

[54] **SOLID STATE RELAY**

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[51] Int. Cl. **H03k 17/64**

[58] Field of Search. **307/241, 242, 244, 253, 254**

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[57] **ABSTRACT**

Solid state switching devices for selectively switching current signals between various load circuits. Normally open and normally closed transistorized switching sections incorporate non-inductive driver stages adapted for high speed operation with excellent isolation between the load circuits and the control or driver circuits. The switching sections are readily combinable to form configurations which are functionally analogous to conventional electromechanical relays and no external voltages are required except normal type control voltages and the voltages which are to be switched to the various load circuits. The switching devices may be constructed to operate in either the "make before break" or "break before make" mode of operation.

25 Claims, 8 Drawing Figures

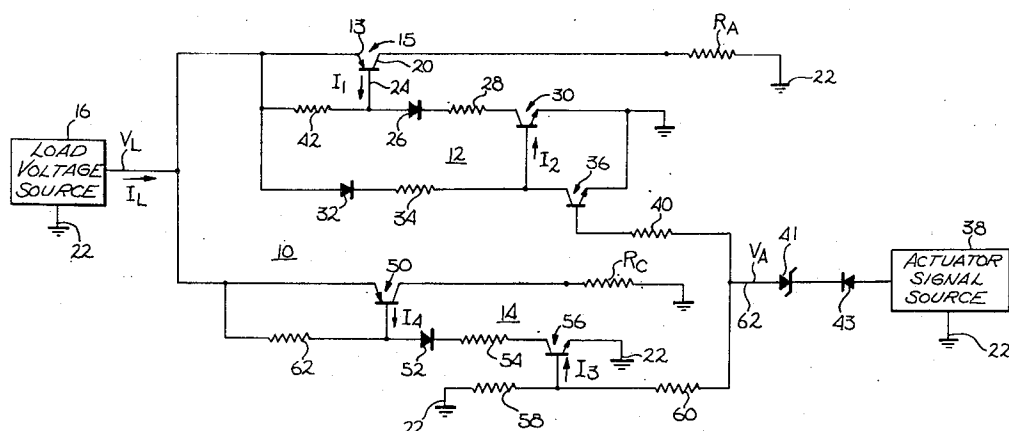


Fig. 1

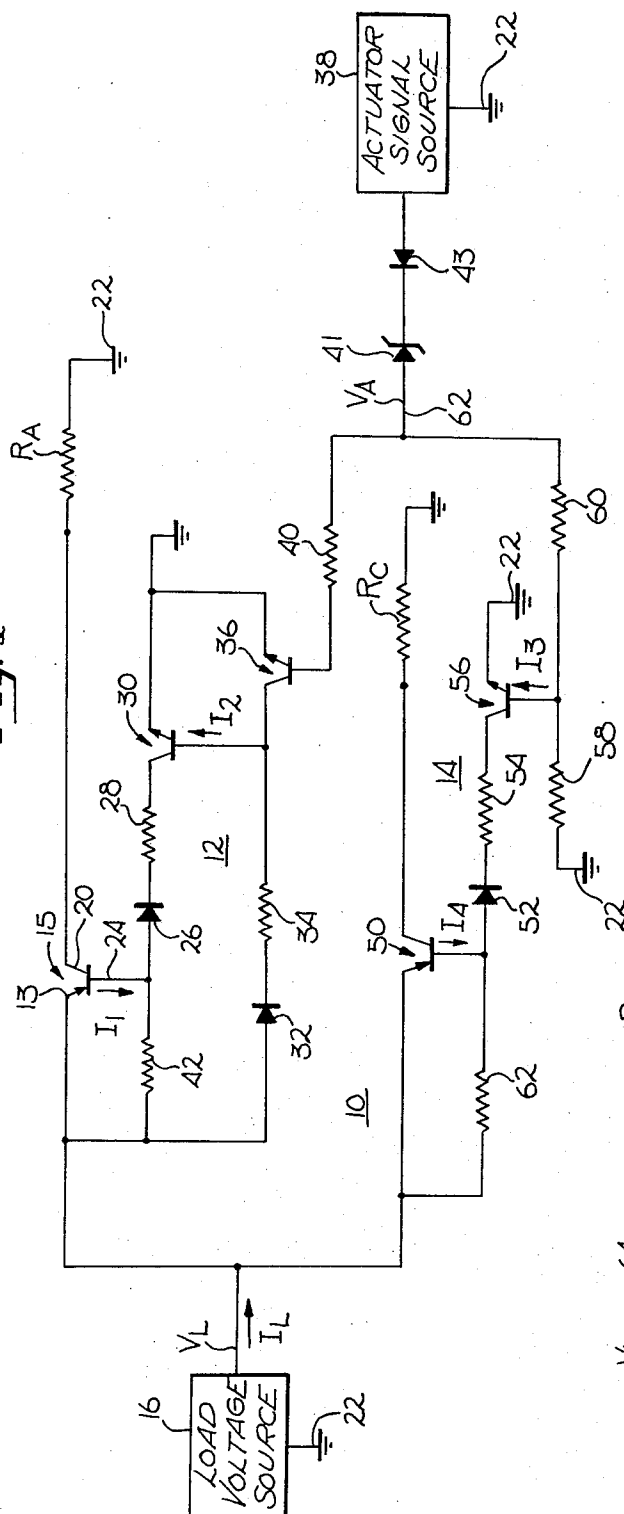


Fig. 3

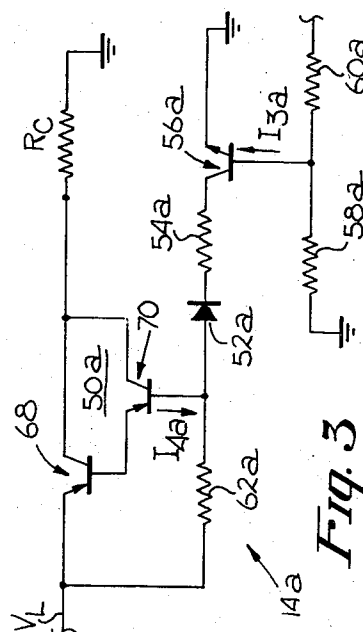
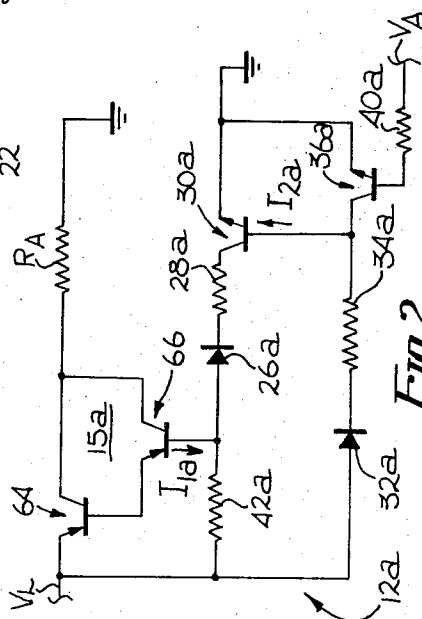


Fig. 2



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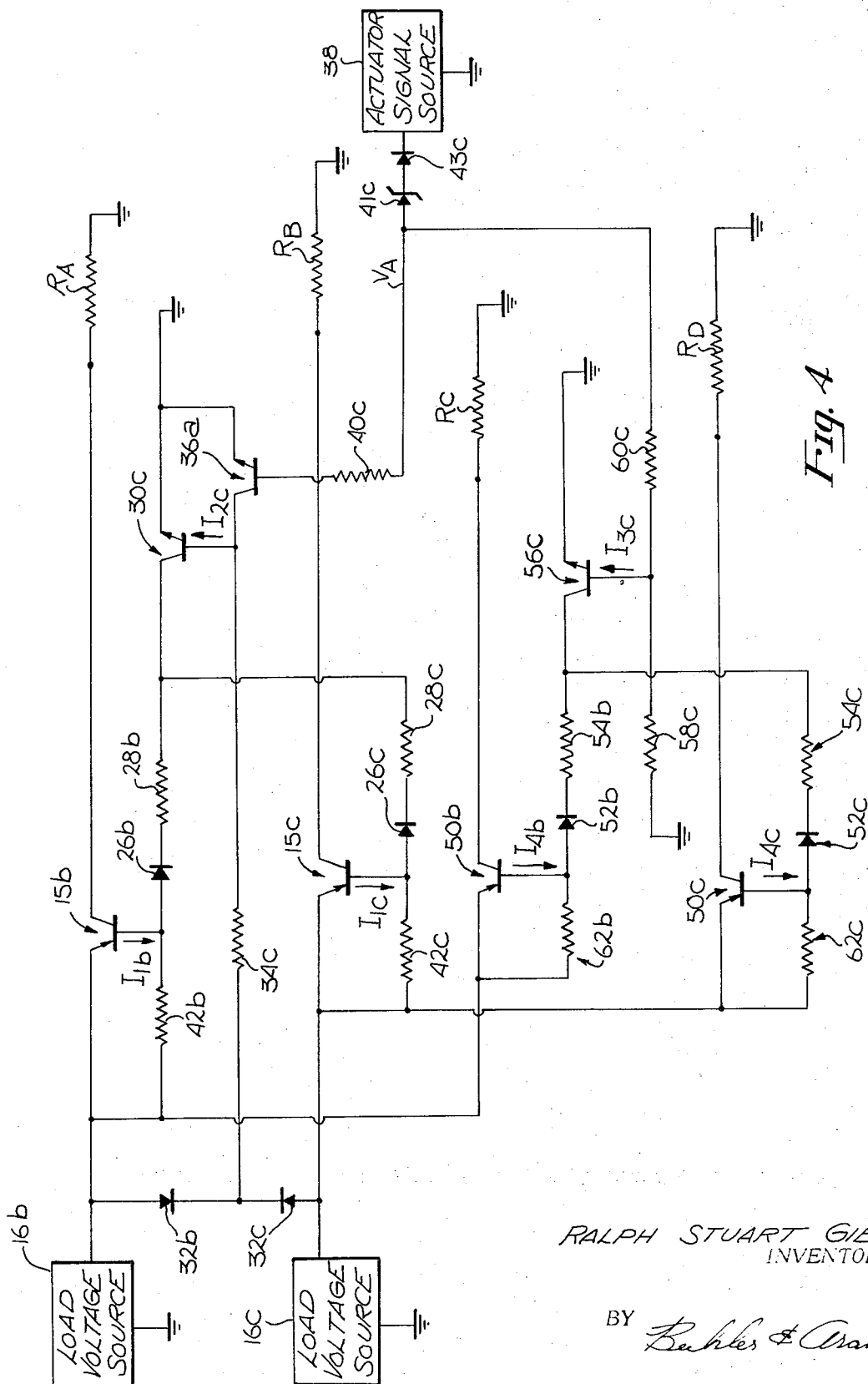


