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(54) **Title**: SYSTEM AND METHOD FOR CONTROLLING RESPECTIVE BRAKING PRESSURES AT WHEELS ON A VEHICLE

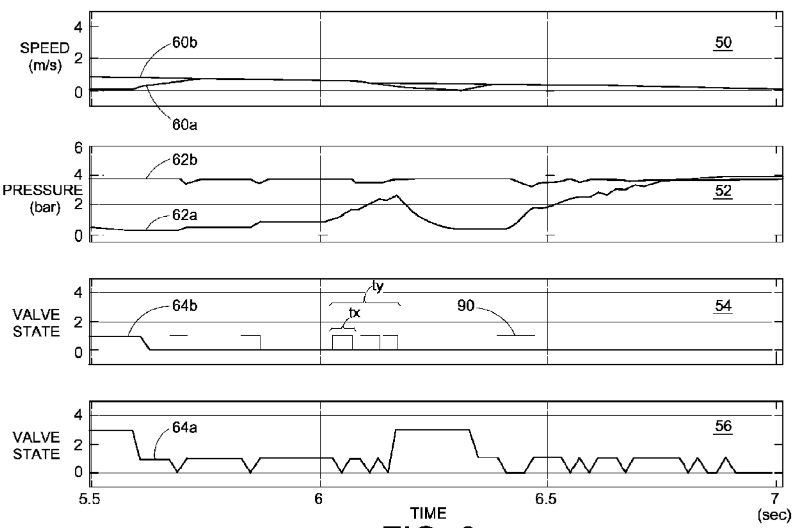

FIG. 6

(57) **Abstract**: A controller controls respective braking pressures at wheels on a vehicle. The controller includes a processor electrically communicating with a first switching valve, which controls a first of the braking pressure at a first of the wheels, and a second switching valve, which controls a second of the braking pressures at a second of the wheels. The processor, during a braking control event, controls the switching valve associated with the higher of the braking pressures to maintain the higher braking pressure while switching a state of the switching valve associated with the lower of the braking pressures to increase the lower braking pressure.

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SYSTEM AND METHOD FOR CONTROLLING RESPECTIVE BRAKING PRESSURES AT WHEELS ON A VEHICLE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to and the benefit of U.S. Application No. 13/967,097, filed August 14, 2013, the entire content of which is incorporated herein by reference.

Background

[0002] The present invention relates to a vehicle braking system. It finds particular application in conjunction with an anti-lock braking system and will be described with particular reference thereto. It will be appreciated, however, that the invention is also amenable to other applications.

[0003] Heavy vehicle braking systems commonly rely on compressed air for operating a vehicle braking system. Compressed air is produced by a compressor and stored in at least one reservoir. Various valves control fluid communication between the at least one reservoir and various brake circuits and individual brake chambers on respective wheels. Opening a valve from a reservoir to a brake circuit or a brake chamber increases the volume available for the compressed air stored in the reservoir. If an increased volume is available for the same amount of compressed air, the pressure of the compressed air in the increased volume drops.

[0004] In general, an anti-lock braking system (ABS) applies, holds, and releases pressure at an individual brake or multiple brakes to improve traction of the associated wheel and, furthermore, enhance vehicle control. Applying, holding, and releasing an individual brake is achieved by actuating and deactuating a valve associated with that brake. As discussed above, if the valve is in the apply state, the volume available for the compressed air increases, thereby decreasing the pressure in the reservoir. Decreased pressure in a brake circuit may impact the braking torque available to other brake chambers in the circuit.

[0005] The present invention provides a new and improved apparatus and method for addressing a decreased pressure available to brake chambers in a circuit when a valve to one of the brake chambers is in the apply state.

Summary

[0006] In one embodiment, a controller controls respective braking pressures at wheels on a vehicle. The controller includes a processor electrically communicating with a first switching valve, which controls a first of the braking pressure at a first of the wheels, and a second switching valve, which controls a second of the braking pressures at a second of the wheels. The processor, during a braking control event, controls the switching valve associated with the higher of the braking pressures to maintain the higher braking pressure while switching a state of the switching valve associated with the lower of the braking pressures to increase the lower braking pressure.

Brief Description of the Drawings

[0007] In the accompanying drawings which are incorporated in and constitute a part of the specification, embodiments of the invention are illustrated, which, together with a general description of the invention given above, and the detailed description given below, serve to exemplify the embodiments of this invention.

[0008] **FIGURE 1** illustrates a schematic representation of a vehicle including a braking system in accordance with one embodiment of an apparatus illustrating principles of the present invention;

[0009] **FIGURE 2** is an exemplary methodology of controlling respective braking pressures at wheels on a vehicle in accordance with one embodiment illustrating principles of the present invention;

[0010] **FIGURE 3** illustrates a graphs of braking pressures versus time for two brake chambers in a circuit;

[0011] **FIGURE 4** illustrates various graphs for a system according to an embodiment of the present invention not including optional time between steps;

[0012] **FIGURE 5** illustrates various graphs for a system according to an embodiment of the present invention including optional time between steps; and

[0013] **FIGURE 6** illustrates enlarged portions of the various graphs shown in **FIGURE 4**.

Detailed Description of Illustrated Embodiment

[0014] With reference to **FIGURE 1**, a simplified component diagram of a vehicle **10** including a compressed air braking system is illustrated in accordance with one embodiment of the present invention. The vehicle **10** includes reservoirs **12** that store compressed air for operating service brakes associated with respective brake chambers **14a, 14b**, **14c**, **14d**, **14e**, **14f** (collectively, **14**) on wheels **16a, 16b**, **16c**, **16d**, **16e**, **16f** (collectively, **16**) of the vehicle **10**. A controller **20** controls delivery of the compressed air from the reservoirs **12** to the brake chambers **14** via switching valves **22a, 22b**, **22c**, **22d** (collectively, **22**) (e.g., solenoid valves) during an ABS event. The switching valves **22** are associated with the brake chambers **14** for applying and releasing the service brakes. In one embodiment, the switching valves **22** are normally open. In an ABS equipped system, the driver will first apply the service foot brake valve **23** which, in turn, opens relays valves **21** for transmitting compressed air to the switching valves **22**. It will be appreciated by one skilled in the art that different methods of control of the compressed air to the brake chambers would be accomplished for a system equipped with a brake controller that can perform electronic stability program (ESP) or electronic braking system (EBS) control.

[0015] In the illustrated embodiment, the brake chambers **14a, 14b** and respective switching valves **22a, 22b** are in a first brake circuit **24**. The brake chambers **14c, 14d, 14e, 14f** and respective switching valves **22c, 22d** are in a second brake circuit **26**.

