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System and Method for Testing Vehicle Brake and Steering Systems

Abstract

A system for testing braking and steering systems of a vehicle includes a steering actuator to cause rotation of the steering wheel and electropneumatic modules associated with each wheel brake that include a solenoid controlling fluid communication between a brake actuator of the wheel brake and one of a fluid source and atmosphere. A controller transmits a first control signal to an electropneumatic module associated with a wheel brake on one side of the vehicle to actuate the solenoid of the electropneumatic module. The controller transmits a second control signal to the steering actuator to cause rotation of the steering wheel during actuation of the solenoid of the electropneumatic module and in a rotational direction towards the same side of the vehicle.

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Background/Summary

BACKGROUND OF THE INVENTION

a. Field of the Invention

[0001] This disclosure relates to a system and method for testing the braking and steering systems in a vehicle. In particular, this disclosure relates to system and method that synchronize testing of the braking and steering systems to increase efficiency of testing and reduce potential confusion of individuals implementing the testing.

b. Background Art

[0002] Conventional vehicles will, upon activation of the vehicle, frequently implement tests of various vehicle systems and components to ensure that those systems and components are working properly before the vehicle begins to travel. For example, commercial vehicles such as tractor-trailers frequently test the valves in pneumatic braking systems upon activation of the vehicle by energizing solenoids in the valves. The energization of the solenoids and movement of fluid through the valves produces audible noises in distinct patterns that enable an operator of the vehicle or bystander to evaluate whether the valves are operating properly. The same vehicles will also frequently test the vehicle's steering system by actuating the steering gear to turn the vehicle wheels in each direction. This movement also causes movement of the vehicle steering wheel through which the operator may receive visual or haptic indicators of steering wiggle resulting from damage to one or more steering system components.

[0003] Because testing of multiple vehicle systems and components may occur simultaneously, it may be difficult for vehicle operators or other observers to monitor all of the testing and to understand and record the results of each test where the outputs of the tests must be observed by the vehicle operator or other observers. This problem can be addressed by arranging for the tests to occur sequentially, but doing so may create undesirable delays in operating the vehicle.

[0004] The inventors herein have recognized a need for a system and method for testing the braking and steering systems in a vehicle that will minimize and/or eliminate one or more of the above-identified deficiencies.

BRIEF SUMMARY OF THE INVENTION

[0005] This disclosure relates to a system and method for testing the braking and steering systems in a vehicle. In particular, this disclosure relates to system and method that synchronize testing of the braking and steering systems to increase efficiency of testing and reduce potential confusion of individuals implementing the testing.

[0006] One embodiment of a system for testing a braking system and a steering system of a vehicle includes a plurality of electropneumatic modules. Each electropneumatic module is associated with a corresponding brake for a corresponding wheel of the vehicle and includes a solenoid configured to control fluid communication between a brake actuator for the corresponding brake and one of a fluid source and atmosphere. The system further includes a steering actuator configured to cause rotation of a steering wheel of the vehicle. The system further includes a controller configured to transmit a first control signal to a first electropneumatic module of the plurality of electropneumatic modules, the first electropneumatic module associated with a first brake for a first wheel on a first side of the vehicle. The first control signal is configured to actuate the solenoid of the first electropneumatic module. The controller is further configured to transmit a second control signal to the steering actuator. The second control signal is configured to cause rotation of the steering wheel during actuation of the solenoid of the first electropneumatic module in a first rotational direction towards the first side of the vehicle.

[0007] One embodiment of an article of manufacture includes a non-transitory computer storage medium having a computer program encoded thereon that when executed by a controller tests a braking system and a steering system of a vehicle. The computer program includes code for transmitting a first control signal to a first electropneumatic module of a plurality of electropneumatic modules on the vehicle. Each electropneumatic module is associated with a corresponding brake for a corresponding wheel of the vehicle and includes a solenoid configured to control fluid communication between a brake actuator of the corresponding brake and one of a fluid source and atmosphere. The first electropneumatic module is associated with a first brake for a first wheel on a first side of the vehicle. The first control signal is configured to actuate the solenoid of the first electropneumatic module. The computer program further includes code for transmitting a second control signal to a steering actuator configured to cause rotation of a steering wheel of the vehicle. The second control signal is configured to cause rotation of the steering wheel during actuation of the solenoid of the first electropneumatic module in a first rotational direction towards the first side of the vehicle.

[0008] One embodiment of a method for testing a braking system and a steering system of a vehicle includes transmitting a first control signal to a first electropneumatic module of a plurality of electropneumatic modules on the vehicle. Each electropneumatic module is associated with a corresponding brake for a corresponding wheel of the vehicle and includes a solenoid configured to control fluid communication between a brake actuator of the corresponding brake and one of a fluid source and atmosphere. The first electropneumatic module is associated with a first brake for a first wheel on a first side of the vehicle. The first control signal is configured to actuate the solenoid of the first electropneumatic module. The method further includes transmitting a second control signal to a steering actuator configured to cause rotation of a steering wheel of the vehicle. The second control signal is configured to cause rotation of the steering wheel during actuation of the solenoid of the first electropneumatic module in a first rotational direction towards the first side of the vehicle.

[0009] A system and method for testing a braking system and a steering system of a vehicle in accordance with the teachings disclosed herein is advantageous relative to conventional systems and methods. In particular, the system and method disclosed herein synchronize testing of the braking system and steering system in manner that enables the tests to be performed at least partially simultaneously while doing so in manner that makes it easier for an operator of the vehicle to observe the outputs of each test. In this manner, the system and method enable the tests to be performed in an efficient manner that prevents operating delays for the vehicle while ensuring that the results of the tests can be adequately monitored and observed by the vehicle operator or other observers.

[0010] The foregoing and other aspects, features, details, utilities, and advantages of the present teachings will be apparent from reading the following description and claims, and from reviewing the accompanying drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. **1** is a diagrammatic view of a braking system for a vehicle.

[0012] FIG. **2** is a cross-section of a modulator of the braking system of FIG. **1**.

[0013] FIG. **3** is a diagrammatic view of a steering system for a vehicle.

[0014] FIG. **4** is a diagrammatic view of one embodiment of a system for testing the braking system of FIG. **1** and the steering system of FIG. **2** in accordance with the teachings set forth herein.

[0015] FIGS. **5**A-B are flow chart diagrams illustrating several steps in one embodiment of a method for testing the braking system of FIG. **1** and steering system of FIG. **2** in accordance with the teachings set forth herein.

