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United States Patent	12396144
Kind Code	B2
Date of Patent	August 19, 2025
Inventor(s)	Korta; Jakub Antoni et al.

Inlet and outlet channels for a heat exchanger

Abstract

A manifold of a cooling system includes an inlet channel and an outlet channel designed to connect to multiple plates of a heat exchanger. The inlet and outlet channels include a junction portion, a connection portion, and a transfer portion. The junction portion includes opposing inclined contact surfaces that are inclined relative to a horizontal plane of the plates and mate with corresponding inclined contact surfaces of the plates. The connection portion accepts coolant hoses. The transfer portion is located between the junction portion and connection portions.

Inventors:	Korta; Jakub Antoni (Cracow, PL), Dolot; Tomasz (Cracow, PL)
Applicant:	Aptiv Technologies AG (Schaffhausen, CH)
Family ID:	1000008766385
Assignee:	Aptiv Technologies AG (Schaffhausen, CH)
Appl. No.:	18/151647
Filed:	January 09, 2023

Prior Publication Data

Document Identifier	Publication Date
US 20230269916 A1	Aug. 24, 2023

Related U.S. Application Data

us-provisional-application US 63268261 20220218

Publication Classification

Int. Cl.: F28F9/02 (20060101); F28F3/12 (20060101); F28F9/26 (20060101); H05K7/20 (20060101); F28F21/06 (20060101)

U.S. Cl.:

CPC **H05K7/20872** (20130101); **F28F3/12** (20130101); **F28F9/0256** (20130101); **F28F9/26** (20130101); F28F21/065 (20130101); F28F2275/025 (20130101); F28F2275/08 (20130101)

Field of Classification Search

CPC: F28D (1/03); F28F (3/12); F28F (9/0248); F28F (9/0256); F28F (9/26); F28F (21/065); F28F (2275/025); F28F (2275/08); F28F (2275/14); F28F (2230/00); F28F (2280/04); H05K (7/20872)

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Primary Examiner: Ruppert; Eric S

Assistant Examiner: Weiland; Hans R

Attorney, Agent or Firm: Harness, Dickey & Pierce, P.L.C.

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION (1) This application claims the benefit of U.S. Provisional Application No. 63/268,261, filed Feb. 18, 2022, the disclosure of which is incorporated by reference herein in its entirety.

TECHNICAL FIELD

(1) The present disclosure concerns a manifold for a cooling system. The present disclosure is particularly relevant for inlet and outlet channels for heat exchangers in automobiles.

BACKGROUND

(2) The growth in the performance of automotive electronics has caused an increase in the sophistication of electronic systems in vehicles. For example, traditional electronic control units (ECUs) are being replaced by domain control units (DCUs) that are designed to control multiple functionalities within a selected domain (e.g., advanced driver assistance systems (ADAS) or infotainment domains). This growth in the performance and number of control units has led to requirements for more efficient cooling means to keep their operating temperatures within safe operating limits. Vehicles often use liquid cooling systems through heat exchangers (e.g., plate heat exchangers) to dissipate excessive thermal energy away efficiently and safely from the control units. However, such heat exchangers must be designed to accommodate tight assembly spaces in vehicles and ensure even coolant distribution among individual portions of the heat exchanger to provide even heat distribution away from the control units.

SUMMARY

(3) This document describes inlet and outlet channels of a manifold to connect to a heat exchanger that provides a compact profile with consistent cooling performances among the heat exchanger plates. The described inlet and outlet channels are especially useful for automotive applications that generally have tight assembly spaces. For example, a manifold of a cooling system includes an inlet channel and an outlet channel designed to connect to a heat exchanger with multiple plates. The inlet channel and the outlet channel include a junction portion, a connection portion, and a transfer portion. The junction portion transfers coolant to and from each plate and includes opposing inclined contact surfaces that are inclined relative to a horizontal plane of the plates. The inclined contact surfaces mate with corresponding inclined contact surfaces of the plates of the heat exchanger. The connection portion accepts coolant hoses. The transfer portion is located between the junction portion and the connection portion.

(4) This Summary introduces concepts related to inlet and outlet channels of a heat exchanger, further described in the Detailed Description and Drawings. This Summary is not intended to identify essential features of the claimed subject matter, nor is it intended to determine the scope of the claimed subject matter.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) Exemplified embodiments of inlet and outlet channels for a heat exchanger are described in this document with reference to the following figures. The same numbers may be used throughout the drawings to reference like features and components:

(2) FIG. 1 illustrates an exemplified cooling system in which inlet and outlet channels for heat exchanger are implemented;

(3) FIGS. 2A and 2B illustrate a side view and top view of an exemplified cooling system with a heat exchanger and the described inlet channel and outlet channel;

(4) FIGS. 3A through 3C illustrate a top view, front view, and side view of an exemplified inlet channel of the heat exchanger;

(5) FIGS. 4A through 4C illustrate a top view, front view, and side view of an exemplified outlet channel of the heat exchanger;

(6) FIGS. 5A through 5E illustrate exemplified cross-sections of the connection portion and the transfer portion of the inlet channel;

(7) FIGS. 6A through 6D illustrate a perspective view, front view, side view, and cross-section

view, respectively, of an exemplified inlet channel and an exemplified outlet channel in assembly positions;

(8) FIG. 7 illustrates a cross-section view of an exemplified heat exchanger with two plates and the junction portion of an exemplified inlet channel; and

(9) FIG. 8 illustrates an exemplified method for installing a manifold with an inlet channel and an outlet channel to a cooling system.