[0016] In one embodiment, the controller **20** electronically controls the compressed air delivered to the brake chambers **14a, 14b**, **14c**, **14d**, **14e**, **14f**, for application of the service brakes during an ABS event, by electronically actuating the respective switching valves **22a, 22b**, **22c**, **22d**. For example, the controller **20** transmits respective signals, via a vehicle communication bus **30**, to set the respective switching valves **22** to one of i) an apply state, ii) a release state, and iii) a hold state. In the apply state, the switching valves **22** are normally open so that the brake chambers **14** fluidly communicate with the reservoirs **12**. Therefore, in the apply state, the compressed air in the reservoirs **12** passes to the respective brake chambers **14** for applying the service brakes. In the release state, the switching valves **22** close so that the brake chambers **14** do not fluidly communicate with the reservoirs **12**. Therefore, in the release state, the compressed air in the reservoirs **12** is prevented from reaching the respective brake chambers **14**. At the same time, while in the release state, any compressed air currently in the respective brake chambers **14** is exhausted from the brake chambers **14** to atmosphere to release the service brakes. In the hold state, the switching valves **22** close so that the brake chambers **14** do not fluidly communicate with the reservoirs **12**. Therefore, in the hold state, the compressed air in the reservoirs **12** is prevented from reaching the respective brake chambers **14**. At the same time, while in the hold state, any compressed air currently in the respective brake chambers **14** is not exhausted from the brake chambers **14** and, instead, is held in the respective brake chambers **14** for maintaining application of the service brakes.

[0017] Although the illustrated embodiment shows the controller **20** transmitting signals to the switching valves **22** via the vehicle communication bus **30**, other embodiments in which the controller **20** transmits signals directly to the switching valves **22** are also considered.

[0018] The controller **20** includes a communication port **32** and an electronic control unit (ECU) **34** (e.g., a processor). The communication port **32** electronically communicates with both the vehicle communication bus **30** and the ECU **34**. In one embodiment, the ECU **34** is an anti-lock braking system (ABS) that controls the service brakes during an anti-lock braking event, by electronically actuating selected ones of the switching valves **22a, 22b**, **22c**, **22d** of the respective brake chambers **14a, 14b**, **14c**, **14d**, **14e**, **14f** to improve vehicle braking during certain conditions (e.g., when the wheels **16a**, **16b**, **16c**, **16d**, **16e**, **16f** slip during braking due to wet or icy road conditions).

[0019] With reference to **FIGURE 2**, an exemplary methodology of the system shown in **FIGURE 1** for controlling respective braking pressures is illustrated. As illustrated, the blocks represent functions, actions and/or events performed therein. It will be appreciated that electronic and software systems involve dynamic and flexible processes such that the illustrated blocks and described sequences can be performed in different sequences. It will also be appreciated by one of ordinary skill in the art that elements embodied as software may be implemented using various programming approaches such as machine language, procedural, object-oriented or artificial intelligence techniques. It will further be appreciated that, if desired and appropriate, some or all of the software can be embodied as part of a device's operating system.

[0020] With reference to **FIGURES 1 and 2**, the controller **20** determines, in a step **210**, that the vehicle service brakes are applied (see $\mathbf{t_0}$ in **FIGURE 3**). For example, the controller **20** determines that a vehicle operator has initiated a service brake application by depressing a pedal associated with the foot brake valve **23** and/or that the service brakes are automatically applied via, for example, ESP or EBS. At this stage, both the first and second valves **22a, 22b** are in the apply state (e.g., normally open).

[0021] With reference to **FIGURE 3**, graph **212** illustrates pressures in the first and second brake chambers **14a**, **14b**, respectively, versus time. In the graph **212**, dashed lines represent the pressure in the first chamber **14a** and solid lines represent the pressure in the second chamber **14b**. The graph **212** shows that the pressures in the first and second brake chambers **14a**, **14b**, respectively, are substantially the same while both the first and second valves **22a, 22b** are in the apply state (e.g., normally open), which is illustrated between time $\mathbf{t_0}$ and time $\mathbf{t_1}$. For illustration purposes, the dashed and solid lines in **FIGURE 3** are slightly offset from each other between the time $\mathbf{t_0}$ and the time $\mathbf{t_1}$.

[0022] With reference again to **FIGURES 1 and 2**, in a step **214**, the controller **20** receives a first wheel speed sensor signal, from, for example, a first one of the wheel speed sensors **36a**, which is associated with the wheel **16a**. The first wheel speed sensor signal is transmitted to the ECU **34** (processor). In a step **216**, the ECU **34** determines whether pressure in the service brake chambers **14a**, **14b** is at driver demand pressure. For example, the ECU **34** determines if the pressure in the service brake chambers **14a**, **14b** are at the expected pressure based on the pedal associated with the foot brake valve **23** being depressed by the vehicle operator and/or the service brakes being automatically applied via, for example, ESP or EBS. If it is determined in the step **216** that the pressure in the service brake chambers **14a**, **14b** are not at the expected pressure, control returns to the step **210**.

[0023] Otherwise, if it is determined in the step **216** that the pressure in the service brake chambers **14a**, **14b** are at the expected pressure, control passes to a step **220** for determining if a brake control event is active at the first wheel **16a**. If it is determined in the step **220** that a brake control event is not active at the first wheel **16a**, control returns to the step **210**. In one embodiment, if it is determined in the step **220** that a brake control event is active at the first wheel **16a**, it is to be understood that the first valve **22a** is in either the hold state or release state, and the second valve **22b** is in the apply state (see $\mathbf{t_1}$ in **FIGURE 3**).

[0024] Then, in a step **222**, the ECU **34** determines if a brake control event is active at the second wheel **16b**. If it is determined in the step **222** that a brake control event is active at the second wheel **16b**, control returns to the step **210**. In one embodiment, if it is determined in the step **222** that a brake control event is not active at the second wheel **16b**, it is to be understood that the first valve **22a** is in either the hold state or release state, and the second valve **22b** is in the apply state, which are the same states discussed above with reference to the step **220** when a brake control event is not active at the first wheel **16a**.

[0025] With reference again to **FIGURES 1 and 3**, the graph **212** further illustrates pressures in the first and second brake chambers **14a**, **14b**, respectively, versus time. More specifically, the graph **212** shows that the pressure in the first brake chamber **14a** becomes relatively lower than the pressure in the second brake chamber **14b** after time $\mathbf{t_1}$ when the first valve **22a** transitions to the release state. The pressure in the second brake chamber **14b** remains relatively higher than the pressure in the first brake chamber **14a** after the time $\mathbf{t_1}$, since the second valve **22b** remains in the apply state.

[0026] With reference to **FIGURES 1–3**, if it is determined in the step **222** that a brake control event is not active at the second wheel **16b**, control passes to a step **224** in which the ECU **34** determines if a pressure difference between two (2) brake chambers in a brake circuit is greater a predetermined pressure. In one embodiment, the predetermined pressure is about one (1) bar. For example, the ECU **34** determines if a pressure difference between the first and second brake chambers **14a**, **14b** in the brake circuit **24** is greater than the predetermined pressure. If it is determined in the step **224** that the pressure difference between the first and second brake chambers **14a**, **14b** in the brake circuit **24** is not greater than the predetermined pressure, control returns to the step **210**.

