

# Pilot Operated Directional Cartridges



## Applications

### **Pilot Operated 4-Way Directional Cartridges**

Sun pilot operated 4-way directional valves can be used in hydraulic system circuits requiring directional control of double acting cylinders, hydraulic motors, brakes and clutches. These cartridges are pilot operated and may be controlled with any type of adequate hydraulic pilot supply.

These directional valves are available in four frame sizes and have nominal flow rates of 7 to 200 gpm (28 to 760 L/min). They are not pressure compensated and will exhibit flow-pressure characteristics commensurate with their effective orifice sizes. Maximum operating pressures are 5000 psi (350 bar) at all ports. Maximum path-to-path leakage is 2 in<sup>3</sup>/min (30 cc/min) at 1000 psi (70 bar) pressure differential. These valves are not adjustable.

Sun offers three basic configurations of pilot operated 4-way directional valves:

- Spring Centered, 4-way, 3-position Directional Cartridges
- Detented, 4-way, 2-position Directional Cartridges
- Spring Biased, 4-way, 2-position Directional Cartridges

### **Pilot Operated 2-way Directional Cartridge with Integral Pilot Control Cavity**

Sun 2-way poppet style directional valves, with integral T-8A pilot control cavity, are vent to shift, two component valves which utilize the Sun T-8A cavity concept. They are available in four frame sizes, with the exception of a 2-1 version in the series 4 frame size. They can be applied in most any application requiring a 2-way, normally open or normally closed hydraulic function, especially where higher flows are required. These valves have nominal flow rates of 15 to 120 gpm (60 to 480 L/min) depending on the model. Maximum operating pressures are 5000 psi (350 bar) at all ports.

### **Pilot Operated Vent-to-shift 3-Way Diverter Cartridges**

Sun pilot operated, 2-position, 3-way diverter valves are vent-to-shift valves that are offered in normally closed and normally open configurations. A typical application for the normally closed version is to bypass a flow divider/combiner in a limited-slip tractive drive circuit (see figure 10 on page 6). The normally open version can be used to select between two pumps or motors in a hydrostatic transmission circuit (see figure 11 on page 6).

These 3-way valves are available in four frame sizes and have nominal flow rates of 15 to 120 gpm (60 to 480 L/min), depending on the model. Maximum operating pressures are 5000 psi (350 bar) at all ports.

## Design Concepts, Features, and Circuit Considerations

### **4-Way, 2 and 3-position Directional Valve Characteristics-DC\*\***

Spool shifting is accomplished by applying pilot pressure to either of two ports on opposing ends of the spool. Minimum required pilot pressure ranges from 125 to 175 psi (9 to 12 bar). Pilot volume for complete shifting ranges from .02 to .42 in<sup>3</sup> (0.33 to 6.9 cc), depending on the model. Applying the minimum pilot pressure to either port 5 or port 6 will cause the valve spool to shift position. Any back pressure on the opposite pilot port will resist shifting on a 1:1 pressure basis. Depending on the valve model, the spool is returned to its original position or shifted to the opposite position by:

- Removing the pilot signal, allowing the return spring to shift the spool
- Removing the original pilot signal and then applying pressure to the opposite pilot port
- Applying equal pilot pressure to both pilot ports

Fluid flow through any spool-type valve creates negative forces on the spool, and these fluid forces dictate an operating envelope. The flow forces are a function of flow rate, differential pressure across the spool lands, and spool geometry. If flow forces are great enough, they will act to prevent the valve from shifting properly or even reverse the position of an already shifted valve. Therefore, flow forces can act to effectively de-rate the maximum allowable flow to a lower value than the published nominal values.

This effect is most pronounced at differential pressures above approximately 3000 psi (207 bar) across the valve and can result in up to a 40% flow de-rating with some spool type valves. A nominal 10 gpm (40 L/min) valve might effectively become a 6 gpm (23 L/min) valve in this extreme case.

Keep in mind that most directional valve applications generate a much lower pressure drop across the valve, typically in the order of 200 to 400 psi (14 to 28 bar). Therefore, flow forces in most cases should not be a significant factor in valve performance.