DETAILED DESCRIPTION

(10) Liquid cooling systems provide an efficient means to dissipate heat produced by electronics in vehicles. Such cooling systems may include heat exchangers that guide the liquid coolant to flow over or under a region of high temperature to absorb excessive thermal energy produced by electronic components (e.g., ECUs, DCUs) and transfer it to another region of the vehicle or the ambient environment.

(11) One type of heat exchanger used in automotive applications with liquid cooling systems is a plate heat exchanger. A plate heat exchanger includes large, flat cooling surfaces (e.g., cold plates) that allow the heat from the electronic components to be efficiently transferred to the coolant. Existing heat exchanger systems, especially those with multiple cold plates, may have difficulty in providing uniform cooling performance among the cold plates due to uneven coolant flow among the cold plates. In addition, these systems may require excessive space for attached hoses and manifolds and may not fit within the tight spacing constraints of many vehicles.

(12) In contrast, this document describes techniques and systems to provide inlet and outlet channels of a manifold for heat exchangers that provide uniform cooling performance within the plates of a heat exchanger and provide a thin profile to save space for assembly within a vehicle. For example, the manifold includes inlet and outlet channels positioned in between multiple plates to allow for an even flow of coolant among the plates. In addition, the inlet and outlet channels are separated from the overall design of the heat exchanger, allowing these components to be designed with different materials and manufactured separately. This example is just one exemplified embodiment of the described inlet and outlet channels for heat exchangers. This document describes other exemplified embodiments and implementations.

(13) FIG. 1 illustrates an exemplified cooling system **100** in which inlet and outlet channels for a heat exchanger are implemented. In the depicted cooling system **100**, a heat exchanger **102** is attached to or positioned near multiple electronic controllers **104** (e.g., DCUs, ECUs, systems-on-chip (SoCs)).

(14) The electronic controllers **104** may control the operations and functionalities of a vehicle (not illustrated). For example, a first electronic controller **104** may control advanced driver assistance systems (ADAS). A second electronic controller **104** may control the navigation and entertainment functionalities of the vehicle. The depicted cooling system **100** includes four electronic controllers **104**. In other implementations, the cooling system **100** may include fewer or additional electronic controllers **104**.

(15) The heat exchanger **102** cools the electronic controllers **104** using a liquid cooling system. The heat exchanger **102** includes multiple plates **106** with an inlet region **108** and an outlet region **110** positioned between the plates **106**. An inlet channel **112** and an outlet channel **114** are connected to the inlet region **108** and the outlet region **110**, respectively. In other implementations, the positioning of the inlet region **108** and the outlet region **110** may be switched. By positioning the inlet region **108** and the outlet region **110** in between the plates **106**, the heat exchanger **102** has a smaller profile and minimizes space for assembly within the vehicle.

(16) The plate **106** acts as a cooling surface to transfer heat from one or more electronic controllers **104** to the ambient environment via liquid coolant (e.g., water) circulating through the heat exchanger **102**. The plates **106** are generally flat and planar and may be sized to have a surface area approximately equal to the surface area of the electronic controllers **104**. A lateral axis **116** and a longitudinal axis **118** define a horizontal plane of the plates **106**. The relatively large and flat

surface area of the plates **106** allows heat to be efficiently transferred from the electronic controllers **104** to the liquid coolant.

(17) In the depicted cooling system **100**, the heat exchanger **102** includes two plates **106** positioned in between four electronic controllers **104**, with an electronic controller **104** positioned above and below each plate **106**. In other implementations, the cooling system **100** may include a different number and arrangement of electronic controllers **104** and plates **106**. For example, the cooling system **100** may include a single heat exchanger **102** with four plates **106** positioned between eight electronic controllers **104**. In another exemplified embodiment, the cooling system **100** may including a heat exchanger **102** with a single plate **106**.

(18) The cooling system **100** introduces the coolant to the heat exchanger **102** via the inlet channel **112**. The inlet channel **112** is designed to divide the liquid coolant between plates **106** equally. In this way, an equal volume ratio of liquid coolant is guided to each plate **106**. After circulating inside the plates **106**, the coolant is directed toward the outlet channel **114**.

(19) As described in greater detail below, the inlet channel **112** and the outlet channel **114** are designed to provide a heat exchanger **102** with a compact design. This compact design is advantageous for some vehicles' relatively tight assembly spaces. The inlet channel **112** and outlet channel **114** also provide equal coolant circulation among the plates **106**, resulting in uniform cooling performance for the cooling system **100**.

(20) The inlet channel **112** and outlet channel **114** are also separate components from the heat exchanger **102**, which simplifies the design of the cooling system **100** and the heat exchanger **102**. The use of individual components also allows the heat exchanger **102** and the plates **106** to be manufactured separately and by different means than the inlet channel **112** and the outlet channel **114**. In this way, the plates **106** may be manufactured from different material than the inlet channel **112** and the outlet channel **114**. For example, the plates **106** are metal (e.g., aluminum alloy) or another thermally conductive material. The inlet channel **112** and outlet channel **114** are a plastic material (e.g., Polyamide 66 (PA66) or reinforced plastic with glass fibers). As a result, the inlet channel **112** and the outlet channel **114** are manufactured with cheaper and lighter material resulting in cost and weight savings for the cooling system **100**.

(21) FIGS. 2A and 2B illustrate a side view **200-1** and top view **200-2** of an exemplified cooling system with a heat exchanger and the described inlet channel **112** and outlet channel **114**. The cooling system and heat exchanger of FIGS. 2A and 2B may be the cooling system **100** and the heat exchanger **102** of FIG. 1, respectively.