DETAILED DESCRIPTION OF THE INVENTION

[0016] Referring now to the drawings wherein like reference numerals are used to identify identical components in the various views, FIG. **1** illustrates a portion of a vehicle **10**. In the illustrated embodiment, vehicle **10** comprises a heavy-duty commercial vehicle and, in particular, a tractor or power unit for a tractor-trailer that may be used to tow one or more trailers or towed units. It should be understood, however, that the systems and methods disclosed herein may find application on other types of commercial vehicles including, for example, buses and may also find application on non-commercial vehicles. Vehicle **10** includes a steer axle **12** and tandem drive axles **14**, **16** each of which support one or more wheels at either end. Vehicle **10** further includes a power unit (not shown) such as an internal combustion engine or motor for generating mechanical energy used to rotate the wheels. Vehicle **10** may further include a battery (not shown) that provides electrical energy for use by various systems in vehicle **10** including, for example, lighting systems, power windows, locks and seating, and operator interface elements, for use in starting vehicle **10**, and for use by the power unit in vehicle **10** in generating the mechanical energy used to drive the wheels.

[0017] Vehicle **10** further includes a braking system **20** configured to brake the wheels on vehicle **10** in order to slow or stop movement of vehicle **10**. System **20** is configured to brake vehicle **10** in response to commands from an operator of vehicle **10**, but may also be configured to implement autonomous braking (i.e., without commands from the operator of vehicle **10**) as part of an advanced driver assistance system (ADAS) or automated driving system (ADS) in order to provide various functions such as automated emergency braking (AEB), anti-lock braking (ABS), collision avoidance, adaptive cruise control, traction control or stability control. Braking system **20** may include wheel brakes **22**, a fluid circuit **24** that supplies fluid pressure to wheel brakes **22**, various sensors **26**, **28**, **30**, **32**, **34** that generate signals indicative of operating conditions of vehicle **10** or the operating environment for vehicle **10**, and a brake controller **36**.

[0018] Wheel brakes **22** are configured to apply a braking force to the wheels. In the illustrated embodiment, brakes **22** comprise disc brakes in which a carrier supports brake pads on opposite sides of a rotor rotating with the wheel and an actuator causes, responsive to fluid pressure delivered by fluid circuit **24**, movement of a caliper relative to the carrier to move the brake pads into and out of engagement with the rotor. It should be understood, however, that one or more of wheel brakes **22** may alternatively comprise drum brakes in which an actuator such as a cam or piston causes, responsive to fluid pressure delivered by fluid circuit **24**, movement of one or more brake shoes into engagement with a braking surface in a brake drum rotating with the wheel.

[0019] Fluid circuit **24** generates fluid pressure within braking system **20** and controls the delivery of fluid pressure to the actuator of each wheel brake **22**. Circuit **24** may include components for generating and storing pressurized fluid including fluid reservoirs **38**, **40**, a compressor **42**, and air dryer **44** and components for routing and delivering fluid pressure to wheel brakes **22** including fluid conduits **46**, glad-hand connectors **48** for routing fluid control signals and fluid pressure to towed units, and various valves and electropneumatic modules including, for example, foot pedal valve **50**, relay valves **52**, **54**, quick release valve **56**, tractor protection valve **58**, trailer control valve **60**, dash control valve **62** and modulators **64**, **66**, **68**, **70**, **72**. Foot pedal valve **50** allows controlled application of wheel brakes **22** by the vehicle operator by selectively releasing fluid pressure from fluid reservoirs **38**, **40** to relay valves **52**, **54** and/or tractor protection valve **58**. Relay valves **52**, **54**, increase the volume of fluid, and therefore the speed, at which fluid is delivered to, and exhausted from, wheel brakes **22** in order to eliminate lag times between the commanded and actual application and release of wheel brakes **22**. Quick release valve **56** increases the speed at which fluid pressure is exhausted from wheel brakes **22** on the drive axles **16**, **18** when the wheel brakes **22** are released. Tractor protection valve **60** transmits pneumatic signals to any towed units in vehicle **10** relating to operation of wheel brakes on the towed units to enable control of the wheel brakes by system **20** and also protects the fluid supply for vehicle **10** in the event of a brake in the fluid connection between the towing and towed units of vehicle **10**. Trailer control valve **62** allows the vehicle operator to control wheel brakes on any towed units independent of the wheel brakes **22** on the towing unit of vehicle **10** by allowing delivery of fluid directly from reservoir **38** to tractor protection valve **60** for delivery to the wheel brakes in any towed units. Dash control valve **62** allows the vehicle operator to implement several functions including releasing parking brakes in wheel brakes **22** on vehicle **10** by supplying fluid pressure to oppose spring forces in the actuators for wheel brakes **22**. Modulators **64**, **66**, **68**, **70**, **72** are provided to implement an anti-lock braking function. During normal braking, modulators **64**, **66**, **68**, **70**, **72** allow fluid pressure to pass from relay valves **52**, **54** to the actuators of wheel brakes **22** without interference. During a loss of traction, however, signals from controller **36** cause modulators **64**, **66**, **68**, **70**, **72** to modulate the fluid pressure to prevent lockup of the wheels.

[0020] Referring now to FIG. **2**, a conventional structure for modulator **64** is illustrated. It should be understood that modulators **66**, **68**, **70**, **72** may have a similar construction. Modulator **64** includes a housing **74**, an exhaust diaphragm **76**, a holding diaphragm **78**, springs **80**, **82**, an exhaust solenoid **84** and a holding solenoid **86**.

[0021] Housing **74** is provided to position and orient the other components of modulator **64** and defines a plurality of fluid chambers and passages through which fluid may be routed through housing **74**. Housing **74** defines an inlet or supply port **88** for delivery of fluid from a fluid source such as reservoir **38**, an outlet or delivery port **90** in fluid communication with an actuator for wheel brake **22** and an exhaust port **92** in fluid communication with ambient atmosphere. Housing **74** further defines various fluid chambers including exhaust cavity **94** and fluid passages including fluid passages **96**, **98**, **100**, **102**, **104**, **106**.

[0022] Exhaust diaphragm **76** controls fluid communication between delivery port **90** and exhaust port **92**. Exhaust diaphragm **76** is normally closed as shown in FIG. **2**, being urged into sealing engagement with a valve seat **108** by spring **80** and by fluid pressure against the control surface of exhaust diaphragm **76** received through fluid passage **96**.

[0023] Holding diaphragm **78** controls fluid communication between supply port **88** and delivery port **90**. Holding diaphragm **78** is normally open as shown in FIG. **2**, being urged away from sealing engagement with a valve seat **110** by fluid pressure at supply port **88** and/or delivery port **90**.

