extended air springs to keep the vehicle level. Through testing, it has now been found that leveling valves often overcompensate in responding to dynamic weight shifts of the vehicle, in which the air springs that were supplied air from the leveling valve tend to have a greater air pressure than the air springs that were purged by the leveling valve. As a result, a pressure difference persists between the two sides of the air suspensions system ever after the leveling valves attempt to level the vehicle. Even though a pressure differential remains between the air springs on opposite sides of the vehicle, the leveling valves return to a neutral mode (e.g., the rotary disk is set within a dead band range), in which there is a lack of pneumatic communication between the air springs on opposite sides of the vehicle. Due to this pressure differential between the air springs, the vehicle remains unlevel even after the leveling valves have adjusted the pressure of the air springs in response to the vehicle weight shift.

[0005] Other types of air suspension systems have replaced mechanical leveling valves with electronic-actuated valves to the control the height of the air bags. While some electronic-actuated valves have been designed to respond to vehicle weight shifts or vehicle rolling, electronic-actuated valves fail to account for pressure differentials between the air springs that persist after the heights of the air springs have been adjusted in response to vehicle weight shifts.

[0006] Accordingly, the present inventors have recognized that there is a need for an air management system that solves the problem of persistent pressure imbalance so that the vehicle may be restored to equilibrium air pressure, level and ride height.

SUMMARY

[0006a] In a first aspect, the present disclosure refers to an air management system for a vehicle, the air management system comprising: a first pneumatic circuit having a first leveling valve configured to adjust independently a height of a first side of the vehicle, wherein the first leveling valve comprises a first cross-flow port and a first valve element; a second pneumatic circuit having a second leveling valve configured to adjust independently a height of a second side of the vehicle, wherein the second leveling valve comprises a second cross-flow port and a second valve element; and a cross-flow line connecting the first leveling valve with the second leveling valve; wherein the first and second leveling valves are configured to establish pneumatic communication between the first and second pneumatic circuits through the cross-flow line when the first valve element of the first leveling valve and the second valve element of the second leveling valve are simultaneously switched to a cross-flow mode to establish pneumatic communication through the first cross-flow port and the second cross-flow port, and wherein the first and second leveling valves are configured to not independently adjust the heights of the first and second sides of the vehicle in the cross-flow mode.

[0006b] In a second aspect, the present disclosure refers to a leveling valve comprising: an upper housing mounted on a lower housing to form a valve body, wherein the valve body defines a chamber extending between the upper housing and the lower housing; the lower housing comprising a plurality of ports communicating with the chamber, wherein the plurality of ports include a supply port, an exhaust port, one or more spring ports, and a cross-flow port; a control arm having a first end attached to a shaft extending through an upper surface of the upper housing, wherein the control arm is configured to rotate about the valve body in response to extension or compression of a vehicle suspension; a rotary disk positioned in the chamber of the valve body and connected to the control arm by the shaft extending through the upper housing, wherein the rotary disk is configured to rotate about the shaft within the chamber of the valve body; and wherein the rotary disk is configured to establish communication between the one or more spring ports and the cross-flow port in a cross-flow mode while neither establishing communication between the one or more spring ports and the supply port nor the one or more spring ports and the exhaust port.

[0006c] In a third aspect, the present disclosure refers to a method for controlling vehicle stability comprising: installing the air management system of the first aspect on the vehicle; and establishing, by the first and second leveling valves, pneumatic communication between the first and second pneumatic circuits through the cross-flow line when the first valve element and the second valve element are simultaneously switched to the cross-flow mode to establish pneumatic communication through the first cross-flow port and the second cross-flow port.

[0006d] In a fourth aspect, the present disclosure refers to a method for adjusting air pressure of an air management system of a vehicle comprising one or more air supply tanks, a first pneumatic circuit disposed on a first side of the vehicle, and a second pneumatic circuit disposed on a second side of the vehicle, the method comprising: adjusting independently the air pressure of the first pneumatic circuit by a first leveling valve such that the first leveling valve is either supplying air from the one or more air supply tanks to the first pneumatic circuit or removing air from the first pneumatic circuit to the atmosphere, wherein the first leveling valve has a cross-flow port and a first valve element, adjusting independently the air pressure of the second pneumatic circuit by a second leveling valve such that the second leveling valve is either supplying air from the one or more air supply tanks to the second pneumatic circuit or removing air from the second pneumatic circuit to the atmosphere, wherein the second leveling valve has a cross-flow port and a second valve element, and establishing pneumatic communication between the first pneumatic circuit and the second pneumatic circuit through a cross-flow line only when the first valve element of the first leveling valve and the second valve element of the second leveling valve are simultaneously switched to a cross-flow mode to establish pneumatic communication through the cross-flow port of the first leveling valve and the cross-flow port of the second leveling valve, wherein each leveling valve is neither supplying air from the one or more air supply tanks or removing air into the atmosphere in the cross-flow mode.

