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(54) **HYDRAULIC CIRCUIT**

(57) The present document relates to a hydraulic circuit (1; 100), comprising: a fluid reservoir (2), a fluid output port (7a), a first hydraulic pump (3) having a first fluid port (3a) and a second fluid port (3b), the first fluid port (3a) of the first hydraulic pump (3) selectively fluidly connected with the fluid reservoir (2), and the second fluid port (3b) of the first hydraulic pump (3) fluidly connected or selectively fluidly connected with the fluid output port (7a), a hydraulic accumulator (6), and at least one accumulator valve (14a, 14b). The at least one accumulator valve (14a, 14b) is configured to be selectively placed in either one of a first configuration and a second configuration, the at least one accumulator valve (14a, 14b) in the first configuration fluidly connecting the hydraulic accumulator (6) with the first fluid port (3a) of the first hydraulic pump (3) and fluidly disconnecting the hydraulic accumulator (6) from the fluid output port (7a), and the at least one accumulator valve (14a, 14b) in the second configuration fluidly connecting or selectively fluidly connecting the hydraulic accumulator (6) with the fluid output port (7a) and fluidly disconnecting the hydraulic accumulator (6) from the first fluid port (3a) of the first hydraulic pump (3). The present document further relates to methods of controlling the hydraulic circuit (1; 100).

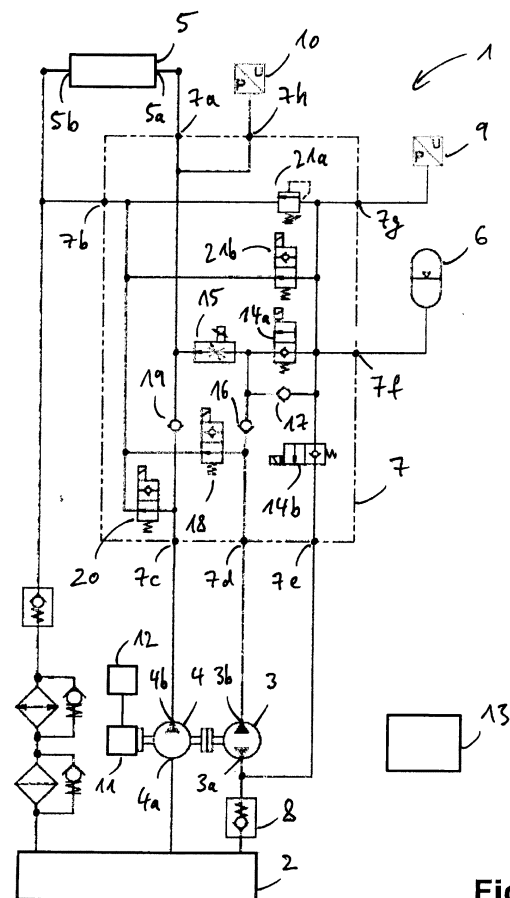


Fig. 1

Description

[0001] The present document relates to a hydraulic circuit and to methods of controlling the hydraulic circuit. Hydraulic circuits of the presently proposed type may be used for driving hydraulic implements such as hydraulic cylinders or hydraulic motors which may be installed on working machines such as wheeled excavators, wheel loaders, tractors or forestry machines, for example.

[0002] Hydraulic implements such as hydraulic cylinders or hydraulic motors are typically driven by a pressure source which may include a hydraulic pump or a hydraulic cylinder. Furthermore, it is known to use hydraulic or hydro-pneumatic accumulators for at least temporarily storing hydraulic energy, typically by compressing a gas, and for releasing the stored hydraulic energy when needed, for example when high fluid flow rates or high hydrostatic pressures have to be provided to the hydraulic implement.

[0003] For instance, WO 2015/117962 A1 describes using hydro-pneumatic accumulators for providing additional power to a travel circuit of a hydrostatic transmission or to a hydraulic cylinder of a hydraulic working assembly of an off-highway vehicle.

[0004] However, there is demand for hydraulic circuits comprising a hydraulic or hydro-pneumatic accumulator in which the hydraulic or hydro-pneumatic accumulator may be used even more efficiently and/or flexibly.

[0005] This object is solved by a hydraulic circuit according to claim 1 and by methods of controlling said hydraulic circuit.

[0006] The presently proposed hydraulic circuit, comprises:

- a fluid reservoir,
- a fluid output port, typically for connection with a hydraulic load such as a hydraulic implement,
- a first hydraulic pump having a first fluid port and a second fluid port, the first fluid port of the first hydraulic pump selectively fluidly connected with the fluid reservoir, and the second fluid port of the first hydraulic pump fluidly connected or selectively fluidly connected with the fluid output port,
- a hydraulic or hydro-pneumatic accumulator, and
- at least one accumulator valve.

[0007] The at least one accumulator valve is configured to be selectively placed in either one of a first configuration and a second configuration. In the first configuration the at least one accumulator fluidly connects the hydraulic or hydro-pneumatic accumulator with the first fluid port of the first hydraulic pump and fluidly disconnects the hydraulic or hydro-pneumatic accumulator from the fluid output port. And in the second configuration the at least one accumulator valve fluidly connects or selectively fluidly connects the hydraulic or hydro-pneumatic accumulator with the fluid output port and fluidly disconnects the hydraulic or hydro-pneumatic accumulator from

the first fluid port of the first hydraulic pump.

[0008] In other words, when the at least one accumulator valve is placed in the first configuration, the hydraulic or hydro-pneumatic accumulator and the first hydraulic pump are fluidly connected in series with the fluid output port so that fluid displaced from the hydraulic or hydro-pneumatic accumulator to the fluid output port or towards the fluid output port passes through the first hydraulic pump. Usually, the hydraulic or hydro-pneumatic accumulator is fluidly connected with the first fluid port by placing the at least one accumulator valve in the first configuration if or when a hydrostatic pressure in the hydraulic or hydro-pneumatic accumulator is at least equal to or exceeds a hydrostatic pressure of the fluid reservoir. This way, the hydrostatic pressure in the hydraulic or hydro-pneumatic accumulator may pressurize the first fluid port of the first hydraulic pump, thereby supporting a pumping operation of the first hydraulic pump and reducing a power or an amount of energy consumed by the first hydraulic pump when the first hydraulic pump pumps fluid from the first fluid port of the first hydraulic pump to the second fluid port of the first hydraulic pump.

[0009] Also, when the hydrostatic pressure in the hydraulic or hydro-pneumatic accumulator is higher than a hydrostatic pressure requested at the fluid output port, such as for driving a hydraulic load or a hydraulic implement fluidly connected with the fluid output port, the hydraulic or hydro-pneumatic accumulator may be fluidly connected with the first fluid port of the first hydraulic pump by placing the at least one accumulator valve in the first configuration for driving an electric generator which may be drivingly engaged with the first hydraulic pump, for example. In this case, an excess power or an excess energy provided by the hydraulic or hydro-pneumatic accumulator may be used to charge an electric or electrochemical accumulator through the first hydraulic pump and the electric generator, for example.

[0010] On the other hand, when the at least one accumulator valve is placed in the second configuration, the hydraulic or hydro-pneumatic accumulator and the first hydraulic pump are fluidly connected with the fluid output port in parallel so that a fluid flow rate provided by the first hydraulic pump and a fluid rate provided by the hydraulic or hydro-pneumatic accumulator add up or may add up at the fluid output port. This way, a particularly high output fluid flow may be provided at the fluid output port. That is, fluidly connecting the first hydraulic pump and the hydraulic or hydro-pneumatic accumulator with the fluid output port in parallel by placing the at least one accumulator valve in the second configuration may be advantageous when a output fluid flow requested at the fluid output port exceeds a fluid flow that may be provided by the first hydraulic pump or by the hydraulic or hydro-pneumatic accumulator alone or when the output fluid flow requested at the fluid output port exceeds a threshold output fluid flow, for example a predetermined threshold output fluid flow.

[0011] The at least one accumulator valve may be con-

figured such that it may be controlled via electromagnetic signals. For example, the at least one accumulator valve may comprise one or more valves some of which or each of which comprise or comprises a solenoid for actuating one or more valve spools of the at least one accumulator valve. Additionally or alternatively, the at least one accumulator valve may be configured such that it may be controlled via a hydrostatic pressure. For example, the at least one accumulator valve may comprise one or more valves some of which or each of which comprise or comprises a pressure-actuatable actuator that may be controlled via a hydrostatic pilot pressure. And the at least one accumulator valve may comprise at least one biasing member such as one or more springs for biasing the at least one accumulator valve toward the first configuration or toward the second configuration.

[0012] Hence, the presently proposed hydraulic circuit allows a particularly flexible and efficient use of the hydraulic or hydro-pneumatic accumulator.

