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METHOD AND SYSTEM FOR CONTROLLING A CLIMATE CONTROL SYSTEM OF A VEHICLE USING A DUCT PURGE STRATEGY

Abstract

A system and method of controlling cabin air within a vehicle includes determining an elevated thermal level within a vehicle, opening a duct purge valve based on the elevated thermal level and communicating air through a primary duct to a purge duct through the purge valve.

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Background/Summary

FIELD

[0001] The present disclosure relates to a climate control system for a vehicle and, more specifically, to a method for purging the ducts upon start-up to increase comfort of the occupant.

BACKGROUND

[0002] This section provides background information related to the present disclosure which is not necessarily prior art.

[0003] Climate control systems in vehicles require input for controlling the conditions in the occupant area. Vehicles may have climate control systems for one or more passengers. That is, the climate control system may have individual controls for controlling the driver front seat, the passenger front seat and one or more rear seats. Climate control settings include the temperature and, airflow or fan speed desired by the occupant. The vents through which the conditioned air travels may also be directed at or away from the occupant or the different parts of the vehicle.

[0004] Air conditioning portion of the climate control system use a blower fan to push air through an evaporator for cooling and drying, then flow it through a series of heating, ventilation and air conditioning (HVAC) ducts toward one or multiple air outlets in the vehicle cabin. The air inside the ducts is subject to heating by the ambient environment when the climate control system is turned off. Upon startup, the stagnant heated air must be pushed out of the HVAC ducts before cool air from the evaporator can reach the occupant. The application of hot air in an already hot vehicle cabin may cause discomfort for the occupant. Additionally, humans are known to be most sensitive to overheating at the head and face region, which is often the warmest portion of a vehicle cabin after the vehicle has been soaking in sunlight for a prolonged amount of time.

[0005] Battery electric vehicles suffer from limited range, a problem that is further exacerbated by the significant weight that a battery adds to a vehicle. Thus, a need exists to increase efficiency and decrease the size of in-vehicle air conditioning systems.

SUMMARY

[0006] This section provides a general summary of the disclosure, and is not a comprehensive disclosure of its full scope or all of its features.

[0007] In one aspect of the disclosure, a method of controlling cabin air within a vehicle includes determining an elevated thermal level within a vehicle, opening a duct purge valve based on the elevated thermal level and communicating air through a primary duct to a purge duct through the purge valve.

[0008] In another aspect of the disclosure, a system includes an elevated thermal level detection circuit determining an elevated thermal level within a cabin of a vehicle, a primary duct having a controllable vent and a duct purge valve, a purge duct coupled to the primary duct at the duct purge valve and a blower moving air within the primary duct. A controller, in a duct purge state, closes the controllable vent and controls the duct purge valve so air through the primary duct is communicated through the purge valve to the purge duct.

[0009] Further areas of applicability will become apparent from the description provided herein. The description and specific examples in this summary are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

Description

DRAWINGS

[0010] The drawings described herein are for illustrative purposes only of selected embodiments and not all possible implementations, and are not intended to limit the scope of the present disclosure.

[0011] FIG. **1**A is a high-level schematic view of a vehicle having the climate control system according to the present disclosure.

[0012] FIG. **1**B is an enlarged view of a vent **42** in an open position.

[0013] FIG. **1**C is a front view of a vent in the closed position.

[0014] FIG. **1**D is a high-level diagrammatic side view of a cabin of a vehicle.

[0015] FIG. **1**E is a thermal plot of stratified air in a vehicle cabin.
[0016] FIG. **1**F is a front perspective view of a vent having horizontal and vertical louvers.
[0017] FIG. **1**G is a side view of the vent of FIG. **1**F.
[0018] FIG. **2** is a block diagrammatic view of the controller of the vehicle.
[0019] FIG. **3** is a high-level flowchart of a method for operating the system.
[0020] FIG. **4** is a high-level diagrammatic view of the duct system of the vehicle.
[0021] FIG. **5**A is a flowchart of a method for initiating the operation of the system.
[0022] FIG. **5**B is a flowchart of a method for purging the ducts.
[0023] FIG. **5**C is a flowchart of a method for de-stratifying the cabin.
[0024] FIG. **5**D is a flowchart of a method for directing cooling the occupant.
[0025] Corresponding reference numerals indicate corresponding parts throughout the several views of the drawings.