[0006e] In a fifth aspect, the present disclosure refers to a vehicle suspension system comprising: a vehicle chassis; at least one axle connected to the vehicle chassis; an air compressor; an air tank pneumatically connected to the air compressor; the air management system of the first aspect; and at least one supply hose pneumatically connecting the air tank to the first and second pneumatic circuits.

[0006f] In a sixth aspect, the present disclosure refers to a vehicle suspension system comprising:

a vehicle chassis; at least one axle connected to the vehicle chassis; an air compressor; an air tank pneumatically connected to the air compressor; a first leveling valve and a second leveling, wherein each of the first and second leveling valves is the leveling valve of the second aspect; at least one supply hose pneumatically connecting the air tank to the first and second leveling valves; a cross-flow line connecting the first leveling valve with the second leveling valve; and at least one air spring connected to the spring port of the first leveling valve and at least one air spring connected to the spring port of the second leveling valve.

[0006g] In a seventh aspect, the present disclosure refers to a cross-flow system of a vehicle comprising: a first pneumatic circuit on a first side of the vehicle; a second pneumatic circuit disposed on a second side of the vehicle, wherein the first side of the vehicle is opposite to the second side of the vehicle; a cross-flow line that connects the first pneumatic circuit to the second pneumatic circuit and wherein the cross-flow line is not directly connected to a supply tank and the cross-flow line is not directly connected to a supply line in fluid communication with the supply tank; and an electronic system in communication with the cross-flow line, wherein actuation of the cross-flow system is linked to the electronic system for braking operation and/or steering control of the vehicle.

[0007] The present disclosure provides, in an example, for an enhanced pneumatic suspension system for a vehicle in which the air management system includes a first pneumatic circuit, a second pneumatic circuit, and a cross-flow mechanism pneumatically connecting the first pneumatic circuit with the second pneumatic circuit. The first pneumatic circuit includes a first leveling valve configured to adjust independently the height of a first side of the vehicle. The second pneumatic circuit includes a second leveling valve configured to adjust independently the height of a second side of the vehicle. The first and second leveling valves are configured to establish pneumatic communication between the first and second pneumatic circuits when the first leveling valve is not independently adjusting the height of the first side of the vehicle and the second leveling valve is not independently adjusting the height of the second side of the vehicle. According to the various examples of the air management systems described herein, all air management systems are

[0013] In one configuration each leveling valve may include a cylindrical-shaped manifold, a valve member disposed in the manifold and in sliding engagement with an interior surface of the manifold, and an electronic actuator operatively linked to the valve member. The manifold may comprise a plurality of openings disposed along a side surface of the manifold. The electronic actuator may be configured to actuate the valve member to slide along the longitudinal axis of the manifold to control the exposure of the plurality of openings such that a respective leveling valve is configured to selectively: (i) supply air to a respective pneumatic circuit, (ii) remove air from a respective pneumatic circuit, or (iii) establish cross-flow between the first and second pneumatic circuits.

[0014] The present disclosure includes a leveling valve. The leveling valve may comprise an upper housing mounted on a lower housing to form a valve body, in which the valve body defines a chamber extending between the upper housing and the lower housing. The lower housing may include a plurality of ports communicating with the chamber, in which the plurality of ports include a supply port, an exhaust port, one or more spring ports, and a cross-flow port. In one configuration, the lower housing may further comprise a dump port, wherein the cross-flow port is disposed on a first end of the lower housing and the dump port is disposed on a second end of the lower housing opposite to the first end. In one configuration, the supply port may be disposed on a first side of the lower housing, and the exhaust port may be disposed on a second side of the lower housing opposite to the first side of the lower housing. In one configuration, the cross-flow port may be disposed on a first end of the lower housing, and the first end may extend between the first and second sides of the lower housing. In one configuration, the one or more spring ports may comprise a first spring port located on one of the first side or the second side of the lower housing. The leveling valve may include a control arm having a first end attached to a shaft extending through an upper surface of the upper housing, in which the control arm is configured to rotate about the valve body in response to extension or compression of the vehicle suspension. The leveling valve may include a rotary disk positioned in the chamber of the valve body and connected to the control arm by the shaft extending through the upper housing, in which the rotary disk is configured to rotate about the supporting element within the chamber of the valve body. The rotary disk may be configured to establish pneumatic communication between the one or more spring ports and the cross-flow port while neither establishing pneumatic communication between the one or more spring ports and the supply port nor the one or more spring ports and the exhaust port.

[0015] The present disclosure may include a method for controlling stability of a vehicle.

The method may comprise the step of providing an air management system comprising a first pneumatic circuit and a second pneumatic circuit. The first pneumatic circuit may include a first leveling valve configured to adjust independently the height of a first side of the vehicle. The second pneumatic circuit may include a second leveling valve configured to adjust independently the height of a second side of the vehicle. The air management system may include a cross-flow line connecting the first leveling valve with the second leveling valve. The method may comprise the step of establishing, by the first and second leveling valves, pneumatic communication between the first and second pneumatic circuits when the first leveling valve is not independently adjusting the height of the first side of the vehicle and the second leveling valve is not independently adjusting the height of the second side of the vehicle.

