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### Driver and diagnostic system for a brake controller

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#### Abstract

A brake control unit includes a processor, a first high side driver and a second high side driver. The processor sends signals to the first high side driver and the second high side driver. The first and second high side drivers process the signals independent of each other. The processor diagnoses faults and locations of faults based on feedback from the high side drivers. The first high side driver controls the braking of a first trailer brake. The second high side driver controls the braking of a second trailer brake.

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## **Background/Summary**

CROSS-REFERENCE TO RELATED APPLICATION (1) This application is a continuation of U.S. patent application Ser. No. 15/707,267, filed on Sep. 18, 2017, and entitled “DRIVER AND DIAGNOSTIC SYSTEM FOR A BRAKE CONTROLLER,” which claims the benefit of U.S. Provisional Patent Application Ser. No. 62/395,439, filed on Sep. 16, 2016 and entitled “FET AND DIAGNOSTIC SYSTEM FOR A BRAKE CONTROLLER,” and U.S. Provisional Patent Application Ser. No. 62/395,444, filed on Sep. 16, 2016 and entitled “TRAILER BRAKE CONTROLLER WITH ASYMMETRIC BRAKING SIGNALS,” the entireties of which are all incorporated herein by reference.

### **FIELD OF THE INVENTION**

(1) The present invention relates generally to brake control units, and more specifically, to a system for diagnosing the existence of a short within an electrical system associated with the brake control unit.

### **BACKGROUND OF THE INVENTION**

(2) A variety of prior art brake control units that provide a brake output signal to the brakes of a towed vehicle have been proposed and/or manufactured. One example of such a brake control unit is provided by U.S. Pat. No. 8,746,812 which is incorporated by reference in its entirety.

(3) In the instance when a short or other fault occurs, many systems associated with the towing, towed vehicle, or brake control unit, may cause the unit to disable itself or will shut down or otherwise cause a potentially undesirable situation. And, if an error occurs in the brake control unit or between the communication of the brake control unit and the towing vehicle, most systems do

not have a way of notifying the operator independent of the brake control unit or storing the error for a technician's review thereof.

(4) Most current brake control units are not integral with the towing vehicle's instrument panel. They are aftermarket units which may not be able to communicate with and communicate over existing systems within the towing vehicle. For example, these units may not be able to warn an operator of an error through the towing vehicle's current warning systems. Further, they may be unable to operate with the rest of the displays on the towing vehicle's instrument panel.

(5) Vehicle manufacturers continue to develop and market vehicles' rated towing capacities. As these towed loads increase, the need for systems to ensure safe towing operations also increases, particularly in the area of sway control.

(6) Generally speaking, trailers and other towed apparatus are designed to carry heavy cargo, with loads possibly even exceeding the weight of the towing vehicle itself. In such scenarios, even distribution of the weight—which is often born by the rear axle of the towing vehicle via any known number of connections or hitches—is essential to the safe operation of the towing vehicle (e.g., steering, braking, etc.). If the weight is not properly distributed, if the cargo is unevenly distributed within the towed apparatus, and/or if environmental conditions exist (e.g., crosswinds, winding roads, uneven or rough driving surfaces, etc.), unwanted and potentially dangerous sway (i.e., lateral or side-to-side movement of the trailer with respect to the towing vehicle) may result.

(7) Excessive sway between the vehicle and towed apparatus may cause the towing vehicle to lose effective steering or braking, thereby creating a safety hazard for vehicle passengers, towed cargo, and the surrounding environment, including pedestrians, roadside structures, and other vehicles. Unwanted, dangerous sway may be further exacerbated as vehicle speed increases. Such lateral movement of the towed apparatus may transfer sufficient side-to-side and lateral forces to the towing vehicle to cause the driver to lose control of the towing vehicle.

(8) Past methods and apparatus for controlling sway focused on extra-vehicular equipment. These past efforts usually relied upon mechanical structures, such as spring arms, attached to the vehicle with additional brackets and/or friction pads connected to the towed apparatus. Installation of the system must be performed in concert with whatever connection mechanism (e.g., ball hitch, coupler, etc.) that might be used to actually tow the trailer. In operation, these systems effectively provide mechanical-based resistance, via friction and/or tension, to minimize and control sway before the movement becomes unmanageable, although certain arrangements prevent the driver from being able to move in reverse when the sway controller is engaged. As these systems age, they are subject to wear, thereby requiring inspection, maintenance, and the eventual replacement of the sway control unit. An example of such a system is described in U.S. Pat. No. 8,186,702.

(9) Generally, brake control units have been unable to provide sufficient diagnostic capabilities related to the brake control system. Thus, it may be desirable to provide a brake control system and method for improving the diagnostic capability of the system to identify the location of a fault or short within the electrical system of the towing or towed vehicle. Further, it may be desirable to provide the capability to report the instance of a fault or short as well as report on the location of the fault or short within a brake control system.

(10) In further view of these shortcomings, a solution that did not involve extraneous equipment that must be installed separately from the existing vehicle towing apparatus would be welcome. In the same manner, a sway control that is not as prone to wear and failure as the aforementioned mechanical devices is needed. Finally, to the extent past sway controllers relying on mechanical actions/friction are not as ubiquitous and familiar to drivers as vehicle braking systems (which drivers are more likely to understand must be periodically inspected and replaced), a sway control that relies upon familiar components that are already known and inherent to towing operations would be useful.

## SUMMARY OF THE INVENTION

(11) A disclosed brake control unit includes a processor, a first driver, and a second driver, wherein

the processor is coupled to the first driver and the second driver. The first driver comprises a power device connect in series to the second driver. The processor operatively provides a first signal to the first driver and a second signal to a second driver. The brake control unit includes at least one output that operatively transmits a signal to be sent to a towed vehicle brake in response to a brake control signal sent from the processor. The signal sent from the output represents at least one of a first signal provided by the first driver, a second signal provided by the second driver, or a third signal provided by a combination of the first high side device and the second driver. The processor receives feedback from at least one of the first driver or second high side drive and determines whether a fault exists. The processor determines a location of the fault that may be a short.