DETAILED DESCRIPTION

[0026] Example embodiments will now be described more fully with reference to the accompanying drawings.
[0027] Referring now to FIG. **1**A, a vehicle **10** is illustrated having a plurality of seating positions **12**A, **12**B, **12**C and **12**D. Seating position **12**A, in this example, is the driver position. The seating position **12**B is the front passenger position. Seat position **12**C is the rear left passenger position and seat position **12**D is in the rear right passenger position. The vehicle **10** has a plurality of doors **14**A, **14**B, **14**C and **14**D adjacent to each of the seat positions **12**A-**12**D. Of course, more seat positions such as a position between seat positions **12**A and **12**B, between **12**C and **12**D and behind **12**C and **12**D may also be provided in the vehicle **10**.
[0028] The vehicle **10** also has a windshield **16**, a rear window **18** and door windows **20**A-**20**D that correspond to the doors **14**A-**14**D, respectively. The amount of solar load from sunshine entering the cabin **22** varies considerably based upon the position and angle of the sun relative to the vehicle. Of course, other windows including a sunroof may be included within the vehicle.
[0029] A climate control system **30** is also included within the vehicle. The climate control system **30** is in communication with an air conditioning system **32** and a heater system **34** to control the outlet temperature of the vents. The air conditioning system **32** may comprise an air conditioning compressor coupled to the engine by way of a belt. The air conditioning system **32**, in an electric vehicle, may be an electric motor that operates a compressor to generate cooling fluid.
[0030] The heater system **34** may be coupled to an engine to remove heat from the engine and provide it to the cabin **22**. The heater system **34** may also be a resistive heater or combinations of a resistive heater and an engine heater.
[0031] One or more fans or blowers **36** may be used to move air from the air conditioning system **32**, the heater system **34** and possibly from air from outside the vehicle as well. The air from the outside of the vehicle is indicated by the arrow **40**. The blower **36** communicates air through ducts **38**. Each individual position may have its own duct or, for example, the seat positions **12**C and **12**D in the rear of the vehicle may spare a common duct. Various possibilities are available for different vehicles.
[0032] The ducts **38** have vents **42** through which controller air is communicated to the cabin **22**. Two vents **42** are illustrated directed to the seat positions **12**A and **12**B. One vent is directed at the seating positions **12**C and **12**D. However, various numbers of vents **42** in various positions may be provided such as at the legs, at various positions of the torso, the arms and the like. The direction of the vents **42** may be controlled laterally, longitudinally, and vertically. The opening and closing of the vents **42** may also be controlled.
[0033] Referring now to FIGS. **1**B and **1**C, the vents **42** illustrated in FIG. **1**A are merely represented by openings. The vents **42** have louvers **44** that are coupled to a vent actuator **46**. The vent actuator **46** is in communication with the climate control system **30**. The climate control system **30** may control the actuator **46** to move the vents **42** and louvers **44** of the vents **42** into