[0016] The present disclosure may include a method for adjusting air pressure of an air management system of a vehicle comprising one or more air supply tanks, a first pneumatic circuit disposed on a first side of the vehicle, and a second pneumatic circuit disposed on a second side of the vehicle. The method may comprise a step of adjusting independently the air pressure of the first pneumatic circuit by a first leveling valve such that the first leveling valve is either supplying air from the one or more air supply tanks to the first pneumatic circuit or removing air from the first pneumatic circuit to the atmosphere. The method may comprise the step of adjusting independently the air pressure of the second pneumatic circuit by a second leveling valve such that the second leveling valve is either supplying air from the one or more air supply tanks to the second pneumatic circuit or removing air from the second pneumatic circuit to the atmosphere. The method may comprise the step of establishing pneumatic communication between the first pneumatic circuit and the second pneumatic circuit only when both the first leveling valve and the second leveling valve are set in a neutral mode such that each leveling valve is neither supplying air from the one or more air supply tanks or removing air into the atmosphere.

[0017] The present disclosure may include a control unit associated with an air spring of an air management system for a vehicle. The control unit may comprise a housing configured to be mounted to a top plate of the air spring, wherein the housing comprises a valve chamber. The control unit may comprise a valve disposed in the valve chamber. The valve may be configured to switch between a plurality of modes including: (i) an active mode wherein the valve is adjusting independently a height of the associated air spring, and (ii) a neutral mode wherein the valve is establishing pneumatic communication between the associated air spring and a cross-flow line connected to a second air spring of the air management system when the valve is not in the active

mode. The control unit may comprise one or more sensors configured to monitor at least one condition of the air spring and generate a measurement signal indicating the at least one condition of the air spring. The control unit may comprise a communication interface configured to transmit and receive data signals to and from a second control unit associated with the second air spring of the air management system. The control unit may comprise a processing module operatively linked to the valve, the one or more sensors, and the communication interface, wherein the processing module is configured to: (i) receive measurement signals from the one or more sensors and data signals from the communication interface, and (ii) actuate the valve to switch between the active mode and the neutral mode based on the received measurement signals from the one or more sensors and the data signals from the communication interface.

[0018] The present disclosure may include an air management system for a vehicle. The air management system may comprise a first pneumatic circuit having one or more air springs disposed at a first side of a vehicle. The air management system may comprise a second pneumatic circuit having one or more air springs disposed on a second side of a vehicle. The air management system may comprise one or more cross-flow lines, wherein each cross-flow line extends from an air spring associated with the first pneumatic circuit to an air spring associated with the second pneumatic circuit. Each air spring may comprise a control unit. Each control unit may comprise a housing configured to be mounted to a top plate of an associated air spring, wherein the housing comprises a valve chamber. Each control unit may comprise a valve disposed in the valve chamber, wherein the valve is configured to switch between a plurality of modes including: (i) an active mode wherein the valve is adjusting independently a height of the associated air spring, and (ii) a neutral mode wherein the valve is establishing pneumatic communication between the associated air spring and a respective cross-flow line when the valve is not in the active mode. Each control unit may comprise one or more sensors configured to monitor at least one condition of the associated air spring and generate a measurement signal indicating the at least one condition of the associated air spring. Each control unit may comprise a communication interface configured to directly transmit and receive data signals to and from other control units associated with other air springs of the air management system. Each control unit may comprise a processing module operatively linked to the valve, the one or more sensors, and the communication interface, wherein the processing module is configured to: (i) receive measurement signals from the one or more sensors and data signals from the communication interface, and (ii) actuate the valve to switch between the active mode and the neutral mode based on the received measurement signals from the one or more sensors and the data

signals from the communication interface.

[0019] The present disclosure may include a method for controlling the stability of a vehicle comprising an air management system, in which the air management system may comprise a first pneumatic circuit having one or more air springs disposed at a first side of a vehicle, a second pneumatic circuit having one or more air springs disposed on a second side of a vehicle, and one or more cross-flow lines, in which each cross-flow line extends from an air spring associated with the first pneumatic circuit to an air spring associated with the second pneumatic circuit. The method may comprise the step of monitoring, by a height sensor and an air pressure sensor, a height and an air pressure of a respective air spring. The method may comprise the step of generating, by the height sensor and the air pressure sensor, a signal indicating the height and the air pressure of the respective air spring. The method may comprise the step of receiving, by a processing module, the signal indicating the height and the air pressure of the respective air spring. The method may comprise the step of calculating, by the processing module, a height differential rate and pressure differential rate of the respective air spring based on the received signal indicating the height of the respective air spring. The method may comprise the step of determining, by the processing module, whether to adjust the height of the air spring independently or establish pneumatic communication between the air spring and a respective cross-flow line. The method may comprise the step of actuating, by the processing module, a valve to switch to one of the modes: (i) an active mode wherein the valve is adjusting independently a height of the associated air spring, and (ii) a neutral mode wherein the valve is establishing pneumatic communication between the associated air spring and a respective cross-flow line when the valve is not in the active mode. In one configuration, the height sensor, processing module, and the valve are disposed in a chamber of the air spring.