(22) As illustrated in the side view **200-1** of FIG. 2A, the heat exchanger **102** includes a plate **106** (e.g., an upper plate) positioned above another plate **106** (e.g., a lower plate). The inlet channel **112** and the outlet channel **114** extend laterally away from the plates **106** to provide the heat exchanger **102** with a thin profile in a first dimension (e.g., vertical direction). As illustrated in the top view **200-2** of FIG. 2B, the inlet channel **112** and the outlet channel **114** extend approximately straight from the plates **106** to provide the heat exchanger **102** with a thin profile in a second dimension (e.g., lateral direction). In this way, the heat exchanger **102** fits within the tight assembly space of many vehicles.

(23) FIGS. 3A through 3C illustrate a top view **300-1**, front view **300-2**, and side view **300-3** of an exemplified inlet channel **112** of the heat exchanger **102**. In other implementations, the inlet channel **112** of FIGS. 3A through 3C may act as the outlet channel **114** of the cooling system **100**. The top view **300-1** depicts a longitudinal axis **302** extending from a connection portion **308** to a junction portion **312** of the inlet channel **112**. The inlet channel **112** also includes a transfer portion **310** extending along the longitudinal axis **302** and located between the connection portion **308** and the junction portion **312**. The top view **300-1** also depicts a lateral axis **304** perpendicular to the longitudinal axis **302**. The side view **300-3** illustrates a vertical axis **306** perpendicular to the longitudinal axis **302**. The transfer portion **310** may include non-uniform cross-sections along the longitudinal axis **302**. For example, proximate the connection portion **308**, the transfer portion **310**

may have an approximately circular cross-section. Proximate the junction portion **312**, the transfer portion **310** may have an approximately rectangular cross-section.

(24) The connection portion **308** may have an approximately circular cross-section. The circular connection portion **308** is adapted to accept a coolant hose. Automotive cooling systems often use hoses to transport liquid coolant in and out of the heat exchanger **102**. For example, the hoses are flexible rubber hoses. A hose may be attached to the connection portion **308** using a clamp or similar attachment means. The connection portion **308** also includes an external stop feature **314** that prevents the hose from sliding along the longitudinal axis **302** onto or into the transfer portion **310**.

(25) The junction portion **312** may have an approximately rectangular cross-section in both the top view **300-1** and the side view **300-3**. The junction portion **312** of the inlet channel **112** transfers the coolant towards the plates **106**. In the depicted implementation, the inlet channel **112** attaches to two plates **106** and the junction portion **312** is a T-junction that equally distributes the coolant to both plates **106**. The approximately rectangular cross-section of the junction portion **312** provides a compact design to minimize the assembly space used by the heat exchanger **102**.

(26) The junction portion **312** also includes an inclined contact surface **316** at opposing surfaces. In particular, the inclined contact surfaces **316** are inclined relative to a horizontal plane of the plates **106** defined by the lateral axis **116** and the longitudinal axis **118**. The inclined contact surfaces **316** of the junction portion **312** are not parallel to one another and incline vertically toward a vertical center of the junction portion **312** along the vertical axis **306**. The inclined contact surfaces **316** mate with or abut corresponding inclined contact surfaces of the plates **106** when the heat exchanger **102** is assembled. As described in greater detail with respect to FIG. 7, the junction portion **312** and the inclined contact surfaces **316** are adapted for a single-move assembly process of the heat exchanger **102** that allows the inlet channel **112** to be assembled to the plates **106** of the heat exchanger **102** along the longitudinal axis **302**. The inclined surfaces **316** allow the inlet channel **112** to be assembled to the plates **106** from the front or side along the horizontal plane of the plates **106**, which may be necessary due to space limitations.

(27) The transfer portion **310** includes a first curved profile **318** and a second curved profile **320** to minimize the assembly space used by the heat exchanger **102**, which is described in greater detail with respect to FIGS. 6A through 6D. The first curved profile **318** introduces a small bend or curve to the right in the inlet channel **112** as it transitions from the connection portion **308** to the junction portion **312**. In other implementations, the first curved profile **318** may result in a left curve in the transfer portion **310**. The first curved profile **318** is present in a plane defined by the longitudinal axis **302** and the lateral axis **304**.

(28) The second curved profile **320** introduces a small bend or curve downward in the inlet channel **112** as it transitions from the connection portion **308** to the junction portion **312**. In other implementations, the second curved profile **320** may result in an upward curve in the transfer portion **310**. The second curved profile **320** is present in a plane defined by the longitudinal axis **302** and the vertical axis **306**.

(29) FIGS. 4A through 4C illustrate a front view **400-1**, top view **400-2**, and side view **400-3** of an exemplified outlet channel **114** of the heat exchanger **102**. In other implementations, the outlet channel **114** of FIGS. 4A through 4C may act as the inlet channel **112** of the cooling system **100**. The side view **400-3** depicts the longitudinal axis **302** extending from the connection portion **308** to the junction portion **312** of the outlet channel **114**. The side view **400-3** also illustrates the vertical axis **306**. The top view **300-1** shows the lateral axis **304**.

(30) The outlet channel **114** of FIGS. 4A through 4C is similar to the inlet channel **112** of FIGS. 3A through 3C. The outlet channel **114** includes the connection portion **308**, the transfer portion **310**, and the junction portion **312**. The transfer portion **310** may include non-uniform cross-sections along the longitudinal axis **302**. For example, proximate the connection portion **308**, the transfer portion **310** may have an approximately circular cross-section. Proximate the junction portion **312**,

the transfer portion **310** may have an approximately rectangular cross-section.

