SUMMARY OF INVENTION

[0004] According to a first aspect of the present invention, there is provided a liquid dispenser, comprising: a dispenser body including: a dispense chamber portion including a dispense chamber therein, the dispense chamber having a first opening at a first portion of the dispense chamber portion and a second opening at a second portion of the dispense chamber portion, wherein the first portion is configured to couple with a dispensing tip, and a piston chamber portion including a piston chamber therein, the piston chamber being connected to the dispense chamber via the second opening and configured to guide a piston in a linear motion within the piston chamber to draw liquid into the liquid dispenser and to dispense liquid out of the liquid dispenser; a first cavity having a sound generator disposed therein and a first connector channel extending from the first cavity to the dispense chamber, wherein the first connector channel has a neck length L and the neck length L represents a distance between the sound generator and said dispense chamber, the sound generator configured to generate a sound to induce acoustic resonance within the dispense chamber; and a second cavity having an acoustic sensor disposed therein and a second connector channel extending from the second cavity to the dispense chamber, the acoustic sensor configured to sense a sound within the dispense chamber, wherein the first cavity and the first connector channel have substantially the same width over their length, and wherein the second cavity and the second connector channel have substantially the same width over their length. The liquid dispenser may further include a control circuit to determine whether a contact of the dispensing tip with liquid has occurred based on the sensed sound.

[0004a] According to a second aspect of the present invention, there is provided a liquid dispenser system, comprising:

a liquid dispenser including:

a dispenser body including:

a dispense chamber portion including a dispense chamber therein, the dispense chamber having a first opening at a first portion of the dispense chamber

portion and a second opening at a second portion of the dispense chamber portion, wherein the first portion is configured to couple with a dispensing tip, and

a piston chamber portion including a piston chamber therein, the piston chamber being connected to the dispense chamber via the second opening and configured to guide a piston in a linear motion within the piston chamber to draw liquid into the liquid dispenser and to dispense liquid out of the liquid dispenser;

a first cavity having a sound generator disposed therein and a first connector channel extending from the first cavity of the dispense chamber, wherein the first connector channel has a neck length *L* and the neck length represents a distance between the sound generator and the dispense chamber, the sound generator configured to generate a sound to induce acoustic resonance within the dispense chamber; and

a second cavity having an acoustic sensor disposed therein and a second connector channel extending from the second cavity to the dispense chamber, the acoustic sensor configured to sense a sound within the dispense chamber; and

a control circuit configured to determine whether a contact of the dispensing tip with liquid has occurred based on the sensed sound,

wherein the first cavity and the first connector channel have substantially the same width over their length, and

wherein the second cavity and the second connector channel have substantially the same width over their length.

[0005] According to a third aspect of the present invention, there is provided a liquid dispenser, comprising: a dispenser body including: a dispense chamber portion including a dispense chamber therein, the dispense chamber having a first opening at a first portion of the dispense chamber portion and a second opening at a second portion of the dispense chamber portion, wherein the first portion is configured to couple with a dispensing tip, one or more side conduits, each of the one or more side conduits having a respective cavity and a respective connector channel having a neck length *L* connecting the respective cavity to the dispense chamber, the respective cavity and the respective connector channel have substantially the same width over their length, and a piston chamber portion including a piston chamber therein, the piston chamber being

connected to the dispense chamber via the second opening and configured to guide a piston in a linear motion within the piston chamber to draw liquid into the liquid dispenser and to dispense liquid out of the liquid dispenser; a sound generator configured to generate a sound to induce acoustic resonance within the dispense chamber; and an acoustic sensor configured to sense a sound within the dispense chamber, wherein at least one of the sound generator or the acoustic sensor is disposed within the respective cavity of one of the one or more side conduits, wherein the respective cavity and the respective connector of each of the one or more side conduits are free from resonance within a frequency range of the sound sensed by the acoustic sensor. The liquid

dispenser may further include a control circuit configured to determine whether a contact of the dispensing tip with liquid has occurred based on the sensed sound.

