CLAIMS

What is claimed is:

1. A fluid control system comprising:

a plurality of flow channels, each flow channel configured for a flow restrictor, a flow regulating valve and a channel pressure sensor to be disposed therein and for the channel pressure sensor to be disposed between the flow restrictor and the flow regulating valve;

a shared flow channel configured to carry fluids to or from the plurality of flow channels, for each flow channel, the flow restrictor being configured for disposal between the channel pressure sensor and the shared flow channel;

a shared pressure sensor configured for disposal in the shared flow channel configured to detect a shared flow channel pressure; and

a controller configured to determine mass flow through each of the flow channels based on channel pressures and the shared flow channel pressure and to control the flow regulating valves of the flow channels to control mass flow through each flow channel wherein the controller is configured to determine, through recursive calculation, (1) channel pressures for positions that are adjacent to the flow restrictors and opposite to the channel pressure sensors of the plurality of flow channels, (2) mass flow through each flow channel, and (3) total mass flow through the shared channel.

2. The fluid control system of claim 1, configured for each flow channel of the plurality of flow channels further to comprise a temperature sensor.

3. The fluid control system of claim 1 or 2, wherein the controller is configured to determine mass flow through each flow channel based on property of the fluid flowing therethrough, property of the flow restrictor, and flow channel property between the flow restrictor and the shared pressure sensor.

4. The fluid control system of claim 3, wherein the flow channel property is the volume and the length of the flow channel from the flow restrictor to the shared pressure sensor.

5. The fluid control system of any one of the preceding claims, wherein the controller is configured to determine mass flow through a flow channel of the plurality of flow channels by (i) assuming a flow channel pressure adjacent to the flow restrictor and opposite to the channel pressure sensor of the flow channel, the channel pressure sensor providing a detected flow channel pressure, (ii) determining the mass flow through the flow channel based on the flow channel pressure adjacent to the flow restrictor and opposite to the channel pressure sensor and the detected flow channel pressure for the flow channel, (iii) determining total mass flow on the basis of mass flows through each of the flow channels of the plurality of flow channels, (iv) calculating the flow channel pressure adjacent to the flow restrictor and opposite to the channel pressure sensor of the flow channel using the total mass flow determined in step (iii), and repeating steps (ii) to (iv).

6. The fluid control system of any one of the preceding claims, configured for the shared flow channel to be downstream from the plurality of flow channels.

7. The fluid control system of any one of claims 1 to 5, configured for the shared flow channel to be upstream from the plurality of flow channels.

8. The fluid control system of any one of claims 1 to 5, further comprising

a second plurality of flow channels, each flow channel of the second plurality of flow channels configured for a flow restrictor, a flow regulating valve and a channel pressure sensor to be disposed therein and for the channel pressure sensor to be disposed between the flow restrictor and the flow regulating valve;

the shared flow channel configured to carry fluids from the plurality of flow channels to the second plurality of flow channels;

for each flow channel of the second plurality of flow channels, the flow restrictor being configured for disposal between the channel pressure sensor and the shared flow channel; wherein the controller is further configured to determine mass flow through each of the flow channels of the second plurality of flow channels based on channel pressures and the shared flow channel pressure and to control the flow regulating valves of the flow channels to control mass flow through each flow channel.

9. The fluid control system of any one of claims 1 to 5, and 8, wherein the controller is configured to calculate a flow channel pressure adjacent to a flow restrictor and opposite to a channel pressure sensor of an i-th flow channel, the *i*-th flow channel being upstream from the shared flow channel, using Equation (1): $P_{d,i} = f_{Pd}(P_d, Q_t, V_i, L_i)$ (1); where f_{Pd} is a function of downstream pressure P_d detected by the shared pressure sensor, total flow through the shared flow channel Q_t, and volume V_i and length L_i of the *i*-th flow channel from its restrictor to the shared pressure sensor.

10. The fluid control system of claim 9, configured to obtain f_{Pd} by empirical data and/or experiment.

11. The fluid control system of claim 9 or 10, wherein $f_{Pd}$is provided by Equation (2): $f_{Pd}(P_d, Q_t, V_i, L_i) = k_{i,1} \cdot P_d + k_{i,2} \cdot Q_t + k_{i,3} \cdot V_i + k_{i,4} \cdot L_i$ (2); where $k_{i,1}$, $k_{i,2}$, $k_{i,3}$ and $k_{i,4}$ are empirically or experimentally obtained linear coefficients.