[0020] According to the various examples of the air management systems described herein, all air management systems include at least two independent pneumatic circuits, in which each independent pneumatic circuit is configured to adjust independently the height of one side of vehicle in response to dynamic vehicle weight shifts. In a state of adjusting independently the height of one side of the vehicle, the respective pneumatic circuit is not in pneumatic communication with the other pneumatic circuit disposed on the opposite of the vehicle such that the air springs on one side of the vehicle are not in pneumatic communication with air springs disposed on the opposite side of the vehicle. According to the various examples of the air management systems described herein, all air management systems may selectively establish cross-flow between the two independent circuits so that the air springs disposed on one side of the vehicle

a passage 473 extending through the body 472 from an first opening 473a defined along the first end 474 to a second opening 473b defined along the second end 476. Unlike the first poppet 460, the size of the first opening 473a in the second poppet 470 is smaller than the size of the second opening 473b. The size and shape of the first opening 473a of the second poppet 470 corresponds to the size and shape of the cross-flow slot 455 in the rotary disk 450. The second poppet 470 is disposed in the cross-flow hole 438c of the lower housing, in which the first end 474 projects of the first surface 436 of the lower housing 436 and engages the rotary disk 450 to provide an air tight seal between the cross-flow slot 455 of the rotary disk 450 and the cross-flow hole 438c.

[00104] In one non-limiting embodiment, the lower housing 430 may comprise a fourth blind hole (not shown) disposed along the first surface 436, whereby the fourth blind hole is aligned with the cross-flow hole 438c and the reservoir cavity 439 is disposed between the fourth blind hole and the cross-flow hole 438c. In some embodiments, the fourth blind hole is ninety degrees separated from the supply and exhaust holes 438a, 438b with respect to the central hole 438d and one-hundred-eighty degrees separated from the cross-flow hole 438c with respect to the central hole 438d. The fourth blind hole is not in pneumatic communication with any one of the supply passage 432a, exhaust passage 432b, first passage 432c, second passage 432d, cross-flow passage 432e, and the dump passage 432f. In some embodiments, a third poppet (not shown) may be disposed in the fourth blind hole. In some embodiments, the third poppet may comprise the same configuration as the first poppet 460 received in the cross-flow hole 438c such that the third poppet comprises a first end configured to project above the first surface 436 of the lower housing 430. When the rotary disk 450 is received on the first surface 436 of the lower housing 430, the third poppet is configured to engage the rotary disk 450 such that a bottom surface of the rotary disk 450 engages four poppets: the pair of first poppets 460 received in the supply and exhaust holes 438a, 438b, the second poppet 470 received in the cross-flow hole, and the third poppet received in the fourth blind hole. By engaging the four poppets that are displaced from each ninety degrees with respect to the center hole 438d, the rotary disk 450 is maintained at a level position.

[00105] FIG. 43 illustrates the relationship between the angle of the control arm and the air pressure at the various ports of the lower housing of a leveling valve in an exemplary embodiment according to the present invention. As shown in FIG. 43, the x-axis reflects the time of motorized operation in seconds, and the y-axis indicates both the angle of the control arm in degrees (i.e., represented by the solid line) and the air pressure in pressure-per-square-inch-gauge (PSIG) of the various valve ports in response to the changing control arm angle (represented by the dotted or

second pneumatic circuit includes either supplying air from the one or more air supply tanks 32, 33 to the second pneumatic circuit or removing air from the second pneumatic circuit to the atmosphere. As shown in FIG. 44, the method 900 comprises a step 930 of establishing pneumatic communication between the first pneumatic circuit and the second pneumatic circuit only when both the first leveling valve 16 and the second leveling valve 17 are set in a neutral mode. In various embodiments, the leveling valve in the neutral mode is neither supplying air from the one or more air supply tanks or removing air into the atmosphere.

[00107] The air management system may include mechanically- or electronically-actuated leveling valves to control communication between the first and second pneumatic circuits. In one exemplary configuration, the air management system may include a leveling valve disposed at each air spring, in which each leveling valve includes a manifold and a plunger disposed in a chamber of the manifold. The plunger is configured to move in the chamber of the manifold between one or more positions including at least a first position to establish cross-flow between the first and second pneumatic circuits and a second position to adjust independently the height of a respective side of the vehicle. Rather than having a control arm to actuate air flow, the manifold may include an electronic actuator to move the plunger between the one or more positions so that air flow may be supplied or removed from the respective air spring. In one exemplary configuration, the air management system may have a central manifold that includes individual ports connected to each air spring of the air management system.