[0027] If, on the other hand, it is determined in the step **224** that the pressure difference between the first and second brake chambers **14a**, **14b** in the brake circuit **24** is greater than the predetermined pressure (see Δp in the graph **212)**, control passes to a step **226**, in which the ECU **34** determines if pressure is to be re-applied to the first brake chamber **14a**. The ECU **34** may determine that pressure is to be re-applied to the first brake **14a** because, for example, of braking controlled by ABS, ESP, or EBS. If it is determined in the step **226** that pressure is not to be re-applied to the first brake chamber **14a**, control returns to the step **210**.

[0028] If, on the other hand, it is determined in the step **226** that pressure is to be re-applied to the first brake chamber **14a**, the ECU **34** causes the second valve **22b** to be transitioned to the hold state in a step **230** (at time $\mathbf{t_2}$ in **FIGURE 3**). Therefore, after step **230**, the first valve **22a** remains in either the hold state or the release state, and the second valve **22b** is in the hold state. Then, in a step **232**, the ECU **34** causes the first valve **22a** to be transitioned from either the hold state or the release state to the apply state. Therefore, after step **232**, the first valve **22a** is in the apply state, and the second valve **22b** is in the hold state. Optionally, the ECU **34** causes the first valve **22a** to be transitioned to the apply state in the step **232** up to about 50 ms after the second valve **22b** is transitioned to the hold state in the step **230**.

[0029] With reference to **FIGURES 1–3**, the graph **212** further illustrates the first valve **22a** is transitioned from the release state or the hold state to the apply state. Therefore, while the first valve **22a** is in the release state or the hold state and the second valve **22b** is in the apply state or hold state (e.g., between the time $\mathbf{t_1}$ and the time $\mathbf{t_2}$) the pressure in the first brake chamber **14a**, which is represented by the dotted line, remains below the pressure in the second brake chamber **14b**, Then, when the first valve **22a** transitions to the apply state, (e.g., after the time $\mathbf{t_2}$), the pressure in the first brake chamber **14a** begins to rise (e.g., between the time $\mathbf{t_2}$ and the time $\mathbf{t_3}$ in **FIGURE 3**).

[0030] After the step **232**, control passes to a step **234** in which the ECU **34** sets the first valve **22a** from the apply state to either the hold state or the release state (see the time $\mathbf{t_3}$ in **FIGURE 3**). Although it is contemplated that the first valve **22a** may be set to either the hold state or the release state at the time $\mathbf{t_3}$, the example illustrated in **FIGURE 3** shows the pressure in the first brake chamber **14a** begins to drop after the time $\mathbf{t_3}$. Therefore, **FIGURE 3** illustrates the embodiment in which the ECU **34** sets the first valve **22a** from the apply state to the release state in the step **234**.

[0031] Then, in a step **236,** the ECU **34** sets the second valve **22b** from the hold state to the apply state. Optionally, the ECU **34** causes the second valve **22b** to be transitioned the apply state in the step **236** up to about 50 ms after the first valve **22a** is transitioned to either the hold state or the release state in the step **234**. In other words, the second valve **22b** to be transitioned the apply state in the step **236** up to about 50 ms after the time $\mathbf{t_3}$. Although the present embodiment is described as the ECU **34** setting the second valve **22b** to the apply state up to about 50 ms after the time $\mathbf{t_3}$, other embodiments in which the ECU **34** setting the second valve **22b** to the apply state based on a pressure in the first brake chamber **14a** (e.g., when the pressure in the first brake chamber **14a** reaches about the same pressure as the second brake chamber **14b**) are also contemplated.

[0032] Control then returns to the step **210**.

[0033] As discussed in more detail below, in one embodiment, the step **232** occurs up to about 50 ms after the step **230**. In addition, the step **236** occurs up to about 50 ms after the step **234**.

[0034] The ECU **34** may act as a means for maintaining a higher braking pressure at the second brake while pressure increases at the first brake during a braking control event, if a braking pressure difference between the first and second brakes is greater than the predetermined threshold pressure. More specifically, the ECU **34** controls the first and second switching valves **22a**, **22b** as discussed herein to reduce pressure drops in the second brake chamber **14b** when pressure is increased in the first brake chamber **14a** due to a brake control event (e.g., ABS, ESP, or EBS).

[0035] With reference to **FIGURE 4**, three graphs **50**, **52**, and **56** representative of a system that does not employ the features of the embodiments described above for the present invention. The graph **50** illustrates speed versus time of the wheel **16a** (see **60a**) and the wheel **16b** (see **60b**). The graph **52** illustrates pressure versus time of the first brake chamber **14a** (see **62a**) and the second brake chamber **14b** (see **62b**). A graph **54** illustrates the states of the second valve **22b** (see **64b**). The graph **54** also illustrates a dotted line **90** representing how the states of the second switching device **22b** are modified to include the hold states in the embodiments of the present invention. The graph **56** illustrates the states of the first valve **22a** (see **64a**). As illustrated in the graph **52**, dips **66**, **70**, **72** in the line **62b**, which represent dips in the pressure in the second brake chamber **14b**, are evident at corresponding times when the line **62a** rises **74**, **76**, **80**, which represent pressure rises in the first brake chamber **14a**.

[0036] **FIGURE 5** illustrates four graphs, which correspond to those illustrated in **FIGURE 4**, representative of a system that does employ the features of the embodiments described above for the present invention. For ease of understanding **FIGURE 5**, the corresponding graphs and other numerals in **FIGURE 4** are designated by like numerals with a primed (') suffix and new components are designated by new numerals.

[0037] With reference to **FIGURES 4 and 5**, the dips **66**, **70**, **72** illustrated in **FIGURE 4** are illustrated as filled portions **82'**, **84'**, **86'** in **FIGURE 5**. The filled portions **82'**, **84'**, **86'** indicate the line **62b'**, which represents the pressure of the second brake chamber **14b**, is relatively smoother than the line **62b** (see **FIGURE 4**), which represents torque gained in the second wheel **16b**. The graph **54'** (see **FIGURE 5**) also illustrates a dotted line **90'** representing how the states of the second switching device **22b** are modified to include the hold states in the embodiments of the present invention.