If the system designer expects a particularly high pressure and/or flow combination, there are potential ways to minimize subsequent problems:

- Choose the next larger directional valve size.
- Make provisions to add an orifice upstream on a particular flow path of the directional valve to reduce maximum flow.
- Apply and maintain pilot pressure above the specified minimum to assist shifting and holding the spool in the selected position.

The system designer is cautioned to thoroughly analyze/test the final circuit under all operating conditions to assure acceptable (and safe) system function.

**Six Port, 4-Way, Spring Centered, Pilot Operated Directional Cartridges – DC\*C**

Sun DC\*C spring centered, 3-position, 4-way valves are available in eleven spool types as shown in figure 1. The spool is shifted by applying the minimum pilot pressure to either port 5 or port 6. The spool will center when the pilot signal is removed. Residual pressure on either pilot port can affect spool position, and will resist shifting on a 1:1 pressure basis. A simple circuit is shown in figure 2.

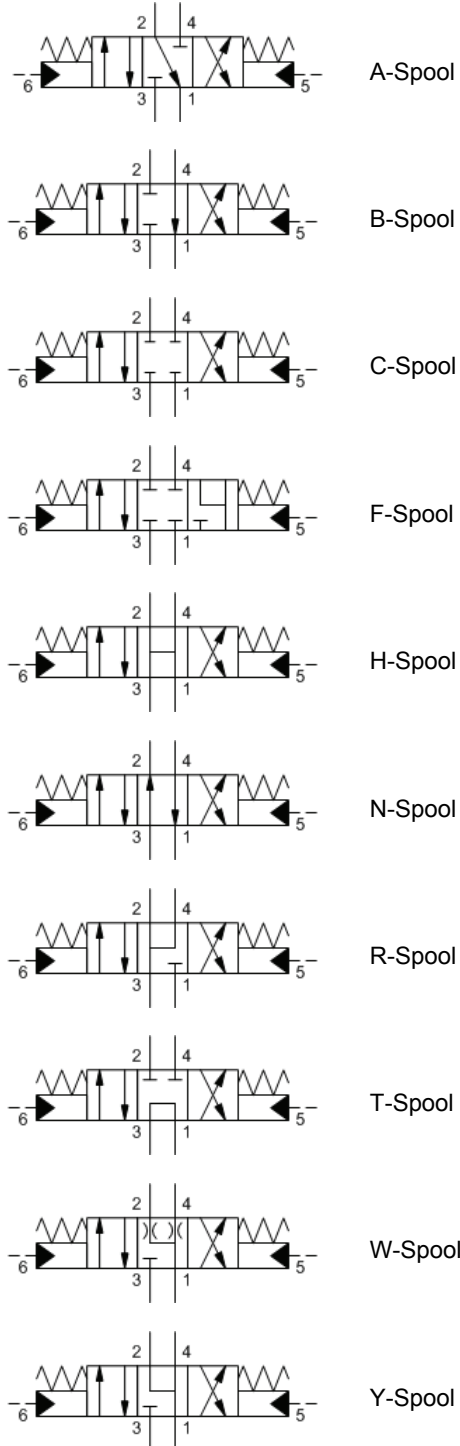


Figure 1

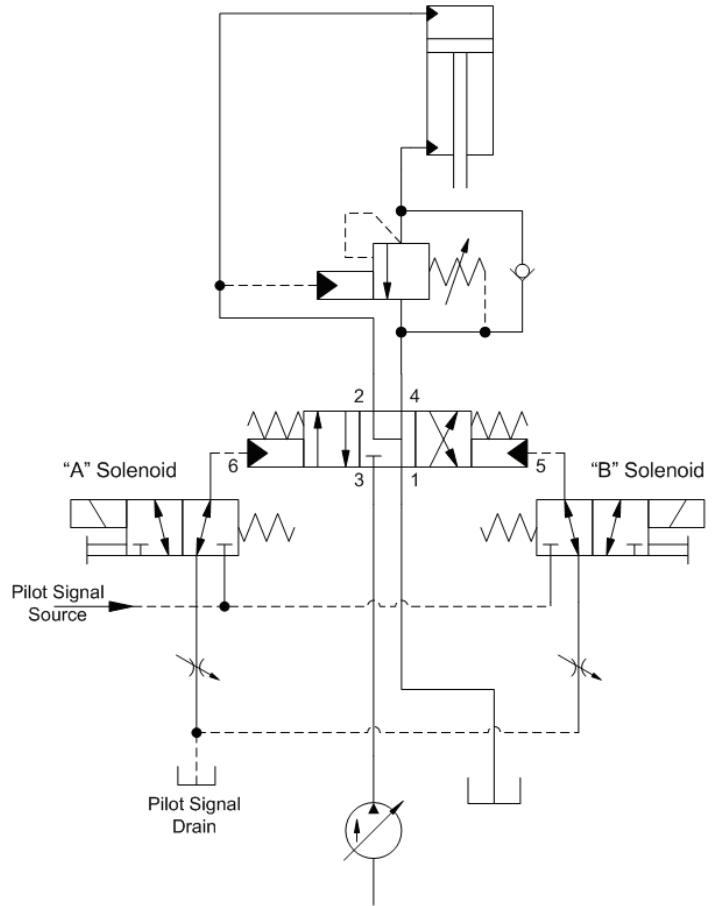
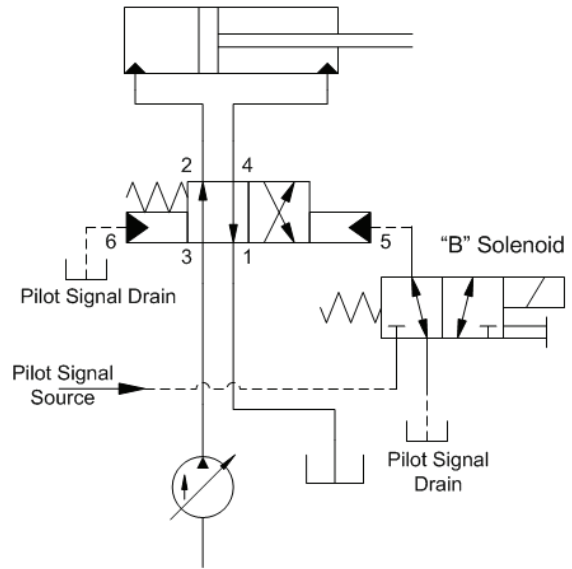
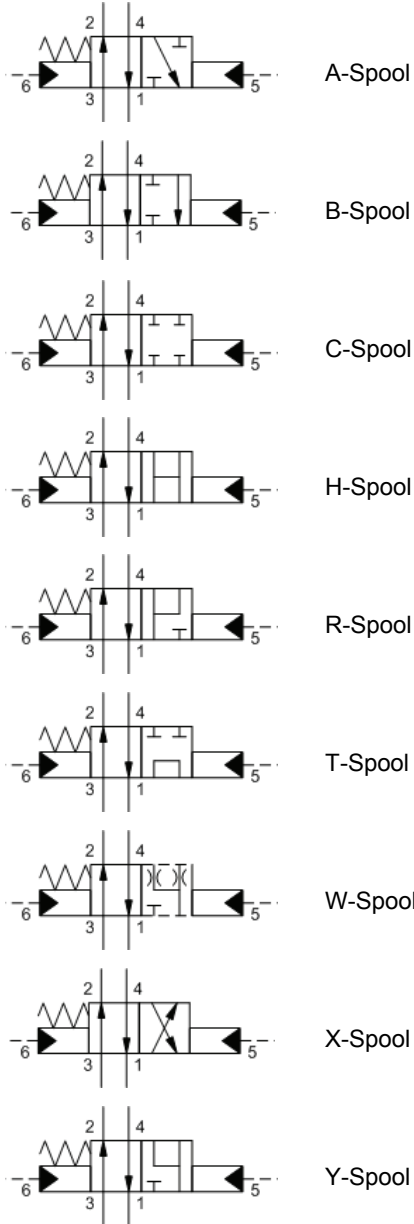


Figure 2.

