(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
6 May 2016 (06.05.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/070052 A1

(51) International Patent Classification:
B60N 2/56 (2006.01) *B62D 1/06* (2006.01) *B60H 1/00* (2006.01)

(21) International Application Number: PCT/US2015/058328

(22) International Filing Date: 30 October 2015 (30.10.2015)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/073,589 31 October 2014 (31.10.2014) US

(71) Applicant: **GENTHERM INC.** [US/US]; 21680 Haggerty Road, Suite 101, Northville, MI 48167 (US).

(72) Inventors: **SCHUMACHER, Darren, Andrew**; 4483 Links Court, Ann Arbor, MI 48108 (US). **GIBERSON, Paul, Cameron**; 336 Russel Woods Drive, Tecumseh, Ontario N8N 4L3 (CA). **STEINL, Gregory, Leo**; 5315 Red Fox Run, Ann Arbor, MI 48105 (US). **KAUFFMAN, Wayne, Swoyer, III**; 23506 Forest Street, Oak Park, MI 48237 (US). **SEBASTIANO, Vincenzo**; 284 Majestic Dr., Tecumseh, Ontario N8N 4K7 (CA). **MARQUETTE, David, Brian**; 32552 Oakwood Court, Farmington Hills, MI 48334 (US).

(74) Agent: **GOTTSCHALK, William, S.**; Carlson, Gaskey & Olds, P.C., 400 West Maple Road, Suite 350, Birmingham, MI 48009 (US).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

[Continued on next page]

(54) Title: VEHICLE MICROCLIMATE SYSTEM WITH TARGETED VASODILATION OF EXTREMITIES FOR IMPROVED OVERALL THERMAL COMFORT AND METHOD OF CONTROLLING SAME

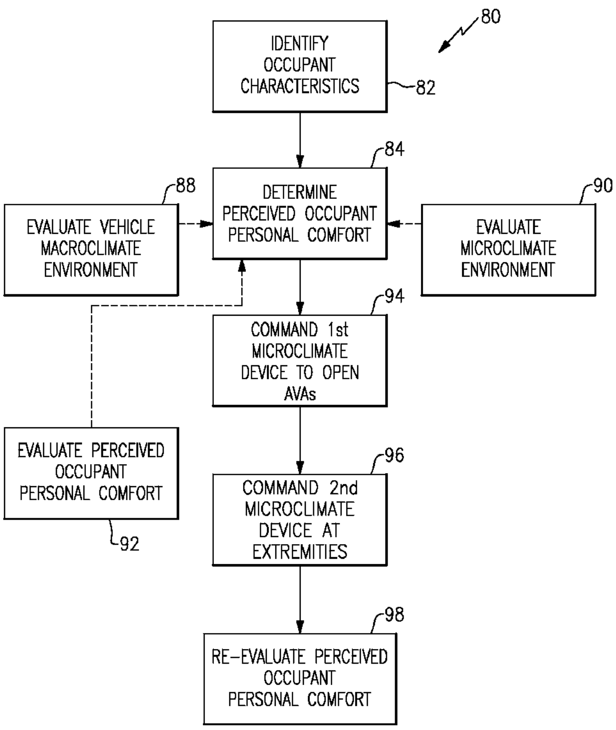

FIG.4

(57) Abstract: A vehicle microclimate system includes a first microclimate device configured to generate a first desired heat flux with an occupant spinal region and create an arteriovenous anastomoses response at an occupant extremity. A second microclimate device is configured to generate a second desired heat flux with an occupant glabrous region. A controller is in communication with the first and second microclimate devices. The controller is configured to determine an occupant personal comfort, and coordinate commands to the first and second microclimate devices in response to the occupant personal comfort to achieve a desired occupant personal comfort.

WO 2016/070052 A1

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

VEHICLE MICROCLIMATE SYSTEM WITH TARGETED VASODILATION OF EXTREMITIES FOR IMPROVED OVERALL THERMAL COMFORT AND METHOD OF CONTROLLING SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to United States Provisional Application No. 62/073,589, which was filed on October 31, 2014 and is incorporated herein by reference.

BACKGROUND

[0002] This disclosure relates to temperature control of a vehicle interior environment, such as within an automobile. More specifically, the disclosure relates to a vehicle microclimate system and a method for controlling the same for increasing an occupant's personal comfort.

[0003] Heating, ventilation and cooling (HVAC) systems are widely used in the automobile industry to control the temperature within the vehicle to increase occupant comfort. Increasingly, vehicles have incorporated additional, auxiliary thermal conditioning devices, such as heated and cooled seats and heated steering wheels. These auxiliary thermal conditioning devices are intended to further enhance occupant comfort.

[0004] The operation of the HVAC system and auxiliary thermal conditioning devices has not been coordinated. Each device within the vehicle is typically controlled independently based upon inputs from the occupant, such as by actuating switches and dials. Additionally, there has been no thermal conditioning system that addresses individual perception of thermal comfort, referred to herein as "occupant personal comfort," which can vary dramatically between different occupants. Moreover, although the vast majority of an occupant's core body (head, neck, back, chest, and pelvis) may be thermally comfortable, thermal discomfort of the extremities results in an overall feeling of thermal discomfort. While attention to this issue has increased, for example, by employing occupant-activated heated steering wheels, these devices presently are not used in a way that recognizes and leverages a human's physiological response to various thermal inputs.

SUMMARY

[0005] In one exemplary embodiment, a vehicle microclimate system includes a first microclimate device that is configured to generate a first desired heat flux with an occupant spinal region and create an arteriovenous anastomoses response at an occupant extremity. A second microclimate device is configured to generate a second desired heat flux with an occupant glabrous region. A controller is in communication with the first and second microclimate devices. The controller is configured to determine an occupant personal comfort and coordinate commands to the first and second microclimate devices in response to the occupant personal comfort to achieve a desired occupant personal comfort.

[0006] In a further embodiment of the above, the first microclimate device is a neck vent that is configured to direct conditioned air at a cervical spine of the occupant to provide the first desired heat flux.

[0007] In a further embodiment of any of the above, the first microclimate device is a thermal element in a seat back that is configured to generate the first desired heat flux at a lumbar spine of the occupant.

[0008] In a further embodiment of any of the above, the first desired heat flux corresponds to applying heat to the occupant spinal region to open the arteriovenous anastomoses.

[0009] In a further embodiment of any of the above, the first desired heat flux corresponds to applying cold to the occupant spinal region to close the arteriovenous anastomoses.

[0010] In a further embodiment of any of the above, the second microclimate device is a steering wheel and the glabrous region is the hands of the occupant.

[0011] In a further embodiment of any of the above, the second microclimate device is a floor mat and the glabrous region is the feet of the occupant.

[0012] In a further embodiment of any of the above, the second microclimate device is an overhead conditioning device and the glabrous region is the face of the occupant.

[0013] In a further embodiment of any of the above, the controller commands the first microclimate device to regulate a heat load, duration, and/or surface area to create the anastomoses response at an occupant extremity.

[0014] In a further embodiment of any of the above, the microclimate device is configured to be arranged within an interior space that provides a macroclimate environment to an occupant. The microclimate device is configured to provide a microclimate environment to the occupant. The microclimate device is configured to be in close proximity to a region of the occupant and has an increased thermoreceptive response compared to other occupant regions exposed to the macroclimate environment.

[0015] In a further embodiment of any of the above, a HVAC thermal conditioning system is configured to provide the macroclimate environment.

[0016] In a further embodiment of any of the above, the system includes at least one of an internal combustion engine, an electric motor system and a fuel cell. The HVAC thermal conditioning system is driven by the at least one of the internal combustion engine, the electric motor system and the fuel cell.

[0017] In a further embodiment of any of the above, the controller includes a memory that has occupant characteristics that provide a user profile that corresponds to the occupant, The controller is configured to use the user profile for determining the occupant personal comfort.

[0018] In a further embodiment of any of the above, the occupant characteristics include at least one of gender, height, weight and occupant-provided comfort data.

[0019] In a further embodiment of any of the above, the memory includes at least one look-up table with a microclimate profile. The controller is configured to modify the microclimate profile based upon at least one user input.

[0020] In a further embodiment of any of the above, an occupant comfort sensor is in communication with the controller. The occupant comfort sensor is configured to detect the occupant characteristics. The controller is configured to use the detected occupant characteristics for determining the occupant personal comfort.

