PVG 32
Using flow or pressure control spools
## Revision history

<table>
<thead>
<tr>
<th>Date</th>
<th>Changed</th>
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<tbody>
<tr>
<td>Feb 2017</td>
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<td>0101</td>
</tr>
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</table>
About this document

References

Related literature: PVG 32 Proportional Valve Group Technical Information, S20L0344, BC00000038

Terms and definitions

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>CB</td>
<td>Counterbalance</td>
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<tr>
<td>FC</td>
<td>Flow Control</td>
</tr>
<tr>
<td>NO</td>
<td>Natural Oscillation</td>
</tr>
<tr>
<td>PC</td>
<td>Pressure Control</td>
</tr>
<tr>
<td>PI</td>
<td>Load pressure</td>
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<tr>
<td>PVG</td>
<td>Proportional Valve Group</td>
</tr>
<tr>
<td>QI</td>
<td>Work Port Flow</td>
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<table>
<thead>
<tr>
<th>Note</th>
<th>Identifies information about practices or circumstances that can cause a hazardous situation, which may lead to personal injury or death, damage or economic loss.</th>
</tr>
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<tbody>
<tr>
<td>Warning</td>
<td>Identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss. Attentions help you identify a hazard, avoid a hazard, and recognize the consequence</td>
</tr>
<tr>
<td>Caution</td>
<td>Identifies information that is critical for successful application and understanding of the product. Identifies a typical use of a functionality or parameter value. Use recommendations as a starting point for the final configuration process of the system.</td>
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</table>
Danfoss introduced the PVG 32 pressure control (PC) spools to the market in the 1990s to overcome instability problems on applications and to control the opening of counterbalance (CB) valves. Typically, a main boom on a crane could be applied with a CB valve for safety reasons. Inertia in the system could lead to oscillations which will be damped when using PC spools.

In this document you can read about the hydraulic functionality and behavior of a PC spool compared to our standard flow control (FC) spools. These hydraulic principles make it easier to know when to apply PC spools instead of FC spools in different applications.
Functionality of a flow control spool

Normally, FC spools are used for most applications. The basic principle is shown in *Basic principle of an FC spool* on page 5. The main spool works as a variable orifice controlling flow $P>A/B$ and $A/B>T$, simultaneously.

*Basic principle of an FC spool*

![Diagram of FC spool](image)

$A(pc->pl) \sim Ql$

$P_l$ is the hydraulic load pressure (determined by the size of the load) that acts in parallel with a spring on one side of the compensator. The other side of the compensator is connected to the $P_c$ pressure. The $P_c$ pressure will remain 7 bar higher than $P_l$. This also means that flow out of the valve is always directly proportional to the opening area of the main spool. This can be seen in *FC spool* on page 5. A certain position of the spool will always give the same amount of flow out of the valve independent of load changes on the work ports.

*FC spool*

![Graph of Area / Pressure vs. Flow](image)
Flow control spools in oscillating systems

As mentioned in the beginning of this document, instability is seen in systems that use FC spools in high inertia systems. An example of such a system is shown in *Natural oscillation example* on page 6.

*Natural oscillation example*

![Diagram showing pressure and time oscillations with FC spool](image)

<table>
<thead>
<tr>
<th>A</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Time</td>
</tr>
<tr>
<td>Yellow line</td>
<td>PI</td>
</tr>
<tr>
<td>Red line</td>
<td>Pc</td>
</tr>
</tbody>
</table>

At any given time, the compensator will try to keep the pressure drop across the main spool at the same level and follow the pressure oscillations from the actuator attached to the valve. When the load pressure is changing, the compensator will follow this frequency to keep the amount of flow from the valve at the same level as the pressure.

So an FC spool offers no damping of the system but maintains a constant flow.
Functionality of a pressure control spool

A PC spool works as a variable orifice controlling flow P>A/B and A/B>T, like an FC spool, and also controls LS>T. See the concept in Basic principle of a PC spool on page 7.

Basic principle of a PC spool

The Pc has a connection to the tank through a fixed orifice in series with a variable orifice (controlled by spool displacement). This means that the LS signal is manipulated by the variable orifice. See the characteristics of a PC spool in PC spool on page 7.

