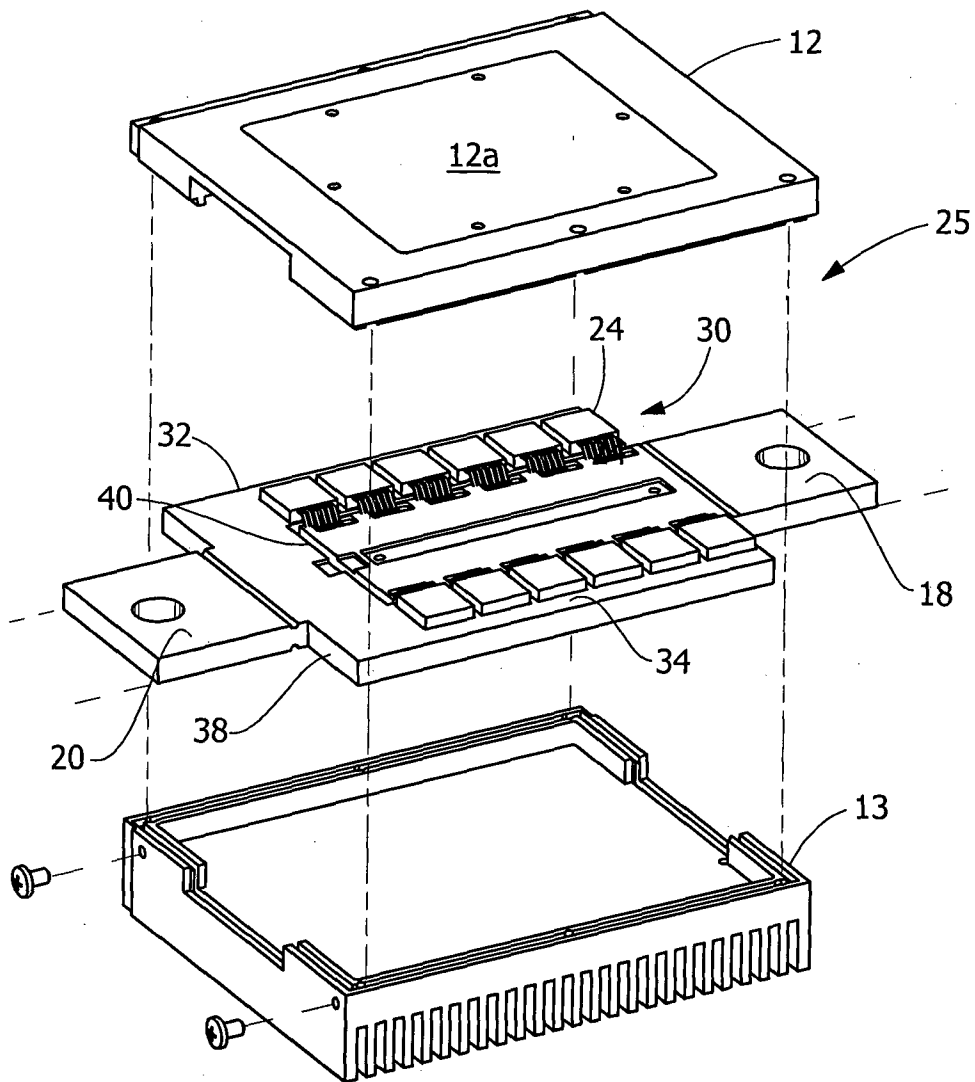


FIG. 2

