Lesson 5: 953/953B and 953C Dual Hydrostatic Drive System Comparison

Introduction

The information in this lesson will allow students to understand how dual hydrostatic drive systems function and the similar functioning of mechanical/hydraulic and electric/hydraulic control systems.

The hydrostatic drive system on the 953 Track Loader and the 953B Track Loader consist of a hydrostatic power control unit with two overcenter, bi-directional, variable pumps driving dual bi-directional, fixed displacement motors.

The 953C Track Loader hydrostatic drive system consists of two independently mounted, overcenter, bi-directional, variable pumps and two bi-directional, variable displacement motors. This system uses electro-hydraulic valves to control the swashplate angle of both the pumps and the motors.

Objectives

Upon completion of this lesson, the student will be able to:

1. Identify components of the 953/953B Track Loader mechanical/hydraulic dual hydrostatic drive system.
2. Identify components of the 953C Track Loader electro-hydraulic dual hydrostatic drive system.
3. State the function of components in both hydrostatic drive systems.
4. State the similarities between the mechanical components in the 953/953B Track Loader and the electrical components in the 953C Wheel Loader.

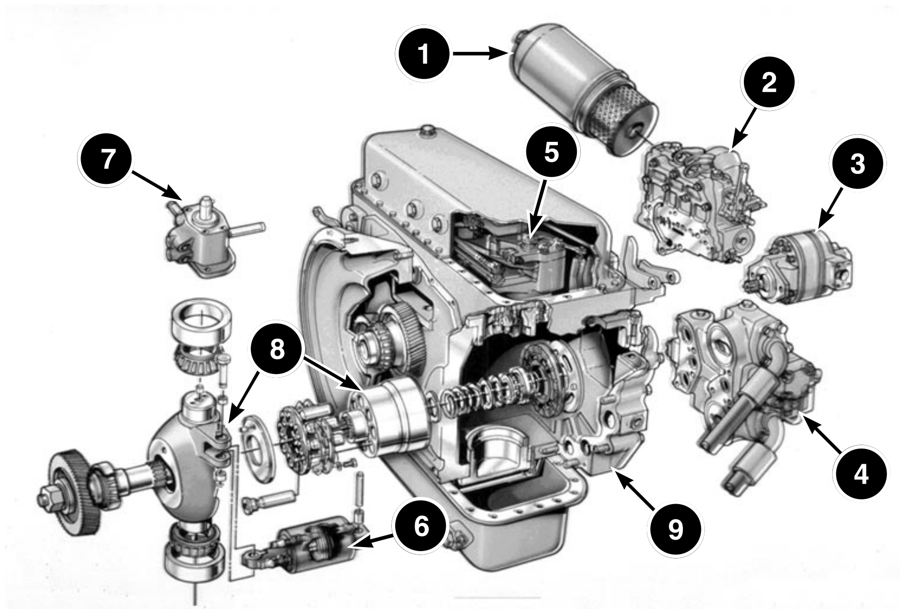

Fig. 3.5.1 953/953B Track Loader Hydrostatic Drive Components

MECHANICAL/HYDRAULIC HYDROSTATIC DRIVE

953/953B Track Loader Hydrostatic Drive System

Although the mechanical hydrostatic drive system is simple in design, some of the components and control mechanisms may be unfamiliar. This presentation will identify the function and operation of each major component. The operation of the complete system will be explained through the use of hydraulic schematics.

The hydrostatic drive system is divided into six separate hydraulic and mechanical systems that function together to transmit engine power to the final drives. Each system either transmits power or controls the amount of power transmitted.

When controlling the hydrostatic drive system, the operator must control the rate and the direction of flow from the variable displacement pump to the motor. Both the flow rate and the direction of flow are determined by the angle of the swashplate inside the variable displacement pump. When the swashplate angle is increased, the rate of flow to the motor is increased. Similarly, a decrease in the swashplate angle results in a decrease in the flow rate to the motor. The rate and direction of flow from the pump to the motor determine the speed and direction of the track.

The major hydrostatic drive components shown in Figure 3.5.1 are:

1. Filter
2. Main control valve
3. Charge pump
4. Right charge and main relief valve
5. Servo Control linkage
6. Servo cylinder
7. Servo valve
8. Piston pump and swashplate group
9. Head

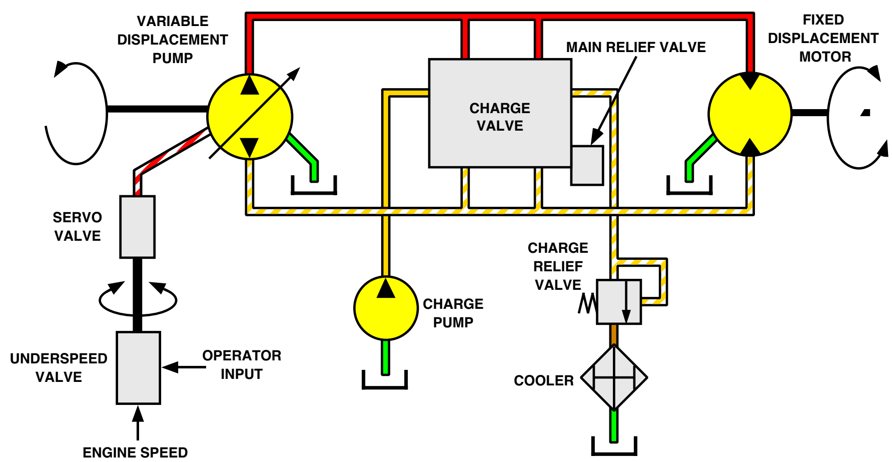

Fig. 3.5.2 953/953B Track Loader Hydrostatic Drive Schematic (Left side)

953/953B Track Loader Hydrostatic Drive Component Function

The hydrostatic power control unit (HPCU) uses a servo valve to control the position of the axial piston pump swashplate. The servo valve movement is mechanically controlled by the underspeed valve and the steering pedal (not shown).

The underspeed valve is connected through a mechanical linkage to the HPCU control lever in the operator's compartment. When the operator changes the position of the HPCU control lever, the servo control linkage, connected through the underspeed valve, will move the servo valve. This causes the position of the swashplate to change.

