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- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*
- *of inventorship (Rule 4.17(iv))*

Published:

- *with international search report (Art. 21(3))*
- *with amended claims and statement (Art. 19(1))*

MULTI-PRESSURE HYDRAULIC CONTROL SYSTEM FOR A CONTINUOUSLY VARIABLE AUTOMATIC TRANSMISSION

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] The present application claims priority to and all the benefits of U.S. Provisional Patent Application No. 62/148,834, filed on April 17, 2015, which is hereby expressly incorporated herein by reference in its entirety.

BACKGROUND OF INVENTION

1. Field of Invention

[0002] The present invention relates generally to powertrain systems and, more specifically, to a multi-pressure hydraulic control system for a continuously variable automatic transmission.

2. Description of the Related Art

[0002] Conventional vehicle powertrain systems known in the art typically include an engine in rotational communication with a transmission. The engine generates rotational torque which is selectively translated to the transmission which, in turn, translates rotational torque to one or more wheels. The transmission multiplies the rotational speed and torque generated by the engine through a series of predetermined gear sets, whereby changing between the gear sets enables a vehicle to travel at different vehicle speeds for a given engine speed. Thus, the gear sets of the transmission are configured such that the engine can operate at particularly desirable rotational speeds so as to optimize performance and efficiency.

[0003] In addition to changing between the gear sets, the transmission is also used to modulate engagement with the engine, whereby the transmission can selectively control engagement with the engine so as to facilitate vehicle operation. By way of example, torque translation between the engine and the transmission is typically interrupted while a vehicle is parked or idling, or when the transmission changes between the gear sets. In conventional automatic transmissions, modulation is achieved via a hydrodynamic device such as a hydraulic

torque converter. Automatic transmissions are typically controlled using hydraulic fluid, and include a pump assembly, one or more solenoid valves, and an electronic controller. The pump assembly provides a source of fluid power to the solenoid valves which, in turn, are actuated by the controller so as to selectively direct hydraulic fluid throughout the automatic transmission to control modulation of rotational torque generated by the engine.

[0004] One type of automatic transmission is known as a continuously variable transmission (CVT). In general, such transmissions take the form of two adjustable pulleys, each pulley having a sheave which is axially fixed and another sheave which is axially movable relative to the first sheave. A flexible belt of metal or elastomeric material or a chain is used to intercouple the pulleys. The interior faces of the pulley sheaves are beveled or chamfered so that, as the axially displaceable sheave is moved, the distance between the sheaves and thus the effective pulley diameter is adjusted. The displaceable sheave includes a fluid-constraining chamber for receiving fluid to increase the effective pulley diameter, and when fluid is exhausted from the chamber, the pulley diameter is decreased. Generally the effective diameter of one pulley is adjusted in one direction as the effective diameter of the second pulley is varied in the opposite direction, thereby effecting a change in the drive ratio between an input shaft coupled to an input pulley and the output shaft coupled to the output pulley. As a result, the drive ratio between the shafts is variable in a continuous, smooth manner. The solenoid valves are also typically used to actuate the sheaves of continuously variable the automatic transmission, and may also be used to control hydraulic fluid used to cool and/or lubricate various components of the transmission in operation.

[0005] Depending on the specific configuration of the automatic transmission, modulation and/or sheave actuation may necessitate operating the pump assembly so as to pressurize the hydraulic fluid at relatively high magnitudes. Conversely, lubrication and/or cooling typically require significantly lower hydraulic fluid pressure, whereby excessive pressure has a detrimental effect on transmission operation and/or efficiency. Moreover, hydraulic fluid heats up during operation of the automatic transmission, and changes in the temperature of the hydraulic fluid result in a corresponding change in the viscosity of the hydraulic fluid. As such, where specific hydraulic pressure is needed to properly operate the automatic transmission, the volume of hydraulic fluid required to achieve the requisite hydraulic pressure varies with operating temperature. Further, where the pump assembly is driven by the powertrain system,

fluid flow is proportional to pump rotational speed. Because fluid flow increases with increased rotational speed, under certain operating conditions, a significant volume of fluid displaced by the pump assembly must be re-circulated to maintain proper fluid flow and pressure requirements throughout the automatic transmission, thereby leading to disadvantageous parasitic loss which results in low efficiency.

[0006] Each of the components and systems of the type described above must cooperate to effectively modulate translation of rotational torque from the engine to the wheels of the vehicle. In addition, each of the components and systems must be designed not only to facilitate improved performance and efficiency, but also so as to reduce the cost and complexity of manufacturing the vehicles.

[0007] The efficiency of the hydraulic control system for an automatic transmission can be improved through the usage of one or more pumps with multiple output ports that feed different portions of the hydraulic control system with fluid that is at different pressure levels and different flow rates. Thus, there is a need in the art to provide a new hydraulic control system for usage with a continuously variable automatic transmission that achieves this efficiency.

SUMMARY OF THE INVENTION

[0008] The present invention provides a multi-pressure hydraulic control system for use with a continuously variable automatic transmission of a vehicle powertrain system including at least one pump having a rotatable pump member, at least one inlet region for receiving fluid to be pumped by the pump member, and at least one outlet region for outputting fluid pumped by the pump member. The multi-pressure hydraulic control system also includes a switching valve receiving at least two separate outputs of fluid pumped by the at least one pump for allowing the at least two outputs to be selectively combined and/or separated. The switching valve has a valve member being movable between at least three positions that produces fluid outputs having a first fluid pressure, a second fluid pressure, and a third fluid pressure to one or more portions of the continuously variable automatic transmission.

[0009] In addition, the present invention provides a method for controlling a multi-pressure hydraulic control system for use with a continuously variable automatic transmission of a vehicle powertrain system including the steps of pumping fluid by at least one pump including

a rotatable pump member, at least one inlet region for receiving fluid to be pumped by the pump member, and at least one outlet region for outputting fluid pumped by the pump member. The method also includes the steps of receiving at a switching valve at least two separate outputs of fluid pumped by the at least one pump, the switching valve having a valve member being
5 movable between at least three positions, and moving the valve member between the at least three positions to produce fluid outputs having a first fluid pressure, a second fluid pressure, and a third fluid pressure to one or more portions of the continuously variable automatic transmission.

[0010] One advantage of the present invention is that a new multi-pressure hydraulic
10 control system is provided for a continuously variable automatic transmission. Another advantage of the present invention is that the multi-pressure hydraulic control system includes one or more pumps with multiple output ports that feed different portions of the hydraulic control system with fluid that is at different pressure levels and different flow rates. Yet another advantage of the present invention is that the multi-pressure hydraulic control system includes a
15 switching valve that allows the outputs of the one or more pumps to be selectively combined to meet the highest flow demand portion of the system. Still another advantage of the present invention is that the multi-pressure hydraulic control system enables the continuously variable automatic transmission to achieve the most of the efficiency benefits of a high complexity system.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Other objects, features, and advantages of the present invention will be readily appreciated as the same becomes better understood after reading the subsequent description taken in connection with the accompanying drawings wherein:

[0012] Figure 1 is a schematic view of a vehicle powertrain system including a
25 continuously variable automatic transmission and a multi-pressure hydraulic control system, according to the present invention;

[0013] Figure 2 is a schematic view of a first embodiment of the multi-pressure hydraulic control system, according to the present invention, for use with the continuously variable
30 automatic transmission of Figure 1;

[0014] Figure 3 is a schematic view of a second embodiment of the multi-pressure hydraulic control system, according to the present invention, for use with the continuously variable automatic transmission of Figure 1; and

[0015] Figure 4 is a schematic view of a third embodiment of the multi-pressure hydraulic control system, according to the present invention, for use with the continuously variable automatic transmission of Figure 1.

DETAILED DESCRIPTION OF THE INVENTION

[0016] Referring now to the figures, where like numerals are used to designate like structure unless otherwise indicated, a vehicle powertrain system is schematically illustrated at 10 in Figure 1. The powertrain system 10 includes an engine 12 in rotational communication with a continuously variable automatic transmission 14. The engine 12 generates rotational torque which is selectively translated to the continuously variable automatic transmission 14 which, in turn, translates rotational torque to one or more wheels, generally indicated at 16. To that end, a pair of continuously-variable joints 18 translates rotational torque from the continuously variable automatic transmission 14 to the wheels 16. It should be appreciated that the engine 12 and the continuously variable automatic transmission 14 of Figure 1 are of the type employed in a conventional “transverse front wheel drive” powertrain system 10. It should also be appreciated that the engine 12 and/or continuously variable automatic transmission 14 could be of any suitable type, configured in any suitable way sufficient to generate and translate rotational torque so as to drive the vehicle, without departing from the scope of the present invention.