(12) Another disclosed brake control unit includes a processor, a power device, and a driver electrically connected to the power device in series. The brake control unit provides an output signal to a brake line, wherein the output signal represents at least one of a first signal provided by the power device, a second signal provided by the driver, and a third signal provided by a combination of the power device and the driver, wherein the first, second, and third signal may be related to an operating condition of an electrical system of the towed vehicle, towing vehicle and brake control unit, wherein the processor receives feedback from at least one of the power device or driver to identify a short or fault and location of the short or fault. The processor operatively transmits at least one test signal to at least one of the power device or the driver. The test signal comprises a first step function representative of a drive signal processed by the power device and a second step function representative of a drive signal processed by the driver. The first step function and the second step function can be cyclically applied at different times, overlapping times, at different magnitudes, or overlapping magnitudes.

(13) Another disclosed brake control unit includes a processor, a first high side driver and a second high side driver, wherein the processor is coupled to the first high side driver through a first connection and the second high side driver through a second connection, and wherein the processor generates a first signal to be applied to the first connection in order to induce braking in at least one first brake of a towed vehicle, and generates a second signal to be applied to the second connection in order to induce braking in at least one second brake of the towed vehicle. The processor determines whether to apply the first signal and the second signal asynchronously. The processor determines to apply the first signal and the second signal asynchronously based on identifying at least one of a brake lock condition, swaying, back-up, or slippage of a vehicle.

(14) These and other features, advantages, and objects of the present invention will be further understood and appreciated by those skilled in the art by reference to the following specification, claims, and appended drawings.

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## Description

### DESCRIPTION OF THE DRAWINGS

(1) Objects and advantages together with the operation of the present teaching may be better understood by reference to the following detailed description taken in connection with the following illustrations, wherein:

(2) FIG. 1 is a schematic diagram of a brake control system in accordance with the present disclosure;

(3) FIG. 2 is an electrical block diagram of the brake control system according to an embodiment of the present disclosure;

(4) FIG. 3A is a graph of an input signal representative of the brake control system of the present embodiment;

(5) FIG. 3B is a graph of a variety of signals representative of the brake control system of the present embodiment.

- (6) FIG. 4 is a schematic illustration of the independent braking circuits according to certain embodiments of the invention;
- (7) FIG. 5 is a block diagram of certain embodiments of the invention illustrating independently controlled, primary and secondary brake circuits;
- (8) FIG. 6 is an electrical schematic of one embodiment of the primary and secondary field effect transistor (FET) drives. The text included in this figure is incorporated as fully written in the body of this specification; and
- (9) FIG. 7 is an exemplary method for controlling the trailer brakes and diagnostics of a brake control unit.

#### DETAILED DESCRIPTION

(10) Reference will now be made in detail to exemplary embodiments of the present teachings, examples of which are illustrated in the accompanying drawings. It is to be understood that other embodiments may be utilized and structural and functional changes may be made without departing from the respective scope of the present teachings. As such, the following description is presented by way of illustration only and should not limit in any way the various alternatives and modifications that may be made to the illustrated embodiments and still be within the spirit and scope of the present teachings.

(11) As used herein, the words “example” and “exemplary” mean an instance, or illustration. The words “example” or “exemplary” do not indicate a key or preferred aspect or embodiment. The word “or” is intended to be inclusive rather than exclusive, unless context suggests otherwise. As an example, the phrase “A employs B or C,” includes any inclusive permutation (e.g., A employs B; A employs C; or A employs both B and C). As another matter, the articles “a” and “an” are generally intended to mean “one or more” unless context suggests otherwise.

(12) The brake control unit and system described herein relies upon asymmetric braking. In operation, this means that the controller will, under selected conditions, provide independent braking signals to each of the brake units it is controlling. In most applications, this means that a trailer having, for example, one axle will receive two separate braking signals—one for the passenger-side wheel and one for the driver-side wheel—on that trailer. Although the separate signals will usually be equivalent, the signals produced by the brake control unit will be different under conditions like sway or a desire by the driver to execute special maneuvers (e.g., small radius turns). The difference in the signals will depend upon the conditions, and the trailer brake control unit may incorporate sensors and/or user inputs that are used to calculate the separate, asymmetric signals.

(13) Disclosed is a brake control system and brake control method. The brake control system may include a brake control unit that generates an output signal to the brakes of a towed vehicle directly related to a variety of input signals sent from the towing vehicle, the towed vehicle, the operator, or a combination of any of the three. An embodiment of the present disclosure is directed to a method for diagnosing the existence of a short or fault within the braking electric system of a towed vehicle. The method comprises providing a brake control unit with a power device and a driver, receiving a first signal through the power device, receiving a second signal through the driver, and processing the first and second signal through a processor to identify if a short or fault exists internally or externally from the brake control unit.

(14) According to yet another embodiment of the present disclosure, a brake control unit comprises a processor, a driver, and a power device. The power device may be electrically connected to the driver in series. The brake control unit provides an output signal to a brake line. The output signal represents at least one of a first signal provided by the power device, a second signal relating to the driver, and a third signal relating to a combination of the power device and the driver. The first, second, and third signal may be related to an operating condition of an electrical system of the towed vehicle, towing vehicle, and brake control unit.

