INTELLIGENT SWITCH SYSTEM AND ASSEMBLY HAVING INTEGRATED PROTECTION CIRCUITRY

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ABSTRACT

A switch system includes a brake pedal having a ferromagnetic target, a main housing that securely retains a brake circuit board and a magnet, a sensor connector subassembly, and a plug connector subassembly. The system also includes a connector circuit board secured within the sensor connector subassembly and in communication with the brake circuit board. The connector circuit board includes at least one positive temperature coefficient (PTC) device electrically connected between the brake circuit board and at least one brake lamp. The connector circuit board may also include at least one circuit to protect against over-voltage or over-current to the at least one brake lamp, detect a fault condition, and determine whether the plug connector subassembly is connected to the sensor connector subassembly.
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CROSS REFERENCE TO RELATED APPLICATIONS


[0002] This application also claims priority to U.S. Provisional Application No. 61/537,845, entitled “Intelligent Brake Switch System”, filed Sep. 22, 2011, which is hereby incorporated by reference in its entirety.

[0003] This application also claims priority to U.S. Provisional Application No. 61/537,830, entitled “Brake Switch System and Assembly”, filed Sep. 22, 2011, which is hereby incorporated by reference in its entirety.

BACKGROUND OF THE DISCLOSURE

[0004] The subject matter disclosed herein relates to an intelligent connector system used in connection with a brake switch system and assembly.

[0005] Many vehicles include safety controls that are configured to ensure protection of the systems and components in the vehicle and to protect the occupants of the vehicle. For example, components are placed within power circuits to protect output circuits and devices downstream of a power surge. Typical systems include fuses, relays and connectors that open when an over-current or over-voltage situation occurs that may damage the downstream circuits. Typically, known connectors used in such applications are simple pass-through connections. Power is supplied to input circuits of a connector by a fused relay and a simple pin connection that transfers power to the output circuits for downstream use. However, the fuse and relay, and their respective connection systems, are normally housed in a remote junction box that increases complexity and components, and poses mounting space issues.

[0006] Additionally, in these connection configurations, a short circuit fault typically blows a fuse and continues to blow fuses (if the fuses are removed and replaced) until the short circuit fault is corrected. Additionally, electronic modules that utilize power from an output of a connector typically must individually provide their own over-voltage protection.

[0007] Automobiles and various other vehicles have brake systems that include rear brake lights. When a driver engages a brake pedal, the rear brake lights are activated in order to signal to other motorists that the vehicle is in the process of slowing down, and/or coming to a halt.

[0008] Mechanical brake light switches have been used for many years with mixed levels of reliability and convenience. For example, typical brake light switches exhibit persistent wear issues and noise level concerns. One safety concern for a vehicle is the need to keep all the lights, specifically the brake lights, in operational order. Typically, a brake light is connected to at least one fuse. If too much current flows to the brake light through the fuse, the fuse may blow, thereby rendering the brake light inoperative. As such, the fuse(s) within the brake light circuit may cause the brake light to not work properly without the driver knowing. Not only is a malfunctioning or non-operational brake light a safety concern, but it may lead to undesirable law enforcement encounters, such as tickets and/or fines. One solution is a fault detection system with an indicator light to notify the vehicle driver when a brake light is not functioning. Again, however, the fuses within the brake light circuit continue to be unreliable and often need replacement.

[0009] Mechanical brake light switches have been used for many years with mixed levels of reliability and convenience. Typically, when a brake pedal is depressed, a portion of the brake pedal physically contacts a switch, which then closes, and current flows to brake lights. These switches, which are used by many original equipment manufacturers, exhibit persistent wear issues and noise level concerns. Nevertheless, mechanical brake light switches continue to be used due to their low cost. However, with continued emphasis on improving reliability and comfort (for example, limiting noise), and the advent of electric vehicles, mechanical brake switches are being reevaluated.

[0010] Another known brake system includes a battery that provides power to a Hall effect sensor or device that is in close proximity to a brake pedal that is electrically connected to a relay, which, in turn, is connected to brake lights. The Hall device is positioned proximate a magnet.

[0011] When the brake pedal is depressed, a ferromagnetic target of the pedal moves away from the Hall device. During this time, the magnetic field emitted from the magnet changes. The Hall device detects this change and switches states, thereby closing the relay, which, in turn, activates the brake lights (closing a circuit from the battery to the brake lights). When the driver removes his/her foot from the brake pedal, the magnetic field changes back, the Hall device switches back to its original state, thereby opening the relay and deactivating the brake lights. As such, the system provides a single non-contacting switch point that activates and deactivates the brake lights depending on whether the brake pedal is depressed or not.

[0012] Various vehicles also include cruise control. A driver typically activates cruise control while driving on a highway, where the driver can operate a vehicle at a consistent rate of speed for an extended period of time. The cruise control feature allows the driver to drive the vehicle without keeping a foot on the accelerator. In order to deactivate the cruise control, the driver typically taps the brake pedal. In doing so, however, the brake lights are typically activated.

[0013] However, the vehicle may not, in reality, be slowing down. Thus, the activation of the brake lights may erroneously indicate that the vehicle is slowing, when the driver actually wishes to increase the velocity of the vehicle.

BRIEF DESCRIPTION OF THE DISCLOSURE

[0014] Certain embodiments provide a switch system including a brake pedal having a ferromagnetic target, a main housing that securely retains a brake circuit board and a magnet, wherein the brake pedal is proximate a portion of the main housing, a plug connector subassembly, and a sensor connector subassembly. The brake circuit board may include a first Hall device proximate the magnet, wherein the first Hall device is configured to switch in relation to a first magnetic field threshold, and a second Hall device proximate the magnet, wherein the second Hall device is configured to switch in relation to a second magnetic field threshold, and wherein the first magnetic field threshold differs from the second mag-
netic field threshold. The sensor connector subassembly may be selectively connectable to the plug connector subassembly. A connector circuit board is secured within the sensor connector subassembly and in communication with the brake circuit board. The connector circuit board includes at least one positive temperature coefficient (PTC) device electrically connected between the brake circuit board and at least one brake lamp, wherein the connector circuit board includes at least one circuit to protect against over-voltage or over-current to the at least one brake lamp, detect a fault condition, and determine whether the plug connector subassembly is properly connected to the sensor connector subassembly.

[0015] Optionally, the brake circuit board and the connector circuit board may be contained within the same housing.