desired positions. That is, the louvers **44** are movable in an open position, a closed position (as shown in FIG. **1**C). Partial opening and closing of the louvers **44** allow direction. The actuator **46** may rotate a housing **48** so that an upward direction and downward direction as well as in a rightward direction or leftward direction (and angular directions therebetween may be achieved). That is, the actuator **46** may move the louvers **44** into various positions including a closed position as illustrated in FIG. **1**C. By opening and closing the louvers **44**, directing the louvers **44**, controlling the fan speed, controlling the air temperature within the ducts **38**, occupant comfort can be controlled precisely. Of course, multiple actuators **60** and multiple vents **42** may be located at various positions around the occupants **52**.
[0034] Inputs to the climate control system **30** include thermal image devices such as thermal cameras **50** that are positioned to view the seating positions **12**A-**12**D. The thermal cameras **50** generate thermal camera signals corresponding to a thermal image of the seating positions **12**A-**12**D. That is, the thermal cameras **50** generate thermal images of the occupants **52** and various aspects of the occupants **52** as will be described in further detail below. The thermal cameras **50** generate thermal image signals that correspond to surface temperatures. Hot spots may therefore be identified. The images are communicated to the climate control system **30** and are processed by a microprocessor therein. Various analysis is used to control the various aspects of the climate control system including the air conditioning **32**, the heater system **34**, the blower fans **36** and the like. Cooling through air conditioning is the specific focus herein.
[0035] The climate control system **30** also is coupled to sun load sensors **54**. The sun load sensors **54** generate a sun load signal corresponding to the sun load at the position at which the sun load sensors **54** are mounted. Other sun load sensors **54** are not connected to the climate control system as illustrated in FIG. **1**A. Those in the art will understand that they are actually coupled to the climate control system **30** but for simplicity of illustration purposes are not illustrated as such. The sun load sensors **54** may be positioned in front of the first and second seating positions **12**A, **12**B, on the sides of the seating positions **12**A, **12**B. in addition, sun load sensors **54** may be located in other systems such as on the outside of seating positions **12**C, **12**D.
[0036] An external or ambient temperature sensor **56** may generate a temperature signal corresponding to the exterior temperature of the vehicle and communicate the exterior temperature signal to the climate control system **30**.
[0037] Although one thermal camera **50** is shown for each seat position **12**A-**12**D, multiple cameras **50** in multiple positions may be used.
[0038] Cabin temperature sensors **58** may be located at various positions throughout the cabin **22**. The temperature sensors **58** generate a cabin temperature signal adjacent thereto including at the various seating positions **12**A-**12**D. One temperature sensor may be used. However, multiple sensors may be distributed in the cabin as described below.
[0039] Referring now also to FIG. **1**D, a simplified version of the primary duct **38** disposed within an instrument panel **70** is set forth. The instrument panel **70** of FIG. **1**D is a simple cutaway view showing the primary duct **38**, a purge duct **72** and a defroster duct **74**. The purge duct **72** has a duct purge valve **76** that opens and closes as illustrated by contrasting FIGS. **1**B and **1**C. When the duct purge valve **76** is closed, as illustrated in FIG. **1**B, air is communicated through the primary duct **38** and through the vent **42** as indicated by the arrows **78**A. In contrast, FIG. **1**C shows the duct purge valve **76** in an open position to allow air from the primary duct **38** to flow into the purge duct **72** as indicated by the arrow **78**B. The purge duct **72** may communicate heated air outside the vehicle **10** or to a location within the vehicle where the hot air can be recycled but does not act on the occupants. See path **72**′ illustrated in FIG. **4** as described below.
[0040] As mentioned above, the vent **42** may be directed in a variety of positions. Vent **42** may be positioned to direct air in an upward position **80**A and a downward position **80**B as indicated by the arrows in FIG. **1**D. By positioning the louvers **44** in the upward direction indicated by arrow **80**A, stratification indicated by the dotted lines **82**A, **82**B, and **82**C may be reduced (destratification).

Stratification refers to the different levels of temperature of the air in the vehicle. Each level may be a range of several degrees. Naturally the highest temperatures are higher in the cabin **22** of the vehicle **10**. The thermal camera **50** may also be used to determine stratification. However, temperature sensors located throughout the cabin **22** such as the temperature sensor **58**A located at or near the roof **84** of the vehicle, temperature sensor **58**B located near the top of the instrument panel **70**, a temperature sensor **58**C located near the bottom or below the instrument panel **70** and a temperature sensor **58**D located near the bottom of the vehicle. By monitoring the difference in the various temperatures indicated by the cabin temperature sensor **58**A-**58**D, the amount of stratification may be determined. Stratification may be determined by a temperature difference between one or more of the temperature sensors **58**A-**58**D. Typically, in a still vehicle, the temperature at the temperature sensor **58**A will be higher. However, when convection is occurring under the operation of the blower **36**, a reduction in stratification (destratification) and therefore an evening out of the temperature may occur. A reduction in the maximum temperature differences may occur.

[0041] The blower **36** is designed to operate at one or more speeds that correspond to an amount of volume displaced. The blower fan speed may correspond to a standard cubic feet per minute (SCFM) flow rate. Knowing the volume within the primary duct **38**, the flow rate and volume may therefore be used to calculate how long the blower is to be operated (a predetermined time) in order to replace the predetermined volume of heated air within the primary duct **38**. It should be noted that although the primary duct **38** is illustrated in the instrument panel, various other ducts directed at different seating positions may be configured and controlled in the same way. That is, FIG. **1**A shows the duct **38** communicating air to various rearward seating positions. The blower **36** may therefore operate together with a purge duct **72** to replace the air in the entire primary duct **38**.

[0042] Referring now to FIG. **1**E, a thermal plot illustrating stratified air in a vehicle cabin. Heated air is shown in the area of the roof **84** as heated air rises. Cooler air is shown lower in the cabin **22**. Stratified air as shown is undesirable for the occupant as the head region that is most sensitive is positioned higher in the cabin closer to the roof **84**.

