Hydraulic Circuits -Identification of Components and Analysis

by

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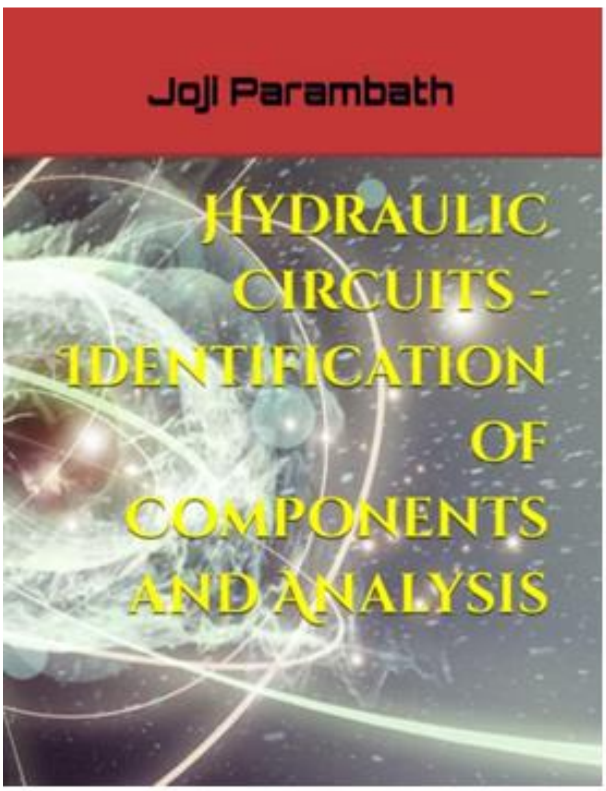

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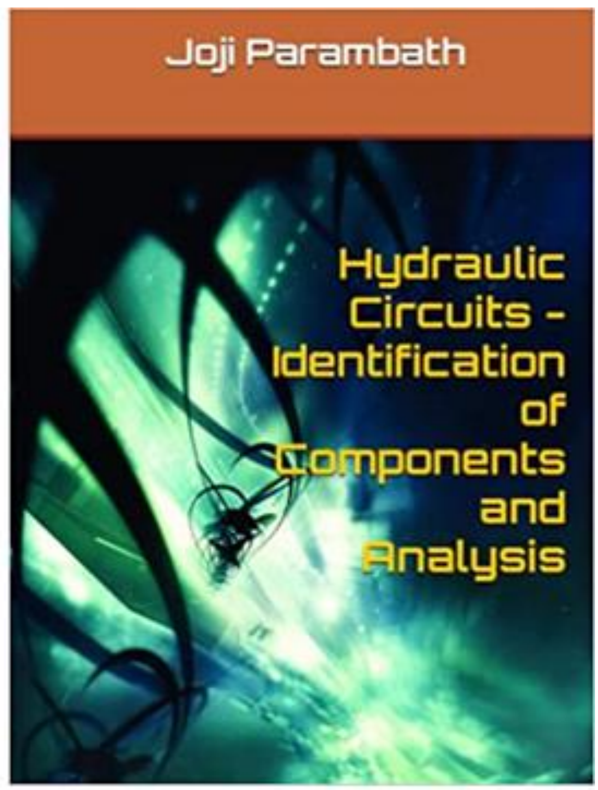

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Hydraulic Circuits

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Sample Texts, Figures, and Schematics Follow

Chapter 2 | Hydraulic Circuits with Directional Control Valves

Symbols - Single-acting Hydraulic Cylinders and Control Components

The actual schematics of hydraulic components are difficult to draw and cannot easily be used in hydraulic circuits. Symbols signify a simplified functional representation of hydraulic components. Therefore, circuits can be drawn easily using symbols. The essential symbols of hydraulic components especially for the control of single-acting hydraulic cylinders are highlighted in Figure 2.1.

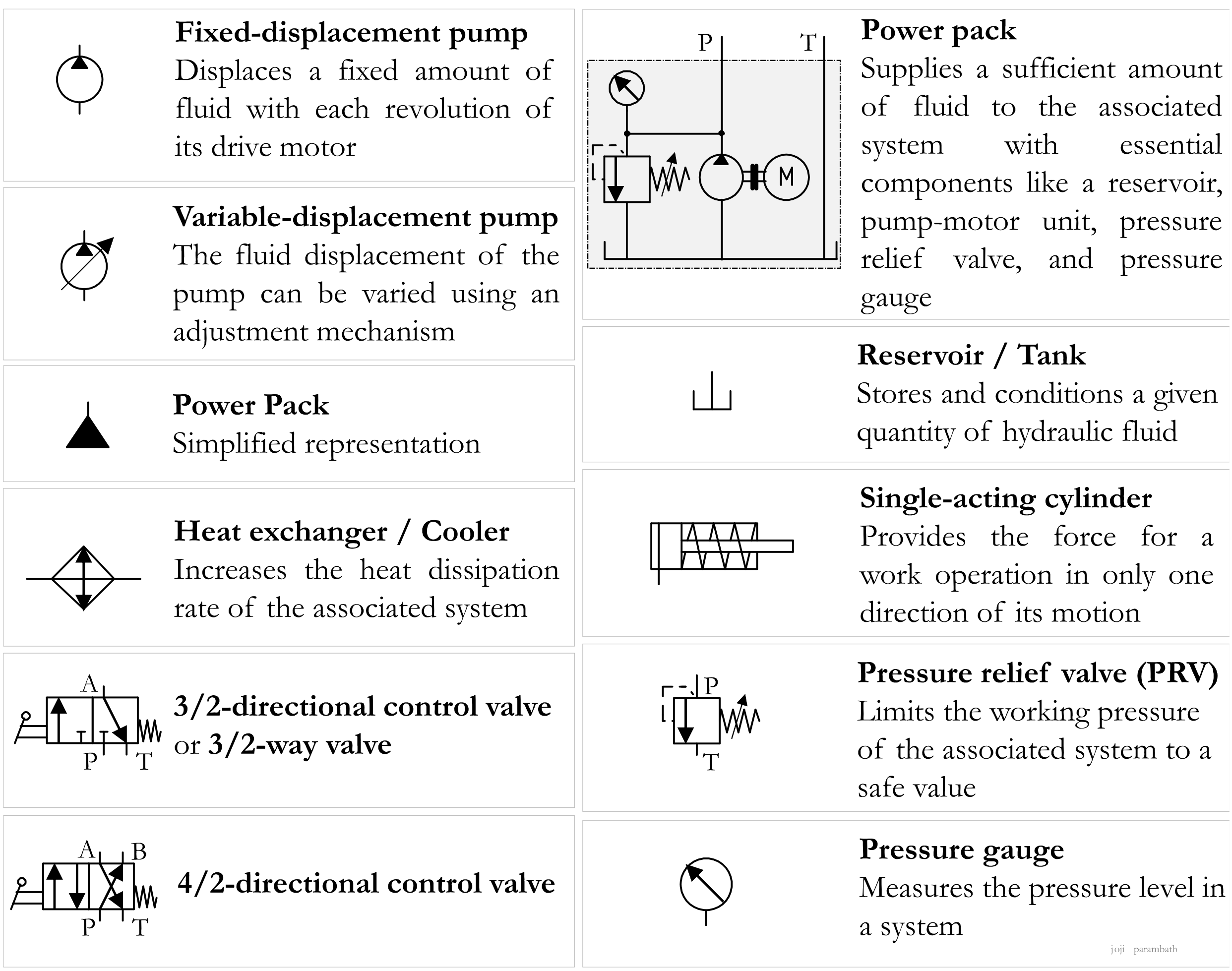
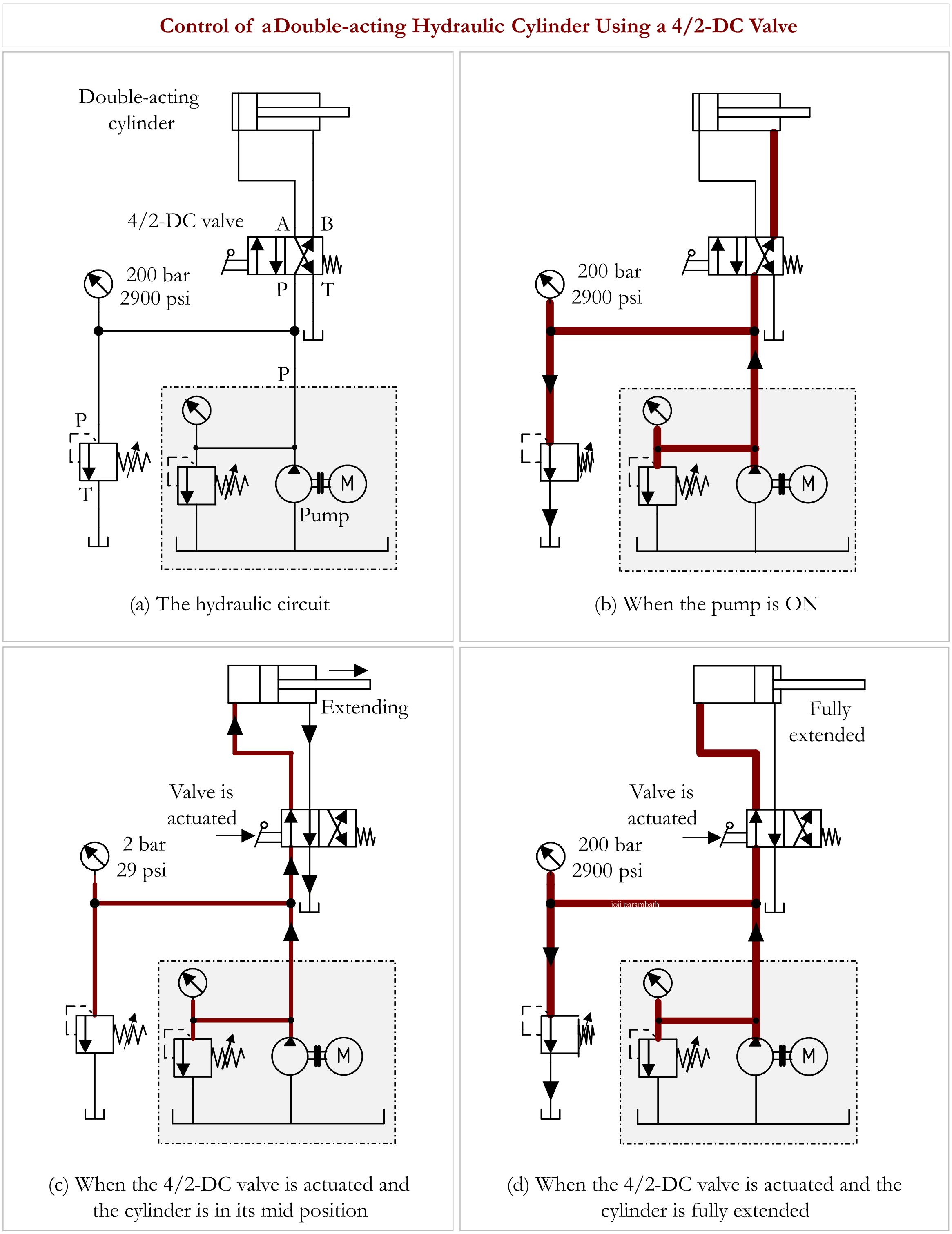


Figure 2.1 | Symbols of basic components in a hydraulic system

Control Task 2.5 | Control of a Double-acting Hydraulic Cylinder Using a 4/2-DC Valve
A double-acting hydraulic cylinder should extend and clamp a workpiece upon operating a lever-actuated valve. The cylinder should remain in the clamping position, as long as the valve is pressed. If the lever is released, the cylinder should retract. Develop a hydraulic circuit to implement the control task. A fixed-displacement hydraulic pump is used as the power source. The system shall be able to set a maximum pressure of 200 bar [2900 psi].