Here, two 3-way valves are used to pilot a DC\*C-XY\* directional valve in lieu of a single 4-way valve. This approach offers additional circuit flexibility, including pressure centering for redundancy. Dual needle valves, "pilot chokes", in the pilot valve tank lines allow for equalizing spool shift speed, whether piloting to one side or spring centering. This feature can help to "tune out" or minimize hydraulic shock caused by fast spool shifting.

**Six Port, 4-Way, 2-Position, Pilot Operated Directional Cartridges – DC\*F**

Sun DC\*F spring offset, 2-position, 4-way valves are available in nine spool types as shown in figure 3. The spool is shifted by applying the minimum pilot pressure to port 5. Port 6 is used as a drain port and must be connected to tank. The spool will return to the offset position when the pilot signal is removed. Residual pressure on the pilot port can affect spool position, and any back pressure on port 6 will resist shifting on a 1:1 pressure basis. A simple circuit is shown in figure 4.



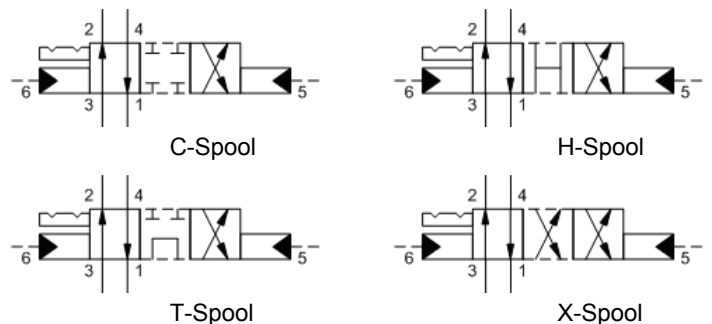
**Figure 4.**

In this example, a 3-way valve is used to pilot a DC\*F-XX\* directional valve. In the de-energized mode, flow is allowed from port 3 to port 2. Energizing the "B" solenoid shifts the spool allowing flow from port 3 to port 4.

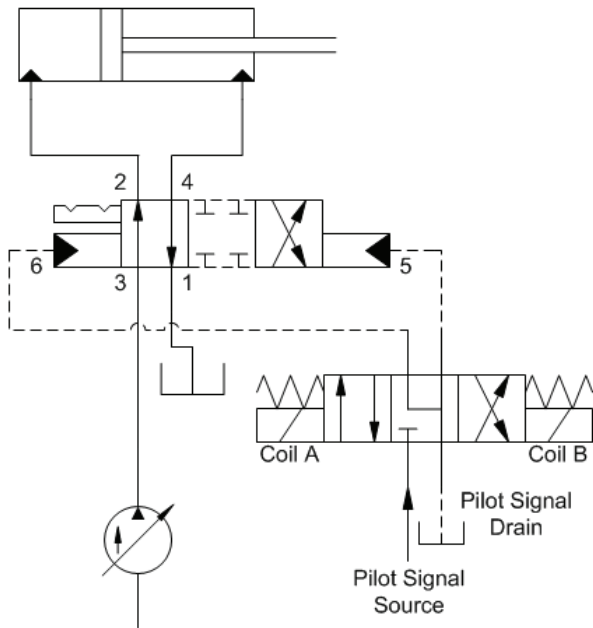
**Six Port, 4-Way, Detented, Pilot Operated Directional Cartridges – DC\*D**

Sun DC\*D detented, 2-position, 4-way valves are available in four spool types. The spool is shifted by applying the minimum pilot pressure to either port 5 or port 6. Upon shifting, an internal mechanical detent will hold the valve in the new position. The spool will remain in that position, with no pilot pressure applied, until a new pilot signal is temporarily applied to the opposite pilot port.

Note that differences in the four spool types available describe the center or crossover condition, while the shifted positions in all cases are P-A / B-T or P-B / A-T (3-2 / 4-1 or 3-4 / 2-1). The transitional centers in the four spool types are: open center, closed center, tandem center and P-B / A-T (3-4 / 2-1) center as shown in figure 5. There is no detent for the center transition position. Care must be taken when specifying a spool type in order to ensure that the transition mode does not negatively affect system function. A basic circuit is shown in figure 6.