[0005a] According to a fourth aspect of the present invention, there is provided a liquid dispenser system, comprising:

a liquid dispenser including:

a dispenser body including:

a dispense chamber portion including a dispense chamber therein, the dispense chamber having a first opening at a first portion of the dispense chamber portion and a second opening at a second portion of the dispense chamber portion, wherein the first portion is configured to couple with a dispensing tip,

a piston chamber portion including a piston chamber therein, the piston chamber being connected to the dispense chamber via the second opening and configured to guide a piston in a linear motion within the piston chamber to draw liquid into the liquid dispenser and to dispense liquid out of the liquid dispenser, and

one or more side conduits, each of the one or more side conduits having a respective cavity and a respective connector having a neck length *L* connecting the respective cavity to the dispense chamber; and

a sound generator configured to generate a sound to induce acoustic resonance within the dispense chamber; and

an acoustic sensor configured to sense a sound within the dispense chamber, wherein at least one of the sound generator or the acoustic sensor is disposed within the dispense chamber portion,

wherein at least one of the sound generator or the acoustic sensor is disposed within the one or more side conduits, wherein the respective cavity and the respective connector have substantially the same width over their length.

[0006] According to a fifth aspect of the present invention, there is provided a liquid dispenser comprising: a dispenser body including: a dispense chamber portion including a dispense chamber therein, the dispense chamber having a first opening at a first portion of the dispense chamber portion and a second opening at a second portion of the dispense chamber

portion, wherein the first portion is configured to couple with a dispensing tip, a piston chamber portion including a piston chamber therein, the piston chamber being connected to the dispense chamber via the second opening and configured to guide a piston in a linear motion within the piston chamber to draw liquid into the liquid dispenser and to dispense liquid out of the liquid dispenser, and an acoustic filter disposed between the dispense chamber and the piston chamber, wherein the acoustic filter is configured to acoustically decouple the dispense chamber from the piston chamber, and one or more side conduits, each of the one or more side conduits having a respective cavity and a respective connector having a neck length L connecting the respective cavity to the dispense chamber; and a sound generator configured to generate a sound to the dispense chamber; and an acoustic sensor configured to sense an acoustic signal resulting from the generated sound, wherein at least one of the sound generator or the acoustic sensor is disposed within the one or more side conduits, wherein the respective cavity and the respective connector have substantially the same width over their length. The liquid dispenser may further include a control circuit configured to determine at least one of: whether contact of the dispensing tip with a liquid has occurred based on the sensed sound, or a volume of the liquid in the dispensing tip based on the sensed sound.

[0006a] According to a sixth aspect of the present invention, there is provided a liquid dispenser system, comprising:

a liquid dispenser comprising:

a dispenser body including:

a dispense chamber portion including a dispense chamber therein, the dispense chamber having a first opening at a first portion of the dispense chamber portion and a second opening at a second portion of the dispense chamber portion, wherein the first portion is configured to couple with a dispensing tip,

a piston chamber portion including a piston chamber therein, the piston chamber being connected to the dispense chamber via the second opening and configured to guide a piston in a linear motion within the piston chamber to draw liquid into the liquid dispenser and to dispense liquid out of the liquid dispenser,

an acoustic filter disposed between the dispense chamber and the piston chamber, wherein the acoustic filter is configured to acoustically decouple the dispense chamber from the piston chamber, and

one or more side conduits, each of the one or more side conduits having a respective cavity and a respective connector having a neck length *L* connecting the respective cavity to the dispense chamber; and

a sound generator configured to generate a sound to the dispense chamber; and

an acoustic sensor configured to sense an acoustic signal resulting from the generated sound; and

a control circuit configured to determine at least one of:

whether a contact of the dispensing tip with liquid has occurred based on the sensed sound, or

a volume of the liquid in the dispensing tip based on the sensed sound,

wherein at least one of the sound generator or the acoustic sensor is disposed within the one or more side conduits, wherein the respective cavity and the respective connector have substantially the same width over their length.