(31) The connection portion **308** may have an approximately circular cross-section. The circular connection portion **308** is adapted to accept a coolant hose. Automotive cooling systems often use hoses to transport liquid coolant in and out of the heat exchanger **102**. For example, the hoses may be flexible rubber hoses. A hose may be attached to the connection portion **308** using a clamp or similar attachment means. The connection portion **308** also includes the external stop feature **314** that prevents the hose from sliding along the longitudinal axis **302** onto or into the transfer portion **310**.

(32) The junction portion **312** may have an approximately rectangular cross-section in both the top view **400-2** and the side view **400-3**. The junction portion **312** of the outlet channel **114** transfers the coolant away from the plates **106**. In the depicted implementation, the outlet channel **114** attaches to two plates **106** and the junction portion **312** is a T-junction that equally distributes the coolant away from both plates **106**. The approximately rectangular cross-section of the junction portion **312** provides a compact design to minimize the assembly space used by the heat exchanger **102**.

(33) The junction portion **312** also includes the inclined contact surface **316** at opposing surfaces. In particular, the inclined surfaces **316** are inclined relative to a horizontal plane of the plates **106** defined by the lateral axis **116** and the longitudinal axis **118**. The inclined contact surfaces **316** of the junction portion **312** are not parallel to one another and incline vertically toward a vertical center of the junction portion **312** along the vertical axis **306**. The inclined contact surfaces **316** mate with or abut corresponding inclined contact surfaces of the plates **106** when the heat exchanger **102** is assembled. As described in greater detail with respect to FIG. 7, the junction portion **312** and the inclined contact surfaces **316** are adapted for a single-move assembly process of the heat exchanger **102** that allows the outlet channel **114** to be assembled to the plates **106** of the heat exchanger **102** along the longitudinal axis **302**. The inclined surfaces **316** allow the outlet channel **114** to be assembled to the plates **106** from the front or side along the horizontal plane of the plates **106**, which may be necessary due to space limitations.

(34) The transfer portion **310** includes the first curved profile **318** and the second curved profile **320** to minimize the assembly space used by the heat exchanger **102**, which is described in greater detail with respect to FIGS. 6A through 6D. The first curved profile **318** introduces a small bend or curve to the left in the outlet channel **114** as it transitions from the connection portion **308** to the junction portion **312**. In other implementations, the first curved profile **318** may result in a right curve in the transfer portion **310**. The first curved profile **318** is present in a plane defined by the longitudinal axis **302** and the lateral axis **304**.

(35) The second curved profile **320** introduces a small bend or curve upward in the outlet channel **114** as it transitions from the connection portion **308** to the junction portion **312**. In other implementations, the second curved profile **320** results in a downward curve in the transfer portion **310**. The second curved profile **320** is present in a plane defined by the longitudinal axis **302** and the vertical axis **306**.

(36) FIGS. 5A through 5E illustrate exemplified cross-sections **500**, **502**, **504**, and **506** of the connection portion **308** and the transfer portion **310** of the inlet channel **112**. The outlet channel **114** has similar cross-sections as the inlet channel **112**. As illustrated by the cross-sections **500** through **506**, the transfer portion **310** has a non-uniform cross-section along the longitudinal axis **302**. In particular, the inlet channel **112** transitions from a first cross-section (e.g., an approximately circular cross-section as illustrated by the cross-sections **500** and **502** of FIGS. 5B and 5C) to a second cross-section (e.g., an approximately rectangular cross-section as illustrated by the cross-sections **504** and **506** of FIGS. 5D and 5E). The first cross-section of the connection portion **308** is adapted for attaching coolant hoses (e.g., rubber hoses) to guide the coolant towards and away from the heat exchanger **102**. The second cross-section of the transfer portion **310** and the junction portion **312** allows for the compact design of the heat exchanger **102**.

(37) FIGS. 6A through 6D illustrate a perspective view **600**, front view **602**, side view **604**, and cross-section view **606**, respectively, of an exemplified inlet channel **112** and an exemplified outlet channel **114** in assembly positions. As described above, the transfer portion **310** of both the inlet channel and the outlet channel **114** includes the first curved profile **318** and the second curved profile **320**. In the depicted implementation, the first curved profile **318** of the inlet channel **112** is a bend to the right while the first curved profile **318** of the outlet channel **114** is a bend to the left along the longitudinal axis **302** from the connection portion **308** to the junction portion **312**. In other implementations, the first curved profile **318** of the inlet channel **112** and the outlet channel **114** may be switched. The first curved profile **318** allows the connection portion **308** of the inlet channel **112** to be positioned at approximately the same lateral position as the connection portion **308** of the outlet channel **114**, as illustrated in the front view **602** of FIG. 6B. In this way, the connection portions **308** of the heat exchanger **102** use a limited lateral assembly space for the coolant hoses.

(38) The perspective view **600** of FIG. 6A also illustrates that the length of the inlet channel **112** is longer than the length of the outlet channel **114**. In other implementations, the inlet channel **112** may be shorter than the outlet channel **114**. The difference in lengths facilitates the compact design of the heat exchanger **102** by staggering the longitudinal positions of the junction portions **312** for the outlet channel **114** and the inlet channel **112**. This compact design allows a combined lateral profile of the junction portion **312** of the inlet channel **112** and the outlet channel **114** to be approximately equal to a lateral width of an individual junction portion **312**.