[0043] Referring now to FIGS. **1**F and **1**G, another example of a vent **42**′ is illustrated in a front perspective view and a side cutaway view respectively. The vent **42**′ has vertical louvers **44**V and horizontal louvers **44**H, the angular positions of which are controlled by the actuator **46**. In this example, the horizontal louvers **44**H are in front of the vertical louvers **44**V. However, the louver positions may be changed. The horizontal louvers **44**H can direct the air upward or downward in the cabin **22**. The vertical louvers **44**V direct the air rightward and leftward relative to the front of the vent **42**′. A damper door **45** opens and closes to block air from exiting the vent **42**′ when commanded by the control system such as when the purge strategy is active. The damper door **45** may be used or louvers that seal well may also be used in the alternative.

[0044] Referring now to FIG. **2**, the system may be controlled in various states by a controller **210** which is coupled to the various sensors. FIG. **2** is simplified in that multiple sensors of the different types may be employed in various locations as illustrated best in FIGS. **1**A and **1**D. The controller **210** is programmed to perform various determinations and generate various intermediate signals used to ultimately control the climate control system. For example, the movement between the various operational states may be determined. The sensors include the sun load sensors **54**, the cabin temperature sensors **58** (**58**A-**58**D), and the thermal cameras **50**.

[0045] The controller **210** may be coupled to driver preferences **214** that may be selected by a user interface **216**. For example, driver preferences **214** may include the desired temperature of the cabin **22** of the vehicle when the last phase of the operation of the system is performed. Driver preferences **214** may be controlled through the user interface **216** which may be touch screen, dials, buttons or the like. The driver preferences **214** may include, but are not limited to, the desired position or amount of blowing of the vent air to the facial region of an occupant, the temperature of the occupant, a temperature differential for the occupant, such as but not limited to warmer at the

feet and cooler at the face.
[0046] The controller **210** is also coupled to an evaporator temperature sensor **220**. The evaporator temperature sensor **220** is in communication with the evaporator **222** that is disposed within the primary duct **38**. That is, the blower **36** draws air over the surfaces of the evaporator **222** to cool the air within the primary duct **38** during the air conditioning process. The evaporator temperature sensor **220** is coupled to the evaporator **222** so that the temperature of the evaporator is known. Examples of the evaporator **222** are set below.
[0047] The controller **210** may also sense the start condition at a start condition sensor **224** of the vehicle **10**. Rotating an ignition switch or pushing an ignition button may start the vehicle **10** and thus the starting condition may be sensed at the starting condition sensor **224**, the signal of which is communicated to the controller **210**. The start condition sensor **224** may be sensed in either an internal combustion engine vehicle or an electric vehicle or a hybrid vehicle.
[0048] A timer **230** may also be coupled to the controller **210**. Although the timer **230** is illustrated outside the controller **210**, the timer **230** may be incorporated therein.
[0049] The controller **210** may be used to control various actuators and functions within the vehicle **10** so that the different states may be achieved. The vent actuator **46**, the blower motor **36**, the duct purge valve **76** may all be controlled by the controller **210**. Likewise, the window actuator **232** and a defrost actuator **234** may be controlled. The window actuator **232** may represent a plurality of actuators, one of which is coupled to each of the windows **20**A-**20**D. The defrost actuator **234** may be used to direct air through the defrost duct **74** illustrated in FIG. **1**D. By directing air through the defrost duct **74** by way of the defrost actuator **234**, destratification may be enhanced.
[0050] The controller **210** may have various states that are described in greater detail below.
[0051] The controller **210** has various sub controllers or circuits therein. In general, the controller **210** has a processor **240** that may be microprocessor based. One or more processors **240** may be represented by the processor **240**. The processor **240** is in communication with a non-transitory memory **242** that stores commands that allow the processor **240** to perform various functions.
[0052] The controller **210**, as mentioned above, is used to perform various functions. An elevated thermal level detection circuit **250** is used to determine an elevated thermal level within the vehicle **10**. In one example, the amount of solar saturation on the instrument panel surface is used to determine an elevated thermal level. As mentioned above, a sun load sensor **54** may be located on the top of the instrument panel. However, the elevated thermal level may be determined in other ways including from one or more images from one or more of the thermal cameras **50** or measuring various temperature sensors or sun load sensors of the vehicle. By providing an indication of surface saturation, the elevated thermal level detection circuit **250** is used as an input to control the vent actuator **46** using the duct actuator controller **252** and controlling the blower **36** by the blower motor controller **254**. As described in greater detail below, the duct actuator controller **252** may control the vent to close and the blower **36** to turn on. Likewise, a purge valve controller **256** may control the operation of the purge valve to an open position to allow air to be purged from the primary duct **38** into the purge duct **72**. A window controller **258** is used to control the window actuator **232**. To increase the amount of cooling, the window controller **258** may move the window to a slightly open position to allow air to be vented therefrom. A defrost vent controller **260** is used to control the defrost actuator **234** to direct air through the defrost duct **74** described above.
[0053] The controller **210** may also have a stratification determination circuit **266**. The stratification determination circuit **266** is used to determine the stratification of air within the cabin **22** of the vehicle and when the air in the cabin **22** is de-stratified. As mentioned above, the temperature sensors **258**A-**258**D may determine stratification or destratification of the cabin. Likewise, images from the thermal camera **50** may also be used to determine stratification and destratification. Stratification and destratification may be determined using a temperature differential between various temperature sensors **58**A-**58**D. In one example, the stratification may be determined when the difference between two or more sensors is above a differential temperature