[0024] Exhaust solenoid **84** controls the position of exhaust diaphragm **76**. In the absence of current, exhaust solenoid **84** allows fluid communication between passage **98** extending from supply port **88** and fluid passage **96** and closes fluid passage **100** to exhaust chamber **94**. When current is provided to exhaust solenoid **84** and exhaust solenoid **84** is energized, exhaust solenoid **84** allows fluid communication between passages **98**, **100** and closes passage **96** whereupon the higher pressure at delivery port **90** forces exhaust diaphragm off of seat **108** to permit venting of the fluid pressure at delivery port **90** through exhaust port **92**.

[0025] Holding solenoid **86** controls the position of holding diaphragm **78**. In the absence of current, holding solenoid **86** closes fluid passage **102** and allows communication between fluid passage **104** which is in the fluid communication with the control surface of holding diaphragm **78** and fluid passage **106** which is in fluid communication with exhaust port **92** through exhaust chamber **84** thereby venting passage **104**. When current is provided to holding solenoid **86** and holding solenoid **86** is energized, holding solenoid **86** closes fluid passage **106** and allows communication between fluid passage **102** which is in fluid communication with supply port **88** and fluid passage **104** thereby providing fluid to the control surface of holding diaphragm **78** which, together with the force of spring **82**, urges holding diaphragm **78** into sealing engagement with valve seat **110** to prevent fluid communication between supply port **88** and delivery port **90**. During normal operation, holding solenoid **86** is typically actuated whenever controller **36** determines, responsive to signals from wheel speed sensors **28**, that a wheel is about to lock up to thereby maintain the pressure level in the actuator for wheel brake **22** (exhaust solenoid **84** may also be actuated to decrease the pressure in the actuator). Holding solenoid **86** is also typically actuated whenever exhaust solenoid **84** is actuated to prevent fluid pressure at supply port **74** from exhausting to atmosphere through exhaust port **92**.

[0026] Referring again to FIG. **1**, sensors **26**, **28**, **30**, **32**, **34** are provided to identify various conditions associated with vehicle **10** and the surrounding environment including conditions that may impact the operation of braking system **20**. Sensor **26** may comprise an engine or transmission speed sensor and generate a signal indicative of the speed of vehicle **10**. Sensor **28** may comprise a wheel speed sensor and also generate a signal indicative of the speed of vehicle **10**. A wheel speed sensor **28** may be disposed proximate each wheel of vehicle **10**. Sensor **30** may comprise a pressure sensor that generates a signal indicative of the fluid pressure at various locations within fluid circuit **24**. Although only one pressure sensor **30** is illustrated in FIG. **1**, it should be understood that pressure sensors **30** may be located throughout fluid circuit **24**. Sensor **32** may comprise a steer angle sensor that generates a signal indicative of a steering angle imparted by a vehicle operator to a steering wheel in vehicle **10**. Sensor **34** may comprise a yaw rate sensor that generates a signal indicative of the angular velocity of vehicle **10** about its vertical (yaw) axis. Sensors **26**, **28**, **30**, **32**, **34** may communicate with controller **36** in a variety of ways including over dedicated wires or other conductors or over a conventional vehicle communications bus implementing a communications network such as a controller area network (CAN) or local interconnect network (LIN) or over a vehicle power line through power line communication (PLC) in accordance with various industry standard protocols including by not limited to SAE J1939, SAEJ1922, and SAE J2497 or a proprietary protocol.

[0027] Brake controller **36** controls the operation of electropneumatic modules such as relay valves **52**, **54** and modulators **64**, **66**, **68**, **70**, **72** in order to control the fluid pressure delivered to wheel brakes **32** and, therefore, the braking force applied to the wheels. Controller **36** may comprise a programmable microprocessor or microcontroller or may comprise an application specific integrated circuit (ASIC). Referring to FIG. **4**, brake controller **36** may include a memory **112** and a central processing unit (CPU) **114**. Brake controller **36** may also include an input/output (I/O) interface **116** including a plurality of input/output pins or terminals through which controller **36** may receive a plurality of input signals and transmit a plurality of output signals. The input and output signals may be transmitted and received over dedicated wires or other conductors or over a conventional vehicle communications bus **118** as described hereinabove. The input signals may include signals received from various sensors including one or more of sensors **26**, **28**, **30**, **32**, **34** and signals received from operator interfaces and other vehicle control systems. In accordance with one aspect of the teachings disclosed herein, the input signals may also include signals from a controller for a steering system for vehicle **10** described in greater detail hereinbelow. The output signals may include signals used to control relay valves **52**, **54** and modulators **64**, **66**, **68**, **70**, **72** and, in particular, the solenoids in relay valves and modulators **64**, **66**, **68**, **70**, **72** such as exhaust solenoid **84** and holding solenoid **86** of each modulator **64**, **66**, **68**, **70**, **72**.

[0028] Referring to FIG. **3**, vehicle **10** further includes a steering system **120**. System **120** provides a means for the operator of vehicle **10** to input steering forces to vehicle **10** to turn one or more steerable wheels **122** (e.g., those on steer axle **14**) on vehicle **10**. System **120** may include a steering column **124**, a power steering system **126**, and a steering linkage **128**.

[0029] Steering column **124** provides a means for the operator to input steering forces and to transfer those forces to steerable wheels **122** on vehicle **10**. Column **124** may include a steering wheel **130** that is rotated by the vehicle operator and that is coupled to, and configured to rotate, a steering shaft **132** that is ultimately coupled to, and provides an input to, the power steering system **126**.

[0030] Power steering system **126** transfers and augments forces input by the vehicle operator through steering column **124** to steering linkage **128** in order to turn the wheels **122**. In certain embodiments, system **126** may also assist the vehicle operator in maintaining the position of vehicle **10** relative to a lane of travel in response to signals generated by a lane keep assist system on vehicle **10**. In accordance with one aspect of the systems and methods disclosed herein, system **126** may further be used in testing steering system **120** by causing predefined rotational movements of steering wheel **130** upon activation of the vehicle **10** that provide visual and/or haptic feedback to the operator of vehicle **10** regarding the operation of steering system **120**. System **126** includes a steering gear **134**, a steering actuator **136** and a steering controller **138**.

[0031] Steering gear **134** transfers forces input by the vehicle operator through steering column **124** to steering linkage **128** in order to turn the wheels **122**. Steering gear **134** may comprise rack and pinion gears or a recirculating ball gear.

[0032] Steering actuator **136** generates a force to cause movement of steering gear **134** responsive to control signals from controller **138**. This force may be added to the forces input through steering column **124** to assist in steering (i.e., a torque overlay). Alternatively, this force may be generated independent of forces input through steering column for lane keep assist functionality and for testing steering system **120** as referenced above. Steering actuator **136** may comprise an electromagnetic actuator in which an energized conductor (which may be paired with a permanent magnet) creates an electromagnetic circuit with rotational components of the steering gear **134** to cause rotation of those components.