[0017] The continuously variable automatic transmission 14 multiplies the rotational speed and torque generated by the engine 12 through a pulley assembly 22. A forward-reverse gear set 20 is disposed between the engine 12 and the pulley assembly 22. The pulley assembly 22 includes an input or primary pulley (not shown) having a fixed sheave (not shown) and a movable sheave (not shown), with a primary sheave servo chamber (not shown) positioned to admit and discharge fluid and thus adjust the position of movable sheave. The pulley assembly 22 includes a secondary or output pulley (not shown) having an axially fixed sheave (not shown) and an axially movable sheave (not shown), with a secondary sheave servo chamber (not shown) positioned to admit and discharge fluid to change the effective diameter of pulley. The pulley

assembly 22 further includes a belt or chain (not shown) intercoupling the pulleys. The output of secondary pulley is passed to a differential assembly (not shown), which passes output drive to the joints 18, in turn, to the wheels 16 of the vehicle. It should be appreciated that this drive train, from the engine 12 to the joints 18 is completed when fluid under pressure is admitted into starting clutch servo chamber.

[0018] In addition, the continuously variable automatic transmission 14 is also used to modulate engagement with the engine 12, whereby the transmission 14 can selectively control engagement with the engine 12 so as to facilitate vehicle operation. By way of example, torque translation between the engine 12 and the continuously variable automatic transmission 14 is typically interrupted while the vehicle is parked or idling, or when the transmission 14 changes between the gear sets. In the continuously variable automatic transmission 14, modulation of rational torque between the engine 12 and transmission 14 is achieved via a hydrodynamic device such as a hydraulic torque converter (not shown, but generally known in the art). An example of a continuously variable (automatic) transmission (CVT) 14 is disclosed in U.S. Patent No. 4,712,453 to Haley, the disclosure of which is hereby incorporated by reference in its entirety. It should be appreciated that the continuously variable automatic transmission 14 is adapted for use with vehicles such as automotive vehicles, but could be used in connection with any suitable type of vehicle. It should also be appreciated, in some CVTs, the torque converter is replaced and used with a starting clutch.

[0019] Irrespective of the specific configuration of the powertrain system 10, the continuously variable automatic transmission 14 is typically controlled using hydraulic fluid. Specifically, the continuously variable automatic transmission 14 is cooled, lubricated, actuated, and modulates torque using hydraulic fluid. To these ends, the continuously variable automatic transmission 14 typically includes a controller 24 in electrical communication with one or more solenoids 26 (see Figure 1) used to direct, control, or otherwise regulate flow of fluid throughout the transmission 14, as described in greater detail below. In order to facilitate the flow of hydraulic fluid throughout the continuously variable automatic transmission 14, the powertrain system 10 includes at least one or more pumps, generally indicated at 28. In one embodiment, the pump 28 may be a positive displacement pump assembly as disclosed in DKT14308A, the disclosure of which is hereby incorporated by reference in its entirety. It should be appreciated

that either a three-output pump 28, three independent pumps 28, or three coaxially driven pumps 28, or any combination of pumps 28 that provides three separate output ports may be used.

[0020] The pump 28 is adapted to provide a source of fluid power to the powertrain system 10. Specifically, the pump 28 provides fluid power to various locations and components of the continuously variable automatic transmission 14, as described in greater detail below. While the pump 28 is described herein as providing fluid power to the continuously variable automatic transmission 14 of the powertrain system 10, those having ordinary skill in the art will appreciate that the pump 28 could be used in connection with any suitable part of the powertrain system 10 without departing from the scope of the present invention. By way of non-limiting example, the pump 28 of the present invention could be used to direct or otherwise provide a source of fluid power to the engine 12, a transfer case (not shown, but generally known in the art), or any other powertrain component that utilizes fluid for lubrication, cooling, control, actuation, and/or modulation.

[0021] In one embodiment, the pump 28 includes a stator 30 having a chamber and a rotatable pump member 34 disposed in the chamber of the stator 30 (Figures 2 through 4). The pump member 34 is disposed in torque translating relationship with the powertrain system 10. More specifically, the pump member 34 receives rotational torque from a prime mover 36 (not shown in detail, but generally known in the art) of the powertrain system 10. In the representative embodiment illustrated herein, the pump member 34 is coupled to an input shaft 37 which, in turn, is disposed in rotational communication with the prime mover 36. However, those having ordinary skill in the art will appreciate that the pump 28 could be configured differently, with or without the use of an input shaft 37, without departing from the scope of the present invention. Moreover, it should be appreciated that the pump member 34 could receive rotational torque from the powertrain system 10 in a number of different ways.

[0022] In the representative embodiment illustrated herein, the pump 28 is disposed in rotational communication with the prime mover 36 that is supported in the continuously variable automatic transmission 14. However, those having ordinary skill in the art will appreciate that the prime mover 36 could be realized by any suitable component of the powertrain system 10 without departing from the scope of the present invention. By way of non-limiting example, the prime mover 36 could be realized by a shaft supported in rotational communication with the

engine 12 and/or the continuously variable automatic transmission 14, or the prime mover 36 could be a shaft of an electric motor (not shown, but generally known in the art).

[0023] As noted above, each pump 28 includes at least one inlet region or port 40 for receiving fluid to be pumped by the pump member 34 and at least one outlet region or port 42 for outputting fluid pumped by the pump member 34. In one embodiment illustrated in Figure 2, a single pump 28 has one inlet region 40 and two outlet regions 42. In other embodiments illustrated in Figures 3 and 4, a single pump 28 has one inlet region 40 and three outlet regions 42. Rotation of the pump member 34 within the chamber displaces fluid such that each of the outlet regions 42 provides a respective and separate source of fluid power to the powertrain system 10. It should be appreciated that the pump 28 can be configured in a number of different ways.

[0024] As noted above, the present invention is also directed toward a multi-pressure hydraulic control system, according to the present invention and generally indicated at 66, for use with the continuously variable automatic transmission. The multi-pressure hydraulic control system 66 directs or otherwise controls fluid power from the outlet regions 42 of the pump 28 to the continuously variable automatic transmission 14, as described in greater detail below. It should be appreciated that the multi-pressure hydraulic control system 66 can be configured in a number of different ways to direct fluid to the continuously variable automatic transmission 14. For the purposes of clarity and consistency, unless otherwise indicated, subsequent discussion of the multi-pressure hydraulic control system 66 will refer to a first embodiment of the multi-pressure hydraulic control system 66 as shown in Figure 2.

[0025] Referring now to Figure 2, a first embodiment of the multi-pressure hydraulic control system 66 and pump 28 is shown in connection with the continuously variable automatic transmission 14. As noted above, the continuously variable automatic transmission systems 14 utilize hydraulic fluid for lubrication, actuation, modulation, and/or control. To that end, the continuously variable automatic transmission 14 includes a sheave actuation portion or circuit 68, a torque converter portion or circuit 70, a forward/reverse clutch actuation portion or circuit 72, and a gearbox cooling and lubrication portion or circuit 74. The sheave actuation circuit 68 is used to selectively actuate the pulley assembly 22 of the continuously variable automatic transmission. The torque converter circuit 70 is used to modulate rotational torque between the engine 12 and the continuously variable automatic transmission 14. The forward/reverse clutch

actuation circuit 72 is used control flow of hydraulic fluid to the forward and reverse gear-selector assembly of the continuously variable automatic transmission 14. Similarly, the gearbox cooling and lubrication circuit 74 is used to control flow of hydraulic fluid to other locations throughout the continuously variable automatic transmission 14, such as shafts, bearings, and the like (not shown in detail, but generally known in the art), for cooling and/or lubrication. Those having ordinary skill in the art will appreciate that there are a number of different ways that the circuits 68, 70, 72, 74 described above could be configured. As such, each of the circuits 68, 70, 72, 74 is depicted generically. Moreover, it will be appreciated that the multi-pressure hydraulic control system 66 could be used to direct fluid power to any suitable number of circuits, configured in any suitable way and for any suitable purpose of the powertrain system 10, without departing from the scope of the present invention. Similarly, while the representative embodiments illustrated herein describe the multi-pressure hydraulic control system 66 as used with hydraulic fluid in the continuously variable automatic transmission 14, those having ordinary skill in the art will appreciate that the multi-pressure hydraulic control system 66 and pump 28 can be adapted to displace or otherwise direct any suitable type of fluid to any suitable component or system of the powertrain system 10 of any suitable type or configuration without departing from the scope of the present invention.