[0016] The connector circuit board may also include a relay switch connected between the at least one PTC and the at least one brake lamp. The at least one PTC restricts current from flowing to the relay switch when current at the at least one PTC exceeds a current threshold. The connector circuit board may also include a Zener diode connected to a relay coil, wherein the Zener diode is configured to allow current to pass to the relay coil when the Zener diode experiences a breakdown voltage, thereby energizing the relay coil to move the relay switch from a closed to an open position. The connector circuit board may also include a metal oxide varistor (MOV) electrically connected between the relay switch and the load.

[0017] The connector circuit board may also include a microcontroller electrically connected to a fault indicator. The microcontroller monitors the at least one PTC to determine whether to activate the fault indicator. The microcontroller may monitor a voltage difference across the at least one PTC to determine whether to activate the fault indicator. The fault indicator may include one or more of a visual or audio indicator.

[0018] The connector circuit board may also include an interlock circuit having an interlock pin. The interlock circuit prevents current from flowing to the brake lamp when the plug subassembly is not properly connected to the sensor connector subassembly. For example, a transistor may be electrically connected to the interlock pin. The transistor is on and connected to ground when the plug connector subassembly is not properly connected to the sensor connector subassembly. The transistor is off and not connected to ground when the plug connector subassembly is properly connected to the sensor connector subassembly.

[0019] The protection against over-current or over-voltage may be automatically resettable without manual intervention.

[0020] The first Hall device may be operatively connected to a cruise control module. The first Hall device switches to deactivate cruise control controlled by the cruise control module.

[0021] The second Hall device may be operatively connected to the connector circuit board. The second Hall device switches to control activation and deactivation of the at least one brake lamp.

[0022] The brake circuit board may also include a relay electrically connected between the second Hall device and the at least one brake lamp.

[0023] The brake circuit board may include a field-effect transistor (FET) electrically connected between the second Hall device and the at least one brake lamp.

[0024] A magnetic field of the magnet may change when the ferromagnetic target moves in relation to the magnet. The first and second magnetic field thresholds may be first and second magnetic field strength thresholds.

[0025] Certain embodiments provide a circuit system including a first Hall device proximate a magnet, wherein the first Hall device is configured to switch in relation to a first magnetic field threshold, a second Hall device proximate the magnet, at least one positive temperature coefficient (PTC) device electrically connected to at least one brake lamp, and at least one circuit to protect against over-voltage or over-current to the at least one brake lamp, detect a fault condition, and determine whether the plug connector subassembly is properly connected to the sensor connector subassembly.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] FIG. 1 illustrates an isometric exploded view of a connector assembly, according to an embodiment.

[0027] FIG. 2 illustrates a schematic circuit diagram of a connector assembly operatively connected to a brake switch circuit, according to an embodiment.

[0028] FIG. 3 illustrates an isometric exploded view of a brake switch connector assembly, according to an embodiment.

[0029] FIG. 4 illustrates a schematic circuit diagram for a brake switch system, according to an embodiment.

[0030] FIG. 5 illustrates a schematic circuit diagram for a brake switch system, according to an embodiment.

[0031] FIG. 6 illustrates a schematic circuit diagram for a brake switch system, according to an embodiment.

[0032] FIG. 7 illustrates a schematic circuit diagram for a brake switch system, according to an embodiment.

DETAILED DESCRIPTION

[0033] FIG. 1 illustrates an isometric exploded view of a connector assembly 50, according to an embodiment. The connector assembly 50 includes a first or plug subassembly 52 configured to securely mate with a second or sensor connector subassembly 54 having a cap 56.

[0034] The plug subassembly 52 includes a main body 58 having a sensor mating face 60 at a mating end 61 and a rear wire exit face 62 at an opposite end 64. As shown, the plug subassembly 52 may be an in-line connector having one or more cavities 66 extending through the plug subassembly 52 from the sensor mating face 60 to the rear wire exit face 62. Each cavity 66 is configured to receive and retain one contact (not shown). Alternatively, the connector assembly 50 may be various other types of connector assemblies that are not inline.

[0035] The cap 56 includes a wire seal 68 and a seal cap 70. The wire seal 68 and the seal cap 70 have one or more openings 72 that receive and retain one or more wires (not shown). As shown, the plug subassembly 52 has twelve cavities 66 and the cap 56 has twelve openings 72, but any number of cavities 66 and openings 72 may be used.

[0036] The sensor connector subassembly 54 is securely mounted between the plug subassembly 52 and the cap 56. The sensor connector subassembly 54 includes a housing 74 having lateral walls 76 integrally formed with upper and lower walls 78 and 80, respectively. The lateral walls 76, upper wall 78, and lower wall 80 define an internal chamber 82. A circuit board subassembly 84 is securely mounted within the internal chamber 82.
The circuit board subassembly 84 includes a printed circuit board (PCB) 86 having components mounted thereto. For example, the PCB 86 supports a relay 88 and one or more positive temperature coefficient devices (PTCs) 90. Each PTC 90 is a passive electronic component used to protect against overcurrent faults in an electronic circuit. In general, each PTC 90 is a non-linear thermistor that acts akin to a resettable fuse and cycles back to a conductive state after a current is removed, acting like a circuit breaker. An exemplary embodiment of the circuit board subassembly 84 is described in more detail with respect to FIG. 2. As further described with respect to FIG. 2, the circuit board subassembly 84 combines functions that previously required numerous modules or control devices into a single, efficient connector assembly 50. Additionally, the connector assembly 50 may be installed in-line upstream of loads, thereby eliminating the need for remotely located modules or control units.

In order to secure the connector assembly 50 together, the plug subassembly 52 connects to the sensor connector assembly 54, which includes the cap 56.

The mating end 61 of the plug subassembly 52 is recessed about an outer perimeter 92 to allow the mating end 61 to plug into the internal chamber 82 of the housing 74 of the sensor connector subassembly 54 at an opposite end from the circuit board subassembly 84. A latch beam 94 extends over a top of the mating end 61 such that there is a clearance gap 96 between a top surface of the mating end 61 and a bottom surface of the latch beam 94. In this manner, a plug edge 98 of the upper wall 78 of the housing 74 is sandwiched between the top of the mating end 61 and the latch beam 94. As the plug subassembly 52 is slid into the housing 74 in the direction of arrow A, the internal surfaces of the housing slide over the outer perimeter 92 of the mating end 61, while the latch beam 94 slides over the plug edge 98 of the upper wall 78. With continued urging in the direction of arrow A, the latch beam 94 engages ramped latch teeth 100 extending upwardly from the upper wall 78 of the housing 74. With continued urging in the direction of arrow A, the latch beam 94 securely latches or hooks onto the latch teeth 100 and a distal end 102 of the latch beam 94 is stopped from further movement in the direction of arrow A by latch stops 104 upwardly extending from the upper wall 78 (additionally, the front end of the housing 74 abuts into a perimetric rim 105 of the main body 58, thereby preventing further movement). The latch beam 94 securely latches the plug subassembly 52 to the sensor connector subassembly 54.