During machine operation, the underspeed valve automatically change the position of the servo valve and the position of the swashplate. The movement of the underspeed valve is controlled by the engine speed.

When a steering pedal is depressed, a mechanical linkage arrangement causes the servo valve to move. As a result, the angle of the swashplate changes.

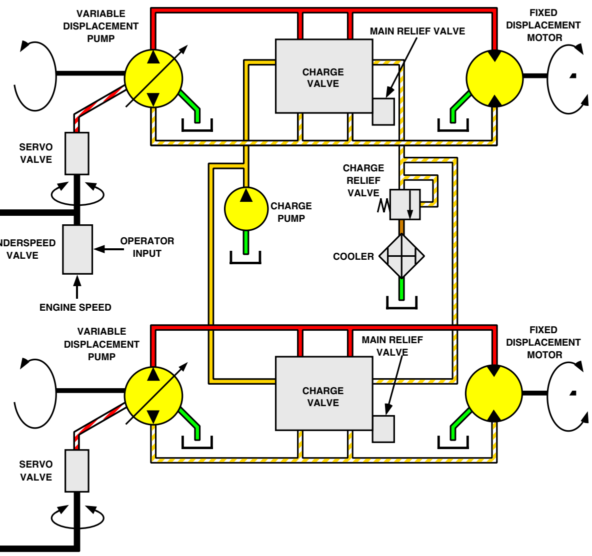

Fig. 3.5.3 953/953B Track Loader Hydrostatic Drive Schematic (Both Sides)

953/953B Track Loader Hydrostatic Drive Shared Components

Figure 3.5.3 shows the left drive circuit at the top and the right drive circuit at the bottom. Each drive loop controls the operation of one track.

The underspeed valve, charge pump, charge relief valve, and oil cooler are common to both circuits. The drive loops are connected through these common components, but operate independently and can be controlled separately by the steering pedals. Each drive loop has its own servo valve and charge valve and main relief valve. The main relief valve limits the maximum drive pressure in that particular circuit.

The distance and direction of servo valve movement is controlled by the positioning of the hydrostatic drive control lever and the underspeed valve. When the HPCU control lever is moved from the PARK position toward either FORWARD or REVERSE, the mechanical linkage from the underspeed valve simultaneously moves both servo valves in the same direction.

The mechanical linkage arrangement connected to the servo valves causes the valves to move the swashplates to identical angles. The correct adjustment of the mechanical linkage arrangement is critical to swashplate positioning. This arrangement ensures that the output (flow) from each pump is the same. If the angles of the swashplates are NOT the same, the outputs will not be equal. As a result, one track will turn at a faster rate and the machine will not travel in a straight line.

Each servo valve also connects to a steering pedal through a linkage arrangement. When the machine is moving in either direction, the operator can depress the respective steering pedal and cause a servo valve to reduce or even reverse the swashplate angle of one pump. This in turn causes the rotation of one track to either slow, stop, or reverse direction.

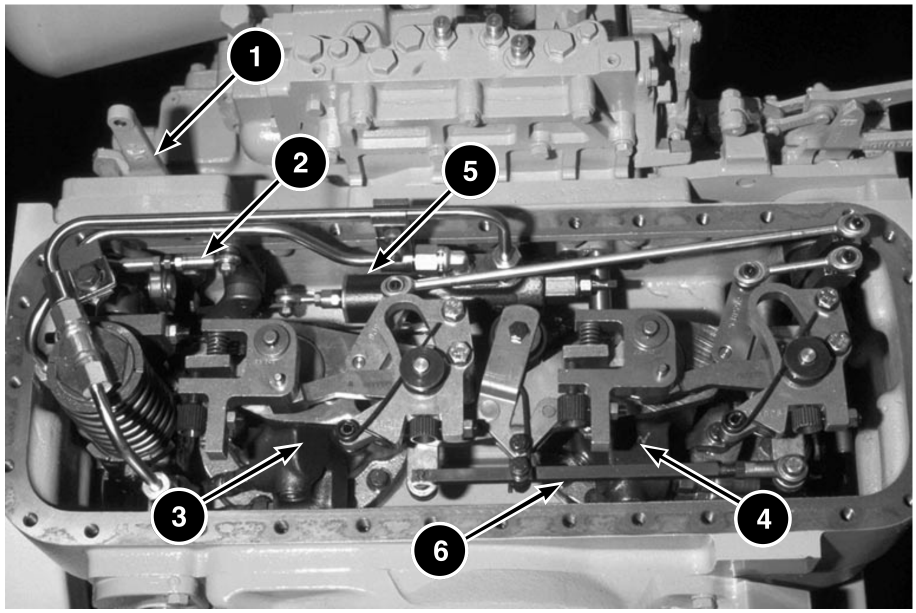

Fig. 3.5.4 953/953B Track Loader Servo Control Linkage

953/953B Track Loader Servo Control Linkage

Figure 3.5.4 shows the servo control linkage for the 953/953B. The control linkage for the HPCU is located below the hydrostatic power control unit (HPCU) top cover. The FORWARD-PARK-REVERSE (FPR) lever (1), directs operator input to the pilot link (2), the direction/speed link (hidden) and pilot valve (5). When the FPR lever is moved to the BRAKES OFF, FORWARD or REVERSE positions, the underspeed valve moves up and the direction/speed link moves the left servo valve (3), which then moves the right servo valve (4) through the combination sync link/centering spring (6).