[00108] In one exemplary configuration, the leveling valves may consist of one or more solenoid valves that allow air to be adjusted to each side of the vehicle independently while selectively allowing cross-flow between the first and second pneumatic circuits to equalize air pressure between the first and second sets of air springs. The air management system may further include a controller in electrical communication (e.g. wireless or wired) with the leveling valves to control the operation of the electronically-actuated leveling valves. The air management system may further include air pressure sensors provided in the air lines to sense pressure changes and imbalances and communicate such data to a controller in electrical communication (e.g. wireless or wired) with the leveling valves or to one or more leveling valves themselves. The air management system may further include inputs based on ride height sensors for height control, flow sensors at one or more of the ports, and communication with electronic systems, e.g., any electronic stability control (ESC), including, but not limited to electronic stability program (ESP), dynamic stability control (DSC), vehicle stability control (VSC), automatic traction control (ATC), and/or roll

plurality of valves 850 operatively linked to the system controller 840. Referring to FIG. 21A, one of the valves 850 is deposed in the first pneumatic circuit 810, and the other one of the valves 850 is disposed in the second pneumatic circuit 820. The system controller 840 allows the air management system 800 to selectively supply air to or remove air from each air spring 830 of the air management system 800 by actuating the plurality of valves 850.

[00142] As shown in FIG. 21A, a cross-flow line 860 connects one valve 850 in the first pneumatic circuit 810 to a valve 850 in the second pneumatic circuit 820, thereby establishing a pneumatic connection between the air springs 830 of the first and second pneumatic circuits 810, 820. Each valve 850 is configured to switch between a plurality of states, including a first mode in which air is released out of the air spring 830, a second mode in which the air is supplied into the spring 830, a neutral mode in which the air spring 830 is pneumatically connected to the cross-flow line 860. The system controller 840 is configured to command each valve 850 to switch to a neutral mode to provide cross-flow between the two air springs 830 of the first and second pneumatic circuits 810, 820 when neither air is supplied from the supply tank 804 to the air springs 830 nor air is removed from the air springs 830 to the atmosphere.

[00143] Referring to FIG. 21A, a height sensor 870 is disposed in the top plate 832 of each air spring 830 and is configured to continuously monitor the height of its associated air spring 830. The height sensor 870 may be any suitable device for monitoring the axial height of the air spring, such as the examples described above. Each height sensor 870 is wired to the system controller 840 so that each height sensor 870 may transmit signals indicating the height of its associated air spring 830 to the system controller 840. In other configurations, the air management system 800 may include an air pressure sensor disposed in the top plate of the 832 of each air spring 830. The air pressure sensor is configured to monitor the air pressure of its associated air spring 830 and generate a signal indicating the air pressure of its associated air spring.

[00144] Similar to the system controller shown in FIG. 23, the system controller 840 shown in FIG. 25 comprises a processing module 842 for determining the desired air pressure and flow rate for each air spring 830 of the air management system 800, a communication interface 846 for relaying signals to and from the processing module 842 and the height sensors of the air springs 830, a memory 844 for storing all necessary software that embodies the control strategy and mathematical formulations for the operation of the system controller 840, and a bus 848 connecting the communication interface 846 and memory 84 to the processing module 842. The system controller 840 further comprises a driver module 845, such as a driving circuit, operatively linking

CLAIMS

1. An air management system for a vehicle, the air management system comprising:

a first pneumatic circuit having a first leveling valve configured to adjust independently a height of a first side of the vehicle, wherein the first leveling valve comprises a first cross-flow port and a first valve element;

a second pneumatic circuit having a second leveling valve configured to adjust independently a height of a second side of the vehicle, wherein the second leveling valve comprises a second cross-flow port and a second valve element; and

a cross-flow line connecting the first leveling valve with the second leveling valve;

wherein the first and second leveling valves are configured to establish pneumatic communication between the first and second pneumatic circuits through the cross-flow line when the first valve element of the first leveling valve and the second valve element of the second leveling valve are simultaneously switched to a cross-flow mode to establish pneumatic communication through the first cross-flow port and the second cross-flow port, and wherein the first and second leveling valves are configured to not independently adjust the heights of the first and second sides of the vehicle in the cross-flow mode.

2. The air management system of claim 1, wherein the first and second leveling valves each include a housing body and a control arm pivotably connected to a shaft extending through the housing body, and the control arm is configured to pivot from a neutral position to one or more response positions.

3. The air management system of claim 2, wherein the first and second leveling valves are configured to establish pneumatic communication between the first and second pneumatic circuits when the control arm of both the first and second level valves are set in the neutral position, and the first and second leveling valves are configured to prevent pneumatic communication between the first and second pneumatic circuits when the control arm of one of the first and second leveling valves is set to the one or more response positions.

4. The air management system of claim 2, wherein the first and second leveling valves each include a control arm sensor configured to detect a position of the control arm.

5. The air management system of claim 4, further comprising a control unit in electrical communication with each control arm sensor, wherein each control arm sensor is configured to transmit the position of the control arm as a control arm position input to the control unit, and the control unit is configured to determine a vehicle height relative to the axle at the first and second sides of the vehicle based on the control arm position input.

6. The air management system of claim 1, wherein the first pneumatic circuit comprises a first set of air springs disposed on the first side of the vehicle, a first supply tank, a first plurality of air lines pneumatically connecting the first set of air springs with the first leveling valve, and a first supply line pneumatically connecting the first leveling valve with the first supply tank; and

the second pneumatic circuit comprises a second set of air springs disposed on the second side of the vehicle, a second supply tank, a second plurality of air lines pneumatically connecting the second set of air springs with the second leveling valve, and a second supply line pneumatically connecting the second leveling valve with the second supply tank.