[0021] In a further embodiment of any of the above, the occupant characteristics include at least one of occupant core temperature, occupant skin temperature, occupant skin moisture, macroclimate humidity, and macroclimate temperature.

[0022] In a further embodiment of any of the above, the controller is configured to adjust the command to the first and second microclimate devices in response to the user profile and a microclimate profile associated with the user profile.

[0023] In another exemplary embodiment, a method of controlling vehicle occupant comfort includes the steps of generating a first desired heat flux with an occupant spinal region to create an anastomoses response at an occupant extremity. A second desired heat flux is generated with an occupant glabrous region to achieve desired occupant personal comfort.

[0024] In a further embodiment of any of the above, the first desired heat flux generating step includes directing conditioned air at a cervical spine of an occupant.

[0025] In a further embodiment of any of the above, the first desired heat flux generating step includes activating a thermal element in a seat back at a lumbar spine of the occupant.

[0026] In a further embodiment of any of the above, the first desired heat flux generating step includes applying heat to the occupant spinal region to open the arteriovenous anastomoses.

[0027] In a further embodiment of any of the above, the first desired heat flux generating step includes applying cold to the occupant spinal region to close the arteriovenous anastomoses.

[0028] In a further embodiment of any of the above, the second desired heat flux generating step includes activating a steering wheel. The glabrous region is the hands of the occupant.

[0029] In a further embodiment of any of the above, the second desired heat flux generating step includes activating a floor mat. The glabrous region is the feet of the occupant.

[0030] In a further embodiment of any of the above, the second desired heat flux generating step includes blowing conditioned air from an overhead conditioning device. The glabrous region is the face of the occupant.

[0031] In a further embodiment of any of the above, the first desired heat flux generating step includes regulate a heat load, duration, and/or surface area to create the anastomoses response at an occupant extremity.

[0032] In a further embodiment of any of the above, the first and second desired flux generating steps are performed simultaneously.

[0033] In a further embodiment of any of the above, the first and second desired flux generating steps are initiated simultaneously.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] The disclosure can be further understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

[0035] Figure 1 is a schematic view of a vehicle having a microclimate system.

[0036] Figure 2 is a schematic view of a controller of the microclimate system and example inputs provided to the controller for the vehicle of Figure 1.

[0037] Figure 3 is a schematic view of the controller in communication with macroclimate devices and microclimate devices for the vehicle of Figure 1.

[0038] Figure 4 is an example flow chart depicting microclimate system control methodology performed by the controller to provided targeted vasodilation of the extremities and improve overall thermal comfort.

[0039] Figure 5A is a schematic view of blood flow through an occupant's body with its arteriovenous anastomoses (AVAs) vasoconstricted at the extremities.

[0040] Figure 5B is a schematic view of blood flow through the occupant's body with the AVAs vasodilated.

[0041] Figure 6 is a schematic view of a blood circulatory system at an extremity of the occupant's body.

[0042] The embodiments, examples and alternatives of the preceding paragraphs, the claims, or the following description and drawings, including any of their various aspects or respective individual features, may be taken independently or in any combination. Features described in connection with one embodiment are applicable to all embodiments, unless such features are incompatible.

DETAILED DESCRIPTION

[0043] A vehicle 10, such as an automobile, is schematically shown in Figure 1. The vehicle 10 includes a cabin or an interior space 12 for one or more occupants 16 that provides a vehicle interior environment in which the occupant experiences thermal comfort. The vehicle 10 is arranged in a vehicle exterior environment 14, which also can affect the thermal comfort of the interior space 12, introducing a thermal energy imbalance in the vehicle's interior space.

[0044] Each occupant typically has a unique occupant personal comfort. That is, a particular occupant detects a level of thermal energy differently than another occupant. As a result, the exact same thermal environment within a vehicle may be perceived as comfortable by one occupant, but as uncomfortable by another occupant. To this end, this disclosure relates to providing an integrated approach to human thermal management by controlling and coordinating both macroclimate devices (e.g., central HVAC system) and microclimate devices (e.g., climate controlled seats (e.g., U.S. Patent Nos. 5,524,439 and 6,857,697), head rest/neck conditioner (e.g., U.S. Provisional App. No. 62/039,125), climate controlled headliner (e.g., U.S. Provisional App. No. 61/900334), steering wheel (e.g., U.S. Patent No. 6,727,467 and U.S. Pub. No. 2014/0090513), heated gear shifter (e.g., U.S. Pub. No. 2013/0061603, etc.) to achieve a personalized microclimate system. The microclimate system provides desired occupant personal comfort in a more automated manner with little or no input from the occupant. It should be understood that microclimate devices alone (i.e. without a macroclimate device) can provide both a macroclimate and a personalized microclimate within the macroclimate. The referenced patents, publications and applications are incorporated herein by reference in their entirety.

[0045] In one example, the vehicle 10 includes an HVAC thermal conditioning system 18 and an auxiliary thermal conditioning system 20 (with microclimate devices), which are in communication with a controller 22. Various inputs 24 may communicate with the controller 22 to affect and control operation of the HVAC thermal conditioning system 18 and/or the auxiliary thermal conditioning system 20.

[0046] In one example microclimate system, the controller 22 receives various inputs via sensors and/or devices within the microclimate system, for example, from a vehicle exterior environment 26 shown in Figure 2. The vehicle exterior environment 26 may include parameters such as vehicle location, vehicle direction and altitude, time of day and date, and weather related parameters (outdoor temperature, outdoor humidity, and solar load on the vehicle).

[0047] A macroclimate environment 28 also communicates parameters to the controller 22. The macroclimate environment parameters may include interior temperature and/or humidity at one or more locations, and current HVAC system settings.

[0048] A microclimate environment 30 communicates parameters to the controller 22. The microclimate environment parameters may include temperature and/or humidity at one or more microclimate devices, auxiliary conditioning system settings, and occupant comfort feedback. Occupant comfort feedback may be provided when the occupant provides an input to control one of the microclimate devices, such as by changing the position of a switch.

[0049] Occupant information 32 is provided to the controller 22 for customizing and accounting for thermoreceptive differences between various occupants. It has been shown, for example, that women and men, generally speaking, react to heat and cold differently, with women reacting more severely and more quickly to cold and men reacting more quickly to heat. Additional factors are, for example, the occupant's body composition, amount of hair, and clothing as well as personal preferences. Additionally, the occupant information 32 can provide information for determining a thermal mass, heat capacity, and internal energy production rate. Occupant information 32 includes such information as gender, height, weight, and other occupant-provided data to provide a user profile. Then, for example, an initial default data set, or microclimate profile, could be defined during the customer vehicle purchase process, prior to any data being collected. Then based on the default microclimate profile the system can begin the process of intuitively collecting data and then adjusting to individual's needs/wants based on the actual inputs by and use from the user over time. This initial microclimate profile could be based on any number of factors, including quantitative factors such as initial purchase location, driver characteristics (sex, height, weight, etc.), as well as qualitative factors, such as a survey where the respondent answers questions about their normal state of thermal comfort/stress. This information can be stored on a key fob or mobile device that is communicated to the controller 22. The user profile and learned microclimate profile can "move" with the occupant via the vehicle data link, the cloud, wireless transmission and/or smartphone, for example.

[0050] Sensed occupant information may also be provided (see, e.g., sensor 79 in Figure 3), for example, by detecting occupant temperature. These sensed occupant personal comfort inputs are provided to the controller 22 for determining a perceived occupant personal comfort. The inputs can include one or more measured physiological parameters such as skin or other body temperatures such as a body core temperature.

[0051] Multiple parameters from the vehicle exterior environment 26, the macroclimate environment 28, the microclimate environment 30, and the occupant information 32 may be stored in memory, such as one or more look-up tables 34. The memory may store information relating to one or more user profiles 31 and microclimate profiles 33 for various use scenarios corresponding to a particular user. The controller 22 may learn from adjustments to the microclimate system made by the occupant and update the microclimate profile 33 in the look-up tables 34 so that the occupant personal comfort may be anticipated and the microclimate system adjusted automatically. Interpolation of look-up table values or another suitable method can be used to determine settings between pre-existing set-points.