threshold. That is, the difference of temperature sensed by the temperature sensor **58**A may be compared with another temperature indicated by another one of the temperature sensors such as the temperature at temperature sensor **58**C or temperature sensor **58**D. When the differential temperature is above the temperature differential threshold, stratification is present. When the temperature differential is less than the temperature differential threshold, destratification has occurred. One example of the temperature differential threshold is 2 degrees Fahrenheit.

[0054] The controller **210** also includes a comparison circuit **268**. The comparison circuit **268** may be used to perform various comparisons such as the comparison of the temperatures mentioned immediately above. The cabin temperature may also be used to determine the amount of heat or thermal level within the vehicle and therefore the surface saturation of the instrument panel from the elevated thermal level detection circuit **250**. The comparison circuit **268** may also compare the outside or ambient temperature from the ambient temperature sensor **56** with a temperature from one or more temperature sensors **58**A-**58**D such as a low mounted temperature sensor **58**C or **58**C. The comparison circuit **268** may also be used to compare a time period from the start of a blower **36** to determine whether predetermined amount of time so that a sufficient amount of air has been used to flush the ducts **38**. The comparison circuit **268** may also be used to determine the solar load and determine whether the solar load is greater than a solar load threshold. In addition, the evaporator temperature may be compared to an evaporator temperature threshold at the comparison circuit **268** to determine whether a direct cooling state may be entered as described in greater detail below.

[0055] A recirculation actuator **236** may be used to control the source of the recirculation air of the vehicle. The recirculation actuator **236** may be a valve or door used for communicating air to the primary duct **38** from the recirculation duct **410** or the fresh air inlet duct **414** (of FIG. **4**). A recirculation actuator controller **262** controls the recirculation actuator **236** to provide either cabin air from the cabin **22** (recirculated cabin air) or fresh air from outside the vehicle to the primary duct **38**. That is, the coolest air from either outside the vehicle (determined from the ambient air temperature sensor **56**) or from within the cabin (from one or more temperature sensors **58**A-**58**D) may be used as the source of air.

[0056] Referring now to FIG. **3**, a high-level flowchart of a method of operating a system is set forth. In step **310**, the vehicle enters the on or start condition state. A prediction of the on-state may also be provided. For example, the system may activate in an electric vehicle as the driver or person with the electronic key approaches the vehicle. The start condition sensor **224** may be used in this determination. Step **310** initiates the process which may include reading various data from the sensors.

[0057] In step **312**, the thermal level within the vehicle is determined. The thermal level may be determined by the solar load on the instrument panel as determined in the elevated thermal level detection circuit **250**. Other indications of the thermal level may include the temperature at one or more of the temperature sensors within the vehicle. The thermal level may also be indicated by an image from one or more of the thermal cameras **50**. When the thermal level is greater than thermal level threshold in step **312**, a duct purge state is entered in step **314**. The duct purge state replaces the heated air within the duct and closes the vent as described in greater detail below.

[0058] After step **314**, the destratification state for air in the cabin **22** is entered in step **316**. The destratification state in step **316** is also entered when the thermal level is not greater than a thermal level threshold.