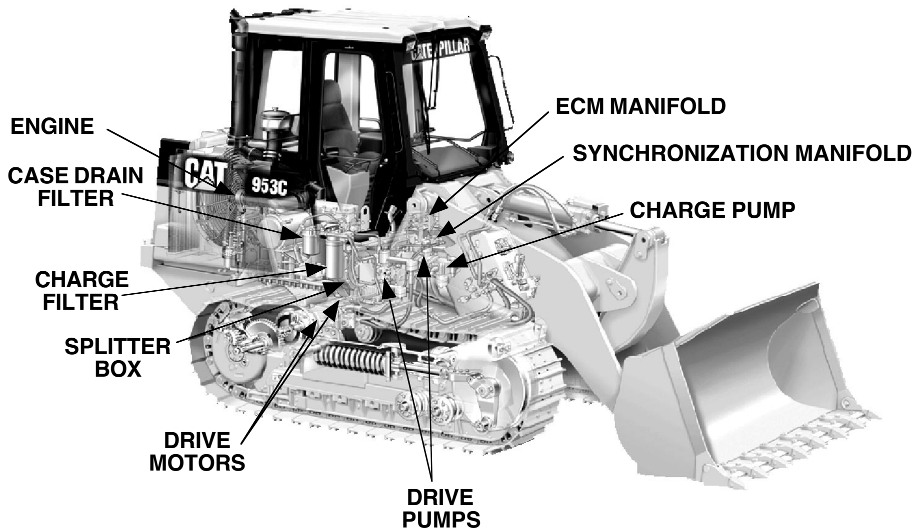

Fig. 3.5.5 953C Track Loader Power Train System Operation

ELECTRO-HYDRAULIC HYDROSTATIC DRIVE

953C Track Loader Power Train System Components

The power train hydrostatic drive system consists of the following major components:

- Engine
- Splitter box
- Drive pumps
- Drive motors
- Charge pump
- Synchronization manifold
- ECM manifold
- Charge filter
- Case drain filter

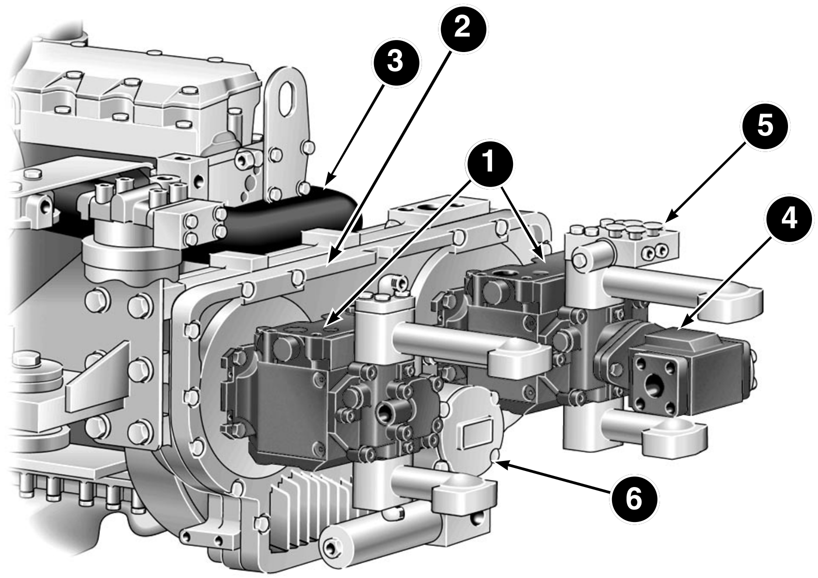

Fig. 3.5.6 953C Track Loader Hydrostatic Drive Pumps

953C Track Loader Hydrostatic Drive Pumps

Each track on the 953C Track Loader is powered by one variable displacement, axial piston pump and one variable displacement, link-type piston motor. The pumps (1) are mounted separately on the splitter box (2). The splitter box is attached to the engine (3).

Each track pump and motor form a closed loop hydraulic circuit. The pump is driven by the engine and sends oil flow through hoses to the piston motor. The motor converts the hydraulic power to mechanical power. The mechanical power passes through the final drive to the tracks. This machine can be driven at infinitely variable speeds up to 10.0 km/hr. (6.2 mph) in either the forward or reverse direction.

While both tracks constantly receive power, one track speed can be increased or decreased relative to the other for right or left turns. One track can be stopped for a sharp turn or counter-rotated for a pivot turn.

The charge pump (4) is located at the rear of the left drive pump and the synchronization manifold (5) is located at the top of the left drive pump. Also shown is the implement hydraulic pump (6).

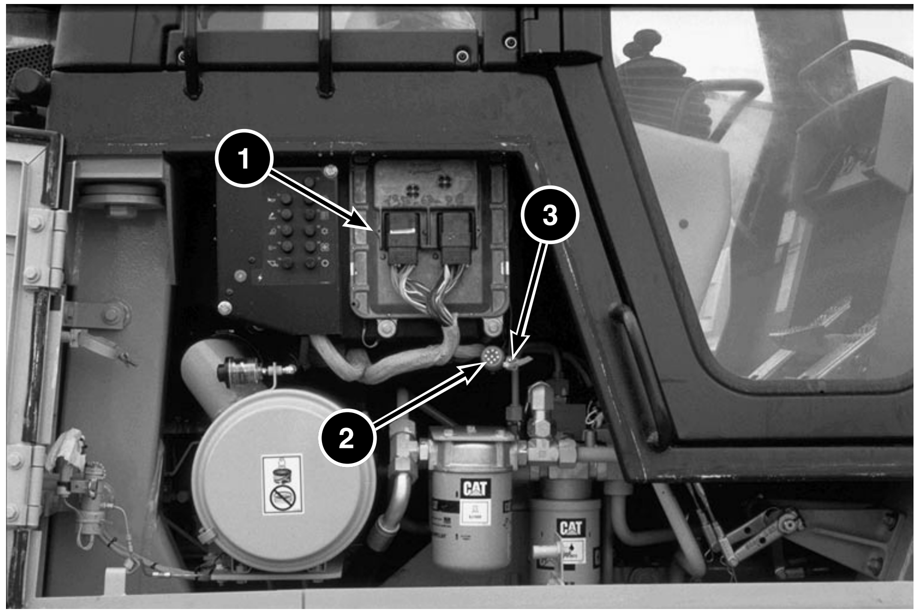

Fig. 3.5.7 953C Track Loader Power Train Electronic Control Module (ECM)

953C Track Loader Power Train Electronic Control Module (ECM)

Figure 3.5.7 shows the power train Electronic Control Module (ECM) (1) that replaces the mechanical linkage used on the 953/953B Hydrostatic Power Control Unit (HPCU). The ECM receives input information such as engine speed, machine direction, steering pressures, braking pressures and temperatures. Using the input information, the ECM makes calculations and energizes solenoids to control the power train hydraulic system.