[0052] Referring in Figure 3, an example HVAC thermal conditioning system 18 is in communication with the controller 22. The HVAC thermal conditioning system 18 includes a heat exchanger 36 in fluid communication with a heating loop connected to an engine 42. The engine 42 may include an internal combustion engine, an electric motor system, and/or a fuel cell. The engine 42 provides a heat source for the HVAC thermal conditioning system 18. An evaporator 40 is arranged in a cooling loop, which may include refrigerant and conventional air conditioning components typically found in a vehicle. It should be understood that a conventional HVAC system can instead be provided by one or more electrically operated microcompressors, if desired. A ventilation system 38, which provides fresh air to the HVAC system, may also be provided. The HVAC thermal conditioning system 18 typically includes ducting 44 providing multiple vents 46a, 46b, 46c. In one example, the vent 46b is directed to a foot well near the occupant's feet, and the vent 46c is provided in a headliner and directed to the occupant's face. One or more valves 48 selectively control airflow from the HVAC system to the vents 46. These HVAC system components provide the macroclimate environment, although the vents may be controlled in a selective manner to provide the microclimate environment.

[0053] The auxiliary thermal conditioning system 20 includes multiple microclimate devices, such as a window defroster/defogger 50, a heated floor mat 51, a roof panel 52, one or more panels 58 in an instrument panel 54, a door panel 60, a door arm rest 62, a center console armrest 63, a seat 64 having thermal element 66 and a neck conditioning device 67 having a neck vent 68 (or other neck conditioning device), and/or a steering wheel 70. These microclimate devices are intended to increase occupant comfort beyond what an HVAC system is capable by providing heating and/or cooling in close proximity to an occupant and thereby a more personalized microclimate environment within the surrounding interior environment. Heating and cooling can be provided by, for example, one or more heating elements, fans, thermoelectric devices, heat pumps, and/or microcompressors.

[0054] The inputs 24 are used to adjust the macroclimate environment and the microclimate environment through the controller 22 to achieve a desired occupant personal comfort. Inputs 24 include sensor signals and other inputs indicative of various parameters of the vehicle exterior environment 26, the macroclimate environment 28, and the microclimate environment 30. Inputs 24 further include one or more switches 72, a key fob 74 containing occupant information, a mobile device 76 containing occupant information and/or a display 78. The display 78 may visually display outputs or operating modes of the HVAC thermal conditioning system 18 and/or the auxiliary thermal conditioning system 20. The display 74 may also provide a means of input via a touchscreen, for example. A sensor 79 may provide real-time, sensed occupant information, such as temperature, moisture, humidity or other information.

[0055] Generally, the vehicle microclimate system includes at least one microclimate device configured to be arranged within the interior space of the vehicle. The interior space 12 provides a microclimate environment to the occupant 16. The microclimate device is configured to provide a microclimate environment to the occupant 16 according to the user profile 31 and the microclimate profile 33. In one example mode of operation, the microclimate device is configured to be in close proximity to a region of the occupant having an increased personal response compared to other occupant regions exposed to the macroclimate environment. These occupant regions may include at least one of a hand, a foot, a neck, a face, a leg, an arm, a head, and a torso.

[0056] The controller 22 is in communication with the microclimate device. The controller is configured to determine an occupant personal comfort, for example, based upon the occupant information 30. The controller 22 commands the microclimate device in response to the occupant personal comfort to provide increased occupant comfort beyond what the HVAC system can provide, thereby fine-tuning the occupant's immediately surrounding environment.

[0057] The HVAC system is largely used to change the equilibrium point of the cabin environment, while the auxiliary thermal comfort system 20 manages the perception of comfort by the occupant. This may enable a reduction in HVAC system size since the thermal comfort of the occupant can be more directly manipulated by more targeted, localized devices. Furthermore, the effort of the two systems can be coordinated to limit the need for the occupant to intervene to change the control settings during operation.

[0058] The microclimate system and its controller can be designed using one or more methodologies. For example, an "open loop" methodology may be used wherein a particular model is implemented in a computing platform, which may or may not be in the vehicle. This model is then utilized to determine how occupant thermal comfort should be manipulated. The model may be populated using data from off-line testing and validation, and then the appropriate control effects would be created based on sensor input (e.g., humidity, external temperature, etc.).

[0059] A "closed loop" methodology may be used wherein a system (e.g., with an infrared camera being a part of the safety system as well as a humidity sensor) ascertains the condition of an occupant, such as a driver, and adjusts thermal conditions based on this information. For example, image processing techniques could determine that the driver is wearing a hat or that the driver is overheated due to exercise based on infrared (IR) imaging.

[0060] A "learning" methodology may be used where the closed loop or open loop methodology is modified over time based on the choices made by a particular occupant or set of occupants to adjust the microclimate profile 33. For example, a vehicle may record the outside temperature, inside temperature, and humidity on the look-up tables 34, and remember the thermal control settings chosen by the driver in these conditions, which could then be replicated (or interpolated) then next time that similar conditions are encountered. The longer that the driver uses the vehicle, the more information that is available, and the more "customized" the microclimate profile for the microclimate system will be to that particular individual. Furthermore, an excellent metric for the suitability of any set of parameters given a particular set of conditions would likely be how long the system is left in a particular state, that is, without an occupant adjusting any thermal settings.

[0061] Temperatures are not uniform throughout the body. Local tissue temperatures are determined primarily by metabolic activity, blood flow, and blood temperature. The body can be compartmentalized based on metabolic activity. For example, referring to Figure 5A, when the occupant 100 is exposed to a cold environment, the body's thermal management system closes (vasoconstricts) its arteriovenous anastomoses (AVAs) 102 at the extremities (e.g., hands and feet) to maintain the core body temperature. Since the temperature of an occupant's hands and feet significantly impacts the sense of overall thermal comfort, a cold environment exacerbates the occupant's feeling of thermal discomfort because the occupant's extremities are receiving a reduced blood flow 104 from the core body due to the constricted AVAs.

[0062] Hands, feet and parts of the face can have such a significant impact on perceived thermal comfort due the type of skin present. The presence or absence of hair follicles defines two types of skin: hairy (or non-glabrous), or non-hairy (glabrous). Nutrient blood flow to these two skin types is similar, but blood flow for heat dissipation is confined only to the glabrous skin regions. Underlying glabrous skin areas—the palms of hands, soles of the feet, and parts of the face and ears—are natural heat exchange portals with unique vascular network structures beneath the surface of the skin.

[0063] These specialized circulatory networks 106 of glabrous skin are shown schematically in Figure 6. Blood circulates out from the heart through arteries 110 to arterioles 112. Papillary capillaries 114 within the glabrous regions are located above the AVAs 104, which interconnect the artery 110 to the vein 118. The capillaries 114 enable heat exchange due to their low mass and high surface area. The AVAs 104 are gated by smooth muscle 108. When the AVAs are closed (Figure 5A), capillaries limit blood flow as they connect the arterioles 112 and venules 116, the small dimension vessels in the microcirculatory system which act as the connectors between arteries 110 and veins 118 respectively to capillaries 114, for carrying nutrients to and removing waste from the surrounding tissues. However, when the AVAs are open (Figure 5B), a lower path of resistance is created directly between the arteries and veins allowing a significantly higher blood flow rate within this region, enabling increased blood flow 124 in the extremities 122 of the occupant 120.

[0064] When the pathway is opened, the AVAs enable a significant increase in blood flow beneath the skin in glabrous regions, as shown in Figure 5B. Dilation and contraction of the AVAs are controlled by the body's thermoregulatory system. When the body perceives conditions which would cause its temperature to rise above normal, the AVAs dilate to increase blood flow near the skin surface, thereby increasing heat loss to the environment. When the body perceives conditions leading to a decrease in core temperature, the AVAs constrict, decreasing blood flow, allowing the body to conserve more of its metabolic heat. A vasoconstricted individual has cooler palms than a vasodilated individual, but other areas of their bodies have similar temperatures. Additional access points for glabrous thermal transfer can be seen on the face of a vasoconstricted individual where the temperature of the nose is measuring a cooler temperature than surrounding areas, yet a comparable temperature to this individual's hand.