PC spool

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
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<tbody>
<tr>
<td>Adrain</td>
<td>variable connection from Pc to tank (manipulates the LS signal)</td>
</tr>
<tr>
<td>A(pc-&gt;Pl)</td>
<td>physical opening area of the spool as a function of its position</td>
</tr>
<tr>
<td>PI</td>
<td>load pressure</td>
</tr>
<tr>
<td>Pc</td>
<td>manipulated LS pressure + spring pressure</td>
</tr>
<tr>
<td>Ql</td>
<td>flow out of the valve</td>
</tr>
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</table>

The example in PC spool on page 7 shows a Ql curve, which is the flow out of the valve. Flow starts when a pressure drop across the spool exist. So in this example, the flow will start and increase when Pc gets higher than Pl. As a result, the spool deadband varies as the size of the load changes.

So for PC spools a certain position of the main spool is proportional to a certain Pc pressure.
Functionality of a pressure control spool

One of the drawbacks of a PC spool is that flow out of the valve is dependent on the size of the load and with variable deadband.

*PC control to B port* on page 8 illustrates a cut through PVB with PC control to one port.

*PC control to B port*
Pressure control spools are beneficial when they are used with oscillating applications. The spool design applies dampening to the port because flow from the valve varies with load change. See *Natural oscillation example* on page 9.

*Natural oscillation example*

A certain position of the spool is given leading to a constant pressure, $P_c$. The load pressure, $P_l$ is oscillating. Over time, the pressure drop across the main spool ($P_c$ minus $P_l$) varies, which leads to a variable flow. The flow out, $Q_l$, is also shown on the graph as a dotted line. The amount of dampening applied is dependent on the relative difference in pressure between spool set point pressure and load varying pressure. The relative difference is shown on the graph as $\Delta P_1$ and $\Delta P_2$. 

A: Pressure  
B: Time  
C: Flow  
Yellow line: $P_l$  
Red line: $P_c$  
Dotted line: $Q_l$
Pressure control spools with counterbalance valves

The main purpose of a PC spool is to control CB valves. In general, the basic functionality of a CB valve is to ensure non-moving actuator in case of hose break. See *Lowering a load through a CB valve* on page 10.

*Lowering a load through a CB valve*

![Diagram](image)

A Pilot connections to force open CB

*Lowering a load with a PC spool*

A PC spool is more applicable when lowering loads in applications with CB valves.

A CB valve can be opened either by a pilot pressure or when the relief setting of the CB valve is reached (shown as an adjustable spring in the previous figure). Normally, the relief setting and pilot pressure have a ratio around 5:13. As a result, if the relief setting is 250 bar, the pilot pressure needed to open the valve is a maximum of 50 bar.

In *Lowering a load through a CB valve* on page 10, a PC spool builds up pressure at the A-port. The pressure on the A-port is used as pilot pressure to open the CB valve on the B-port. The load is held by the CB valve and, with the pressure build-up on A-port, the opening of the CB valve is controlled. PC is proportional to spool position and as a result the opening of the CB valve is proportional to the spool position.

If the pressure is lowered with a FC spool, then there is no control of the pressure. So when the pressure has increased to a level that opens the pilot for B-Port, flow is allowed back to tank. It also means that the pressure in the A-Port will decrease with a risk of getting below the opening pressure for pilot control. As a result, the system becomes unstable and tends to jump when lowering the pressure because the CB valve switches between opened and closed.

Typically, a spool with FC in one direction (lifting) and PC in the other direction (lowering) is used for applications with CB valves to provide the best controllability in both cases.
Summary

In certain applications, you can use a PVG with a pressure control (PC) spool instead of a traditional flow control (FC) spool. The PC spool provides a dampening effect on natural oscillations because the PC spool maintains a constant pressure on the work port while allowing a variable flow, depending on changes in the work port load.

A situation in which PC spools are of great value is when you are lowering a load in an application that uses counterbalance (CB) valves. A combined FC and PC spool, with the FC in the lifting port and the PC in the lowering port, results in optimal controllability.
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