[0059] In step **316**, the cabin **22** is de-stratified by operating the blower **36** and directing the outlets and the desired direction as described in greater detail below.

[0060] After step **316**, the occupant direct cool state is entered in step **318**. The occupant direct cool state directly cools the occupant with chilled air.

[0061] Referring now to FIG. **4**, a simplified version of a cabin cooling system **400** is illustrated. In this example, a recirculation air inlet duct **410** is coupled to the recirculation actuator **236** such as a recirculation valve which, in turn, is coupled to a fresh air inlet **414**. The recirculation actuator **236** is controlled by way of the recirculation actuator controller **262** of the controller **210** to select either the air from within the cabin **22** or the air external to the vehicle **10** through the fresh air inlet **414**. The blower **36** draws the air from either the recirculation air inlet **410** or the fresh air inlet **414** and mover the air within the primary duct. The evaporator **222** cools the air when the evaporator **222** has been cooled for a sufficient amount of time. That is, the thermal mass of the evaporator **222** takes some finite time to achieve cool surfaces. The duct purge valve **76** is controlled by the purge valve controller **256** of the controller **210** as described above and in greater detail below. Ultimately, the duct purge valve **76** allows air to exit to the cabin **22** through the vents **42** or exit through the purge duct **72** and external to the cabin of the vehicle **10** through the purge outlet **418**. As mentioned above, the purge duct **72** may have an alternate path **72**′ to a location within the vehicle cabin **22** not acting on the occupant.

[0062] Referring now to FIG. **5**A, the vehicle **10** is started in step **510** and the process is started. In step **512**, the stratification of cabin air within the cabin **22** is determined. As mentioned above, the stratification may correspond to the difference between at least two different temperature sensors. In step **514**, the external solar load on the vehicle is determined using the solar load sensor **54** described above. Based upon the stratification determined in the stratification step **512** and the external solar load determined in step **514**, step **516** determines an elevated thermal level within the vehicle **10**. By way of example, the instrument panel circuit solar load may be determined. As mentioned above, steps **512** and **514** may not be used when a direct solar load sensor on the instrument panel is used. Other ways to determine thermal levels include but are not limited to the use of the temperature sensors **58**A-**58**D.

[0063] After step **516**, step **518** determines whether the thermal level such as the IP solar load is greater than a thermal level threshold such as an IP solar load threshold. When the IP solar load is greater than an IP threshold, the duct purge state is performed in step **520** to purge the primary duct **38** as described below in FIG. **5**B. However, when the thermal level is not greater than the IP solar load threshold, step **522** de-stratifies the air in the cabin **22** as described below in FIG. **5**C.

[0064] Referring now to FIG. **5**B, the duct purge state is described. In step **530**, the duct purge state is entered after FIG. **5**A, step **520**. In step **532**, the air outlets, such as the louvers of the vents, are closed in the instrument panel or elsewhere. In step **534**, the purge valve is controlled to open the purge duct. In step **536**, the blower fan is started so that the heated air within the primary duct **38** is moved to begin to be replaced to start the purge process. In step **538**, the timer **230** starts to measure the time period since starting of the blower as a measure of whether the air in the primary duct has been replaced. In step **540**, when the time is not greater than a purge threshold time, step **540** continues in which the blower fan continues to operate, and the purge valve is continued to be open to allow the purging through the purge duct **72**. In the duct purge process, fresh air is received through the fresh air inlet and routed through the recirculation door **412** through the blower **36** and the evaporator **222** so that fresh air is directed through the primary duct **38**, through the duct purge valve **76**, which is in the open state and through the purge duct **72**. When the timer is greater than the purge time threshold in step **540**, this indicates that the amount of volume within the purge duct has been achieved and therefore the air within the purge duct has been replaced. In step **542**, a destratification state is entered as described in FIG. **5**C.