(39) In the depicted implementation, the second curved profile **320** of the inlet channel **112** is a bend down while the second curved profile **320** of the outlet channel **114** is a bend up along the longitudinal axis **302** from the connection portion **308** to the junction portion **312**. In other implementations, the second curved profile **320** of the inlet channel **112** and the outlet channel **114** may be switched. The second curved profile **320** allows the connection portion **308** of the inlet channel **112** to be positioned above the connection portion **308** of the outlet channel **114**, as illustrated in the front view **602** of FIG. 6B. In this way, the connection portions **308** use a limited lateral assembly space for the coolant hoses. In other implementations, the transfer portions **310** of the inlet channel **112** and the outlet channel **114** may include different curved profiles to provide a minimal vertical assembly space for the coolant hoses.

(40) FIG. 7 illustrates a cross-section view **700** of an exemplified heat exchanger **102** with two plates **106** and the junction portion **312** of an exemplified inlet channel **112**. The junction portion **312** of the outlet channel **114** has a similar cross-section with the same features as described with respect to the cross-section view **700**.

(41) The junction portion **312** may be joined to the plates **106** using an adhesive **702** on the inclined contact surfaces **316** of the inlet channel **112** (or the outlet channel **114**). The adhesive **702** provides a tight and leakproof joint between the inlet channel **112** (or the outlet channel **114**) and the plates **106**. In addition, the adhesive **702** allows dissimilar materials (e.g., aluminum for the plates **106** and plastic for the inlet channel **112** and the outlet channel **114**) to be joined. The adhesive **702** also compensates for geometrical inaccuracies (e.g., misalignments) in the assembly of the heat exchanger **102**, which may result from manufacturing or assembly tolerances. For example, a thickness or viscosity of the adhesive **702** is configured to account for the manufacturing or assembly tolerances of the junction portion **312** and the plates **106**, potentially resulting in cheaper manufacturing costs by lowering tolerances for the junction portion **312** and the plates **106**.

(42) As described with respect to FIGS. 3A through 3C and 4A through 4C, the junction portion **312** of the inlet channel **112** includes opposing inclined contact surfaces **316**. The inclined contact surfaces **316** are inclined relative to a horizontal plane of the plates **106** and adapted to mate or abut corresponding inclined contact surfaces of the plates **106**. The inclined contact surface **316** provides a simplified assembly process with a one-direction or single-motion connection. The inclined contact surface **316** of the junction portion **312** and the corresponding inclined contact

surface of the plates **106** are designed to provide a controlled flow of the adhesive **702** during assembly and an appropriate gap or space for glue distribution. The inclined contact surface **316** and the plates **106** are also designed to facilitate correct positioning of the inlet channel **112** (or the outlet channel **114**) and retention or clamping thereof

(43) Before assembly, the adhesive **702** may be applied to the inclined contact surface **316** of the junction portion **312** of the inlet channel **112** (or the outlet channel **114**). The adhesive **702** is applied onto the inclined contact surface **316** near a groove **706**. The shape of the groove **706** is designed to provide a recess in the inclined contact surface **316** and receive excess adhesive **702** during assembly. During the assembly, the distance between the inclined contact surfaces **316** is reduced and the adhesive **702** flows into the space between the plates **106** and the junction portion **312**, partially defined by the groove **706**. Distancers **710** on the plates **106** protrude from the inclined contact surface **316** adjacent to a coolant channel **704** that guides the coolant into or out of each plate **106**. The distancers **710** prevent the adhesive **702** flowing out of the application area and the groove **706** into the coolant channel **704** during the assembly process. The distancers **710** also ensure a correct space or gap dimension between the junction portion **312** and the plates **106**.

(44) The plates **106** also include hard stops **712** to maintain a position of the junction portion **312** of the inlet channel **112** (or the outlet channel **114**) during assembly and when attached to the heat exchanger **102**. Together with the hard stops **712**, tube clasps **708** provide a tight connection between the assembled components. The tube clasps **708** protrude from the inclined surfaces **316** of the junction portion **312** and are positioned at an opposite lateral end from the hard stops **712**. The tube clasps **708** maintain a position of the junction portion **312** of the inlet channel **112** (or the outlet channel **114**) when it is attached to the heat exchanger **102**.

(45) In other implementations, the heat exchanger **102** may use an elastic gasket or similar component in lieu of the adhesive **702**. The elastic gasket fills the groove **706** and the gap in between the inclined contact surface **316** of the junction portion and the corresponding inclined contact surface of the plate **106** when the heat exchanger **102** is assembled. The junction portion **312** may be attached to the plates **106** and the heat exchanger **102** using a clasp on an exterior of the plate **106** or the inlet channel **112** (or the outlet channel **114**).

(46) FIG. **8** illustrates an exemplified method **800** for installing a manifold with an inlet channel and an outlet channel to a cooling system in accordance with techniques of this disclosure. The cooling system may include a heat exchanger with two plates. Method **800** is shown as sets of operations (or acts) performed, but not necessarily limited to the order or combinations in which the operations are shown herein. Further, any one or more of the operations may be repeated, combined, or reorganized to provide other methods.

(47) At step **802**, the inlet channel **112** of a manifold is connected to the two plates **106** of the heat exchanger **102** by mating opposing inclined contact surfaces **316** of the junction portion **312** of the inlet channel **112** to corresponding inclined contact surfaces of the two plates **106**. The inlet channel **112** guides coolant toward the two plates **106**. The inclined contact surfaces **316** of the junction portion **312** are inclined relative to a horizontal plane of the two plates **106**. The inlet channel **112** may be connected to the two plates **106** using the adhesive **702** or a combination of a gasket and exterior clasp.