[0026] Those having ordinary skill in the art will appreciate that each of the circuits 68, 70, 72, 74 may require respectively different pressure and/or flow requirements. By way of non-limiting example, in the representative embodiment of the multi-pressure hydraulic control system 66 described herein, the sheave actuation circuit 68 requires a relatively high or first hydraulic fluid pressure (for example, ~ 30 - 50 bar) for the sheave actuation. This portion of the system requires only a small flow rate of fluid in steady state operation, but requires large flow rates of fluid when doing some sheave ratio change events. The forward/reverse clutch actuation circuit 70 and torque converter circuit 72 require a medium or second hydraulic fluid pressure (for example, ~ 10 bar) required for operating the forward/reverse clutch and the torque converter or launch clutch. Similar to the high pressure circuit, this portion usually only requires a low flow rate of fluid in normal operation. In the embodiment illustrated in Figure 2, the gearbox cooling and lubrication circuit 74 can be configured to receive the medium hydraulic fluid pressure. In the embodiments illustrated in Figures 3 and 4, the gearbox cooling and lubrication circuit 74 requires a low or third hydraulic fluid pressure (for example, ~ 2 bar) for

system lubrication. This portion of the system requires a flow rate dependent on the speed and torque that the continuously variable automatic transmission 14 is operating at.

[0027] To facilitate the competing flow and pressure requirements of the circuits 68, 70, 72, 74, the multi-pressure hydraulic control system 66 includes a plurality of fluid lines, generally indicated at 76, and a switching valve, generally indicated at 78, that cooperate with the pump 28. In the representative embodiment illustrated in Figure 2, one fluid line 76A of the fluid lines 76, also known as a main line, is disposed in fluid communication with one of the output regions 42 of the pump 28, the switching valve 78, and the sheave actuation circuit 68. The sheave actuation circuit 68 has the highest relative or first hydraulic fluid pressure requirements of the continuously variable automatic transmission 14. As illustrated in Figure 2, another fluid line 76B is disposed in fluid communication with the switching valve 78 and the circuits 70, 72, and 74. The circuits 70, 72, and 74 have the medium or second hydraulic fluid pressure requirements of the continuously variable automatic transmission 14. It should be appreciated that the fluid lines 76 could be defined in any suitable way, disposed in fluid communication with any suitable component or circuit of the multi-pressure hydraulic control system 66, without departing from the scope of the present invention.

[0028] The switching valve 78 includes a movable valve member 79 having at least a first position and a second position. In this embodiment, when the switching valve 78 is in the first position, fluid power from one of the outlet regions 42 is directed to the fluid line 76A and fluid power from the other outlet regions 42 is directed away from the fluid line 76A. When the switching valve 78 is in the second position, fluid power from the two outlet regions 42 is directed to the fluid line 76A. The switching valve 78 is selectively moveable between the positions so as to control flow of fluid power from the outlet regions 42 of the pump 28 to the fluid line 76A. In one embodiment, the switching valve 78 is a directional valve as disclosed in DKT15046, the disclosure of which is hereby incorporated by reference in its entirety. It should be appreciated that the switching valve 78 may be used to direct some of the flow back to the inlet region(s) 40 of the pump 28 to bypass all actuation circuits. It should be appreciated that the switching valve 78 has the ability to selectively control the three outputs of the pump 28 to meet the flow and pressure demands of all portions of the multi-pressure hydraulic control system 66 while also minimizing wasted energy.

[0029] As will be appreciated from the subsequent description below, the positions of the switching valve 78 described above enable the pump 28 to combine fluid power from the outlet regions 42 in predetermined ways so as to ensure proper hydraulic fluid pressure at the fluid line 76A under different operating conditions of the continuously variable automatic transmission 14.

5 It should be appreciated that the continuously variable automatic transmission 14 and/or multi-pressure hydraulic control system 66 could have significantly different operating requirements, depending on the application. It should be appreciated that the switching valve 78 could be configured with any suitable number of positions adapted to direct fluid from the pump 28 in a number of different ways, without departing from the scope of the present invention.

10 [0030] In one embodiment, the multi-pressure hydraulic control system 66 includes a sump 80 for providing a source of hydraulic fluid to the inlet region(s) 40 of the pump 28. More specifically, the sump 80 is adapted to store non-pressurized hydraulic fluid and is disposed in fluid communication with all inlet region(s) 40 of the pump 28. However, while the multi-pressure hydraulic control system 66 depicted herein utilizes a common sump 80 for all inlet
15 regions 40, it should be appreciated that a plurality of sumps 80 could be utilized. By way of non-limiting example, each inlet region 40 could be disposed in fluid communication with a different sump (not shown, but generally known in the art). In one embodiment, when the switching valve 78 is in the first position, fluid power is at least partially directed to the sump 80. Similarly, when the switching valve 78 is in the first position, fluid power is at least partially
20 directed to the circuits 70, 72 and/or 74.

[0031] In one embodiment, the multi-pressure hydraulic control system 66 includes a pressure regulator valve 88 interposed in fluid communication between the fluid line 76A and the fluid line 76B. The pressure regulator valve 88 cooperates with the switching valve 78 so as to direct fluid power from the outlet regions 42 of the pump 28 so as to accommodate the pressure
25 and flow requirements of the circuits 68, 70, 72, 74 and ensure proper operation under different operating conditions of the continuously variable automatic transmission 14. The pressure regulator valve 88 regulates the line pressure of the fluid line 76A in responding to instantaneous sheave actuation pressure demand. It should be appreciated that regulating and maintaining the correct line pressure by the pressure regulator valve 88 ensures the proper operation of the
30 powertrain system 10.

[0032] Specifically, the pressure regulator valve 88 has at least a first pressure regulator position, a second pressure regulator position, and a third pressure regulator position. When the pressure regulator valve 88 is in the first pressure regulator position, when the engine is at low speed, such as idle, the flow is limited. The pressure regulator valve 88 is fully closed so that all the flow from the pump 28 is used to create the pressure needed for sheave actuation. When the pressure regulator valve 88 is in the second pressure regulator position, while engine speed increases, the pump flow increases proportionally due to the fixed ratio between the pump 28 and the prime mover 36. At such position, a port opens and partial flow will be directed to the torque converter circuit 70, forward/reverse clutch circuit 72, and/or the gearbox cooling and lubrication circuit 74. When the pressure regulator valve 88 is in the third pressure regulator position, at even higher engine speed, after satisfying the line pressure demand and lubrication/cooling demand, any more excess flow is routed back through the recirculation circuit to the pump inlet region 40 of the pump 28. The pressure regulator valve 88 is selectively movable between the regulator positions so as to cooperate with the switching valve 78 as noted above. Those having ordinary skill in the art will appreciate that the positions of the pressure regulator valve 88 may correlate with the positions of the switching valve 78 or may be selected independent and irrespective of the positions of the switching valve 78. As is described in greater detail below, the pressure regulator valve 88 and switching valve 78 can be controlled, configured, oriented, or disposed in a number of different ways. It should be appreciated that the pressure regulator valve 88 is a proportional valve and has infinite positions when it is continuously regulating even though there are only two positions described. It should also be appreciated that the pressure regulator valve 88 could be omitted from the multi-pressure hydraulic control system 66 or modified to have a different number of positions and different movement through these positions without departing from the scope of the present invention.

[0033] As noted above, the multi-pressure hydraulic control system 66 may include a controller 24 in electrical communication with one or more solenoid valves 26 used to control the switching valve 78. In one embodiment, the switching valve 78 is further defined with a spring-biased valve member 79 having a hydraulic switch inlet (not shown). The controller 24, via the solenoid valve 26, controls the switching valve 78, whereby the solenoid valve 26 is interposed in fluid communication between the fluid line 76A and the hydraulic switch inlet. It

should be appreciated that the switching valve 78 could be of any suitable type, controlled in any suitable way, without departing from the scope of the present invention.