While the latch beam 94 is shown on an upper portion of the plug subassembly 52, additional latch beams may be used. For example, the latch beam 94 may be on an underside and/or lateral portions of the plug subassembly (and latch teeth 100 and latch stops 104 may be formed on the housing 74 accordingly) in addition to, or in place of the top surface. Moreover, the housing 74 may include more or less latch teeth 100 than shown. Further, the housing 74 may include more or less latch stops 104. For example, the latch stop may simply be a single bar extending upwardly from the upper wall 78. Optionally, the housing 74 may not include latch stops 104. Additionally, instead of a latching mechanism, the plug subassembly 52 may include tabs, and the housing 74 may include slots, or vice versa, and the plug assembly 52 may snapably secure to the housing 74. Additionally, instead of a latching member, the plug subassembly 52 may secure to the housing 74 through an interference fit, for example. In other words, the plug subassembly 52 may secure to the housing 74 through a wide variety of securing configurations that are not shown or explicitly described.

As noted above, the circuit board subassembly 84 is slid into the internal chamber 82 of the housing 74 in the direction of arrow A. The circuit board subassembly 84 may be slid into channels, slots, grooves, or the like and may be secured within the internal chamber 82 through a variety of securing configurations. Once the circuit board subassembly 84 is secured within the internal chamber 82, the cap 56 may be urged into the internal chamber in the direction of arrow A. Much like the mating end 61, the outer perimeter 106 of the wire seal 68 is smaller than the internal perimeter 108 of the seal end 110 of the housing 74. The outer perimeter 106 of the wire seal 68 is configured to sealingly mate and engage into the seal end 110 of the housing 74, providing a sealing interface therebetween. The main portion of the cap 56 fits over the seal end 110, while an internal stop abuts into the outer edges 112 of the seal end 110, thereby preventing the cap 56 from being further urged into the housing 74.

The plug subassembly 52 may be configured to be securely and latchably connected to the sensor connector subassembly 54. The circuit board subassembly 84 may be securely connected within the housing 74. Electrical contacts or wires that pass into the openings 72 and the cavities 66 may connect to one another or other components within the connector assembly 50. The contacts or wires may pass over or around the components of the circuit board subassembly 84, for example.

The connector assembly 50 provides multiple functions including safe-connect (for example, an interlock), self-protect (for example, over-voltage and over-current protection) and fault detection. The connector assembly 50 provides resettable over-current and over-voltage protection. The cap assembly 50 may provide integrated fault detection, such as an indication of a non-functioning brake light. As further described below, the connector assembly 50 includes an interlock that prevents power supplied to its circuit outputs if the connector assembly 50 is not properly connected. The connector assembly 50 provides safe handling during connection and disconnection by removing power at the connector assembly 50 output until the connector assembly 50 is properly mated to an electrical system circuit.

While typical resettable over-current protection devices use resettable fusing of the power connection, the connector assembly 50 utilizes PTCs 90, thereby eliminating the need for unreliable fuses.

While the connector assembly 50 is shown including a plug subassembly 52 and a sensor connector subassembly 54 having the cap 56, the connector assembly 50 may include various other subassemblies instead of plug and sensor connector subassemblies. For example, the connector assembly 50 may include a single main housing that retains all of the components noted above. For example, the circuit board subassembly 84 may be retained within a single housing having contact openings at either end.

FIG. 2 illustrates a schematic circuit diagram of the circuit board subassembly 84 of the connector assembly 50 operatively connected to a brake switch circuit 120, according to an embodiment. FIG. 2 illustrates a schematic of a connector circuit board, for example. The circuit board subassembly 84 is electrically connected to the brake switch system 120, 120', 120", or 120" (which is operatively connected to vehicle brakes), ground 122, brake lamps 124, an interlock indicator 126, and a fault indicator 128. The brake switch systems 120, 120', 120", and 120" are shown and described with respect to FIGS. 4, 5, 6, and 7, respectively. The circuit board assembly 84 may be electrically connected to any one of the brake switch systems 120, 120', 120", or 120".

FIG. 3 illustrates an isometric exploded view of a brake switch assembly 130, which includes any one of the brake switch systems 120, 120', 120", or 120", according to an embodiment. The assembly 130 includes a main housing 132 having an internal chamber 134 formed therein. The internal chamber 134 is configured to receive and retain a printed circuit board (PCB) subassembly 136 and a magnet 138. Any one of the brake switch systems 120, 120', 120", or 120" may be secured to, or otherwise part of, the PCB subassembly 136. For example, each of the brake switch systems 120, 120', 120", or 120" may include circuits that are supported on the PCB subassembly 136.

The housing 132 includes a stub nose 140 at a distal end. A ferromagnetic target of a brake pedal assembly, such as the plungor of a brake pedal, may be configured to be proximate the stub nose 140. The PCB subassembly 136 includes a printed circuit board (PCB) 142 that securely supports two Hall devices 144 and 146 proximate a distal end 148 that is configured to be secured proximate to the stub nose 140 of the housing 132. The PCB subassembly 136 also supports electrical components 150, such as capacitors, diodes, resistors, and the like, as well as an electromechanical relay 152.

The magnet 138 may be a U-shaped magnet. The magnet 138 may be secured in the housing 132 proximate the distal end 148 of the PCB subassembly 136 such that the Hall devices 144 and 146 are positioned within an internal gap 154 defined between opposed posts 156 and a cross-beam 158. While the magnet 138 is shown as a U-shaped magnet, the size and shape of the magnet 138 may be various other shapes and sizes. For example, the magnet 138 may be a bar magnet positioned proximate the Hall device 144 and 146.

After the PCB subassembly 136 is secured within the housing 132, such as through soldering, and the magnet 138 is secured with respect to the Hall devices 144 and 146, a cover 160, which may include potting material, for example, may be securely housed within the PCB 136. Optionally, the cover 160 may include, or be formed of, metal, plastic, elastomeric materials, and the like. The cover 160 ensures that the PCB 136 is securely and safely contained within the housing 132.