[0013] The hydraulic circuit may comprise an accumulator pressure sensing unit for sensing a hydrostatic pressure in the hydraulic or hydro-pneumatic accumulator. The hydraulic circuit may comprise an output pressure sensing unit for sensing a hydrostatic output pressure at the fluid output port. The hydraulic circuit may comprise an input device such as a switch, a lever, a knob, a joystick or the like for entering an input command. The input command may be indicative of a requested output fluid flow rate at the fluid output port or of a hydrostatic output pressure at the fluid output port, for example. The hydraulic circuit may further comprise a control unit. The control unit may comprise electric circuitry. For example, the control unit may comprise a programmable microprocessor or an FPGA. The control unit may be in communication with at least one of the accumulator pressure sensing unit, the output pressure sensing unit, the input device and the at least one accumulator valve.

[0014] The control unit may be configured to selectively place the at least one accumulator valve in either one of the first configuration and the second configuration, for example based on at least one of the requested output fluid flow rate at the fluid output port, the requested hydrostatic output pressure at the fluid output port, a hydrostatic pressure in the fluid reservoir, a hydrostatic pressure in the hydraulic or hydro-pneumatic accumulator, a maximum fluid flow rate that may be provided by the first hydraulic pump, and a maximum fluid flow rate that may be provided by the hydraulic or hydro-pneumatic accumulator.

[0015] The hydraulic circuit may comprise a reservoir valve configured to selectively fluidly disconnect the first fluid port of the first hydraulic pump from the fluid reservoir, in particular when the at least one accumulator valve is placed in the first configuration and fluidly connects the hydraulic or hydro-pneumatic accumulator with the first fluid port of the first hydraulic pump. This way the draining of fluid from the hydraulic or hydro-pneumatic accumulator to the fluid reservoir may be prevented. The

reservoir valve may comprise a first check valve, for example. The first check valve may be configured such that it allows a flow of fluid from the fluid reservoir to the first fluid port of the first hydraulic pump through the first check valve, and such that it prevents a flow of fluid from the first fluid port of the first hydraulic pump to the fluid reservoir through the first check valve.

[0016] The hydraulic circuit may comprise a hydraulic load or a hydraulic implement fluidly connected or selectively fluidly connected with the fluid output port for pressurizing the hydraulic implement via the fluid output port. The hydraulic load or the hydraulic implement may comprise one or more hydraulic cylinders and/or one or more hydraulic motors, for example. Typically, the hydraulic load or the hydraulic implement has a first fluid port fluidly connected or selectively fluidly connected with the fluid output port, and a second fluid port fluidly connected or selectively fluidly connected with the fluid reservoir.

[0017] The hydraulic circuit may comprise a proportional valve fluidly connecting or selectively fluidly connecting at least one of the first hydraulic pump and the hydraulic or hydro-pneumatic accumulator with the fluid output port. The proportional valve may be used to control or to additionally control a fluid flow rate provided at the fluid output port. Typically, the proportional valve has a first fluid port fluidly connected or selectively fluidly connected with at least one of or both of the first hydraulic pump and the hydraulic or hydro-pneumatic accumulator, and a second fluid port fluidly connected or selectively fluidly connected with the fluid output port. The proportional valve may be configured such that a minimum cross section of the proportional valve may be controlled via electromagnetic signals. For example, the proportional valve may be controllable by the above-mentioned control unit. Additionally or alternatively, the proportional valve may be configured such that a minimum cross section of the proportional valve may be controlled via a hydrostatic pressure. For example, the proportional valve may comprise one or more pressure-controllable actuators that may be controlled via a hydrostatic pilot pressure.

[0018] The hydraulic circuit may comprise at least one charge valve selectively fluidly connecting the second fluid port of the first hydraulic pump with the hydraulic or hydro-pneumatic accumulator for charging the hydraulic or hydro-pneumatic accumulator via the at least one charge valve using the first hydraulic pump. For example, the at least one charge valve may comprise at least one second check valve. The at least one second check valve may then be configured such that it allows a flow of fluid from the first hydraulic pump, in particular from the second fluid port of the first hydraulic pump, to the hydraulic or hydro-pneumatic accumulator through the at least one second check valve, and such that it prevents a flow of fluid from the hydraulic or hydro-pneumatic accumulator to the first hydraulic pump, in particular to the second fluid port of the first hydraulic pump, through the at least one second check valve.

[0019] The hydraulic circuit may comprise at least one accumulator safety valve selectively fluidly connecting the hydraulic or hydro-pneumatic accumulator with the fluid reservoir. For example, the at least one accumulator safety valve may be used to automatically or selectively drain fluid from the hydraulic or hydro-pneumatic accumulator to the fluid reservoir, for example when the hydrostatic pressure in the hydraulic or hydro-pneumatic accumulator exceeds a threshold pressure such as a predetermined threshold pressure. For instance, the at least one accumulator safety valve may include a relief valve and/or a shut-off valve. The shut-off valve may then be configured as an electromagnetically controllable shut-off valve, for example. For instance, the shut-off valve may include a solenoid for selectively opening and closing the shut-off valve.

[0020] The hydraulic circuit may comprise at least one of an electric motor and an internal combustion engine drivingly engaged or selectively drivingly engaged with the first hydraulic pump for driving the first hydraulic pump.

[0021] The hydraulic circuit may further comprise a second hydraulic pump connected with or drivingly engaged with the first hydraulic pump. For example, the first hydraulic pump and the second hydraulic pump may be connected to each other or may be drivingly engaged with each other in such a way that they always turn at the same frequency. The second hydraulic pump typically has a first fluid port fluidly connected or selectively fluidly connected with the fluid reservoir, and a second fluid port fluidly connected or selectively fluidly connected with the fluid output port. The first hydraulic pump and the second hydraulic pump may be fluidly connected with the fluid output port in parallel, so that a fluid flow rate provided by the first hydraulic pump and a fluid flow rate provided by the second hydraulic pump add up or may add up at the fluid output port.

[0022] The hydraulic circuit may comprise an electric generator drivingly engaged or selectively drivingly engaged with at least one of the first hydraulic pump and the second hydraulic pump. And the hydraulic circuit may further comprise an electrical or electrochemical accumulator electrically connected or selectively electrically connected with the electric generator. The electrical or electrochemical accumulator may be electrically connected or selectively electrically connected with the first hydraulic pump for driving the first hydraulic pump and/or the electrical or electrochemical accumulator may be electrically connected or selectively electrically connected with the second hydraulic pump for driving the second hydraulic pump, for example. Additionally or alternatively, the electrical or electrochemical accumulator may be electrically connected or selectively electrically connected with one or more solenoids of the at least one accumulator valve and/or with the control unit for providing electrical power to the at least one accumulator valve and/or to the control unit.

[0023] The hydraulic circuit may comprise a first by-

pass valve selectively fluidly connecting the second fluid port of the first hydraulic pump with the fluid reservoir. For example, fluidly connecting or directly fluidly connecting the second fluid port of the first hydraulic pump with the fluid reservoir through the first bypass valve may be useful when the hydraulic or hydro-pneumatic accumulator is fluidly connected with the first fluid port of the first hydraulic pump and fluid from the hydraulic or hydro-pneumatic accumulator is displaced through the first hydraulic pump for driving the electric generator drivingly engaged with the first hydraulic pump, as described above.

[0024] The hydraulic circuit may further comprise a second bypass valve selectively fluidly connecting the second fluid port of the second hydraulic pump with the fluid reservoir. For example, fluidly connecting or directly fluidly connecting the second fluid port of the second hydraulic pump with the fluid reservoir through the second bypass valve may be useful when the hydraulic or hydro-pneumatic accumulator is fluidly connected with the first fluid port of the first hydraulic pump and fluid from the hydraulic or hydro-pneumatic accumulator is displaced through the first hydraulic pump for driving the electric generator drivingly engaged with the first hydraulic pump and with the second hydraulic pump, as described above.

[0025] At least one of the first bypass valve and the second bypass valve may be an electromagnetically controllable valve. For example, the above-described control unit may be configured to control at least one of the first bypass valve and the second bypass valve.

[0026] The hydraulic circuit may comprise a valve block. The valve block may comprise a rigid casing, for example. One or more of or all of the at least one accumulator valve, the proportional valve, the fluid output port, the accumulator safety valve, the first bypass valve, the second bypass valve and the charge valve may be integrated in or mounted on the valve block. The valve block may comprise fluid ports for fluidly connecting or for selectively fluidly connecting the at least one accumulator valve and the proportional valve with the fluid reservoir, with at least one of the first hydraulic pump and the second hydraulic pump, and with the hydraulic or hydro-pneumatic accumulator.

[0027] A first method of controlling the above-described hydraulic circuit comprises the steps:

fluidly disconnecting the first fluid port of the first hydraulic pump from the fluid reservoir, and
placing the at least one accumulator valve in the first configuration for pressurizing the first fluid port of the first hydraulic pump using the hydraulic or hydro-pneumatic accumulator.

[0028] The first method may further comprise the steps:

drivingly engaging an internal combustion engine or an electric motor with the first hydraulic pump, and

displacing pressurized hydraulic fluid from the hydraulic or hydro-pneumatic accumulator through the first hydraulic pump, thereby driving the internal combustion engine or the electric motor through the first hydraulic pump, such as for driving an electric generator.