[0033] Steering controller **138** is provided to control steering actuator **136**. During normal operation of vehicle **10**, steering controller **138** receives input signals from steer angle and torque sensors on the steering column **124**, such as steer angle sensor **32**, indicative of inputs from the vehicle operator and generates output signals to control steering actuator **136** to assist movement of steering gear **134**. Steering controller **138** may also generate output signals to control steering actuator **136** independent of movement of the steering column **124** by the vehicle operator. For example, steering controller **138** may generate and transmit output signals to steering actuator **136** responsive to signals from various sensors (e.g., cameras) or a separate lane keep assistance controller indicating that vehicle **10** is unintentionally drifting out of the lane of travel. In accordance with the systems and methods disclosed herein, steering controller **138** may also generate and transmit output signals to steering actuator **136** to cause movement of steering gear **134** and, as a result, steering column **124**, to test the operation of steering system **120** and provide visual and/or haptic feedback to the vehicle operator regarding the operation of steering system **120**. Steering controller **138** may comprise a programmable microprocessor or microcontroller or may comprise an application specific integrated circuit (ASIC). Referring to FIG. **4**, steering controller **138** may include a memory **140** and a central processing unit (CPU) **142**. Steering controller **138** may also include an input/output (I/O) interface **144** including a plurality of input/output pins or terminals through which steering controller **138** may receive a plurality of input signals and transmit a plurality of output signals. The input and output signals may be transmitted and received over dedicated wires or other conductors or over a conventional vehicle communications bus **118** as described hereinabove. The input signals may include signals received from various sensors including the steer angle and torque sensors referenced above and signals from sensor or systems indicating unintentional departure from a lane of travel. In accordance with one aspect of the teachings disclosed herein, the input signals may also include signals from brake controller **36** for braking system **20**. The output signals may include signals used to control steering actuator **136** and, therefore, movement of steering gear **134**.

[0034] Referring again to FIG. **3**, steering linkage **128** translates movement of steering gear **134** into corresponding movement of wheels **122**. Linkage **128** includes a combination of rods and levers that are moved laterally by steering gear **134** to turn wheels **122**. Linkage **128** may, for example include steering knuckles, tie rods, links, an idler arm and a Pittman arm that is driven by steering gear **134**

[0035] Referring again to FIG. **4**, one embodiment of a system **146** for testing braking system **20** and steering system **120** of vehicle is illustrated. System **146** combines elements of braking system **20** including electropneumatic modules such as relay valves **52**, **54** and/or modulators **64**, **66**, **68**, **70** and brake controller **36** and elements of steering system **120** including steering actuator **136** and steering controller **138**. In accordance with one aspect of the systems and methods disclosed herein, system **146** synchronizes testing of braking system **20** and steering system **120** to enable the tests to be performed at least partially simultaneously while doing so in manner that makes it easier for an operator of vehicle **10** or other observes to observe the outputs of each test. In the illustrated embodiment, controllers **36**, **138** communicated with each another to synchronize generation of control signals to electropneumatic modules such as relay valves **52**, **54** and/or modulators **64**, **66**, **68**, **70** and steering actuator **136**. It should be understood, however, other embodiments may combine the relevant functionality of controllers **36** and **138** into a single controller that synchronizes the timing of control signals to electropneumatic modules such as relay valves **52**, **54** and/or modulators **64**, **66**, **68**, **70** and steering actuator **136** based on the internal programming of the controller and without the exchange of signals between controllers **36** and **138** in system **146**.

[0036] Referring now to FIGS. **5**A-B, in accordance with the present teachings controllers **36** and **138** may be configured with appropriate programming instructions (i.e., software or a computer program) to implement several steps in a method for testing braking system **20** and steering system **120** of vehicle **10**. The instructions or computer program may be encoded on one or more non-transitory computer storage mediums such as memories **122**, **140** or another memory accessible by controllers **36**, **138**. The program and method are intended to implement testing of the braking system **20** and steering system **122** in a synchronized manner that enables the tests to be performed at least partially simultaneously while doing so in manner that makes it easier for an operator of vehicle **10** or other observers to observe the outputs of each test. In this manner, the system and method enable the tests to be performed in an efficient manner that prevents operating delays for vehicle **10** while ensuring that the results of the tests can be adequately monitored and observed by the vehicle operator or other observers.

[0037] The method may begin with the steps **148**, **150** of determining whether the brake pedal has been actuated and whether vehicle **10** has been started or activated. Controllers **36**, **138** may use actuation of the brake pedal while activating vehicle **10** as a trigger to initiate subsequent testing of the braking system **20** and steering system **120** by controllers **36**, **138**. The operator of vehicle **10** may actuate the brake pedal by depressing the brake pedal associated with foot pedal valve **50**. The operator of vehicle **10** may activate vehicle **10** by, for example turning a key or pushing a button. Controllers **36** and/or **138** may detect actuation of the brake pedal by the vehicle operator and activation of vehicle **10** by the vehicle operator based on signals from various sensors and systems on vehicle **10**. For example, as to actuation of the foot pedal, a position sensor may generate a signal indicative of the change in position of the foot pedal or a pressure sensor may generate a signal indicative of a change in pressure in fluid circuit **24**. As to activation of vehicle **10**, position sensors indicative of the position or state of a start or ignition switch, voltage or current sensors indicative of the delivery of voltage or current from the vehicle battery, sensors indicative of the activation of various systems on vehicle **10** (e.g., power transmission systems or exhaust systems in vehicles where vehicle **10** includes an internal combustion engine or motors used to drive the vehicle wheels where vehicle **10** comprises an electric or hybrid vehicle) may provide an indication that vehicle **10** has moved from an inactive state to an active state.

[0038] If brake controller **36** determines that the brake pedal has been actuated and that vehicle **10** has been activated, the method may continue with the step **152** of testing the solenoids in electropneumatic modules such as relay valves **52**, **54** and modulators **64**, **66**, **68**, **70** to determine whether any of the solenoids are electrically open or shorted. If any of the solenoids are electrically open or shorted, the method may conclude with the step **154** of generating one or more warnings to the operator of vehicle **10** or to other individuals or vehicle systems and terminating the method. Brake controller **36** may, for example, generate and transmit a signal to an operator interface to cause the interface to provide a visual, audio and/or haptic warning to the operator of vehicle **10**. Brake controller **36** may also generate and transmit a signal to a remote system (e.g., fleet management) through a telematics unit on vehicle **10**. Brake controller **36** may further record information regarding the electrically open or short solenoid(s) in memory **112** or another memory for later retrieval by conventional diagnostic tools. Finally, brake controller **36** may generate and transmit a signal to steering controller **138** indicating that further testing of steering system **120** should be terminated.