The magnet 138 and Hall devices 144 and 146 may be secured at a distal end 148 of the PCB subassembly 136, which is located proximate the stub nose 140 of the housing 132. In this manner, as a brake pedal that includes a ferromagnetic target or plungor that moves away from the stub nose 140, the Hall devices 144 and 146 detect the changing magnetic field and switch ON or OFF in response. For example, the Hall device 144 that is operatively connected to the cruise control module may turn OFF. For example, switch from a high output to a low output, (thereby deactivating the cruise control), while the Hall device 146 that is operatively connected to the brake lights may turn ON, for example, switch from a low output to a high output, (thereby activating the brake lights). As the brake pedal approaches the stub nose 140, such as when a driver releases pressure from the brake pedal, the Hall devices 144 and 146 may switch to their previous states.

Optionally, the system may be configured such that when the brake pedal moves toward the stub nose 140, the Hall devices 144 and 146 switch OFF and ON, respectively. Also, alternatively, the system may be configured such that the Hall device 144 switches ON to deactivate the cruise control, while the Hall device 146 switches OFF to activate the brake lights.

The front Hall device 144 may be closer to the stub nose 140 than the rear Hall device 146. As such, the front Hall device 144 may sense a changing magnetic field before the rear Hall device 146, and/or the Hall devices 144 and 146 may be programmed such that the Hall device 144 switches states before the Hall device 146 switches states.

The front Hall device 144 may be configured to deactivate cruise control, while the rear Hall device 146 may be configured to close and open the relay 152 in order to activate and deactivate brake lights. The cruise control may be deactivated with a slight tap of the brake pedal. With increased pressure on the brake pedal, the rear Hall device 146 then switches to an ON state and the brake lights may be activated. Note, however, that the cruise control may be deactivated with a slight tap of the brake pedal prior to the brake lights being activated, as discussed in more detail below.

Alternatively, the front Hall device 144 may be configured to control the brake lights, while the rear Hall device 146 may be configured to deactivate the cruise control. In this embodiment, the Hall devices 144 and 146 may be programmed to detect predetermined trigger points that are separate and distinct from one another in order to switch states and control their respective functions accordingly.

Also, alternatively, and as noted above, the magnet 138 may be various other shapes and sizes. For example, the Hall devices 144 and 146 may be secured on the PCB 136 in relation to a bar magnet that is positioned in front of, behind, or to the side of the Hall devices 144 and 146. Optionally, the bar magnet may be positioned between the Hall devices 144 and 146. In any embodiment, the Hall devices 144 and 146 may be programmed to switch states at predetermined trigger points (that is, when a change in magnetic field is detected).

Alternatively, instead of using a relay, the brake switch assembly 130 may include a field-effect transistor (FET). The FET is a transistor that relies on an electric field to control the shape and therefore the conductivity of a channel of one type of charge carrier in a semiconductor material. The FET may be a metal-oxide-semiconductor field effect transistor (MOSFET), which may be used to switch electronic signals.

FIG. 4 illustrates a schematic circuit diagram for a brake switch system 120, according to an embodiment. The brake switch system 120 is a brake circuit board that may be housed within the brake switch assembly 130 (such as on the PCB sub-assembly 136). The Hall devices 144 and 146 are supplied with power through a battery 162. If the brake pedal is not depressed, the Hall device 146 may be OFF (for example, outputting a low output). Optionally, the Hall device 146 may be ON (for example, outputting a high output). When the brake pedal is not depressed, the transistor 164 is
Therefore, the output of the Hall device 146 is grounded. In this scenario, the relay 152 is open because the relay 166 is not energized (and therefore unable to switch the relay switch to the closed position).

Similarly, if the brake pedal is not depressed and cruise control is active, the Hall device 144 may be on (for example, high output). Optionally, the Hall device 146 may be off (for example, low output).

However, once the brake pedal is tapped, and assuming cruise control is active, the ferromagnetic target of the brake pedal moving in relation to the magnetic fields 138 and the front Hall device 144 causes a change in the magnetic field. The Hall device 144 is programmed to detect this change and switch states. The voltage output from the Hall device 144 switches from high to low (or low to high, depending on how the system is configured), and a signal is sent to the cruise control module 168 to deactivate the cruise control. The Hall device 144 may be programmed to switch from the ON state to the OFF state when it detects a magnetic field having a threshold strength, which is programmed into the Hall device 144. Optionally, other magnetic field change characteristics may be used to switch the Hall device 144 between states.

The cruise threshold strength may be less than a magnetic field strength that switches the Hall device 146 from an OFF to an ON state (that is, the brake light threshold strength). In this manner, the cruise control may be deactivated with a slight tap of the brake pedal, before the brake lights are activated.

However, with increased pressure on the brake pedal, the Hall device 146 is switched from an OFF state to an ON state, or vice versa, depending on how the Hall device 146 is programmed. That is, the Hall device 146 is programmed to detect a change in magnetic field strength that is different (for example, lower or higher, depending on how the Hall devices 144 and 146 are programmed) than the cruise threshold strength. Optionally, other magnetic field change characteristics may be used to switch the Hall device 146 between ON and OFF states. When the Hall device 146 detects the brake light threshold strength, which is different than the cruise threshold strength, the Hall device 146 switches from an OFF state to an ON state. Therefore, the voltage output from the Hall device 146 is high, and the transistor 164 is activated, thereby energizing the relay 166, which then causes the relay switch 152 to close, and the brake lights 124 to activate.

Again, the Hall devices 144 and 146 switch states depending on a detected change in magnetic field. The Hall device 144 may switch from ON to OFF to deactivate the cruise control, or the Hall device 144 may switch from OFF to ON to deactivate the cruise control. Similarly, the Hall device 146 may switch from OFF to ON to activate the brake lights, or the Hall device 146 may switch from ON to OFF to activate the brake lights. In any case, the switching points that are detected by changes in magnetic field are different for each of the Hall devices 144 and 146. That is, the Hall device 144 switches at a different detected magnetic field characteristic as compared to the Hall device 146.

Once the driver removes his/her foot from the brake pedal, the ferromagnetic target moves toward its at-rest position, and the Hall device 146 returns to the OFF state. Thus, the transistor 164 is deactivated, the relay 152 is opened, and the brake lights 124 are deactivated.

The Hall devices 144 and 146 may be programmed at different magnetic field levels that do not overlap with one another. That is, the point at which the Hall device 144 switches may not be the same as the point at which the Hall device 146 switches. Therefore, the Hall device 144 switches before the Hall device 146 switches, or vice versa, depending on the particular application.