7. The air management system of claim 6, wherein the first plurality of air lines and the second plurality of air lines have substantially the same diameter and length, and the first supply line and the second supply line have substantially the same diameter and length.

8. The air management system of claim 1, wherein the first and second leveling valves are each rotary valves comprising a housing body and a rotary disk configured to rotate within the housing body to alter communication between the first and second pneumatic circuits.

9. The air management system of claim 1, wherein the first and second leveling valves each include a manifold housing, an electronic actuator, the respective first or second valve element disposed in a bore of the manifold housing, which is configured to move in the bore of the manifold housing to one or more positions including at least a neutral position to establish pneumatic communication between the first and second pneumatic circuits and a supply position to supply air to a respective pneumatic circuit from an air supply tank, and an exhaust position to remove air from the respective pneumatic circuit into the atmosphere, and the electronic actuator is configured to trigger movement of the respective first or second valve element between the one or more positions.

10. The air management system of claim 9, wherein the respective first or second valve element is selected from the group consisting of a plunger, a rotary disk, and a poppet.

11. The air management system of claim 9, wherein the electronic actuator is selected from the group consisting of a solenoid, a servomotor, and a stepper motor.

12. The air management system of claim 9, further comprising a control module in electrical communication with the electronic actuator of each leveling valve, wherein the control module is configured to transmit a command to each electronic actuator to trigger movement of the respective first or second valve element between the neutral, supply, and exhaust positions.

13. The air management system of claim 12, further comprising one or more leveling sensors, wherein each leveling sensor is configured to detect vehicle height relative to an axle of the vehicle along a position of the vehicle and transmit the detected vehicle height to the control module as a vehicle leveling input.

14. The air management system of claim 1, wherein the first pneumatic circuit comprises one or more air springs, and the second pneumatic circuit comprises one or more air springs; and

wherein the first leveling valve and the second leveling valve are each an electronically-actuated valve disposed in a chamber of a respective air spring.

15. The air management system of claim 1, wherein the first and second leveling valves each include, a cylindrical-shaped manifold, a valve member disposed in the manifold and in sliding engagement with an interior surface of the manifold, and an electronic actuator operatively linked to the valve member;

wherein the manifold comprises a plurality of openings disposed along a side surface of the manifold, and the electronic actuator is configured to actuate the valve member to slide along the longitudinal axis of the manifold to control the exposure of the plurality of openings such that a respective leveling valve is configured to selectively: (i) supply air to a respective pneumatic circuit, (ii) remove air from a respective pneumatic circuit, or (iii) establish cross-flow between the first and second pneumatic circuits.

16. A leveling valve comprising:

an upper housing mounted on a lower housing to form a valve body, wherein the valve body defines a chamber extending between the upper housing and the lower housing;

the lower housing comprising a plurality of ports communicating with the chamber, wherein the plurality of ports include a supply port, an exhaust port, one or more spring ports, and a cross-flow port;

a control arm having a first end attached to a shaft extending through an upper surface of the upper housing, wherein the control arm is configured to rotate about the valve body in response to extension or compression of a vehicle suspension;

a rotary disk positioned in the chamber of the valve body and connected to the control arm by the shaft extending through the upper housing, wherein the rotary disk is configured to rotate about the shaft within the chamber of the valve body; and

wherein the rotary disk is configured to establish communication between the one or more spring ports and the cross-flow port in a cross-flow mode while neither establishing communication between the one or more spring ports and the supply port nor the one or more spring ports and the exhaust port.

17. The leveling valve of claim 16, wherein the lower housing comprises a dump port, wherein the cross-flow port is disposed on a first side of the lower housing and the dump port is disposed on a second side of the lower housing opposite to the first side.

18. The leveling valve of claim 16, wherein the control arm induces the rotary disk to rotate between a plurality of angular positions to alter communication between the supply port, the exhaust port, the one or more spring ports, and the cross-flow port, wherein the plurality of angular positions include (i) a neutral position, in which the one or more spring ports pneumatically communicate with the cross-flow port, and neither the supply port nor the exhaust port pneumatically communicates with the one or more spring ports, (ii) a supply position, in which the one or more spring ports pneumatically communicate with the supply port, and neither the exhaust port nor the cross-flow port pneumatically communicates with the one or more spring ports, and (iii) an exhaust position, in which the one or more spring ports pneumatically communicate with the exhaust port, and neither the supply port nor the cross-flow port pneumatically communicates with the one or more spring ports.

19. The leveling valve of claim 18, wherein the lower housing comprises a first surface mating with a lower surface of the upper housing, wherein the first surface defines a supply hole directly communicating with the supply port; an exhaust hole directly communicating with the exhaust port; a reservoir cavity directly communicating with the one or more spring ports.

