



HydraForce Axle/Cabin Suspension Solutions Smooth Ride for Off-Highway Vehicles

Comfort, Productivity, Profit

Off-highway vehicles operate in demanding conditions but operators don't have to take a beating. There are many strategies available to smooth the ride. Suspension and damping isn't just about operator comfort: it's about performance, productivity, and profit. New regulations for daily permissible vibration exposure limits can shorten work time and impact productivity. Let HydraForce apply our years of experience on a custom-designed system for your vehicle.

Suspension Systems:

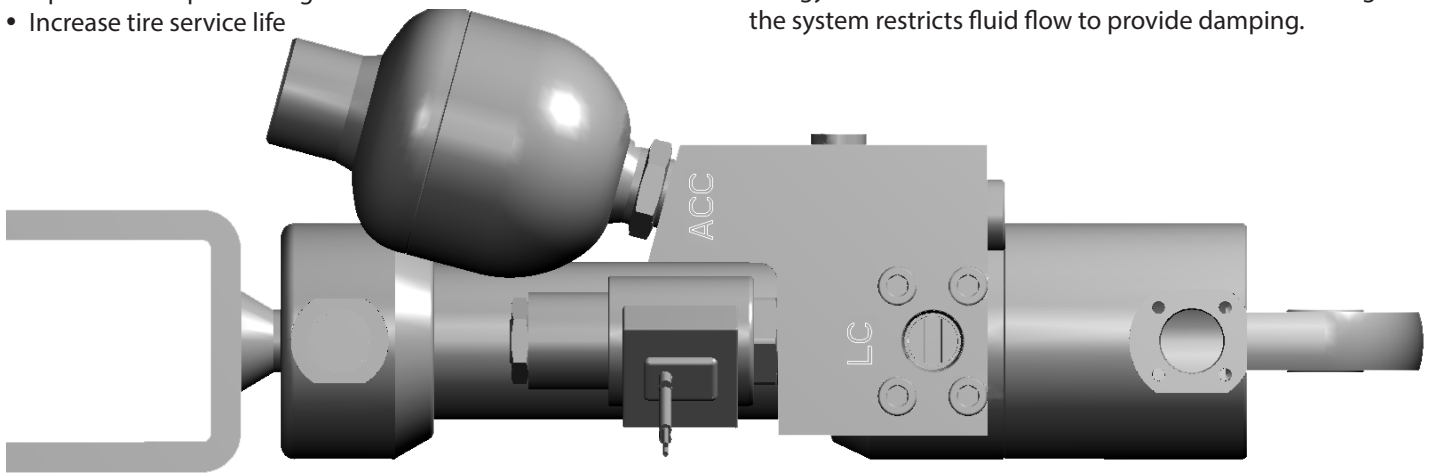
- Increase operator comfort
- Increase controllability
- Improve traction
- Allow faster transport speeds
- Improve roll stability
- Optimize axle positioning
- Increase tire service life

Traditional Systems

Traditional suspension systems isolate the axle and frame using mechanical springs. These springs absorb energy from abrupt changes in terrain elevation. They also help keep the wheels in contact with the ground, improving traction. Hydraulic shock absorbers provide damping to reduce system oscillation. The damping response in traditional systems is fixed and therefore can be susceptible to resonance that may cause bouncing or amplify variations in terrain.

Hydro-Pneumatic Suspension Systems

Hydro-pneumatic systems replace steel springs and shock absorbers with a hydraulic cylinder coupled to a gas-charged accumulator. Displacing fluid into an accumulator compresses its gas charge to absorb energy. Hydrostatic fluid transmits energy from the wheel/axle to the accumulator. Orificing in the system restricts fluid flow to provide damping.



Cylinder mounted suspension manifold and accumulator components of a distributed hydro-pneumatic suspension system.

For detailed information and specifications, visit www.hydraforce.com or contact your local HydraForce representative at www.hydraforce.com/distrib/world.htm

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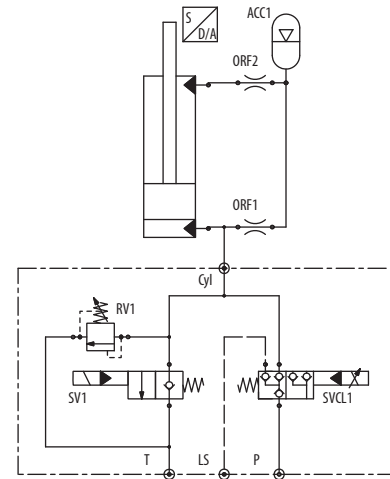
Three Types

Here we discuss three basic classifications of hydro-pneumatic suspension systems. Each system provides a solution with differing degrees of sophistication. These examples use a basic design for illustration. There are many components and possible circuit configurations at our disposal to provide you with a proprietary system optimized to your vehicle's unique requirements.

Passive Systems

Passive systems, like traditional systems, have fixed damping. The advantage of this system is that it can provide level control to ensure optimum response under differing load conditions.