Fig. 4

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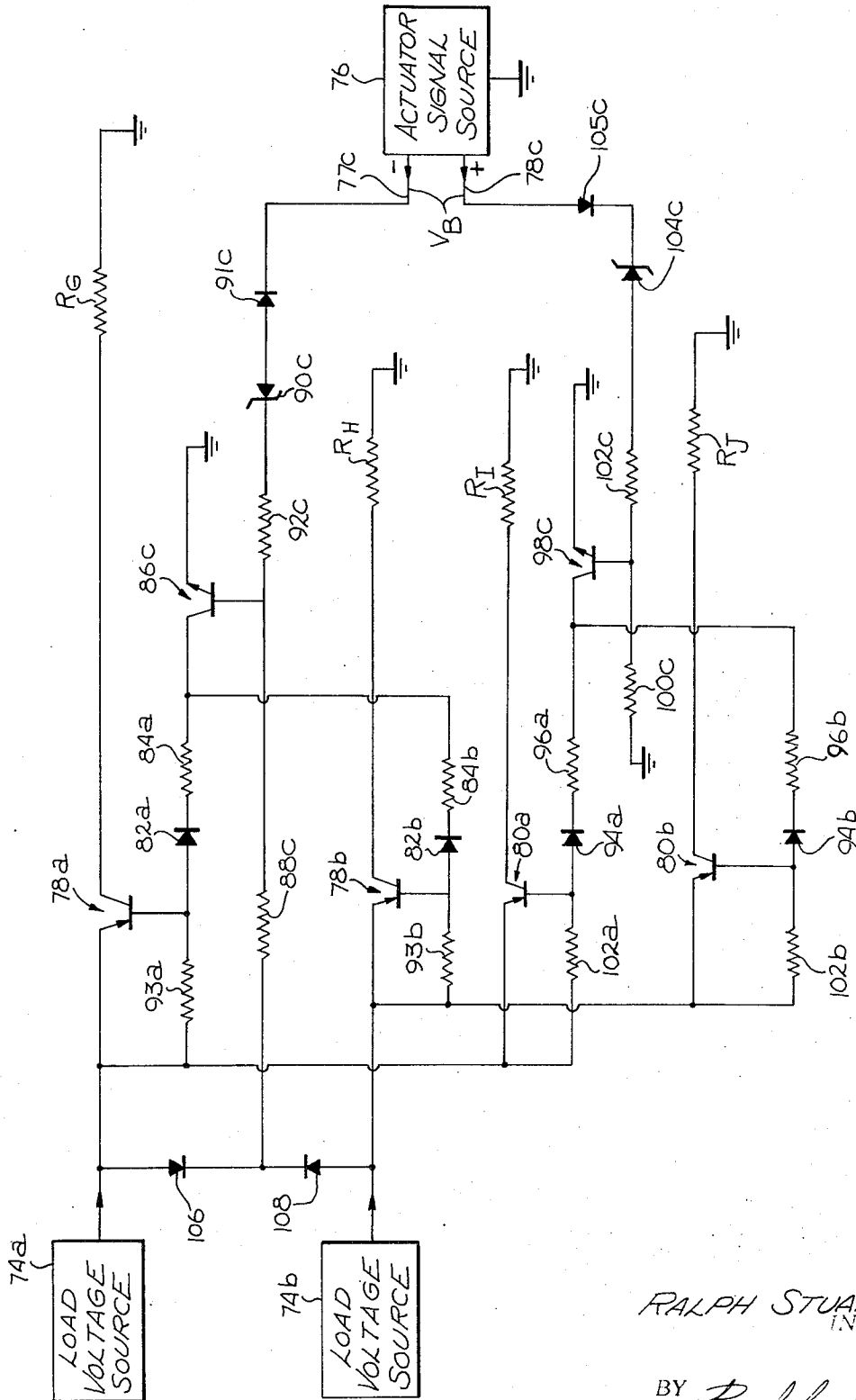


Fig. 6

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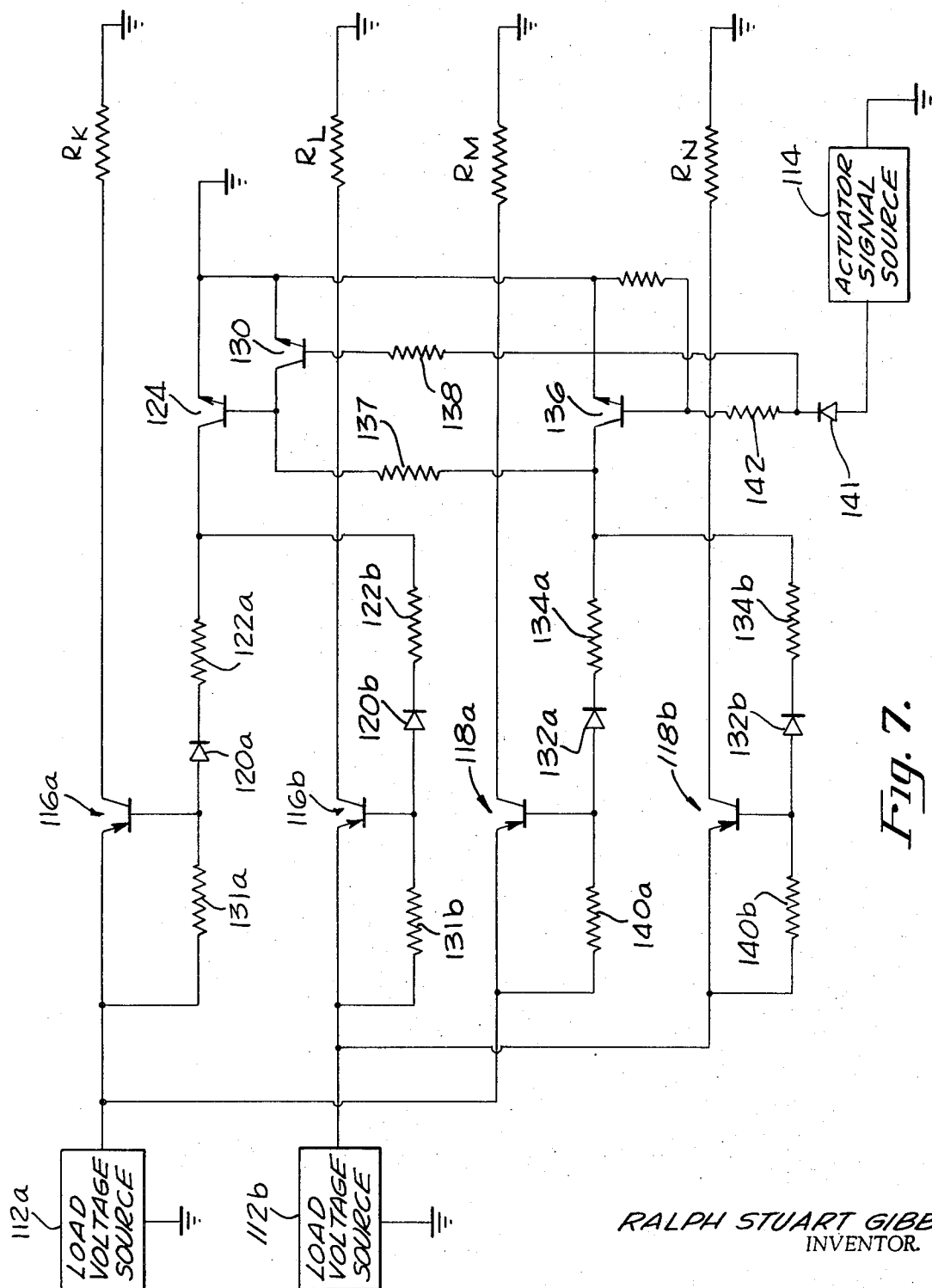


Fig. 7.