[0007] There is disclosed a method of detecting contact of a liquid dispenser with a liquid. The method includes acquiring, via an acoustic sensor, a plurality of voltage values associated with sound sensed by the acoustic sensor within a time window. The method further includes squaring each of the plurality of voltage values to obtain a plurality of squared voltage values for the time window. The method further includes calculating an average value of the plurality of squared voltage values for the time window. The method further includes determining whether a contact of a dispenser tip of the liquid dispenser with liquid has occurred during the time window based on the average value of the plurality of squared voltage values.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The foregoing and other features, objects and advantages of the invention will be apparent from the following description of embodiments hereof as illustrated in the

CLAIMS

What is claimed is:

1. A liquid dispenser, comprising:

a dispenser body including:

a dispense chamber portion including a dispense chamber therein, the dispense chamber having a first opening at a first portion of the dispense chamber portion and a second opening at a second portion of the dispense chamber portion, wherein the first portion is configured to couple with a dispensing tip, and

a piston chamber portion including a piston chamber therein, the piston chamber being connected to the dispense chamber via the second opening and configured to guide a piston in a linear motion within the piston chamber to draw liquid into the liquid dispenser and to dispense liquid out of the liquid dispenser;

a first cavity having a sound generator disposed therein and a first connector channel extending from the first cavity to the dispense chamber, wherein the first connector channel has a neck length L and the neck length L represents a distance between the sound generator and said dispense chamber, the sound generator configured to generate a sound to induce acoustic resonance within the dispense chamber; and

a second cavity having an acoustic sensor disposed therein and a second connector channel extending from the second cavity to the dispense chamber, the acoustic sensor configured to sense a sound within the dispense chamber,

wherein the first cavity and the first connector channel have substantially the same width over their length, and

wherein the second cavity and the second connector channel have substantially the same width over their length.

2. The liquid dispenser of claim 1, wherein the sound generator and the acoustic sensor are positioned to face each other or are positioned on a same side.

3. The liquid dispenser of any one of claims 1 or 2, wherein the dispense chamber is enclosed except at the first opening and the second opening.

4. The liquid dispenser of any one of claims 1 to 3, further comprising:

a control circuit configured to determine whether a contact of the dispensing tip with liquid has occurred based on the sensed sound.

5. The liquid dispenser of claim 4, wherein the control circuit is further configured to:

identify information about the dispensing tip based on the sensed sound.

6. The liquid dispenser of claim 5, wherein the sensed sound includes a sound pressure sensed within the dispense chamber, and the information about the dispensing tip is identified based on the sensed sound pressure.

7. The liquid dispenser of any one of claims 4 to 6, wherein the control circuit is further configured to:

determine whether the dispensing tip is completely coupled with the first portion of the dispensing chamber portion based on the sensed sound.

8. A liquid dispenser system, comprising:

a liquid dispenser including:

a dispenser body including:

a dispense chamber portion including a dispense chamber therein, the dispense chamber having a first opening at a first portion of the dispense chamber portion and a second opening at a second portion of the dispense chamber portion, wherein the first portion is configured to couple with a dispensing tip, and

a piston chamber portion including a piston chamber therein, the piston chamber being connected to the dispense chamber via the second opening and configured to guide a piston in a linear motion within the piston chamber to draw liquid into the liquid dispenser and to dispense liquid out of the liquid dispenser;

a first cavity having a sound generator disposed therein and a first connector channel extending from the first cavity of the dispense chamber, wherein the first connector channel has a neck length L and the neck length represents a distance between the sound

generator and the dispense chamber, the sound generator configured to generate a sound to induce acoustic resonance within the dispense chamber; and

a second cavity having an acoustic sensor disposed therein and a second connector channel extending from the second cavity to the dispense chamber, the acoustic sensor configured to sense a sound within the dispense chamber; and

a control circuit configured to determine whether a contact of the dispensing tip with liquid has occurred based on the sensed sound,

wherein the first cavity and the first connector channel have substantially the same width over their length, and

wherein the second cavity and the second connector channel have substantially the same width over their length.