Solution



Control of aDouble-acting Hydraulic Cylinder Using a 4/2-DC Valve

(a) The hydraulic circuit

(b) When the pump is ON

(c) When the 4/2-DC valve is actuated and the cylinder is in its mid position

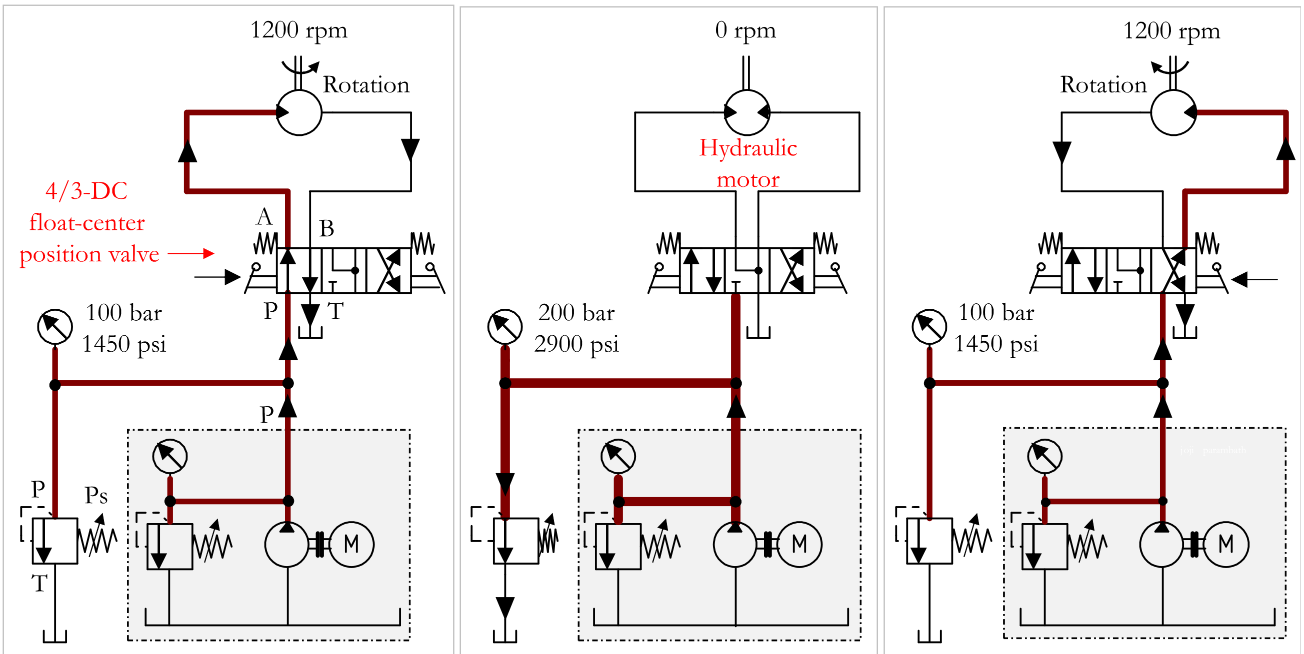
(d) When the 4/2-DC valve is actuated and the cylinder is fully extended

Control Task 2.10 | Control of a Hydraulic Motor Using a 4/3-DC, Float-center-position Valve

A 4/3-DC valve is used to run a hydraulic motor in clockwise and anti-clockwise directions, in a hydraulic system with a fixed-displacement pump. The circuit should provide a soft stop of the motor. The circuit should be designed in such a way as to support the independent control of multiple actuators to be connected to the system. The system shall be able to set a maximum pressure of 100 bar (1450 psi). Develop a hydraulic circuit to implement the above control requirements.

Solution

Control of a Hydraulic Motor Using a 4/3-DC Float-center Valve for its Bi-directional Rotation



(a) When the DC valve is shifted to its left envelope position

(b) When the motor comes to a smooth stop

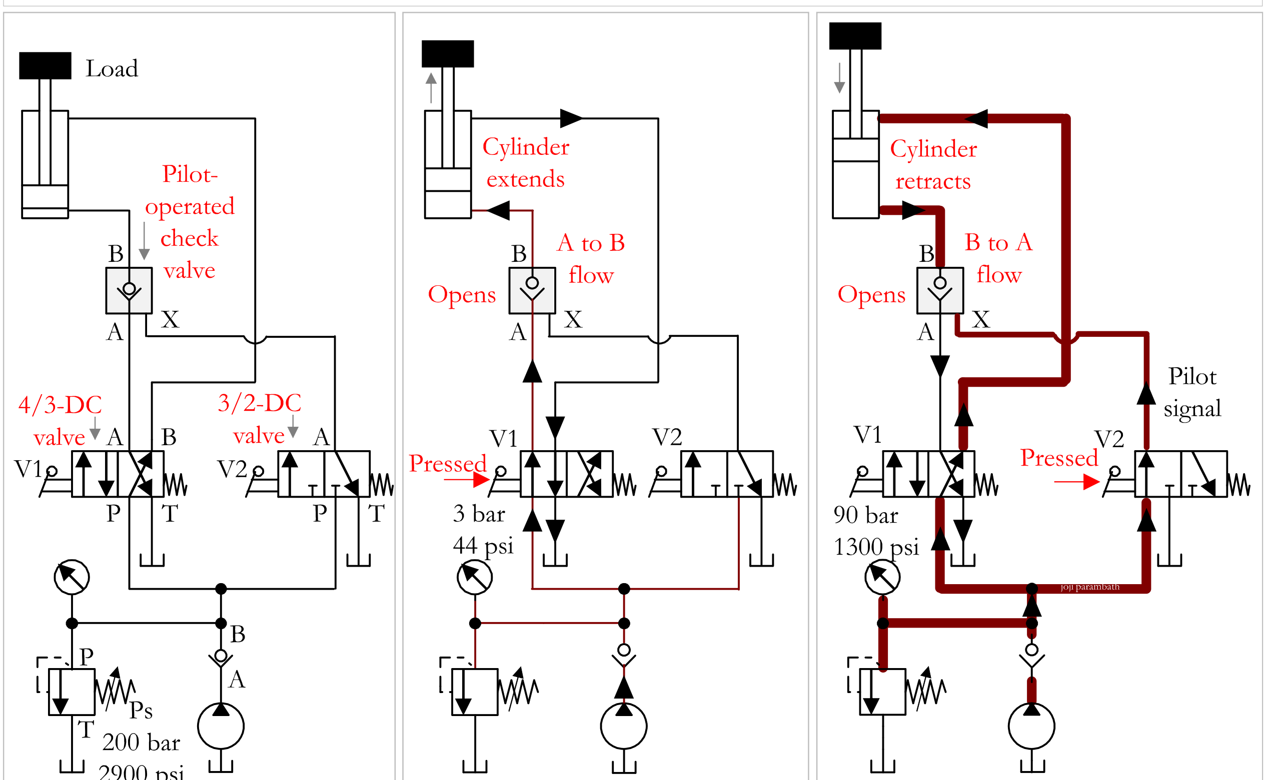
(c) When the DC valve is shifted to its right envelope position

Chapter 3 | Hydraulic Circuits with Check Valves

Control Task 3.4 | An alternative Circuit for the Load-holding Hydraulic System
A vertically-mounted double-acting cylinder in a hydraulic system is to move with a load. The extension stroke of the cylinder should be controlled by a 4/2-DC valve and a pilot-operated check valve. The retraction stroke should be controlled by pilot line control of the check valve through a 3/2-DC valve. The motion of the cylinder should stop midway in either direction when the respective DC valve is released. A fixed-displacement pump is used as the power source. The system shall be able to set a maximum pressure of 200 bar (2900 psi). Develop a hydraulic circuit to implement the control scheme.

Solution

An Alternative Circuit for the Load Holding Hydraulic System



(a) The hydraulic circuit (b) When 4/3-DC valve is pressed (c) When 3/2-DC valve is pressed

Chapter 4 | Hydraulic Circuits with Flow Control Valves

The speed of hydraulic actuators (cylinders and motors) can be reduced conventionally by using flow control valves. The speed of an actuator may be required to be controlled in one or both directions. An essential function of a flow control valve is to offer hydraulic resistance to the flow of the system fluid and hence to control the flow rate of the fluid.

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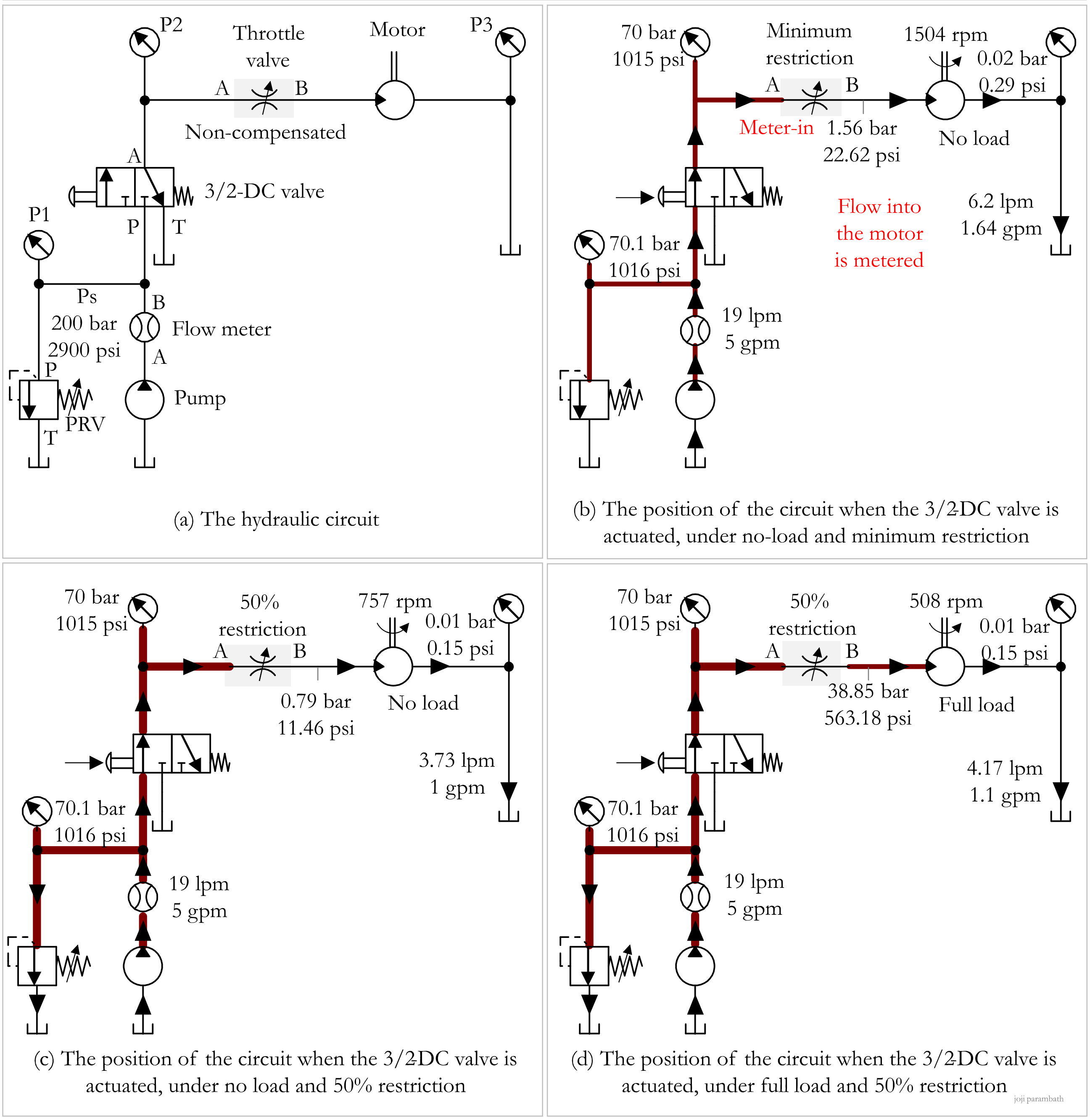
.Control Task 4.2 | Speed Control of a Unidirectional Hydraulic Motor Using a Non-compensated Throttle Valve for Meter-in Connection