[0029] And a second method of controlling the above-described hydraulic circuit comprises the steps:

fluidly connecting the first fluid port of the first hydraulic pump with the fluid reservoir, and placing the at least one accumulator valve in the second configuration for pressurizing the fluid output port through the first hydraulic pump and through the hydraulic or hydro-pneumatic accumulator.

[0030] Embodiments of the presently proposed hydraulic circuit and of methods of operating said hydraulic circuit are depicted in the Figures and further described in the following detailed description in which:

- Fig. 1 depicts a schematic of a hydraulic circuit of the presently proposed type according to a first embodiment;
- Fig. 2 depicts a schematic of a detail of the hydraulic circuit of Fig. 1 according to a first mode of operation;
- Fig. 3 depicts a schematic of a detail of the hydraulic circuit of Fig. 1 according to a second mode of operation;
- Fig. 4 depicts a schematic of a detail of the hydraulic circuit of Fig. 1 according to a third mode of operation; and
- Fig. 5 depicts a schematic of a hydraulic circuit of the presently proposed type according to a second embodiment.

[0031] Fig. 1 shows a hydraulic circuit 1 comprising a fluid reservoir or fluid tank 2, a first hydraulic pump 3 having a first fluid port 3a and a second fluid port 3b, an optional second hydraulic pump 4 having a first fluid port 4a and a second fluid port 4b, a hydraulic load 5 having a first fluid port 5a and a second fluid port 5b, a hydraulic or hydro-pneumatic accumulator 6, a rigid valve block 7 and a reservoir valve 8. Alternative embodiments of the hydraulic circuit 1 may only include the first hydraulic pump 3. The hydraulic pumps 3, 4 may be configured as gear pumps or piston pumps, for example. However, it is understood that other types of hydraulic pumps could be used. The hydraulic load 5 may comprise one or more hydraulic implements such as one or more hydraulic cylinders and/or one or more hydraulic motors, for example.

[0032] A hydrostatic pressure in the fluid reservoir 2

may be at atmospheric pressure of about 1 bar, for example. However, it is understood that the hydrostatic pressure in the fluid reservoir 2 may also be above atmospheric pressure. The hydraulic accumulator 6 may be a compressed gas accumulator including, for instance, an elastic diaphragm, a closed bladder or a floating piston. A hydrostatic pressure in the hydraulic accumulator 6 is typically higher than the hydrostatic pressure in the fluid reservoir 2. For example, the hydrostatic pressure in the hydraulic accumulator may be at least 2 bar, at least 20 bar, or at least 50 bar. The valve block 7 comprises a plurality of valves integrated in or mounted on the valve block 7 and a plurality of fluid ports 7a-h, including an fluid output port 7a. The valve block 7 fluidly connects or selectively fluidly connects the hydraulic pumps 3, 4 and the hydraulic accumulator 6 with the fluid reservoir 2 and with the hydraulic load 5 via the fluid ports 7a-h. The valve block 7 further selectively fluidly connects the hydraulic accumulator 6 with the first hydraulic pump 3.

[0033] The hydraulic circuit 1 may be installed on a working machine such as an excavator. For example, the hydraulic load 5 may include one or more hydraulic cylinders for moving and tilting a bucket, and one or more hydraulic motors for rotating a house of the excavator relative to an undercarriage. However, it is understood that the hydraulic circuit 1 is not limited to applications related to working machines. For example, it is conceivable that the hydraulic circuit 1 may be used for actuating a roboter arm or for other applications.

[0034] Here, the first hydraulic pump 3 is as a reversible hydraulic pump configured to deliver fluid in two directions, and the second hydraulic pump 4 is a non-reversible pump configured to deliver fluid only from the fluid reservoir 2 towards the valve block 7 and the hydraulic load 5. However, it is understood that in alternative embodiments of the hydraulic circuit 1 each of the hydraulic pumps 3, 4 could be configured as either one of a reversible and a non-reversible hydraulic pump. Further in the embodiment of Fig. 1 a hydraulic displacement of the second hydraulic pump 4 is larger than a hydraulic displacement of the first hydraulic pump 3, for example by a factor of two or more. However, it is understood that in other embodiments of the hydraulic circuit 1 the hydraulic pumps 3, 4 may have the same hydraulic displacement or the hydraulic displacement of the first hydraulic pump may be larger than the hydraulic displacement of the second hydraulic pump 4. The hydraulic pumps 3, 4 are mechanically connected or drivingly engaged in such a way that the first hydraulic pump 3 and the second hydraulic pump 4 turn at the same speed or at the same frequency at all times. In alternative embodiments of the hydraulic circuit 1, the hydraulic pumps 3, 4 could be selectively coupled through a clutch or through a transmission that may provide a fixed gear ratio or a modifiable gear ratio between the hydraulic pumps 3, 4.

[0035] In the embodiment depicted in Fig. 1 the hydraulic circuit 1 further comprises an accumulator pres-

sure sensing unit 9 for measuring or for sensing a hydrostatic pressure in the hydraulic accumulator 6, an output pressure sensing unit 10 for measuring or for sensing a hydrostatic pressure at the fluid output port 7a, an electric motor/generator 11 drivingly engaged or selectively drivingly engaged with one or both of the hydraulic pumps 3, 4, and an electric or electromechanical accumulator 12 electrically connected with the electric generator. The electric motor/generator 11 is configured to selectively either drive one or both of the hydraulic pumps 3, 4 or to charge the accumulator 12. In alternative embodiments the hydraulic circuit 1 may comprise an internal combustion engine for driving one or both of the hydraulic pumps 3, 4. The internal combustion engine may then replace the electric motor/generator 11 or may be used as a supplement to the electric motor/generator 11.

[0036] The hydraulic circuit 1 shown in Fig. 1 further includes an electronic control unit 13. For example, the control unit 13 may comprise one or more programmable microprocessors or an FPGA. The control unit 13 may be in communication with the accumulator pressure sensing unit 9, the output pressure sensing unit 10, the electric motor/generator 11 and one or more of the valves of the valve block 7. For example, the control unit 13 may be configured or programmed to control the electric motor/generator 11 and/or one or more of the valves of the valve block 7 based on a pressure signal received from the accumulator pressure sensing unit 9 and/or based on a pressure signal received from the output pressure sensing unit 10. Additionally or alternatively, the control unit 13 may be configured to control the electric motor/generator 11 and/or one or more of the valves of the valve block 7 based on an input signal received from an input device (not shown) which may include a lever, a joystick or a switch, for example, and which may be actuated by an operator.

[0037] The valve block 7 comprises a first accumulator valve 14a which may be switched between an open position and a closed position for selectively fluidly connecting and disconnecting the hydraulic or hydro-pneumatic accumulator 6 with or from the fluid output port 7a. In Fig. 1 the first accumulator valve 14a is in the closed position. The control unit 13 may be configured to actuate the first accumulator valve 14a through electromagnetic signals, for example via a solenoid. Here, the first accumulator valve 14a is biased toward the closed position by a biasing member such as a spring.

[0038] The fluid output port 7a is fluidly connected with the first fluid port 5a of the hydraulic load 5. The second fluid port 5b of the hydraulic load 5 is fluidly connected with the fluid reservoir 2. That is, as a quantity of fluid is displaced toward the first fluid port 5a of the hydraulic load 5 via the fluid output port 7a for actuating the hydraulic load 5, an equal quantity of fluid is displaced or may be displaced from the second fluid port 5b of the hydraulic load 5 toward the fluid reservoir 2.

[0039] The valve block 7 further comprises a proportional valve 15 configured to control a flow of fluid from

the hydraulic accumulator 6 toward the fluid output port 7a and toward the hydraulic load 5 when the first accumulator valve 14a is in the open position. The control unit 13 may be configured to actuate the proportional valve 15 through electromagnetic signals, for example via a solenoid. That is, the hydraulic or hydro-pneumatic accumulator 6 is selectively fluidly connected with the fluid output port 7a via the first accumulator valve 14a and the proportional valve 15.

[0040] The valve block 7 further comprises a second accumulator valve 14b which may be switched between an open position and a closed position for selectively fluidly connecting and disconnecting the hydraulic or hydro-pneumatic accumulator 6 with or from the first fluid port 3a of the first hydraulic pump 3. That is, the hydraulic or hydro-pneumatic accumulator 6 is selectively fluidly connected with the first fluid port 3a of the first hydraulic pump via the second accumulator valve 14b. In Fig. 1 the second accumulator valve 14b is in the closed position. The control unit 13 may be configured to actuate the second accumulator valve 14b through electromagnetic signals, for example via a solenoid. Here, the second accumulator valve 14b is biased toward the closed position by a biasing member such as a spring.