- Valves SV1 and SVCL1 provide level control to allow full travel of the cylinder under any load condition.
 - SV1 activates to lower the system.
 - SVCL1 activates to raise the system.
 - SVCL1 is a multi-function valve that provides check-isolated signal to a load-sensing hydraulic supply.
- Both valves are poppet-style for load holding.
- Stroke sensor relays cylinder position to the control unit.
- Relief valve RV1 protects the cylinder and accumulator from pressure spikes.
- ORF1 and ORF2 provide fixed flow restriction for damping.
- ACC1 provides spring force.

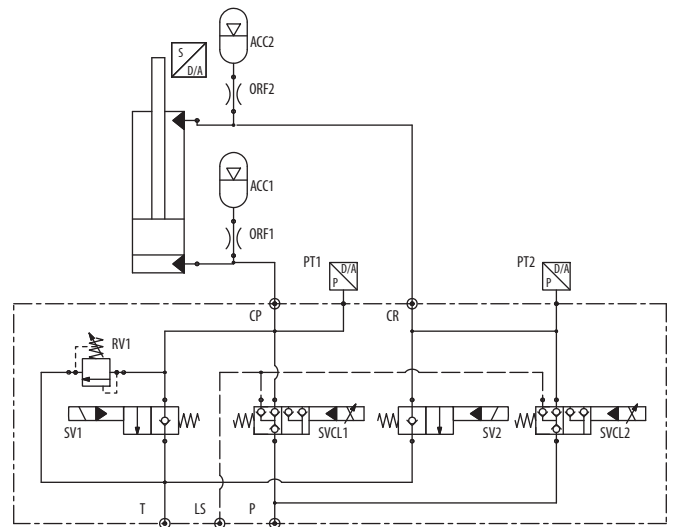


Passive system provides suspension with fixed damping and level control.

Semi-active Systems

Semi-active systems can change accumulator charge to vary spring rate. This offers a user-selectable response.

- Valves SV1, 2 and SVCL1, 2 provide level control and variable accumulator charge.
 - SV1/SVCL1 modulate piston-side pressure/charge in ACC1 with fixed damping through ORF1
 - SV2/SVCL2 modulate rod-side pressure/charge in ACC2 with fixed damping through ORF2
 - SVCL1, 2 are multi-function valves that provide check-isolated signal to a load-sensing hydraulic supply.
- All valves are poppet-style for load holding.
- Stroke sensor relays cylinder position to the control unit.
- Pressure transducers PT1, 2 provide feedback to the control unit.
- Relief valve RV1 protects the cylinder and accumulators from pressure spikes.

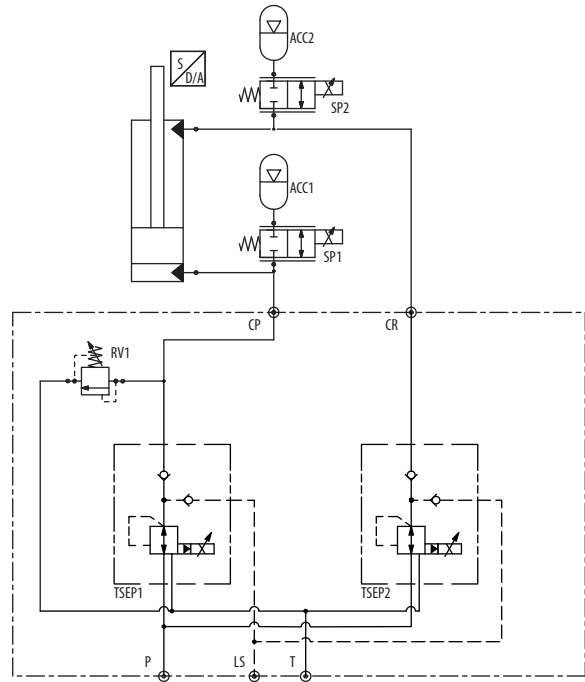


Semi-active system provides variable spring-rate suspension with fixed damping and level control.

Active Systems

Active systems combine variable spring-rate and damping with accelerometers and sophisticated software control. This type of adaptable system can achieve a damping profile following the sky-hook principle: performing as if the chassis or cab were magically suspended from the sky.

- Valves TSEP1, 2 provide variable accumulator charge, and leveling control.
 - TSEP1 modulates piston-side pressure/charge in ACC1.
 - TSEP2 modulates rod-side pressure/charge in ACC2.
- TSEP1, 2 are multi-function proportional pressure reducing valves with load holding element that also provide check-isolated signal to a load-sensing hydraulic supply.
- SP1, 2 provide variable damping to the accumulators ACC1, 2.
- Stroke sensor relays cylinder position to the control unit allowing control of ride-height under varying vehicle load conditions.
- Relief valve RV1 protects the cylinder and accumulators from pressure spikes.



Active system provides variable spring-rate suspension with variable damping and level control.