A hydraulic motor is used as a rotary drive for a uni-directional machine operation with varying load and speed requirements. Develop a circuit for the speed control of the motor using a non-compensated throttle valve (Needle valve). A 3/2-DC valve can be used for the start-and-stop control of the motor. A fixed displacement pump without a case drain port is used as the power source. A PRV is used to set the maximum pressure to 70 bar (1000 psi).

Solution

Speed Control of a Unidirectional Hydraulic Motor Using a Throttle Valve for Meter-in Connection



(a) The hydraulic circuit

(b) The position of the circuit when the 3/2-DC valve is actuated, under no-load and minimum restriction

(c) The position of the circuit when the 3/2-DC valve is actuated, under no load and 50% restriction

(d) The position of the circuit when the 3/2-DC valve is actuated, under full load and 50% restriction

Control Task 4.11 | Speed Control of a Double-acting Hydraulic Cylinder Using a By-pass Flow Control (Bleed-off) Method

Develop a circuit for the speed control for the forward stroke of a double-acting cylinder with leak-tight piston seals in a single pump single actuator hydraulic system using the bypass flow control method. The speed of the return stroke is uncontrolled. A 4/3-DC tandem-center-position valve is used for directional control of the cylinder. A pressure-compensated flow control valve is preferred. A fixed displacement pump is used as the power source with a fluid delivery of, say, 5 lpm (1.32 gpm). A PRV is used to set the maximum pressure to 200 bar (2900 psi).

Solution

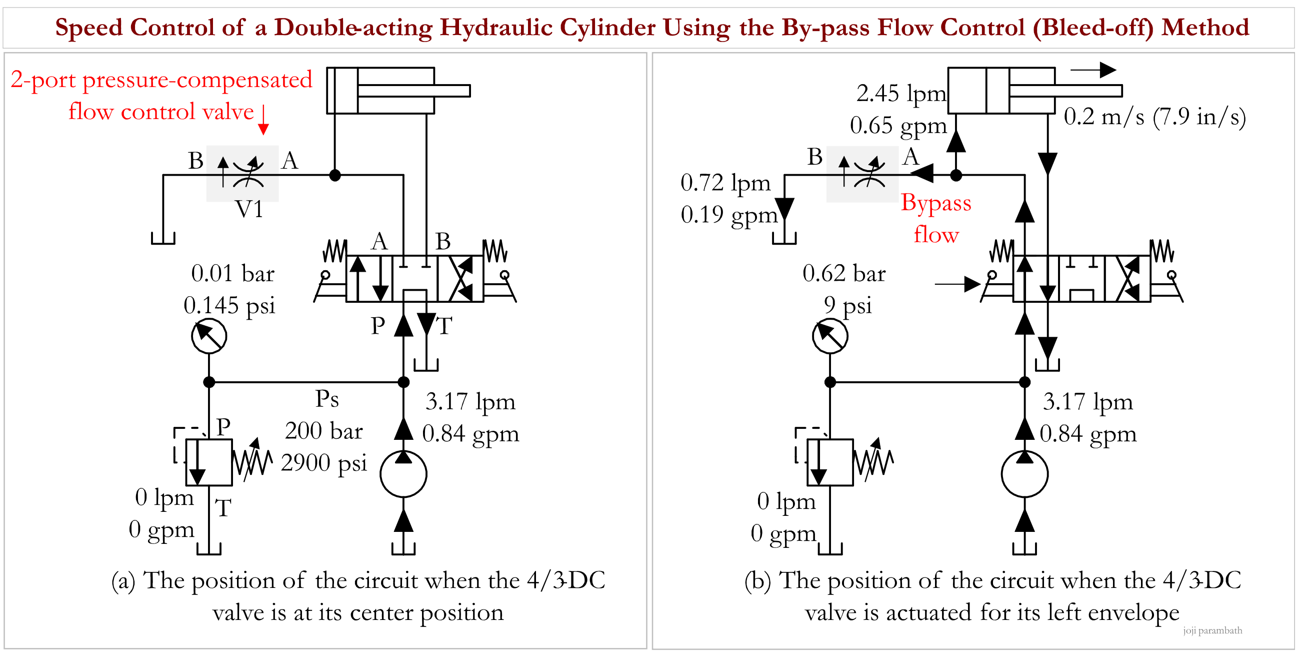


Figure 4.12 | Speed control of a hydraulic cylinder using the bypass flow method (Control Task 4.11)

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Hose Burst Check Valves

A hydraulic cylinder can be used for moving heavy loads downward using the pressurized fluid medium, as in a crane or earthmoving equipment. The fluid will flow to the atmosphere in case the flexible hose connected to the output port of the cylinder ruptures. This situation would bring the load downward in a very dynamic and dangerous way causing damage to machinery and a possible injury to personnel. Such a negative load application should have a provision, in case of a hose burst situation, to hold the load in place without the development of dynamic pressure peaks.

Control Task 4.16 | A Hydraulic Cylinder Circuit with a Hose Burst Check Valve

A hydraulic cylinder is used in a crane for bringing a heavy load downward using a 4/2-DC valve. The cylinder ports need to be connected to the DC valve using flexible hoses. It is also necessary to protect the circuit against hose rapture due to the development of high shock pressures. Develop a hydraulic circuit incorporating a hose burst valve.

Circuit Omitted

Chapter 5 | Hydraulic Circuits with Flow Dividers and Combiners

Flow Divider/Combiner

A flow divider is a hydraulic device that divides a single inlet flow from a source into two or more prescribed outlet flows regardless of the load pressures at the outlet ports. A flow combiner is a hydraulic device that combines flow from two sources into a single flow. A flow divider may not combine two return flows in the prescribed proportion to form a single stream. A valve that can divide and combine in prescribed proportions requires a special spool. There are two common types of flow divider devices. They are: (1) rotary type and (2) sliding-spool type. Combiners are only of the sliding spool types. The symbols of flow dividers and combiners are given in the following section.

Control Task 5.6 | Synchronized Movement of Two Bi-directional Hydraulic Motors attached with Negative Loads Using a Sliding Spool Flow Combiner

Two hydraulic motors subjected to negative loading are to be operated synchronously. A spool-type flow combiner is used to combine the fluid streams released from the motors. A constant-displacement pump supplies a constant flow to the system. Incorporate an appropriate directional control valve and pressure relief valves into the circuit. Develop a basic circuit for realizing the control Task.

Solution

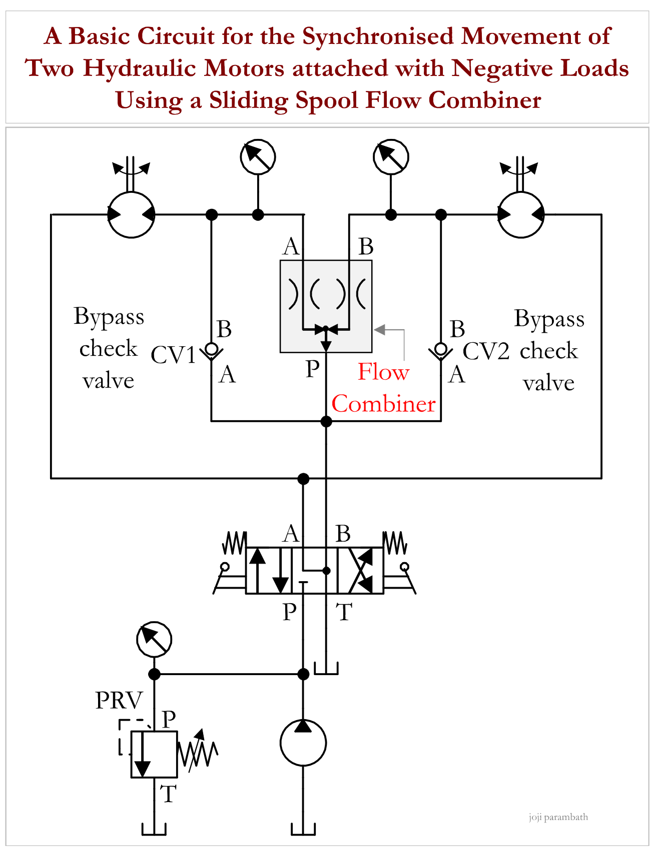


Figure 5.10 | A circuit for the synchronized movement of two bi-directional hydraulic motors

Figure 5.10 shows a circuit for the synchronous movement of two bi-directional hydraulic motors attached with negative loads. A fixed displacement pump supplies fluid to the system. A flow divider combines the fluid streams released from the motors. A 4/3-DC valve is used for directional control of the motors.

Chapter 6 | Hydraulic Circuits with Pressure Control Valves

Pressure control valves are used in hydraulic systems for obtaining pressure-related control tasks.

Control Task 6.1 | Operational Parts with Different Set Pressures in a Single-pump System Using a 2-way Pressure Reducing Valve

Develop a single pump hydraulic circuit that employs a high pressure in one section of the circuit, say, for a high bending force, and a reduced pressure in another part of the circuit, say, for a low clamping force.