**Figure 5**



**Figure 6.**

A 3-position, 4-way valve is used to pilot a DC\*D-XC\* detented directional valve in this example. Two 3-way valves should not be used as they can possibly pilot both ends of the spool at the same time, which is undesirable.

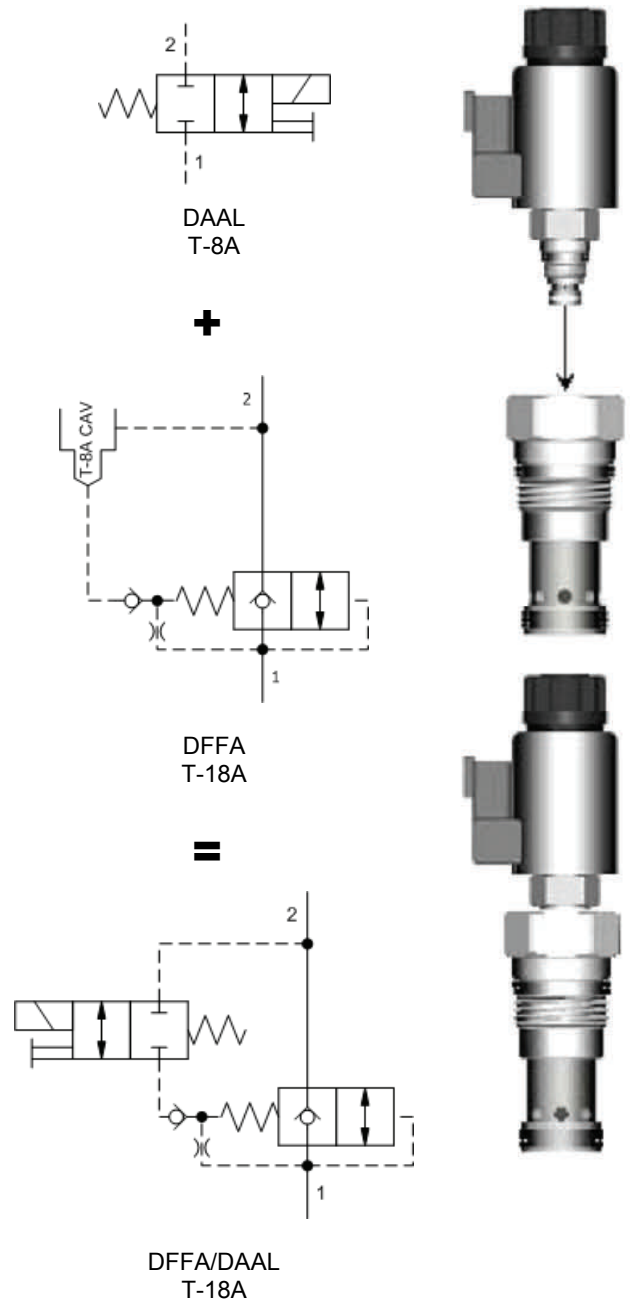
In addition to the fluid force comments, detented valves have another concern. System shocks, either mechanically or hydraulically generated, can force a shifted valve out of the detent position. As an example, a snowplow traveling down a bumpy highway may impart high G forces on the retracted blade and its support cylinders. The subsequent pressure spikes in the fluid lines could shift the directional valve out of the commanded detent position. Further, even if the hydraulic pressure spikes are not sufficient to shift the valve, sharp mechanical movements could possibly cause the spool to shift, especially if the valve is mounted so that the centerline of the spool is in a vertical plane.

**Two Port, 2-Way, Cartridges with Integral Pilot Control Cavity – DF\*A and DF\*B**

Sun DF\*A and DF\*B cartridges are vent-to-operate, 2-way poppet style valves and are available in two configurations; control 1-2 (DF\*A), and control 2-1 (DF\*B), which simply describes which port is connected to the internal venting orifice. These valves are not pressure compensated and will exhibit flow-pressure characteristics commensurate with their effective orifice sizes when the main stage is fully piloted open. Cracking pressure is approximately 50 psi (3,5 bar) for all models. These valves are not adjustable.