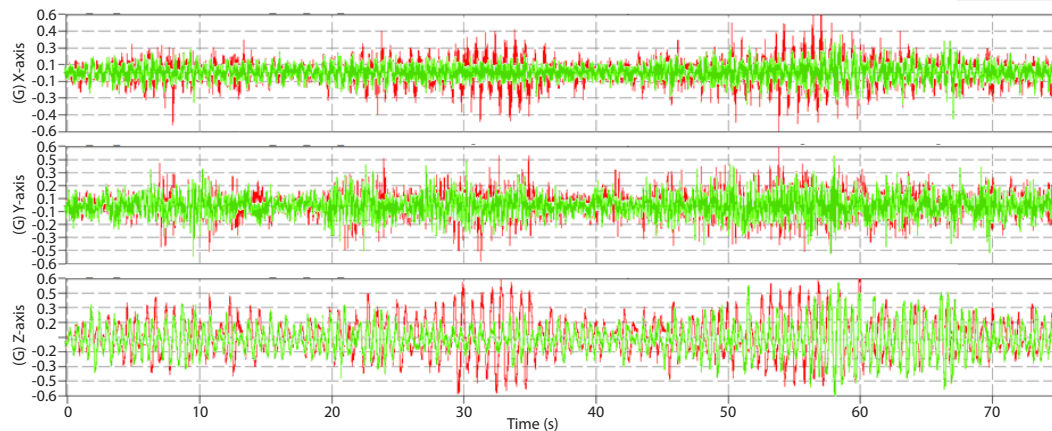
TSEP Pressure Control for Suspension Systems

(patent pending)

Hydraforce offers superior pressure control in the hydro-pneumatic suspension with the multifunction TSEP cartridge. This proportional pressure relief valve with load-holding element performs very accurate control of accumulator charge and therefore spring-rate of the suspension system. With sensors for cylinder stroke, TSEP is also able to control the ride-height dynamically. One TSEP replaces two solenoid valves previously needed to perform this function.

Performance

With rear axle suspension on a harvesting vehicle, vibration exposure to the operator was reduced by 50%.



Legend

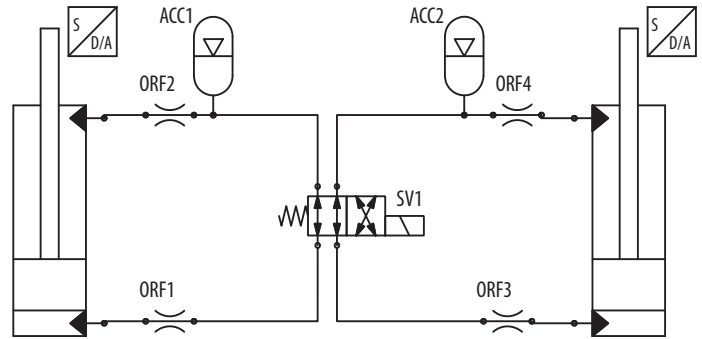
Three axis acceleration (Gs) on the operators seat.

- Red = locked suspension
- Green = active suspension with TSEP

Roll Stabilization

Cross-connecting suspension cylinders on opposite sides of the vehicle can provide roll stabilization. When cornering, centrifugal forces tend to roll the chassis about its center of mass. Cross-connected cylinders can transfer outboard force to the inboard cylinder leveling the chassis. This offers better performance than the torsional sway-bar.

- The circuit features a flow path between opposite cylinders.
- Orifices ORF1-4 restrict flow for damping.
- Accumulator ACC1, 2 provide spring force.
- Valve SV1 connects the left rod to the right piston and the right rod to the left piston, switching the feature on/off.



Cross-connecting cylinders adds roll-stability when cornering.

Challenges

High development cost and time have been barriers to adoption of hydro-pneumatic suspension technology. HydraForce's expertise in compact hydraulic system design, space-saving multi-function valves, and proportional pressure controls allow us to develop a custom cost-optimized solution based on available components in much less time. And our enhanced plating/corrosion resistance package gives you the freedom to locate suspension components anywhere on the vehicle without exposure concerns.

Possible Applications of Hydro-Pneumatic Suspension

- Cabin suspension – isolate cabin from chassis
- Axle suspension – isolate chassis from axle
- Independent suspension – isolate each wheel from chassis
- Seat suspension – isolate the operator's seat from the cabin/chassis
- Load/boom/head suspension – isolate vehicle load or operating components

Advantages

The hydro-pneumatic suspension can achieve performance and flexibility that spring systems cannot. Advantages include:

- Level control: keep suspension in optimum range regardless of vehicle load.
- Variable spring-rate: smoothest possible ride in all conditions.
- Variable damping: avoid resonance and bouncing.
- Control system with sophisticated sensors
- Adaptable response
- Roll stability
- Improved traction
- Compact system

Ride control is a rough road for all off-highway mobile equipment, but there are many opportunities to develop a custom system approach that elevates your vehicle above the competition. HydraForce is here to smooth the way.