(15) In an aspect, a brake control system for a towed vehicle, e.g., a trailer. The brake control

system may include a brake control unit that generates an output signal to the brakes of the towed vehicle to apply a certain brake load thereto. The output signal may be related to a variety of input signals received by the brake control unit from the towing vehicle, the towed vehicle, the operator, or any combination of the three. Additionally, the brake control unit may have the capability of providing diagnostic information related to the existence of a short or fault located within the electrical system of the towed and towing vehicles. Additionally, the brake control system may have the capability of providing diagnostic information related to the location of the short or fault and whether the short or fault is located within the electrical system of the towed and towing vehicles or within the brake control unit. This information can assist an operator or a service technician in diagnosing a location of the fault or short within the system.

(16) The present brake control unit can be an original equipment manufactured (OEM) unit that is installed in the towing vehicle at the factory. Alternatively, the trailer brake control unit can be incorporated into the towing vehicle as an after-market component. The brake control unit can be installed in the dashboard of the towing vehicle, much like a car radio is. In either embodiment, the trailer brake control unit is integrated with the towing vehicle as an electronic control device that provides variable braking power to electric brakes on a vehicle towed by the towing vehicle.

(17) More specifically, the brake control unit generates and applies a particular voltage to the brakes of the towed vehicle so as to apply a brake load to slow-down or stop the towed vehicle. The voltage applied is related to the input signals available on and/or from the towing vehicle, among other available inputs. These additional input signals may come directly from the operator of the towing vehicle, from the towed vehicle, or a combination of any of the three.

(18) The brake control unit may use a variety of preselected or continuously modified algorithms to generate the appropriate output to the towed vehicle brakes based on the received inputs. A processor on the towing vehicle (although it may be located on the towed vehicle or brake control unit) receives the input signals from the source (such as the ABS system, a speed meter, the ignition, the brake pedal, other processors on the towing vehicle, etc.) and generates the appropriate output signal. The algorithms stored within the processor may be updated by having new algorithms entered therein or having the existing algorithms modified automatically or manually. It should be noted that the brake control unit is capable of being reprogrammed meaning that the algorithms stored therein can be modified by a technician or a completely new set of algorithms may be entered therein by a technician. This allows the brake control unit to be updated with new information regarding the towing vehicle, the towed vehicle, or the brake control unit itself. The algorithms stored in the brake control unit correspond to each unique combination of inputs. The selection of the appropriate algorithm or algorithms is done by the processor once it receives the appropriate input information. Further, depending upon changes in the input(s), the processor may select a different algorithm or algorithms to generate the appropriate brake output signal. Of course, the processor or a technician/operator may alter the algorithms stored to generate an appropriate brake output signal.

(19) The brake output signal controlled by the brake control unit based on information it receives can be represented as a transfer function. It should be understood, however, that the transfer function can include any or all of the input signals listed above in any manner or combination. Additionally, it should be understood that the transfer function is not limited to those input signals listed above.

(20) The braking signals produced by the trailer may comprise a pulse width modulation. For example, in U.S. Pat. Nos. 6,068,352 and 8,746,812, which are both currently owned by Horizon Global Americas Inc. and incorporated by reference as if fully rewritten herein, brake control units are described that, at least in part, produce or rely on pulse width modulated braking signals.

(21) As shown in the electrical block diagram of FIG. 1, the brake control unit **100** includes a power device **110** that can receive and send signals to a driver **120**. The controller may include a communication bus, such as the high speed controlled area network (HSCAN) bus. For example,

the brake control unit **100** can receive and send signals relating to wheel speeds of the towing and/or towed vehicle, vehicle state information from ABS, brake-on-off, etc. The brake control unit **100** can also receive signals from various systems related to the towing vehicle, and can also receive a power signal.

(22) The brake control unit **100** may be in communication with a display **130**. It should be understood that any sort of display system can be used. The brake control unit **100** may drive the display **130** thereof to communicate information such as percentage of brake signal output, gain value settings, and trailer connectivity status. Additionally, the display **130** may include an operator notification system to indicate a connected and disconnected state or a short/fault and the particular location that the short/fault that may exist in the electrical system.

(23) The brake control unit **100** can be fully integrated with the towing vehicle. This allows the brake control unit to be originally installed equipment in a towing vehicle. In other words, the brake control unit can be a factory-installed option on a towing vehicle. In such circumstances, the display **130** and the controls for the brake control unit may be integrated into the instrument panel of the towing vehicle. As such, the controls of the brake control unit may operate similarly to the other controls contained in the towing vehicle's instrument panel. Alternatively, the brake control unit **100** may be an after market device capable of being connected to the towing or towed vehicle. Further, the brake control unit **100** may be configured to be inserted into the towing or towed vehicle as an after market component that is inserted into a designated space to make it appear as if it were integrated at time of assembly of the towing or towed vehicle, as applicable.

(24) Accordingly, the brake control unit **100** and display **130** may incorporate a mechanism via software and hardware interface to adjust the various features and functionality of the brake control system. The brake control unit may be controlled through communication with the display and other elements, such as by wireless or serial communication. Further, to operate the components above, the brake control unit **100** may include a processor **140**. As used herein, the term "processor" may include a general-purpose processor, a microcontroller (e.g., an execution unit with memory, etc., integrated within an integrated circuit), a digital signal processor (DSP), a programmable logic device (PLD), or an application specific integrated circuit (ASIC), among other processing devices. The processor must have enough on-board memory to contain the software requirements to communicate with the towing vehicle's communication bus (such as the CAN or a high-speed controlled area network (HSCAN)), or other communication systems (such as a local interconnect network (LIN) and a J1850), in-vehicle diagnostics, and required functionality for interpreting vehicle and driver inputs. It may have the capabilities to provide proper control to the: brakes of the towed vehicle, towing vehicle stop lamps during a manual braking event, towed vehicle stop lamps during a manual braking event, and display information accessible to the operator.