Also shown are the data link connector (2) and the configuration harness code plug (3).

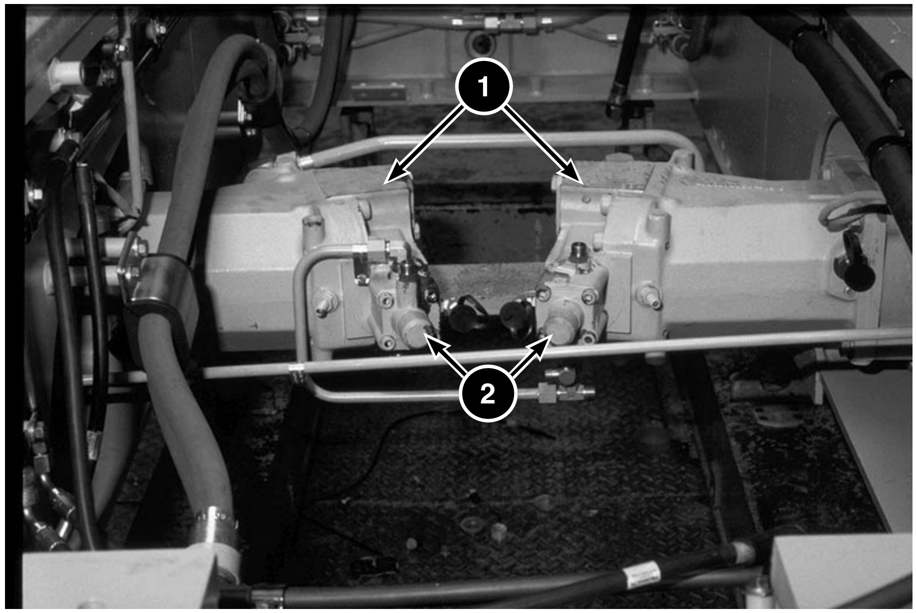

Fig. 3.5.8 953C Track Loader Hydrostatic Drive Motors

953C Track Loader Hydrostatic Drive Motors

The variable displacement, link-type drive motors (1) shown in Figure 3.5.8 are located below the engine and mounted to the brake housing. Pilot pressure from the ECM manifold is directed to the pumps and motors. The pilot pressure controls the displacement of the pumps and the motors. Each motor has a drive motor control valve (2) that contains an actuator piston and servo valve.

As the machine speed begins to increase, the drive motors are at **maximum** displacement and the pumps are at **minimum** displacement. As the speed continues to increase, the drive pumps go to maximum flow at 3.5 km/hr. (2.2 mph), and the motors will begin to destroke. The motor output speeds will increase until the motors are at **minimum** displacement, and the speed of the machine will be approximately 10 km/hr. (6.2 mph).

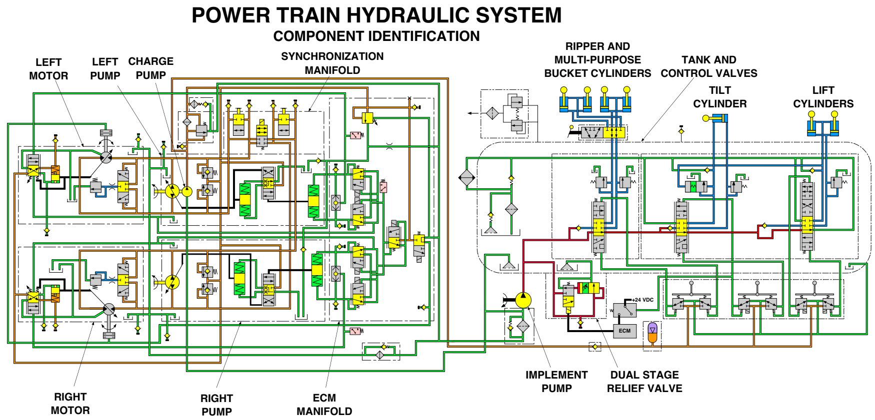

Fig. 3.5.9 953C Track Loader Power Train and Implement Hydraulic System Schematic

953C Track Loader Power Train and Implement Hydraulic System

This schematic shows the major power train and implement hydraulic system components:

- Hydraulic tank and control valves
- Implement pump
- Ripper and multi-purpose bucket, tilt, and lift cylinders
- Dual stage implement relief valve
- Left pump
- Left motor
- Right pump
- Right motor
- ECM manifold
- Synchronization manifold
- Charge pump

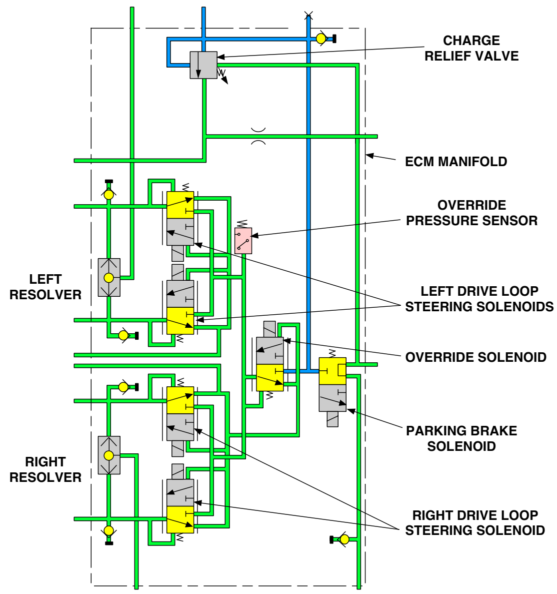

Fig. 3.5.10 953C Track Loader ECM Manifold Component Schematic

953C Track Loader ECM Manifold Components

The power train Electronic Control Module (ECM) manifold contains the following components:

- Charge pressure relief valve
- Override pressure sensor
- Left drive loop steering solenoid valves
- Left resolver
- Right drive loop steering solenoid valves
- Right resolver
- Override solenoid valve
- Parking brake solenoid valve

The functions of the ECM manifold are:

- Control the displacement of the variable pumps and variable motors
- Engage and release the parking brakes
- Limit the maximum pressure of the charge pump oil
- Use the override pressure sensor to direct the pressure signal to the hydrostatic drive ECM
- Supply control oil (charge oil) to all the solenoids

The left and right resolvers direct the forward or reverse signal oil pressure to the motors. Each drive loop has a resolver.