(48) At step **804**, the outlet channel **114** of a manifold is connected to the two plates **106** of the heat exchanger **102** by mating opposing inclined contact surfaces **316** of the junction portion **312** of the outlet channel **114** to corresponding inclined contact surfaces of the two plates **106**. The outlet channel **114** guides coolant away from the two plates **106**. The inclined contact surfaces **316** of the junction portion **312** are inclined relative to a horizontal plane of the two plates **106**. The outlet channel **114** may be connected to the two plates **106** using the adhesive **702** or a combination of a gasket and exterior clasp.

(49) The inclined contact surfaces **316** of the junction portion **312** allow the inlet channel **112** and the outlet channel **114** to be inserted into position for assembly to the two plates **106** of the heat

exchanger **102** along the longitudinal axis **302**. In other words, the inlet channel **112** and the outlet channel **114** may be inserted in plane with the horizontal plane of the plates **106** from a front portion or side portion of a vehicle to accommodate tight spacing constraints.

(50) At step **806**, coolant hoses are attached to the connection portion **308** of both the inlet channel **112** and the outlet channel **114** of the manifold. The inlet channel **112** and the outlet channel **114** also include the transfer portion **310** between the junction portion **312** and the connection portion **308** that extends along the longitudinal axis **302**. The longitudinal axis **302** is parallel with the horizontal plane of the two plates **106**.

Additional Exemplified Embodiments

(51) Some additional exemplified embodiments for inlet and outlet channels for a heat exchanger are provided below.

(52) Exemplified Embodiment 1. A manifold for a cooling system, the manifold comprising: an inlet channel configured to connect to a heat exchanger of the cooling system that includes multiple plates, the inlet channel being configured to guide coolant toward the multiple plates of the heat exchanger; and an outlet channel configured to connect to the heat exchanger, the outlet channel being configured to guide the coolant away from the multiple plates of the heat exchanger, the inlet channel and the outlet channel including: a junction portion configured to transfer coolant to and from the multiple plates of the heat exchanger, the junction portion comprising opposing inclined contact surfaces that are inclined relative to a horizontal plane of the multiple plates and configured to mate with corresponding inclined contact surfaces of the multiple plates; a connection portion configured to accept a coolant hose; and a transfer portion between the junction portion and the connection portion, the transfer portion extending along a longitudinal axis.

(53) Exemplified Embodiment 2. The manifold of Exemplified Embodiment 1, wherein the transfer portion of the inlet channel and the outlet channel has a non-uniform cross-section along the longitudinal axis that transitions from a first cross-section proximate the connection portion to a second cross-section proximate the junction portion.

(54) Exemplified Embodiment 3. The manifold of Exemplified Embodiment 1 or 2, wherein the connection portion of the inlet channel and the outlet channel includes an external stop feature to stop the coolant hose from extending into the transfer portion.

(55) Exemplified Embodiment 4. The manifold of any previous Exemplified Embodiment, wherein the inlet channel and outlet channel are plastic or reinforced plastic.

(56) Exemplified Embodiment 5. The manifold of any previous Exemplified Embodiment, wherein the inclined contact surfaces of the junction portion are configured to allow the inlet channel and the outlet channel to be assembled to the multiple plates of the heat exchanger along the longitudinal axis of the transfer portion.

(57) Exemplified Embodiment 6. The manifold of any previous Exemplified Embodiment, wherein the junction portion of the inlet channel and the outlet channel is configured to attach to the multiple plates of the heat exchanger using an adhesive on the inclined contact surfaces of the inlet channel and the outlet channel.

(58) Exemplified Embodiment 7. The manifold of Exemplified Embodiment 6, wherein the inclined contact surfaces of the junction portion include a groove, the groove forming a recess in the inclined contact surfaces of the junction portion and being configured to receive excess adhesive.

(59) Exemplified Embodiment 8. The manifold of any previous Exemplified Embodiment, wherein the inclined contact surfaces of the junction portion include a tube clasp located at a lateral end of the inclined contact surfaces, the tube clasp being configured to maintain a position of the junction portion of the inlet channel and the outlet channel when the junction portion is attached to the heat exchanger.

(60) Exemplified Embodiment 9. The manifold of any one of Exemplified Embodiment 1 through 5 or 8, wherein the inclined contact surfaces of the junction portion include a groove, the groove

forming a recess in the inclined contact surfaces and being configured to allow an elastic gasket to fill a space in between the inclined contact surfaces of the junction portion and the corresponding inclined contact surfaces of the multiple plates when the junction portion is attached to the heat exchanger.

(61) Exemplified Embodiment 10. The manifold of Exemplified Embodiment 9, wherein the junction portion is configured to attach to the heat exchanger using an external clasp.

(62) Exemplified Embodiment 11. The manifold of any previous Exemplified Embodiment, wherein the transfer portion of the inlet channel and the outlet channel include a first curved profile along a first plane defined by the longitudinal axis and a lateral axis, the lateral axis being orthogonal to the longitudinal axis, the first curved profile resulting in a left curve or right curve as the inlet channel and the outlet channel transition from the junction portion to the connection portion, the first curved profile of the inlet channel being in a direction opposite that of the first curved profile of the outlet channel.