(25) As illustrated by FIG. 1, the processor **140** may be operably coupled to a power device **110** and driver **120**. The driver **120** may be operable to generate an output signal **114** based on a variety of information received from the towing vehicle (as well as other information from the operator and the towed vehicle). This towing vehicle information can be received through hard-wired inputs from a brake pressure transducer, a brake on-off switch, and an ignition run line. Additional vehicle provided information can be received through the towing vehicle's communication bus. The brake control unit also sends out information on the brake control unit system status via the towing vehicle's communication bus. These messages may be displayed on the display **130**. In an aspect, the processor **140** may generate signals that may be sent to various circuits within the brake control unit **100**. For instance, the brake control unit **100** may generate asymmetric signals to be sent to different driving circuits (e.g., such as high side drivers operatively connected to vehicle brakes), and drivers that are interconnected to test connectivity and diagnose potential causes for irregularities.

(26) As illustrated by the circuit diagram of FIG. 2, the brake control system may include one or

more diagnostic circuit(s) **200** configured to identify if a fault or a short exists in the electrical system of the brake control unit. In an example, the brake control unit **100** may include a plurality of drivers, as described in more detail herein that may each operatively drive a brake or set of brakes. Each of the drivers may include test circuits. This may allow the brake control unit **100** to identify issues or diagnose causes in one or more brakes, brake lines, driving circuits or the like.

(27) In at least one embodiment, the power device **210** may be configured to receive a first signal such as a drive signal **212**. The power device **210** may be in series communication with the driver **220**. The power device **210** may be at least one of a field effect transistor (FET), a transistor, a switch, a relay. For instance, the power device **210** may comprise a high side driver that may be packaged with other circuitry, such as current sensing circuitry, or the like. However, this disclosure contemplates that the power device **210** may be any number of electrical devices configured to be connected in series with a driver and process a signal as described.

(28) In this embodiment, the driver **220** may be a high side driver **220** configured with one or more transistors such as a field effect transistor (FET). As illustrated in this circuit diagram of FIG. 2, the driver **220** may be one or more FETs that are electrically connected in parallel, such as four (4) FETs. In one embodiment, the driver **220** may be a high side driver with four (4) FETs in parallel electrical connection. However, this disclosure contemplates that any number and type of relays, switches, transistors or FETs may be utilized with the driver **220**.

(29) In operation, the driver **220** may receive a drive signal **222** to be processed as an output signal **224** to be communicated with the brakes of the towed vehicle. Additionally, the power device **210** may receive a drive signal **212** that may be also processed through the driver **220** as the output signal **224**. The signal **212** may be toggled by the power device **210** to generate the output signal **224** that may be processed to determine the existence of a short or fault exists within the electrical system in communication between the towing vehicle, towed vehicle and brake control unit. The signal may also be toggled by the power device **210** to generate an output signal **224** that may be processed to determine the location of the short or fault as it exists within the electrical system of the towing vehicle, towed vehicle, and brake control unit.

(30) FIGS. 3A and 3B illustrate exemplary wave forms of diagnostic test pulse signals processed by the circuit of FIG. 2. FIG. 3A illustrates a diagnostic pulse signal **300** representative of the output signal **224** of the brake control unit **100** that includes the drive signal **212** provided by the power device **210** and the drive signal **222** provided by the driver **220**. The test pulse **300** includes a first step function **312** representative of the drive signal **212** processed by the power device **210** and a second step function **322** representative of the drive signal **222** processed by the driver **220**. In one embodiment, the second step function occurs for approximately 1.5 msec while the combination of the first and second step functions **312** and **322** may occur cyclically at four (4) second intervals along the test pulse **300**. These functions may be programmed to cyclically occur at different times and magnitudes and this disclosure is not limited to the cyclical times or voltage magnitudes of the first and second step functions.

(31) In one embodiment, the first step function **312** illustrates that the diagnostic pulse signal **300** includes a brief interruption of source voltage of the output signal **224**. This brief interruption may be caused by the power device **210**. The second step function **322** illustrates the source voltage processed by the driver **220**. Notably, first diagnostic pulse **310** illustrates the first step function **312** without source voltage provided by the driver **220**. Further, test pulse **320** illustrates the second step function **322** without the source voltage interruption provided by the power device **210**.

(32) In operation, the brake control system **100** may include circuitry **200** to process signals that may be evaluated to indicate the existence and location of a short or fault within the electrical system. More particularly, diagnostic pulse **330** represents an output signal for the brake control unit that indicates that there exists no fault or short within the electrical system. Diagnostic pulse **330** includes the first and second step functions **312** and **322** as they may be generated by the power device and driver, respectively. This diagnostic pulse **330** illustrates the voltage source of the

brake control unit **100** with a normal test pulse.

(33) Diagnostic pulse **340** represents an output signal for the brake control unit that indicates that there exists a fault or short with the internal circuitry of the brake control unit **100** within the electrical system. Diagnostic pulse **340** includes the first step function **312** and does not include a representative signal of the second step function **322** as it may be generated by the driver. This diagnostic pulse **340** illustrates the voltage source of the brake control unit **100** with a short located at the driver **220**.

(34) Diagnostic pulse **350** represents an output signal for the brake control unit that indicates that there exists a fault or short with the internal circuitry of the brake control unit **100** within the electrical system. Diagnostic pulse **350** includes the second step function **322** and does not include a representative signal of the first step function **312** as it may be generated by the power device **210**. This diagnostic pulse **350** illustrates the voltage source of the brake control unit **100** with a short located at the power device **210**.

(35) Diagnostic pulse **360** represents an output signal for the brake control unit that indicates that there exists a fault or short within the electrical system that is external from the brake control unit circuitry **200**. Diagnostic pulse **360** does not include a representative signal of the first or the second step function **312** and **322** as they may be generated by the power device **210** and driver **220**, respectively. This diagnostic pulse **360** illustrates the voltage source of the brake control unit **100** with a short located within the electrical system of the towed or towing vehicles and not within the brake control unit **100**.