NOTE: The Electronic Control Module (ECM) is the box that receives and sends electric signals. The ECM manifold shown in Fig. 3.5.10, contains the solenoid valves that receive the electric signals from the Electronic Control Module (ECM).

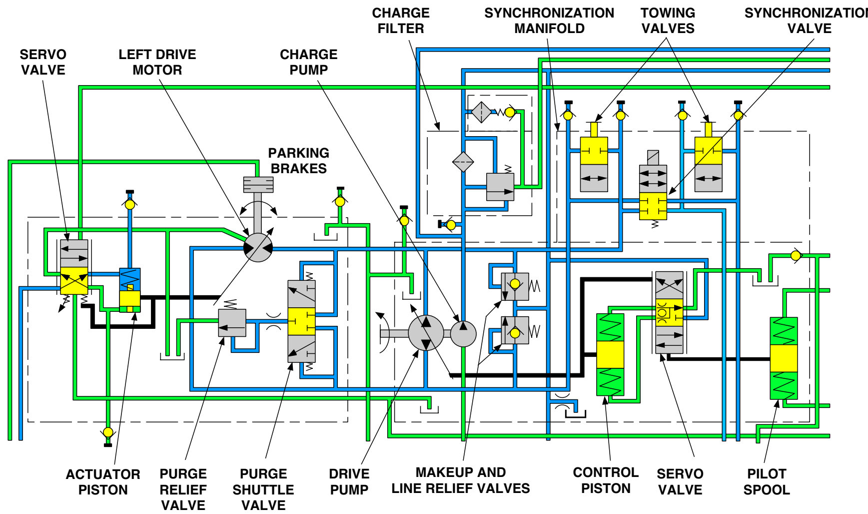

Fig. 3.5.11 953C Track Loader Hydrostatic Left Drive Loop (ENGINE OFF)

953C Track Loader Hydrostatic Left Drive Loop

This schematic shows the left drive loop of the power train system when the engine is off. The major components are:

- Left drive pump group
  - Makeup and line relief valves
  - Control piston
  - Servo valve
  - Pilot spool
- Left drive motor group
  - Actuator piston
  - Purge relief valve
  - Purge shuttle valve
  - Servo valve
- Synchronization manifold
  - Synchronization valve
  - Towing valves (earlier machines only)
- Brakes
- Charge pump (mounted on the left drive pump)
- Charge filter

The various functions of the left drive loop are:

- Direct oil from the variable drive pump to the variable drive motor
- Provide makeup oil and line relief protection to the forward and reverse sides of the drive loop
- Control the displacement of the pump using the pilot spool, the servo valve, and the control piston
- Control the displacement of the motor using the servo valve and actuator piston
- Constantly direct flushing oil to the motor case through the purge shuttle valve and purge relief valve
- Provide a mechanical connection from the engine to the charge pump through the left drive pump

The purpose of the synchronization manifold is to:

- Provide the left and right drive loops with a common connection (synchronization valve) that is open during straight travel and closed during a turn
- Provide two mechanical valves (towing valves) that can be opened when towing the machine with a nonfunctional engine. (The towing valves are removed from later machines. Pull the axles on machines without towing valves to tow the machine.)

The purpose of the charge filter is to:

- Remove contaminants from the charge oil before it flows to the drive loops and the control system

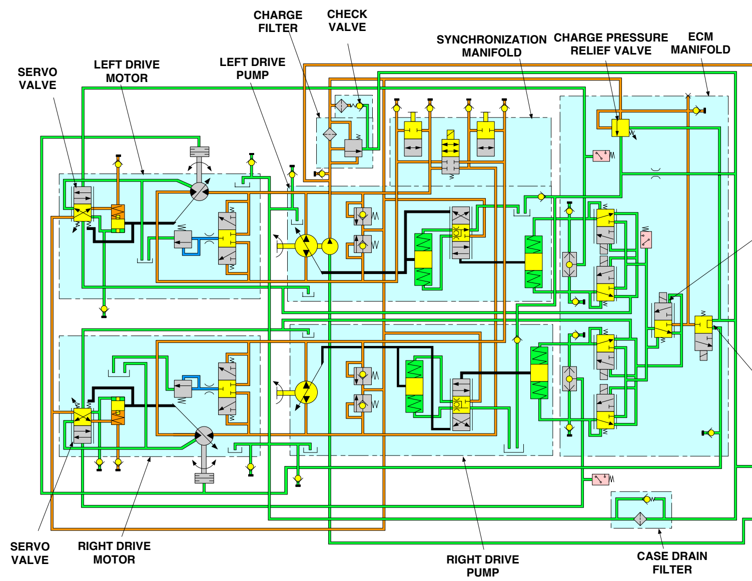

Fig. 3.5.12 953C Track Loader Power Train Schematic (PARK)

953C Track Loader Power Train System in PARK with Parking Brakes Engaged

Figure 3.5.12 shows the engine running and the speed/direction control lever in the PARK position. The charge pump draws oil from the combination implement and power train hydraulic tank (Figure 3.5.9) and sends oil flow to the charge oil filter group. The charge oil filter is rated at 5 microns. The bypass valve contained within the housing will open at a differential pressure (ΔP) of 345 kPa (50 psi). This differential will occur when the oil is cold or the filter is restricted due to contamination. When the differential pressure exceeds the specification, the oil from the charge pump is directed to the tank and not to the drive loops or control system. The machine will not move until the differential pressure is below the specifications.

From the charge oil filter, the oil flows to:

The makeup and line relief valves and the swashplate controls in the left and the right pumps.