[0039] If none of the solenoids in electropneumatic modules such as relay valves **52**, **54** and modulators **64**, **66**, **68**, **70** are electrically open or shorted, the method may continue with steps **156**, **158** to synchronize further testing of braking system **20** and steering system **120**. The testing of braking system **20** and steering system **120** may be synchronized in several ways. In one embodiment, testing is synchronized through an initial exchange of synchronization request and acknowledgment signals and establishment of times in each of controllers **36**, **138** for subsequent steps based on those signals. In step **156** one of brake controller **36** or steering controller **138** may establish a time for transmission of a corresponding control signal to a solenoid of an electropneumatic module in braking system **20** or the steering actuator **136** of steering system **120** and transmit a synchronization request signal to the other of controllers **36**, **138** establishing proposed timing for further steps in the testing of braking system **20** and steering system **120**. In step **158**, the controller **36** or **138** receiving the synchronization request signal may establish a time for transmission of the other of the corresponding control signal to a solenoid of an electropneumatic module in braking system **20** or the steering actuator **136** of steering system **120** and transmit a synchronization acknowledgement signal to the controller **36** or **138** transmitting the synchronization request signal acknowledging and approving the proposed timing for further steps in the testing of braking system **20** and steering system **122**. Steps **156**, **158** may be repeated until controllers **36**, **138** agree on the timing of further steps in the testing of braking system **20** and steering system **120** and an appropriate synchronization acknowledgement signal is generated. In another embodiment, testing is synchronized through an initial exchange of synchronization request and acknowledgment signals and continuous exchange of synchronization state signals indicative of the state of each of braking system **20** and steering system **120**. Once a synchronization request issued by one of controllers **36**, **138** has been acknowledged, the requesting controller **36**, **138** may transmit a corresponding control signal and, substantially contemporaneously, a synchronization state signal to the other controller **36**, **138** indicating generation and transmission of the control signal and, therefore, actuation of a solenoid in an electropneumatic module or steering actuator **136**. In this case, substantially contemporaneously means at the same time that the control signal is generated and transmitted or within a period of time after generation and transmission of the control signal sufficient to permit simultaneous actuation of the solenoid and steering actuator **136** as discussed below. Receipt of the synchronization state signal will cause the other, receiving controller **36**, **138** to generate a corresponding control signal to cause actuation of a solenoid in an electropneumatic module or steering actuator **136**. Controllers **36**, **138** may continue to generate and exchange synchronization state signals substantially contemporaneously with generation of each control signal to trigger a sequence of actions by each controller **36**, **13** as discussed below. It should be understood that either controller **36**, **138** may initiate the synchronization process. It should further be understood that, in embodiments with a single controller for braking system **20** and steering system **120**, steps **156**, **158** may be omitted and the timing of subsequent testing steps managed by the single controller.

[0040] Referring now to FIG. **5**B, once the synchronization acknowledgement signal is received, the method may continue with additional testing of braking system **20** and steering system **120** synchronized in any of several ways as discussed above. For example, the initial steps may be performed after a predetermined time delay that is either preset in controllers **36**, **138** and triggered by transmission (for controller **138**) and receipt (for controller **36**) of the synchronization acknowledgement signal or established by, and agreed to by, controllers **36**, **138** during the synchronization steps **156**, **158** discussed above. Alternatively, controllers **36**, **138** may continuously exchange synchronization state signals as each controller generates corresponding control signals.

[0041] Subsequent steps in the testing of braking system **20** are intended to determine whether any of the solenoids in an electropneumatic module are mis-wired. For example, each modulator **64**, **66**, **68**, **70** typically has three wires-a first wire through which current is provided to both exhaust solenoid **84** and holding solenoid **86**, a second wire acting as a ground for exhaust solenoid **84** and a third wire acting as a ground for holding solenoid **86**. Subsequent steps in the method may identify situations in which the ground wires for exhaust solenoid **84** and holding solenoid **86** in any of modulators **64**, **66**, **68**, **70** have been reversed. In addition, or alternatively, subsequent steps in the method may identify situations in which a wire to one electropneumatic module has been incorrectly routed from the intended electropneumatic module to a different electropneumatic module. The method identifies situations in which the ground wires for exhaust solenoid **84** and holding solenoid **86** in modulators **64**, **66**, **68**, **70** are reversed by actuating each of exhaust solenoid **84** and holding solenoid **86** of a given modulator **64**, **66**, **68**, **70** in a different manner. Actuation of exhaust solenoid **84** creates an audible “popping” noise (commonly referred to as a “chuff”) as fluid is exhausted to atmosphere. Actuation of holding solenoid **86** does not result in a similar noise because holding solenoid **86** controls the flow of fluid to the actuator for a wheel brake **22** such that the vehicle operator or another observer will only hear a brief clicking sound. Therefore, for example, in one embodiment exhaust solenoid **84** is actuated for a first period of time (e.g., 10 ms) and holding solenoid **86** is actuated for a second period of time (e.g., 30 ms) different than the first period of time. In situations where the wires to the exhaust solenoid **84** and holding solenoid **86** have been reversed, exhaust solenoid **84** will be actuated for a longer period of time (e.g., 30 ms) leading to a distinctly different (louder) sound. It should be understood that particular periods of time over which solenoids **84**, **86** are actuated may be varied from the example and that the manner in which solenoids **84**, **86** are actuated may also be varied in other ways so long as solenoids **84**, **86** are actuated in different manners to allow for an identifiable audible sound from actuation of exhaust solenoid **84**. For example, in another embodiment, exhaust solenoid **84** may be actuated a first predetermined number of times while holding solenoid **86** is actuated a second predetermined number of times different than the first number of predetermined times. The method identifies situations in which any of the wires have been incorrectly routed from the intended electropneumatic module to a different electropneumatic module by actuating the solenoids of the electropneumatic module in a predetermined pattern. In the illustrated embodiment, the method actuates the solenoids **84**, **86** of modulator **64** (the right front modulator), followed (as described below) by the solenoids **84**, **86** of modulator **66** (the left front modulator), modulator **68** (the right rear modulator), and modulator **70** (the left rear modulator). Because the sounds generated by actuation of solenoid **84** in each modulator **64**, **68**, **70**, **72** will come from a different location relative to the vehicle operator or another observer, the operator or observer will be able to identify which modulator **64**, **68**, **70**, **72** is being actuated at any given time. If the modulators **64**, **68**, **70**, **72** are not activated in the predetermined pattern, (e.g., right front, left front, right rear, left rear), the operator will be able to identify that one or more wires has been misrouted.