Maximum port to port leakage is 10 drops/min at 5000 psi (0,7 cc/min at 350 bar). (*Pilot valve leakage is additional and must be considered in the final calculations.*)

The T-8A cavity concept allows building a multitude of customized control solutions using standard components. A typical assembly using a DFFA is shown in figure 7. The table in figure 8 shows available combinations of pilot and main stages.



**Figure 7.**

In this example, a small solenoid operated switching valve acts as the pilot and is mated with a larger main stage DFFA, control 1-2 cartridge, to create a 120 gpm (480 L/min.) two-way normally closed directional valve. Changing the pilot to a normally open version would make the complete assembly normally open.

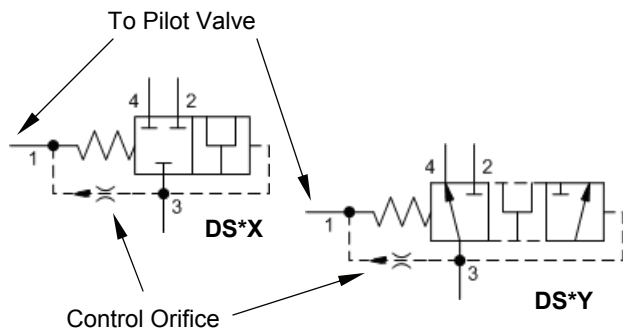
Model	Control	Main Stage Cavity	Nominal Capacity	T-8A Pilot Stage Options		
				On-Off Solenoids	Air Operated	Misc.
DFCA	1 to 2	T-13A	15 gpm (60 L/min.)	DAAA DAAL DAALS DAAC*	DAAP	DAAH DAAM
DFDA		T-5A	30 gpm (120 L/min.)			
DFEA		T-16A	60 gpm (240 L/min.)			
DFFA		T-18A	120 gpm (480 L/min.)			
DFCB	2 to 1	T-13A	15 gpm (60 L/min.)			
DFDB		T-5A	30 gpm (120 L/min.)			
DFEB		T-16A	60 gpm (240 L/min.)			

\*CSA Approved

**Figure 8.**  
Available pilot control cartridges for DF\*\* directional valves.

**Four Port, 3-Way, Vent-to-shift Diverter Cartridges – DS\*X and DS\*Y**

Sun DS\*X and DS\*Y cartridges are vent-to-operate, 2-position, 3-way valves. They are available in normally closed (DS\*X) and normally open, transitional center, (DS\*Y) configurations. (See figure 9.)



**Figure 9:**  
DS\*\* Vent-to-shift diverter valves

Pilot control pressure is sourced via Port 3. A separate pilot valve downstream of Port 1 is used to block or vent the control signal pressure, thus determining the valve position and resulting flow path. With a closed flow path via port 1, the spool is biased to its normal position by a return spring acting in conjunc-