FIG. 5 illustrates a schematic circuit diagram for a brake switch system 120°, according to an embodiment. The brake switch system 120° may be a brake circuit board that may be housed within the brake switch assembly 130 (such as on the PCB sub-assembly 136). The brake switch system 120° is similar to the brake switch system 120° shown in FIG. 4, except that the Hall device 144 is configured to be normally ON when the brake pedal is at rest, and switch OFF when the Hall device 144 detects a threshold to deactivate the cruise control.

FIG. 6 illustrates a schematic circuit diagram for a brake switch system 120°, according to an embodiment. The brake switch system 120° may be a brake circuit board that may be housed within the brake switch assembly 130 (such as on the PCB sub-assembly 136). The brake switch system 120° may include a FET 182.

FIG. 7 illustrates a schematic circuit diagram for a brake switch system 120°, according to an embodiment. The brake switch system 120° may be a brake circuit board that may be housed within the brake switch assembly 130 (such as on the PCB sub-assembly 136). The brake switch system 120° may use the FET 182.

Referring to FIGS. 3-7, as discussed above, the Hall devices 144 and 146 may be programmed such that either or both are ON or OFF when the brake pedal is not engaged. For example, both may be ON, or both may be OFF, while the other is OFF. When the brake pedal is pressed, the Hall devices 144 and 146 detect changes in magnetic field at different points. As such, the Hall devices 144 and 146 will switch at different times, thereby deactivating the cruise control and activating the brake lights at different times (notably, the cruise control will be deactivated before the brake lights are activated). Again, the Hall devices 144 and 146 may be programmed to be ON or OFF and switch accordingly.

Thus, embodiments provide a brake switch assembly that is configured to activate and deactivate brake lights, as well as deactivate cruise control. More generally, embodiments provide a connector assembly having a first Hall device configured to control a first component, and a second Hall device configured to control a second component.

Embodiments provide a non-contacting sensor connector assembly having two separate and distinct switching points.

Embodiments provide a contactless device having a single target, single magnet, and two Hall devices in a single package or connector assembly, in which the Hall devices are configured to switch two separate and distinct components. Each Hall device is programmed to switch at a separate and distinct switching point.

Additionally, the connector assembly may be used to activate and deactivate brake lights, as well as deactivate cruise control and be used in conjunction with the circuit board subassembly 84 to protect against over-current, over-voltage, and detect faults, as explained in U.S. application Ser. No. 13/269,675, entitled “Connector System and Assembly Having Integrated Protection Circuitry”, filed Oct. 10, 2011, which claims priority to U.S. Provisional Application No. 61/455,107, entitled “Intelligent Connector System,” filed Oct. 14, 2010, and U.S. Provisional Application No.
61/537,845, entitled “Intelligent Brake Switch System,” filed Sep. 22, 2011, all of which are incorporated by reference in their entireties.

[0076] Referring again to FIG. 2, the brake switch circuit 120, 120', 120", or 120"" is electrically connected to two parallel PTCs 190 and 192. While two parallel PTCs 190 and 192 are shown, more or less PTCs may be used, depending on the desired current rating. For example, the circuit may include only one PTC, or it may include three, four, or more PTCs. With two PTCs 190 and 192, the current is split up among both PTCs 190 and 192. As such, the two PTCs 190 and 192 provide a higher current rating, than if only one PTC were used. Additional parallel PTCs increase the current rating.

[0077] In general, the PTCs 190 and 192 allow a certain amount of current to pass therethrough. For example, each PTC 190 and 192 may allow 5 A of current to pass therethrough (for a total of 10 A). However, once the current passing through the PTCs 190 and 192 exceeds that threshold, the PTCs 190 and 192 act to provide an open circuit. Thus, as shown in FIG. 2, when current is below the current threshold, the current flows from the brake switch system 120, 120', 120", or 120"" through the PTCs 190 and 192, and to the load, in this case, the brake lamps 124. In other words, when functioning properly, when a driver engages the brakes, current flows from the brake switch system (such as any of brake switch systems 120, 120', 120", or 120""") through the PTCs 190 and 192, and onto the brake lamps 124.

[0078] However, when current above a particular current threshold flows to the PTCs 190 and 192, the PTCs 190 and 192 trip, and the resistance increases exponentially. Accordingly, the PTCs 190 and 192 restrict the current flow, and allow only a very small amount of current to pass through the PTCs 190 and 192 to the brake lamps 124. As an example, when the PTCs 190 and 192 are tripped by the over-current condition, the resistance of the PTCs 190 and 192 increases rapidly to greater than 1 MOhm. Using V=IR, 12 Volts/1 MOhm yields 12 microamps of current passing therethrough. In this manner, the PTCs 190 and 192 protect against over-current flowing to the brake lamps 124. Thus, embodiments provide over-current protection to the load.

[0079] Once the current falls below the current or short threshold, the PTCs 190 and 192 automatically reset and allow current to pass therethrough, instead of acting as super-resistors. Therefore, the circuit adapts to changing circumstances, and is automatically reseatable.

[0080] With respect to over-voltage, a Zener diode 198 is a special kind of diode that allows current to flow in the forward direction, just as an ideal diode, but will also permit current to flow in the reverse direction when the voltage is above a certain value (a breakdown voltage).

[0081] In terms of over-voltage protection, relay switch 200 is in a normally-closed position (that is, current can flow therethrough into the load, such as the brake lamps 124), as shown in FIG. 2. In this position, the relay coil 219 is not energized, and therefore does not move the relay switch 200 from the closed position to the open position.

[0082] When the relay switch 200 is in the closed position, current is able to flow from the brake switch system 120, 120', 120", or 120"" through the PTCs 190 and 192, and then through the closed relay 200 into the brake lamps 124. At the same time, the Zener diode 198 prevents current from flowing therethrough. Instead, current passes from the PTCs 190 and 192 to the relay switch 200 and into the brake lamps 124.

[0083] The Zener diode 198 continues to block current from passing therethrough, until the Zener diode 198 reaches a preset breakdown voltage (for example, 28V). However, once the Zener diode 198 reaches the breakdown voltage, for example, a voltage spike, then the Zener diode 198 breaks down, and allows current to pass through the diode 196, and to ground 122. In this manner, current flows from the PTCs 190 and 192 and through the relay coil 219, thereby energizing the relay coil 219, which then magnetically attracts the relay switch 200 from the closed position to an open position, thereby preventing current from flowing to the brake lamps 124. In this manner, the brake lamps 124 are protected from an over-voltage condition that could cause damage.