9. The liquid dispenser system of claim 8, further comprising:

a liquid dispenser transporter configured to move the liquid dispenser; and

a piston mover configured to move the piston within the piston chamber.

10. The liquid dispenser system of claims 8 or 9, wherein the sound generator and the acoustic sensor are positioned to face each other or are positioned on a same side.

11. The liquid dispenser system of any one of claims 8 to 10, wherein the dispense chamber is enclosed except at the first opening and the second opening.

12. The liquid dispenser system of any one of claims 8 to 11, wherein the control circuit is further configured to:

identify information about the dispensing tip based on the sensed sound.

13. The liquid dispenser system of claim 12, wherein the sensed sound includes a sound pressure sensed within the dispense chamber, and the information about the dispensing tip is identified based on the sensed sound pressure.

14. The liquid dispenser system of any one of claims 8 to 13, wherein the control circuit is further configured to:

determine whether the dispensing tip is completely coupled with the first portion of the dispensing chamber portion based on the sensed sound.

15. A liquid dispenser, comprising:

a dispenser body including:

a dispense chamber portion including a dispense chamber therein, the dispense chamber having a first opening at a first portion of the dispense chamber portion and a second opening at a second portion of the dispense chamber portion, wherein the first portion is configured to couple with a dispensing tip,

one or more side conduits, each of the one or more side conduits having a respective cavity and a respective connector channel having a neck length L connecting the respective cavity to the dispense chamber, the respective cavity and the respective connector channel have substantially the same width over their length, and

a piston chamber portion including a piston chamber therein, the piston chamber being connected to the dispense chamber via the second opening and configured to guide a piston in a linear motion within the piston chamber to draw liquid into the liquid dispenser and to dispense liquid out of the liquid dispenser;

a sound generator configured to generate a sound to induce acoustic resonance within the dispense chamber; and

an acoustic sensor configured to sense a sound within the dispense chamber, wherein at least one of the sound generator or the acoustic sensor is disposed within the respective cavity of one of the one or more side conduits, wherein the respective cavity and the respective connector of each of the one or more side conduits are free from resonance within a frequency range of the sound sensed by the acoustic sensor.

16. The liquid dispenser of claim 15, further comprising:

a control circuit configured to determine whether a contact of the dispensing tip with liquid has occurred based on the sensed sound.

17. The liquid dispenser of claims 15 or 16, wherein the respective cavity and the respective connector of each of the one or more side conduits are free from Helmholtz resonance.

18. The liquid dispenser of claim 17, wherein a lateral dimension of the respective cavity is same as a lateral dimension of the respective connector for each of the one or more side conduits.

19. The liquid dispenser of any one of claims 15 to 18, wherein acoustic resonance within the one or more side conduits is outside of a frequency range of 100 Hz – 4 kHz.

20. The liquid dispenser of claim 19, wherein the acoustic resonance within the one or more side conduits is outside of a frequency range of 200 Hz – 1 kHz.

21. The liquid dispenser of any one of claims 15 to 20, wherein the respective cavity of each of the one or more side conduits is configured to house at least one of the sound generator or the acoustic sensor.

22. The liquid dispenser of claim 21, wherein the one or more side conduits include a single side conduit, and wherein one of the sound generator and the acoustic sensor is housed within the single side conduit and the other one of the sound generator and the acoustic sensor is housed within the dispense chamber portion.

23. A liquid dispenser system, comprising:

a liquid dispenser including:

a dispenser body including:

a dispense chamber portion including a dispense chamber therein, the dispense chamber having a first opening at a first portion of the dispense chamber portion and a second opening at a second portion of the dispense chamber portion, wherein the first portion is configured to couple with a dispensing tip,

a piston chamber portion including a piston chamber therein, the piston chamber being connected to the dispense chamber via the second opening and

configured to guide a piston in a linear motion within the piston chamber to draw liquid into the liquid dispenser and to dispense liquid out of the liquid dispenser, and

one or more side conduits, each of the one or more side conduits having a respective cavity and a respective connector having a neck length *L* connecting the respective cavity to the dispense chamber; and

a sound generator configured to generate a sound to induce acoustic resonance within the dispense chamber; and

an acoustic sensor configured to sense a sound within the dispense chamber, wherein at least one of the sound generator or the acoustic sensor is disposed within the dispense chamber portion,

wherein at least one of the sound generator or the acoustic sensor is disposed within the one or more side conduits, wherein the respective cavity and the respective connector have substantially the same width over their length.