The servo valve in the left and the right drive motors.

The charge pressure relief valve located in the ECM manifold;

and

The override and brake solenoid valves.

Located directly above the charge oil filter on the schematic is a spring loaded check valve that functions in extremely cold weather. Cold charge oil that is bypassed by the filter is directed to the check valve which helps the charge system maintain adequate lubrication flow until the system oil is warm enough to flow through the filter.

The charge pressure relief valve is set at 2850 kPa (415 psi). The main purpose of the charge system is to provide makeup oil to the low (return) pressure side of the drive loops. The charge oil constantly replenishes any leakage through the rotating groups of the pumps and motors and supplies cool oil to the drive loops. A portion of the excess charge oil from the charge relief valve is directed to the drive pump cases and to the suction side of the implement pump (Figure 3.5.9). The charge oil entering the pump cases flushes both contaminants and hot oil out of the cases to the case drain oil filter located on the right side of the machine.

The charge pump also supplies the working pressure and flow to control the pumps and motors via the solenoid valves. The override pressure sensor, located in the ECM manifold, converts an input pressure into a signal. The power train ECM uses this signal to measure the override pressure in the system. A warning is issued to the Caterpillar Monitoring System if the override pressure decreases below the specified level required to keep the brakes (spring engaged, hydraulically released) from engaging while the machine is moving. A warning is also issued if the override pressure sensor senses 1000 kPa (145 psi) or greater while the machine is in PARK.

The synchronization solenoid valve is energized in PARK. Energizing the synchronization solenoid allows left and right drive loops to be connected.

In PARK, the pumps are at 0° swashplate angle and the motors are at maximum displacement.

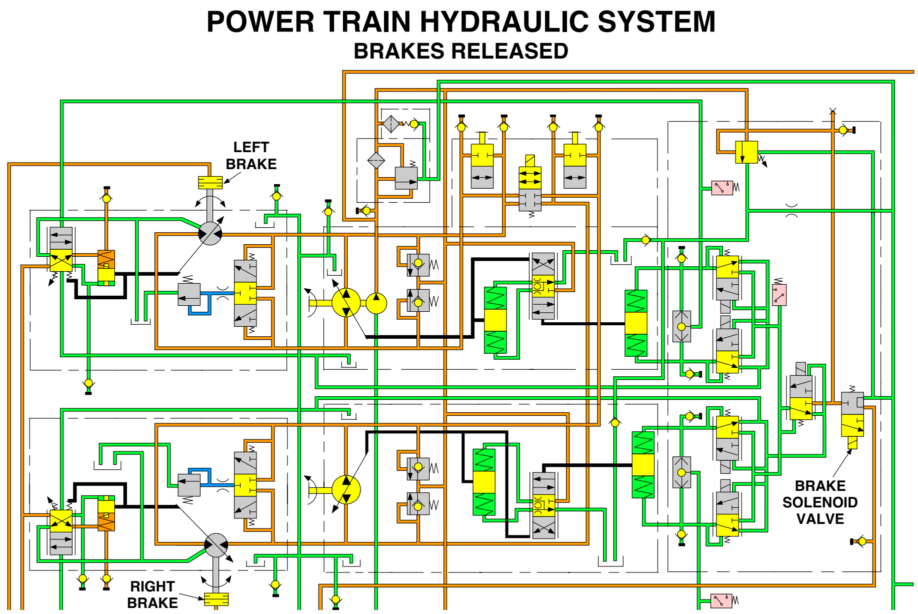

Fig. 3.5.13 953C Track Loader Power Train Schematic (BRAKES OFF)

953C Track Loader Power Train System in BRAKES OFF with Parking Brakes Released

Figure 3.5.13 shows the conditions when the speed and direction lever is moved to the BRAKES OFF position. The power train ECM processes the input information from the movement of the speed and direction lever and directs an output signal to the brake solenoid valve. When the brake solenoid is energized, charge oil is directed to the left and right brake housings to release the brakes.

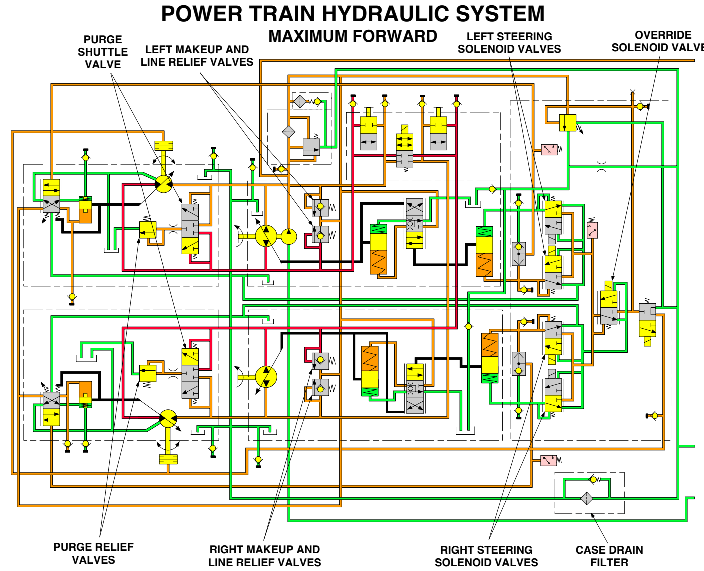

Fig. 3.5.14 953C Track Loader Power Train Schematic (MAXIMUM FORWARD)

953C Track Loader Power Train System in MAXIMUM FORWARD

When the speed and direction lever is moved to the maximum FORWARD position, the power train ECM processes the input signal from the lever sensor and directs output signals to the override solenoid valve and to the left and right steering solenoid valves. In the brakes engaged (PARK) and released (BRAKES OFF) conditions, the override solenoid valve is de-energized to block charge oil to the four steering valves. Therefore, a potential electrical short in the solenoid wiring circuit will not cause the pumps to upstroke.

When the steering valve solenoids are energized, a proportional pilot pressure signal is directed to the respective pump and motor. The pilot signal to the pumps causes the swashplate to move sending pump oil flow to the motors. The pressure in the high pressure side of the drive loop is limited by the makeup and line relief valves to a maximum pressure of 42000 kPa (6100 psi).