Solution

A Hydraulic Circuit with a 2-way Pressure Reducing Valve

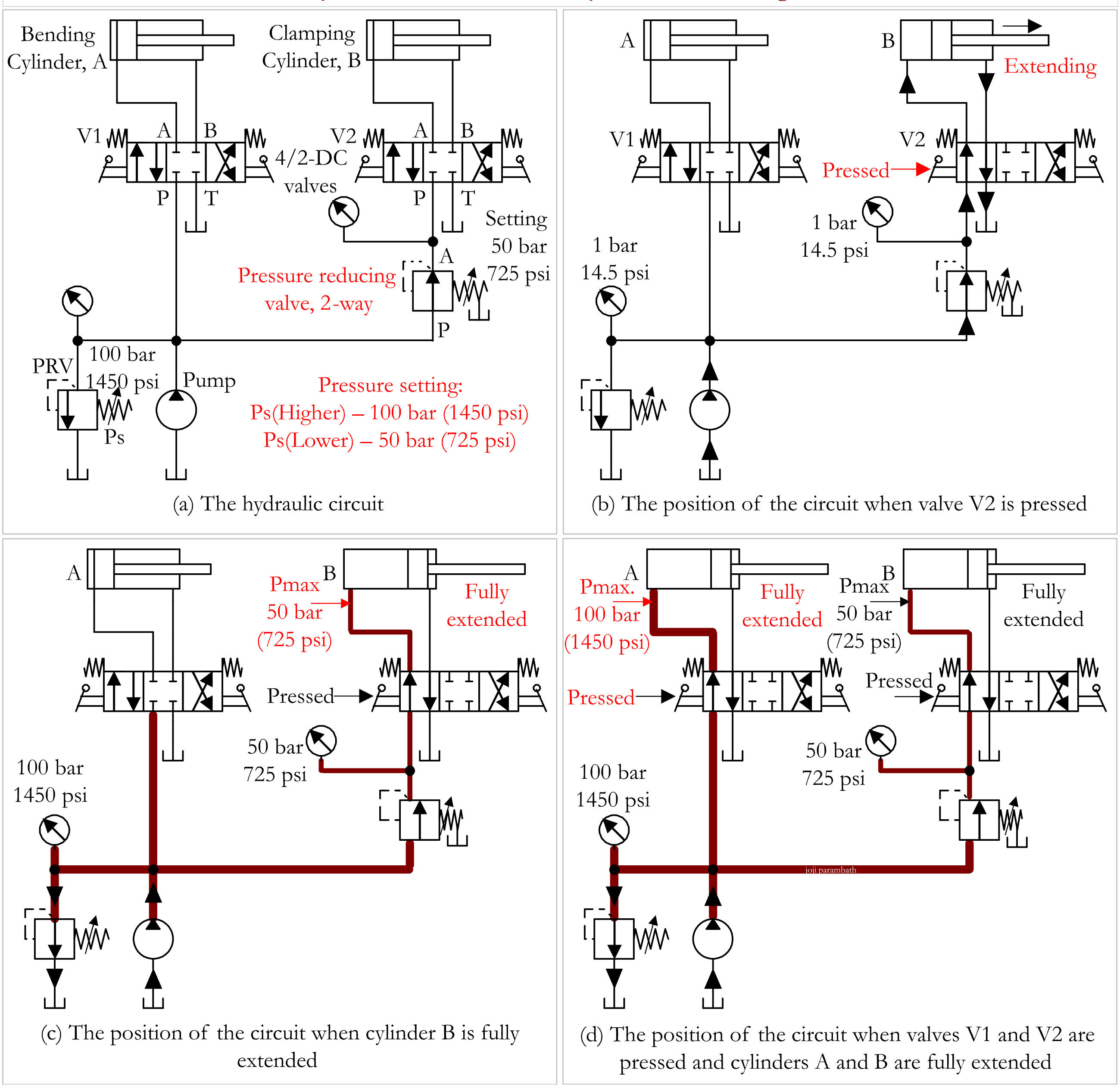


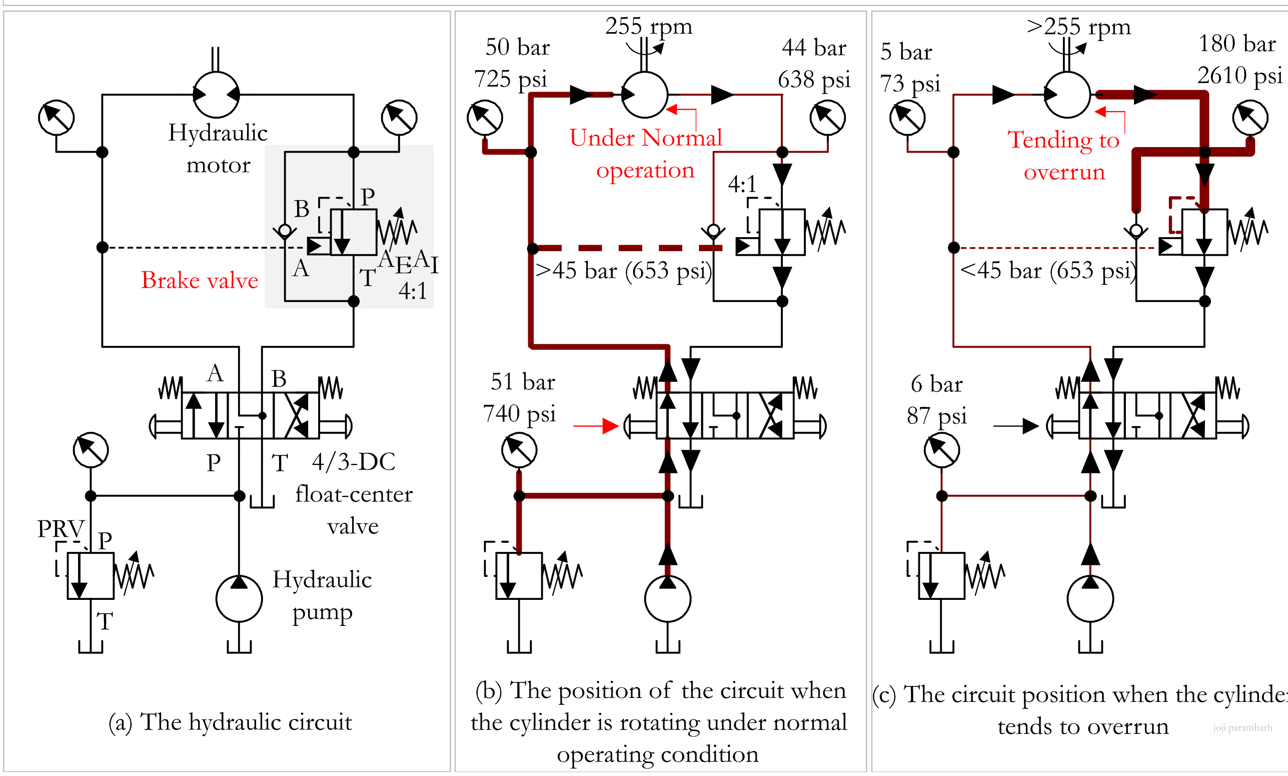
Figure 6.2 | A hydraulic circuit with a 2-way pressure-reducing valve (Control Task 6.1)

Control Task 6.8 | Braking a Hydraulic Motor Using a Brake Valve

A braking arrangement using a hydraulic brake valve, with an internal pilot and external pilot, is to be incorporated into a hydraulic motor driving a conveyor. It requires a pressure of 45 bar (653 psi) at the motor inlet to keep the brake valve open. If the conveyor begins to run the motor faster than the pump flow does and the pressure drops below 45 bar (652 psi), then the brake valve operates. It requires a pressure of 180 bar (2610 psi) at the internal pilot to open the brake valve. Develop a suitable hydraulic circuit.

Solution

A Circuit for the Braking Operation of a Hydraulic Motor Using a Brake Valve



(a) The hydraulic circuit

(b) The position of the circuit when the cylinder is rotating under normal operating condition

(c) The circuit position when the cylinder tends to overrun

Chapter 7 | Hydraulic Circuits with Accumulators

An accumulator is a device used for absorbing shock pressures and storing energy in a hydraulic system. It mainly consists of a vessel in which a hydraulic fluid is held under pressure by a raised weight, spring, or volume of compressed gas. It is, thus, possible to store potential energy in the accumulator, when the associated system pressure remains higher than that of the accumulator. The accumulator can release the stored energy back into the system for performing some useful hydraulic task when the system pressure falls below that of the accumulator.

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Symbols – Hydraulic Accumulators

The symbols of different types of accumulators and their descriptions are given in Figure 7.1.

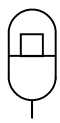
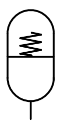
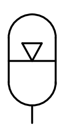
	**Weight-loaded accumulator** It consists of a vertically-mounted steel cylinder with a movable piston. A series of dead weights is placed on the top of the piston. A fluid chamber is formed on one side which is connected to the hydraulic side. The piston along with the dead weight is raised when the fluid under pressure works against the piston. The weight exerts a downward push on the piston as a result of the force of gravity and thereby energizes the fluid.
	**Spring-loaded accumulator** It consists of a cylinder body and a piston preloaded with a spring. A fluid chamber is formed on one side which is connected to the hydraulic side. The spring is compressed when the pressurized fluid enters the chamber. The compressed spring can act against the piston. As the system pressure reduces, the fluid from the accumulator is forced out by the charged spring.
	**Gas-charged accumulator** It consists of a steel shell with a physical barrier, such as a diaphragm, bag, or floating piston, which separates the shell into a gas chamber and a fluid chamber. Accordingly, gas-charged accumulators can be classified into the diaphragm, bag, and piston types. The gas chamber is pre-charged with pure nitrogen gas. The fluid chamber is connected to the hydraulic system. A gas-charged accumulator draws the fluid from the system when the system pressure goes up, thus compressing the gas. When the system pressure drops, the pressurized gas expands and forces the fluid back into the system

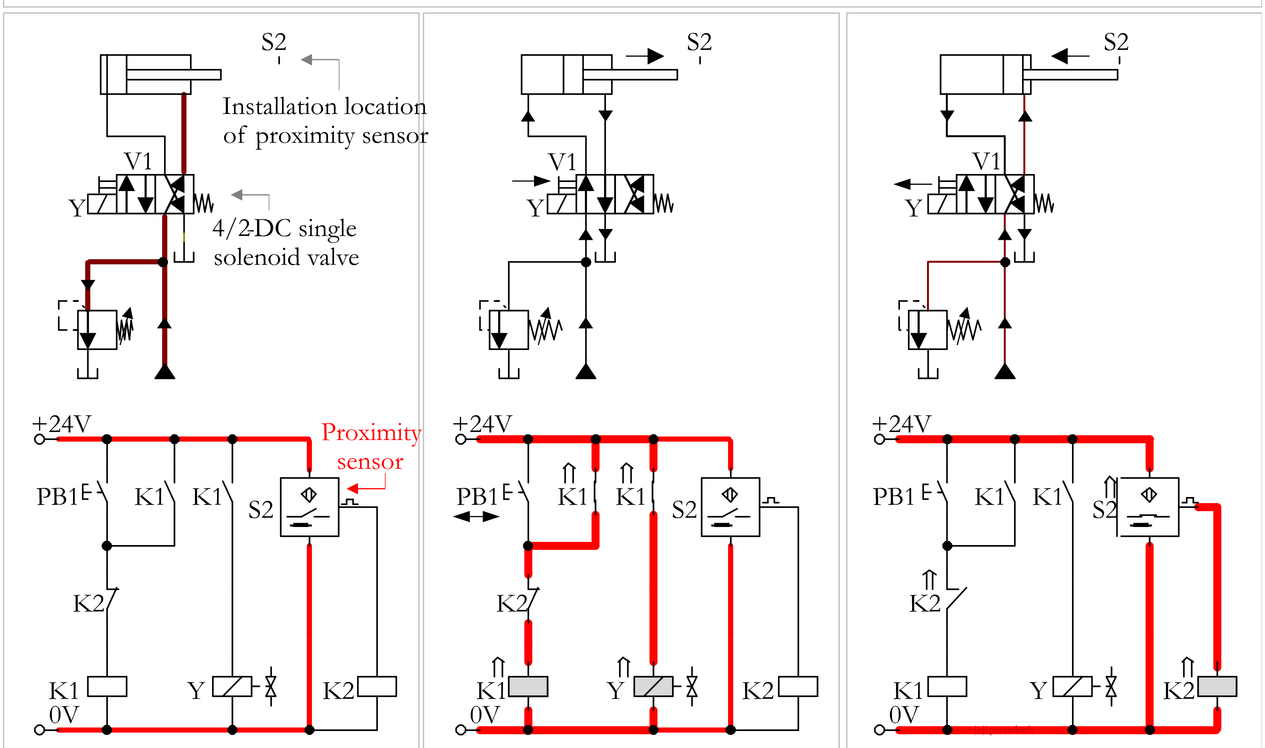
Figure 7.1 | Symbols and functions of different types of hydraulic accumulators

Control Task 9.9 | Semi-automatic Operation of a Double-acting Hydraulic Cylinder Using a 4/2-DC Single-solenoid Valve and a Proximity Sensor

A double-acting cylinder is to extend when a pushbutton is pressed. On reaching the end position, the cylinder is to retract automatically. A 4/2-DC single-solenoid valve is used as the final control element. Develop an electro-hydraulic control circuit to implement the control task using a proximity sensor for the semi-automatic operation of the cylinder.