[0038] **FIGURE 6**, illustrates an enlarged view of the graphs **50**, **52**, **54**, **56** (see FIGURE 4) between about 5.5 seconds and about 7.0 seconds). As noted above, the dotted line **90** in the graph **54** represents the states of the second valve **22b**, and the graph **56** illustrates the states of the first valve **22a**. As illustrated during the time period $\mathbf{t_x}$, the second valve **22**a is set to hold (see the step **230** in **FIGURE 2**) and then the first valve **22a** is substantially immediately set to the apply state (see the step **232** in **FIGURE 2**). The first valve **22a** is then set from the apply state to the hold state (see the step **234** in **FIGURE 2**) and then the second valve **22b** is substantially immediately set to the apply state (see the step **236** in **FIGURE 2**). Therefore, the first valve **22a** and the second valve **22b** switch states substantially immediately after each other.

[0039] The optional times (e.g., 50 ms) between the steps **230** and **232** and between the steps **234** and **236** may act to reduce the number of times the second valve **22b** switches between states. For example, in **FIGURE 5** the optional times are incorporated between the steps **230** and **232** and between the steps **234** and **236**. While the second valve **22b** switches to the hold state three (3) times during a time period $\mathbf{t_y}$ in **FIGURE 4**, which does not include the optional times between the steps **230** and **232** and between the steps **234** and **236**, the second valve **22b** switches to the hold state only one time during the time period $\mathbf{t_y}$ in **FIGURE 5**, Therefore, optional times between the steps **230** and **232** and between the steps **234** and **236** are expected to result in less wear on the second valve **22b** and, in addition, capture more pressure at the second chamber **14b**.

[0040] While the present invention has been illustrated by the description of embodiments thereof, and while the embodiments have been described in considerable detail, it is not the intention of the applicants to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. Therefore, the invention, in its broader aspects, is not limited to the specific details, the representative apparatus, and illustrative examples shown and described. Accordingly, departures may be made from such details without departing from the spirit or scope of the applicant's general inventive concept.

I/We claim:

1. A controller controlling respective braking pressures at wheels on a vehicle, the controller comprising:

a processor electrically communicating with a first switching valve, which controls a first of the braking pressure at a first of the wheels, and a second switching valve, which controls a second of the braking pressures at a second of the wheels, the processor, during a braking control event, controlling the switching valve associated with the higher of the braking pressures to maintain the higher braking pressure while switching a state of the switching valve associated with the lower of the braking pressures to increase the lower braking pressure.

2. The controller as set forth in claim 1, wherein the first switching valve is associated with the lower braking pressure and the second switching valve is associated with the higher braking pressure:

the processor transmits a signal to set the second switching valve to a hold state if the processor determines to increase the braking pressure at the first wheel during the braking control event.

3. The controller as set forth in claim 2, wherein:

the first wheel and the second wheel are included in a common brake circuit.

4. The controller as set forth in claim 2, wherein:

the first switching valve is in one of a hold state and a release state while the second switching valve is set to the hold state; and

the processor maintains the second switching valve in the hold state while the first switching valve is set from the one of the hold state and the release state to an apply state.

5. The controller as set forth in claim 2, wherein:

while the second switching valve is in the hold state, the processor transmits a signal to set the first switching valve to an apply state.

6. The controller as set forth in claim 5, wherein:

the processor transmits the signal to set the first switching valve to the apply state up to about 50 ms after transmitting the signal to set the second switching valve to the hold state.

7. The controller as set forth in claim 5, wherein:

while the second switching valve is in the hold state, the processor transmits a signal to set the first switching valve from the apply state to one of a hold state and a release state.

8. The controller as set forth in claim 7, wherein:

while the first switching valve is in the one of the hold state and the release state, the processor transmits a signal to set the second switching valve from the hold state to an apply state.

9. The controller as set forth in claim 8, wherein:

the processor transmits the signal to set the second switching valve from the hold state to the apply state up to about 50 ms after transmitting the signal to set the first switching valve to the one of the hold state and the release state.

10. The controller as set forth in claim 2, wherein:

the respective signals transmitted from the processor to the first switching valve and the second switching valve are transmitted via a vehicle communication bus.

11. The controller as set forth in claim 1, wherein:

the processor controls the switching valve associated with the higher of the braking pressures during the braking control event only if a pressure difference between the first and second braking pressures is greater than a predetermined threshold pressure.

12. The controller as set forth in claim 11, wherein:

the predetermined threshold pressure is about 1 bar.

13. A vehicle braking system, comprising:

a brake circuit including a first brake associated with a first wheel and a second brake associated with a second wheel;

a first switching valve associated with the first brake;

a second switching valve associated with the second brake; and

a braking controller controlling respective braking pressures at the first and second brakes, the controller comprising:

a processor electrically communicating with the first switching valve, which controls pressure at the first brake, and a second switching valve, which controls the pressure at the second brake, the processor controlling the switching valve associated with the higher of the braking pressures, during a braking control event, to maintain the higher braking pressure while switching a state of the switching valve associated with the lower of the braking pressures to increase the lower braking pressure.

14. The vehicle braking system as set forth in claim 13, wherein:

the processor maintains the higher braking pressure by switching the switching valve associated with the higher braking pressure to a hold state before switching the switching valve associated with the lower pressure to an apply state.

15. The vehicle braking system as set forth in claim 13, wherein:

the processor transmits a signal to set the switching valve associated with the higher braking pressure to a hold state up to about 50 ms before transmitting a signal to set the switching valve associated with the lower braking pressure to the apply state.

16. The vehicle braking system as set forth in claim 15, wherein:

after transmitting the signal to set the switching valve associated with the lower braking pressure to the apply state, the processor transmits a signal to set the switching valve associated with the lower braking pressure to one of a hold state and a release state.

17. The vehicle braking system as set forth in claim 15, wherein:

after transmitting the signal to set the switching valve associated with the lower braking pressure to the one of the hold state and the release state, the processor transmits a signal to set the switching valve associated with the higher pressure to the apply state up to about 50 ms after transmitting the signal to set the switching valve associated with the lower braking pressure to the one of the hold state and the release state.

18. The vehicle braking system as set forth in claim 13, wherein:

the processor controls the switching valve associated with the higher of the braking pressures, during the braking control event, if a braking pressure difference between the first and second brakes is greater than a predetermined threshold pressure.

19. The vehicle braking system as set forth in claim 13, wherein the predetermined threshold pressure is about 1 bar.

20. A method for controlling respective braking pressures at wheels in a common braking circuit on a vehicle, the method comprising:

determining if a braking control event is active;

if the braking control event is active, identifying one of the wheels associated with a higher braking pressure and one of the wheels associated with a lower braking pressure; and

if the braking control event is active, maintaining the braking pressure at the wheel associated with the higher pressure when increasing the pressure at the brake chamber associated with the lower pressure.

21. The method for controlling respective braking pressures at wheels on a vehicle as set forth in claim 20, wherein the maintaining step includes:

setting a switching valve associated with the wheel having the higher braking pressure to a hold state.

22. The method for controlling respective braking pressures at wheels on a vehicle as set forth in claim 21, wherein the maintaining step further includes:

setting a switching valve associated with the lower braking pressure from one of a hold state and a release state to an apply state.