[0065] The AVAs are direct shunts between arteries and veins that bypass capillaries, and provide a low-resistance pathway for the movement of blood through the glabrous skin regions. The receiving venous structures (retia venosa) are arranged in a plexus or large network of vessels that has a large surface-to-volume ratio and can contain a large volume of blood. Thus, the venous plexus acts as a radiator. Vasodilation defines the condition in which the AVAs are open and blood is flowing freely through the venous plexuses; vasoconstriction defines the condition in which the AVAs are closed and blood is not flowing through the venous plexuses.

[0066] The human body employs a thermal management system in which AVAs are constricted to maintain the body's heat within its core. When a warm stimulus is applied to the back of the neck (or specifically the cervical spine), the body's core thermal management system interprets this thermal input as the body having excessive heat that it needs to dissipate via its natural heat exchangers—the hands, feet, and parts of the face—and will switch out of heat conservation mode thereby opening the AVAs. When the AVAs are open, there is a very high blood flow, and therefore heat transport, into the low resistance venous radiators; when the AVAs are closed, a greatly reduced blood flow goes through the high-resistance capillaries of the skin. In the normothermic individual, a person whose thermoregulation is within the normal range, proportional control of the AVAs balances internal heat production and heat loss.

[0067] Figure 4 illustrates an example control methodology of the microclimate system. In operation, the controller 22 includes a method 80 that provides overall thermal comfort by targeted vasodilation of the extremities. Multiple microclimate devices are coordinated to target dilation of the AVAs at the occupant's extremities and heat (or cool) the extremities to provide improved overall thermal comfort.

[0068] Occupant characteristics are identified, as indicated at block 82, such as the occupant information 32 (Figure 2) to provide the user profile 31. This includes some level of occupant detection and personal identification, which can employ various vehicle systems. For example, many vehicles have "pre-sets" which identify the driver. Furthermore, weight sensors which detect the occupant's presence and can add another level of information used to identify the occupant. Interior visual systems (e.g., as a part of safety/airbag deployment, etc.) can greatly enhance the identification of a particular occupant. Bluetooth connected smartphones has also greatly simplified this task. Voice recognition or fingerprint identification may also be used. The presence of a particular device will provide driver (and in some cases passenger) identification with a high degree of certainty. This information can then be used to create the occupant's user profile 31 and the associated "thermal profile" data to produce the microclimate profile 33 used to implement the disclosed thermal management scheme. This information may then be stored on the phone or in the vehicle, allowing the transference of this information from one vehicle to another.

[0069] The controller 22 then determines occupant personal comfort, as indicated at block 84. The occupant personal comfort may be determined based upon evaluating the macroclimate environment (block 88; 28 in Figure 2) and/or evaluating the microclimate environment (block 90; 30 in Figure 2). Occupant personal comfort inputs may also be evaluated (block 92; 32 in Figure 2), for example, by using an infrared camera (e.g., sensor 79 in Figure 3) to detect a body temperature or other condition of the occupant.

[0070] In particular, in a cold environment, the human body employs a thermal management system in which AVAs are constricted to maintain the body's heat within its core. When a warm stimulus is applied to the back of the neck (or specifically the cervical spine), the body's core thermal management system thinks it has excessive heat that it needs to dissipate via its natural heat exchangers—the hands, feet, and parts of the face—and will switch out of heat conservation mode. The controller 22 determines that the occupant perceives thermal discomfort (too hot or too cold) as a function of temperature, conditioned surface area and exposure time, for example. The perceived thermal discomfort can be used to infer the state of the AVAs (vasoconstricted or vasodilated). To this end, once the occupant personal comfort has been determined, a first microclimate device is commanded according to the microclimate profile 33, as indicated at block 94, to provide a first desired heat flux and activate a physiological response in the occupant's spinal region to vasoconstrict or vasodilate the AVAs in a desired manner. Vasodilation is realized when blood flows to the vascular structure within glabrous skin areas. The lower the ambient temperature relative to the body's normal core temperature, the heat load, duration, and/or surface area of application will typically need to be increased. In one example, the first microclimate device is provided by the neck conditioning device 67 (Figure 3), which heats cabin air and directs the heated air at the occupant's cervical spinal region via the neck vent 68. Peripheral conditioning devices can work in tandem with the neck conditioning device 67 to trigger vasodilation by delivering a positive heat flux to the occupant at a fixed temperature and/or rate. For example, the thermal element 66 in the seat back also can be activated to heat the lumbar spinal region. Other devices may also be used.

[0071] The spinal heating device in the seat head rest is designed to initiate a thermoregulatory trigger within the occupant in order to vasodilate the AVAs to allow increased blood flow to the hands, feet and face (the glabrous regions) and coordinate (and control) the heating (and cooling) of the steering wheel, overhead conditioning devices and floor mats to achieve maximum thermal comfort perception on the part of the occupant.

[0072] With the AVAs dilated, a second microclimate device at the occupant's extremities is activated, as indicated at block 96 to provide a second desired heat flux with one or more glabrous regions of the occupant. The second microclimate device may be provided by the foot well vent 46b, overhead vent 46c, heated floor mat 51 and/or steering wheel heater 70 (Figure 3), for example.

[0073] In one example, the second microclimate device or devices are powered simultaneously and in parallel with the first microclimate device (e.g., neck conditioning device 67). Initially, the temperature, air flow, and transfer set-points are established in response to the ambient environment. Regulation and control can be autonomous with onboard sensing technology (e.g., sensor 79). Actively targeting the occupant allows for faster time to sensation and comfort over a traditional HVAC system. Power to the neck conditioning device 67 can be limited to an initial start-up phase to enable first sensation and vasodilation trigger where the peripheral devices focus on maintenance of core body temperature by minimizing heat loss through the application of positive heat flux (in heating mode).

[0074] The steering wheel heater 70 will deliver heating through the hands via the body's natural heat exchanger through the body's circulatory system to enable local and overall thermal comfort. In one example, the temperature is pinned and controlled just below the burn threshold to minimize exposure time to the hands. Similarly, the floor heater 51 can be utilized to allow positive heat flux to move through the feet into the body's circulatory system when the thermoregulatory system is switched out of heat conservation mode (when the AVAs are vasoconstricted) and allow higher blood flow to be directed to the hands and feet. The floor heater 51 does need to be in direct contact with the glabrous skin for this method to be effective. With positive heat flux into the natural heat exchanger (foot) it is possible to reverse the heat loss and uncomfortable, cold feeling created by negative heat flux out of the body through the same natural heat exchanger. Also, an overhead vent conditioning device including the vent 46c can be utilized to pump heat into the occupant via the glabrous skin areas of the head/face following the vasodilation trigger created by the neck conditioning device.

[0075] In this manner, the first and second microclimate devices are coordinated to target dilation of the AVAs at the occupant's extremities and heat (or cool) the extremities to provide improved overall thermal comfort. This zonal approach to thermal management allows comfort optimization by targeting the occupant rather than the cabin and static heat sinks. Power (for internal combustion engines) and/or range extension (for electric vehicles) is realized as an alternative to onboard large-scale PTC heating systems. The warm stimulus to the spine as a vasodilation trigger can also be applied for zonal cooling where the overhead and steering wheel cooling devices are in use. This approach better enables occupant comfort within a vehicle application. Applying neck conditioning achieves first sensation and opens the pathway to effective heat exchange directly to the body's thermal regulation system.

[0076] The occupant personal comfort may be reevaluated, as indicated at block 98, by adjusting the microclimate profile 33. This feedback may be provided by the occupant providing additional inputs via switches or other input devices, which indicates that the occupant is not yet comfortable, or by actively sensing the comfort of the occupant.

[0077] The controller 22 learns from the settings typically used by the occupant for a given set of conditions. The controller 22 also learns from adjustments to the settings during periods of automatic control when the microclimate system is operating according to an occupant's microclimate profile 33 associated with their user profile 31. For example, the seat neck warmer could be triggered in order to vasodilate blood flow to the hands while coordinating the conditioning of the steering wheel to achieve maximum thermal comfort perception on the part of the driver, as explained above. When the vehicle learns what a particular occupant likes, based on their not adjusting the thermal management system during operation, those same conditions can be replicated the next time that they occur.