(36) By obtaining the appropriate diagnostic test signal, the brake control unit **100** may process the appropriate signal to the display to indicate at the display the status of the electrical system. The status may indicate NO FAULT, HS FET SHORT, SERIES FET SHORT, or WIRING SHORT as appropriate to diagnose a potential voltage shortage within the system. However, any such display indication may be utilized and this disclosure is not limited.

(37) Another performance feature is that the brake control unit circuits may be continuously monitored and diagnosed in the event a short or fault does occur. The short circuit sensing may be continuous and the output voltage may be monitored.

(38) Other optional configurations may include using two or more FETs in parallel, one or more power MOSFETs in parallel, or one or more power transistors in parallel. The driver **220** may deliver a PWM (Pulse Width Modulated) drive to the brake lines.

(39) In another aspect, disclosed brake control units may utilize multiple signals sent from a processor to power MOSFETs to control different brakes or sets of brakes of a towed vehicle. In an aspect, test signals may be disabled during such applications.

(40) For instance, a brake control unit and system described herein relies upon asymmetric braking. In operation, this means that the controller will, under selected conditions, provide independent braking signals to each of the brake units it is controlling. In most applications, this means that a trailer having, for example, one axle will receive two separate braking signals—one for the passenger-side wheel and one for the driver-side wheel—on that trailer. Although the separate signals will usually be equivalent, the signals produced by the brake control unit will be different under conditions like sway or a desire by the driver to execute special maneuvers (e.g., small radius turns). The difference in the signals will depend upon the conditions, and the trailer brake control unit may incorporate sensors and/or user inputs that are used to calculate the separate, asymmetric signals.

(41) FIG. 4 illustrates the configuration of one embodiment of the present system **400**. Tow vehicle **410** is coupled to trailer **420** via a connection device **430**. Connection device **430** may be any number of hitch connections and, more particularly, those that require or are compatible with the use of a sway controller. Such hitch connection might include a hitch, a hitch bar, and a coupler.

(42) Vehicle **410** may be an automobile, general purpose pick-up truck, or any other common, general purpose motor vehicle. The system **400** is expected to have particular utility as an after-



market product that may be selectively installed on vehicle **410** by the end user.

(43) Trailer **420** may, likewise, comprise a general purpose trailer with any number of axles. Such trailers are often used for hauling animals, other vehicles, regular consumer-based cargo, and/or special purpose consumer-oriented items that are produced for a wide base of consumers (and in contrast to commercial trailers and applications). These trailers may have any number of axles, although FIG. 4 illustrates an embodiment with two axles having four wheels on each axle and individual brake units **422** associate with each wheel. At least one, and possibly as many as all, of the axles will be equipped with brake units **422**.

(44) Brake units **422** are controlled by a trailer brake control unit **510** via independent braking wire connections located on the driver's side and passenger's side, respectively **424** and **426**.

Connections **424** and **426** may be integrated into the vehicle **410**, trailer **420**, and/or connection device **430** by way of dedicated wires, fiber optic cables, and other similar means which may be routed through harness connections **428**. Although separate, dedicated signals are contemplated for at least the driver's and passenger's side wheels (or, in some embodiments, a plurality signals corresponding to a plurality of wheels on each side of the trailer), it is possible for all dedicated wire connections **424** and **426**, etc. to encompass within a single connection bus.

(45) Trailer brake control unit **510** is provided with a power source (not indicated in FIG. 4) to allow for operation of the controller, including generation of appropriate electrical braking signals, as is known in the art and as will be described herein. Controller **510** may also be connected to the fuse block **412** of vehicle **410**.

(46) A rotational sensor is included, preferably in or on the connection device **430**. This sensor will indicate when sway conditions are sensed and prompt the trailer brake control unit **510** accordingly, and it may be positioned on or integrated with the hitch ball, as one example. Additionally or alternatively, the sensor may operate by monitoring the relative positioning of distinct points on any two or three way combinations of the vehicle, the connection device, and the trailer (e.g., by comparing the distance between the vehicle and the front end of the trailer at points on both the driver's and passenger's side, oscillations or continuous/irregular changes in those distances relative to one another may indicate sway). Further, such a sensor may measure the yaw between the towed and towing vehicle. The sensor may be of any appropriate configuration, including, without limitation, a camera, yaw sensor, hitch ball angle sensor, or the like. The present teachings are not limited to the type and configuration of sensor utilized.

(47) Such a sensor may incorporate accelerometers, motion detection, global positioning systems, laser or infrared range finders (i.e., monitoring changes in distance between two fixed points over time), load sensing (i.e., tongue weight shifts to an extreme, peripheral point on the hitch ball as a result of swaying or shifting load), and rotational sensing (e.g., via hall Effect sensors and the like) as indicators of sway or the beginning/intensification of sway conditions. The use of micro electromechanical systems (MEMS) and similar electronics can enable the use of an array of sensors and/or the positioning of the sensors at a discrete location. Also, such sensors are likely to have processing and logic capabilities to help analyze and interpret the data.

(48) The sensor itself may be connected, via appropriate wiring or communications systems, to the brake units **422**, the connector **560** (described below), and/or any of the components comprising the trailer brake control unit **510** as described in FIGS. 2 and 3 below. The sensor may also require a power supply, which can come from the vehicle, the braking system, or by way of a discrete supply (e.g., a battery).

(49) As seen in FIG. 5, trailer brake control unit **510** includes a microprocessor **540**.

Microprocessor **540** allows for programmable logic. In this context, "logic" refers to any information and/or data that may be applied to direct the operation of a processor. Logic may be formed from instruction signals stored in a memory (e.g., a non-transitory memory). Software is one example of logic. In another aspect, logic may include hardware, alone or in combination with software. For instance, logic may include digital and/or analog hardware circuits, such as hardware

circuits comprising logical gates (e.g., AND, OR, XOR, NAND, NOR, and other logical operations). Furthermore, logic may be programmed and/or include aspects of various devices and is not limited to a single device.