[0041] The first fluid port 3a of the first hydraulic pump 3 is selectively fluidly connected with the fluid reservoir 2 via the reservoir valve 8. The reservoir valve 8 comprises a check valve configured to allow a flow of fluid from the fluid reservoir 2 to the first fluid port 3a of the first hydraulic pump 3 through the reservoir valve 8, and to prevent a flow of fluid from the first fluid port 3a of the first hydraulic pump 3 to the fluid reservoir 2 through the reservoir valve 8. The reservoir valve 8 is further configured to prevent a flow of fluid from the hydraulic accumulator 6 to the fluid reservoir 2 through the reservoir valve 8. That is, the reservoir valve is configured to prevent the draining of fluid from the hydraulic accumulator 6 to the fluid reservoir 2. This way, when the hydrostatic pressure in the hydraulic accumulator 6 is higher than the hydrostatic pressure in the fluid reservoir 2, fluidly connecting the hydraulic accumulator 6 with the first fluid port 3a of the first hydraulic pump 3 by switching the second accumulator valve 14b to the open position reduces or may reduce the power or the amount of energy the motor/generator 11 needs to expend to drive the first hydraulic pump 3.

[0042] The second fluid port 3b of the first hydraulic pump 3 is selectively fluidly connected with the fluid output port 7a, for example for pressurizing the hydraulic load 5. That is, the first hydraulic pump 3 may displace fluid from the fluid reservoir 2 toward the fluid output port 7a and toward the first fluid port 5a of the hydraulic load 5. Specifically, the second fluid port 3b of the first hydraulic pump 3 is selectively fluidly connected with the fluid output port 7a via a check valve 16 and via the proportional valve 15. Thus, the proportional valve 15 is further configured to control a flow of fluid from the first hydraulic pump 3 toward the fluid output port 7a and toward the

hydraulic load 5. The check valve 16 is integrated in the valve block 7. The check valve 16 is configured to allow a flow of fluid from the second fluid port 3b of the first hydraulic pump 3 toward the fluid output port 7a through the check valve 16, and to prevent a flow of fluid from the fluid output port 7a or from the hydraulic accumulator 6 toward the second fluid port 3b of the first hydraulic pump 3 through the check valve 16. Also, the check valve 16 prevents a flow of fluid from the hydraulic accumulator 6 toward the second fluid port 3b of the first hydraulic pump 3 through the check valve 16 when the first accumulator valve 14a is in the open position.

[0043] The second fluid port 3b of the first hydraulic pump 3 is selectively fluidly connected with the hydraulic accumulator 6 via the check valve 16 and via another check valve 17. Like the check valve 16, the check valve 17 is integrated in the valve block 7. The check valves 16, 17 are configured to allow a flow of fluid from the second fluid port 3b of the first hydraulic pump 3 toward the hydraulic accumulator 6 through the check valves 16, 17, in particular irrespective of whether the accumulator valves 14a, 14b are in the open position or in the closed position, respectively. And the check valves 16, 17 are configured to prevent a flow of fluid from the hydraulic accumulator 6 toward the second fluid port 3b of the first hydraulic pump 3 through the check valves 16, 17, in particular irrespective of whether the accumulator valves 14a, 14b are in the open position or in the closed position, respectively. That is, the first hydraulic pump 3 is configured to charge the hydraulic accumulator 6 by displacing fluid from the fluid reservoir 2 to the hydraulic accumulator 6 through the check valves 16, 17.

[0044] The valve block 7 further comprises a first bypass valve 18 which may be switched between an open position and a closed position for selectively fluidly connecting and disconnecting the second fluid port 3b of the first hydraulic pump 3 to or from the fluid reservoir 2. In Fig. 1 the first bypass valve 18 is in the open position. The control unit 13 may be configured to actuate the first bypass valve 18 through electromagnetic signals, for example via a solenoid. Here, the first bypass valve 18 is biased toward the open position by a biasing member such as a spring.

[0045] The first fluid port 4a of the second hydraulic pump 4 is fluidly connected with the fluid reservoir 2, and the second fluid port 4b of the second hydraulic pump 4 is selectively fluidly connected with the fluid output port 7a via another check valve 19. The check valve 19 is integrated in the valve block 7. The check valve 19 is configured to allow a flow of fluid from the second fluid port 4b of the second hydraulic pump 4 toward the fluid output port 7a through the check valve 19, and to prevent a flow of fluid from the fluid output port 7a toward the second fluid port 4b of the second hydraulic pump through the check valve 19. Iso, the check valve 19 prevents a flow of fluid from the hydraulic accumulator 6 toward the second fluid port 4b of the second hydraulic pump 4 when the first accumulator valve 14a is in the open position.

That is, the second hydraulic pump 4 may pressurize or additionally pressurize the hydraulic load 5 via the fluid output port 7a by displacing fluid from the fluid reservoir 2 toward the first fluid port 5a of the hydraulic load 5 via the fluid output port 7a.

[0046] The valve block 7 further comprises a second bypass valve 20 which may be switched between an open position and a closed position for selectively fluidly connecting and disconnecting the second fluid port 4b of the second hydraulic pump 4 to or from the fluid reservoir 2. In Fig. 1 the second bypass valve 20 is in the open position. The control unit 13 may be configured to actuate the second bypass valve 20 through electromagnetic signals, for example via a solenoid. Here, the second bypass valve 20 is biased toward the open position by a biasing member such as a spring.

[0047] The valve block 7 further comprises a first accumulator safety valve 21a and a second accumulator safety valve 21b. Each of the accumulator safety valves 21a, 21b have an open position and a closed position. Both the first accumulator safety valve 21a and the second accumulator safety valve 21b selectively fluidly connect the hydraulic accumulator 6 with the fluid reservoir 2. That is, when one of the accumulator safety valves 21a, 21b is in its open position, the hydraulic accumulator 6 is fluidly connected with the fluid reservoir 2 and fluid from hydraulic accumulator 6 may be drained to the fluid reservoir 2, for example for reducing the hydrostatic pressure in the hydraulic accumulator 6. In Fig. 1 the accumulator safety valves 21a, 21b are in their closed position, respectively. In the embodiment depicted in Fig. 1 the first accumulator safety valve 21a is configured as a relief valve which automatically drains fluid from the hydraulic accumulator 6 to the fluid reservoir 2 when the hydrostatic pressure in the hydraulic accumulator 6 exceeds a threshold pressure. The second accumulator safety valve 21b is configured as a shut-off valve. The control unit 13 may be configured to actuate the second accumulator safety valve 21b through electromagnetic signals such as via a solenoid, for example based on a pressure signal received from the accumulator pressure sensing unit 9. Here, the second accumulator safety valve 21b is biased toward the closed position by a biasing member such as a spring.

[0048] In the Figures crossing fluid lines are fluidly connected with one another only if the point at which they cross is explicitly marked with a dot.

[0049] Figs. 2-4 show the valve block 7 of Fig. 1 wherein the valves of the valve block 7 are in different positions in each case to illustrate different methods of controlling the hydraulic circuit 1 of Fig. 1. Here and in the following recurring features are designated with the same reference signs.

[0050] In the method of controlling the hydraulic circuit 1 of Fig. 1 illustrated in Fig. 2 the control unit 13 switches the first accumulator valve 14a to the open position and the second accumulator valve 14b to the closed position, for example based on an input command provided by an

operator, based on a pressure signal received from the accumulator pressure sensing unit 9 and/or based on a pressure signal received from the accumulator pressure sensing unit 10. In this configuration, the hydraulic accumulator 6 is fluidly connected with the hydraulic load 5 via the first accumulator valve 14a, the proportional valve 15 and the fluid output port 7a, and the closed second accumulator valve 14b fluidly isolates or fluidly disconnects the hydraulic accumulator 6 from the first fluid port 3a of the first hydraulic pump 3. Fluid from the hydraulic accumulator 6 may then be displaced toward the first fluid port 5a of the hydraulic load 5 via the fluid output port 7a for pressurizing the hydraulic load 5.

[0051] In Fig. 2 the control unit 13 further switches the bypass valves 18, 20 to their closed position, respectively, to fluidly disconnect the second fluid ports 3b, 4b of the hydraulic pumps 3, 4 from the fluid reservoir 2. Further in Fig. 2, the accumulator safety valves 21a, 21b are in their closed position, thereby fluidly isolating or fluidly disconnecting the hydraulic accumulator 6 from the fluid reservoir 2.

[0052] The control unit 13 may further control the electric motor/generator 11 to drive the hydraulic pumps 3, 4 so that the hydraulic pumps 3, 4 may pump fluid from the fluid reservoir 2 toward the first fluid port 5a of the hydraulic load 5 for pressurizing or for additionally pressurizing the hydraulic load 5. The electric motor/generator 11 may be powered or at least partially powered by energy stored in the accumulator 12. In order to open the check valves 16, 19, the hydrostatic pressure provided by the hydraulic pumps 3, 4 needs to reach the hydrostatic pressure exerted on the check valves 16, 19 by the hydraulic accumulator 6. As long as the hydrostatic pressure exerted on the check valves 16, 17, 19 by the hydraulic accumulator 6 exceeds the hydrostatic pressure produced by the hydraulic pumps 3, 4, the check valves 16, 17, 19 prevent the draining of fluid from the hydraulic accumulator 6 toward the hydraulic pumps 3, 4. The control unit 13 may control the fluid flow from the hydraulic accumulator 6 and possibly from the first hydraulic pump 3 toward the hydraulic load 5 by controlling the proportional valve 15. In Fig. 2 the fluid flow or the possible fluid flow from the hydraulic accumulator 6 and the hydraulic pumps 3, 4 toward the hydraulic load 5 via the fluid output port 7a is indicated by arrows 25.