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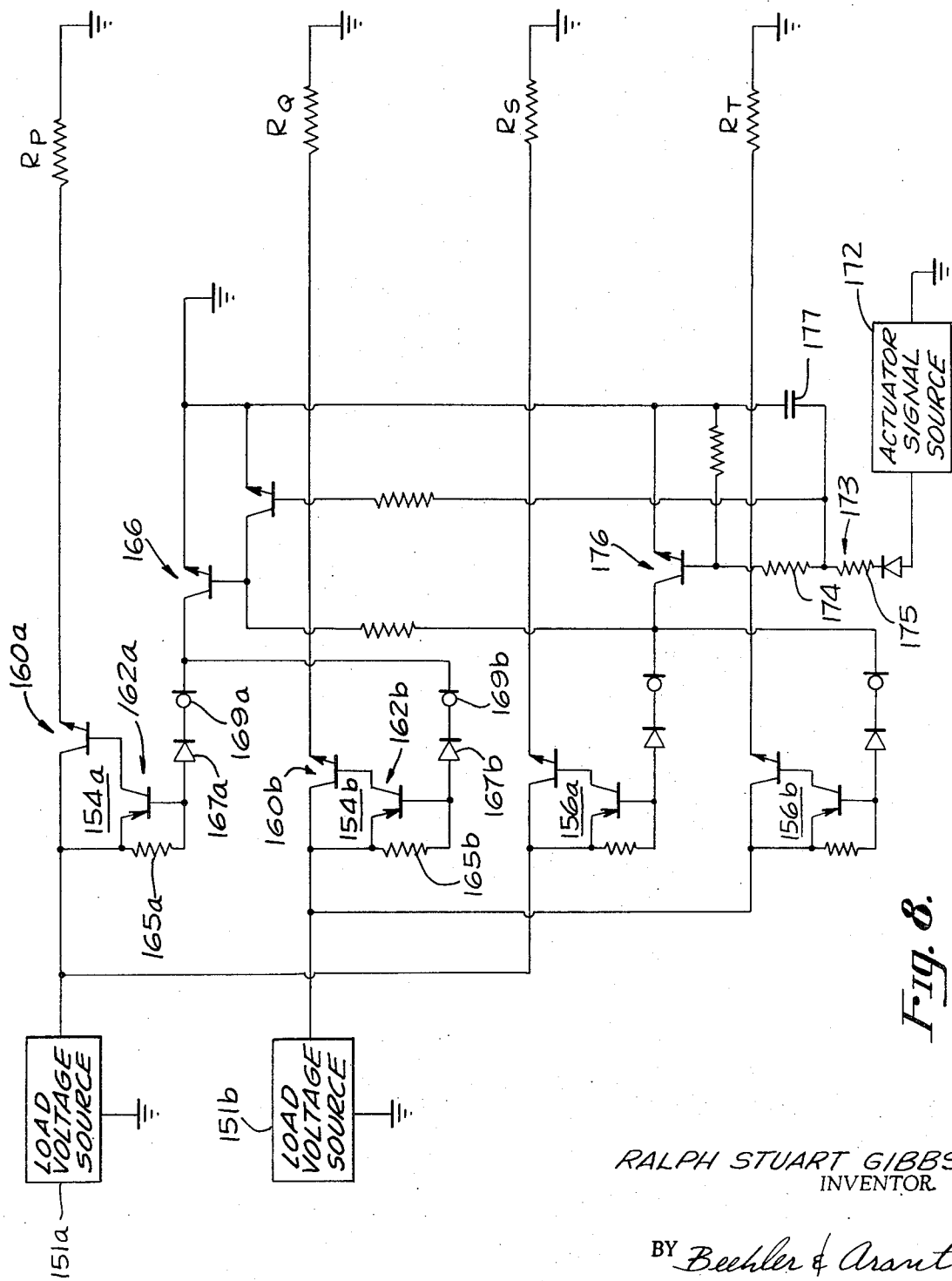


Fig. 8.

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SOLID STATE RELAY

This application is a continuation-in-part of copending application for U.S. Letters Patent, Ser. No. 855,957, filed Sept. 8, 1969 now abandoned.

BACKGROUND OF THE INVENTION

This invention relates generally to solid state switching devices and particularly to such devices which are functionally analogous to, and interchangeable with, conventional electromechanical relays.

Solid state relays offer the advantage of lower noise injection; increased relay operational life, reliability, and switching speed; and improved performance under vibration conditions; as well as a reduction in physical size, operating power requirements, and cost. Prior attempts to develop solid state relays have been hindered by design approaches which included inductive driving circuits that reduce switching speed, complex circuits which lower reliability and increased costs, or designs which provide poor isolation between the control circuit and the load circuit. This last mentioned isolation problem is of primary importance in computer switching applications, such as those for switching a source of potential through telephone lines to a load circuit under the control of the computer's output circuits.

Also, if a solid state relay is to be readily interchangeable with conventional electromechanical relays, it should not require external supply voltages, except for a control signal and the potential to be switched. Further, it would be desirable if the solid state relay could be configured to be controlled by either a single unipolar control signal or by a pair of complementary control signals.

Hence, a high speed solid state relay of relatively low complexity which is readily interchangeable with electro-mechanical relays would be a significant contribution to the art. The value of such a solid state relay would be enhanced if it could be designed for either "make before break" or "break before make" switching modes. Further, it would be desirable that such solid state relays be adapted to economical production in microminiature hybrid or integrated circuit assemblies.

SUMMARY OF THE INVENTION

The devices in accordance with principles of the subject invention provide relatively noncomplex solid state switching circuitry which exhibits increased switching speed as well as excellent isolation between driving circuits and load circuits.

In one preferred embodiment, normally open and normally closed switching sections are combined to function as a single pole double throw relay in response to a control signal of a single polarity. Driver circuits incorporated into both sections of the last mentioned polarity type provide the desired isolation while allowing the design choice of parameter values so that either the "make before break" or "break before make" mode of operation may be mechanized. The entire switching device is operable solely in response to control signals and the potential to be switched. Hence, no additional voltage supplies are needed, and the subject solid state devices are readily interchangeable with conventional electromechanical relays. A Darlington pair transistor circuit is included as the load switching device for high current level configurations.

In another preferred embodiment, normally open and normally closed switching sections are combined to function as a multiple pole double throw relay having all the previously described features of interchangeability, speed, and isolation. In such a configuration each switching section includes switching transistors which provide for simultaneously switching a plurality of voltage supplies between a first plurality of load circuits and a second plurality of load circuits under control of common driver circuits incorporated in each of the sections. In the present invention, each voltage supply biases an associated switching transistor in each of the sections which is used for switching the voltage supply across its associated load circuit. Inasmuch as the potential levels of the separate voltage supplies being thus switched between the load circuits are permitted to be different in the usual application of an electromechanical relay, the solid state relay of the present invention provides for isolating each of the switching transistors and, consequently, the load circuits associated therewith, in each of the sections, from the effects of the differences in potentials of the respective supply voltages to assure that the switching transistors which are supposed to be cut off are not inadvertently turned on during the operation of the relay.

Accordingly, it is a primary object of the invention to provide solid state switching devices which are completely interchangeable with electromechanical relays.

It is another object of the invention to provide a relatively noncomplex solid state switching circuit that exhibits excellent isolation and increased switching speed.

Another object is to provide basic, normally open and normally closed solid state switching sections which may be combined to function in an analogous manner to electromechanical relays.

A further object is to provide a solid state relay that provides an acceptable degree of isolation between the driver circuit and the load circuit without incorporating inductive components, and which is adaptable to microminiature hybrid and integrated circuit construction.

Still another object is to provide solid state relays comprising normally open and normally closed switching sections, which may be functionally combined to operate in either the "make before break" or "break before make" mode of operation by the choice of parameter values in the driver sections.

Yet a further object is to provide a solid state switching device of relatively simple design which is economical to manufacture and may be reliably applied to switching applications requiring high isolation between control and load circuits, such as in computer-telephone network interface systems, for example.

Another object is to provide a solid state switching device which may be configured to be driven from high impedance, low voltage control signal sources either by a single unipolar signal or by a pair of complementary control signals.

Another object of the invention is to provide a solid state relay circuit comprised of multiple pole normally open and normally closed switching sections in which provision is made for insuring that the load circuits associated with the respective poles in each of these sections are isolated from each other.

Another object of the invention is to provide a multiple pole double throw solid state relay circuit in which any one of the voltage sources being switched by the circuit is capable of biasing the common driver circuit associated with the normally closed switching section of the relay circuit.

Still another object of the invention is to provide for forward biasing the common driving transistor associated with the normally closed switching section of a multiple pole double throw relay by a base current derived from the bias and coupling network associated with the base terminal of any one of the switching transistors of the normally open switching section.

With these and other objects in view, the invention consists of the construction, arrangement, and combination of the various parts of the device, whereby the objects contemplated are attained as herein set forth, pointed out in the appended claims and illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic and block diagram of a solid state switching device, in accordance with one preferred embodiment of the subject invention, which is analogous to a single pole double throw electromechanical relay.

FIG. 2 is a schematic diagram of a solid state, normally closed switching section which may be utilized in the device of FIG. 1 and which incorporates a Darling-ton pair transistorized circuit as the load switching device.

FIG. 3 is a schematic diagram of a normally open solid state switching section which may be utilized in the device of FIG. 1 and which incorporates a Darling-ton pair transistorized circuit as the load switching device.

FIG. 4 is a schematic and block diagram of a solid state switching device, in accordance of one preferred embodiment of the subject invention, which is analogous to a double pole double throw electromechanical relay.