[0034] The controller 24, sometimes referred to in the related art as an “electronic control module,” may also be used to control other components of the continuously variable automatic transmission 14. Further, in one embodiment, the multi-pressure hydraulic control system 66 includes at least one sensor 96 disposed in fluid communication with the fluid line 76A and disposed in electrical communication with the controller 24 (electrical connection not shown in detail, but generally known in the art). The sensor 96 generates a signal representing at least one of hydraulic pressure, temperature, viscosity, and/or flowrate. The controller 24 may be configured to monitor the sensor 96 to move the switching valve 78 between the positions. In one embodiment, the sensor 96 is a pressure transducer for generating a signal representing the hydraulic fluid pressure occurring at the fluid line 76A. While a single sensor 96 is utilized in the representative embodiment illustrated herein, it should be appreciated that the multi-pressure hydraulic control system 66 could include any suitable number of sensors, of any suitable type, arranged in any suitable way, without departing from the scope of the present invention.

[0035] A second embodiment of the multi-pressure hydraulic control system 66 of the present invention is shown in Figure 3. In the description that follows, like components of the second embodiment of the multi-pressure hydraulic control system are provided with the same reference numerals used in connection with the first embodiment of the multi-pressure hydraulic control system 66, and different components are provided with reference numerals increased by one hundred (100).

[0036] In the second embodiment, to facilitate the competing flow and pressure requirements of the circuits 68, 70, 72, 74, the multi-pressure hydraulic control system 166 includes a plurality of fluid lines, generally indicated at 176, and a switching valve, generally indicated at 178, that cooperate with the pump 28. In the representative embodiment illustrated herein, one fluid line 176A of the fluid lines 76 is disposed in fluid communication with one of the output regions 42 of the pump 28, the switching valve 78, and the sheave actuation circuit 68, which has the highest or first hydraulic fluid pressure requirements of the continuously variable automatic transmission 14. As illustrated in Figure 3, another fluid line 176B is disposed in fluid communication with the switching valve 178 and the forward/reverse clutch actuation circuit 72, which has the medium or second hydraulic fluid pressure requirements of the continuously

variable automatic transmission 14. As illustrated in Figure 3, another fluid line 176C is disposed in fluid communication with the switching valve 178 and the torque converter circuit 70 and the gearbox cooling and lubrication circuit 74, which has the low hydraulic fluid pressure requirements of the continuously variable automatic transmission 14. It should be appreciated that the fluid lines 176 could be defined in any suitable way, disposed in fluid communication with any suitable component or circuit of the multi-pressure hydraulic control system 166, without departing from the scope of the present invention.

[0037] The switching valve 178 includes a movable valve member 179 having a first position, a second position, and a third position. In this embodiment, when the switching valve 178 is in the first position, fluid power from one of the outlet regions 42 is directed to the fluid line 176A and fluid power from the other two outlet regions 42 is directed away from the fluid line 176A. When the switching valve 178 is in the second position, fluid power from two of the outlet regions 42 is directed to the fluid line 176A and fluid power from the other outlet region 42 is directed away from the fluid line 176A. When the switching valve 178 is in the third position, fluid power from all three of the outlet regions 42 is directed to the fluid line 176A. The switching valve 178 is selectively moveable between the positions so as to control flow of fluid power from the outlet regions 42 of the pump 28 to the fluid line 176A.

[0038] As will be appreciated from the subsequent description below, the positions of the switching valve 178 described above enable the pump 28 to combine fluid power from the three outlet regions 42 in predetermined ways so as to ensure proper hydraulic fluid pressure at the fluid line 176A under different operating conditions of the continuously variable automatic transmission 14. In the exemplary embodiment of the positions described above and illustrated in Figure 3, the multi-pressure hydraulic control system 166 directs fluid power from all three outlet regions 42 to the fluid line 176A with the switching valve 178. However, those having ordinary skill in the art will appreciate that the continuously variable automatic transmission 14 and/or multi-pressure hydraulic control system 166 could have significantly different operating requirements, depending on the application. It should be appreciated that the switching valve 178 could be configured with any suitable number of positions adapted to direct fluid from the pump 28 in a number of different ways, without departing from the scope of the present invention.

[0039] In one embodiment, the multi-pressure hydraulic control system 166 includes a pressure regulator valve 188 interposed in fluid communication between the fluid line 176A, fluid line 176B, and fluid line 176C. The pressure regulator valve 188 cooperates with the switching valve 178 so as to direct fluid power from the outlet regions 42 of the pump 28 so as to accommodate the pressure and flow requirements of the circuits 68, 70, 72, 74 and ensure proper operation under different operating conditions of the continuously variable automatic transmission 14. The pressure regulator valve 188 regulates the line pressure of the fluid line 176A in responding to instantaneous sheave actuation pressure demand. It should be appreciated that regulating and maintaining the correct line pressure by the pressure regulator valve 188 ensures the proper operation of the powertrain system 10.

[0040] Specifically, the pressure regulator valve 188 has a first pressure regulator position, a second pressure regulator position, a third pressure regulator position, and a fourth position. When the pressure regulator valve 188 is in the first pressure regulator position, when the engine is at low speed, such as idle, the flow is limited. The pressure regulator valve 188 is fully closed so that all the flow from the pump 28 is used to create the pressure needed for sheave actuation. When the pressure regulator valve 188 is in the second pressure regulator position, while engine speed increases, the pump flow increases proportionally due to the fixed ratio between the pump 28 and the prime mover 36. At such position, a port opens and partial flow will be directed to the forward/reverse clutch circuit 72. When the switching valve 178 is in the third position, another port opens and partial flow will be directed to the forward/reverse clutch circuit 72, torque converter 70, and gearbox cooling and lubrication circuit 74. When the pressure regulator valve 188 is in the fourth pressure regulator position, at even higher engine speed, after satisfying the line pressure demand and other pressure demands, any more excess flow is routed back to the pump inlet regions 40 through the suction return fluid circuit to prevent higher drag torque caused by high fluid flow in the sheave and other components. The pressure regulator valve 188 is selectively movable between the regulator positions so as to cooperate with the switching valve 178 as noted above. Those having ordinary skill in the art will appreciate that the positions of the pressure regulator valve 188 may correlate with the positions of the switching valve 178 or may be selected independent and irrespective of the positions of the switching valve 178. As is described in greater detail below, the pressure regulator valve 188 and switching valve 178 can be controlled, configured, oriented, or disposed

in a number of different ways. It should be appreciated that the pressure regulator valve 188 is a proportional valve and has infinite positions when it is continuously regulating even though there are only three positions described. It should also be appreciated that the pressure regulator valve 188 could be omitted from the multi-pressure hydraulic control system 166 without departing from the scope of the present invention. It should be appreciated that operation of the multi-pressure hydraulic control system 166 is similar to the multi-pressure hydraulic control system 66.

[0041] Referring to Figure 4, a third embodiment of the multi-pressure hydraulic control system 66 of the present invention is shown. In the description that follows, like components of the second embodiment of the multi-pressure hydraulic control system are provided with the same reference numerals used in connection with the first embodiment of the multi-pressure hydraulic control system 66, and different components are provided with reference numerals increased by two hundred (200).

[0042] In the third embodiment, to facilitate the competing flow and pressure requirements of the circuits 68, 70, 72, 74, the multi-pressure hydraulic control system 266 includes a plurality of fluid lines, generally indicated at 276, and a switching valve, generally indicated at 278, that cooperate with the pump 28. In the representative embodiment illustrated herein, one fluid line 276A of the fluid lines 276 is disposed in fluid communication with one of the output regions 42 of the pump 28, the switching valve 78, and the sheave actuation circuit 68, which has the highest or first hydraulic fluid pressure requirements of the continuously variable automatic transmission 14. As illustrated in Figure 4, another fluid line 276B is disposed in fluid communication with the switching valve 278 and the forward/reverse clutch actuation circuit 72, which has the medium or second hydraulic fluid pressure requirements of the continuously variable automatic transmission 14. Yet another fluid line 276C is disposed in fluid communication with the switching valve 278 and the torque converter circuit 70 and the gearbox cooling and lubrication circuit 74, which have the low hydraulic fluid pressure requirements of the continuously variable automatic transmission 14. It should be appreciated that the fluid lines 276 could be defined in any suitable way, disposed in fluid communication with any suitable component or circuit of the multi-pressure hydraulic control system 266, without departing from the scope of the present invention.