[0065] Referring now to FIG. **5**C, the destratification state is entered in step **542** as described above. After step **542**, step **544** determines the temperature at the low mounted cabin temperature sensor. After step **544**, step **546** determines the ambient temperature sensor signal and the ambient temperature corresponding thereto. In step **548**, the low mounted temperature sensor signal is compared to the ambient temperature indicated by the ambient temperature signal to determine whether recirculation from the cabin **22** or through the fresh air inlet is to be used. That is, when the temperature from the low mounted temperature signal is greater than the ambient temperature, step **550** adjusts the recirculation actuator **236** to open a pathway so that fresh air is communicated to the blower **36** through the fresh air inlet **414**. In step **548**, when the low mounted temperature signal is not greater than the ambient temperature, meaning that the cabin temperature is lower than the temperature external to the vehicle, step **552** is performed. In step **552**, the recirculation actuator **236** is adjusted to admit the air from the exterior of the cabin through the recirculation air inlet **412**. After step **550** and **552**, step **554** aims the louvers **44** of the vents **42** in an upward direction to initiate the recirculation process and reduce the amount of stratification. In step **556**, an optional step of opening the window or sunroof/moonroof may be executed by the system. That is, the window actuator **232** illustrated in FIG. **2** may be used to open a window opening. The window or sunroof may be open a small amount to provide an air path to the exterior of the vehicle. After step **556**, another optional step of turning on the defroster may be performed. The defroster allows the blower **36** to direct air through the defrost duct **74** along the windshield **16** of the vehicle which, in turn, directs the air toward the vehicle roof **84**.

[0066] After step **558**, the evaporator temperature is determined.

[0067] After step **560**, the amount of destratification is determined in step **562**. As mentioned above, the amount of stratification or destratification may be based upon the differential temperature between a temperature sensor located high in the vehicle and a temperature sensor low in the vehicle. Of course, more than two sensors may be used to determine destratification. Alternatively, the thermal camera may be used to determine stratification/destratification. After step **562**, step **564** determines whether the evaporator temperature is less than an evaporator temperature threshold and whether the destratification is less than a destratification threshold. The evaporator temperature is not greater than the evaporator temperature and the destratification is not greater than the destratification threshold, step **560** continues monitoring the process. The process continues to operate the blower fan to direct the vents and the louvers therein to circulate air within the vehicle. When the evaporator temperature is less than the evaporator threshold and the destratification is less than the destratification threshold, step **566** ends the destratification state and enters a direct cooling state. The direct cooling state is entered when the vehicle cabin **22** is sufficiently stratified.

[0068] Referring now to FIG. **5**D, step **566** enters the occupant direct cool state as indicated in FIG. **5**C step **566**. In step **568**, the thermal camera image is obtained. Hotspots may be located in step **570** based upon the thermal image and the vents are directed to the hotspots in step **572**. Knowledge of the occupant thermal state, clothing coverage, position of the occupant and the like may be used as set forth in U.S. Applications (Attorney dockets 711881US and 712038US), the disclosures of which are incorporated by reference herein. As mentioned briefly above, the hotspots are the hotspots on an occupant of the vehicle. For example, the face and head area of the vehicle are typical hotspots. Determining where the sun is shining directly on an occupant may be used to determine where to direct the vents. The vents may be directed by rotating the vents and opening and closing the louvers to direct air into the desired position to cool the occupant.

[0069] By moving through the various states described in FIGS. **5**A-**5**D, the cabin **22** of the vehicle may be efficiently cooled and provide rapid comfort to the occupant of the vehicle. The system is particularly useful for electric vehicles because of the efficiency of the system. However, internal combustion vehicles and hybrid vehicles may also benefit from the implementation of this system.

[0070] Example embodiments are provided so that this disclosure will be thorough and will fully convey the scope to those who are skilled in the art. Numerous specific details are set forth such as examples of specific components, devices, and methods, to provide a thorough understanding of embodiments of the present disclosure. It will be apparent to those skilled in the art that specific details need not be employed, that example embodiments may be embodied in many different forms and that neither should be construed to limit the scope of the disclosure. In some example embodiments, well-known processes, well-known device structures, and well-known technologies are not described in detail.

[0071] The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting. As used herein, the singular forms “a,” “an,” and “the” may be intended to include the plural forms as well, unless the context clearly indicates otherwise. The terms “comprises,” “comprising,” “including,” and “having,” are inclusive and therefore specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. The method steps, processes, and operations described herein are not to be construed as necessarily requiring their performance in the particular order discussed or illustrated, unless specifically identified as an order of performance. It is also to be understood that additional or alternative steps may be employed.