Inside each motor are a purge shuttle valve and purge relief valve which allow continuous flow of charge oil from the low pressure side of drive loop to the motor case. The purge flow removes contaminants from the loop. The purge flow also removes hot oil from the loop. In both the brakes engaged (PARK) and released (BRAKES OFF) conditions, the purge shuttle valve is in the center position because the high and low sides of the drive loop are equally pressurized by charge oil.

In Figure 3.5.14, the pressure in the high side of the drive loop causes the purge shuttle valve to move and direct the charge oil flow through the valve to the orifice and purge relief valve. The orifice provides a restriction to the charge oil flow. The purge relief valve maintains approximately 1600 kPa (238 psi) back pressure to the charge pressure flow before the oil dumps into the motor case.

The motor case drain oil consists of leakage from the rotating group and oil from the purge shuttle valve. The case drain oil flows through the case drain filter.

The synchronization valve (Figure 3.5.11) maintains the correct tracking of the machine in both FORWARD and REVERSE. When the power train ECM energizes the synchronization solenoid, the synchronization valve opens and equalizes drive pressures between the left and right drive loops. The solenoid is energized during non-steer conditions and de-energized when a steering pedal is depressed, during extreme underspeed conditions or in test Mode 5. During high or extreme engine loading, the synchronizing solenoid valve automatically de-energizes, and the drive loops are separated until the power train ECM reduces the load on the engine.

To reach the maximum FORWARD speed of the machine, both drive pumps must upstroke to the maximum angle. This provides approximately one third of the total machine speed. At this point, the drive motors will begin to destroke toward minimum angle. The speed will continue to increase until the machine reaches the maximum speed of approximately 10 km/hr. (6.2 mph).

The electronic underspeed control functions when the drawbar load begins to lug the engine speed. In this loaded condition, the underspeed control overrides the operator speed signal as necessary.

To maintain the engine speed at the designated rpm, the ECM underspeed control energizes or de-energizes the drive loop steering solenoids. Engine speed is maintained regardless of the changing drawbar or implement loads. The designated rpm is determined by the programmed software in the power train ECM and is not adjustable.

The implement system has first priority for available engine power and the power train uses the remaining power.

Using the magnetic engine speed sensor that is mounted on the engine flywheel housing, the power train ECM monitors the total load of the hydrostatic drive system and the implement hydraulic system. This sensor generates a signal frequency that varies in proportion to the engine speed. The signal from the magnetic engine speed sensor and the governor lever switch signal, provide the inputs necessary to perform the engine underspeed (anti-stall) function.

The governor lever switch is a two position switch that signals the hydrostatic drive ECM when the governor lever is in the HIGH IDLE notch. This determination allows the underspeed (anti-stall) function to operate properly for the governor lever position.

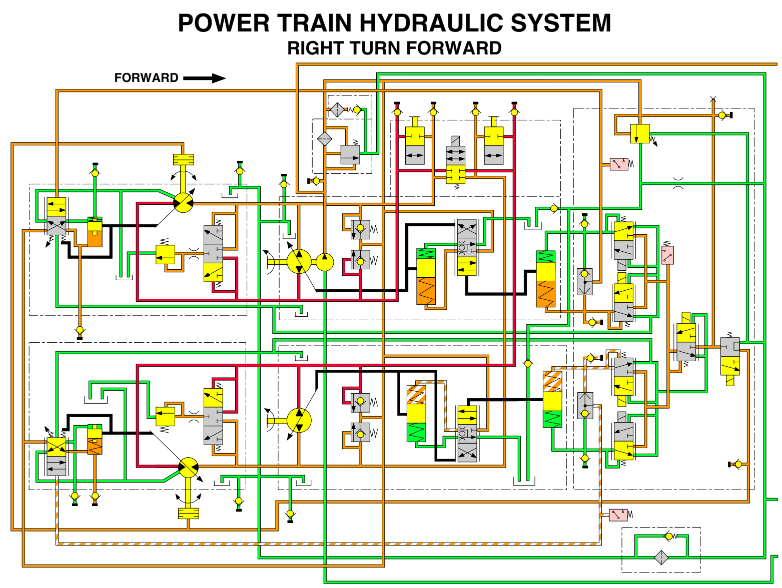

Fig. 3.5.15 953C Track Loader Hydrostatic Drive Schematic (RIGHT TURN FORWARD)

953C Track Loader Power Train System During RIGHT TURN FORWARD

When the machine is travelling in the FORWARD direction and the right steer pedal is partially depressed, the synchronization valve (Figure 3.5.11) is de-energized to separate the drive loops.

When the steer pedal is partially depressed, the rotary sensor on the pedal sends a signal to the power train ECM. The power train ECM signals the right FORWARD steering solenoid valve (Figure 3.5.14), to reduce the pilot signal pressure to the right pump and motor.The right track will slow and the left track will maintain the original speed. If the machine speed is maximum, only the right motor displacement will increase as the operator partially depresses the right steer pedal. The machine will move toward the right.

When the steer pedal is further depressed, the rotary sensor on the pedal sends a different signal to the power train ECM. The power train ECM signals the right FORWARD solenoid steering valve to further reduce the pilot signal pressure to the right pump and motor. The machine makes a sharper turn to the right.