[0078] The more degrees of freedom present for control, the more responsive the microclimate system can become to the occupant. The addition of humidity sensors in strategic locations, or the use of low power IR sensors to sense skin temperature (or a combination of both) could be used to directly manipulate the perception of thermal comfort. Furthermore, coordination with the HVAC system allows the vehicle microclimate system to possess a feed forward component, enabling the microclimate system to achieve a smooth transition from the dynamic state or environment (seat thermal elements on full power, HVAC system on full power) to a desired static/homeostatic state or environment. The transition can simultaneously manage a temperature transition within the interior 12 and an occupant thermal comfort transition.

[0079] It should be noted that a controller 22 can be used to implement the various functionality disclosed in this application. The controller 22 may include one or more discrete units. Moreover, a portion of the controller 22 may be provided in the vehicle 10, while another portion of the controller 22 may be located elsewhere. In terms of hardware architecture, such a computing device can include a processor, memory, and one or more input and/or output (I/O) device interface(s) that are communicatively coupled via a local interface. The local interface can include, for example but not limited to, one or more buses and/or other wired or wireless connections. The local interface may have additional elements, which are omitted for simplicity, such as controllers, buffers (caches), drivers, repeaters, and receivers to enable communications. Further, the local interface may include address, control, and/or data connections to enable appropriate communications among the aforementioned components.

[0080] The controller 22 may be a hardware device for executing software, particularly software stored in memory. The controller 22 can be a custom made or commercially available processor, a central processing unit (CPU), an auxiliary processor among several processors associated with the controller, a semiconductor-based microprocessor (in the form of a microchip or chip set) or generally any device for executing software instructions.

[0081] The memory can include any one or combination of volatile memory elements (e.g., random access memory (RAM, such as DRAM, SRAM, SDRAM, VRAM, etc.)) and/or nonvolatile memory elements (e.g., ROM, hard drive, tape, CD-ROM, etc.). Moreover, the memory may incorporate electronic, magnetic, optical, and/or other types of storage media. The memory can also have a distributed architecture, where various components are situated remotely from one another, but can be accessed by the processor.

[0082] The software in the memory may include one or more separate programs, each of which includes an ordered listing of executable instructions for implementing logical functions. A system component embodied as software may also be construed as a source program, executable program (object code), script, or any other entity comprising a set of instructions to be performed. When constructed as a source program, the program is translated via a compiler, assembler, interpreter, or the like, which may or may not be included within the memory.

[0083] The disclosed input and output devices that may be coupled to system I/O interface(s) may include input devices, for example but not limited to, a keyboard, mouse, scanner, microphone, camera, mobile device, proximity device, etc. Further, the output devices, for example but not limited to, a printer, display, macroclimate device, microclimate device, etc. Finally, the input and output devices may further include devices that communicate both as inputs and outputs, for instance but not limited to, a modulator/demodulator (modem; for accessing another device, system, or network), a radio frequency (RF) or other transceiver, a telephonic interface, a bridge, a router, etc.

[0084] When the controller 22 is in operation, the processor can be configured to execute software stored within the memory, to communicate data to and from the memory, and to generally control operations of the computing device pursuant to the software. Software in memory, in whole or in part, is read by the processor, perhaps buffered within the processor, and then executed.

[0085] It should also be understood that although a particular component arrangement is disclosed in the illustrated embodiment, other arrangements will benefit herefrom. Although particular step sequences are shown, described, and claimed, it should be understood that steps may be performed in any order, separated or combined unless otherwise indicated and will still benefit from the present invention.

[0086] Although the different examples have specific components shown in the illustrations, embodiments of this invention are not limited to those particular combinations. It is possible to use some of the components or features from one of the examples in combination with features or components from another one of the examples.

[0087] Although an example embodiment has been disclosed, a worker of ordinary skill in this art would recognize that certain modifications would come within the scope of the claims. For that reason, the following claims should be studied to determine their true scope and content.

CLAIMS

What is claimed is:

1. A vehicle microclimate system comprising:

a first microclimate device configured to generate a first desired heat flux with an occupant spinal region and create an arteriovenous anastomoses response at an occupant extremity;

a second microclimate device configured to generate a second desired heat flux with an occupant glabrous region; and

a controller in communication with the first and second microclimate devices, wherein the controller is configured to determine an occupant personal comfort, and coordinate commands to the first and second microclimate devices in response to the occupant personal comfort to achieve a desired occupant personal comfort.

2. The vehicle microclimate system according to claim 1, wherein the first microclimate device is a neck conditioning device configured to direct conditioned air at a cervical spine of the occupant to provide the first desired heat flux.

3. The vehicle microclimate system according to claim 1, wherein the first microclimate device is a thermal element in a seat back configured to generate the first desired heat flux at a lumbar spine of the occupant.

4. The vehicle microclimate system according to claim 1, wherein the first desired heat flux corresponds to applying heat to the occupant spinal region to open the arteriovenous anastomoses.

5. The vehicle microclimate system according to claim 1, wherein the first desired heat flux corresponds to applying cold to the occupant spinal region to close the arteriovenous anastomoses.

6. The vehicle microclimate system according to claim 1, wherein the second microclimate device is a steering wheel and the glabrous region is the hands of the occupant.

7. The vehicle microclimate system according to claim 1, wherein the second microclimate device is a floor mat and the glabrous region is the feet of the occupant.

8. The vehicle microclimate system according to claim 1, wherein the second microclimate device is an overhead conditioning device and the glabrous region is the face of the occupant.

9. The vehicle microclimate system according to claim 1, wherein the controller commands the first microclimate device to regulate a heat load, duration, and/or surface area to create the anastomoses response at an occupant extremity.

10. The vehicle microclimate system according to claim 1, wherein the microclimate device is configured to be arranged within an interior space that provides a macroclimate environment to an occupant, the microclimate device is configured to provide a microclimate environment to the occupant different than the macroclimate, the microclimate device configured to be in close proximity to a region of the occupant having an increased thermoreceptive response compared to other occupant regions exposed to the macroclimate environment.

11. The vehicle microclimate system according to claim 10, comprising a HVAC thermal conditioning system configured to provide the macroclimate environment.

12. The vehicle microclimate system according to claim 11, comprising at least one of an internal combustion engine, an electric motor system and a fuel cell, the HVAC thermal conditioning system driven by the at least one of the internal combustion engine, the electric motor system and the fuel cell.

13. The vehicle microclimate system according to claim 10, wherein the controller includes a memory that stores occupant characteristics providing a user profile that corresponds to the occupant, the controller configured to use the user profile for determining the occupant personal comfort.

14. The vehicle microclimate system according to claim 13, wherein the occupant characteristics include at least one of gender, height, weight and occupant-provided comfort data.

15. The vehicle microclimate system according to claim 13, wherein the memory includes at least one look-up table with a microclimate profile, the controller configured to modify the microclimate profile based upon at least one user input.

16. The vehicle microclimate system according to claim 13, comprising an occupant comfort sensor in communication with the controller, the occupant comfort sensor configured to detect the occupant characteristics, the controller configured to use the detected occupant characteristics for determining the occupant personal comfort.

17. The vehicle microclimate system according to claim 16, wherein the occupant characteristics include at least one of occupant core temperature, occupant skin temperature, occupant skin moisture, macroclimate humidity, and macroclimate temperature.

18. The vehicle microclimate system according to claim 16, wherein the controller is configured to adjust the command to the first and second microclimate devices in response to the user profile and a microclimate profile associated with the user profile.

19. A method of controlling vehicle occupant comfort comprising the steps of:

generating a first desired heat flux with an occupant spinal region to create an anastomoses response at an occupant extremity; and

generating a second desired heat flux with an occupant glabrous region to achieve desired occupant personal comfort.

20. The method according to claim 19, wherein the first desired heat flux generating step includes directing conditioned air at a cervical spine of an occupant.

21. The method according to claim 19, wherein the first desired heat flux generating step includes activating a thermal element in a seat back at a lumbar spine of the occupant.

22. The method according to claim 19, wherein the first desired heat flux generating step includes applying heat to the occupant spinal region to open the arteriovenous anastomoses.

23. The method according to claim 19, wherein the first desired heat flux generating step includes applying cold to the occupant spinal region to close the arteriovenous anastomoses.

24. The method according to claim 19, wherein the second desired heat flux generating step includes activating a steering wheel, and the glabrous region is the hands of the occupant.

25. The method according to claim 19, wherein the second desired heat flux generating step includes activating a floor mat, and the glabrous region is the feet of the occupant.