[0084] When the voltage at the Zener diode 198 falls back below the breakdown voltage, the Zener diode 198 blocks current from flowing therethrough, and current stops flowing to the relay coil 219, so that the relay coil 219 is no longer energized. The relay switch 200 then moves back to the closed position and current flows to the brake lamps 124. In this manner, the circuit automatically resets, and adapts to changing circumstances.

[0085] Notably, however, when switching between closed and open positions, the relay switch 200 experiences a certain amount of time lag. For example, the relay switch 200 may take 3-10 milliseconds to move from closed to open positions. During this time, in order to prevent a voltage spike from damaging the break lamps 124, a metal oxide varistor (MOV) may be connected between the relay switch 200 and the brake lamps 124 to ground 122. The MOV may include a bulk semiconductor material (such as sintered granular zinc oxide) that can conduct large current when presented with a voltage above its rated voltage. The MOV may be configured to limit voltages to about three to four times the normal circuit voltage by diverting surge current to ground 122 instead of the protected load (such as the brake lamps 124).

[0086] The MOV acts much faster than the relay coil 219 and the relay switch 200. Thus, if the relay switch 200 is starting to open, but is not fast enough to prevent a current spike from passing therethrough in the short time it takes the relay switch 200 to open, the MOV trips and current flow is shunted away from the brake lamps 124, into the MOV, and to ground 122. In essence, the MOV provides similar protection to the brake lamps 124 as the relay switch 200, but the MOV reacts much faster. Thus, in the short period of time it takes the relay switch 200 to open, the MOV trips and diverts the current spike to ground 122. After the relay switch 200 opens, the MOV resets and no longer diverts the current spike to ground 122. Thus, the MOV provides over-voltage protection during the 3-10 millisecond time frame that it takes the relay switch 200 to open.

[0087] As explained above, when the voltage at the Zener diode 198 falls below the breakdown voltage, the Zener diode 198 acts to close the relay switch 200 so that current may flow to the brake lamps 124. Similarly, when current flowing through the PTCs 190 and 192 falls below the current threshold at which the PTCs 90 and 92 restrict current, the current simply passes through the PTCs 190 and 192, through the closed relay switch 200, and into the brake lamps 124.

[0088] Additionally, in a situation where jumper cables are being used to restart a battery or cable heads are reversed, the circuit board subassembly 84 provides protection from an improper connection in which power is supplied to ground, and ground is supplied power. In this situation, current will flow from ground 122 (again, power is improperly supplied at
this point) to diode 194 (note, current is blocked by diode 196). The current will then flow through the Zener diode 198, which then energizes the relay coil 219, which, in turn, moves the relay switch 200 from the closed position to an open position, thereby providing reverse battery protection. As such, current will not flow to the brake lamps 124. In this manner, the brake lamps 124 are protected from an improper jumper cable connection.

[0089] With respect to the brake light fault detection, the brake switch system 120, 120', 120", or 120"' and the PTCs 190 and 192 are electrically connected to resistors 204 and 206. A microcontroller 208 (for example, a processor, integrated circuit, or the like) having a comparator, for example, is electrically connected between the resistors 204 and 206. Resistors 204 and 206 form a voltage divider of input voltage to the PTCs 190 and 192, as do resistors 210 and 212. The voltage drop across the PTCs 190 and 192 is used as inputs to a comparator within the microcontroller 208. If the voltage threshold is exceeded, transistor 218 is turned on, as discussed below. Note, the transistor 224 is used in conjunction with Zener diode 226 as the power supply for the microcontroller 208.

[0090] The microcontroller 208 is also electrically connected to the fault indicator 128 through a transistor 218. Additionally, the PTCs 190 and 192 are also electrically connected to the microcontroller 208 through the junction of resistors 210 and 212 and resistors 204 and 206, with resistors 212 and 206 being connected to ground 122. In this manner, the voltage drop across the PTCs 190 and 192 is differentially measured by the microcontroller 208. That is, the voltage at point 214 (before current flows into the PTCs 190 and 192), and the voltage at point 216 (after current flows through the PTCs 190 and 192) are measured by the microcontroller 208. As such, if the microcontroller 208 determines that there is a difference in current flow/voltage drop between points 214 and 216, then the microcontroller 208 may activate the fault indicator 128 (which is connected to a visual or audio signal within the vehicle) to alert an operator that there is a brake light fault.

[0091] For example, the microcontroller 208 may determine the voltage difference between the points 214 and 216 (again, V=IR). If the difference between the voltages at points 214 and 216 is too great (for example, the voltage drop across PTCs 190 and 192 is greater than an acceptable amount), then the microcontroller 208 determines that there is too much current flowing through the PTCs 190 and 192, and a fault within the circuit is present. Notably, the PTCs 190 and 192 are used as shunt resistors. During a manufacturing or calibration process, an acceptable voltage drop across the PTCs 190 and 192 (acting as a shunt resistor) is stored in the microcontroller 208. If the microcontroller 208 measures a substantially lower or higher voltage drop (as compared to the acceptable voltage drop) across the PTCs 190 and 192, the microcontroller 208 determines that one or more bulbs of the brake lights are out and will then turn on the fault indicator 128. In either case, the microcontroller 208 may activate the fault indicator 128 (which may be a light-emitting diode (LED), for example, or any other such light emitting device) by turning on the transistor 218, which is electrically connected to the fault indicator 128. If the transistor 218 is off, then the fault indicator 128 is not active, because the transistor 218 is not connected to ground 122. Once the microcontroller 208 determines that the voltage drop is within an acceptable range, the microcontroller 208 turns off the transistor 218, and the fault indicator 128 is deactivated.

[0092] If the difference between the voltages at points 216 and 214 is at a predetermined reference voltage range, the microcontroller 208 does not activate the fault indicator 128. Instead, the circuit operates normally.

[0093] As noted, the fault indicator 128 may be any device capable of emitting a visual or audio signal. The fault indicator 128 may be an LED within a dashboard of a vehicle. Optionally, the fault indicator 128 may be a standard light bulb, digital read-out, or the like. Additionally, the fault indicator 128 may be a speaker that emits an audio signal such as a buzzing sound, or a prerecorded voice message.