(63) Exemplified Embodiment 12. The manifold of Exemplified Embodiment 11, wherein the transfer portion of the inlet channel and the outlet channel include a second curved profile along a second plane defined by the longitudinal axis and a vertical axis, the second plane being orthogonal to the first plane, the second curved profile resulting in an upward curve or downward curve as the inlet channel and the outlet channel transition from the junction portion to the connection portion, the second curved profile of the inlet channel being in another direction opposite that of the second curved profile of the outlet channel.

(64) Exemplified Embodiment 13. The manifold of Exemplified Embodiment 12, wherein a length of the inlet channel is different than a length of the outlet channel.

(65) Exemplified Embodiment 14. The manifold of Exemplified Embodiment 13, wherein: the connection portion of the inlet channel is positioned at approximately a same lateral position along the lateral axis as the connection portion of the outlet channel; and the connection portion of the inlet channel is positioned above or below the connection portion of the outlet channel along the vertical axis.

(66) Exemplified Embodiment 15. The manifold of Exemplified Embodiment 14, wherein a combined lateral profile of the connection portion of both the inlet channel and the outlet channel along the lateral axis is approximately equal to a diameter of the connection portion.

(67) Exemplified Embodiment 16. A cooling system comprising: a heat exchanger comprising at least one plate configured to transfer heat away from electronic components, each plate of the heat exchanger comprising a first inclined contact surface that is inclined relative to a horizontal plane of each plate; and a manifold comprising: an inlet channel configured to connect to the at least one plate of the heat exchanger and guide coolant toward each plate of the heat exchanger; and an outlet channel configured to connect to the at least one plate of the heat exchanger and guide the coolant away from each plate of the heat exchanger, the inlet channel and the outlet channel including: a junction portion configured to transfer coolant to and from each plate of the heat exchanger, the junction portion comprising second inclined contact surfaces that are inclined relative to the horizontal plane of each plate and configured to mate with the corresponding first inclined contact surfaces of each plate; a connection portion configured to accept a coolant hose; and a transfer portion between the junction portion and the connection portion, the transfer portion extending along a longitudinal axis.

(68) Exemplified Embodiment 17. The cooling system of Exemplified Embodiment 16, wherein the heat exchanger is made of a first material and the manifold is made of a second material that is different than the first material.

(69) Exemplified Embodiment 18. The cooling system of Exemplified Embodiment 16 or 17, wherein: the second inclined contact surfaces of the junction portion include a groove, the groove forming a recess in the second inclined contact surfaces of the junction portion and being configured to receive excess adhesive; the first inclined contact surface of each plate of the heat

exchanger includes distancers positioned in between the groove of the junction portion and a coolant channel of each plate when the junction portion is attached to the heat exchanger, the distancers configured to prevent the adhesive from entering the coolant channel that guides the coolant into or out of each plate; and each plate of the heat exchanger includes a hard stop configured to maintain a position of the junction portion of the inlet channel and the outlet channel when the junction portion is attached to the heat exchanger.

(70) Exemplified Embodiment 19. The cooling system of any one of Exemplified Embodiment 16 through 18, wherein the cooling system is configured to be installed in a vehicle.

(71) Exemplified Embodiment 20. A method of installing a manifold to a cooling system, the cooling system comprising a heat exchanger with two plates, the method comprising: connecting an inlet channel of the manifold to the two plates of the heat exchanger by mating opposing inclined contact surfaces of a junction portion of the inlet channel to corresponding inclined contact surfaces of the two plates, the inlet channel being configured to guide coolant toward the two plates, the opposing inclined contact surfaces of the junction portion being inclined relative to a horizontal plane of the two plates; connecting an outlet channel of the manifold to the two plates of the heat exchanger by mating the opposing inclined contact surfaces of the junction portion of the outlet channel to corresponding inclined contact surfaces of the two plates, the outlet channel being configured to guide the coolant away from the two plates; and attaching coolant hoses to a connection portion of both the inlet channel and the outlet channel of the manifold, the inlet channel and the outlet channel further including a transfer portion between the junction portion and the connection portion that extends along a longitudinal axis, the longitudinal axis being parallel with the horizontal plane of the two plates.

CONCLUSION

(72) While various embodiments of the disclosure are described in the foregoing description and shown in the drawings, it is to be understood that this disclosure is not limited thereto but may be variously embodied to practice within the scope of the following claims. From the foregoing description, it will be apparent that various changes may be made without departing from the scope of the disclosure as defined by the following claims.

Claims

1. A manifold for a cooling system, the manifold comprising: an inlet channel configured to connect to a heat exchanger of the cooling system that includes multiple plates, the inlet channel being configured to guide coolant toward the multiple plates of the heat exchanger; and an outlet channel configured to connect to the heat exchanger, the outlet channel being configured to guide the coolant away from the multiple plates of the heat exchanger, the inlet channel and the outlet channel including: a junction portion configured to transfer coolant to and from the multiple plates of the heat exchanger, the junction portion comprising opposing inclined contact surfaces that are inclined relative to a horizontal plane of the multiple plates and configured to mate with corresponding inclined contact surfaces of the multiple plates; a connection portion configured to accept a coolant hose; and a transfer portion between the junction portion and the connection portion, the transfer portion extending along a longitudinal axis.
2. The manifold of claim 1, wherein the transfer portion of the inlet channel and the outlet channel has a non-uniform cross-section along the longitudinal axis that transitions from a first cross-section proximate the connection portion to a second cross-section proximate the junction portion.
3. The manifold of claim 1, wherein the connection portion of the inlet channel and the outlet channel includes an external stop feature to stop the coolant hose from extending into the transfer portion.
4. The manifold of claim 1, wherein the inlet channel and outlet channel are plastic or reinforced plastic.