Solution

Semi-automatic Operation of a Double-acting Hydraulic Cylinder Using a 4/2-DC Single-solenoid Valve and a Proximity Sensor



(a) The electro-hydraulic circuit

(b) When PB1 is pressed and released

(c) When sensor S2 is just pressed

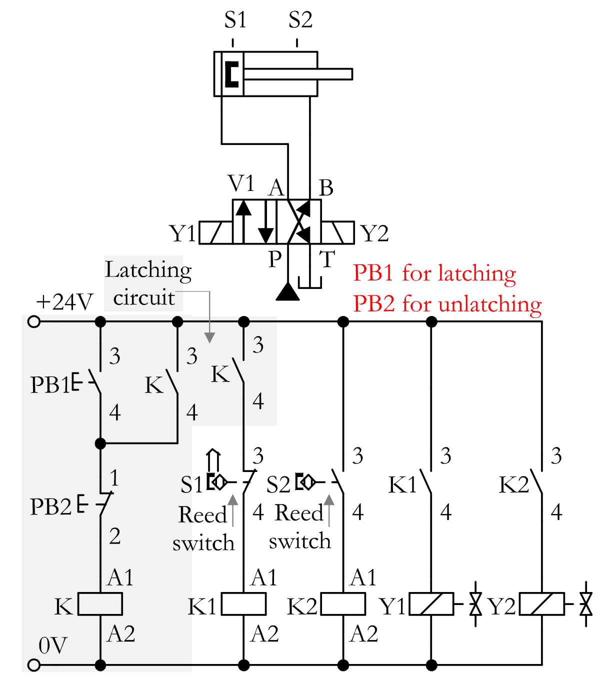
Figure 9.12 | Multiple positions of an electro-hydraulic circuit for the automatic return motion of a double-acting cylinder using a 4/2-DC single-solenoid valve and proximity sensor (Control Task 9.9)

Figure 9.12(a) shows the circuit for the automatic return motion of a double-acting hydraulic cylinder using a proximity sensor. A 4/2-DC single-solenoid, spring-return valve is used as the final control element.

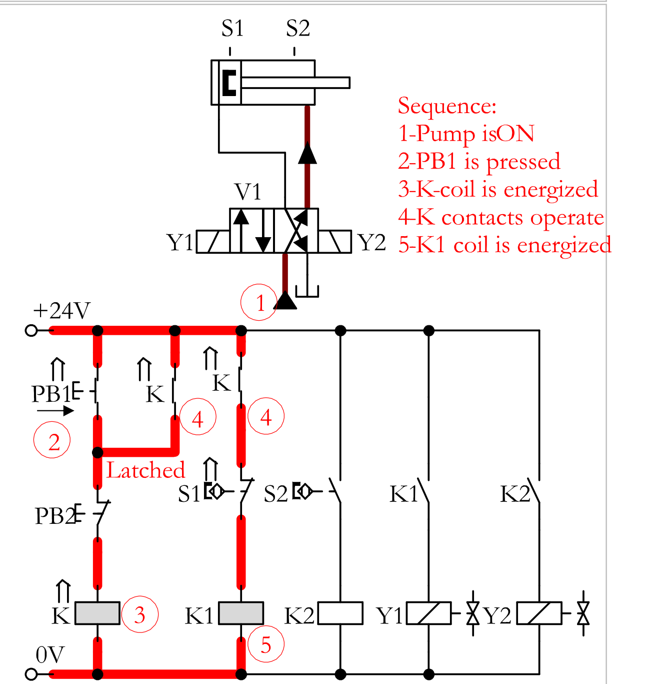
Figure 9.12(b) shows the circuit when pushbutton PB1 is momentarily pressed. The electrical circuit is latched when pushbutton PB1 is pressed. Solenoid coil Y is energized and actuates valve V1. The valve remains in the actuated position even when pushbutton PB1 is released. The cylinder starts moving forward.

A Complete Electro-hydraulic Circuit for the Fully-automatic Operation of the Cylinder

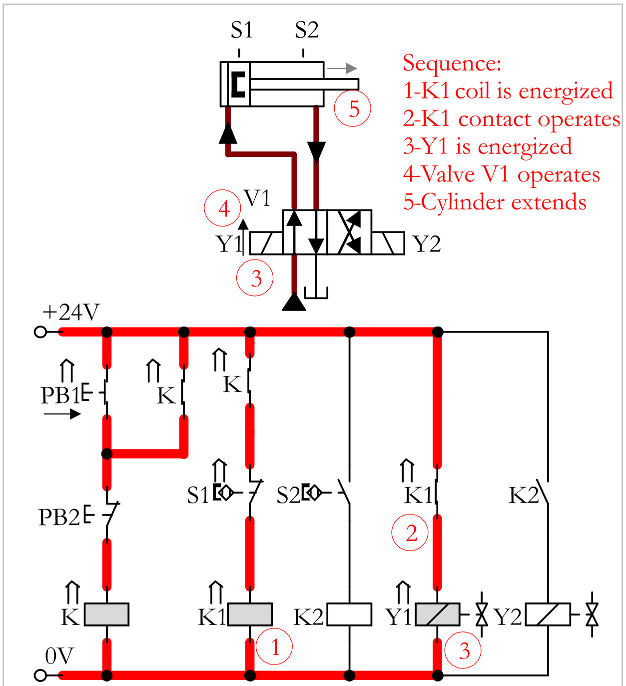
The Cyclic Operations of a Double-acting Hydraulic Cylinder



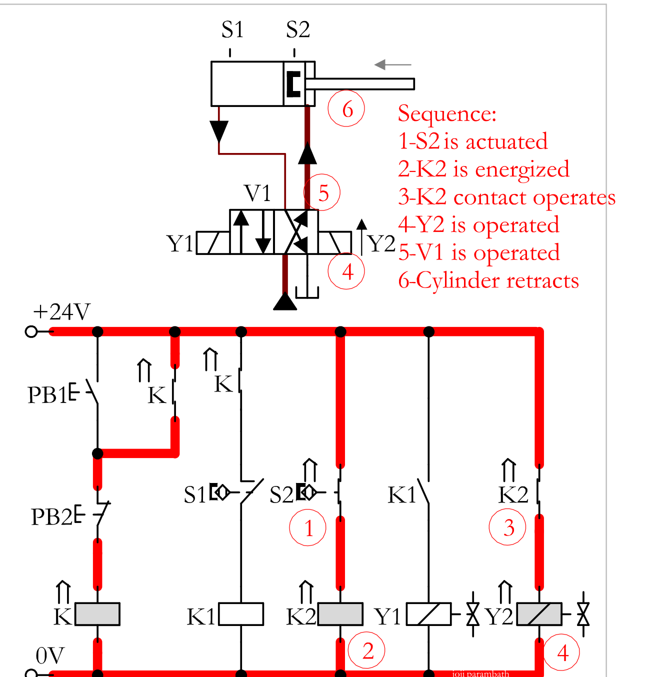
(a) The electro-hydraulic circuit for the cyclic operation of a hydraulic cylinder, Sensor S1 is initially activated



(b) The position of the circuit when PB1 is pressed, the circuit is latched through the K contact, Relay K1 picks up



(c) The position of the circuit when solenoid coil Y1 is energized, 4/2 DC valve is actuated, and cylinder extends

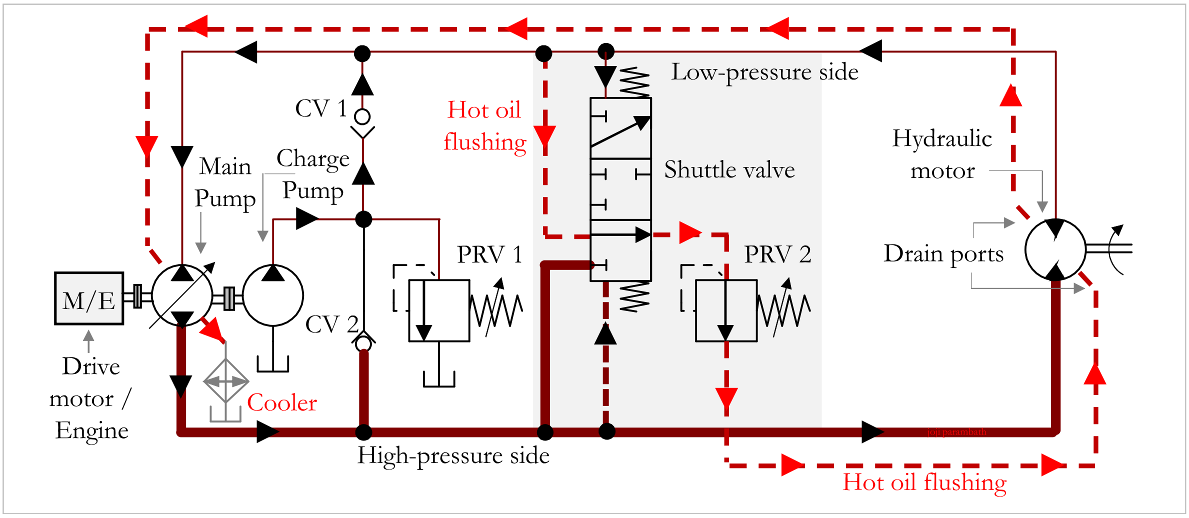


(d) The position of the circuit when Sensor S2 is activated, Relay K2 picks up, Solenoid coil Y2 is energized, and cylinder retracts

Chapter 10 | Circuits for Closed-circuit Hydro-static Transmissions (HSTs)

Control Task 10.4 | A Closed-circuit HST with Loop Flushing and Cooling

A Closed-circuit HST with a Charge Pump and Loop Flushing Circuit for Cooling



Summary of Progression of Closed-circuit HSTs

A closed-circuit HST can be thought of as consisting of several circuits like a charge pump circuit, flushing circuits, high-pressure PRVs, and accumulators. Table 10.1 gives the progression of closed-circuit HSTs and the functions of the circuit parts.