[0094] As an additional example, a vehicle may have multiple brake lights. For example, each brake light assembly may include three separate and distinct light bulbs. Thus, when a driver steps on the brake, a certain amount of current will flow to the three light bulbs. For example, when lit up, a brake light bulb may have 2 A flowing therethrough. Thus, if the brake light assembly includes three light bulbs, when a driver steps on the brake pedal, there should be a total of 6 A flowing through the brake light assembly. The microcontroller 208 determines the voltage at the PTCs 190 and 192 that is correlated to the normal state of 6 A flowing through the three bulbs of the brake light assembly.

[0095] If one of the bulbs is out, however, then there will only be 4 A flowing through the brake light assembly. In this case, the microcontroller 208 detects a fault, namely, that only two of three bulbs are functioning. Therefore, the microcontroller 208 may intermittently activate the transistor 218 to activate the fault indicator 128 in order to alert the driver of this condition. For example, the fault indicator may flash at a first rate. If the microcontroller 208 detects that only one of three bulbs are functioning (for example, 2 A flowing through the brake light assembly), the microcontroller 208 may activate the fault indicator 128 at a second rate that is faster than the first rate. For example, the fault indicator 128 may flash at a double-time rate. If the microcontroller 208 detects that no current is flowing through the brake light assembly, based on the voltage measured at points 214 and 216 of the PTCs 190 and 192, then the microcontroller 208 will activate the fault indicator 128 so that it is simply on (that is, a fault indicating device connected to the switch 188 constantly emits a steady light or signal).

[0096] Additionally, the circuit is configured to detect whether the connector assembly 50 (shown in FIG. 1) is properly connected. When the plug subassembly 52 is properly mated with sensor connector subassembly 54, the interlock pin 116 is pulled to ground 112. If, however, the connector assembly 50 is not properly mated, the interlock pin 126 will not be grounded. Therefore, the transistor 221 will remain on, thereby allowing current to flow through the relay coil 219. Accordingly, the relay coil 219 will be energized and move the relay switch 200 to the open position.

[0097] Referring to FIGS. 1 and 2, once the plug subassembly 52 is properly connected to the sensor connector subassembly 54 (which includes the cap 56), the interlock pin 126, which may be in the sensor connector subassembly 54, will mate with a reciprocal structure in the plug subassembly 52 and be grounded. That is, when the interlock pin 126 within the sensor connector subassembly 54 is fully mated with a reciprocal pin, for example, in the plug subassembly 52, the interlock pin 126 becomes a ground.
However, when the plug subassembly 52 is not mated, or improperly mated, with the sensor connector subassembly 54, the interlock pin 126 will not mate with the reciprocal structure within the plug subassembly 52. Thus, if the brake switch system 120, 120', 120", or 120" closes during the non-connected or improperly connected state, current will not flow to the PTCs 190 and 192, or to the pull-up resistor 222. With no current flowing to ground 122, the transistor 221 will remain ON, thereby providing a path to ground 122. Notably, the transistor 221 also connects to the relay coil 219. Accordingly, the relay coil 219 is then energized, which then causes the relay switch 200 to open. Because the voltage is below the breakdown voltage, the Zener diode 198 blocks current from flowing therethrough. Therefore, when the interlock pin 126 is not mated, the transistor 221 will be on, and current will flow through the PTCs 190 and 192, into the relay coil 219, into the transistor 221 and to ground 122, but not through the Zener diode 198. As long as the transistor 221 is on, there will be no power to the brake lamps 124.

However, when the interlock pin 126 is fully connected, the interlock pin 126 is grounded, and no current flows to the transistor 221. Thus, the transistor 221 turns off, the relay coil 219 is no longer energized, and the relay switch 200 moves to the closed position. Thus, the interlock pin 126 is configured to ensure that current only flows to the brake lamps 124 when the plug subassembly 52 is properly connected to the sensor connector subassembly 54 (which includes the cap 56). The interlock feature of the connector assembly 50 provides an automatic safety device for handling the assembly 50. That is, when not properly connected, current is not supplied to the brake lamps 124, as discussed above.

While the circuit as shown has the protections discussed above of the PTCs 190 and 192, Zener diode 198, and the relay switch 200, and the fault detection of the fault indicator 128 and microcontroller 208, and the interlock pin 126, the circuit may include less than all of these features. For example, an embodiment may include only the over-current or over-voltage detection circuit, the interlock indication, or just the fault indication circuit. Further, the circuit may include just two of these features.

Certain embodiments of the connector assembly include a circuit assembly as shown in FIG. 2 that may allow the circuit to operate such that under a short circuit condition, the connector assembly 50 may open (that is, not allow current to flow therethrough) the power circuit connection. The circuit stays open until the short circuit fault is remedied and then automatically returns the circuit to normal operation without additional or manual intervention. The over voltage feature provides over-voltage protection from downstream electronic modules, eliminating the need for individual protection.

As noted above, the connector assembly 50 and circuit board subassembly 84 may be used with any of the embodiments of the brake switch system 120, 120', 120", or 120" shown and described with respect to FIGS. 4-7. Indeed, the components of the circuit board subassembly 84 may be housed in the same housing as the brake switch assembly 130. Both circuits 84 and 120 (or 120', 120", or 120") shown in FIG. 2 may be housed in a single structure, such as a connector assembly, single main housing, or the like. Thus, embodiments provide a system for dual-point touchless contact for cruise control deactivation and brake light activation/deactivation, while at the same time protecting the brake lights from damage caused by over-current and over-voltage, for example.

In the exemplary embodiment, the fault detection feature is for a non-functioning brake light. Although, various other fault detection circuits may use the connector system described herein. The connector assembly 50, may include an indicator lamp that is activated to warn of the non-functioning brake light. This module may be a power pass through only for the brake lamps. Power switching is done external through the brake pedal switch circuit and connected to the brake switch system 120, 120', 120", or 120". In other words, the brake switch is the input from the brake pedal so that when the driver activates the brakes, this is the switched line input. The interlock pin or pin 126 is a control input, normally connected to ground externally so that if for any reason the connector is separated and the brake switch system 120, 120', 120", or 120" has power, the transistor 221 will energize the relay coil 219 causing the relay switch 200 to switch from the normally closed state to the normally open state, removing power from the brake lamps 124 to protect from arcing.

Thus, embodiments provide a smart connector system that is configured to protect against over-current and/or over-voltage to a load (such as brake lights), while at the same time providing a more efficient and reliable brake switch system. Embodiments also provide a smart connector system configured to automatically detect faults within the system. Moreover, embodiments provide a connector system configured to determine whether the connector is properly mated and connected. Embodiments may provide a connector system performing more than one of these features. For example, embodiments may provide a connector system that performs all of these functions.