12. The fluid control system of any one of claims 1 to 5, and 8 to 11, wherein the controller is configured to calculate a flow channel pressure adjacent to a flow restrictor and opposite to a channel pressure sensor of a *j*-th flow channel using Equation (6): $P_{u,j} = f_{Pu}(P_u, Q_t, V_j, L_j)$ (6); where f_{Pu} is a function of upstream pressure P_u detected by the shared pressure sensor, total flow through the shared flow channel Q_t, and volume V_j and length L_j of the *j*-th flow channel from its restrictor to the shared pressure sensor.

13. The fluid control system of claim 12, configured to obtain f_{Pu} by empirical data and/or experiment.

14. The fluid control system of claim 12 or 13, wherein $f_{Pu}$is provided by Equation $f_{Pu}(P_u, Q_t, V_j, L_j) = k_{j,1} \cdot P_u + k_{j,2} \cdot Q_t + k_{j,3} \cdot V_j + k_{j,4} \cdot L_j$ (7); where $k_{j,1}$, $k_{j,2}$, $k_{j,3}$ and $k_{j,4}$ are empirically or experimentally obtained linear coefficients.

15. The fluid control system of any one of claims 8 to 14, configured for each flow channel of the second plurality of flow channels further to comprise a temperature sensor.

16. The fluid control system of any one of the preceding claims, wherein the plurality of flow channels is part of an integrated system.

17. The fluid control system of any one of claims 8 to 15, wherein the plurality of flow channels and the second plurality of flow channels are part of an integrated system.

18. The fluid control system of claim 17, wherein the shared pressure sensor is not part of the integrated system.

19. The fluid control system of any one of the preceding claims, wherein the fluid is a gas.

20. A fluid control method, comprising

flowing fluids through a plurality of flow channels, each flow channel comprising a flow restrictor and a flow regulating valve;

flowing fluids to or from the plurality of flow channels through a shared flow channel;

detecting a shared flow channel pressure in the shared flow channel;

detecting a flow channel pressure for each flow channel between its flow regulating valve and its flow restrictor;

determining mass flow through each of the flow channels based on the flow channel pressures and the shared flow channel pressure by recursively calculating (1) mass flow through each flow channel, (2) channel pressures for positions that are adjacent to the flow restrictors and opposite to the channel pressure sensors of the plurality of flow channels, and (3) total mass flow through the shared channel; and

controlling the flow regulating valves of the flow channels to control mass flow through each flow channel.

21. The fluid control method of claim 22, further comprising detecting a flow channel temperature for each flow channel between its flow regulating valve and its flow restrictor.

22. The fluid control method of claim 20 or 21, wherein mass flow through each flow channel is determined based on property of the fluid flowing therethrough, property of

the flow restrictor, and flow channel property between the flow restrictor and where the shared flow channel pressure is detected.

23. The fluid control method of any one of claims 20 to 22, wherein determining mass flow through a flow channel of the plurality of flow channels comprises (i) assuming a flow channel pressure adjacent to the flow restrictor and opposite to the channel pressure sensor of the flow channel, (ii) determining the mass flow through the flow channel based on the flow channel pressure adjacent to the flow restrictor and opposite to the channel pressure sensor and the detected flow channel pressure for the flow channel, (iii) determining total mass flow on the basis of mass flows through each of the flow channels of the plurality of flow channels, (iv) calculating the flow channel pressure adjacent to the flow restrictor and opposite to the channel pressure sensor of the flow channel using the total mass flow determined in step (iii), and repeating steps (ii) to (iv).

24. The fluid control method of any one of claims 20 to 23, further comprising

flowing fluids from the plurality of flow channels through the shared channel and into a second plurality of flow channels, each flow channel of the second plurality of flow channels comprising a flow restrictor and a flow regulating valve;

detecting a flow channel pressure and flow channel temperature for each flow channel of the second plurality of flow channels between its flow regulating valve and its flow restrictor; and

determining mass flow through each of the flow channels of the second plurality of flow channels based on the flow channel pressures and the shared flow channel pressure.