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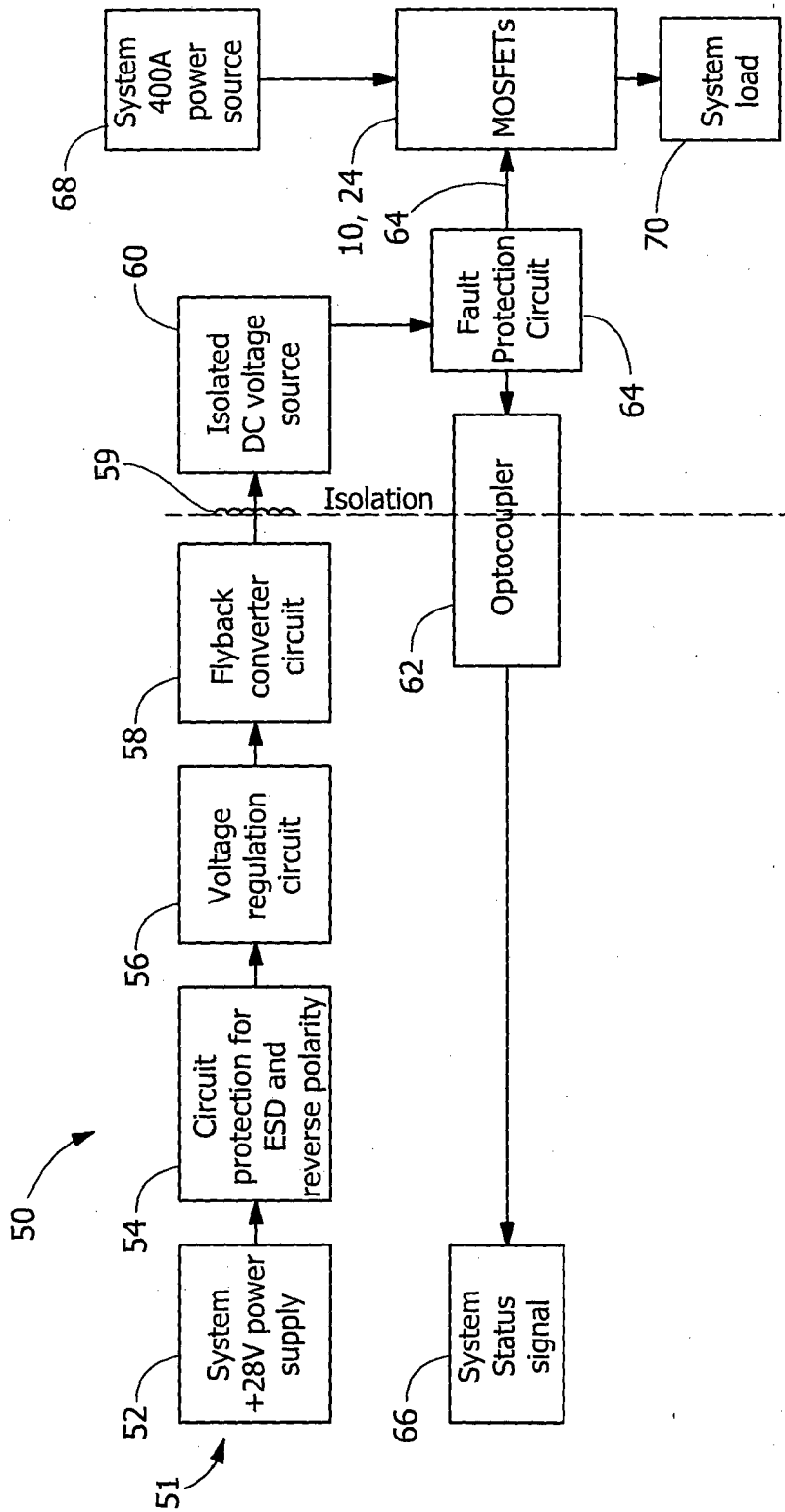