Table 10.1 | A typical progression of closed-circuit HSTs

HST Progression	Function	Remarks
Basic closed-circuit HST with a pump and hydraulic motor	The pump delivers fluid to the motor and the fluid discharged from the motor outlet flows to the inlet of the pump.	The drawback is the leakage of fluid through the case drains of the pump and motor
Closed-circuit HST with charge pump circuit	The charge pump circuit, with a low-pressure pump, PRV, and check valves, is added to the basic HST to compensate for the leakage flows	-The flow rate of the charge pump should be at least 20% of the flow rate of the main pump. -The PRV is set to 10 to 35 bar (145 to 500 psi).
Closed-circuit HST with charge pump circuit and flushing circuit	A flushing circuit is integrated into the HST to direct the hot fluid purged from the transmission loop to the reservoir preferably through the series-connected case drain lines of the pump and motor for flushing and lubricating and for increased cooling and filtering.	The flushing relief valve is typically set at a pressure that is 2 bar (29 psi) less than the set pressure of the charge pump PRV.
Closed-circuit HST with charge pump circuit, flushing circuit, and high-pressure PRVs	High-pressure PRVs must be added to an HST circuit to limit the maximum operating pressure of the entire system and prevent an inadvertent overload on the hydraulic motor.	High-pressure HSTs can be added with a cross-port configuration or with a back-to-back configuration linked to the charge pump circuit.
Closed-circuit HST with charge pump, flushing circuit, high-pressure PRVs, and Accumulators	An accumulator can be used in a closed-circuit HST to absorb shock pressures in the high-pressure loop or to provide instantaneous low-pressure loop make-up flow.	-Accumulators can be placed on the high-pressure side and low-pressure side of the HST loop. -An accumulator on the high-pressure side dampens pressure fluctuations. -An accumulator on the low-pressure side reduces the possibility of cavitation.

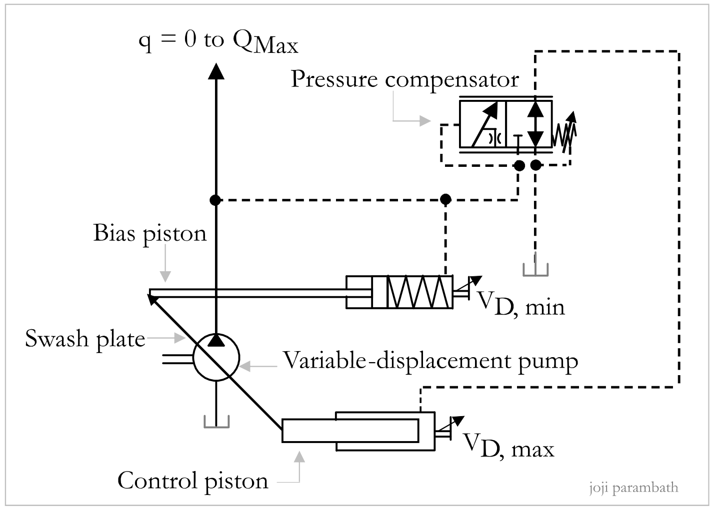
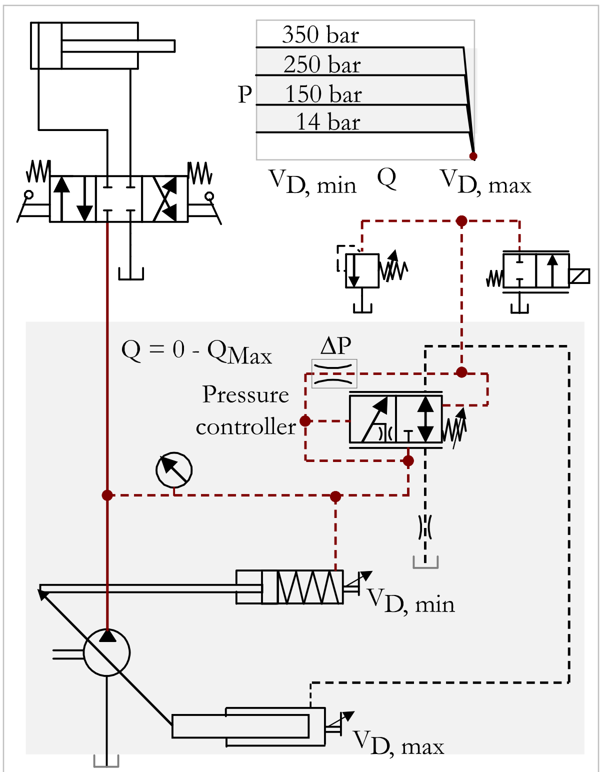


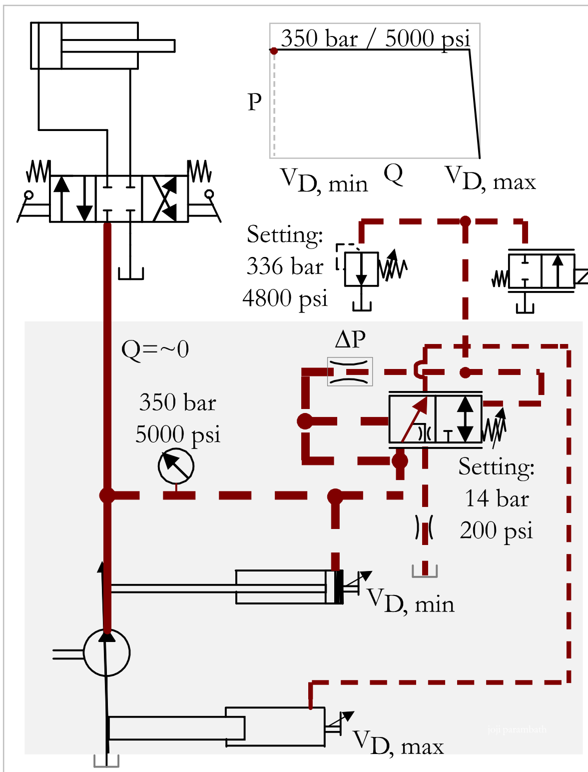
Figure 11.2 | A basic circuit of a servo-controlled variable displacement pump

Control Task 11.4 | Axial Piston Variable Displacement Pump with a Pressure Controller, Hydraulically Remote Controlled

An Variable-displacement Pump with a Pressure Controller, Hydraulically Remote Controlled

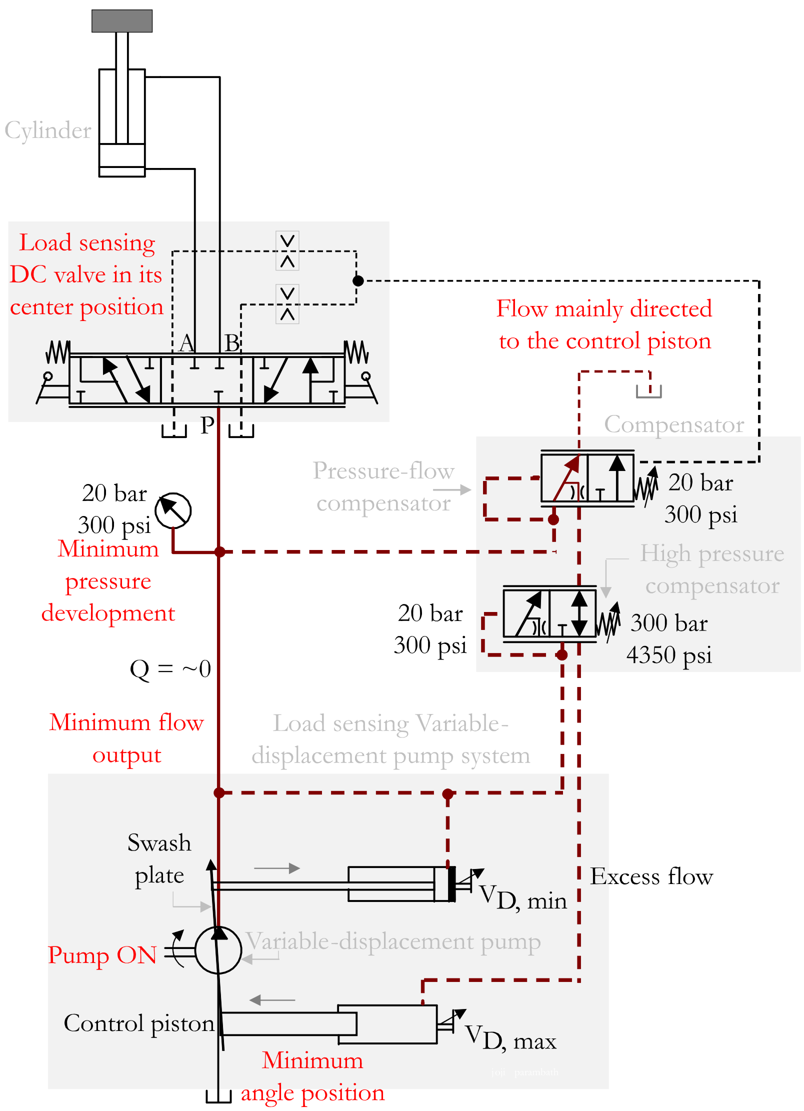


(a) An axial piston variable-displacement pump with a pressure controller – Circuit diagram



(b) The variable-displacement pump with a pressure controller when set pressure is reached

A Load Sensing Hydraulic System – Low-pressure Standby Mode



The pump flow acts on the left-hand side of the pressure-flow compensator spool and high-pressure compensator spool when the pump is switched on.

When the pressure reaches slightly above 20 bar (300 psi), the pressure-flow compensator spool moves to the right against the low-pressure spring, and the flow is directed to the control piston.

This flow causes the control piston to extend and makes the swash plate swing to its minimum angle position and the pump to deliver a minimum flow at low pressure.

In the standby mode of operation, the pump provides only enough flow to make up for the internal leakage in the system.

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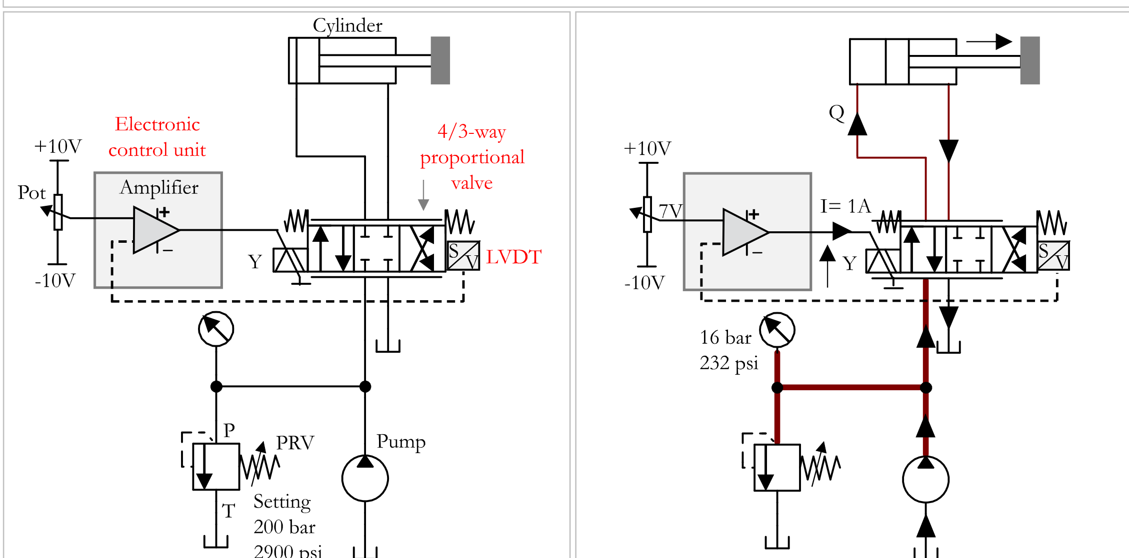
Control Task 13.2 | A Closed-loop Electro-hydraulic Circuit for the Control of a Double-acting Hydraulic Cylinder Using a 4/3-way Proportional Valve and an LVDT

A closed-loop control system is to be designed for the feed motion control of a double-acting hydraulic cylinder, for a more accurate lathe drive, using a 4/3-way proportional solenoid valve and LVDT. The direction of motion and the speed of the cylinder are to be controlled. A fixed-displacement pump delivers the required flow to the system and a PRV can be used to set the pressure in the system. Develop a control circuit.