[0042] Subsequent steps in the testing of steering system **120** are intended to determine whether there is damage to one or more components of steering system **120** by controlling steering actuator **136** to cause movement of the steering column **124**, steering gear **134**, steering linkage **128** and wheels **22**. The movement of steering wheel **130** on steering column **124** may be visually and/or haptically observed by the operator of vehicle **10** with the absence of movement or excess vibration or “wiggle” of steering wheel **130** indicating potential damage to one or more components of steering system **120**.

[0043] The above-described testing of braking system **20** and steering system **120** are known in the art and additional description of the testing of the braking system **20** may be found in U.S. U.S. Pat. Nos. 5,327,781 A and 6,237,401 B1, the entire disclosures of which are incorporated herein by reference. Because the vehicle operator or other observers must account for visual, audio, or haptic outputs resulting from the testing of each system **20**, **120**, it can be difficult for the operator or observer to monitor the testing and to understand and record the results of each test if the tests are performed contemporaneously. This issue can be addressed by arranging for the testing of systems **20**, **120** to occur sequentially, but doing so may create undesirable delays in operating vehicle **10**. The systems and methods disclosed herein address these competing demands by synchronizing the testing of systems **20**, **120** in a logical manner to allow the testing of systems **20**, **120** to be performed simultaneously or to overlap while still enabling the vehicle operator or another observer to monitor and understand the results of the testing of both systems **20**, **120**.

[0044] Referring again to FIG. 5B, the method may continue with the steps **160**, **162**, **164** in which brake controller **36** generates and transmits one control signal to modulator **64** configured to actuate exhaust solenoid **84** of modulator **64** and another control signal to modulator **64** configured to actuate holding solenoid **86** of modulator **64** and steering controller **138** generates and transmits a control signal to steering actuator **136** configured to cause rotation of steering wheel **130**. As discussed above, the control signals transmitted to exhaust solenoid **84** and holding solenoid **86** are configured to actuate exhaust solenoid **84** and holding solenoid **86** in different manners (e.g., for different periods of time) to allow the vehicle operator or another observer to determine if wiring to solenoids **84**, **86** has been reversed. If modulator **64** is wired properly, the control signals to modulator **64** should result in a distinctive sound from the area of modulator **64** observable by the vehicle operator or others as described above. If modulator **64** is not wired properly, a different sound will be produced or the sound will come from a different modulator/location. If steering system **120** is functioning properly, the vehicle operator will observe (visually or haptically), movement of steering wheel **130** without substantial vibration of steering wheel **130**. If steering system **120** is not functioning properly, the vehicle operator may observe the absence of movement of steering wheel **130** or substantial vibration during movement of steering wheel **130**. As illustrated in FIG. 5B, step **164** occurs simultaneously with one or both of steps **160**, **162** such that the performance of step **164** at least partially overlaps with the performance of one or both of steps **160**, **162** and rotation of the steering wheel **130** occurs during actuation of one or both of exhaust solenoid **84** and holding solenoid **84** of modulator **64**. In this manner, testing of braking system **20** and steering system **120** may be performed more efficiently than if the testing of systems **20**, **120** was performed sequentially thereby avoiding undesirable delays in operating vehicle **10**. It should be understood that the overlap between steps **160**, **162** and step **164** may vary such that the performance of step **164** at least partially overlaps with the performance of one of steps **160**, **162** or both of steps **160**, **162**. Where steps **160**, **162** cause solenoids **84**, **86** to be actuated during a first period of time and a second period of time, respectively, the performance of step **164** may occur during a portion of at least one of the first period of time and second period of time. As illustrated in FIG. 5B, the control signal for steering actuator **136** will also cause steering wheel **130** to rotate in the direction of modulator **64** (to the right in the illustrated embodiment). As a result, the operator is able to more easily monitor and process the results of the simultaneous testing of braking system **20** and steering system **120**.

[0045] Following the completion of steps **160**, **162**, **164** and either a predetermined time delay determined by, and agreed to by, controllers **36**, **138** during the synchronization steps **154**, **156** discussed above or the exchange of one or more synchronization state signals, the method may continue with the steps **166**, **168**, **170** in which brake controller **36** generates and transmits one control signal to modulator **66** configured to actuate exhaust solenoid **84** of modulator **66** and another control signal to modulator **66** configured to actuate holding solenoid **86** of modulator **66** and steering controller **138** generates and transmits a control signal to steering actuator **136** configured to cause rotation of steering wheel **130**. Referring to FIG. **1**, in the illustrated embodiment, modulator **66** is disposed on the same axle **12** as modulator **64**, but on the opposite side of vehicle **10**. As illustrated in FIG. 5B, step **170** again occurs simultaneously with one or both of steps **166**, **168** such that the performance of step **170** at least partially overlaps with the performance of one or both of steps **166**, **168** and rotation of the steering wheel **130** occurs during actuation of one or both of exhaust solenoid **84** and holding solenoid **84** of modulator **66**. The control signal for steering actuator **136** will cause steering wheel **130** to rotate in the direction of modulator **66** (to the left in the illustrated embodiment) again enabling the operator to more casily monitor and understand the results of the simultaneous testing of braking system **20** and steering system **120**.

[0046] Following the completion of steps **166**, **168**, **170** and another predetermined time delay determined by, and agreed to by, controllers **36**, **138** during the synchronization steps **154**, **156** discussed above or the exchange of one or more synchronization state signals, the method may continue with the steps **172**, **174**, **176** in which brake controller **36** generates and transmits one control signal to modulator **68** configured to actuate exhaust solenoid **84** of modulator **68** and another control signal to modulator **68** configured to actuate holding solenoid **86** of modulator **68** and steering controller **138** generates and transmits a control signal to steering actuator **136** configured to cause rotation of steering wheel **130**. Referring again to FIG. **1**, in the illustrated embodiment modulator **68** is disposed on a different axle **14** relative to modulators **64**, **66** and on the same side of the vehicle as modulator **64**. As illustrated in FIG. 5B, step **176** again occurs simultaneously with one or both of steps **172**, **174** such that the performance of step **176** at least partially overlaps with the performance of one or both of steps **172**, **174** and rotation of the steering wheel **130** occurs during actuation of one or both of exhaust solenoid **84** and holding solenoid **84** of modulator **68**. The control signal for steering actuator **136** will again cause steering wheel **130** to rotate in the direction of modulator **68** (to the right in the illustrated embodiment) enabling the operator to more easily monitor and understand the results of the simultaneous testing of braking system **20** and steering system **120**.