[0053] The method of controlling the hydraulic circuit 1 illustrated in Fig. 2 may be particularly useful when high fluid flow rates are requested at the fluid output port 7a, for instance when an operator requests a fast movement of an actuator of the hydraulic load 5.

[0054] In the method of controlling the hydraulic circuit 1 of Fig. 1 illustrated in Fig. 3 the control unit 13 switches the first accumulator valve 14a to the closed position and the second accumulator valve 14b to the open position, for example based on an input command provided by an operator, based on a pressure signal received from the accumulator pressure sensing unit 9 and/or based on a pressure signal received from the accumulator pressure

sensing unit 10. In this configuration, the hydraulic accumulator 6 is fluidly connected with the first fluid port 3a of the first hydraulic pump 3 via the second accumulator valve 14b, while the closed first accumulator valve 14a fluidly isolates or fluidly disconnects the hydraulic accumulator 6 from the fluid output port 7a. Fluid from the hydraulic accumulator 6 may then be displaced toward the first fluid port 3a of the first hydraulic pump 3 for pressurizing or for supporting the first hydraulic pump 3. Due to the fact that the hydrostatic pressure in the hydraulic accumulator 6 exceeds the hydrostatic pressure in the fluid reservoir 2, the reservoir valve 8 closes and fluidly isolates or fluidly disconnects the hydraulic accumulator 6 and the first fluid port 3a of the first hydraulic pump 3 from the fluid reservoir 2. That is, the reservoir valve 8 prevents the draining of fluid from the hydraulic accumulator 6 toward the fluid reservoir 2.

[0055] In Fig. 3 the control unit 13 further switches the bypass valves 18, 20 to their closed position, respectively, to fluidly disconnect the second fluid ports 3b, 4b of the hydraulic pumps 3, 4 from the fluid reservoir 2. Further in Fig. 3, the accumulator safety valves 21a, 21b are in their closed position, thereby fluidly isolating or fluidly disconnecting the hydraulic accumulator 6 from the fluid reservoir 2.

[0056] In Fig. 3 the control unit 13 further controls the electric motor/generator 11 to drive the hydraulic pumps 3, 4 so that the hydraulic pumps 3, 4 pump fluid from the fluid reservoir 2 toward the fluid output port 7a for pressurizing the hydraulic load 5. The electric motor/generator 11 may be powered or at least partially powered by energy stored in the accumulator 12. As the high pressure hydraulic accumulator 6 is fluidly connected with the low pressure fluid port 3a of the first hydraulic pump 3 in this configuration, a reduced power or a reduced amount of energy needs to be expended by the electric motor/generator 11 for driving the first hydraulic pump 3. At a high enough hydrostatic pressure in the hydraulic accumulator 6, the hydraulic accumulator may even drive the electric motor/generator 11 through the first hydraulic pump 3 by displacing fluid from the hydraulic accumulator 6 through the first hydraulic pump 3 in order to charge the accumulator 12. As the hydrostatic pressure in the hydraulic accumulator 6 is typically higher than the hydrostatic pressure provided by the first hydraulic pump 3 at its high pressure fluid port 3b, the check valve 17 usually closes and prevents the draining of fluid from the hydraulic accumulator 6 toward the second fluid port 3b of the first hydraulic pump 3 through the check valve 17.

[0057] In Fig. 3, the control unit 13 may control the fluid flow from the first hydraulic pump 3 toward the hydraulic load 5 by controlling the proportional valve 15. Again, in Fig. 3 the fluid flow from the hydraulic accumulator 6 toward the first fluid port 3a of the first hydraulic pump 3 and from the hydraulic pumps 3, 4 toward the hydraulic load 5 via the fluid output port 7a is indicated by arrows 25.

[0058] Controlling the hydraulic circuit 1 according to the method illustrated in Fig. 3 may be particularly ad-

vantageous when the hydrostatic pressure in the hydraulic accumulator 6 exceeds a hydrostatic pressure requested at the fluid output port 7a and when the fluid flow rate provided by the hydraulic pumps 3, 4 is sufficient to meet the fluid flow rate requested at the fluid output port 7a, for example.

[0059] The method of controlling the hydraulic circuit 1 of Fig. 1 illustrated in Fig. 4 is a variant of the method illustrated in and described with respect to Fig. 3. The position of the valves of the valve block 7 according to Fig. 4 differs from the position of the valves of the valve block 7 according to Fig. 3 in that in Fig. 4 the control unit 13 switches the bypass valves 18, 20 to their open position, respectively, thereby fluidly connecting the second fluid ports 3b, 4b of the hydraulic pumps 3, 4 with the fluid reservoir 2. In this manner, fluid delivered by the hydraulic pumps 3, 4 may be diverted directly to the fluid reservoir 2 without pressurizing the output fluid port 7a.

[0060] Controlling the hydraulic circuit 1 according to the method illustrated in Fig. 4 may be particularly advantageous for starting the electric motor/generator 11 or an internal combustion engine, or for charging the accumulator 12 when no output fluid flow or no output pressure is requested at the output fluid port 7a.

[0061] Fig. 5 shows a hydraulic circuit 100 which is a variant of the hydraulic circuit 1 of Fig. 1. Like the hydraulic circuit 1 of Fig. 1 the hydraulic circuit 100 of Fig. 5 comprises a fluid reservoir or fluid tank 2, hydraulic pump 3 having a first fluid port 3a and a second fluid port 3b, an electric motor/generator 11 drivingly or selectively drivingly engaged with the hydraulic pump, a hydraulic or hydro-pneumatic accumulator 6, and a rigid valve block 7. The valve block 7 of the hydraulic circuit 100 of Fig. 5 comprises a plurality of valves integrated in or mounted on the valve block 7 and a plurality of fluid ports 7a-b, 7d-g, 7j and 7k, including an fluid output port 7a. The valve block 7 of the hydraulic circuit 100 of Fig. 5 fluidly connects or selectively fluidly connects the hydraulic pump 3 and the hydraulic accumulator 6 with the fluid reservoir 2. A hydraulic load like the hydraulic load 5 of the hydraulic circuit 1 depicted in Fig. 1 may be fluidly connected with the fluid output port 7a of the valve block 7. And as in the hydraulic circuit 1 of Fig. 1, the valve block 7 of the hydraulic circuit 100 of Fig. 5 further selectively fluidly connects the hydraulic accumulator 6 with the hydraulic pump 3. The hydraulic circuit 100 of Fig. 5 may further include an electronic control unit like the control unit 13 of the hydraulic circuit 1 of Fig. 1 for controlling one or more of the valves of the valve block 7.

[0062] In a first configuration of the accumulator valves 14a, 14b in which the first accumulator valve 14a is closed and the second accumulator valve 14b is open the hydraulic accumulator 6 is fluidly connected with the first fluid port 3a of the hydraulic pump 3 and the hydraulic accumulator 6 is fluidly disconnected from the fluid output port 7a. In a second configuration of the accumulator valves 14a, 14b in which the first accumulator valve 14a is open and the second accumulator valve 14b is closed

the hydraulic accumulator 6 is fluidly disconnected from the first fluid port 3a of the hydraulic pump 3 and the hydraulic accumulator 6 is fluidly connected with the fluid output port 7a.

[0063] For simplicity, in the following only the differences between the hydraulic circuit 100 of Fig. 5 with respect to the hydraulic circuit 1 of Fig. 1 are explained.

[0064] The hydraulic circuit 100 of Fig. 5 differs from the hydraulic circuit 1 of Fig. 1 in that the hydraulic circuit 100 of Fig. 5 comprises only a single hydraulic pump 3 and only a single bypass valve 18 for selectively fluidly connecting the second fluid port 3b of the hydraulic pump 3 with the fluid reservoir 2. Further, the hydraulic circuit 100 of Fig. 5 comprises a pump pressure sensing unit 23 configured to measure or to sense a hydrostatic pressure at the second fluid port 3b of the hydraulic pump 3, and a load sensing pressure unit 24 configured to measure or to sense a hydrostatic pressure acting on the hydraulic load fluidly connected with the fluid output port 7a. The load sensing pressure is designated as LS in Fig. 5. Also, in the hydraulic circuit 100 of Fig. 5 the reservoir valve 8 is integrated in or mounted on the valve block 7.

[0065] Further in the hydraulic circuit 100 of Fig. 5, the proportional valve 15 has two control positions 15', 15" and two pressure controllable actuators 15a, 15b for switching the proportional valve 15 between the two control positions 15', 15". The first pressure controllable actuator 15a is fluidly connected with the load sensing pressure LS and biases the proportional valve 15 toward the first control position 15'. When the proportional valve 15 is switched to the first control position 15', the proportional valve 15 fluidly connects the second fluid port 3b of the hydraulic pump 3 with the fluid output port 7a, and selectively fluidly connects the hydraulic accumulator 6 with the fluid output port 7a via the first accumulator valve 14a. The second pressure controllable actuator 15b is fluidly connected with the fluid output port 7a and biases the proportional valve 15 toward the second control position 15". When the proportional valve 15 is switched to the second control position 15", the proportional valve 15 fluidly connects the second fluid port 3b of the hydraulic pump 3 with the hydraulic accumulator 6 via the check valves 16, 17, and fluidly connects the second fluid port 3b of the hydraulic pump 3 with the fluid output port 7a through an orifice. Alternatively, the second control position 15" could completely fluidly disconnect the second fluid port 3b of the hydraulic pump 3 from the fluid output port 7a (not shown in Fig. 5). In Fig. 5 the proportional valve 15 is additionally biased toward the first control position 15' by a biasing member such as a spring.