FIG. 4

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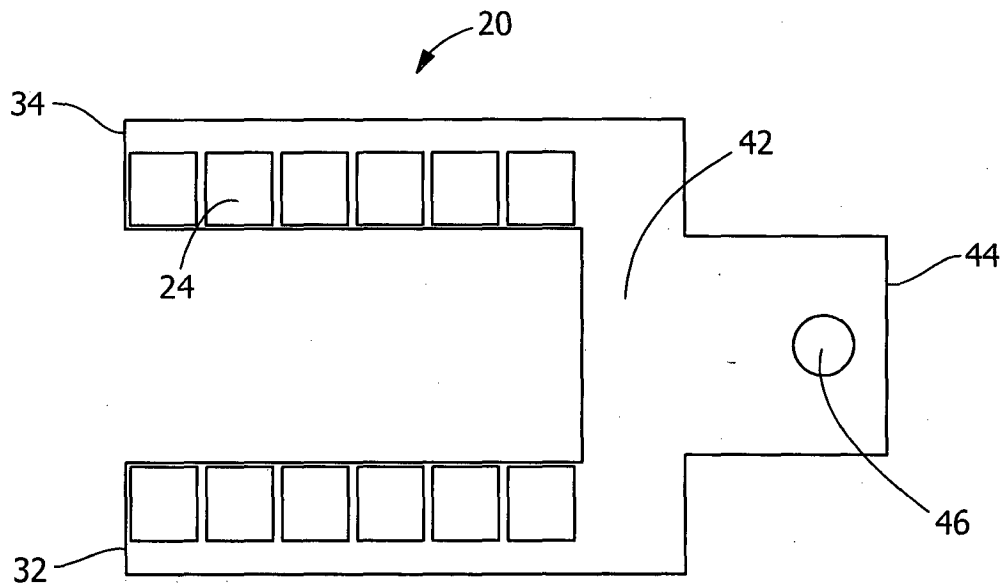


FIG. 3

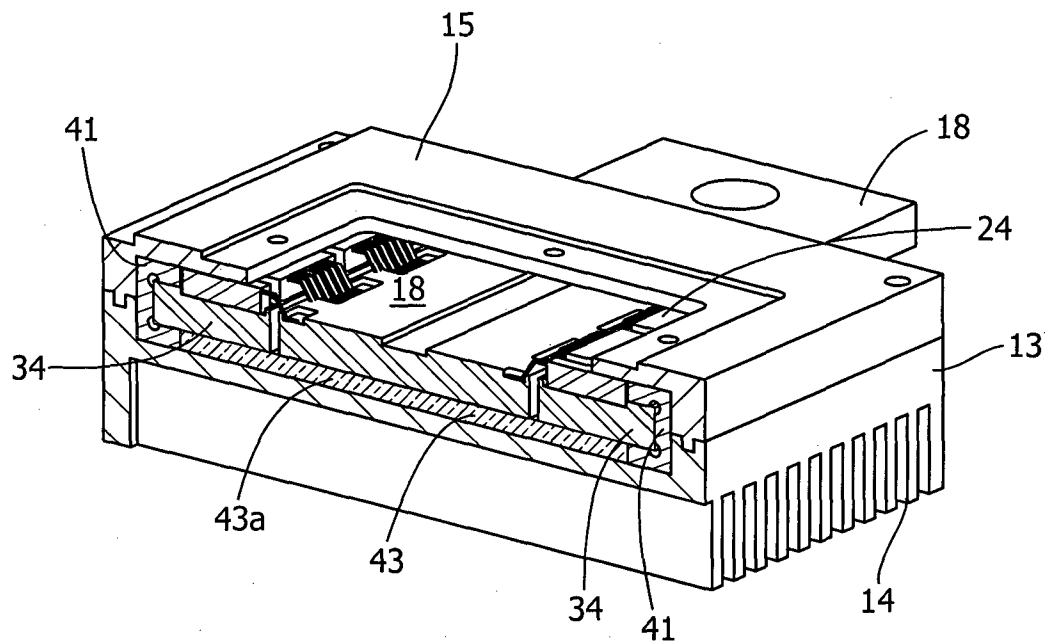


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/IN2015/000093

A. CLASSIFICATION OF SUBJECT MATTER INV. H03K17/12 H01L25/11 H05K7/20 H02M7/00 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) H02M H05K H03K H01L		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 432 030 A2 (VLT CORP [US]) 23 June 2004 (2004-06-23) figure 1 paragraph [0009]	1-10,20
X	----- US 2006/261368 A1 (FOGLEMAN H F [US]) 23 November 2006 (2006-11-23) figures 3-5 -----	1-10,20
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 8 October 2015	Date of mailing of the international search report 04/01/2016	
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Simon, Volker	

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IN2015/000093

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-10, 20

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-10, 20

A solid state relay.

2. claims: 11-19

A package suitable for a solid state relay.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IN2015/000093

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