26. The method according to claim 19, wherein the second desired heat flux generating step includes blowing conditioned air from an overhead conditioning device, and the glabrous region is the face of the occupant.

27. The method according to claim 19, wherein the first desired heat flux generating step includes regulate a heat load, duration, and/or surface area to create the anastomoses response at an occupant extremity.

28. The method according to claim 19, wherein the first and second desired flux generating steps are performed simultaneously.

29. The method according to claim 19, wherein the first and second desired flux generating steps are initiated simultaneously.

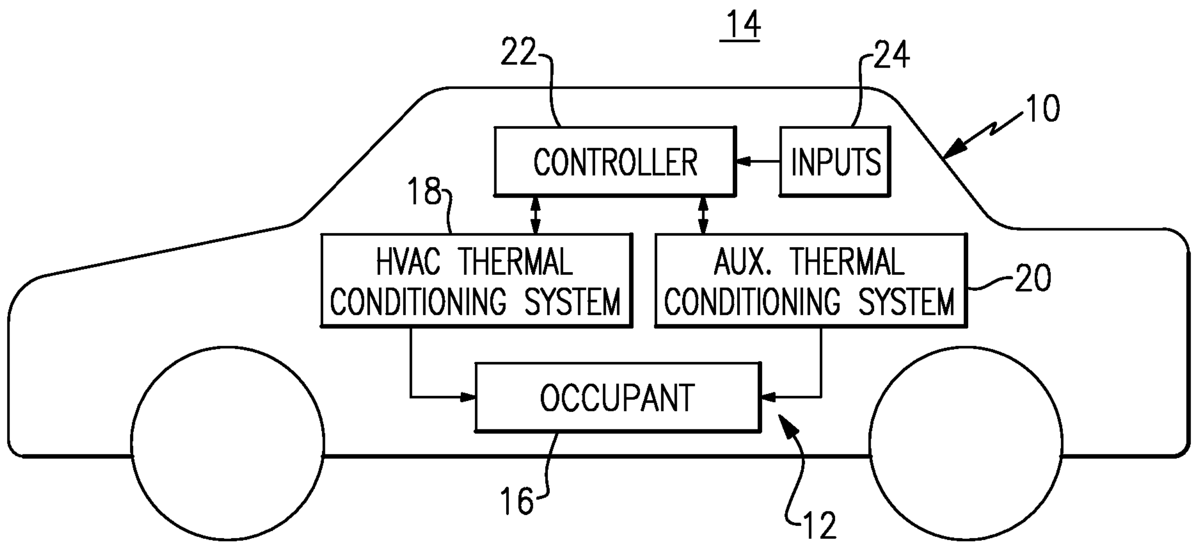
14
22
24
10
CONTROLLER
INPUTS
18
HVAC THERMAL CONDITIONING SYSTEM
AUX. THERMAL CONDITIONING SYSTEM
20
OCCUPANT
16
12

FIG.1

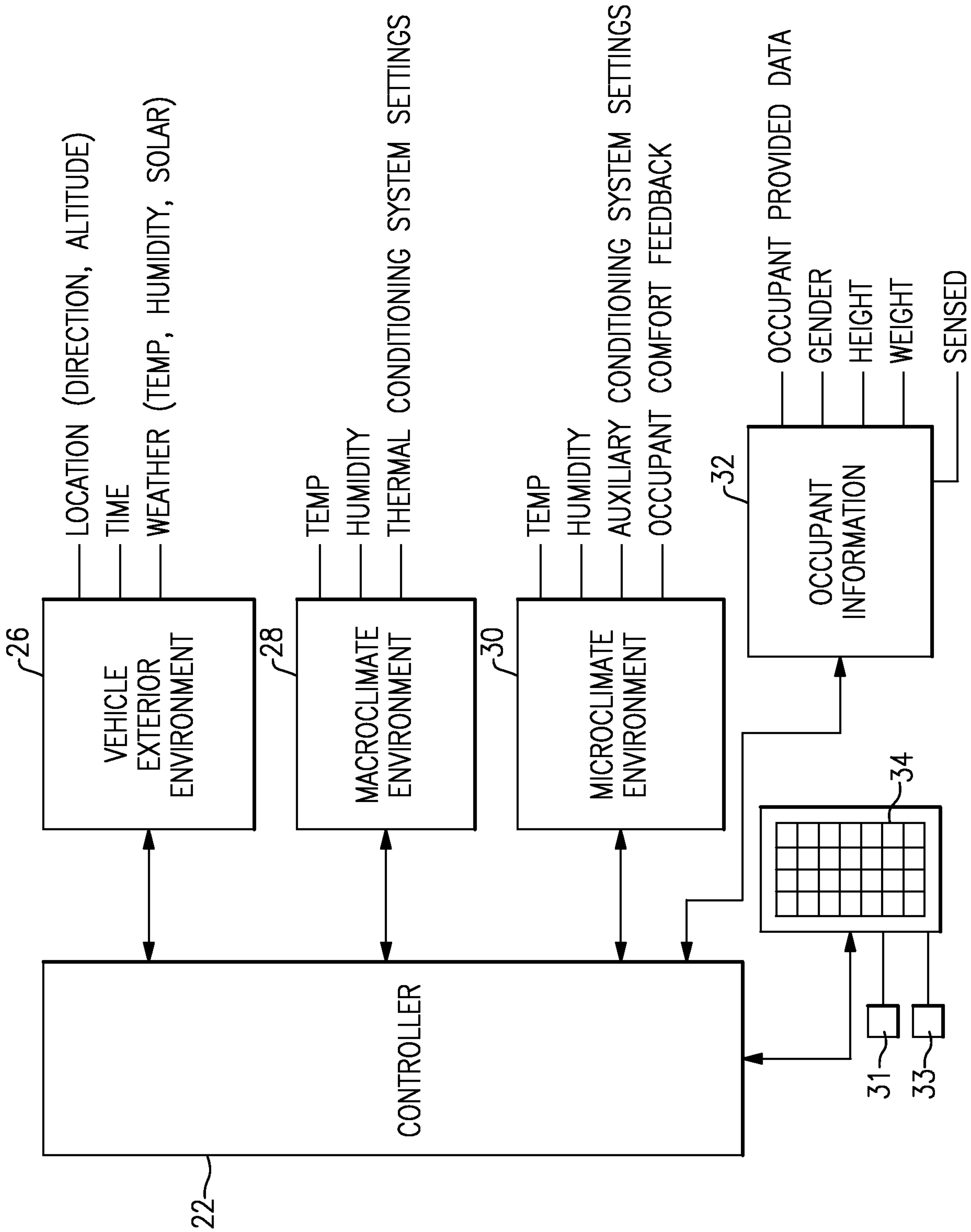
LOCATION (DIRECTION, ALTITUDE)
TIME
WEATHER (TEMP, HUMIDITY, SOLAR)
26
VEHICLE EXTERIOR ENVIRONMENT
TEMP
HUMIDITY
THERMAL CONDITIONING SYSTEM SETTINGS
28
MACROCLIMATE ENVIRONMENT
TEMP
HUMIDITY
AUXILIARY CONDITIONING SYSTEM SETTINGS
OCCUPANT COMFORT FEEDBACK
30
MICROCLIMATE ENVIRONMENT
OCCUPANT PROVIDED DATA
GENDER
HEIGHT
WEIGHT
SENSED
32
OCCUPANT INFORMATION
34
CONTROLLER
22
31
33