Claims

1. Hydraulic circuit (1; 100), comprising:

a fluid reservoir (2),

- a fluid output port (7a),
 a first hydraulic pump (3) having a first fluid port (3a) and a second fluid port (3b), the first fluid port (3a) of the first hydraulic pump (3) selectively fluidly connected with the fluid reservoir (2), and the second fluid port (3b) of the first hydraulic pump (3) fluidly connected or selectively fluidly connected with the fluid output port (7a),
 a hydraulic accumulator (6), and
 at least one accumulator valve (14a, 14b);
 wherein the at least one accumulator valve (14a, 14b) is configured to be selectively placed in either one of a first configuration and a second configuration, the at least one accumulator valve (14a, 14b) in the first configuration fluidly connecting the hydraulic accumulator (6) with the first fluid port (3a) of the first hydraulic pump (3) and fluidly disconnecting the hydraulic accumulator (6) from the fluid output port (7a), and the at least one accumulator valve (14a, 14b) in the second configuration fluidly connecting or selectively fluidly connecting the hydraulic accumulator (6) with the fluid output port (7a) and fluidly disconnecting the hydraulic accumulator (6) from the first fluid port (3a) of the first hydraulic pump (3).
2. The hydraulic circuit (1; 100) of claim 1, further comprising a reservoir valve (8) configured to selectively fluidly disconnect the first fluid port (3a) of the first hydraulic pump (3) from the fluid reservoir (2), in particular when the at least one accumulator valve (14a, 14b) is placed in the first configuration and fluidly connects the hydraulic accumulator (6) with the first fluid port (3a) of the first hydraulic pump (3).
 3. The hydraulic circuit (1; 100) of claim 2, wherein the reservoir valve (8) comprises a check valve, the check valve allowing a flow of fluid from the fluid reservoir (2) to the first fluid port (3a) of the first hydraulic pump (3) through the check valve, and the check valve preventing a flow of fluid from the first fluid port (3a) of the first hydraulic pump (3) to the fluid reservoir (2) through the check valve.
 4. The hydraulic circuit (1; 100) of any one of the preceding claims, further comprising a hydraulic implement fluidly connected or selectively fluidly connected with the fluid output port (7a) for pressurizing the hydraulic implement via the fluid output port (7a).
 5. The hydraulic circuit (1; 100) of any one of the preceding claims, further comprising a proportional valve (15) fluidly connecting or selectively fluidly connecting the first hydraulic pump (3) and the hydraulic accumulator (6) with the fluid output port (7a).
 6. The hydraulic circuit (1; 100) of any one of the preceding claims, further comprising a first bypass valve (18) selectively fluidly connecting the second fluid port (3b) of the first hydraulic pump (3) with the fluid reservoir (2).
 7. The hydraulic circuit (1; 100) of any one of the preceding claims, further comprising at least one charge valve (16, 17) selectively fluidly connecting the second fluid port (3b) of the first hydraulic pump (3) with the hydraulic accumulator (6) for charging the hydraulic accumulator (6) via the at least one charge valve (16, 17) using the first hydraulic pump (3).
 8. The hydraulic circuit (1; 100) of any one of the preceding claims, further comprising at least one accumulator safety valve (21a, 21b) selectively fluidly connecting the hydraulic accumulator (6) with the fluid reservoir (2).
 9. The hydraulic circuit (1; 100) of any one of the preceding claims, further comprising at least one of an electric motor (11) and an internal combustion engine drivingly engaged or selectively drivingly engaged with the first hydraulic pump (3) for driving the first hydraulic pump (3).
 10. The hydraulic circuit (1; 100) of any one of the preceding claims, further comprising a second hydraulic pump (4) drivingly engaged with the first hydraulic pump (3) and having a first fluid port (4a) and a second fluid port (4b), the first fluid port (4a) of the second hydraulic pump (4) fluidly connected or selectively fluidly connected with the fluid reservoir (2), and the second fluid port (4b) of the second hydraulic pump (4) fluidly connected or selectively fluidly connected with the fluid output port (7a).
 11. The hydraulic circuit (1; 100) of any one of the preceding claims, further comprising an electric generator drivingly engaged or selectively drivingly engaged with the first hydraulic pump (3), and an electrical or electrochemical accumulator (12) electrically connected or selectively electrically connected with the electric generator.
 12. The hydraulic circuit (1; 100) of any one of claims 5-11, wherein at least the at least one accumulator valve (14a, 14b), the proportional valve (15) and the fluid output port (7a) are integrated in or mounted on a valve block (7), the valve block (7) comprising fluid ports (7a-h) for fluidly connecting or for selectively fluidly connecting the at least one accumulator valve (14a, 14b) and the proportional valve (15) with the fluid reservoir (2), with the first hydraulic pump (3) and with the hydraulic accumulator (6).
 13. A first method of controlling the hydraulic circuit (1;

100) of any one of the preceding claims, comprising the steps:

fluidly disconnecting the first fluid port (3a) of the first hydraulic pump (3) from the fluid reservoir (2), and 5
placing the at least one accumulator valve (14a, 14b) in the first configuration for pressurizing the first fluid port (3a) of the first hydraulic pump (3) through the hydraulic accumulator (6). 10

14. The method of claim 13, further comprising the steps:

drivingly engaging an internal combustion engine or an electric motor (11) with the first hydraulic pump (3), and 15
displacing pressurized hydraulic fluid from the hydraulic accumulator (6) through the first hydraulic pump (3), thereby driving the internal combustion engine or the electric motor (11) 20
through the first hydraulic pump (3).

15. A second method of controlling the hydraulic circuit (1; 100) of any one of claims 1 to 12, comprising the steps: 25

fluidly connecting the first fluid port (3a) of the first hydraulic pump (3) with the fluid reservoir (2), and
placing the at least one accumulator valve (14a, 14b) in the second configuration for pressurizing the fluid output port (7a) through the first hydraulic pump (3) and through the hydraulic accumulator (6). 30
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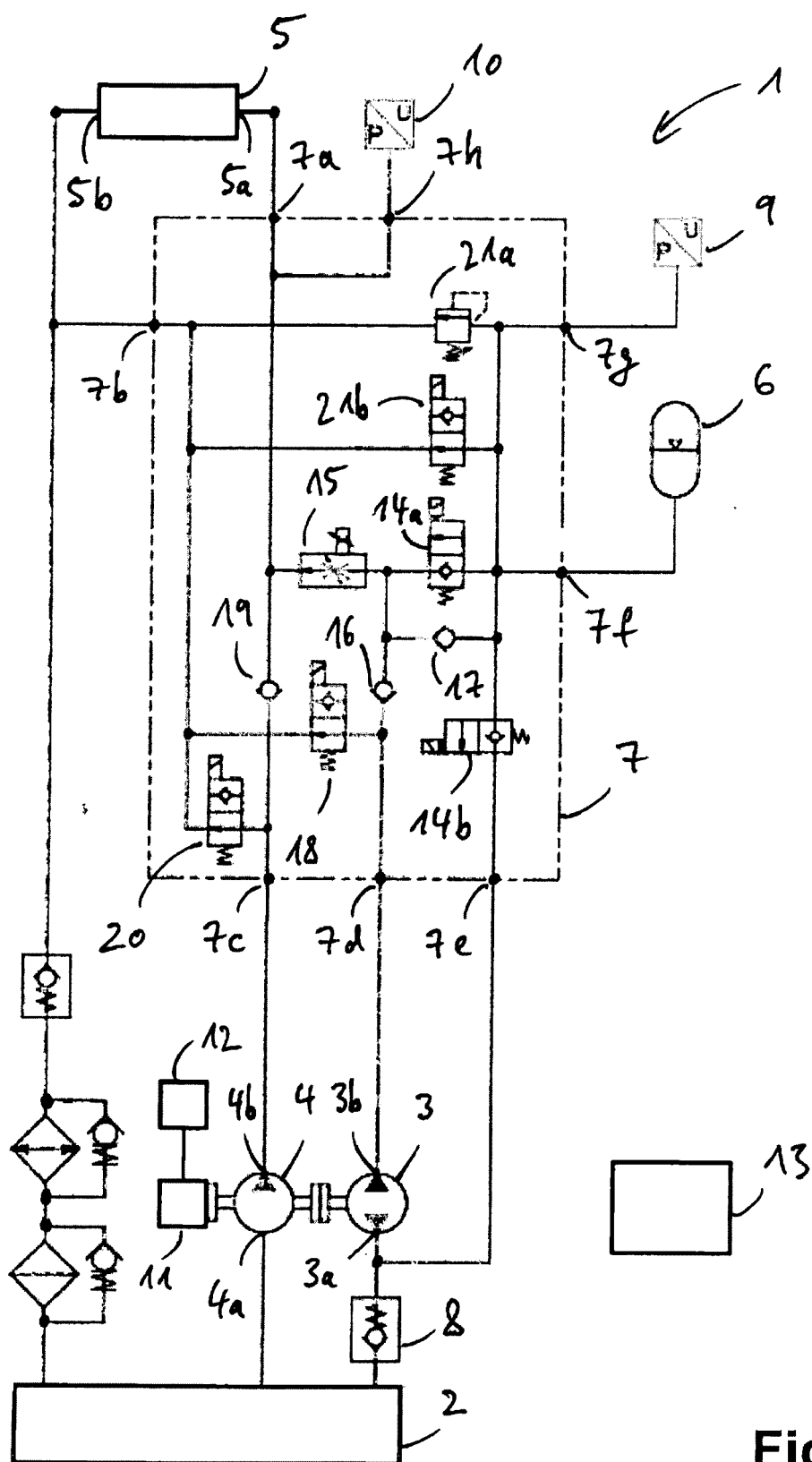