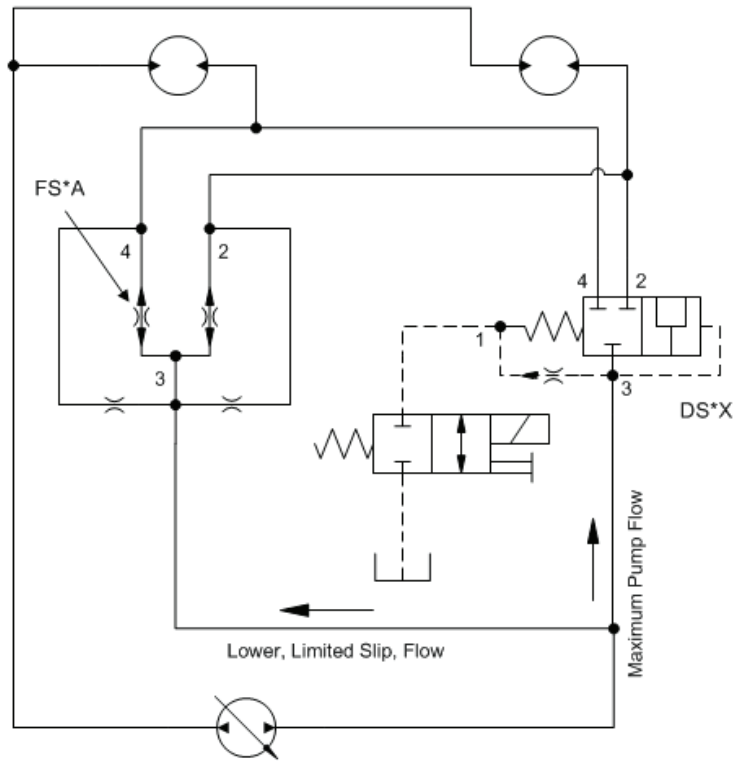
tion with port 3 pressure. When the downstream pilot valve on port 1 is opened or vented, pressure on the opposite side of the spool overcomes the spring and causes the spool to shift. The pressure differential between port 3 and port 1 must be of sufficient magnitude to shift the valve. Both styles are available with minimum control pressure settings of 30, 50, and 75 psi (2, 3,5 and 5 bar). These valves are not adjustable.

Nominal vent flow out of port 1 ranges from 23 to 35 in<sup>3</sup>/min (0,38 to 0,60 L/min) depending on model, and will remain fairly constant, as it is pressure compensated. Because of the continuous Port 3 supply through the control orifice and out Port 1, the vent-to-shift function is self flushing and contamination resistant.

Both valves are not bi-stable, meaning they are capable of modulating between the two end positions. Neither valve is pressure compensated in the fully shifted mode. However, as the P1 control pressure is vented and the valves begin to shift from one end position to the other, the pressure/flow curves take on a flatter pressure compensated characteristic until the valve spools are stroked completely. At that point flow is governed by the effective orifice size.

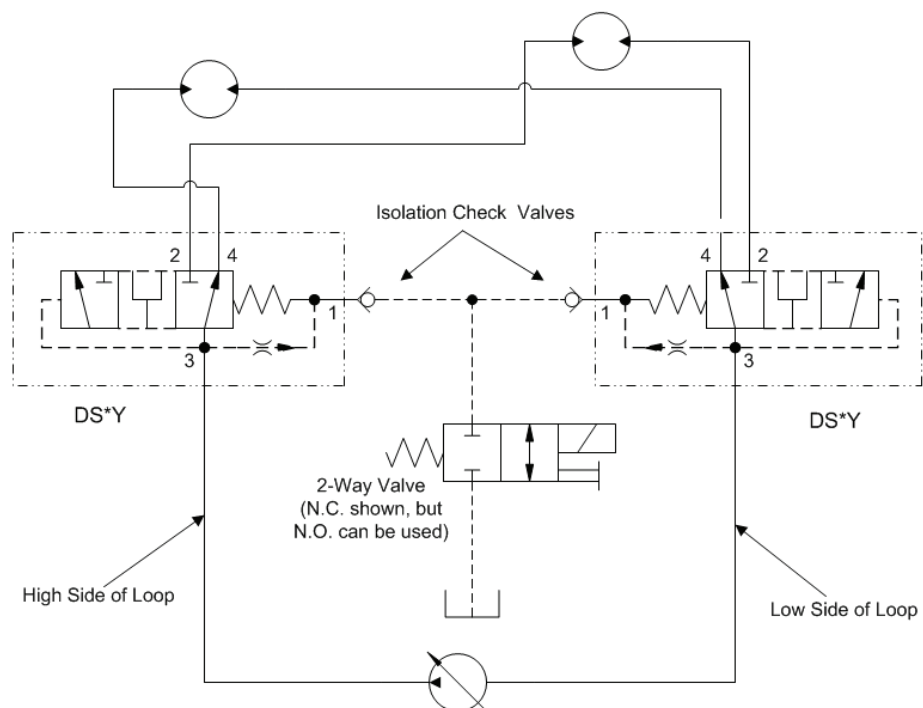
Due to the relatively short pressure compensated flow range (up to the minimum control pressure), these valves are not recommended as modulating devices.