[0047] Following the completion of steps **172**, **174**, **176** and another predetermined time delay determined by, and agreed to by, controllers **36**, **138** during the synchronization steps **154**, **156** discussed above or the exchange of one or more synchronization state signals, the method may continue with the steps **178**, **180**, **182** in which brake controller **36** generates and transmits one control signal to modulator **70** configured to actuate exhaust solenoid **84** of modulator **70** and another control signal to modulator **70** configured to actuate holding solenoid **86** of modulator **70** and steering controller **138** generates and transmits a control signal to steering actuator **136** configured to cause rotation of steering wheel **130**. Referring again to FIG. **1**, in the illustrated embodiment modulator **70** is disposed on same axle **14** as modulator **68**, but on a different side of vehicle **10** relative to modulator **68**. As illustrated in FIG. 5B, step **182** again occurs simultaneously with one or both of steps **178**, **180** such that the performance of step **182** at least partially overlaps with the performance of one or both of steps **178**, **180** and rotation of the steering wheel **130** occurs during actuation of one or both of exhaust solenoid **84** and holding solenoid **84** of modulator **70**. The control signal for steering actuator **136** will again cause steering wheel **130** to rotate in the direction of modulator **70** (to the left in the illustrated embodiment of FIG. **1**) enabling the operator to more easily monitor and understand the results of the simultaneous testing of braking system **20** and steering system **120**.

[0048] In the illustrated embodiment, modulators **64**, **66**, **80**, **70** on two axles **14**, **16** are tested. It should be understood, however, that the same tests may be performed on additional axles on vehicle **10** where additional modulators are present. As indicated in FIG. 5B, steps **160** through **182** may be repeated one or more times depending on the embodiment.

[0049] Although particular embodiments of systems and methods for testing braking system **20** and steering system **120** have been described and illustrated herein, it should be appreciated that a number of variations are possible. For example, the testing of braking system **20** may include actuation of solenoids in additional or different electropneumatic modules such as modulator **72** and/or relay valves **52**, **54**. The systems and methods disclosed herein could also be extended to synchronize the testing of other vehicle systems such as power transmissions systems, operator interfaces, access (door and window) control systems, lighting systems and audio systems.

[0050] A system **146** and method for testing a braking system **20** and a steering system **120** of a

vehicle **10** in accordance with the teachings disclosed herein is advantageous relative to conventional systems and methods. In particular, the system **146** and method disclosed herein synchronize testing of the braking system **20** and steering system **120** in manner that enables the tests to be performed at least partially simultaneously while doing so in manner that makes it easier for an operator of the vehicle **10** to observe the outputs of each test. In this manner, the system **146** and method enable the tests to be performed in an efficient manner that prevents operating delays for the vehicle **10** while ensuring that the results of the tests can be adequately monitored and observed by the vehicle operator or other observers.
[0051] While the invention has been shown and described with reference to one or more particular embodiments thereof, it will be understood by those of skill in the art that various changes and modifications can be made without departing from the spirit and scope of the invention.

Claims

1. A system for testing a braking system and a steering system of a vehicle, comprising: a plurality of electropneumatic modules, each electropneumatic module associated with a corresponding brake for a corresponding wheel of the vehicle and including a first solenoid configured to control fluid communication between a brake actuator for the corresponding brake and one of a fluid source and atmosphere; a steering actuator configured to cause rotation of a steering wheel of the vehicle; and, a controller configured to transmit a first control signal to a first electropneumatic module of the plurality of electropneumatic modules, the first electropneumatic module associated with a first brake for a first wheel on a first side of the vehicle, the first control signal configured to actuate the first solenoid of the first electropneumatic module; and, transmit a second control signal to the steering actuator wherein the second control signal is configured to cause rotation of the steering wheel during actuation of the first solenoid of the first electropneumatic module in a first rotational direction towards the first side of the vehicle.
2. The system of claim 1 wherein the controller is further configured to: transmit a third control signal to a second electropneumatic module of the plurality of electropneumatic modules, the second electropneumatic module associated with a second brake for a second wheel on a second side of the vehicle opposite the first side of the vehicle, the third control signal configured to actuate the first solenoid of the second electropneumatic module; and, transmit a fourth control signal to the steering actuator, the fourth control signal wherein the fourth control signal is configured to cause rotation of the steering wheel during actuation of the first solenoid of the second electropneumatic module in a second rotational direction opposite the first rotational direction and towards the second side of the vehicle.
3. The system of claim 2 wherein the first wheel and second wheel are supported on the same axle of the vehicle.
4. The system of claim 1 wherein the controller is further configured to: transmit a third control signal to a second electropneumatic module of the plurality of electropneumatic modules, the second electropneumatic module associated with a second brake for a second wheel on the first side of the vehicle, the third control signal configured to actuate the first solenoid of the second electropneumatic module; and, transmit a fourth control signal to the steering actuator wherein the fourth control signal is configured to cause rotation of the steering wheel during actuation of the first solenoid of the second electropneumatic module in the first rotational direction.
5. The system of claim 1 wherein each electropneumatic module of the plurality of electropneumatic modules further includes a second solenoid configured to control fluid communication between the brake actuator for the corresponding brake and the other of the fluid source and atmosphere, the controller is further configured to transmit a third control signal to the first electropneumatic module, the third control signal configured to actuate the second solenoid of the first electropneumatic module, and the first control signal is configured to actuate the first

solenoid of the first electropneumatic module in a first manner and the third control signal is configured to actuate the second solenoid of the first electropneumatic module in a second manner different than the first manner.

6. The system of claim 1 wherein each electropneumatic module of the plurality of electropneumatic modules further includes a second solenoid configured to control fluid communication between the brake actuator for the corresponding brake and the other of the fluid source and atmosphere, the controller is further configured to transmit a third control signal to the first electropneumatic module, the third control signal configured to actuate the second solenoid of the first electropneumatic module, the first control signal is configured to actuate the first solenoid of the first electropneumatic module for a first period of time and the third control signal is configured to actuate the second solenoid of the first electropneumatic module for a second period of time different than the first period of time and the second control signal is configured to actuate the steering actuator during a portion of at least one of the first period of time and the second period of time.

7. The system of claim 1 wherein the controller includes: a brake controller configured to generate the first control signal; and, a steering controller configured to generate the second control signal; and wherein one of the brake controller and the steering controller is configured to establish a first time for transmission of a corresponding one of the first and second control signals and to transmit a synchronization request signal to another one of the brake controller and the steering controller and the another one of the brake controller and the steering controller is configured to receive the synchronization request signal and establish a second time for transmission of the other corresponding one of the first and second control signals, the first and second times synchronized to cause rotation of the steering wheel during actuation of the first solenoid of the first electropneumatic module.