Fig. 1

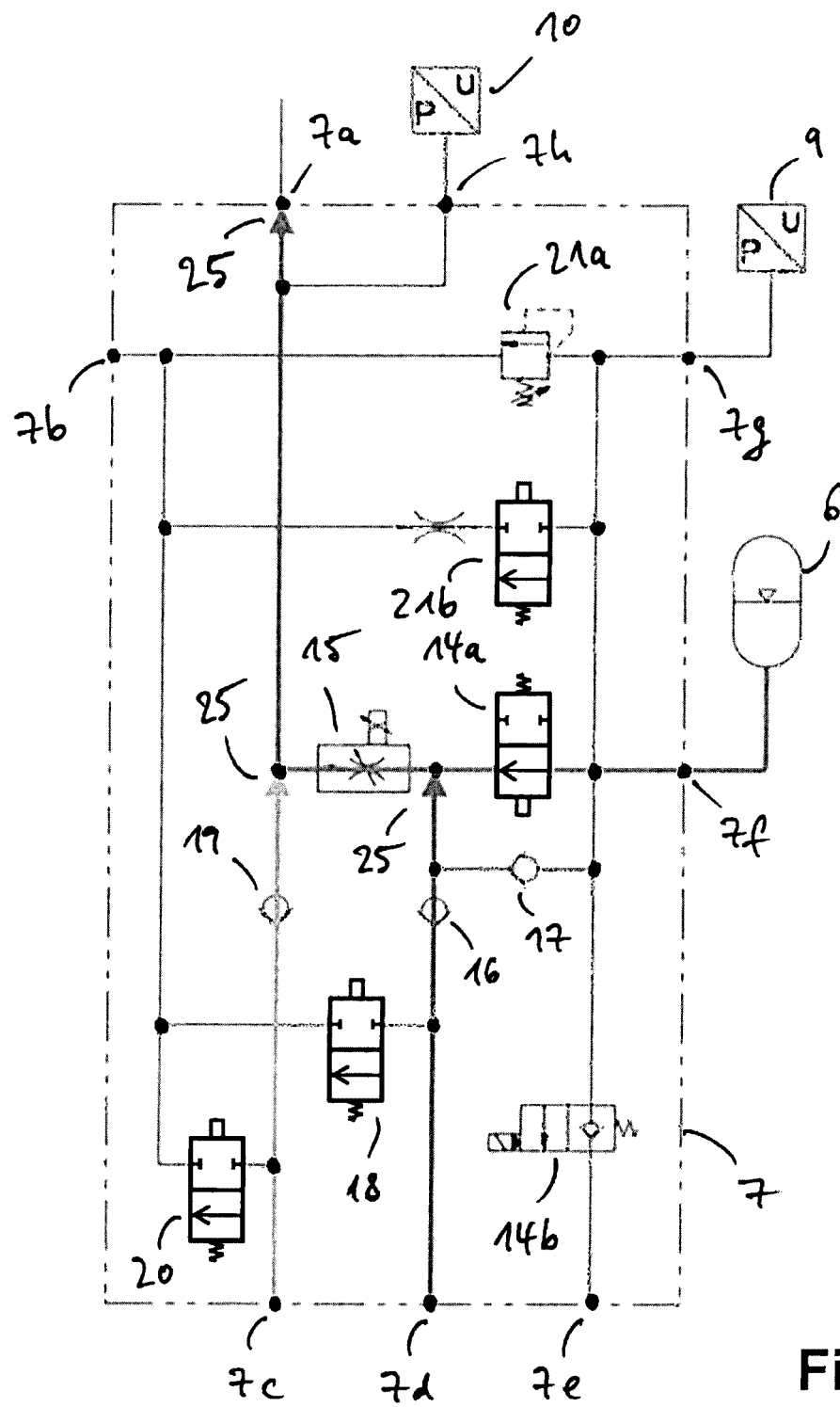
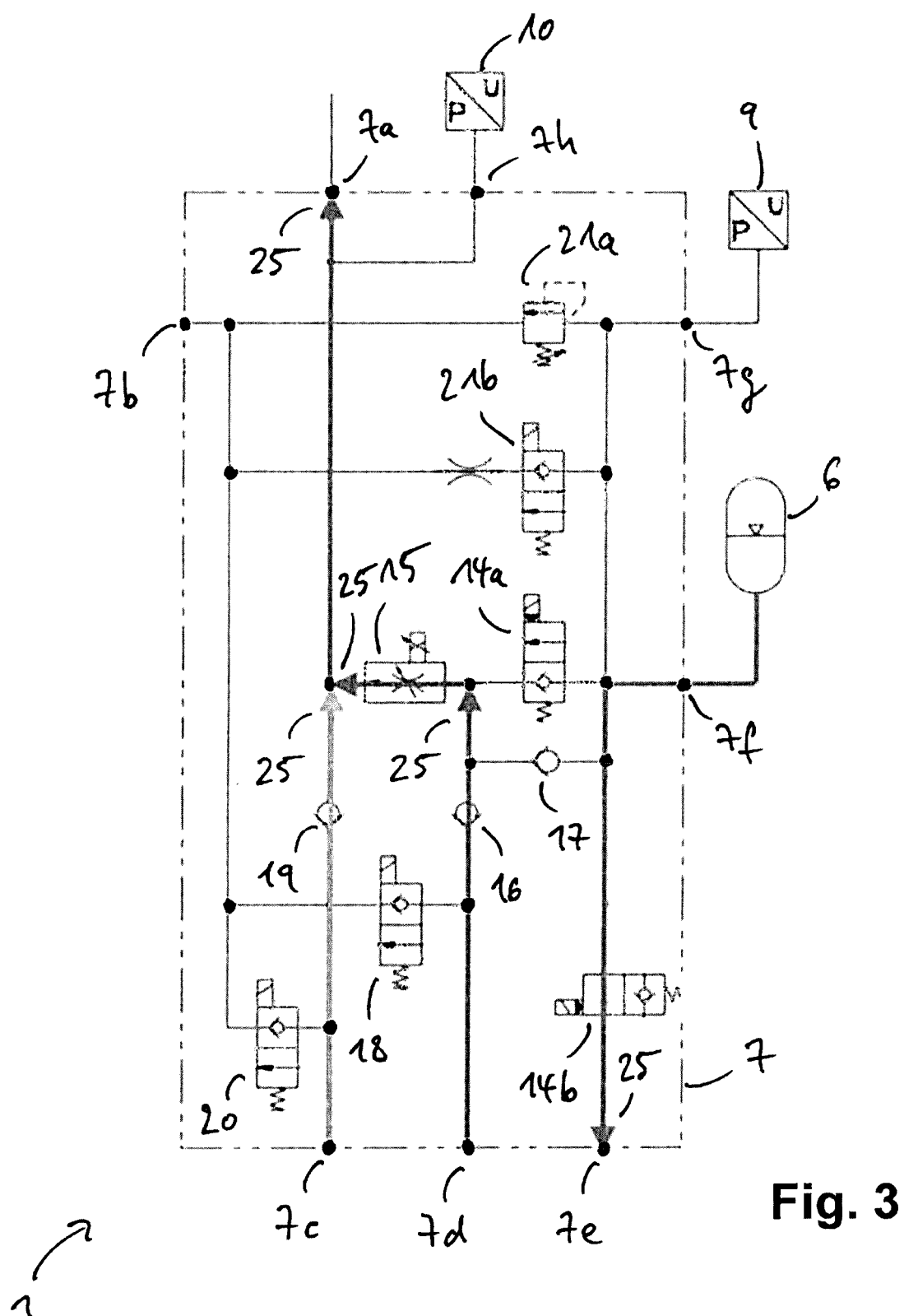