(50) Also, the term “microprocessor” may include a general-purpose processor, a microcontroller (e.g., an execution unit with memory, etc., integrated within an integrated circuit), a digital signal processor (DSP), a programmable logic device (PLD), or an application specific integrated circuit (ASIC), among other processing devices. The processor must have enough on-board memory to contain the software requirements to communicate with the towing vehicle's communication bus, in-vehicle diagnostics, and required functionality for interpreting vehicle and driver inputs.

(51) The trailer brake control unit **510** provides proper control to the: brakes of the towed vehicle, towing vehicle stop lamps during a manual braking event, towed vehicle stop lamps during a manual braking event, and display information accessible to the operator. To facilitate these operations, the brake control unit **510** may also have a user interface, optionally including a display, keyboard/input device, dedicated input buttons, output indicators/LEDs, and the like.

(52) The brake control unit **510** generates and applies a particular voltage to the brake units **422** in the trailer **420** so as to apply a brake load to slow-down or stop the trailer **420** and the vehicle **410** at compatible rates. The voltage applied is related to the input signals available on and/or from the towing vehicle **410**, among other available inputs. These additional input signals may come from or be characteristic of the operator of the towing vehicle **410**, from the vehicle **410** itself, from the trailer **420**, or a combination of any of the three.

(53) The brake control unit **510** may use a variety of preselected or continuously modified algorithms to generate the appropriate output to the towed vehicle brakes based on the received inputs. A processor on the towing vehicle (although it may be located on the towed vehicle) receives the input signals from the source (such as the ABS system, a speed meter, the ignition, the brake pedal, other processors on the towing vehicle, etc.) and generates the appropriate output signal. The algorithms stored within the processor may be updated by having new algorithms entered therein or having the existing algorithms modified automatically or manually. It should be noted that the brake control unit **510** is capable of being reprogrammed meaning that the algorithms stored therein can be modified by a technician or a completely new set of algorithms may be entered therein by a technician. This allows the brake control unit **510** to be updated with new information regarding the towing vehicle, the towed vehicle, or the brake control unit **510** itself. The algorithms stored in the brake control unit **510** correspond to each unique combination of inputs. The selection of the appropriate algorithm or algorithms is done by the processor once it receives the appropriate input information. Further, depending upon changes in the input(s), the processor may select a different algorithm or algorithms to generate the appropriate brake output signal. Of course, the processor or a technician/operator may alter the algorithms stored to generate an appropriate brake output signal.

(54) In order to produce the asymmetric braking signals, the trailer brake control unit **510** will be programmed to produce independent signals in response to sway detection and/or in response to special commands/requests from the user. In these instances, separate algorithms may be applied to produce separate braking signals according to the circuitry described below. Generally speaking, these separate signals will vary in the intensity and/or frequency of how the individual brakes are applied, with relatively greater braking force applied when the appropriate trailer side is approaching or at its maximum yaw/sway. Insofar as sway is a recurring condition, these algorithms may ramp up and decrease breaking force in response to the intensity of the sway detected by the sensors so as to allow for a controlled and smooth elimination of sway (as opposed to immediately attempting to stop the condition, which may cause cascading problems in the operation and control of the vehicle itself).

(55) Returning to FIG. 5, microprocessor **540** is configured to send and receive data from a controller area network (CAN) transceiver **544** that may receive a signal from a vehicle CAN **516**.

CAN transceiver **544** is also operatively connected to a voltage regulator **548** as illustrated in FIG. 5. A main output or flyback circuit **50** and a secondary output or flyback circuit **555** are also in operative communication with the microprocessor **540**, CAN transceiver **544**, and voltage regulator **548**. In turn, transceiver **544**, regulator **548**, and main and secondary flyback circuits **550** and **555** are connected to electrical connector **560**.

(56) Such flyback circuits **550** and **555** produce braking control signals in concert with the microprocessor **540**. Further, because circuits **550** and **555** provide separate signals via the connector **560**, the controller unit **510** creates independent outputs that may be provided separately to any combination of the wheels on trailer **420** (provided appropriate wire connections **424** and **426** are established). To the extent a plurality of output signals beyond those shown in FIG. 5 are desired, additional flyback circuits can be included.

(57) Electrical connector **560** interfaces with the vehicle controller area network, the battery **414**, and an appropriate grounding source, as well as connections **424** and **426**. While illustrated as a single block in the schematic of FIG. 5, it will be understood that the connector **560** itself may be distributed among several, discrete locations and/or pieces of hardware.

(58) FIG. 6 illustrates an exemplary schematic diagram of a portion of brake control unit **600** comprising circuitry according to an embodiment of the present system. This figure relies upon standard symbology commonly used in electrical schematic diagrams. In an aspect, the brake control unit generally comprises a processor **650** in communication with a plurality of driver circuits **610** and **622**

(59) The brake control unit **600** and the plurality of driver circuits **610** and **622** may be configured to produce independent braking signals, as associated with the flyback circuits described above. For instance, the processor **650** may produce a plurality of brake control signals, such as brake control signal **624** (which may drive the primary high side driver **610** to produce primary output **612**) and a brake control signal **636** (which may drive the secondary high side driver **622** to produce primary output **622**). Both the primary high side driver **610** and the secondary high side driver **620** include at least one, and more preferably a plurality of, field effect transistors (FET). In operation, these circuits are coupled to the microprocessor to controllably produce the braking signals as contemplated by this disclosure. In regular, non-sway conditions, the signal from only one of the circuits **610** and **622** is provided to effect braking in the trailer **420**, although the circuits could also work in parallel with the net effect of producing identical braking signals in regular, non-sway conditions. Additional circuitry may be provided to allow the secondary circuit **622** to be switched on and off, possibly at the discretion of the driver/user, as a safeguard during operation, or for any number of other circumstances in which the possibility of asymmetric signals may not be desirable.