[0043] The switching valve 278 includes a movable valve member 279 having a first position, a second position, and a third position. In this embodiment, when the switching valve 278 is in the first position, fluid power from one of the outlet regions 42 is directed to the fluid line 276A and fluid power from the other two outlet regions 42 is directed away from the fluid line 276A. When the switching valve 278 is in the second position, fluid power from two of the outlet regions 42 is directed to the fluid line 276A and fluid power from the other outlet region 42C is directed away from the main line 68. When the switching valve 278 is in the third position, fluid power from all three of the outlet regions is directed to the fluid line 276A. The switching valve 278 is selectively moveable between the positions so as to control flow of fluid power from the outlet regions 42A, 42B, 42C of the pump 28 to the fluid line 276A.

[0044] As will be appreciated from the subsequent description below, the positions of the switching valve 278 described above enable the pump 28 to combine fluid power from the three outlet regions 42 in predetermined ways so as to ensure proper hydraulic fluid pressure at the fluid line 276A under different operating conditions of the continuously variable automatic transmission 14. In the exemplary embodiment of the positions described above and illustrated in Figure 4, the multi-pressure hydraulic control system 266 directs fluid power from all three outlet regions 42 to the fluid line 276A when the switching valve 278 is in the third position. However, those having ordinary skill in the art will appreciate that the continuously variable automatic transmission 14 and/or multi-pressure hydraulic control system 266 could have significantly different operating requirements, depending on the application. It should be appreciated that the switching valve 278 could be configured with any suitable number of positions adapted to direct fluid from the pump 28 in a number of different ways, without departing from the scope of the present invention.

[0045] The multi-pressure hydraulic control system 266 further includes an accumulator 298 disposed in fluid communication with the fluid line 276A of the fluid lines 276 for storing pressurized hydraulic fluid. More specifically, the accumulator 298 is adapted to store hydraulic fluid under certain operating conditions of the continuously variable automatic transmission 14 so that pressurized fluid energy can subsequently be made available at the fluid line 276A under different operating conditions of the continuously variable automatic transmission 14. The accumulator 298 is a conventional gas-charged hydraulic accumulator, but those having ordinary skill in the art will appreciate that the accumulator 298 could be of any suitable type, or could be

omitted entirely, without departing from the scope of the present invention. In one embodiment, the multi-pressure hydraulic control system 266 further includes a check valve 300 on the fluid line 276A between the switching valve 278 and the accumulator 298 to prevent back-flow of fluid from the accumulator 298 to the switching valve 278. It should be appreciated that operation of the multi-pressure hydraulic control system 266 is similar to the multi-pressure hydraulic control system 66.

[0046] In this way, the pump 28 and multi-pressure hydraulic control system 66, 166, 266 of the present invention significantly improve the efficiency of the vehicle powertrain system 10 by providing a plurality of sources of fluid power while, at the same time, significantly minimizing parasitic losses, packaging size, and weight. In particular, the pump 28 facilitates compensating for changes in prime mover speed and hydraulic fluid viscosity without necessitating pumping and subsequently bypassing a large volume of fluid, while providing adequate fluid pressure during different operating conditions. Thus, the present invention ensures proper responsiveness and consistent operation of the powertrain system 10 in a simple and cost effect manner. Further, the present invention reduces the cost and complexity of manufacturing vehicles that have superior operational characteristics, such as high efficiency, reduced weight, and improved emissions, component packaging, component life, and vehicle drivability.

[0047] The present invention has been described in an illustrative manner. It is to be understood that the terminology which has been used is intended to be in the nature of words of description rather than of limitation.

[0048] Many modifications and variations of the present invention are possible in light of the above teachings. Therefore, within the scope of the appended claims, the invention may be practiced other than as specifically described.

What is claimed is:

1. A multi-pressure hydraulic control system for use with a continuously variable automatic transmission (14) of a vehicle powertrain system (10), said hydraulic control system (66, 166, 266) comprising:

5 a least one pump (28) including a rotatable pump member (34), at least one inlet region (40) for receiving fluid to be pumped by said pump member (34), and at least one outlet region (42) for outputting fluid pumped by said pump member (34);

a switching valve (78, 178, 278) receiving at least two separate outputs of fluid pumped by said at least one pump (28) for allowing the at least two outputs to be selectively combined and/or separated, said switching valve (78, 178, 278) having a valve member (79, 179, 279) being movable between at least three positions that produces fluid outputs having a first fluid pressure, a second fluid pressure, and a third fluid pressure to one or more portions of the continuously variable automatic transmission (14).

15 2. A multi-pressure hydraulic control system (66, 166) as set forth in claim 1 including a pressure regulator (88, 188) fluidly communicating with at least one of said at least three separate outputs of fluid pumped by said at least one pump (34) and with at least one of the fluid outputs having the at least two of the first fluid pressure and the second fluid pressure to regulate the pressure of the fluid to the one or more portions of the continuously variable automatic transmission (14).

20 3. A multi-pressure hydraulic control system (266) as set forth in claim 1 including a fluid accumulator (298) fluidly communicating with at least one of the three fluid outputs of said switching valve (278) and with one or more portions of the continuously variable automatic transmission (14).

25 4. A multi-pressure hydraulic control system (66, 166, 266) as set forth in any one of claims 1-3 wherein one of said at least three fluid outputs having the first fluid pressure fluidly communicates with a sheave portion (68) of the continuously variable automatic transmission (14).

5. A multi-pressure hydraulic control system (66, 166, 266) as set forth in any one of claims 1-4 wherein one of said at least three fluid outputs having the second fluid pressure fluidly communicates with at least one of a torque converter portion (70) and a forward/reverse clutch portion (72) of the continuously variable automatic transmission (14).

6. A multi-pressure hydraulic control system (66, 166, 266) as set forth in any one of claims 1-5 wherein one of said at least three fluid outputs having the third fluid pressure fluidly communicates with a gearbox portion (74) of the continuously variable automatic transmission (14).

7. A multi-pressure hydraulic control system (66, 166) as set forth in any one of claim 1 including a pressure regulator (88, 188) fluidly connected to one of said at least three separate outputs of fluid pumped by said at least one pump (28) and one of said at least three fluid outputs having the first fluid pressure, the second fluid pressure, and the third fluid pressure.

8. A multi-pressure hydraulic control system (266) as set forth in any one of claims 1 wherein said fluid accumulator (298) is fluidly connected to one of said at least three fluid outputs having the first fluid pressure.

9. A multi-pressure hydraulic control system (66, 166, 266) as set forth in any one of claims 1-8 wherein said at least one pump (28) comprises a stator (30) having a chamber and said pump member (34) being disposed in said chamber and cooperating with said stator (30) so as to define at least three pumping regions in said chamber with each of said at least three pumping regions having said at least one inlet region (40) and said at least one outlet region (42), wherein rotation of said pump member (34) displaces fluid across each of said at least three pumping regions such that each said at least one outlet region provides a separate source of fluid power to said switching valve (78, 178, 278).

10. A method for controlling a multi-pressure hydraulic control system (66, 166, 266) for use with a continuously variable automatic transmission (14) of a vehicle powertrain system (10), said method comprising the steps of:

pumping fluid by at least one pump (28) including a rotatable pump member (34), at least one inlet region (40) for receiving fluid to be pumped by the pump member (34), and at least one outlet region (42) for outputting fluid pumped by the pump member (34); and

receiving at a switching valve (78, 178, 278) at least two separate outputs of fluid pumped by the at least one pump (28), the switching valve (78, 178, 278) having a valve member (79, 179, 279) being movable between at least three positions, and moving the valve member (79, 179, 279) between the at least three positions to produce fluid outputs having a first fluid pressure, a second fluid pressure, and a third pressure to one or more portions of the continuously variable automatic transmission (14).

11. A method as set forth in claim 10 including the step of providing a pressure regulator (88, 188) and fluidly communicating the pressure regulator (88, 188) with at least one of the at least two separate outputs of fluid pumped by the at least one pump (28) and with at least two of the fluid outputs of the switch valve (78, 178) to regulate the pressure of the fluid to the one or more portions of the continuously variable automatic transmission (14).