It is to be understood that the above description is intended to be illustrative, and not restrictive. For example, the above-described embodiments (and/or aspects thereof) may be used in combination with each other. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the various embodiments of the disclosure without departing from their scope. While the dimensions and types of materials described herein are intended to define the parameters of the various embodiments of the disclosure, the embodiments are by no means limiting and are exemplary embodiments. Many other embodiments will be apparent to those of skill in the art upon reviewing the above description. The scope of the various embodiments of the disclosure should, therefore, be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. In the appended claims, the terms “including” and “in which” are used as the plain-English equivalents of the respective terms “comprising” and “wherein.” Moreover, in the following claims, the terms “first,” “second,” and “third,” etc. are used merely as labels, and are not intended to impose numerical requirements on their objects. Further, the limitations of the following claims are not written in means-plus-function format and are not intended to be interpreted based on 35 U.S.C. §112, sixth paragraph, unless and until such claim limitations expressly use the phrase “means for” followed by a statement of function void of further structure.

This written description uses examples to disclose the various embodiments of the disclosure, including the best mode, and also to enable any person skilled in the art to practice the various embodiments of the disclosure, including
making and using any devices or systems and performing any incorporated methods. The patentable scope of the various embodiments of the disclosure is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if the examples have structural elements that do not differ from the literal language of the claims, or if the examples include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

1. A system, comprising:
   a brake pedal having a ferromagnetic target;
   a main housing that securely retains a brake circuit board and a magnet, wherein the brake pedal is proximate a portion of the main housing, the brake circuit board comprising:
   a first Hall device proximate the magnet, wherein the first Hall device is configured to switch in relation to a first magnetic field threshold; and
   a second Hall device proximate the magnet, wherein the second Hall device is configured to switch in relation to a second magnetic field threshold, and wherein the first magnetic field threshold differs from the second magnetic field threshold;
   a plug connector subassembly;
   a sensor connector subassembly that is selectively connectable to the plug connector subassembly; and
   a connector circuit board secured within the sensor connector subassembly and in communication with the brake circuit board, the connector circuit board comprising:
   at least one positive temperature coefficient (PTC) device electrically connected between the brake circuit board and at least one brake lamp; and
   a circuit to protect against over-voltage or over-current to the at least one brake lamp, detect a fault condition, and determine whether the plug connector subassembly is properly connected to the sensor connector subassembly.

2. The system of claim 1, wherein the connector circuit board further comprises:
   a relay switch connected between the at least one PTC and the at least one brake lamp, wherein the at least one PTC restricts current from flowing to the relay switch when current at the at least one PTC exceeds a current threshold; and
   a Zener diode connected to a relay coil, wherein the Zener diode is configured to allow current to pass to the relay coil when the Zener diode experiences a breakdown voltage, thereby energizing the relay coil to move the relay switch from a closed to an open position.

3. The system of claim 2, further comprising a metal oxide varistor (MOV) electrically connected between the relay switch and the load.

4. The system of claim 1, wherein the connector circuit board further comprises a microcontroller electrically connected to a fault indicator.

5. The system of claim 4, wherein the microcontroller monitors a voltage difference across the at least one PTC to determine whether to activate the fault indicator.

6. The system of claim 4, wherein the fault indicator comprises one or more of a visual or audio indicator.

7. The system of claim 1, wherein the connector circuit board further comprises an interlock circuit having an interlock pin, wherein the interlock circuit prevents current from flowing to the at least one brake lamp when the plug subassembly is not properly connected to the sensor connector subassembly.

8. The system of claim 7, further comprising a transistor electrically connected to the interlock pin, wherein the transistor is on and connected to ground when the plug connector subassembly is not properly connected to the sensor connector subassembly, and wherein the transistor is off and not connected to ground when the plug connector subassembly is properly connected to the sensor connector subassembly.

9. The system of claim 1, wherein the at least one PTC comprises at least two PTCs connected in parallel.

10. The system of claim 1, wherein the protection against over-current or over-voltage is automatically resettable without manual intervention.

11. The system of claim 1, wherein the magnet is a U-shaped magnet having opposed posts connected by a cross beam, wherein the opposed posts and the cross beam define an internal gap, and wherein the first and second Hall devices are positioned within the internal gap.

12. The system of claim 1, wherein the first Hall device is operatively connected to a control module, and wherein the first Hall device switches to deactivate control of the brake control module.

13. The system of claim 1, wherein the second Hall device is operatively connected to the connector circuit board, and wherein the second Hall device switches to control activation and deactivation of the at least one brake lamp.

14. The system of claim 13, wherein the brake circuit board further comprises a relay electrically connected between the second Hall device and the at least one brake lamp.

15. The system of claim 13, wherein the brake circuit board further comprises a field-effect transistor (FET) electrically connected between the second Hall device and the at least one brake lamp.

16. The system of claim 1, wherein a magnetic field of the magnet changes when the ferromagnetic target moves relative to the magnet.

17. The system of claim 1, wherein the first and second magnetic field thresholds are first and second magnetic field strength thresholds.

18. A system comprising:
   a brake circuit board comprising:
   a first Hall device proximate a magnet, wherein the first Hall device is configured to switch in relation to a first magnetic field threshold; and
   a second Hall device proximate the magnet, wherein the second Hall device is configured to switch in relation to a second magnetic field threshold, and wherein the first magnetic field threshold differs from the second magnetic field threshold;
   a connector circuit board secured within the sensor connector subassembly and in communication with the brake circuit board, the connector circuit board comprising:
   at least one positive temperature coefficient (PTC) device electrically connected between the brake circuit board and at least one brake lamp; and
   a circuit to protect against over-voltage or over-current to the at least one brake lamp, detect a fault condition, and determine whether the plug connector subassembly is properly connected to the sensor connector subassembly.
19. A circuit system, comprising:

- a first Hall device proximate a magnet, wherein the first Hall device is configured to switch in relation to a first magnetic field threshold;
- a second Hall device proximate the magnet, wherein the second Hall device is configured to switch in relation to a second magnetic field threshold, and wherein the first magnetic field threshold differs from the second magnetic field threshold;

at least one positive temperature coefficient (PTC) device electrically connected to at least one brake lamp; and

at least one circuit to protect against over-voltage or over-current to the at least one brake lamp, detect a fault condition, and determine whether the plug connector subassembly is properly connected to the sensor connector subassembly.

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