FIG. 5 is a schematic and block diagram of a solid state switching device in accordance with another embodiment of the subject invention, which device is analogous in operation to a single pole double throw electromechanical relay and which is adapted to be controlled by a pair of complementary control signals.

FIG. 6 is a schematic and block diagram of a solid state switching device of the type shown in FIG. 5 but which is functionally analogous to a double pole double throw relay.

FIG. 7 is a schematic and block diagram of a simplified version of the double pole double throw relay shown in FIG. 4.

FIG. 8 is a schematic and block diagram of still another version of the double pole double throw relay.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the embodiment of the subject invention shown in FIG. 1, the switching device 10 is adapted to function in a manner analogous to a single pole double throw electromechanical relay and to be interchangeable therewith in a majority of applications. The switching device 10 includes a normally closed switching section 12 and a normally open switching section 14 for con-

trolling the application of the load current I_L to load resistors R_A and R_C respectively.

Normally closed switching section 12 includes a switching transistor 15 having an emitter electrode 13 connected to a load voltage source 16, and having a collector terminal connected through a load resistor R_A to a ground potential plane 22.

Although the load, R_A , is shown as a resistor, it should be understood that in accordance with the invention any type electrical circuit may be driven as a load. Also, it is noted that although the return path for the load current I_L is indicated, in the interests of simplifying the explanation, as comprising the path through resistor R_A and the ground potential plane 22, the current I_L need not utilize a ground bus for its return. For example, in one particular application the load voltage source 16 and the load R_A are coupled by telephone lines with the current I_L flowing between positive and negative voltage sources of the telephone network.

A base electrode 24 of the switching transistor 15 is connected through a diode 26 and a resistor 28 to the collector terminal of a driving transistor 30. The emitter terminal of the driving transistor 30 is connected to the ground potential plane (ground).

The voltage applied to the base electrode of the driving transistor 30 is derived from a bias network which comprises a diode 32 connected between the load voltage source 16 and a resistor 34. The resistor 34 is connected to the base terminal of the driving transistor 30.

A control transistor 36 has collector and emitter terminals connected to the base terminal of the driving transistor 30 and to the ground potential plane, respectively. The base terminal of the control transistor 36 is coupled through a resistor 40, a Zener diode 41 and a diode 43 to an actuator signal source 38. Zener diode 41 and diode 43 provide improved isolation between the load voltage source 16 and the actuator signal V_A .

In the operation of the normally closed switching section 12 of FIG. 1, the load voltage source 16 provides a positive direct current (DC) voltage V_L which is applied to the emitter 13 of the switching transistor 15, and through the diode 32 and the resistor 34 to the base terminal of the driving transistor 30. In the absence of a positive voltage V_A , applied from the actuator signal source 38, the base-emitter junction of the driving transistor 30 is forward biased by current that flows from the load voltage source 16 through the diode 32. In response to this forward bias current, driving transistor 30 couples one terminal of the resistor 28 to the ground potential plane, thereby allowing bias current to flow in the base-emitter junction of the switching transistor 15. In response to the bias current flowing in the just mentioned base-emitter junction of transistor 15, this transistor is switched to a low impedance state, hence, applying the voltage source potential, V_L , to the load resistor R_A .

During the time of application of a signal V_A from the actuator signal source 38, the switching section 12 is open and the load current I_L is blocked by the switching transistor 15 from reaching the load R_A . In the embodiment of FIG. 1, V_A may be a positive signal. The actuator signal source 38 may be the output circuit of a computer that controls the line current I_L in a pair of telephone lines which are connected to an electromechanical print out device (analogous to R_A).

The control signal V_A is applied through a resistor 40 to the base of control transistor 36. In response to this signal, the control transistor 36 shorts the base of driving transistor 30 to the ground reference plane, thereby causing transistor 30 to cease conduction, hence, interrupting the bias current through the base-emitter junction of the switching transistor 15.

Resistor 42 is connected between the emitter terminal 13 and the base terminal of the switching transistor 15 to improve the turn off response and the cutoff characteristics of the transistor. In applications where turn off speed, leakage current and cutoff voltage are not critical, the resistor 42 may be omitted at the expense of some degradation in the performance of these just listed features.

The resistors 28 and 34, as well as the diodes 26 and 32, provide additional isolation between the load voltage V_L and the actuator signal V_A . The diode 26 also functions to protect the base-emitter junction of the transistor 15 against excessive back bias voltage.

Normally open switch section 14 comprises a switching transistor 50 having an emitter terminal coupled to the load voltage source 16 and a collector terminal coupled through the load resistor R_C to the ground potential plane. The base terminal of the switching transistor 50 is coupled through a diode 52 and a resistor 54 to the collector terminal of a driving transistor 56. The emitter terminal of the driving transistor 56 is connected to the ground potential plane, and its base is biased by a bias network comprising resistors 58 and 60. These two last mentioned resistors are series connected between the actuator signal source 38 and ground.

A resistor 62a is connected between the emitter and base terminals of the switching transistor 50 to improve the high speed performance of the circuit, as discussed previously relative to resistor 42.

In operation of the switching section 14, in the absence of the application of the control signal V_A , the driving transistor 56 is nonconducting. Hence, the switching transistor 50 is biased to the nonconductive state. Upon application of a signal V_A , the driving transistor 56 is biased to a low impedance state, thereby forward biasing the switching transistor 50 and allowing the load current I_L to flow through the terminal 50 to the load R_C .

In the absence of the application of a positive signal V_A to the lead 62, base currents I_1 and I_2 flow in the transistors 15 and 30, respectively, of the switching section 12; and little, if any, base current I_4 and I_3 flow in the transistors 50 and 56, respectively, of the normally open section 14.

Since the turn off speed of a transistor is dependent upon the base current which flows prior to the time of attempted turn off, by adjusting the parameter values of the bias elements, such as resistors 28, 34, and 40, the magnitude of the "on current" I_1 and I_2 can be selected so that the switching transistor 15 will turn off (switch to the high impedance state) either before or after the switching transistor 50 of the normally closed section 14 is turned on by the application of a positive signal V_A . By the same token, resistors 58, 60, and 54 may be selected such that transistor 50 will selectedly turn off either before or after transistor 15 is turned on upon the removal of the actuation signal V_A .

This just discussed regulation of the turn on and turn off characteristics of the circuit 10 is important as it allows the circuit to be designed in either a "make before break" or "break before make" configuration. Hence, the load current I_L may be applied to the second load before it is disconnected from the first load, or the circuit may be so designed by selecting the values of the previously mentioned parameters that the converse switching arrangement is obtained.

The normally closed switching section 12a, shown in FIG. 2, is adapted for switching applications requiring high level currents and/or voltages. In the circuit of FIG. 2, components that are similar or identical to those of section 12 (FIG. 1) are given the same reference numeral, followed by a small letter *a*. The structure and function of the normally closed switching device 12a is the same as that of the section 12 of FIG. 1, except that the switching transistor 15 of section 12 is replaced by a Darlington pair circuit 15a in the switching section 12a.

The Darlington pair circuit 15a includes transistors 64 and 66 with the emitter and collector terminals of the transistor 64 coupled between the load voltage source 16 (FIG. 1) and the load resistor R_A . The base terminal of the transistor 64 is connected to the emitter terminal of the transistor 66 and the collector terminal of the transistor 66 is connected to the load transistor R_A . The base terminal of the last mentioned transistor is connected to the driving network, which includes transistor 30a, at a junction point between the resistor 42a and the diode 26a.

The high current configuration of the normally open switch section is shown in FIG. 3 and is designated by the reference symbol 14a. As was the case with the circuit of FIG. 2, in the circuit of FIG. 3 components which are identical or similar to those of FIG. 1 are assigned the same reference numerals followed by a distinguishing small letter *a*. The construction and operation of the high current, normally open switching section 14a is identical to that of section 14, except that switching transistor 50 of section 14 is replaced in the configuration of FIG. 3 by transistors 68 and 70 connected in a Darlington pair circuit configuration 50a.

In the circuit 50a, the emitter and collector terminals of transistor 68 are connected between the load voltage source 16 (FIG. 1) and the load resistor R_C . The base terminal of the transistor 68 is connected to the emitter terminal of the transistor 70, and the collector terminal of the transistor 70 is connected to the load resistor R_C . The base terminal of the transistor 70 is controlled by a bias network which includes resistors 62a, diode 52a, resistor 54a, and a control driver network that includes the transistor 56a. The design and function of these just mentioned bias components are similar to that described for their corresponding counterparts of the circuit shown in FIG. 1.

The normally closed section 12a and the normally open section 14a of FIGS. 2 and 3, respectively, may be connected in the single pole double throw configuration of FIG. 1, as well as operating as separate switching sections. For example, the sections 12 or 12a could be used in applications where it is desired that a voltage source be normally connected to a load, except during the periods of application of a control signal (actuation signal). The normally open section 14 or

14a may be used for the switching applications in a manner similar to that of a normally open relay.

Having described the normally closed sections, such as 12 or 12a, and the normally open sections, such as 14 or 14a of a single pole double throw solid state relay, a description will now be presented of how these sections can be arranged to provide for a plurality of voltage sources to be respectively connected by switching transistors in each of the sections to a plurality of first or second load circuits. The arrangement is such that the switching transistors in each section are driven by a single driving transistor to thus provide synchronized multiple pole switching while permitting the potential levels of the respective load voltage sources to vary relative to each other without affecting the reliability of the operation of the solid state relay.