23. The method for controlling respective braking pressures at wheels on a vehicle as set forth in claim 22, wherein the maintaining step further includes:

setting the switching valve associated with the lower braking pressure from the apply state to the one of the hold state and the release state.

24. The method for controlling respective braking pressures at wheels on a vehicle as set forth in claim 23, wherein the maintaining step further includes:

setting the switching valve associated with the higher braking from the hold state to the apply state.

25. The method for controlling respective braking pressures at wheels on a vehicle as set forth in claim 24, wherein:

the step of setting the switching valve associated with the lower braking pressure from one of a hold state and a release state to an apply state is performed up to about 50 ms before the step of setting the switching valve associated with the higher braking pressure from the one of the hold state and the release state to the apply state; and

the step of setting the switching valve associated with the lower braking pressure from the apply state to the one of the hold state and the release state is performed up to about 50 ms before the step of setting the switching valve associated with the higher braking from the hold state to the apply state.

26. A controller controlling respective braking pressures at wheels on a vehicle, the controller comprising:

first and second switching valves, associated with respective first and second brakes at respective first and second ones of the wheels on the vehicle; and

a processor electrically communicating with the first switching valve, which controls the first brake, and the second switching valve, which controls the second brake, if a braking pressure difference between the first and second brakes is greater than a predetermined threshold pressure during a braking control event, the processor controlling the first switching valve and the second switching valve to increase the lower braking pressure at the first wheel while maintaining the higher braking pressure at the second wheel.

27. The controller controlling respective braking pressures at wheels on a vehicle as set forth in claim 26, wherein:

the first and second brakes are associated with a common brake circuit.

28. The controller controlling respective braking pressures at wheels on a vehicle as set forth in claim 26, wherein:

the processor causes the second switching valve to switch from an apply state to a hold state.

29. The controller controlling respective braking pressures at wheels on a vehicle as set forth in claim 28, wherein:

the processor causes the first switching valve to switch from one of a hold state and a release state to an apply state; and then

the processor causes the first switching valve to switch from the apply state to one of the hold state and the release state; and then

the processor causes the second switching valve to switch from the hold state to the apply state.

30. The controller controlling respective braking pressures at wheels on a vehicle as set forth in claim 29, wherein:

the processor causes the first switching valve to switch from one of the hold state and the release state to the apply state up to about 50 ms after the processor causes the second switching valve to switch from the apply state to the hold state; and

the processor causes the second switching valve to switch from the hold state to the apply state up to about 50 ms after the processor causes the first switching valve to switch from the apply state to one of the hold state and the release state.

31. A vehicle braking system, comprising:

a brake circuit including a first brake associated with a first wheel and a second brake associated with a second wheel;

a first switching valve associated with the first brake;

a second switching valve associated with the second brake; and

means for maintaining a higher braking pressure at the second wheel while pressure increases at the first wheel during a braking control event.

32. The controller controlling respective braking pressures at wheels on a vehicle as set forth in claim 31, wherein:

the means for maintaining determines if a braking pressure difference between the first and second brakes is greater than a predetermined threshold pressure; and

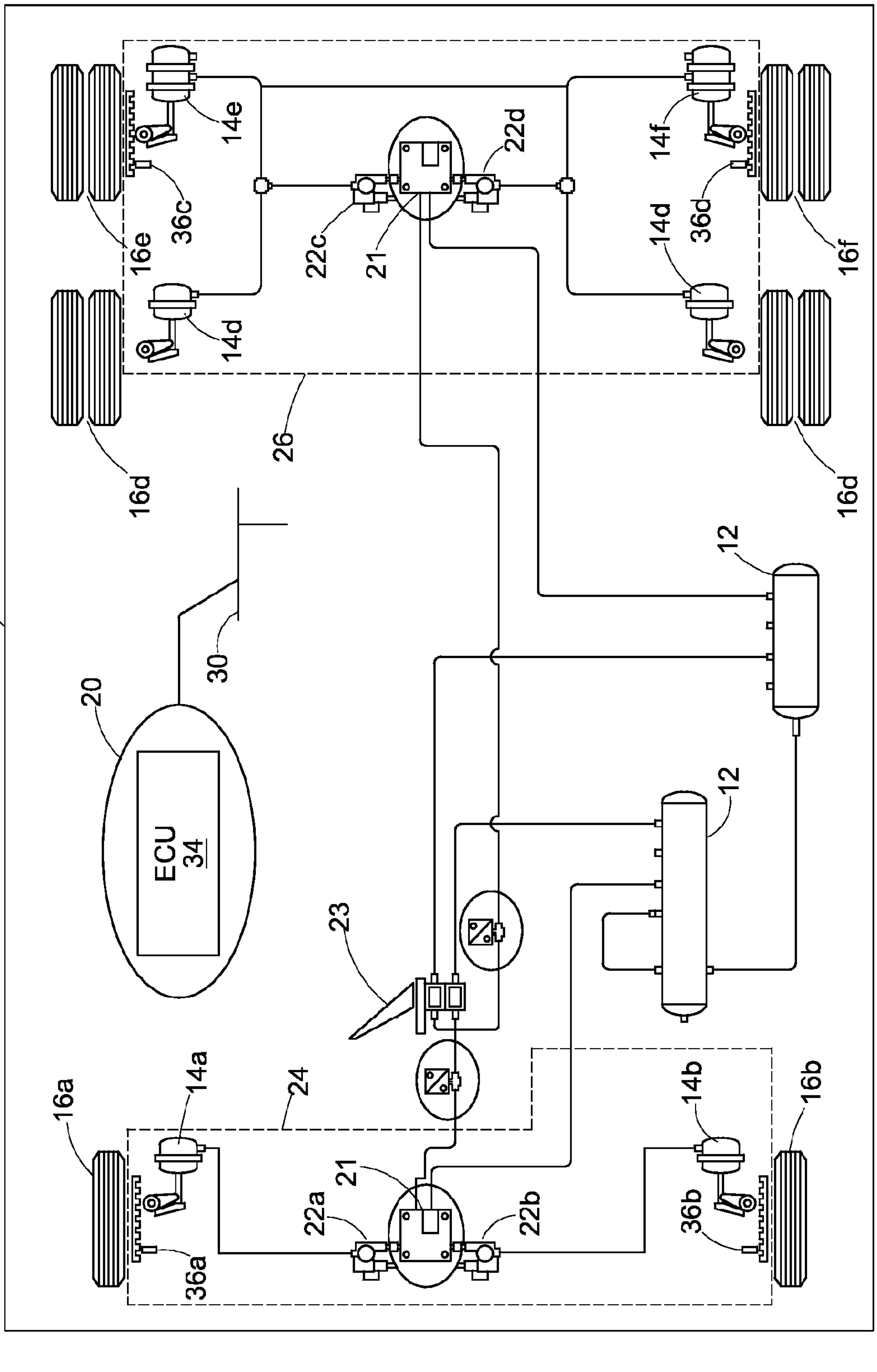
the means for maintaining maintains the higher braking pressure at the second wheel while pressure increases at the first wheel during a braking control event if the braking pressure difference between the first and second brakes is greater than the predetermined threshold pressure.