20. The leveling valve of claim 19, wherein the rotary disk comprises a central aperture for receiving the shaft, a plurality of oblong-shaped slots, and a cross-flow slot, wherein the plurality of oblong-shaped slots and cross-flow slot are spaced around the central aperture with dead band defined there between and along the periphery of the rotary disk.

21. The leveling valve of claim 20, wherein the cross-flow slot is configured to overlie the cross-flow hole of the lower housing when the rotary disk is set at the neutral position.

22. The leveling valve of claim 20, wherein the oblong-shaped slots are symmetrically spaced from a central axis extending along a face of the rotary disk, and the cross-flow slot overlies the central axis.

23. A method for controlling vehicle stability comprising:

installing the air management system of claim 1 on the vehicle; and

establishing, by the first and second leveling valves, pneumatic communication between the first and second pneumatic circuits through the cross-flow line when the first valve element and the second valve element are simultaneously switched to the cross-flow mode to establish pneumatic communication through the first cross-flow port and the second cross-flow port.

24. The method of claim 23, wherein the first and second leveling valves each include a housing and a control arm pivotably connected to a shaft extending through the housing, and the control arm is configured to pivot from a neutral position to one or more response positions.

25. The method of claim 24, further comprising:

preventing, by the first and second leveling valves, pneumatic communication between the first and second pneumatic circuits when the control arm of one of the first and second leveling valves is set to the one or more response positions.

26. The method of claim 23, wherein the first pneumatic circuit comprises a first set of air springs disposed on the first side of the vehicle, a first supply tank, a first plurality of air lines pneumatically connecting the first set of air springs with the first leveling valve, and a first supply line pneumatically connecting the first leveling valve with the first supply tank; and

the second pneumatic circuit comprises a second set of air springs disposed on the second side of the vehicle, a second supply tank, a second plurality of air lines pneumatically connecting the second set of air springs with the second leveling valve, and a second supply line pneumatically connecting the second leveling valve with the second supply tank.

27. The method of claim 26, wherein the first plurality of air lines and the second plurality of air lines being of the substantially the same diameter and length, and the first supply line and the second supply line being of substantially the same diameter and length.

28. The method of claim 23, wherein the first pneumatic circuit comprises one or more air springs, and the second pneumatic circuit comprises one or more air springs; and

wherein the first leveling valve and the second leveling valve are each an electronically-actuated valve disposed in a chamber of a respective air spring.

29. The method of claim 23, wherein the first and second leveling valves each include, a cylindrical-shaped manifold, a valve member disposed in the manifold and in sliding engagement with an interior surface of the manifold, and an electronic actuator operatively linked to the valve member;

wherein the manifold comprises a plurality of openings disposed along a side surface of the manifold, and the electronic actuator is configured to actuate the valve member to slide along the longitudinal axis of the manifold to control the exposure of the plurality of openings such that a respective leveling valve is configured to selectively: (i) supply air to a respective pneumatic circuit, (ii) remove air from a respective pneumatic circuit, or (iii) establish cross-flow between the first and second pneumatic circuits.

30. A method for adjusting air pressure of an air management system of a vehicle comprising one or more air supply tanks, a first pneumatic circuit disposed on a first side of the vehicle, and a second pneumatic circuit disposed on a second side of the vehicle, the method comprising:

adjusting independently the air pressure of the first pneumatic circuit by a first leveling valve such that the first leveling valve is either supplying air from the one or more air supply tanks to the first pneumatic circuit or removing air from the first pneumatic circuit to the atmosphere, wherein the first leveling valve has a cross-flow port and a first valve element,

adjusting independently the air pressure of the second pneumatic circuit by a second leveling valve such that the second leveling valve is either supplying air from the one or more air supply tanks to the second pneumatic circuit or removing air from the second pneumatic circuit to the atmosphere, wherein the second leveling valve has a cross-flow port and a second valve element, and

establishing pneumatic communication between the first pneumatic circuit and the second pneumatic circuit through a cross-flow line only when the first valve element of the first leveling valve and the second valve element of the second leveling valve are simultaneously switched to a cross-flow mode to establish pneumatic communication through the cross-flow port of the first leveling valve and the cross-flow port of the second leveling valve, wherein each leveling valve is neither supplying air from the one or more air supply tanks or removing air into the atmosphere in the cross-flow mode.

31. The method of claim 30, wherein each leveling valve includes a housing body comprising a supply port connected to the air supply tank, an exhaust port for purging air into the atmosphere, one or more ports connected to one or more air springs, and the cross-flow port connected to the other one of the first or second leveling valves.

32. The method of claim 31, wherein each leveling valve includes the respective first or second valve element disposed in a chamber of the housing body and an actuator configured to trigger movement of the valve element, wherein the respective first or second valve element is configured to move between a plurality of positions to alter communication between the plurality of ports.

33. The method of claim 32, wherein the plurality of positions include a neutral position comprising a dead-band position and a cross flow position that establishes pneumatic communication between the first and second pneumatic circuits, a supply position to supply air from the one or more air supply tanks to a respective pneumatic circuit, and an exhaust position to remove air from the respective pneumatic circuit into the atmosphere.