Referring now primarily to FIG. 4, the solid state switching device there shown is analogous to a double pole double throw electromechanical relay. In the configuration of FIG. 4, a first load voltage source 16b is switchable between load resistors R_A and R_C ; and a second load voltage source 16c is switchable between load resistors R_B and R_D in response to an actuation signal V_A applied by the actuator signal source 38.

In FIG. 4 the switching transistors associated with the sources 16b and 16c, which are analogous to switching transistor 15 of FIG. 1, have been assigned reference designations 15b and 15c, respectively. The biasing networks associated with these switching devices have been designated by the reference numeral of the corresponding component in FIG. 1 with the addition of a letter *b* or *c*. The driving circuits associated with transistors 30c and 36c in FIG. 4 correspond to the similar circuits associated with transistors 30 and 36, respectively, in FIG. 1, except that the collector of driving transistor 30c is coupled to the input biasing networks of both switching transistors 15b and 15c.

By the same token, the circuits associated with the switching transistors 50b and 50c in FIG. 4 have been designated by the same numeral used for the corresponding component in FIG. 1, with a letter added to distinguish the different parallel sections of the normally open circuits in FIG. 4. The driving transistor 56c, shown in FIG. 4, controls both switching transistors 50b and 50c.

In operation of the double pole double throw solid state switching device of FIG. 4, switching transistors 15b and 15c are normally conducting in the absence of the actuation signal V_A ; and therefore the load voltage sources 16b and 16c are coupled to load resistors R_A and R_B respectively. These switching devices are driven from a common driver stage which comprises the driving transistor 30c. This just designated transistor is biased on by a current which flows through the resistor 34c from the load voltage source 16b or 16c—which ever source is at the greater positive potential. The diode steering network comprising diodes 32b and 32c arrange for the voltage source of the higher potential to be connected to the resistor 34c. It should be noted that the purpose for thus coupling the bias circuit to both load voltage sources 16b or 16c is because it is possible in a particular application or use of the solid state relay of the present invention that only one of these load voltage sources will be actually connected across the terminals thereof. Hence, coupling of the bias circuit

for the normally closed driving transistor 30c to both of the voltage load sources by way of the diode steering network insures that transistor 30c will be biased on, such as to make the solid state relay operative, as long as any one of the voltage sources is coupled across the terminals of the solid state relay.

Upon application of a signal V_A , the control transistor 36c is switched to the "on" state thereby shorting the base terminal of the driving transistor 30c to the ground potential plane. Hence, the transistor 30c is biased out of conduction, and the flow of biasing current for the switching transistors 15b and 15c is interrupted.

The application of the actuation signal V_A from the signal source 38 also turns "on" driving transistor 56c, which in turn causes switching transistors 50b and 50c to conduct.

The "make before break" and "break before make" features, discussed previously, may be incorporated into the double pole double throw circuit configuration of FIG. 4 in the same manner explained relative to FIG. 1—i.e., by selecting the parameters that control the base circuits, I_{1b} , I_{1c} , I_{2c} , I_{4b} , I_{4c} , and I_{3c} .

Next to be discussed in connection with the double pole double throw solid state relay shown in FIG. 4 is the function of the isolating diodes 26b and 26c in the respective circuits coupling the base terminals of switching transistors 15b and 15c to the collector terminal of driving transistor 30c, and the isolating diodes 52b and 52c in the respective circuits coupling the base terminals of switching transistors 50b and 50c to the collector terminal of the driving transistor 56c.

In connection herewith it should be noted that in the electromechanical relay art the term "multiple pole" indicates the number of separate, isolated circuits simultaneously controlled by contacts of the relay. It should be further appreciated that in a general application of an electromechanical relay, the poles referred to could be at different potential levels or at least each of the line voltages selectively supplied to the separate circuits is normally permitted to have a potential level different from the others. Since it is not known what the potential levels of the voltage sources will be, all possibilities and variations should be accounted for in the design of a solid state relay. It is thus seen that in order for the double pole double throw solid state relay of the present invention to be interchangeable with a conventional electromechanical relay, the load circuits R_A and R_C connected to be selectively supplied by energy from load voltage source 16b should thus be separate circuits isolated as completely as possible from the load circuits R_B and R_D connected to be selectively supplied by energy from load voltage source 16c.

Inasmuch as the base circuits of the normally open switching transistors 50b and 50c in FIG. 4 are coupled together to the collector of the single driving transistor 56c so as to be simultaneously controlled thereby, the load voltage sources 16b and 16c, respectively, connected to these switching transistors are electrically intercoupled at the base input circuits of the respective switching transistors. This creates a problem inasmuch as these voltage sources when of different potential level can cause current to conduct therebetween, via the base input networks. Such a flow of current could modify the bias on the base terminals of the switching

transistors which are supposed to be cut off, such as to cause any one of these switching transistors to inadvertently conduct.

The provision of a diode 52b and 52c in the base circuit of each of the switching transistors overcomes this problem of the load voltage source differential creating a current flow in the base circuit of the nonconducting switching transistor 50b or 50c which could inadvertently turn on either one of these switching transistors.

More particularly, if the diodes 52b and 52c were not present in the base terminal circuits of the respective transistors 50b and 50c when these latter switching transistors are at cut-off, the switching transistors, and accordingly the lines feeding the load circuits R_C and R_D , would not be isolated from each other. For example, in a particular application, if the voltage source 16c is at a higher potential level than the load voltage source 16b, in the absence of diodes 52b and 52c, current would flow from source 16c through the resistor 62c through the resistor 54c through resistor 54b and resistor 62b to the load voltage source 16b. Such a current flow would cause transistor 50c to at least partially conduct which would result in a current flow through to the load R_D when such a flow is not desired.

It should be noted that in certain applications of the solid state relay in FIG. 4, the resistors 62b, 62c are not provided across the emitter-base terminals of the respective switching transistors 50b and 50c. In such applications, in the absence of diodes 52b and 52c, the difference in potential level of the load voltage sources 16b and 16c can vary until the back bias of the base-emitter junction of the switching transistor is exceeded, before creating a current flow in the base terminal of the nonconducting switching transistor 50b or 50c which could inadvertently turn on either one of these switching transistors. However, a transistor typically tends to be back biased by only a few volts differential, and accordingly, the diodes 52b and 52c are required to assure that the double pole double throw solid state relay will operate reliably over a wide range of differential voltage levels.

It should be further noted that when the solid state relay receives an actuating signal from actuator signal source 38 the switching transistors 50b and 50c are rendered conductive and the switching transistors 15b and 15c are now switched to cutoff. Accordingly, if diodes 26b and 26c were not included in the base terminals of these latter switching transistors, and if the load voltage source 16c were at a higher potential level than the load voltage source 16b, this difference in potential could cause the switching transistor 15c to at least partially conduct, as previously discussed, thus providing a current to the load R_B when it is not supposed to be energized.

In view of the above, it should now be clearly understood that the double pole double throw solid state relay of the present invention is intended to be used without concern as to whether the voltage sources 16b and 16c happen to be of equal or different potential levels. Thus, the provision of an isolating diode in each of the base terminals of the switching transistors insures the reliable operation of the solid state relay by providing for isolating each of the base terminals of the switching transistors from the higher potential of any of the load voltage sources applied to the common input to the driving transistor.

It should now be clear that one of the primary advantages of the subject invention is the increased isolation between parallel lines, e.g., increased isolation of the line connected to the load resistor R_A from the lines connected to the load resistors R_B , R_C and R_D in FIG. 4. This improved isolation between parallel lines is achieved by providing very high impedance levels between the various lines to be switched and the controlling circuits; and by controlling the switching transistors, such as transistor 15b, by means of switching their base terminals through an isolating diode-resistor network to the ground potential plane.

A solid state switching device adapted for use in conjunction with a pair of complementary control signals is shown in FIG. 5. In the circuit of FIG. 5, the load voltage source 74 is switched between load resistors R_E and R_F in response to a pair of complementary signals which are together designated as V_B . The signal V_B is supplied from an actuator signal source 76 on a pair of leads 77 and 78. In the embodiment, shown in FIG. 5, when the signal V_B is applied, the potential applied to the lead 77 is negative with respect to the ground potential plane and the signal applied to the lead 78 is positive with respect to the ground potential plane. In the absence of the signal V_B the transistor 78 is biased to a low impedance state (switched on) and the switching transistor 80 is biased to a high impedance state (switched off). Upon the application of the actuation signal V_B , the transistor 78 is switched off and the transistor 80 is switched on.

The emitter and collector terminals of the transistor 78 are coupled between the load voltage source 74 and the resistor R_E . The base terminal of the transistor 78 is coupled through a diode 82 and a resistor 84 to the collector terminal of a transistor 86. The emitter terminal of the transistor 86 is coupled to ground.

The base terminal of the transistor 86 is normally biased so that the transistor is held on by the load voltage V_L applied through a diode 87 and a resistor 88. Upon the application of the pair of complementary signals V_B , a negative potential is applied through a diode 91, a zener diode 90 and through the coupling resistor 92 to the base of the driving transistor 86, thereby switching the transistor 86 off.

The "speed up" resistor 93 is connected between the emitter and the base terminals of the transistor 78 for the same purpose as was explained previously relative to resistor 42 of FIG. 1.