8. The system of claim 1 wherein the controller includes: a brake controller configured to generate the first control signal; and, a steering controller configured to generate the second control signal; and wherein one of the brake controller and the steering controller is configured to transmit a synchronization state signal to another one of the brake controller and the steering controller substantially contemporaneously with transmission of a corresponding one of the first and second control signals, the synchronization state signal causing the another one of the brake controller and the steering controller to generate the other of the corresponding one of the first and second control signals.

9. An article of manufacture, comprising: a non-transitory computer storage medium having a computer program encoded thereon that when executed by a controller tests a braking system and a steering system of a vehicle, the computer program including code for transmitting a first control signal to a first electropneumatic module of a plurality of electropneumatic modules on the vehicle, each electropneumatic module associated with a corresponding brake for a corresponding wheel of the vehicle and including a first solenoid configured to control fluid communication between a brake actuator of the corresponding brake and one of a fluid source and atmosphere, the first electropneumatic module associated with a first brake for a first wheel on a first side of the vehicle, the first control signal configured to actuate the first solenoid of the first electropneumatic module; and, transmitting a second control signal to a steering actuator configured to cause rotation of a steering wheel of the vehicle wherein the second control signal is configured to cause rotation of the steering wheel during actuation of the first solenoid of the first electropneumatic module in a first rotational direction towards the first side of the vehicle.

10. The article of manufacture of claim 9 wherein the computer program further includes code for: transmitting a third control signal to a second electropneumatic module of the plurality of electropneumatic module, the second electropneumatic module associated with a second brake for a second wheel on a second side of the vehicle opposite the first side of the vehicle, the third control signal configured to actuate the first solenoid of the second electropneumatic module; and, transmitting a fourth control signal to the steering actuator wherein the fourth control signal is configured to cause rotation of the steering wheel during actuation of the first solenoid of the second electropneumatic module in a second rotational direction opposite the first rotational direction and towards the second side of the vehicle.

11. The article of manufacture of claim 10 wherein the first wheel and second wheel are supported on the same axle of the vehicle.

12. The article of manufacture of claim 9 wherein the computer program further includes code for: transmitting a third control signal to a second electropneumatic module of the plurality of electropneumatic module, the second electropneumatic module associated with a second brake for a second wheel on the first side of the vehicle, the third control signal configured to actuate the first solenoid of the second electropneumatic module; and, transmitting a fourth control signal to the steering actuator wherein the fourth control signal is configured to cause rotation of the steering wheel during actuation of the first solenoid of the second electropneumatic module in the first rotational direction.

13. The article of manufacture of claim 9 wherein each electropneumatic module of the plurality of electropneumatic modules further includes a second solenoid configured to control fluid communication between the brake actuator for the corresponding brake and the other of the fluid source and atmosphere and the computer program further includes code for transmitting a third control signal to the first electropneumatic module, the third control signal configured to actuate the second solenoid of the first electropneumatic module, the first control signal configured to actuate the first solenoid of the first electropneumatic module in a first manner and the third control signal configured to actuate the second solenoid of the first electropneumatic module in a second manner different than the first manner.

14. The article of manufacture of claim 9 wherein each electropneumatic module of the plurality of electropneumatic modules further includes a second solenoid configured to control fluid communication between the brake actuator for the corresponding brake and the other of the fluid source and atmosphere and the computer program further includes code for transmitting a third control signal to the first electropneumatic module, the third control signal configured to actuate the second solenoid of the first electropneumatic module, the first control signal configured to actuate the first solenoid of the first electropneumatic module for a first period of time and the third control signal configured to actuate the second solenoid of the first electropneumatic module for a second period of time different than the first period of time and the second control signal configured to actuate the steering actuator during a portion of at least one of the first period of time and the second period of time.

15. A method for testing a braking system and a steering system of a vehicle, comprising: transmitting a first control signal to a first electropneumatic module of a plurality of electropneumatic modules on the vehicle, each electropneumatic module associated with a corresponding brake for a corresponding wheel of the vehicle and including a first solenoid configured to control fluid communication between a brake actuator of the corresponding brake and one of a fluid source and atmosphere, the first electropneumatic module associated with a first brake for a first wheel on a first side of the vehicle, the first control signal configured to actuate the first solenoid of the first electropneumatic module; and, transmitting a second control signal to a steering actuator configured to cause rotation of a steering wheel of the vehicle wherein the second control signal is configured to cause rotation of the steering wheel during actuation of the first solenoid of the first electropneumatic module in a first rotational direction towards the first side of the vehicle.

16. The method of claim 15, further comprising: transmitting a third control signal to a second electropneumatic module of the plurality of electropneumatic module, the second electropneumatic module associated with a second brake for a second wheel on a second side of the vehicle opposite the first side of the vehicle, the third control signal configured to actuate the first solenoid of the second electropneumatic module; and, transmitting a fourth control signal to the steering actuator wherein the fourth control signal is configured to cause rotation of the steering wheel during actuation of the first solenoid of the second electropneumatic module in a second rotational direction opposite the first rotational direction and towards the second side of the vehicle.

17. The method of claim 16 wherein the first wheel and second wheel are supported on the same axle of the vehicle.

18. The method of claim 15, further comprising: transmitting a third control signal to a second electropneumatic module of the plurality of electropneumatic module, the second electropneumatic module associated with a second brake for a second wheel on the first side of the vehicle, the third control signal configured to actuate the first solenoid of the second electropneumatic module; and, transmitting a fourth control signal to the steering actuator wherein the fourth control signal is configured to cause rotation of the steering wheel during actuation of the first solenoid of the second electropneumatic module in the first rotational direction.

19. The method of claim 15 wherein the first control signal is generated by a brake controller, the second control signal is generated by a steering controller and further comprising the steps of: establishing, in one of the brake controller and the steering controller, a first time for transmission of a corresponding one of the first and second control signals; transmitting a synchronization request signal to another one of the brake controller and the steering controller; receiving the synchronization request signal in the another one of the brake controller and the steering controller; and, establishing, in the another one of the brake controller and the steering controller a second time for transmission of the other corresponding one of the first and second control signals wherein the first and second times are synchronized to cause rotation of the steering wheel during actuation of the first solenoid of the first electropneumatic module.

20. The method of claim 15 wherein the first control signal is generated by a brake controller, the second control signal is generated by a steering controller and further comprising the step of transmitting, from one of the brake controller and the steering controller, a synchronization state signal to another one of the brake controller and the steering controller substantially contemporaneously with transmission of a corresponding one of the first and second control signals, the synchronization state signal causing the another one of the brake controller and the steering controller to generate the other of the corresponding one of the first and second control signals.