(60) The independent braking also affords the possibility, through appropriate coordination of signals (e.g., via programming/software, appropriate integrated circuits, etc.), to execute special maneuvers with the vehicle and trailer (e.g., sharp turns, etc.). For example, a command could be provided from the trailer brake control unit located in the vehicle that would lock or apply significantly greater braking force to the wheels located on one side of the trailer, effectively anchoring those wheels in position and allowing the opposing side to rotate more freely so as to enable the trailer to execute a turning maneuver with a smaller radius than might otherwise be necessary when all wheels can rotate at the same rate. The command could be executed via a graphical user interface, separate dedicated buttons or switches, or other input means. The controller can be programmed with default safety checks to ensure any such specialized commands are only executed under specified conditions (e.g., the braking sequence could only be initiated when the vehicle is fully stopped).

(61) One advantage of the present system is that it allows users to eliminate separate sway control and trailer brake control devices. The corresponding reduction in equipment simplifies installation, reduces maintenance (insofar as the friction pads and other mechanisms of previous sway

controllers are effectively eliminated), and provides for a more seamless user experience.

(62) In view of the subject matter described herein, methods that may be related to various embodiments may be better appreciated with reference to the flowchart of FIG. 7. While the method **700** is shown and described as a series of blocks, it is noted that associated methods or processes are not limited by the order of the blocks. It is further noted that some blocks and corresponding actions may occur in different orders or concurrently with other blocks. Moreover, different blocks or actions may be utilized to implement the methods described hereinafter. Various actions may be completed by one or more users, mechanical machines, automated assembly machines (e.g., including one or more processors or computing devices), or the like.

(63) At **702**, a system (e.g., brake control unit **100** and **510**, etc.) may receive input from at least one of sensors, towing vehicle systems, or towed vehicle systems. For instance, a tow brake control unit may receive input via a network of a vehicle, sensors on a towed or towing vehicle, and/or user input. The input may relate to user actions (e.g., brake application, turn signal activation, gain/sensitivity adjustments), sensed parameters from a towing vehicle (e.g., ABS sensors, wheel speed sensors, light sensors, etc.), or the like.

(64) At **704**, the system may determine one or more output signals to be generated to power circuitry. In an aspect, a brake control unit may determine whether it is appropriate to apply a test signal(s), apply asymmetric braking, or apply a standard braking. This determination may be made according to the various aspects described herein.

(65) At **706**, the system may generate output signals to power circuitry (e.g., high side drivers, FETS, power devices, etc.). The power circuitry receives the signals as input and generates an appropriate output. For instance, if the signal comprises a test signal, feedback data may be provided to a processor. If the signal is a brake activation signal that is meant to induce braking, the power circuitry applies an appropriate amount of braking as described herein. It is noted that the braking may be asymmetric or not asymmetric as described herein.

(66) At **708**, the system may monitor feedback from power circuitry. For instance, a processor may monitor a feedback pin and may process data received therefrom. The processor may diagnose issues based on the feedback as described herein. In another aspect, the processor may control an output device (e.g., display, user interface, etc.) based on the feedback information.

(67) In some embodiments, a brake controller may include all or some of the features of either of the brake controller **100** and brake controller **510** as described above. For the sake of brevity, however, every possible combination is not disclosed herein, but is contemplated hereby.

(68) Modification of the disclosure will occur to those skilled in the art and to those who make or use the invention, including, without limitation, the values provided for the various elements disclosed above. It should be understood that such values are exemplary values and the present invention is not limited to those values. Therefore, it is understood that the embodiments shown in the drawings and described above are merely for illustrative purposes and not intended to limit the scope of the invention, which is defined by the following claims as interpreted according to the principles of patent law, including the Doctrine of Equivalents.

## Claims

1. A brake control unit comprising: a power device; a processor coupled to the power device; a first high side driver coupled to the processor; and a second high side driver coupled to the processor, and wherein the processor generates a first signal to be applied to the first high side driver in order to induce braking in a first brake of a towed vehicle, and generates a second signal to be applied to the second high side driver in order to induce braking in a second brake of the towed vehicle, wherein the first signal is different from the second signal; and wherein the processor is configured to send and receive at least one diagnostic pulse signal for the power device, the first high side driver, and the second high side driver to determine whether a fault exists in the brake control unit

and a location of the fault in the power device, the first high side driver, and the second high side driver.

2. The brake control unit of claim 1, wherein the processor applies the first signal and the second signal asynchronously based on a brake lock condition of the towed vehicle, swaying of the towed vehicle, back-up of the towed vehicle, and slippage of the towed vehicle.

3. The brake control unit of claim 2, further comprising a sensor assembly coupled to a hitch mechanism of the towing vehicle for determining at least one of the swaying, the back-up, and the slippage.

4. The brake control unit of claim 1, wherein the first high side driver comprises a first diagnostic circuit and the second high side drive comprises a second diagnostic circuit.