The base terminal of the transistor 80 is connected through a diode 94 and a resistor 96 to the collector terminal of a driving transistor 98. The emitter of the transistor 98 is connected to ground. The base terminal of the driving transistor 98 is connected through a resistor 100 to ground and also through a resistor 102, a zener diode 104 and a diode 105 to the positive lead 78 from the actuator signal source 76.

In the absence of a signal V_B , the transistor 98 is off, hence interrupting the flow of bias current from the base of the switching transistor 80 and disconnecting the load voltage source from the load resistor R_F . Upon the application of the signal V_B , the driving transistor 98 is switched on, thereby turning on the switching transistor 80, hence connecting the load voltage source 74 to the load resistor R_F .

The solid state switching device of FIG. 6 is similar in operation to the circuit just discussed relative to FIG. 5.

However, in the configuration shown in FIG. 6, the circuit is functionally analogous to a double pole double throw electromechanical relay. In the circuit of FIG. 6, in the absence of the complementary pair of actuator signals, V_B , the switching transistors 78a and 78b are biased to a low impedance state by the transistor driving stage comprising the transistor 86c. The bias current to the base terminal of the transistor 86c is supplied through the isolation resistor 88c. The load voltage source, which supplies this just referenced bias current, is selected from the sources 74a and 74b by a steering diode network comprising diodes 106 and 108. This diode network connects the load voltage source which supplies the highest positive potential signal to the resistor 88c. During the period of application of the signal V_B , the negative potential applied on the lead 77c through diode 91c, zener diode 90c and coupling resistor 92c biases the transistor 86c to the nonconductive state, thereby switching transistors 78a and 78b to the off condition.

During the absence of the control signal V_B , the transistor 98c, which controls the switching transistor 80a and 80b, is biased to the off condition. Upon the application of the signal V_B on the lead 78c, the driver transistor 98c is biased into conduction, thereby providing a path for the base current of transistors 80a and 80b. Therefore, upon the application of the signal V_B , the voltage sources 74a and 74b are connected to load resistors R_I and R_J , respectively.

Referring next to FIG. 7, another embodiment of the double pole double throw solid state relay is shown. In the configuration of FIG. 7, a first load voltage source 112a is switchable between load resistors R_K and R_M , and a second load voltage source 112b is switchable between load resistors R_L and R_N in response to an actuation signal source 114.

In FIG. 7, the normally closed switching transistors associated with the sources 112a and 112b have been assigned reference designation 116a and 116b, respectively. The biasing network for the switching transistor 116a includes a resistor 131a connected between its emitter and base, and a diode 120a in series with a resistor 122a which couples the base of switching transistor 116a to the collector of driving transistor 124. Similarly, the biasing network for the switching transistor 116b includes a resistor 131b connected between its emitter and base, and a diode 120b in series with a resistor 122b which couples the base of switching transistor 116b to the collector of driving transistor 124.

In a similar manner, the normally open switching transistors associated with the sources 112a and 112b have been assigned reference designations 118a and 118b, respectively. The biasing network of the switching transistor 118a includes a resistor 140a connected between its emitter and base, and a diode 132a connected in series with a resistor 134a which couples the base of switching transistor 118a to the collector of driving transistor 136. In a similar manner, the biasing network for the switching transistor 118b includes a resistor 140b connected between its emitter and base, and a diode 132b connected in series with a resistor 134b which couples the base of switching transistor 118b to the collector of the driving transistor 136.

It should be particularly noted that the circuit configuration in FIG. 7 differs from that in FIG. 4 by the arrangement used to bias the driving transistor 124 into a normally conductive condition. Thus, the diode steering network in FIG. 4 comprised of diodes 32b, 32c and resistor 34c connected to the base of driving transistor 30c, is eliminated in FIG. 7. This function is obtained in FIG. 7, instead, by connecting the common junction of the base terminal circuits of the normally open switching transistors 118a and 118b to the base terminal of the driving transistor 124 by way of a resistor 137. It should be thus noted that transistor 124 is normally forward biased by receiving base current from the load voltage source 112a through resistor 140a, diode 132a, resistor 134a and resistor 137, or from load voltage source 112b through resistor 140b, diode 132b, resistor 134b and resistor 137, depending upon which of the voltage sources 112a or 112b is at the higher potential. Resistor 137 is large so that transistors 118a and 118b remain reverse biased.

The circuit of FIG. 7 is actuated to be switched by a signal from actuator signal source 114. In response to a positive signal from 114, the normally off driving transistor 136 is turned on and the control transistor 130 is likewise turned on. The turning on of control transistor 130 shorts the base of the driving transistor 124 to ground causing it to be cut off and thus switching off the normally closed switching transistor 116a and 116b and cutting off the supply of current from the load voltage source 112a and 112b to the respective loads R_K and R_L . The simultaneous turning on of driving transistor 136 switches switching transistors 118a and 118b to a conduction condition, thus enabling these transistors to supply current from the load voltage source 112a and 112b to the respective loads R_M and R_N .

Reference will next be made to FIG. 8 which shows another circuit configuration for a double pole double throw solid state relay, in which a first load voltage source 151a is switchable between load resistor R_P and R_S , and a second voltage load source 151b is switchable between load resistors R_Q and R_T . This relay circuit configuration is generally similar to the one shown in FIG. 7 but is especially adapted for switching functions requiring high level currents and/or voltages. This relay circuit also provides for the voltage drop across the collector-emitter terminals of the switching transistors to be independent of the magnitude of the load voltage source. Thus, in FIG. 8, the normally closed switching transistors 116a and 116b in FIG. 7 are replaced by transistor pair circuits 154a and 154b, and the normally open switching transistors 118a and 118b in FIG. 7 are replaced by transistor pair circuits 156a and 156b. Furthermore, each of the resistors coupled to the base terminals of the switching transistors, such as resistor 122a, in FIG. 7, is replaced in FIG. 8 by a constant current diode, such as diode 169.

The transistor pair circuit 154a includes an n-p-n transistor 160a and a p-n-p transistor 162a with the collector and emitter terminals of the transistor 160a respectively coupled to the load voltage source 151a and the load resistor R_P . The base terminal of the transistor 160a is connected to the collector terminal of the transistor 162a, and the emitter terminal of the transistor 162a is connected to the load voltage source

151a. A resistor 165a is connected between the emitter and the base terminals of the transistor 162a. The base terminal of the last mentioned transistor is connected to the collector of a driving transistor 166 by way of conventional diode 167a and the constant current diode 169a.

The transistor pair circuit 154b, which is similarly arranged to transistor pair circuit 154a, has the collector of its n-p-n transistor 160b connected to load voltage source 151b and the emitter of 160b connected to load R_Q. Likewise, transistor pair circuit 156a and transistor pair circuit 156b are similarly arranged with the former coupling load voltage source 151a to load R_S and the latter coupling load voltage source 151b to load R_T. The transistor pair circuits 156a and 156b are both coupled to driving transistor 176.

The advantage of the transistor pair circuit configuration of FIG. 8 over the Darlington pair circuit shown in FIG. 2 is that the former uses an n-p-n transistor, which has a higher current, higher voltage, and higher Beta characteristic than a p-n-p transistor, for actually switching the load voltage sources between the loads. Furthermore, the V_{BE} saturation voltage is lower in an n-p-n transistor as compared to a p-n-p transistor, and this is of importance in a solid state relay in that it results in less heat being dissipated during the operation of the circuit. Furthermore, the provision of the p-n-p transistor for effectively driving the n-p-n transistor has the advantage that it makes it possible for the "turn on" switching voltage for the relay circuit to be at or near ground level which is desirable in many applications. In addition, the replacement of the resistor in the base terminal circuit with a constant current diode 169a, for example, provides for a constant current flow in the base circuit of transistor 162a and consequently in the base circuit of 160a, irrespective of the level of the applied load voltage from source 151a. Thus, the switching transistor 160a is maintained at its optimum saturation point, and the voltage drop across the collector-emitter terminals of transistor 160a remains constant irrespective of the magnitude of the applied voltage. This is of advantage in the solid state relay of the present invention because it more nearly simulates the constant voltage drop across the contacts of an electromechanical relay. The circuit configuration of FIG. 8 further shows a driving circuit arrangement which differs from the circuit of FIG. 7 in one respect. In FIG. 8 the input 173 is provided with series resistors 174 and 175, the midpoint of which is connected by a capacitor 177 to the reference potential plane. This arrangement provides for the actuator signal to be applied to or removed from the input with a more gradual slope, and has the effect of increasing the delay time between the reversing of the bias on the base terminals of the driving transistors 166 and 176, thus assuring that the making and breaking actions of the normally open and normally closed switching sections of the relay occur in a controlled sequence.

Thus there has been described several preferred embodiments of solid state switching devices which provide improved performance at a reduced cost. One of the primary advantages of these devices over prior art electronic switches is that the subject devices do not require additional supply voltages for their operation. Hence, they are readily interchangeable with elec-

tromechnical relays. For applications involving high speed switching requirements, the subject devices are preferable to electromechanical relays. Also, they are more economical of operating power and maintenance costs than comparable electromechanical relays.

Although the preferred embodiments have been described in detail herein, it will be apparent to those skilled in the art that numerous modifications and substitutions may be made within the scope of the invention. In particular, although for the sake of clarity the disclosed embodiments are adapted to operate with positive source voltages, it should be understood that the polarity of the voltages is not limiting. Voltage sources of various polarities and output voltage levels may be accommodated by the proper selection of solid state switching device types, such as field effect transistors, unipolar transistors and silicon controlled rectifiers. Also, although in the interest of brevity, only single pole double throw and double pole double throw configurations have been shown herein, it will now be apparent that any combination of the basic switching sections may be combined so as to be functionally analogous to all types of electromechanical relays presently used in the art.