33. The controller controlling respective braking pressures at wheels on a vehicle as set forth in claim 31, wherein, if the higher braking pressure is at the second brake:

the means for maintaining switches the second switching valve to a hold state between about 50 ms before switching the first switching valve to an apply state;

the means for maintaining switches the first switching valve from the apply state to one of a hold state and a release state; and then

the means for maintaining switches the second switching valve from the hold state to the apply state up to about 50 ms after the first switching valve is switched from the apply state to one of the hold state and the release state.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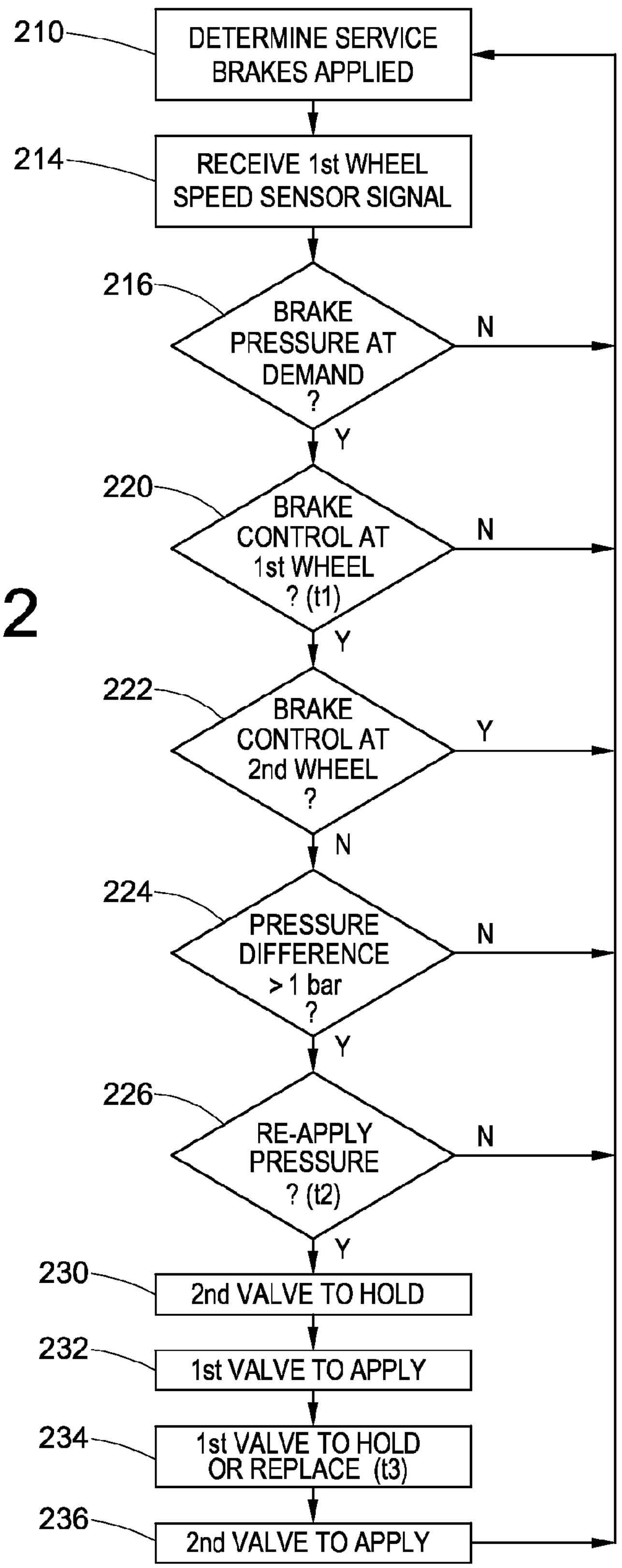
16e
16f
36a
36b
36c
36d

FIG. 1

FIG. 2


210
DETERMINE SERVICE BRAKES APPLIED
214
RECEIVE 1st WHEEL SPEED SENSOR SIGNAL
216
BRAKE PRESSURE AT DEMAND ?
N
Y
220
BRAKE CONTROL AT 1st WHEEL ? (t1)
N
Y
222
BRAKE CONTROL AT 2nd WHEEL ?
Y
N
224
PRESSURE DIFFERENCE > 1 bar ?
N
Y
226
RE-APPLY PRESSURE ? (t2)
N
Y
230
2nd VALVE TO HOLD
232
1st VALVE TO APPLY
234
1st VALVE TO HOLD OR REPLACE (t3)
236
2nd VALVE TO APPLY