Fig. 2





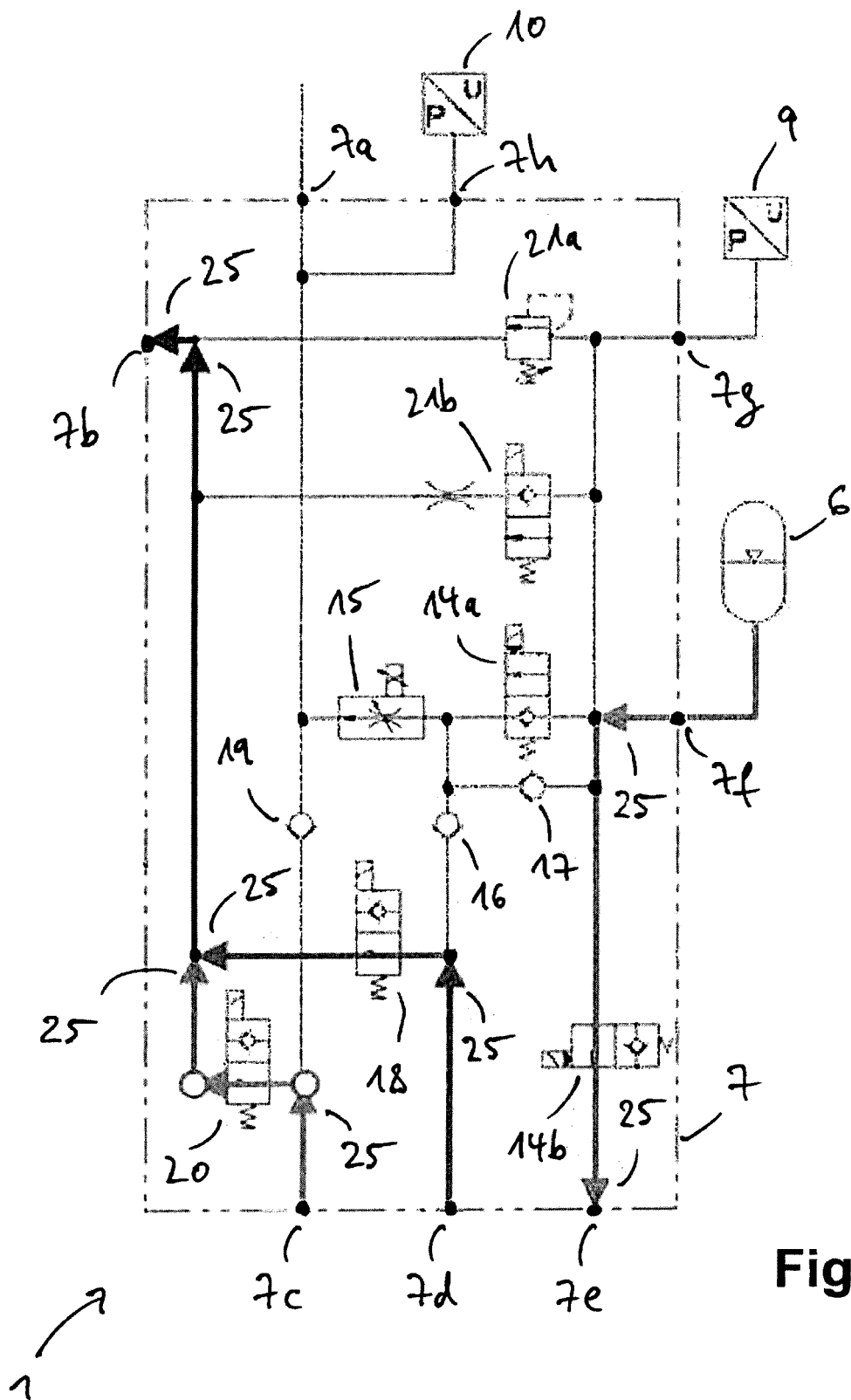


Fig. 4

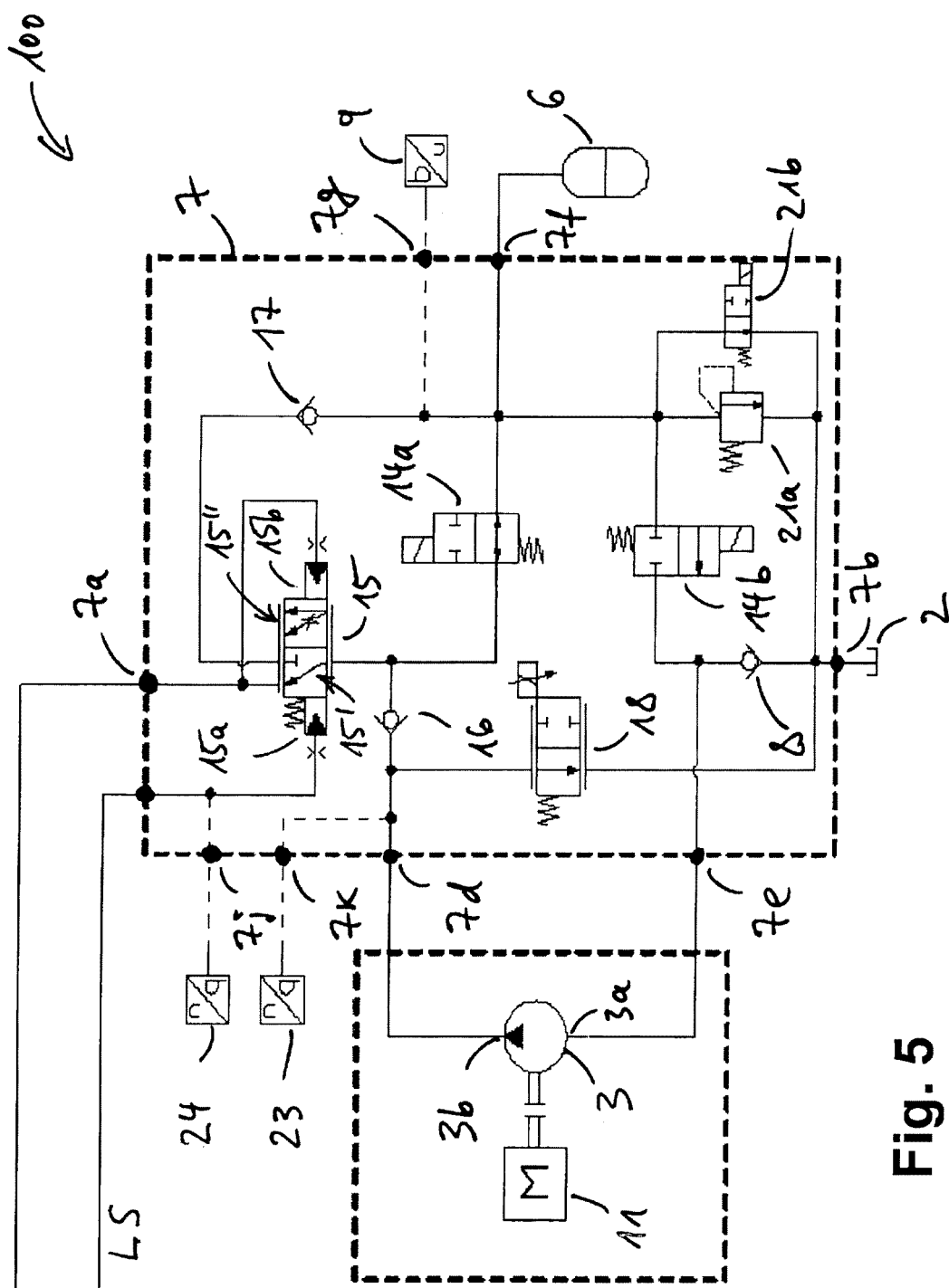


Fig. 5



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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 20 August 2019	Examiner Deligiannidis, N
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A	* col. 7-8; electronic control 40 with pressure sensor 34 control valves col.10 lines 5-8, 26-27 and 42-43; process of using pump and accumulator to start engine col. 11 lines 16-30; pump/motor starts/drives combustion engine, col.6, lines 55-61 and col.11, line 64-67; figure 3; examples 1,2,4,6,7,9,20,25,32,34,40,52,55,60 *	5-7,11, 12	
X	WO 2012/125798 A1 (LOWMAN ROGER [US]; STEGEMANN PATRICK [US]; PARKER HANNIFIN CORP [US]) 20 September 2012 (2012-09-20)	1-4,6,9, 13-15	
Y	* proportional valve 46, para. 0018;	12	
A	electronic control 40 with sensors 32,34 control engine and circuit, para 0011-00013; pump and accumulator drive/start engine para. 0015-0016;; paragraphs [0011], [0012]; figure 1; examples 12,14,16,18,22,24,32,34,40,42,44,46 *	5,7,8, 10,11	TECHNICAL FIELDS SEARCHED (IPC)
Y	CN 108 953 419 A (HANGCHA GROUP CO LTD) 7 December 2018 (2018-12-07)	12	
	* proportional control valve block 7 connected to pump and hydraulic device and having further ports; figure 1 *		
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 20 August 2019	Examiner Deligiannidis, N
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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