What is claimed is:

1. A solid state relay for switching a source of electrical energy between first and second load circuits in response to actuation signals applied thereto, said solid state relay comprising:

a first semiconductor device having an input terminal coupled to said energy source and an output terminal coupled to the first load circuit, and having a control terminal;

a second semiconductor device having an input terminal coupled to said energy source and an output terminal coupled to the second load circuit, and having a control terminal;

a first isolating diode;

first actuator means coupled through said first isolating diode to the control terminal of said first semiconductor device and controlled by said energy from said source of electrical energy in the absence of an actuation signal for permitting said first isolating diode to conduct and causing the impedance between said input and output terminals of said first semiconductor device to be at a low impedance level during periods of absence of said actuation signal, and controlled in response to the actuation signal for preventing said first isolating diode from conducting and causing said first semiconductor device to be at a high impedance level during periods of application of the actuation signal;

a second isolating diode; and

second actuator means coupled through said second isolating diode to the control terminal of said second semiconductor device and coupled to the reference potential plane of the energy source for preventing said second isolating diode from conducting and causing the impedance between said input and output terminals of said second semiconductor device to be at the high impedance level during periods of absence of said actuation signal, and controlled in response to the actuation signal for permitting said second isolating diode to con-

duct and for causing the impedance between said input and output terminals of said second semiconductor device to be at a low level during periods the actuation signal is applied;

whereby said energy source is coupled to conduct through said first semiconductor device to said first load circuit in the absence of said actuation signals, and said energy source is coupled to conduct through said second semiconductor device to said second load circuit during the periods of application of said actuation signals.

2. The device of claim 1 wherein said first and second semiconductor devices are transistors and said input, output and control terminals are emitter, collector and base terminals respectively.

3. The device of claim 1 wherein said first and second semiconductor devices are each Darlington pair transistor circuits.

4. The invention in accordance with claim 1 including a resistor coupled between the input terminal and the control terminal of each of said first and second semiconductor devices.

5. The device of claim 1 wherein said first actuator means comprises:

a driver circuit including a transistor having emitter, collector, and base terminals, with said collector terminal coupled through said first isolating diode to the control terminal of said first semiconductor device, and the emitter terminal coupled to the reference potential plane of the energy source;

first bias means coupled to said base terminal for electrically coupling said base terminal to the reference potential plane in response to the actuation signals; and

second bias means coupled to said base terminal for electrically coupling said base terminal to said energy source in the absence of the actuation signal.

6. The invention in accordance with claim 5 wherein said second bias means includes said second isolating diode.

7. The device of claim 5 wherein said second actuator means comprises a transistor having emitter, collector and base terminals, with the last mentioned collector terminal coupled through said second isolating diode to the control terminal of said second semiconductor device, the last mentioned emitter terminal coupled to the reference potential plane of the energy source; and further includes means for applying the actuation signals to the last mentioned base terminal.

8. A solid state switching device for switching a source of electrical energy between first and second load circuits in response to actuation signals applied thereto, said switching device comprising:

a first semiconductor device having an input terminal and an output terminal series coupled between the energy source and the first load circuit, and having a control terminal;

a second semiconductor device having an input terminal and an output terminal series coupled between the energy source and the second load circuit, and having a control terminal;

a first isolating diode;

first actuator means coupled through said first isolating diode to the control terminal of said first

semiconductor device and controlled by said energy from said source of electrical energy in the absence of an actuation signal for causing the impedance between said input and output terminals of said first semiconductor device to be a first level during periods of absence of said actuation signal, and controlled in response to the actuation signal for causing said first semiconductor device to be at a second impedance level during periods of application of the actuation signal;

a second isolating diode; and

second actuator means coupled through said second isolating diode to the control terminal of said second semiconductor device and responding to the actuation signals for causing the impedance between said input and output terminals of said second semiconductor device to be at a first level during periods the actuation signal is applied and at the second level during periods of absence of said actuation signal;

whereby said energy source is coupled through said first semiconductor device to said first load circuit in the absence of said actuation signals, and said energy source is coupled through said second semiconductor device to said second load circuit during the periods of application of said actuation signals; and

wherein said first and second actuator means include means for switching the impedance level of the semiconductor device which is at the second impedance level to the first impedance level before switching the other of said semiconductor device to the second impedance level from the first impedance level during the transition periods upon application or removal of the actuation signals.

9. A solid state switching device for switching a source of electrical energy between first and second load circuits in response to actuation signals applied thereto, said switching device comprising:

a first semiconductor device having an input terminal and an output terminal series coupled between the energy source and the first load circuit, and having a control terminal;

a second semiconductor device having an input terminal and an output terminal series coupled between the energy source and the second load circuit, and having a control terminal;

a first isolating diode;

first actuator means coupled through said first isolating diode to the control terminal of said first semiconductor device and controlled by said energy from said source of electrical energy in the absence of an actuation signal for causing the impedance between said input and output terminals of said first semiconductor device to be a first level during periods of absence of said actuation signal, and controlled in response to the actuation signal for causing said first semiconductor device to be at a second impedance level during periods of application of the actuation signal;

a second isolating diode; and

second actuator means coupled through said second isolating diode to the control terminal of said second semiconductor device and responding to the actuation signals for causing the impedance

between said input and output terminals of said second semiconductor device to be at a first level during periods the actuation signal is applied and at the second level during periods of absence of said actuation signal;

whereby said energy source is coupled through said first semiconductor device to said first load circuit in the absence of said actuation signals, and said energy source is coupled through said second semiconductor device to said second load circuit during the periods of application of said actuation signals; and

wherein said first and second actuator means include means for switching the impedance level of the semiconductor device which is at the first impedance level to the second impedance level before switching the other of said semiconductor device to the first impedance level from the second impedance level during the transition periods upon application or removal of the actuation signals.

10. A solid state switching device for switching a source of electrical energy between first and second load circuits in response to actuation signals applied thereto, said switching device comprising:

a first semiconductor device having an input terminal and an output terminal series coupled between the energy source and the first load circuit, and having a control terminal;

a second semiconductor device having an input terminal and an output terminal series coupled between the energy source and the second load circuit, and having a control terminal;

a first isolating diode;

first actuator means coupled through said first isolating diode to the control terminal of said first semiconductor device and controlled by said energy from said source of electrical energy in the absence of an actuation signal for causing the impedance between said input and output terminals of said first semiconductor device to be a first level during periods of absence of said actuation signal, and controlled in response to the actuation signal for causing said first semiconductor device to be at a second impedance level during periods of application of the actuation signal;

a second isolating diode; and

second actuator means coupled through said second isolating diode to the control terminal of said second semiconductor device and responding to the actuation signals for causing the impedance between said input and output terminals of said second semiconductor device to be at a first level during periods the actuation signal is applied and at the second level during periods of absence of said actuation signal;

whereby said energy source is coupled through said first semiconductor device to said first load circuit in the absence of said actuation signals, and said energy source is coupled through said second semiconductor device to said second load circuit during the periods of application of said actuation signals;

wherein said first actuator means comprises:

a driver circuit including a transistor having emitter, collector, and base terminals, with said collector

terminal coupled through said first isolating diode to the control terminal of said first semiconductor device, and the emitter terminal coupled to the reference potential plane of the energy source;

first bias means coupled to said base terminal for electrically coupling said base terminal to the reference potential plane in response to the actuation signals; and

second bias means coupled to said base terminal for electrically coupling said base terminal to said energy source in the absence of the actuation signal, said second bias means comprising a series diode-resistor combination.

11. A solid state relay circuit for switching a first and second voltage source between a first pair and a second pair of load circuits, said first and second voltage sources having different potential levels, said relay circuit comprising:

a pair of first switching transistors, each said first switching transistor having a control terminal, and having an input and an output terminal series coupled between one of said voltage sources and its associated first load circuits, and having a resistor coupled between the input and control terminals;

a pair of second switching transistors, each said second switching transistor having a control terminal, and having an input and an output terminal series coupled between one of said voltages sources and its associated second load circuits, and having a resistor coupled between the input and control terminals;

a first and second driving transistor, each having an input terminal, an output terminal and a base terminal, with the output terminal coupled to the reference potential plane of the energy sources;

a first coupling means including an isolating diode for coupling the control terminal of each said first switching transistor to the input terminal of the first driving transistor;

a second coupling means including an isolating diode for coupling the control terminal of each said second switching transistor to the input terminal of the second driving transistor;

bias means coupled to the base terminals of each of the first and second driving transistors such that the first driving transistor is normally conducting and the second driving transistor is normally non-conducting;

whereby the pair of first switching transistors coupled to the first driving transistor are normally conducting from the respective first and second voltage sources to the associated first load circuits and the pair of second switching transistors coupled to the second driving transistor are normally not conducting from the respective first and second voltage sources to the associated second load circuits; and

input means coupled to the base terminals of said first and second driving transistors capable of reversing the conduction of said first and second driving transistors, whereby the pair of second switching transistors are conducting from the respective first and second voltage sources to the associated second load circuits, and the pair of first switching transistors are not conducting from

the respective first and second voltage sources to the associated first load circuits; and

whereby said isolating diodes for coupling the pair of switching transistors to a non-conductive driving transistor are effective to prevent current flow in the control terminals of said switching transistors resulting from the different potential levels of said voltage sources and thus prevent said switching transistors from inadvertently conducting.