5. The manifold of claim 1, wherein the inclined contact surfaces of the junction portion are configured to allow the inlet channel and the outlet channel to be assembled to the multiple plates of the heat exchanger along the longitudinal axis of the transfer portion.
6. The manifold of claim 1, wherein the junction portion of the inlet channel and the outlet channel is configured to attach to the multiple plates of the heat exchanger using an adhesive on the inclined contact surfaces of the inlet channel and the outlet channel.
7. The manifold of claim 6, wherein the inclined contact surfaces of the junction portion include a groove, the groove forming a recess in the inclined contact surfaces of the junction portion and being configured to receive excess adhesive.
8. The manifold of claim 1, wherein the inclined contact surfaces of the junction portion include a tube clasp located at a lateral end of the inclined contact surfaces, the tube clasp being configured to maintain a position of the junction portion of the inlet channel and the outlet channel when the junction portion is attached to the heat exchanger.
9. The manifold of claim 1, wherein the inclined contact surfaces of the junction portion include a groove, the groove forming a recess in the inclined contact surfaces and being configured to allow an elastic gasket to fill a space in between the inclined contact surfaces of the junction portion and the corresponding inclined contact surfaces of the multiple plates when the junction portion is attached to the heat exchanger.
10. The manifold of claim 9, wherein the junction portion is configured to attach to the heat exchanger using an external clasp.
11. The manifold of claim 1, wherein the transfer portion of the inlet channel and the outlet channel include a first curved profile along a first plane defined by the longitudinal axis and a lateral axis, the lateral axis being orthogonal to the longitudinal axis, the first curved profile resulting in a left curve or right curve as the inlet channel and the outlet channel transition from the junction portion to the connection portion, the first curved profile of the inlet channel being in a direction opposite that of the first curved profile of the outlet channel.
12. The manifold of claim 11, wherein the transfer portion of the inlet channel and the outlet channel include a second curved profile along a second plane defined by the longitudinal axis and a vertical axis, the second plane being orthogonal to the first plane, the second curved profile resulting in an upward curve or downward curve as the inlet channel and the outlet channel transition from the junction portion to the connection portion, the second curved profile of the inlet channel being in another direction opposite that of the second curved profile of the outlet channel.
13. The manifold of claim 12, wherein a length of the inlet channel is different than a length of the outlet channel.
14. The manifold of claim 13, wherein: the connection portion of the inlet channel is positioned at approximately a same lateral position along the lateral axis as the connection portion of the outlet channel; and the connection portion of the inlet channel is positioned above or below the connection portion of the outlet channel along the vertical axis.
15. The manifold of claim 14, wherein a combined lateral profile of the connection portion of both the inlet channel and the outlet channel along the lateral axis is approximately equal to a diameter of the connection portion.
16. A cooling system comprising: a heat exchanger comprising at least one plate configured to transfer heat away from electronic components, each plate of the heat exchanger comprising a first inclined contact surface that is inclined relative to a horizontal plane of each plate; and a manifold comprising: an inlet channel configured to connect to the at least one plate of the heat exchanger and guide coolant toward each plate of the heat exchanger; and an outlet channel configured to connect to the at least one plate of the heat exchanger and guide the coolant away from each plate of the heat exchanger, the inlet channel and the outlet channel including: a junction portion configured to transfer coolant to and from each plate of the heat exchanger, the junction portion comprising second inclined contact surfaces that are inclined relative to the horizontal plane of

each plate and configured to mate with the corresponding first inclined contact surfaces of each plate; a connection portion configured to accept a coolant hose; and a transfer portion between the junction portion and the connection portion, the transfer portion extending along a longitudinal axis.

17. The cooling system of claim 16, wherein the heat exchanger is made of a first material and the manifold is made of a second material that is different than the first material.

18. The cooling system of claim 16, wherein: the second inclined contact surfaces of the junction portion include a groove, the groove forming a recess in the second inclined contact surfaces of the junction portion and being configured to receive excess adhesive; the first inclined contact surface of each plate of the heat exchanger includes distancers positioned in between the groove of the junction portion and a coolant channel of each plate when the junction portion is attached to the heat exchanger, the distancers configured to prevent the adhesive from entering the coolant channel that guides the coolant into or out of each plate; and each plate of the heat exchanger includes a hard stop configured to maintain a position of the junction portion of the inlet channel and the outlet channel when the junction portion is attached to the heat exchanger.

19. The cooling system of claim 16, wherein the cooling system is configured to be installed in a vehicle.

20. A method of installing a manifold to a cooling system, the cooling system comprising a heat exchanger with two plates, the method comprising: connecting an inlet channel of the manifold to the two plates of the heat exchanger by mating opposing inclined contact surfaces of a junction portion of the inlet channel to corresponding inclined contact surfaces of the two plates, the inlet channel being configured to guide coolant toward the two plates, the opposing inclined contact surfaces of the junction portion being inclined relative to a horizontal plane of the two plates; connecting an outlet channel of the manifold to the two plates of the heat exchanger by mating the opposing inclined contact surfaces of the junction portion of the outlet channel to corresponding inclined contact surfaces of the two plates, the outlet channel being configured to guide the coolant away from the two plates; and attaching coolant hoses to a connection portion of both the inlet channel and the outlet channel of the manifold, the inlet channel and the outlet channel further including a transfer portion between the junction portion and the connection portion that extends along a longitudinal axis, the longitudinal axis being parallel with the horizontal plane of the two plates.