12. A method as set forth in claim 10 including the step of providing a fluid accumulator (298) and fluidly communicating the fluid accumulator (298) with at least one of the three fluid outputs of the switching valve (278) and with one or more portions of the continuously variable automatic transmission (14).

13. A method as set forth in any one of claims 10-12 including the step of fluidly communicating one of the at least three fluid outputs having the first fluid pressure with a sheave portion (68) of the continuously variable automatic transmission (14).

14. A method as set forth in any one of claims 1-13 including the step of fluidly communicating one of the at least three fluid outputs having the second fluid pressure with at

least one of a torque converter portion (70) and a forward/reverse clutch portion (72) of the continuously variable automatic transmission (14).

15. A method as set forth in any one of claims 10-14 including the step of fluidly communicating one of the at least three fluid outputs having the third fluid pressure with a gearbox portion (74) of the continuously variable automatic transmission (14).

16. A method as set forth in any one of claims 10 including the step of fluidly connecting the pressure regulator (88, 188, 288) to one of the at least three separate outputs of fluid pumped by the at least one pump (28) and one of the at least three fluid outputs having the first fluid pressure, the second fluid pressure, and the third fluid pressure.

17. A method as set forth in any one of claims 10 including the step of fluidly connecting the fluid accumulator (298) to one of the at least three fluid outputs having the first fluid pressure.

18. A method as set forth in any one of claims 10-17 including the step of providing the at least one pump (28) with a stator (30) having a chamber and the pump member (34) being disposed in the chamber and cooperating with the stator (30) so as to define at least three pumping regions in the chamber with each of the at least three pumping regions having the at least one inlet region (40) and the at least one outlet region (42), wherein rotation of the pump member (34) displaces fluid across each of the at least three pumping regions such that each of the at least one outlet region (42) provides a separate source of fluid power to the switching valve (78, 178, 278).

AMENDED CLAIMS

received by the International Bureau on 08 September 2016 (08.09.2016)

What is Claimed is:

1. A multi-pressure hydraulic control system for use with a continuously variable automatic transmission (14) of a vehicle powertrain system (10), said hydraulic control system (66, 166, 266) comprising:

a least one pump (28) including a rotatable pump member (34), at least one inlet region (40) for receiving fluid to be pumped by said pump member (34), and at least one outlet region (42) for outputting fluid pumped by said pump member (34);

a switching valve (78, 178, 278) receiving at least two separate outputs of fluid pumped by said at least one pump (28) as fluid inlets to said switching valve (78, 178, 278) and producing at least three fluid outputs for allowing the at least two outputs to be selectively combined and/or separated, said switching valve (78, 178, 278) having a valve member (79, 179, 279) being movable between at least three positions that produces the at least three fluid outputs from said switching valve having a first fluid pressure, a second fluid pressure, and a third fluid pressure to one or more portions of the continuously variable automatic transmission (14).

2. A multi-pressure hydraulic control system (66, 166) as set forth in claim 1 including a pressure regulator (88, 188) fluidly communicating with at least one of said at least three separate outputs of fluid pumped by said at least one pump (34) and with at least one of the at least three fluid outputs having the at least two of the first fluid pressure and the second fluid pressure to regulate the pressure of the fluid to the one or more portions of the continuously variable automatic transmission (14).

3. A multi-pressure hydraulic control system (266) as set forth in claim 1 including a fluid accumulator (298) fluidly communicating with at least one of the at least three fluid outputs of said switching valve (278) and with one or more portions of the continuously variable automatic transmission (14).

4. A multi-pressure hydraulic control system (66, 166, 266) as set forth in any one of claims 1-3 wherein one of said at least three fluid outputs having the first fluid pressure fluidly

communicates with a sheave portion (68) of the continuously variable automatic transmission (14).

5. A multi-pressure hydraulic control system (66, 166, 266) as set forth in any one of claims 1-3 wherein one of said at least three fluid outputs having the second fluid pressure fluidly communicates with at least one of a torque converter portion (70) and a forward/reverse clutch portion (72) of the continuously variable automatic transmission (14).

6. A multi-pressure hydraulic control system (66, 166, 266) as set forth in any one of claims 1-3 wherein one of said at least three fluid outputs having the third fluid pressure fluidly communicates with a gearbox portion (74) of the continuously variable automatic transmission (14).

7. A multi-pressure hydraulic control system (66, 166) as set forth in claim 1 including a pressure regulator (88, 188) fluidly connected to one of said at least three separate outputs of fluid pumped by said at least one pump (28) and one of said at least three fluid outputs having the first fluid pressure, the second fluid pressure, and the third fluid pressure.

8. A multi-pressure hydraulic control system (266) as set forth in claim 3 wherein said fluid accumulator (298) is fluidly connected to one of said at least three fluid outputs having the first fluid pressure.

9. A multi-pressure hydraulic control system (66, 166, 266) as set forth in any one of claims 1-3 wherein said at least one pump (28) comprises a stator (30) having a chamber and said pump member (34) being disposed in said chamber and cooperating with said stator (30) so as to define at least three pumping regions in said chamber with each of said at least three pumping regions having said at least one inlet region (40) and said at least one outlet region (42), wherein rotation of said pump member (34) displaces fluid across each of said at least three pumping regions such that each said at least one outlet region provides a separate source of fluid power to said switching valve (78, 178, 278).

10. A method for controlling a multi-pressure hydraulic control system (66, 166, 266) for use with a continuously variable automatic transmission (14) of a vehicle powertrain system (10), said method comprising the steps of:

pumping fluid by at least one pump (28) including a rotatable pump member (34), at least one inlet region (40) for receiving fluid to be pumped by the pump member (34), and at least one outlet region (42) for outputting fluid pumped by the pump member (34); and

receiving at a switching valve (78, 178, 278) at least two separate outputs of fluid pumped by the at least one pump (28) as fluid inlets to the switching valve (78, 178, 278) and producing at least three fluid outputs, the switching valve (78, 178, 278) having a valve member (79, 179, 279) being movable between at least three positions, and moving the valve member (79, 179, 279) between the at least three positions to produce the at least three fluid outputs having a first fluid pressure, a second fluid pressure, and a third pressure to one or more portions of the continuously variable automatic transmission (14).

11. A method as set forth in claim 10 including the step of providing a pressure regulator (88, 188) and fluidly communicating the pressure regulator (88, 188) with at least one of the at least two separate outputs of fluid pumped by the at least one pump (28) and with at least two of the at least three fluid outputs of the switch valve (78, 178) to regulate the pressure of the fluid to the one or more portions of the continuously variable automatic transmission (14).

12. A method as set forth in claim 10 including the step of providing a fluid accumulator (298) and fluidly communicating the fluid accumulator (298) with at least one of the at least three fluid outputs of the switching valve (278) and with one or more portions of the continuously variable automatic transmission (14).

13. A method as set forth in any one of claims 10-12 including the step of fluidly communicating one of the at least three fluid outputs having the first fluid pressure with a sheave portion (68) of the continuously variable automatic transmission (14).

14. A method as set forth in any one of claims 10-12 including the step of fluidly communicating one of the at least three fluid outputs having the second fluid pressure with at

least one of a torque converter portion (70) and a forward/reverse clutch portion (72) of the continuously variable automatic transmission (14).

15. A method as set forth in any one of claims 10-12 including the step of fluidly communicating one of the at least three fluid outputs having the third fluid pressure with a gearbox portion (74) of the continuously variable automatic transmission (14).