12. A solid state relay circuit for switching a plurality of electrical energy sources between a plurality of first and a plurality of second load circuits wherein a different set of first and second load circuits is associated with each of the energy sources, said solid state relay circuit comprising:

a plurality of first switching transistors, each said first switching transistors having an input and an output terminal series coupled between a different one of said energy sources and its associated first load circuit, and each of said first switching transistors having a control terminal;

a plurality of second switching transistors, each said second switching transistors having an input and an output terminal series coupled between a different one of said energy sources and its associated second load circuit, and each of said second switching transistors having a control terminal;

a first driving transistor having an input and output terminal, and a base terminal, with the output terminal coupled to the reference potential plane of the energy sources;

coupling means including an isolating diode for coupling the control terminal of each of said first switching transistors to the input terminal of said first driving transistor;

a second driving transistor having an input and output terminal, and a base terminal, with the output terminal coupled to the reference potential plane of the energy source;

coupling means including an isolating diode for coupling the control terminal of each of said second switching transistors to the input terminal of said second driving transistor;

bias means including circuit means coupling at least one of said energy sources to the base terminal of said first driving transistor for normally biasing said first driving transistor in a conductive state and said second driving transistor in a non-conductive state; and

input means including circuit means coupled to the base terminals of said first and second driving transistors capable of reversing the state of conduction of said first and second driving transistors;

whereby the isolating diodes coupled to the control terminals of said first switching transistors are effective to enable each of the energy sources coupled to its associated first load circuit through one of said first switching transistors to operate as a separate isolated circuit; and

whereby the isolating diodes coupled to the control terminals of said second switching transistors are effective to enable each of the energy sources coupled to its associated second load circuit through one of said second switching transistors to operate as a separate isolated circuit.

13. The invention in accordance with claim 12 wherein said bias means for coupling at least one of the energy sources to the base terminal of said first driving circuit includes the coupling means for coupling the plurality of second switching transistors to the collector terminal of said second driving circuit.

14. A solid state switching device for switching a source of electrical energy between first and second load circuits in response to actuation signals applied thereto, said switching device comprising:

a first semiconductor device having an input terminal and an output terminal series coupled between the energy source and the first load circuit, and having a control terminal;

a second semiconductor device having an input terminal and an output terminal series coupled between the energy source and the second load circuit, and having a control terminal;

a first isolating diode;

first actuator means coupled through said first isolating diode to the control terminal of said first semiconductor device and controlled by said energy from said source of electrical energy in the absence of an actuation signal for causing the impedance between said input and output terminals of said first semiconductor device to be a first level during periods of absence of said actuation signal, and controlled in response to the actuation signal for causing said first semiconductor device to be at a second impedance level during periods of application of the actuation signal;

a second isolating diode; and

second actuator means coupled through said second isolating diode to the control terminal of said second semiconductor device and responding to the actuation signals for causing the impedance between said input and output terminals of said second semiconductor device to be at a first level during periods the actuation signal is applied and at the second level during periods of absence of said actuation signal;

whereby said energy source is coupled through said first semiconductor device to said first load circuit in the absence of said actuation signals, and said energy source is coupled through said second semiconductor device to said second load circuit during the periods of application of said actuation signals; and

wherein each said first and second semiconductor devices include an n-p-n-transistor, and a p-n-p transistor, each said transistor having collector, emitter and base terminals with the collector and emitter terminals of said n-p-n transistor corresponding to the input and output terminal of said semiconductor device, with the collector and emitter terminals of said p-n-p transistor respectively coupled between the base terminal of said n-p-n transistor and said energy source, and with the base terminal of said p-n-p transistor corresponding to the control terminal of said semiconductor device.

15. A solid state switching device for switching a source of electrical energy between first and second load circuits in response to actuation signals applied thereto, said switching device comprising:

a first semiconductor device having an input terminal and an output terminal series coupled between the energy source and the first load circuit, and having a control terminal;

a second semiconductor device having an input terminal and an output terminal series coupled between the energy source and the second load circuit, and having a control terminal;

a first isolating diode;

first actuator means coupled through said first isolating diode to the control terminal of said first semiconductor device and controlled by said energy from said source of electrical energy in the absence of an actuation signal for causing the impedance between said input and output terminals of said first semiconductor device to be a first level during periods of absence to said actuation signal, and controlled in response to the actuation signal for causing said first semiconductor device to be at a second impedance level during periods of application of the actuation signal;

a second isolating diode; and

second actuator means coupled through said second isolating diode to the control terminal of said second semiconductor device and responding to the actuation signals for causing the impedance between said input and output terminals of said second semiconductor device to be at a first level during periods the actuation signal is applied and at the second level during periods of absence of said actuation signal;

whereby said energy source is coupled through said first semiconductor device to said first load circuit in the absence of said actuation signals, and said energy source is coupled through said second semiconductor device to said second load circuit during the periods of application of said actuation signals; and

wherein the coupling of each said first and second actuator means to the respective control terminals of said first and second semiconductor devices includes a constant current diode.

16. A solid state switching device for switching a plurality of electrical energy sources between a plurality of first and second load circuits wherein a different set of first and second load circuits is exclusively associated with each one of the energy sources, said switching device comprising:

a plurality of first semiconductor devices, each said first semiconductor device having an input and an output terminal series coupled between a different one of said energy sources and its associated first load circuit, and each of said first semiconductor devices having a control terminal;

a plurality of second semiconductor devices, each of said second semiconductor devices having an input terminal and an output terminal series coupled between a different one of said energy sources and its associated second load circuit, and each of said second semiconductor devices having a control terminal;

first actuator means coupled to the control terminal of each of said first semiconductor devices and controlled by the electrical energy from the source of electrical energy of the largest potential mag-

nitude in the absence of an actuation signal for causing the impedance between the input and output terminals of each said first semiconductor device to be at a first impedance level during the absence of the actuation signal, and controlled in response to the actuation signal for causing the impedance level of each said first semiconductor device to be at a second level during the periods of application of the actuation signal;

said coupling of the first actuator means to the control terminal of each of said first semiconductor devices including isolating means for isolating each of said first semiconductor devices such that the current path from each energy source through its associated first semiconductor device to its associated first load circuit operates as a separate, isolated circuit;

second actuator means coupled to the control terminal of each said second semiconductor device and responding to said actuation signal for causing the impedance level between the input and output terminals of each said second semiconductor device to be at a first level during periods the actuation signal is applied and at a second level during periods of absence of said actuation signal;

said coupling of the second actuator means to the control terminal of each of said second semiconductor devices including isolating means for isolating each of said second semiconductor devices such that the current path from each energy source through its associated second semiconductor device to its associated load circuit operates as a separate isolated circuit;

whereby each of said plurality of energy sources is coupled through its associated first semiconductor device to its associated first load circuit in the absence of said actuation signal, and each of said plurality of said energy sources is coupled through its associated second semiconductor device to its associated second load circuit during the periods of application of said actuation signal.

17. The device of claim 16 wherein said first and second actuator means includes means for momentarily holding the impedance level between the input and output terminals of the semiconductor devices of each of said sets of first and second semiconductor devices which are at the first impedance level at that level until the impedance of the other semiconductor device of the set is switched to the first level during the transition periods upon application or removal of the actuation signal.

18. The device of claim 16 wherein said first and second actuation means includes means for switching the impedance level of one of the semiconductor devices of each set of semiconductor devices from the first to the second impedance level before switching the other semiconductor device of each set from the second to the first impedance level during the transition period upon application or removal of the actuation signal.

19. The device of claim 16 wherein said first and second actuation means includes means for switching the impedance level of one of the semiconductor devices of each set of semiconductor devices from the second to the first impedance level before switching the

other semiconductor device of each set from the first to the second impedance level during the transition period upon application or removal of the actuation signal.

20. The invention in accordance with claim 16 including a resistor coupled between the input terminal and the control terminal of each of said first and second semiconductor devices.

21. The invention in accordance with claim 16 wherein said isolating means for isolating each of said first and second semiconductor devices comprises a diode connected into the control terminal of each of said first and second semiconductor devices for preventing current flow therein when said electrical energy sources are at different potential levels.

22. The invention in accordance with claim 21 wherein said switching transistors and said driving transistors are of complementary type.

23. The device of claim 16 wherein said first actuator means comprises:

a driver circuit including a transistor having emitter, collector and base terminals, wherein said isolating means includes isolating diodes, and wherein said collector terminal is coupled to the control terminal of each of said first semiconductor devices

through one of said isolating diodes, and said emitter terminal of said transistor is coupled to the reference potential plane of the energy sources; first bias means coupled to the base terminal for electrically coupling said base terminal to the reference potential plane in response to the actuation signals; and

second bias means coupled to said base terminal for electrically coupling said base terminal to the energy source of the largest potential magnitude in the absence of said actuation signal.

24. The device of claim 23 wherein said second bias means comprises a diode-resistor network for connecting the energy source of the largest voltage magnitude to the base terminal of the driver circuit.

25. The device of claim 23 wherein said second actuator means comprises a transistor having emitter, collector, and base terminals with the collector terminal coupled to said control terminal of each of said second semiconductor devices through one of said isolating diodes, said emitter terminal coupled to the reference potential plane of said energy sources, and including means for applying the actuation signal to said last mentioned base terminal.

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