34. The method of claim 32, wherein the respective first or second valve element is selected from the group consisting of a plunger, a rotary disk, and a poppet.

35. The method of claim 32, wherein the actuator is a control arm pivotably connected to a shaft extending through the housing body and the respective first or second valve element is a rotary disk.

36. The method of claim 35, wherein the control arm is configured to pivot from a neutral position to one or more response positions, and each leveling valve is set in a neutral mode when the control arm is set in the neutral position, and each leveling valve is adjusting independently the air pressure of a respective pneumatic circuit when the control arm is set to the one or more response positions.

37. The method of claim 32, wherein the actuator is an electronic actuator selected from the group consisting of a solenoid, a servomotor, and a stepper motor.

38. The method of claim 37, further comprising a control module in electrical communication with the electronic actuator of each leveling valve, wherein the control module is configured to transmit a command to each electronic actuator to trigger movement of the respective first or second valve element between the plurality of positions.

39. The method of claim 38, further comprising one or more leveling sensors, wherein each leveling sensor is configured to detect vehicle height relative to an axle of the vehicle along a position of the vehicle and transmit the detected vehicle height to the control module as a vehicle leveling input.

40. The method of claim 30, wherein the first pneumatic circuit comprises a first set of air springs disposed on the first side of the vehicle, a first plurality of air lines pneumatically connecting the first set of air springs with the first leveling valve, and a first supply line pneumatically connecting the first leveling valve with at least one of the one or more air supply tanks; and

the second pneumatic circuit comprises a second set of air springs disposed on the second side of the vehicle, a second plurality of air lines pneumatically connecting the second set of air

springs with the second leveling valve, and a second supply line pneumatically connecting the second leveling valve with at least one of the one or more air supply tanks.

41. The method of claim 30, wherein the first pneumatic circuit comprises one or more air springs, and the second pneumatic circuit comprises one or more air springs; and

wherein the first leveling valve and the second leveling valve are each an electronically-actuated valve disposed in a chamber of a respective air spring.

42. A vehicle suspension system comprising:

a vehicle chassis;

at least one axle connected to the vehicle chassis;

an air compressor;

an air tank pneumatically connected to the air compressor;

the air management system of claim 1; and

at least one supply hose pneumatically connecting the air tank to the first and second pneumatic circuits.

43. A vehicle suspension system comprising:

a vehicle chassis;

at least one axle connected to the vehicle chassis;

an air compressor;

an air tank pneumatically connected to the air compressor;

a first leveling valve and a second leveling, wherein each of the first and second leveling valves is the leveling valve of claim 16;

at least one supply hose pneumatically connecting the air tank to the first and second leveling valves;

a cross-flow line connecting the first leveling valve with the second leveling valve; and

at least one air spring connected to the spring port of the first leveling valve and at least one air spring connected to the spring port of the second leveling valve.

44. The air management system of claim 1, further comprising one or more air pressure sensors or one or more air flow sensors in fluid communication with each of the first pneumatic circuit and the second pneumatic circuit, wherein said one or more air pressure sensors or one or

more air flow sensors are configured to output information regarding air pressure or air flow within one or both of the first pneumatic circuit and the second pneumatic circuit to an electronic system of the vehicle, wherein operation of the air management system is synced with braking operation and/or steering control of the vehicle.

45. The air management system of claim 1, wherein the air management system further comprises or is in fluid communication with an air pressure sensor, an air flow sensor, a ride height sensor, a stability control sensor, or a combination thereof.

46. The air management system of claim 1, wherein the air management system further comprises or is in fluid communication with one or more sensors configured to detect and communicate information regarding air pressure or air flow within the air management system to an electronic system of the vehicle.

47. The air management system of claim 1 in communication with an electronic stability control (ESC) system, further comprising a controller linking the air management system with the ESC,

wherein operation of the air management system is synced with braking operation and/or steering control of the vehicle.

48. The air management system of claim 47, wherein the ESC system includes one or more of electronic stability program (ESP), dynamic stability control (DSC), vehicle stability control (VSC), automatic traction control (ATC), and roll stability control (RSC) systems.

49. A cross-flow system of a vehicle comprising:

a first pneumatic circuit on a first side of the vehicle;

a second pneumatic circuit disposed on a second side of the vehicle, wherein the first side of the vehicle is opposite to the second side of the vehicle;

a cross-flow line that connects the first pneumatic circuit to the second pneumatic circuit and wherein the cross-flow line is not directly connected to a supply tank and the cross-flow line is not directly connected to a supply line in fluid communication with the supply tank; and

an electronic system in communication with the cross-flow line,

wherein actuation of the cross-flow system is linked to the electronic system for braking operation and/or steering control of the vehicle.

50. The cross-flow system of claim 49, further comprising one or more air pressure or one or more air flow sensors, wherein said one or more air pressure or air flow sensors are configured to output information regarding air pressure or air flow within the cross-flow line to the electronic system.

51. The cross-flow system of claim 49, further comprising a cross-flow controller device connected to the cross-flow line or to each of the first and second pneumatic circuits.