FIG.2

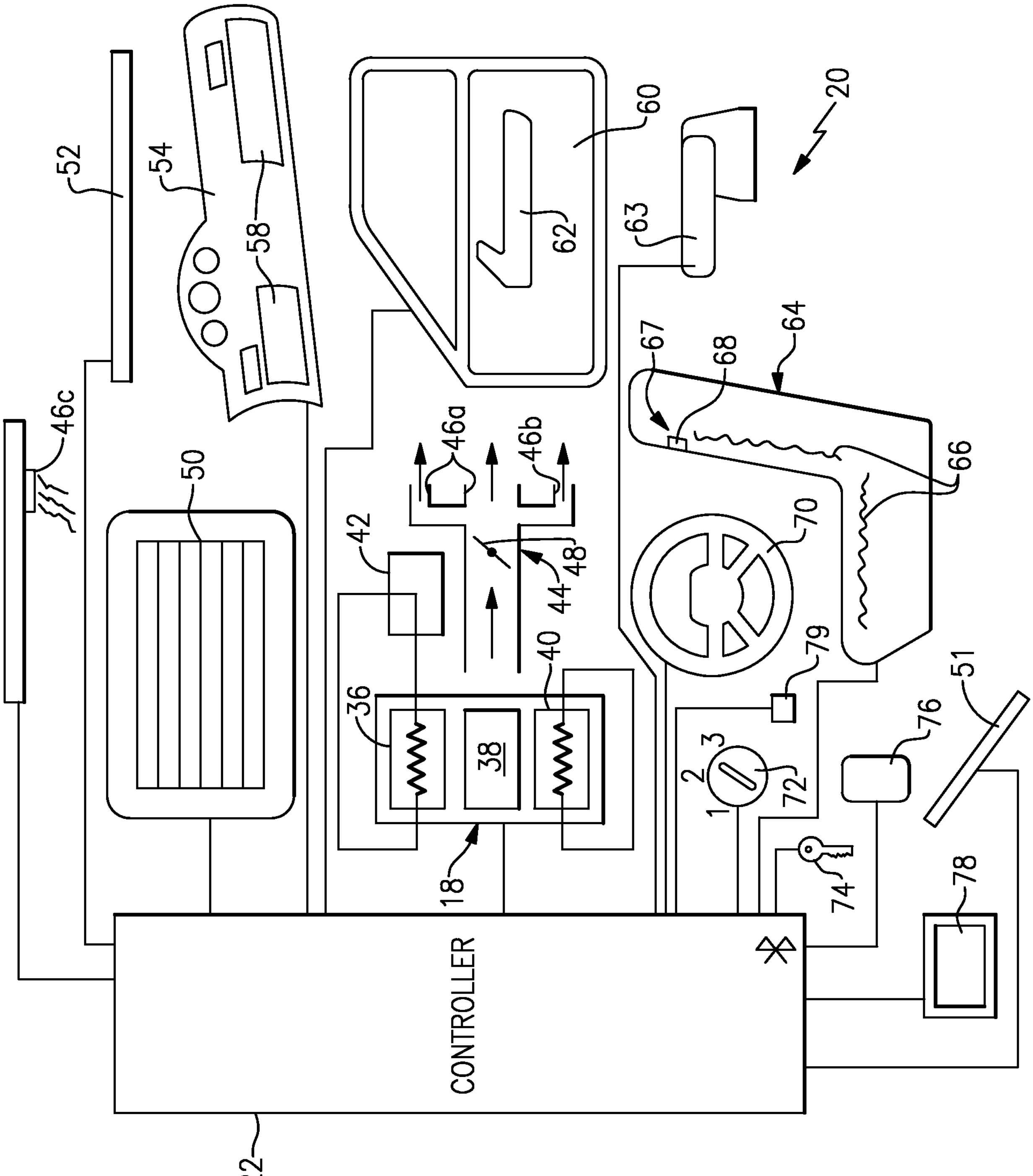
CONTROLLER
22
18
20
36
38
40
42
44
46a
46b
46c
48
50
51
52
54
58
60
62
63
64
66
67
68
70
72
74
76
78
79
1
2
3

FIG.3

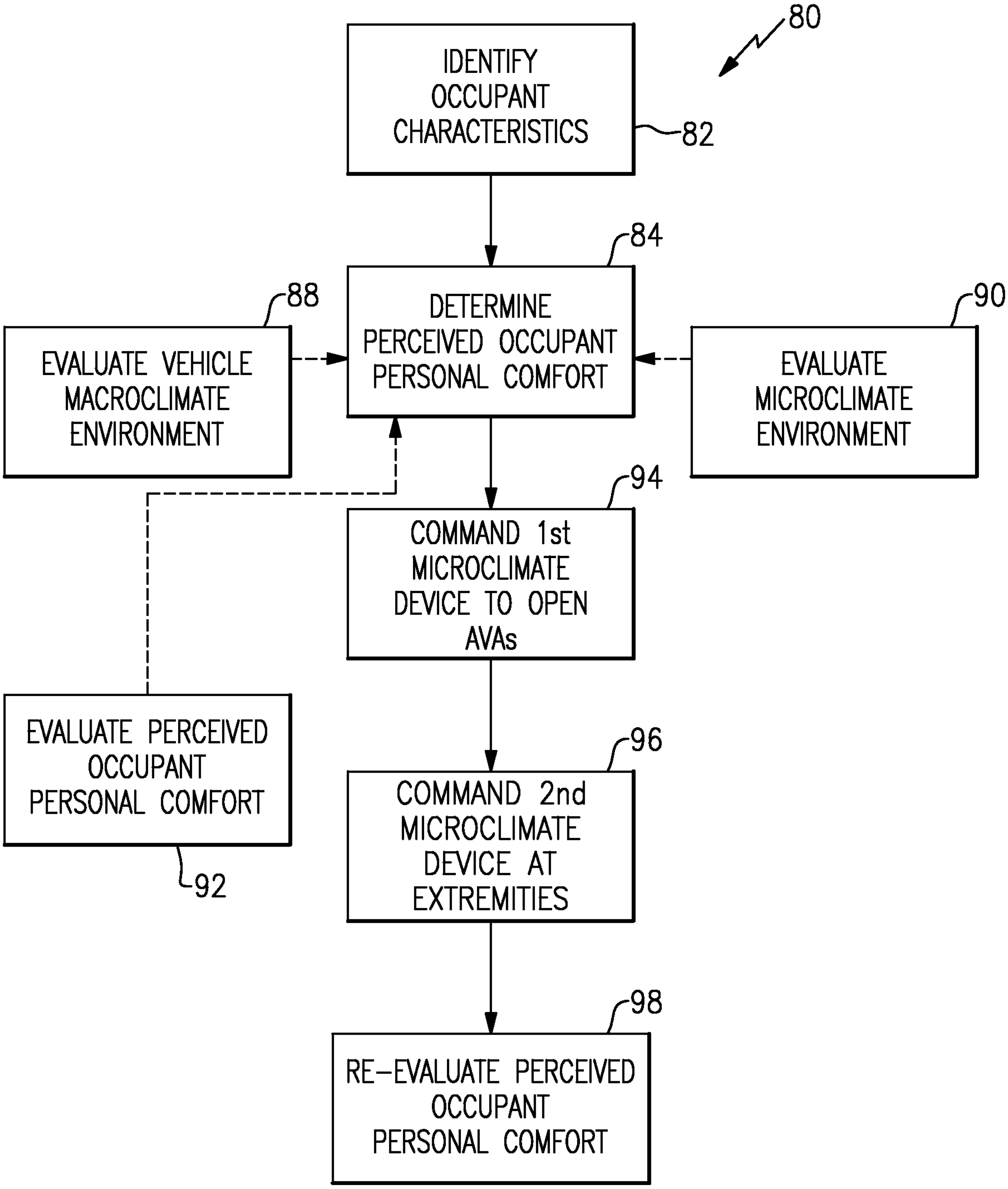
80
IDENTIFY OCCUPANT CHARACTERISTICS
82
84
DETERMINE PERCEIVED OCCUPANT PERSONAL COMFORT
88
EVALUATE VEHICLE MACROCLIMATE ENVIRONMENT
90
EVALUATE MICROCLIMATE ENVIRONMENT
94
COMMAND 1st MICROCLIMATE DEVICE TO OPEN AVAs
EVALUATE PERCEIVED OCCUPANT PERSONAL COMFORT
92
96
COMMAND 2nd MICROCLIMATE DEVICE AT EXTREMITIES
98
RE-EVALUATE PERCEIVED OCCUPANT PERSONAL COMFORT