24. The liquid dispenser system of claim 23, further comprising:

a liquid dispenser transporter configured to move the liquid dispenser; and

a piston mover configured to move the piston within the piston chamber.

25. The liquid dispenser system of claim 24, further comprising:

a control circuit configured to determine whether a contact of the dispensing tip with liquid has occurred based on the sensed sound.

26. The liquid dispenser system of any one of claims 23 to 25, wherein the respective cavity and the respective connector of each of the one or more side conduits are free from Helmholtz resonance.

27. The liquid dispenser system of any one of claims 23 to 26, wherein a lateral dimension of the respective cavity is same as a lateral dimension of the respective connector for each of the one or more side conduits.

28. The liquid dispenser system of any one of claims 23 to 27, wherein acoustic resonance within the one or more side conduits is outside of a frequency range of 100 Hz – 4 kHz.

29. The liquid dispenser system of claim 28, wherein the acoustic resonance within the one or more side conduits is outside of a frequency range of 200 Hz – 1 kHz.

30. The liquid dispenser system of any one of claims 26 to 29, wherein the cavity of each of the one or more side conduits is configured to house at least one of the sound generator or the acoustic sensor.

31. The liquid dispenser system of claim 30, wherein the one or more side conduits include a single side conduit, and wherein one of the sound generator and the acoustic sensor is housed within the single side conduit and the other one of the sound generator and the acoustic sensor is housed within the dispense chamber portion.

32. A liquid dispenser, comprising:

a dispenser body including:

a dispense chamber portion including a dispense chamber therein, the dispense chamber having a first opening at a first portion of the dispense chamber portion and a second opening at a second portion of the dispense chamber portion, wherein the first portion is configured to couple with a dispensing tip,

a piston chamber portion including a piston chamber therein, the piston chamber being connected to the dispense chamber via the second opening and configured to guide a piston in a linear motion within the piston chamber to draw liquid into the liquid dispenser and to dispense liquid out of the liquid dispenser,

an acoustic filter disposed between the dispense chamber and the piston chamber, wherein the acoustic filter is configured to acoustically decouple the dispense chamber from the piston chamber, and

one or more side conduits, each of the one or more side conduits having a respective cavity and a respective connector having a neck length L connecting the respective cavity to the dispense chamber; and

a sound generator configured to generate a sound to the dispense chamber; and

an acoustic sensor configured to sense a sound resulting from the generated sound,

wherein at least one of the sound generator or the acoustic sensor is disposed within the one or more side conduits, wherein the respective cavity and the respective connector have substantially the same width over their length.

33. The liquid dispenser of claim 32, further comprising:

a control circuit configured to determine a volume of the liquid in the dispensing tip based on the sensed sound.

34. The liquid dispenser of claims 32 or 33, wherein a length of air column resonance in the dispense chamber is unaffected by movement of the piston.

35. The liquid dispenser of any one of claims 32 to 34, wherein the acoustic filter includes at least one of sound-reflective filter or a sound-absorbent filter.

36. The liquid dispenser of claim 35, wherein the sound-reflective filter is configured to isolate a length of air column resonance in the dispense chamber from a length of air column resonance in the piston chamber.

37. The liquid dispenser of claims 35 or 36, wherein the sound-reflective filter is impermeable to air.

38. The liquid dispenser of any one of claims 35 to 37, wherein the sound-absorbent filter is configured to reduce sound caused by movement of the piston.

39. The liquid dispenser of any one of claims 35 to 38, wherein the sound-absorbent filter is air-permeable and sound suppressing.

40. The liquid dispenser of any one of claims 32 to 39, wherein the acoustic filter is made of at least one of an open-cell foam, a closed-cell foam with an air passage, or a fibrous material.