[0072] When an element or layer is referred to as being “on,” “engaged to,” “connected to,” or “coupled to” another element or layer, it may be directly on, engaged, connected or coupled to the other element or layer, or intervening elements or layers may be present. In contrast, when an element is referred to as being “directly on,” “directly engaged to,” “directly connected to,” or “directly coupled to” another element or layer, there may be no intervening elements or layers present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., “between” versus “directly between,” “adjacent” versus “directly adjacent,” etc.). As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

[0073] Although the terms first, second, third, etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms may be only used to distinguish one element, component, region, layer or section from another region, layer or section. Terms such as “first,” “second,” and other numerical terms when used herein do not imply a sequence or order unless clearly indicated by the context. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the example embodiments.

[0074] Spatially relative terms, such as “inner,” “outer,” “beneath,” “below,” “lower,” “above,” “upper,” and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. Spatially relative terms may be intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as “below” or “beneath” other elements or features would then be oriented “above” the other elements or features. Thus, the example term “below” can encompass both an orientation of above and below. The device may be otherwise oriented (rotated **90** degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[0075] The foregoing description of the embodiments has been provided for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosure. Individual elements or features of a particular embodiment are generally not limited to that particular embodiment, but, where applicable, are interchangeable and can be used in a selected embodiment, even if not specifically shown or described. The same may also be varied in many ways. Such variations are not to be regarded as a departure from the disclosure, and all such modifications are intended to be included within the scope of the disclosure.

Claims

1. A method comprising: determining an elevated thermal level within a cabin of a vehicle; opening a duct purge valve based on the elevated thermal level; and communicating air through a primary duct to a purge duct through the purge valve.

2. The method of claim 1 wherein determining elevated thermal level comprises determining a cabin temperature.

3. The method of claim 1 wherein determining elevated thermal level comprises determining a solar load on an instrument panel of the vehicle.
4. The method of claim 1 wherein determining elevated thermal level comprises determining the elevated thermal level using a thermal camera.
5. The method of claim 1 wherein communicating air through the primary duct to the purge duct through the purge valve comprises communicating air through the duct purge valve and the purge duct for a predetermined time.
6. The method of claim 1 wherein communicating air through the primary duct to the purge duct through the purge valve comprises communicating air through the duct purge valve and the purge duct until a predetermined volume of air in the primary duct is purged.
7. The method of claim 6 wherein after the primary duct is purged, de-stratifying the cabin of the vehicle.
8. The method of claim 7 wherein de-stratifying comprises determining stratification of the cabin based on a thermal image.
9. The method of claim 7 wherein de-stratifying comprises determining stratification of the cabin based on a temperature sensors in the cabin of the vehicle.
10. The method of claim 7 wherein de-stratifying comprises directing air from a controllable vent toward a roof, closing the purge valve and selecting a coolest of ambient air or recirculated cabin air to be communicated to a blower.
11. The method of claim 10 further comprising ending de-stratifying when the cabin air is de-stratified and an evaporator temperature is below an evaporator threshold.
12. The method of claim 11 wherein after de-stratifying, directing the vent toward an occupant.
13. A system comprising: an elevated thermal level detection circuit determining an elevated thermal level within a cabin of a vehicle; a primary duct having a controllable vent and a duct purge valve; a purge duct coupled to the primary duct at the duct purge valve; a blower moving air within the primary duct; and a controller, in a duct purge state, closing the controllable vent and controlling the duct purge valve so air through the primary duct is communicated through the purge valve to the purge duct.
14. The system of claim 13 wherein the elevated thermal level detection circuit is coupled to a thermal camera and determines then elevated thermal level based on a thermal image from the thermal camera.
15. The system of claim 13 wherein the elevated thermal level detection circuit determines the elevated thermal level based on a solar load of an instrument panel.
16. The system of claim 13 wherein the controller performs the duct purge state for a predetermined amount of time.
17. The system of claim 16 wherein, after the predetermined amount of time, the controller enters a destratification state by directing the controllable vent to direct the air toward a roof of the vehicle and closes the duct purge valve.
18. The system of claim 17 further comprising a recirculation valve, a cabin temperature sensor generating a cabin temperature signal and ambient temperature sensor generating an ambient temperature signal, said controller controlling the recirculation valve to recirculate cabin air or ambient air based on the cabin temperature signal and the ambient temperature signal in the destratification state.
19. The system of claim 18 further comprising an evaporator and an evaporator temperature sensor generating an evaporator temperature signal, said controller determining destratification and based on destratification and the evaporator temperature signal, entering an occupant direct cool state.
20. The system of claim 19 wherein the controller, in the direct cool state, directs the controllable vent toward a hot spot of vehicle occupant based on a thermal image form a thermal camera.