Solution

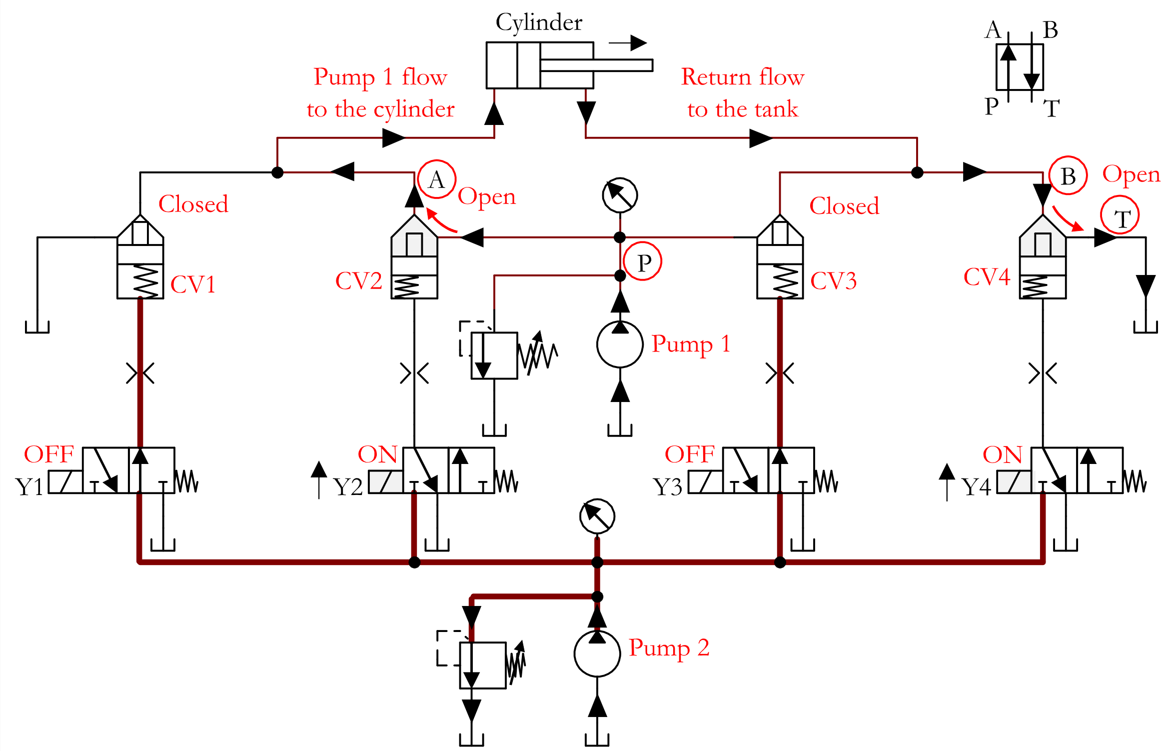
A Closed-loop Circuit for the Control of a Double-acting Hydraulic Cylinder Using a 4/3-way Proportional Valve and a LVDT



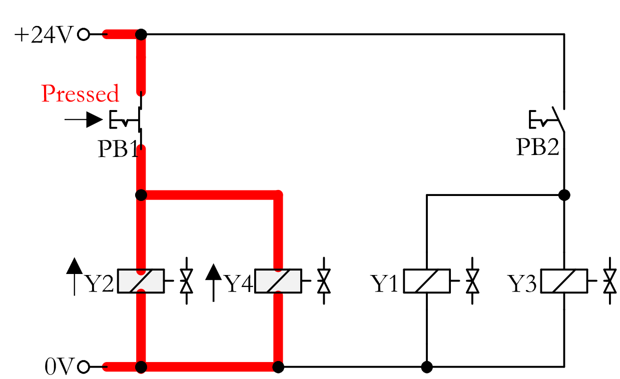
(a) The closed-loop circuit for the direction and speed controls of a double-acting cylinder using a 4/3-way proportional valve and a LVDT

(b) The position of the circuit when the potentiometer is set for a voltage, say 7V, and the cylinder is extending

The Position of the Circuit When Pushbutton PB1 is Pressed



(a) The position of the circuit when pushbutton PB1 ispressed and the cylinder is extending



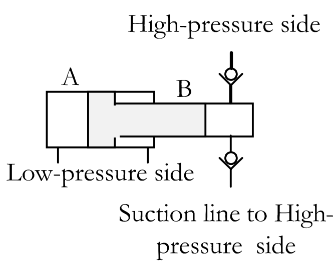
(b) The position of theelectric circuit when pushbutton PB1 is pressed

Chapter 16 | Hydraulic Circuits with Pressure Intensifiers

Hydraulic pressure intensifiers (Pressure boosters) are devices used for obtaining very high pressures from low-pressure power sources. Pressure intensifiers can typically provide intensification ratios up to 1:20.

Symbols - Pressure Intensifiers

Symbols of two types of hydraulic pressure intensifiers are given in Figure 16.1.



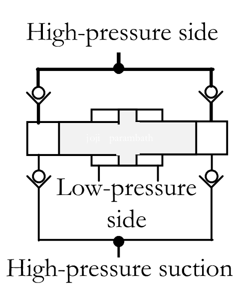
Single-stroke (One-shot) Pressure Intensifier

It mainly consists of a larger cylinder A and a smaller cylinder B. Let the larger cylinder A has a piston area of A_1, and the smaller cylinder B has a piston area of A_2 $(A_1 > A_2)$. The ratio of the larger piston area to the smaller piston area (A_1/A_2) is the pressure intensification ratio. The pistons are connected by a common rod. Check valves separate the suction and discharge lines of the intensifier.

A low-pressure supply fluid is drawn into the fluid compression chamber of cylinder B through the suction line when the piston and piston-rod assembly retracts. When a high-flow-low-pressure fluid is applied to the large piston of cylinder A, it develops a force that is transferred mechanically to the smaller piston of cylinder B and pushes it. The smaller piston generates a higher-pressure fluid with each stroke and a low-flow-high-pressure hydraulic fluid is forced out from cylinder B. The output pressure increases by a factor equal to the pressure intensification ratio. That is,

Output pressure = Inlet pressure x Intensification ratio

The larger piston can be retracted by spring, air or oil. In a single-stroke intensifier, the high-pressure flow is intermittent.



Reciprocating Type Pressure Intensifier

It consists of a centrally mounted low-pressure piston on a double-ended piston rod and high-pressure chambers at either end of the low-pressure piston. The large piston on the low-pressure side can be made to reciprocate with a suitable control scheme.

A continuous high-pressure flow output can be obtained with the use of two back-to-back single-stroke intensifiers feeding the same system with staggered strokes.

Figure 16.1 | Symbols of pressure intensifiers

Control Task 16.3 | A High-pressure Circuit for a Plastic Injection Molding Machine

The mold parts of a molding machine require high clamping force and therefore these parts are supplied with a higher pressure of, say, 700 bar (10000 psi) than that used for other normal operations in the machine. The normal pressure employed is, say, 70 bar (1450 psi). A pressure intensifier (1:10 ratio) is to be used for realizing the higher pressure requirement for the clamping operation. Develop a circuit with a high-pressure-rated double-acting cylinder to clamp the mold parts.

Solution

A High-pressure Circuit for a Plastic Injection Molding Machine

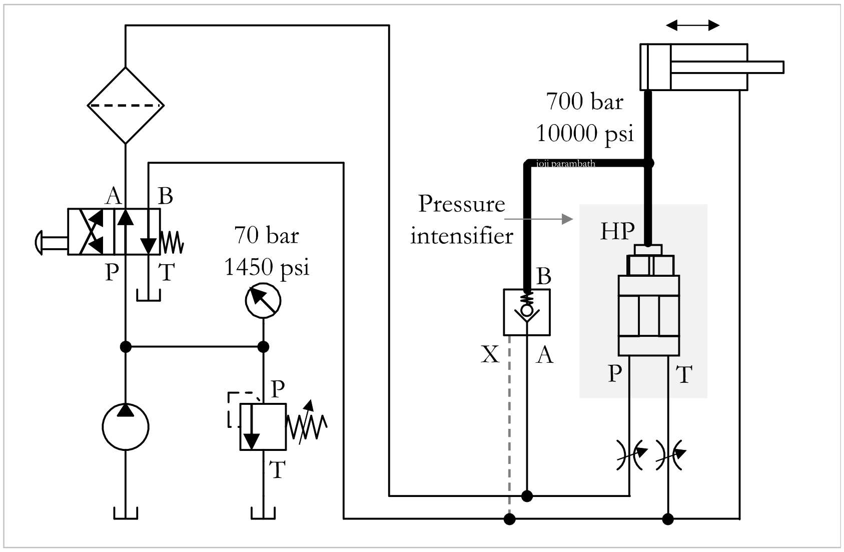


Figure 16.5 | Reciprocating pressure intensifier, continuous delivery (Control Task 16.3)