Figures 10 and 11 show circuit examples using DS\*X and DS\*Y cartridges.



**Figure 10.**

In this tractive drive circuit, a flow divider/combiner is used for low flow, limited slip control when needed. Energizing the 2-way valve shifts the DS\*X valve bypassing the flow divider/combiner, making maximum pump flow available to both motors.



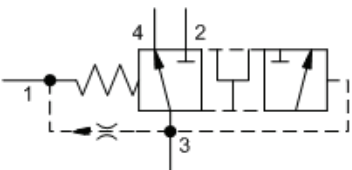
**Figure 11.**

In this non-reversing high pressure circuit, one pilot valve is used to control two DS\*Y valves. Isolation check valves prevent circuit interaction. With only one pump to motor(s) flow direction used, an aluminum manifold can be used on the low pressure side of the loop, with ductile iron being required on the high side.

**Pilot Operated Directional Cartridge Valves Overview**

Function	Description	Nominal Capacity	Model	Cavity	Symbol
4-Way	3-Position, 4-Way, Pilot Operated	7-10 gpm (28 - 40 L/min.) 11-30 gpm (38-120 L/min.) 25-100 gpm (95-380 L/min.) 50-200 gpm (200-760 L/min.)	<a href="#">DCCG</a> <a href="#">DCDC</a> <a href="#">DCEC</a> <a href="#">DCFC</a>	T-61A T-62A T-63A T-64A	
4-Way	2-Position, 4-Way, Pilot Operated	7-10 gpm (28 - 40 L/min.) 11-30 gpm (38-120 L/min.) 25-100 gpm (95-380 L/min.) 50-200 gpm (200-760 L/min.)	<a href="#">DCCF</a> <a href="#">DCDF</a> <a href="#">DCEF</a> <a href="#">DCFF</a>	T-61A T-62A T-63A T-64A	
4-Way	2-Position, Detented 4-Way, Pilot Operated	10-13 gpm (40 - 50 L/min.) 20-30 gpm (80-120 L/min.) 40-60 gpm (160-240 L/min.) 80-120 gpm (320-480 L/min.)	<a href="#">DCCD</a> <a href="#">DCDD</a> <a href="#">DCED</a> <a href="#">DCFD</a>	T-61A T-62A T-63A T-64A	
2-Way	Poppet, Control 1 to 2 with Integral Pilot Control Cavity	15 gpm (60 L/min.) 30 gpm (120 L/min.) 60 gpm (240 L/min.) 120 gpm (480 L/min.)	<a href="#">DFCA</a> <a href="#">DFDA</a> <a href="#">DFEA</a> <a href="#">DFFA</a>	T-13A T-5A T-16A T-18A	
2-Way	Poppet, Control 2 to 1 with Integral Pilot Control Cavity	15 gpm (60 L/min.) 30 gpm (120 L/min.) 60 gpm (240 L/min.)	<a href="#">DFCB</a> <a href="#">DFDB</a> <a href="#">DFEB</a>	T-13A T-5A T-16A	

**Pilot Operated Directional Cartridge Valves Overview**

Function	Description	Nominal Capacity	Model	Cavity	Symbol
3-Way	Vent-to-Shift, Normally Open Diverter	15 gpm (60 L/min.) 30 gpm (120 L/min.) 60 gpm (240 L/min.) 120 gpm (480 L/min.)	<a href="#">DSCY</a> <a href="#">DSEY</a> <a href="#">DSGY</a> <a href="#">DSIY</a>	T-31A T-32A T-33A T-34A	
3-Way	Vent-to-Shift, Normally Closed Diverter	15 gpm (60 L/min.) 30 gpm (120 L/min.) 60 gpm (240 L/min.) 120 gpm (480 L/min.)	<a href="#">DSCX</a> <a href="#">DSEX</a> <a href="#">DSGX</a> <a href="#">DSIX</a>	T-31A T-32A T-33A T-34A	