5. A brake control unit comprising: a power device; a processor coupled to the power device and configured to: receive braking control signals corresponding to braking commands; process the received braking control signals to determine a braking actuation response; generate a primary pulse-width modulation (PWM) output signal and a secondary PWM output signal based on the braking actuation response; transmit the primary and secondary PWM output signals; a primary high side driver electrically connected to the processor and configured to receive the primary PWM output signal, the primary high side driver comprising: a plurality of high-side switching transistors arranged in a switching configuration, each transistor having a gate terminal, a source terminal, and a drain terminal; at least one gate drive circuit electrically coupled to the gate terminals of the high-side switching transistors, the gate drive circuit configured to regulate transistor activation based on the primary PWM output signal; an output terminal configured to deliver a first modulated braking current to a primary braking output; and a feedback path configured to transmit a current sense signal indicative of the first modulated braking current to the processor; and a secondary high side driver electrically connected to the processor and the primary high side driver, the secondary high side driver configured to receive the secondary PWM output signal, the secondary high side driver comprising: a plurality of high-side switching transistors arranged in a switching configuration, each transistor having a gate terminal, a source terminal, and a drain terminal; at least one gate drive circuit electrically coupled to the gate terminals of the high-side switching transistors, the gate drive circuit configured to regulate transistor activation based on the secondary PWM output signal; an output terminal configured to deliver a second modulated braking current to a secondary braking output; and a feedback path configured to transmit a current sense signal indicative of the second modulated braking current to the processor, wherein: the processor dynamically adjusts the primary PWM output signal and the secondary PWM output signal based on the current sense signals indicative of the first and second modulated braking currents to regulate braking force applied to the primary and secondary braking outputs, thereby enabling adaptive and controlled braking operation, and the processor is configured to transmit a diagnostic signal to the power device, primary high side driver, and/or secondary high side driver to determine whether a fault exists in the brake control unit and a location of the fault in the power device, the primary high side driver, and the second high side driver.

6. The brake control unit of claim 5, wherein the processor dynamically adjusts the primary PWM output signal and the secondary PWM output signal asynchronously.

7. The brake control unit of claim 5, wherein the processor dynamically adjusts the primary PWM output signal and the secondary PWM output signal asynchronously based on identifying at least one of a brake lock condition, swaying, back-up, or slippage of a vehicle.

8. The brake control unit of claim 5, wherein the primary high side driver comprises a first diagnostic circuit and the secondary high side drive comprises a second diagnostic circuit, each diagnostic circuit including at least one of a flyback diode, a snubber capacitor, or a transient voltage suppressor, configured to mitigate electrical transients during switching operations.

9. A brake control unit for generating and applying a particular voltage to brake units of a trailer, the brake control unit comprising: a microprocessor configured to send and receive data from a

controller area network (CAN) transceiver, the microprocessor configured to receive braking commands from a towing vehicle CAN; a main output circuit and a secondary output circuit in operative communication with the microprocessor and CAN transceiver, the main output circuit and the secondary output circuit configured to produce braking control signals based on data received from the microprocessor; an electrical connector operatively connected to the CAN transceiver, main output circuit, and secondary output circuit, the electrical connector configured to output a time base correction output to the brake units of the trailer based on the braking control signals received from the main output circuit and the secondary output circuit; wherein: the braking control signals received from the main output circuit and the secondary output circuit by the electrical connector are separate signals such that the electrical connector creates independent outputs via the main output circuit and the secondary output circuit, and provides the braking control signals separately to a combination of wheels on the trailer.

10. The brake control unit of claim 9, wherein the microprocessor dynamically adjusts the braking control signals asynchronously.

11. The brake control unit of claim 9, wherein the microprocessor dynamically adjusts the braking control signals asynchronously based on identifying at least one of a brake lock condition, swaying, back-up, or slippage of the trailer.

12. The brake control unit of claim 9, wherein the main output circuit comprises a first diagnostic circuit and the secondary output circuit comprises a second diagnostic circuit, each diagnostic circuit including at least one of a flyback diode, a snubber capacitor, or a transient voltage suppressor, configured to mitigate electrical transients during switching operations.

13. A trailer brake control system for a trailer brake system, the system comprising: a power source for supplying power to the trailer brake control system; a Controller Area Network (CAN) bus having a CAN High (CAN H) signal line and a CAN Low (CAN L) signal line; a CAN transceiver, operatively connected to the CAN bus, the CAN transceiver configured to: receive differential CAN signals via the CAN H and CAN L signal lines; convert the received differential CAN signals; transmit the converted differential CAN signals; a processor, electrically coupled to the CAN transceiver and configured to: receive the converted differential CAN signals from the CAN transceiver, the converted differential CAN signals being indicative of braking instructions from a towing vehicle; process the received converted differential CAN signals to determine a braking control response; generate a primary and secondary pulse-width modulation (PWM) output signal based on the determined braking control response; transmit the primary and secondary PWM output signals; a flyback main circuit, operatively connected to the processor and the trailer brake system, the flyback main circuit configured to: receive the primary PWM output signal from the processor; modulate electrical power supplied to the trailer brake system based on the primary PWM signal; generate a first controlled braking current based on the modulated electrical power; a flyback secondary circuit, operatively connected to the flyback main circuit, the processor, and the trailer brake system, the flyback secondary circuit configured to: receive the secondary PWM output signal from the processor; modulate electrical power supplied to the trailer brake system based on the secondary PWM signal; and generate a second controlled braking current based on the modulated electrical power; and a current sense feedback loop, operatively connected to the flyback main circuit, the flyback secondary circuit, and the processor, the current sensing mechanism configured to: measure an electrical current delivered to the trailer brake system via the first controlled braking current and second controlled braking current; generate a current sense feedback signal; and transmit the current sense feedback signal to the processor; wherein the processor is further configured to receive the current sense feedback signal and dynamically adjust the primary and secondary PWM output signals based on the current sense feedback signal to regulate a braking force applied to the trailer brake system, enabling real-time adjustment of braking force.

14. The trailer brake control system of claim 13, wherein the processor adjusts the primary and

secondary PWM output signals asynchronously.

15. The trailer brake control system of claim 13, wherein the processor adjusts the primary and secondary PWM output signals asynchronously based on identifying at least one of a brake lock condition, swaying, back-up, or slippage of the towed vehicle.

16. The trailer brake control system of claim 13, wherein the flyback main output circuit comprises a first diagnostic circuit and the flyback secondary output circuit comprises a second diagnostic circuit, each diagnostic circuit including at least one of a flyback diode, a snubber capacitor, or a transient voltage suppressor, configured to mitigate electrical transients during switching operations.

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