25. The fluid control method of any one of claims 20 to 24, further comprising calculating a flow channel pressure adjacent to a flow restrictor and opposite to a channel pressure sensor of an i-th flow channel, the *i*-th flow channel being upstream from the shared flow channel, using Equation (1): $P_{d,i} = f_{Pd}(P_d, Q_t, V_i, L_i)$ (1); where f_{Pd} is a function of downstream pressure P_d detected by the shared pressure sensor, total flow through the shared flow channel Q_t, and volume V_i and length L_i of the *i*-th flow channel from its restrictor to the shared pressure sensor.

26. The fluid control method of claim 25, wherein f_{Pd} is obtained by empirical data and/or experiment.

27. The fluid control method of claim 25 or 26, wherein f_{Pd} is provided by Equation (2): $f_{Pd}(P_d, Q_t, V_i, L_i) = k_{i,1} \cdot P_d + k_{i,2} \cdot Q_t + k_{i,3} \cdot V_i + k_{i,4} \cdot L_i$ (2); where $k_{i,1}$, $k_{i,2}$, $k_{i,3}$ and $k_{i,4}$ are empirically or experimentally obtained linear coefficients.

28. The fluid control method of any one of claims 20 to 27, further comprising calculating a flow channel pressure adjacent to a flow restrictor and opposite to a channel pressure sensor of a j-th flow channel, the *j*-th flow channel being downstream from the shared flow channel, using Equation (6): $P_{u,j} = f_{Pu}(P_u, Q_t, V_j, L_j)$ (6); where f_{Pd} is a function of upstream pressure P_u detected by the shared pressure sensor, total flow through the shared flow channel Q_t, and volume V_j and length L_j of the *j*-th flow channel from its restrictor to the shared pressure sensor.

29. The fluid control method of claim 28, wherein f_{Pu} is obtained by empirical data and/or experiment.

30. The fluid control method of claim 28 or 29, wherein f_{Pu} is provided by Equation (7): $f_{Pu}(P_u, Q_t, V_j, L_j) = k_{j,1} \cdot P_u + k_{j,2} \cdot Q_t + k_{j,3} \cdot V_j + k_{j,4} \cdot L_j$ (7); where $k_{j,1}$, $k_{j,2}$, $k_{j,3}$ and $k_{j,4}$ are empirically or experimentally obtained linear coefficients.

31. The fluid control method of claim 24, further comprising detecting a flow channel temperature for each flow channel of the second plurality of flow channels between its flow regulating valve and its flow restrictor.

32. The fluid control method of any one of claims 20 to 31, wherein the fluids are gases.

~~33. A fluid control system comprising:~~

~~a plurality of flow channels, each flow channel configured for a flow restrictor, a flow regulating valve and a channel pressure sensor to be disposed therein and for the channel pressure sensor to be disposed between the flow restrictor and the flow regulating valve;~~

a shared flow channel configured to carry fluids to or from the plurality of flow channels, for each flow channel, the flow restrictor being configured for disposal between the channel pressure sensor and the shared flow channel;

a shared pressure sensor configured for disposal in the shared flow channel configured to detect a shared flow channel pressure; and

a controller configured to determine mass flow through each of the flow channels based on channel pressures and the shared flow channel pressure and to control the flow regulating valves of the flow channels to control mass flow through each flow channel, wherein the controller is configured to determine mass flow through each flow channel based on property of the fluid flowing therethrough, property of the flow restrictor, and flow channel property between the flow restrictor and the shared pressure sensor and wherein the flow channel property is the volume and the length of the flow channel from the flow restrictor to the shared pressure sensor.

34. A fluid control method, comprising

flowing fluids through a plurality of flow channels, each flow channel comprising a flow restrictor and a flow regulating valve;

flowing fluids to or from the plurality of flow channels through a shared flow channel;

detecting a shared flow channel pressure in the shared flow channel;

detecting a flow channel pressure for each flow channel between its flow regulating valve and its flow restrictor;

determining mass flow through each of the flow channels based on the flow channel pressures and the shared flow channel pressure, wherein mass flow through each flow channel is determined based on property of the fluid flowing therethrough, property of the flow restrictor, and flow channel property between the flow restrictor and where the shared flow channel pressure is detected and wherein the flow channel property is the volume and the length of the flow channel from the flow restrictor to the shared pressure sensor; and

controlling the flow regulating valves of the flow channels to control mass flow through each flow channel.