Chapter 17 | Layouts of Hydraulic Reservoirs

Control Task 17.1 | Trace Power Pack - Layout 1

Typical Configuration of a Hydraulic Power Pack: Layout 1

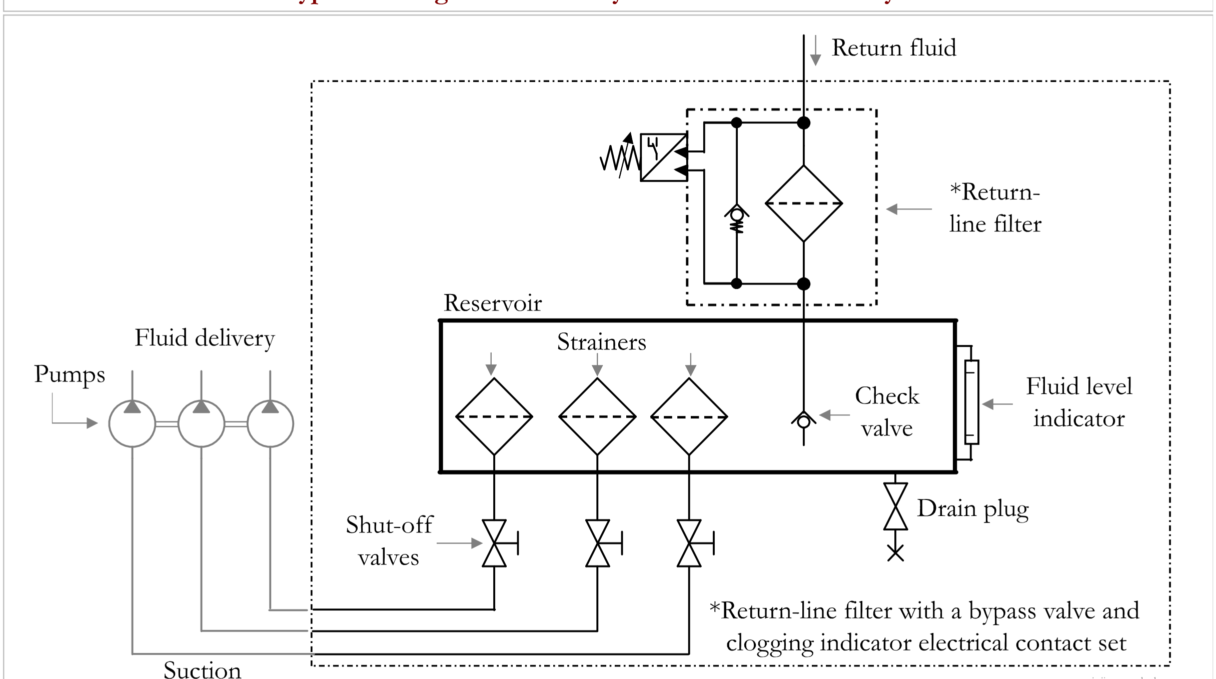


Figure 17.2 | A typical configuration of a hydraulic power pack (Layout 1)

Control Task 17.6 | Trace Fluid Cooling System with an Auxiliary Pump and a Hydraulic-motor-operated Heat Exchanger

Fluid Cooling System with an Auxiliary Pump and a Hydraulic-motor-operated Heat Exchanger

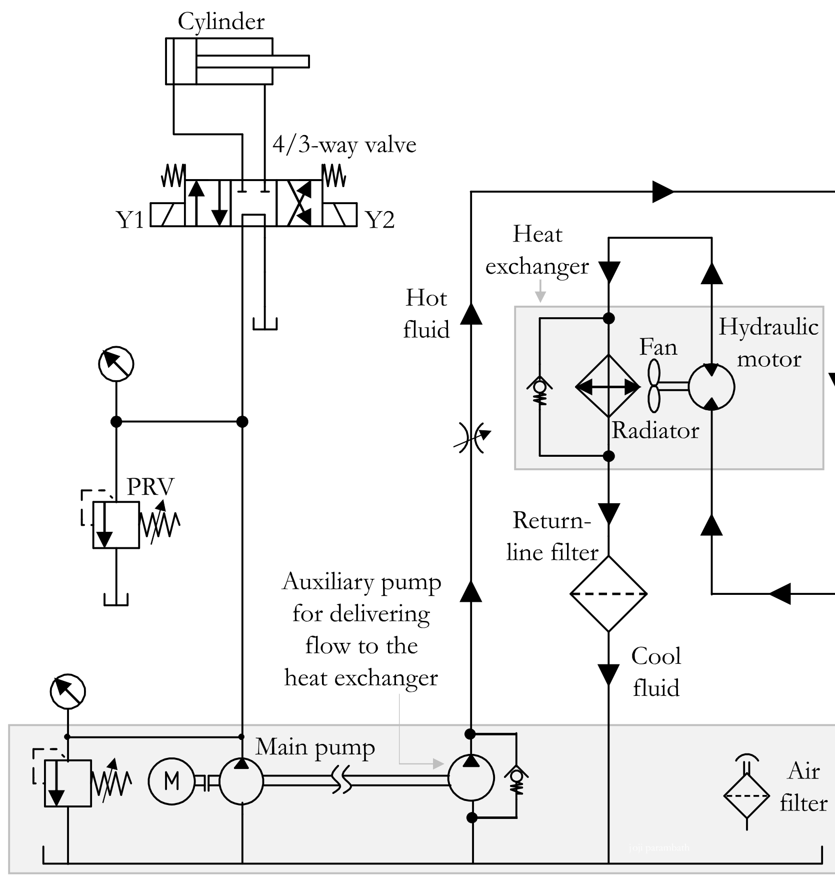
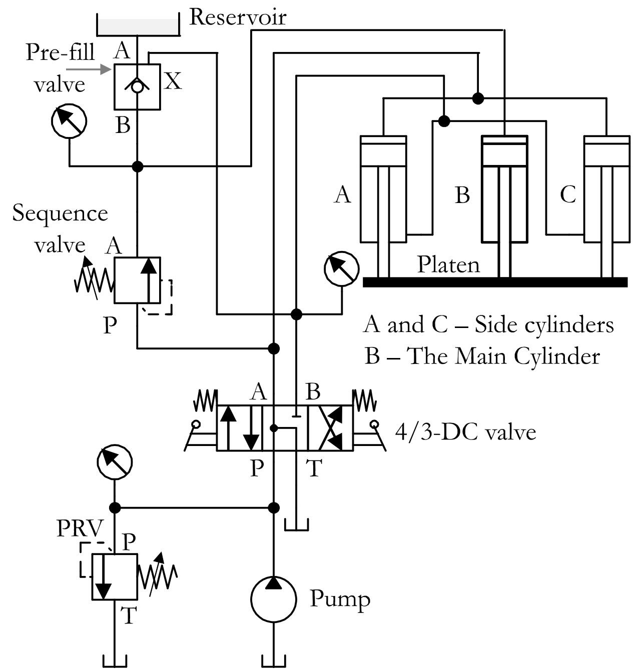
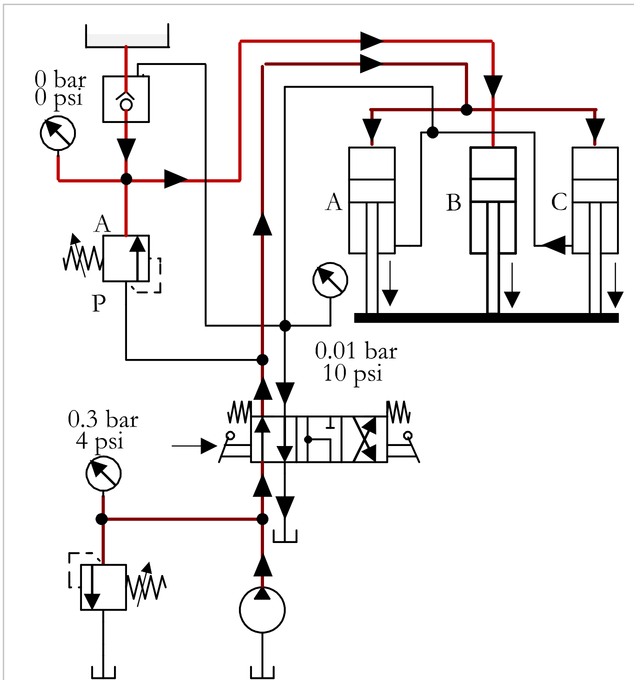


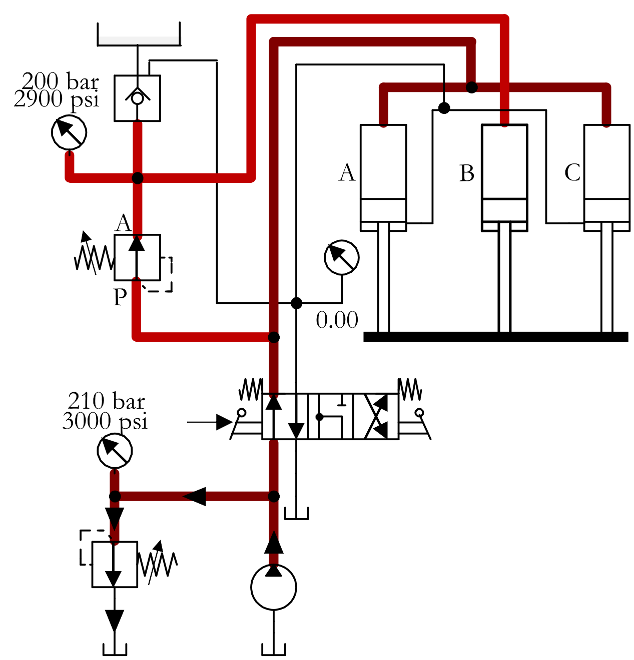
Figure 17.7 | A typical configuration of a hydraulic power pack with a heat exchanger (Layout 6)



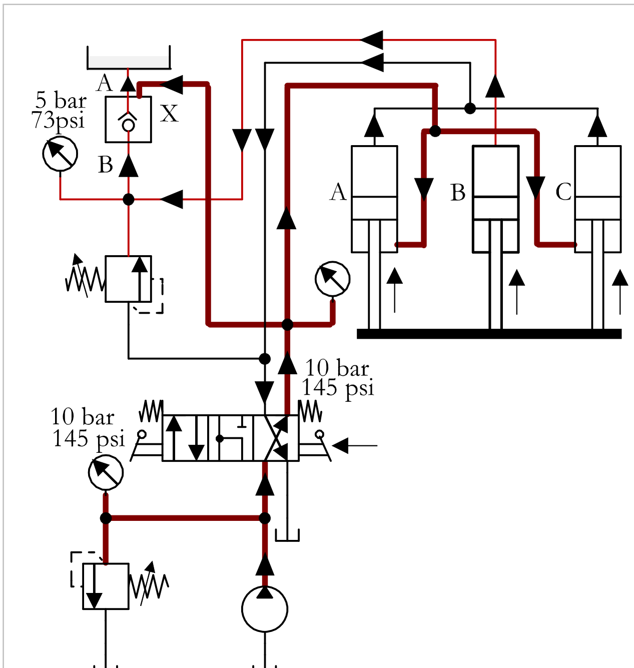
(a) The hydraulic circuit of a press with the main cylinder and two side cylinders



(b) The position of the circuit when the 4/3-DC valve is actuated for its left envelope and the cylinders are extending



(c) The position of the circuit when the 4/3-DC valve is actuated for its left envelope and the cylinders are extended



(d) The position of the circuit when the 4/3-DC valve is actuated for its right envelope and the cylinders are retracting

List of Control Tasks

Description
Hydraulic Circuits with Directional Control Valves
Control of a Single-acting Hydraulic Cylinder
Control of a Single-acting Cylinder with Filters and a Heat Exchanger
Control of a Single-acting Cylinder (Alternative Circuits with 4/2-DC Valves)
Control of a Hydraulic Motor for Unidirectional Operation
Control of a Double-acting Hydraulic Cylinder Using a 4/2-DC Valve
Control of a Double-acting Cylinder Using a 4/3-DC Tandem-center Valve
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Develop a Circuit for the Control of Multiple Hydraulic Cylinders with Series-connected Tandem-center Position Valves
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Speed Control of a Double-acting Hydraulic Cylinder for the feed motion of a cutting force Using the Meter-out method
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Semi-automatic Operation of a Double-acting Hydraulic Cylinder Using a 4/2-DC Double-solenoid Valve and a Proximity Sensor
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