FIG.4

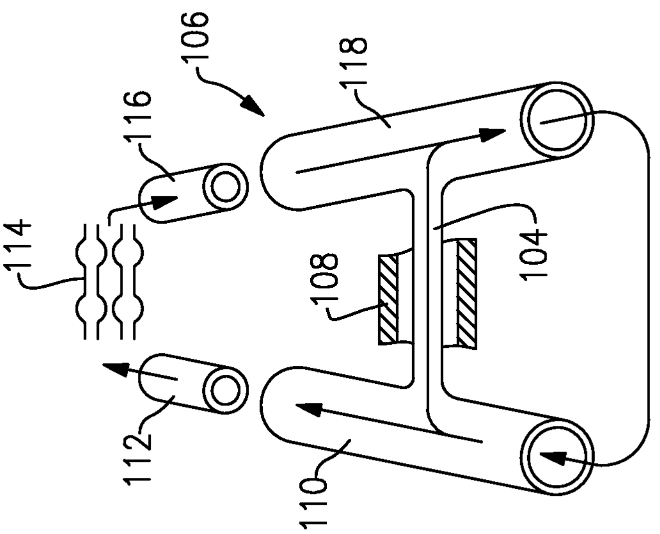

FIG.6

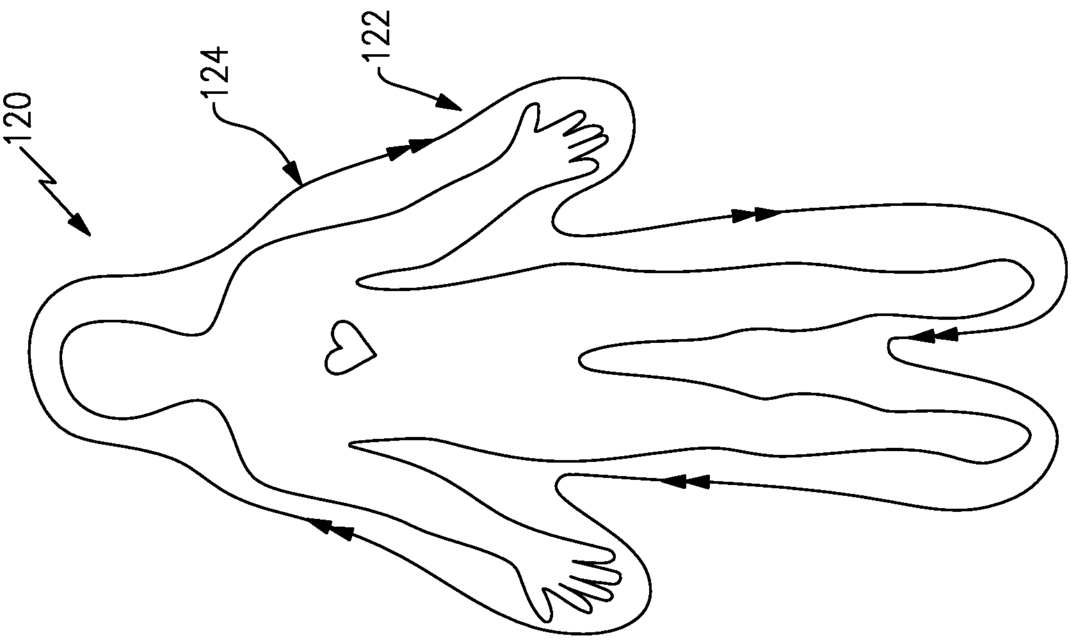

FIG.5B

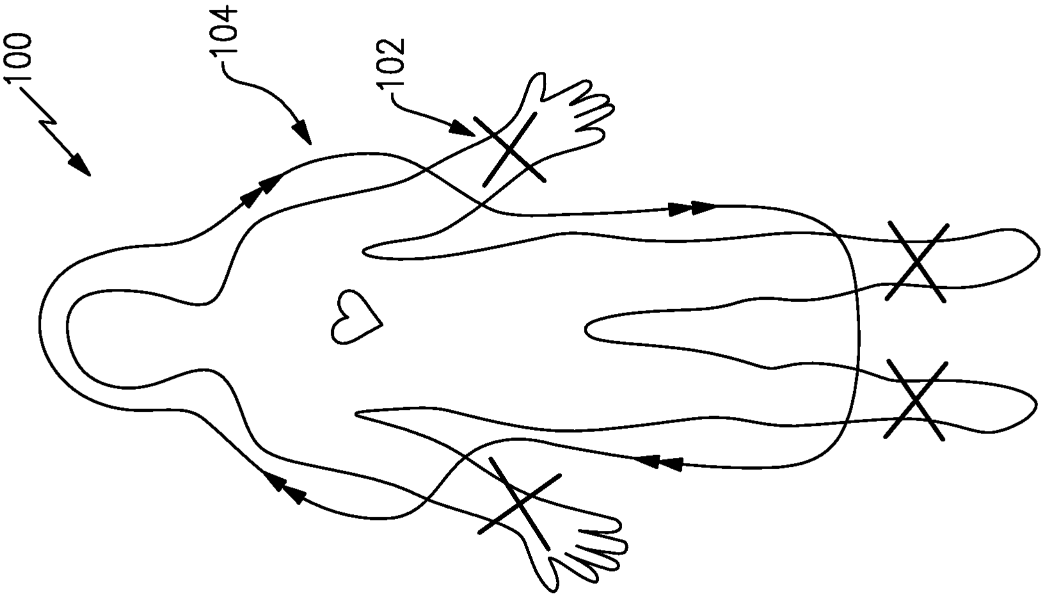

FIG.5A

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/058328

A. CLASSIFICATION OF SUBJECT MATTER
INV. B60N2/56 B60H1/00 B62D1/06
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B60N B62D B60H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	EP 2 008 865 A1 (TOYOTA MOTOR CO LTD [JP]) 31 December 2008 (2008-12-31) paragraphs [0028] - [0050], [0077] - [0093]; figures 1,4-5,7-15 -----	1-12,16, 17,19-29 13-15,18
A	US 4 920 759 A (TANAKA MASAKAZU [JP] ET AL) 1 May 1990 (1990-05-01) columns 3-4; claims; figures 2-6 -----	1-29
A	JP 2008 168769 A (DENSO CORP) 24 July 2008 (2008-07-24) paragraphs [0004], [0009] - [0016], [0024]; figures 1-5 -----	2,20
A	US 2011/272131 A1 (MIKAT DANIEL C [US]) 10 November 2011 (2011-11-10) the whole document ----- -/--	6,24

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 January 2016	29/01/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Chavel, Jérôme

1

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 10 2013 007080 A1 (DAIMLER AG [DE]) 27 March 2014 (2014-03-27) paragraphs [0025], [0028] - [0030]; figures 1-2	9-12,27
Y	WO 2014/014862 A2 (FLEXTRONICS AP LLC [US]) 23 January 2014 (2014-01-23) paragraphs [0115] - [0116]; claims; figures 2-3	13-15,18
A	US 2013/255930 A1 (PRAKAH-ASANTE KWAKU O [US] ET AL) 3 October 2013 (2013-10-03) claims; figures	13-15,18
A	EP 2 517 907 A2 (DELPHI TECH INC [US]) 31 October 2012 (2012-10-31) the whole document	1-29
X	GB 2 344 647 A (ROVER GROUP [GB]) 14 June 2000 (2000-06-14) the whole document	1-29

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2015/058328

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2008865 A1	31-12-2008	CN 101331034 A	24-12-2008
		EP 2008865 A1	31-12-2008
		JP 2007283932 A	01-11-2007
		KR 20080015131 A	18-02-2008
		US 2010130808 A1	27-05-2010
		WO 2007123127 A1	01-11-2007
US 4920759 A	01-05-1990	JP H01273715 A	01-11-1989
		JP H07115576 B2	13-12-1995
		US 4920759 A	01-05-1990
JP 2008168769 A	24-07-2008	JP 4318054 B2	19-08-2009
		JP 2008168769 A	24-07-2008
		US 2008168787 A1	17-07-2008
US 2011272131 A1	10-11-2011	NONE	
DE 102013007080 A1	27-03-2014	NONE	
WO 2014014862 A2	23-01-2014	CN 104470735 A	25-03-2015
		DE 112013003595 T5	30-04-2015
		JP 2015531714 A	05-11-2015
		WO 2014014862 A2	23-01-2014
US 2013255930 A1	03-10-2013	CN 203358278 U	25-12-2013
		DE 102013204988 A1	09-10-2014
		US 2013255930 A1	03-10-2013
EP 2517907 A2	31-10-2012	CN 202764652 U	06-03-2013
		EP 2517907 A2	31-10-2012
		US 2012276831 A1	01-11-2012
GB 2344647 A	14-06-2000	NONE	