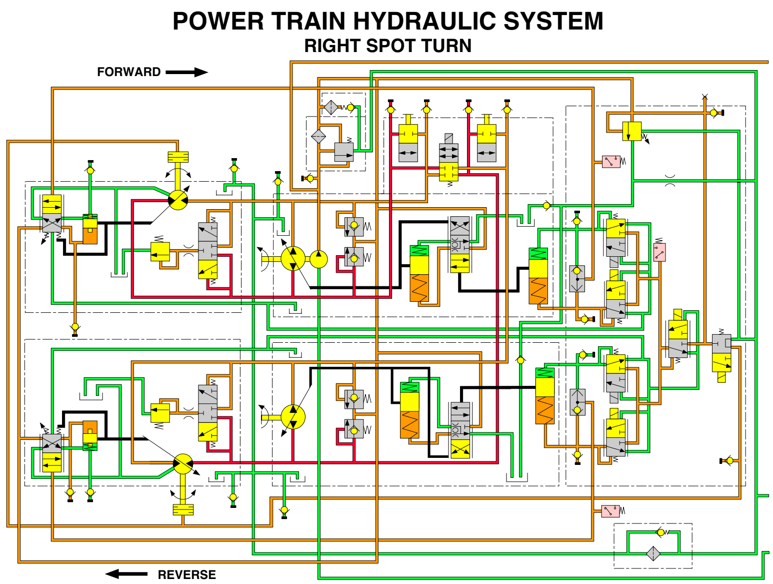

Fig. 3.5.16 953C Track Loader Hydrostatic Drive Schematic (RIGHT SPOT TURN)

953C Track Loader Power Train System during RIGHT SPOT TURN

When the operator depresses the right steer pedal completely, the power train ECM stops the signal to the right FORWARD steer valve and sends an output signal to the right REVERSE steering solenoid valve. The right REVERSE steering solenoid valve then directs pilot signal pressure to the right pump and drive motor causing the right pump to send oil flow to the REVERSE side of the drive loop. The right drive motor rotates in the REVERSE direction, while the left drive motor continues to rotate in the FORWARD direction. The machine performs a RIGHT SPOT TURN.

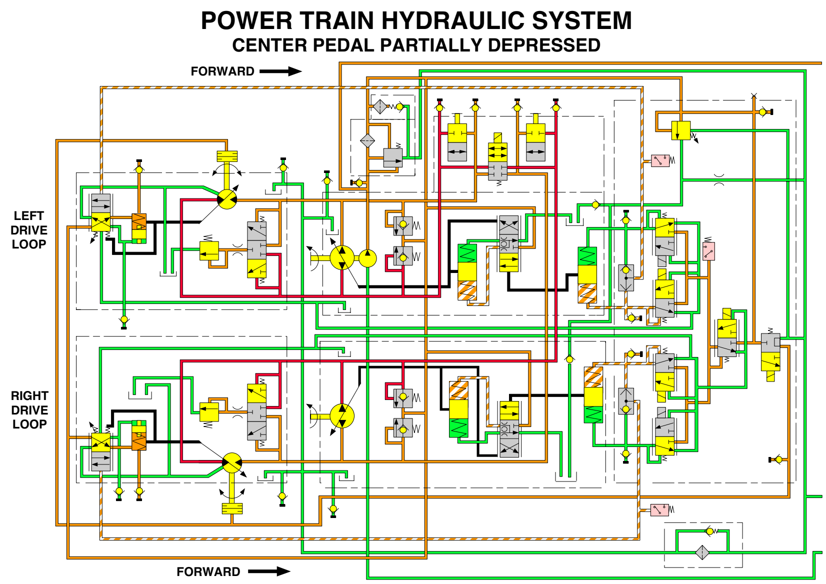

Fig. 3.5.17 953C Track Loader Hydrostatic Drive Schematic (CENTER PEDAL PARTIALLY DEPRESSED

953C Track Loader Power Train System with CENTER PEDAL PARTIALLY DEPRESSED

When the operator partially depresses the center pedal, the power train ECM reduces the signal to the energized steering solenoid valves (Figure 3.5.14). When the machine is travelling at maximum forward speed, the motors move to **maximum** displacement and the pumps move toward **minimum** displacement.

NOTE: This schematic is nearly identical to MAXIMUM FORWARD. The difference is that the speed and direction lever still functions, but the range of speed is greatly reduced.

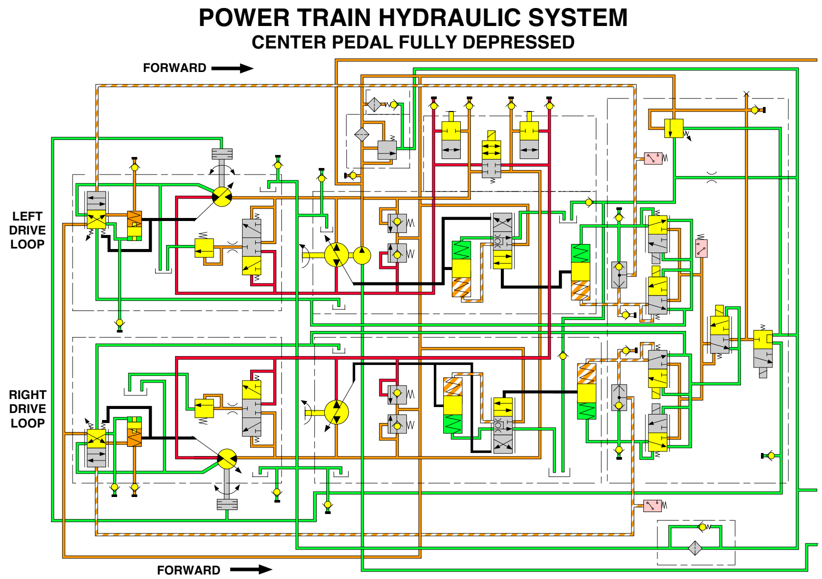

Fig. 3.5.18 953C Track Loader Hydrostatic Drive Schematic (CENTER PEDAL FULLY DEPRESSED

953C Track Loader Power Train System with CENTER PEDAL FULLY DEPRESSED

When the operator fully depresses the center pedal, the power train ECM reduces the signal to the steering solenoid valves. When the machine is travelling at maximum forward speed, the motors move to **maximum** displacement, and the pumps move to **minimum** displacement. The machine comes to an abrupt stop due to the dynamic braking of the power train hydrostatic drive system. The parking brakes automatically engage. Because the pump swashplates remain at a very slight angle while the brakes are holding the motors, a slight "growling" from the power train hydraulic system may be audible .

The operator may also use the center pedal while working on a slope to prevent "rollback." With the speed and direction lever in PARK and the center pedal fully depressed, the operator can move the speed and direction lever to any FORWARD or REVERSE speed and slowly raise the center pedal for precise control of the machine.

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