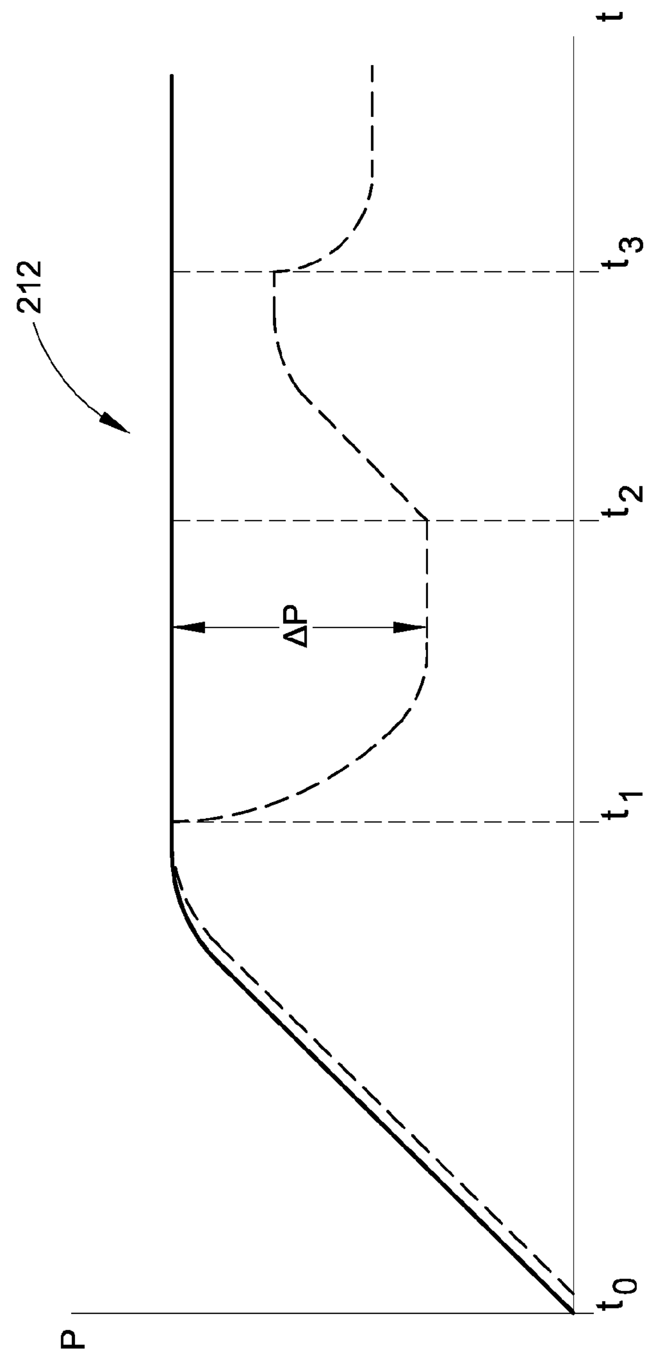


FIG. 3

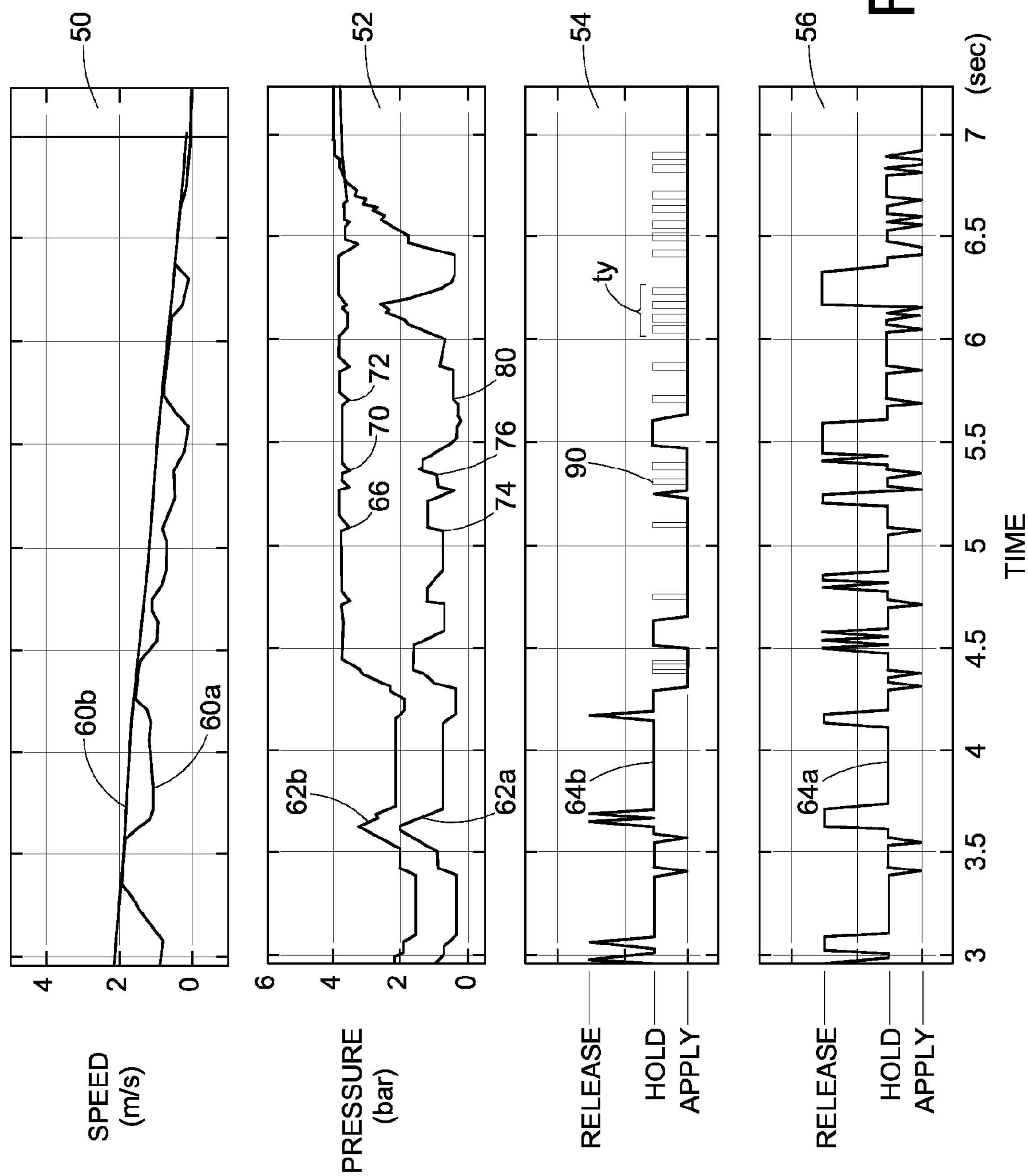

SPEED (m/s)
PRESSURE (bar)
RELEASE
HOLD
APPLY
RELEASE
HOLD
APPLY
TIME
(sec)
3
3.5
4
4.5
5
5.5
6
6.5
7
0
2
4
0
2
4
6
50
52
54
56
60a
60b
62a
62b
64a
64b
66
70
72
74
76
80
90
ty