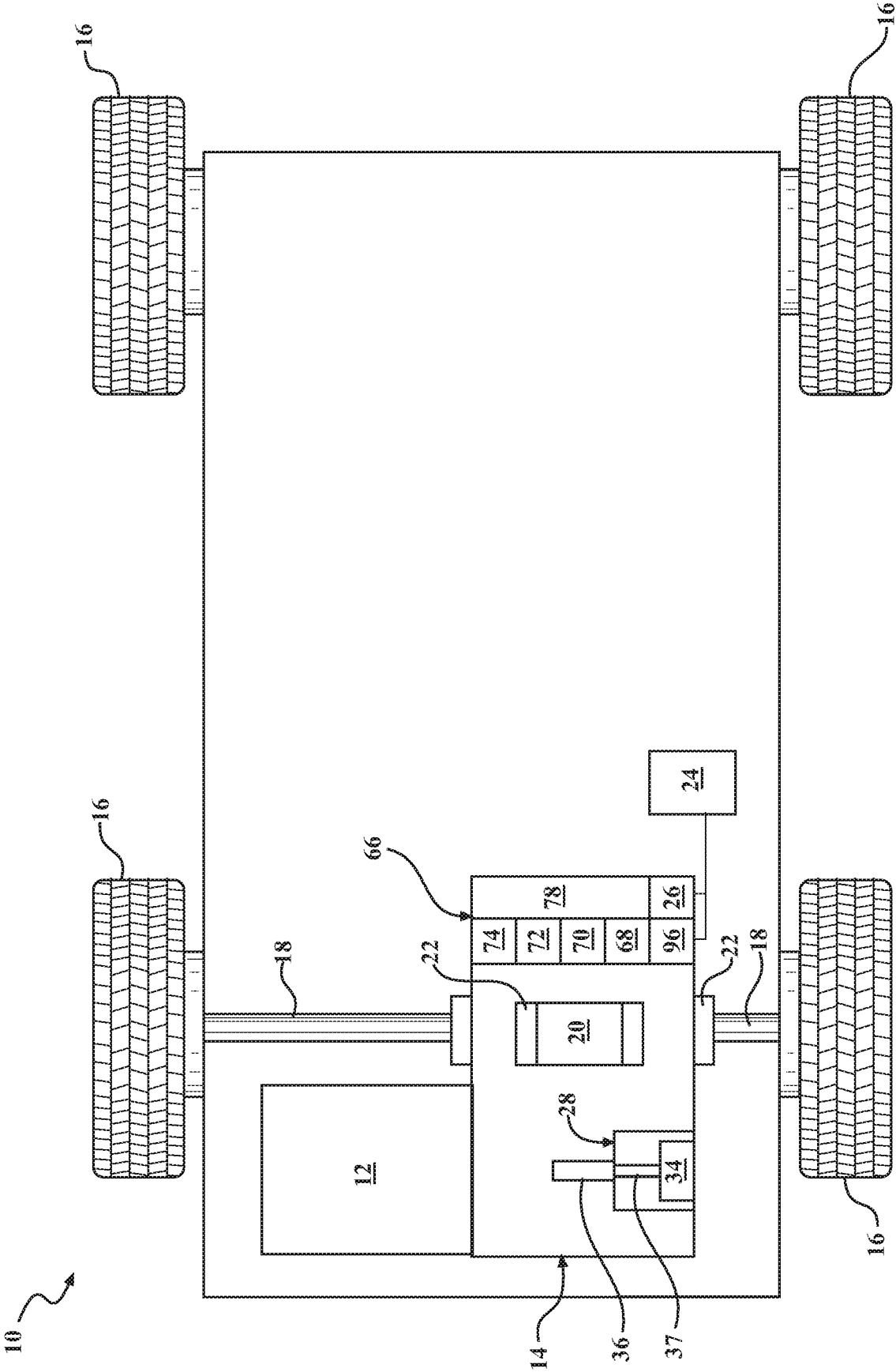
16. A method as set forth in any one of claims 10-12 including the step of fluidly connecting the pressure regulator (88, 188, 288) to one of the at least three separate outputs of fluid pumped by the at least one pump (28) and one of the at least three fluid outputs having the first fluid pressure, the second fluid pressure, and the third fluid pressure.

17. A method as set forth in any one of claims 10-12 including the step of fluidly connecting the fluid accumulator (298) to one of the at least three fluid outputs having the first fluid pressure.

18. A method as set forth in any one of claims 10-12 including the step of providing the at least one pump (28) with a stator (30) having a chamber and the pump member (34) being disposed in the chamber and cooperating with the stator (30) so as to define at least three pumping regions in the chamber with each of the at least three pumping regions having the at least one inlet region (40) and the at least one outlet region (42), wherein rotation of the pump member (34) displaces fluid across each of the at least three pumping regions such that each of the at least one outlet region (42) provides a separate source of fluid power to the switching valve (78, 178, 278).

STATEMENT UNDER ARTICLE 19(1)

After entry of this Amendment, claims 1-18 are pending in the application. Claims 1-3, 5-12, and 14-18 are hereby amended. Claims 4 and 13 are unchanged.