41. The liquid dispenser of any one of claims 32 to 40, wherein at least one of the sound generator or the acoustic sensor is disposed within the dispense chamber portion.

42. The liquid dispenser of any one of claims 32 to 41, wherein the respective cavity and the respective connector of each of the one or more side conduits are free from resonance within a frequency range of the sensed sound.

43. The liquid dispenser of any one of claims 33 to 42, wherein the control circuit is further configured to:

identify information about the dispensing tip based on the sensed sound.

44. The liquid dispenser of claim 33, wherein the control circuit is further configured to:

determine whether the dispensing tip is completely coupled with the first portion of the dispensing chamber portion based on the sensed sound.

45. A liquid dispenser system, comprising:

a liquid dispenser comprising:

a dispenser body including:

a dispense chamber portion including a dispense chamber therein, the dispense chamber having a first opening at a first portion of the dispense chamber portion and a second opening at a second portion of the dispense chamber portion, wherein the first portion is configured to couple with a dispensing tip,

a piston chamber portion including a piston chamber therein, the piston chamber being connected to the dispense chamber via the second opening and configured to guide a piston in a linear motion within the piston chamber to draw liquid into the liquid dispenser and to dispense liquid out of the liquid dispenser,

an acoustic filter disposed between the dispense chamber and the piston chamber, wherein the acoustic filter is configured to acoustically decouple the dispense chamber from the piston chamber, and

one or more side conduits, each of the one or more side conduits having a respective cavity and a respective connector having a neck length *L* connecting the respective cavity to the dispense chamber; and

a sound generator configured to generate a sound to the dispense chamber; and

an acoustic sensor configured to sense an acoustic signal resulting from the generated sound; and

a control circuit configured to determine at least one of:

whether a contact of the dispensing tip with liquid has occurred based on the sensed sound, or

a volume of the liquid in the dispensing tip based on the sensed sound,

wherein at least one of the sound generator or the acoustic sensor is disposed within the one or more side conduits, wherein the respective cavity and the respective connector have substantially the same width over their length.

46. The liquid dispenser system of claim 45, further comprising:

a liquid dispenser transporter configured to move the liquid dispenser; and

a piston mover configured to move the piston within the piston chamber.

47. The liquid dispenser system of claims 45 or 46, wherein a length of air column resonance in the dispense chamber is unaffected by movement of the piston.

48. The liquid dispenser system of any one of claims 45 to 47, wherein the acoustic filter includes at least one of sound-reflective filter or a sound-absorbent filter.

49. The liquid dispenser system of claim 48, wherein the sound-reflective filter is configured to isolate a length of air column resonance in the dispense chamber from a length of air column resonance in the piston chamber.

50. The liquid dispenser system of any one of claims 48 or 49, wherein the sound-reflective filter is impermeable to air.

51. The liquid dispenser system of any one of claims 48 to 50, wherein the sound-absorbent filter is configured to reduce sound caused by movement of the piston.

52. The liquid dispenser system of any one of claims 48 to 51, wherein the sound-absorbent filter is air-permeable and sound suppressing.

53. The liquid dispenser system of any one of claims 45 to 52, wherein the acoustic filter is made of at least one of an open-cell foam, a closed-cell foam with an air passage, or a fibrous material.

54. The liquid dispenser system of any one of claims 46 to 53, wherein at least one of the sound generator or the acoustic sensor is disposed within the dispense chamber portion.

55. The liquid dispenser system of any one of claims 45 to 54, wherein the dispenser body further comprises wherein the respective cavity and the respective connector of each of the one or more side conduits are free from resonance within a frequency range of the sound sensed by the acoustic sensor.

56. The liquid dispenser system of any one of claims 45 to 55, wherein the control circuit is further configured to:

identify information about the dispensing tip based on the sensed sound.

57. The liquid dispenser system of any one of claims 46 to 56, wherein the control circuit is further configured to:

determine whether the dispensing tip is completely coupled with the first portion of the dispensing chamber portion based on the sensed sound.