FIG. 4

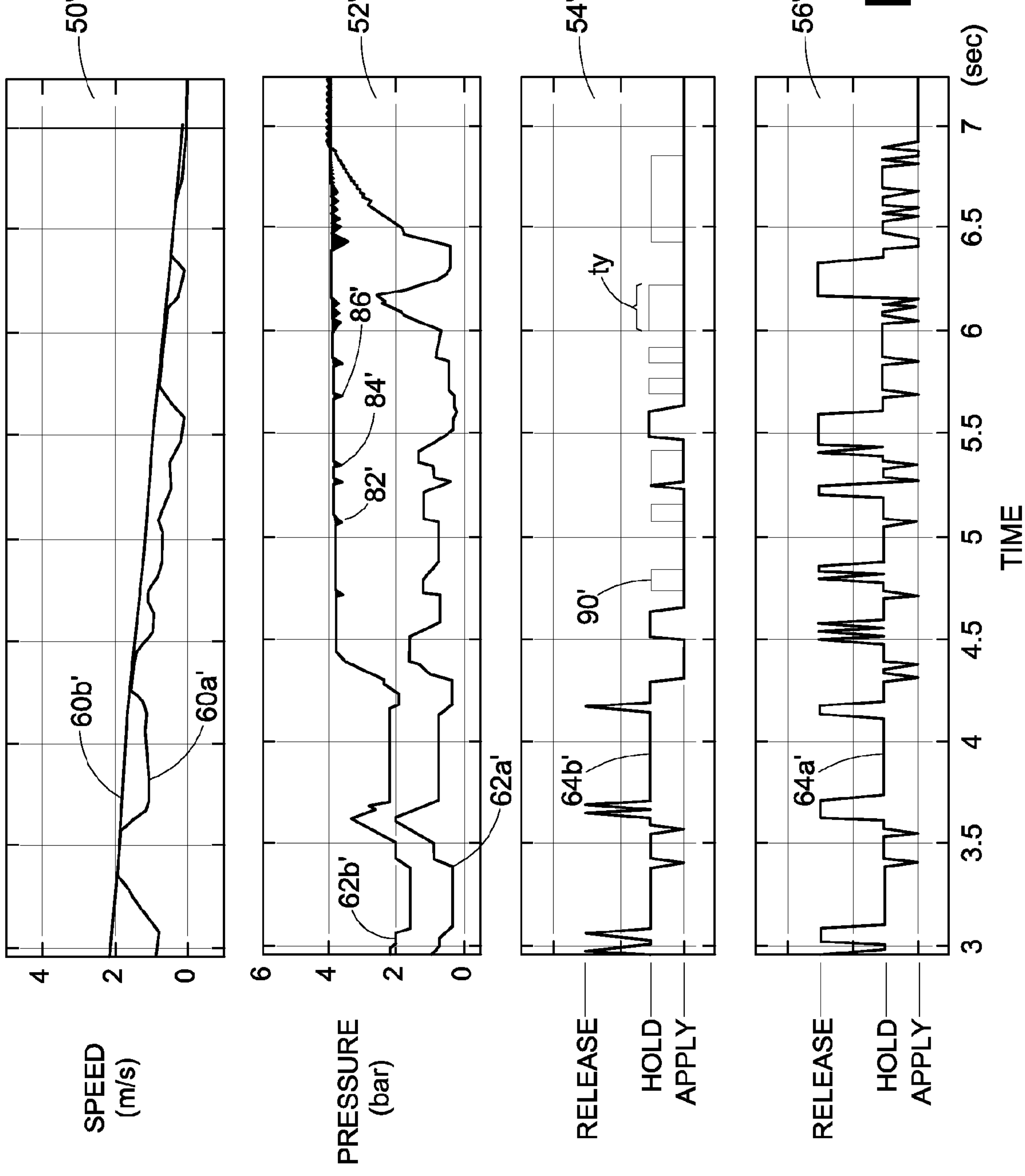
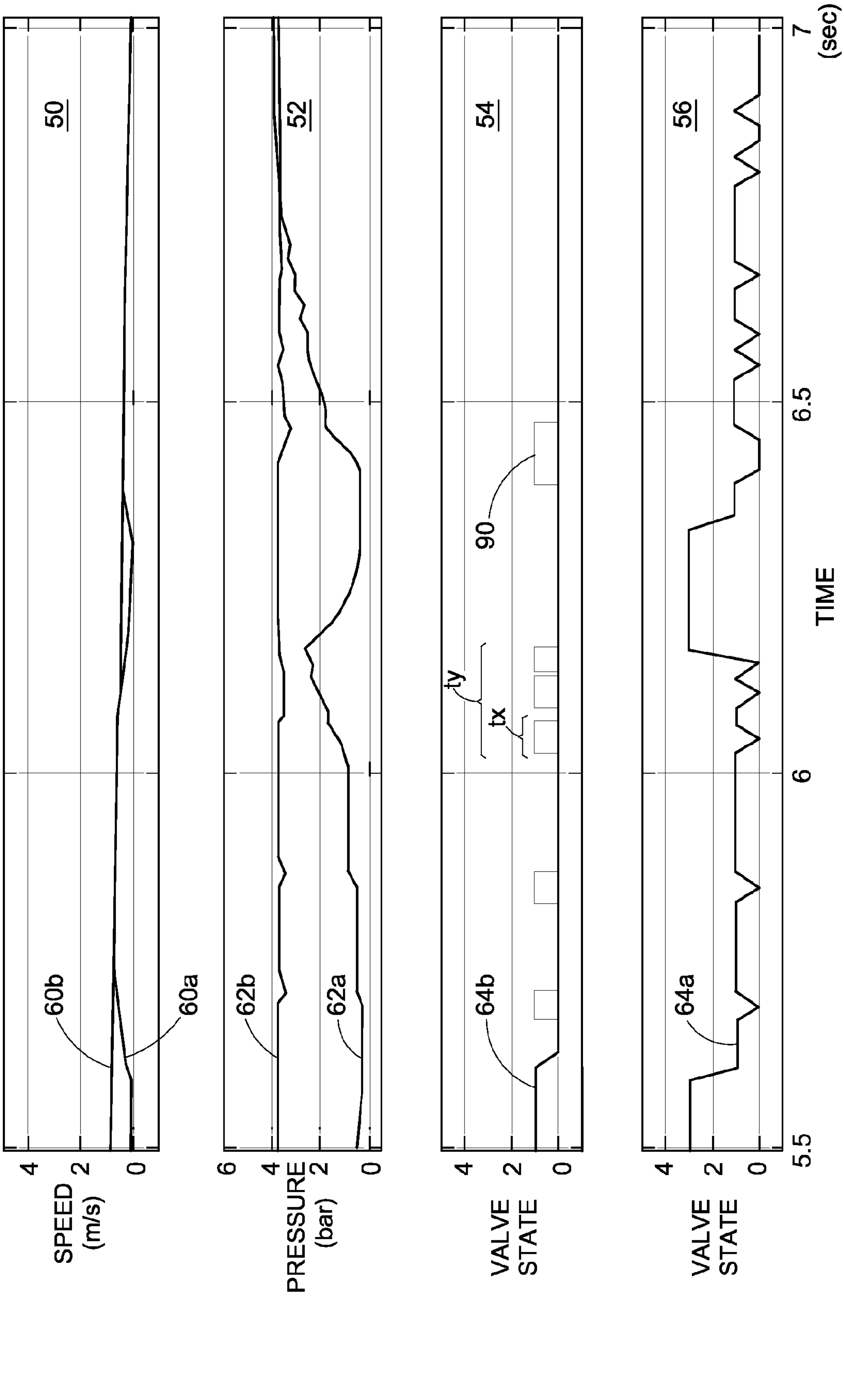

SPEED (m/s)
PRESSURE (bar)
RELEASE
HOLD
APPLY
TIME
(sec)
50'
52'
54'
56'
60a'
60b'
62a'
62b'
64a'
64b'
82'
84'
86'
90'
ty

FIG. 5



SPEED (m/s)
PRESSURE (bar)
VALVE STATE
VALVE STATE
50
52
54
56
60a
60b
62a
62b
64a
64b
90
tx
ty
TIME
5.5
6
6.5
7 (sec)

FIG. 6