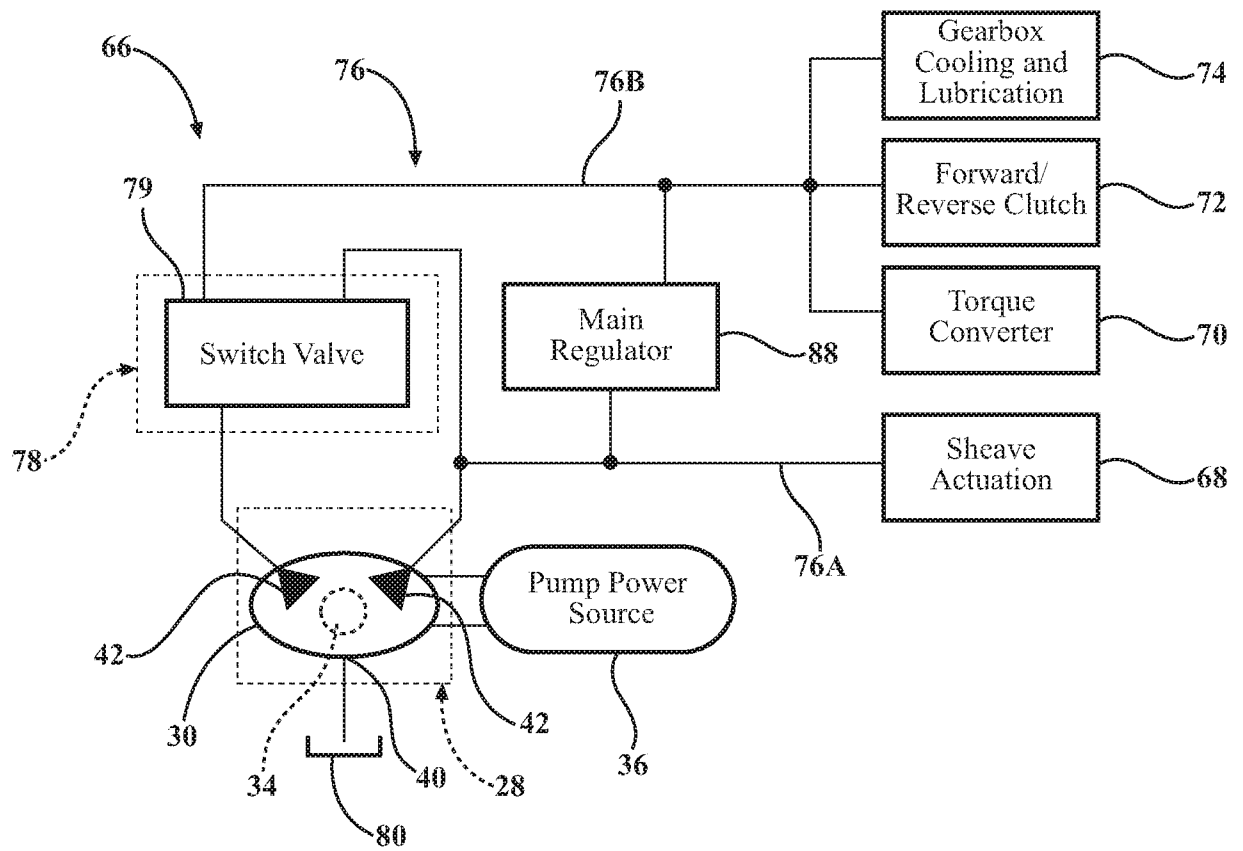


FIG. 2

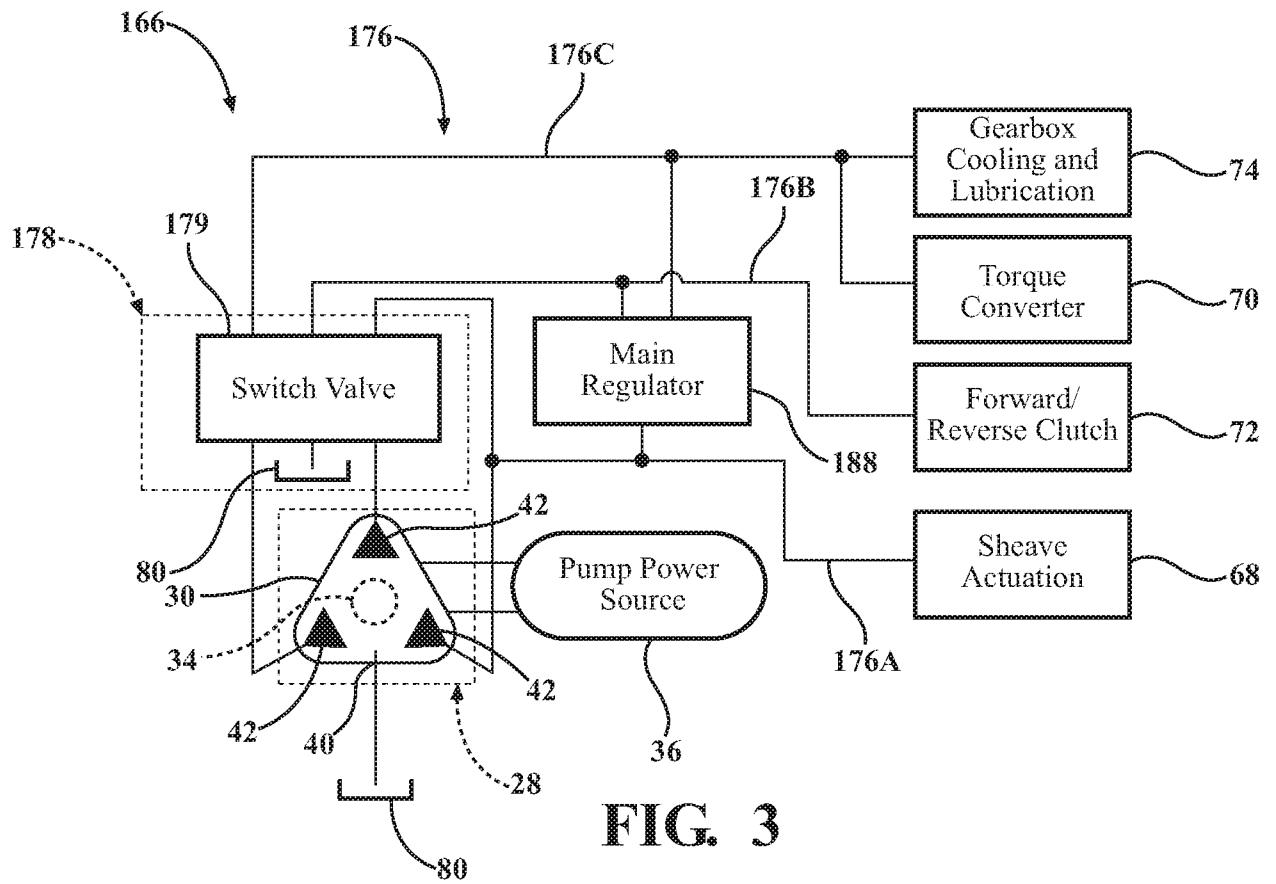


FIG. 3

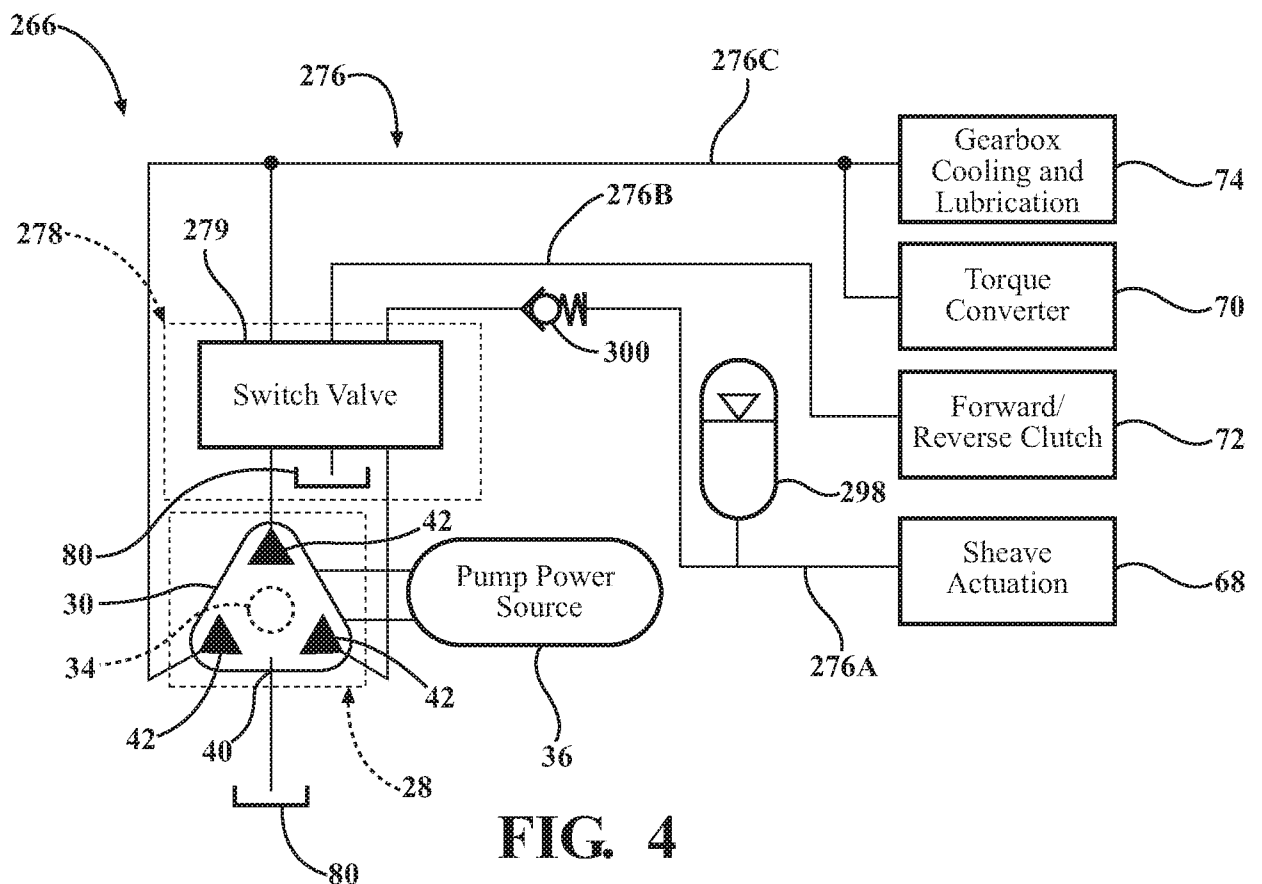


FIG. 4

A. CLASSIFICATION OF SUBJECT MATTER**F16H 61/66(2006.01)i, F16H 61/4035(2010.01)i, F16H 61/4165(2010.01)i**

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)

F16H 61/66; F16H 59/00; F04C 15/04; F16H 61/4026; F15B 21/00; F16D 31/02; F16H 61/00; F04C 2/344; F16H 63/00; F16H 61/4035; F16H 61/4165

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & keywords: CVT, pressure control, switch valve, pump, outlet port, and accumulator

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015-0075152 A1 (HYUNDAI MOTOR COMPANY) 19 March 2015 See paragraphs [0038]-[0081] and figures 1-3.	1, 2, 4-7, 9-11, 13-16 , 18
Y		3, 8, 12, 17
Y	US 2002-0160867 A1 (KATOU, YOSHIAKI) 31 October 2002 See paragraphs [0010], [0015], [0020], [0021] and figure 1.	3, 8, 12, 17
A	JP 2001-140771 A (HONDA MOTOR CO., LTD.) 22 May 2001 See paragraphs [0008]-[0024] and figures 1-4.	1-18
A	US 2011-0173965 A1 (HOLMES et al.) 21 July 2011 See paragraphs [0020]-[0024] and figure 1.	1-18
A	US 5941786 A (VAN WIJK et al.) 24 August 1999 See column 4, lines 8-59 and figure 2.	1-18



Further documents are listed in the continuation of Box C.



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

21 July 2016 (21.07.2016)

Date of mailing of the international search report

21 July 2016 (21.07.2016)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/027015

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