

Innercept™ Digital Proportional Control Plug-n-play Simplicity with Servo Valve Accuracy

INNERCEPT™

DIGITAL PROPORTIONAL CONTROL

Overview

Control for critical applications like autonomous steering have brought about complex strategies to manage hysteresis, threshold, coil temperature, and other challenging variables in mobile hydraulics. Although reliable control has been achieved, it comes with costly development and intensive tuning efforts to meet system and valve to valve variation. Servo control is an excellent technology used widely in industrial hydraulics but cost has proven to be a prohibitive barrier in mobile applications. Cartridge valves and manifolds fit very well in a broad range of mobile applications and compete well against stack and monoblock type valves because of design flexibility and compact packaging.

HydraForce has now married servovalve accuracy and repeatability with cartridge flexibility and compactness, at a fraction of the cost of industrial-style servovalves. Introducing the **Digital Proportional Control** (US and international patent(s) pending). We have fitted a **SP10-P57FL** fast-acting minimum-lap proportional directional valve with spool position feedback provided by an **integrated LVDT** (Linear Variable Differential Transformer). The digital proportional control is paired with HydraForce **ESDR-0201A (Electronic Servovalve Driver)** to form a **plug-n-play** closed loop directional flow control. Now you can provide digital flow control to your critical application with a simple **CAN message**. You need precisely 50% opening of the valve? Just ask and the digital proportional control delivers: **Every. Single. Time.**



HydraForce SP10-P57FL minimum-lap directional proportional valve with LVDT position sensor, ESDR closed-loop control, and integral load-sensing port.

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

HYDRAFORCE INC

HYDRAFORCE HYDRAULICS LTD Advanced Manufacturing Hub

HYDRAFORCE HYDRAULICS SYSTEMS (CHANGZHOU) CO., LTD

HYDRAFORCE HYDRAULICS LTDA

500 Barclay Blvd.
Lincolnshire, IL 60069
Phone: +1 847 793 2300
Fax: +1 847 793 0086
Email: sales-us@hydraforce.com

Member: National Fluid Power Assoc.
ISO 9001

250 Aston Hall Road
Birmingham B6 7FE United Kingdom
Phone: +44 121 333 1800
Fax: +44 121 333 1810
Email: sales-uk@hydraforce.com

Member: British Fluid Power Association
and Verband Deutscher Maschinen-
und Anlagenbau e.V. (VDMA)
ISO 9001 & ISO 14001

388 W. Huanghe Road, Building 15A
GDH Changzhou Airport Indl Park
Xinbei District
Changzhou, China 213022
Phone: +86 519 6988 1200
Fax: +86 519 6988 1205
Email: Vincentz@hydraforce.com

ISO 9001

Av. Laurita Ortega Mari,
499 Taboao da Serra
São Paulo, 06766-360 Brazil
Phone: +55 (11) 4786-4555
Fax: +55 (11) 4786-2050
Central@hydraforce.com

Inside the LVDT and ESDR

The new digital proportional control integrates a new LVDT (Linear Variable Differential Transformer) position sensor with a coil-mounted closed-loop control. The integrated LVDT gives spool position accurate to within 0.11 mm (0.005 in). On board electronics process this into a 0 to 5 V signal that forms the feedback leg of a full-featured PID control in the ESDR.

The **ESDR-0201A** is new to the HydraForce ExDR family of valve drivers. With two PWM outputs and one analog voltage input, its main function is a closed-loop PID controller. Parameters can be set using HF-Impulse configuration and programming software, available for free download at www.hydraforce.com/electronics. This simple but powerful control offers greater stability with advanced parameters such as:

- Feed forward
- Output limit
- Integral hold
- Windup guard
- Derivative cycles
- Duty cycle minimum

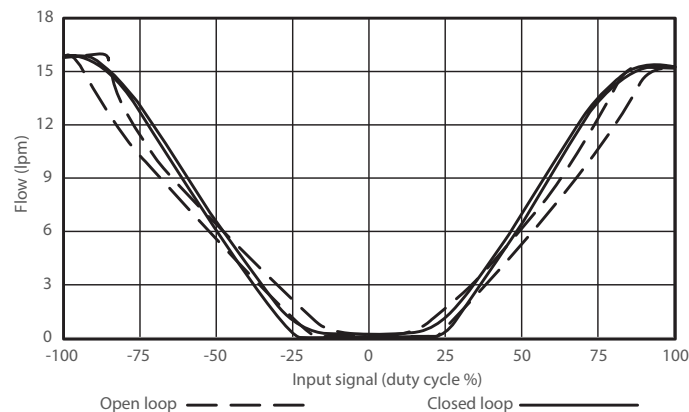
These additional features allow fast response and greater control when tuning a PID loop.

Performance is Dialed In

HydraForce has precisely tuned this loop to optimize performance. This tuning will fit most applications, however with the flexibility built in to the ESDR-0201A, you have complete control over all available parameters.

Hysteresis is History

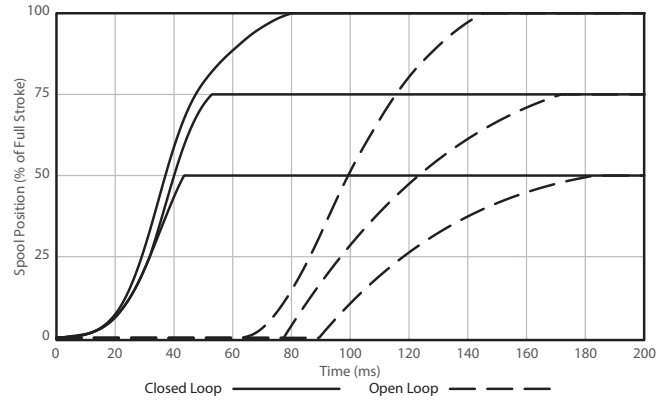
Because the PID loop controls for spool position, not coil current as with other closed-loop controls, it is able to virtually eliminate hysteresis which typically limits the accuracy and repeatability of hydraulic controls. Also, the control, because of the out-of-the-box optimized tuning, exhibits excellent step-response and is therefore suitable for critical applications such as steering control in autonomous vehicles.



Hysteresis can be seen in the graph as space between traces as the command voltage sweeps from minimum to maximum and back to minimum. The closed-loop control (solid line) demonstrates very low hysteresis compared with the open-loop control (dashed line).

Ultra-Responsive

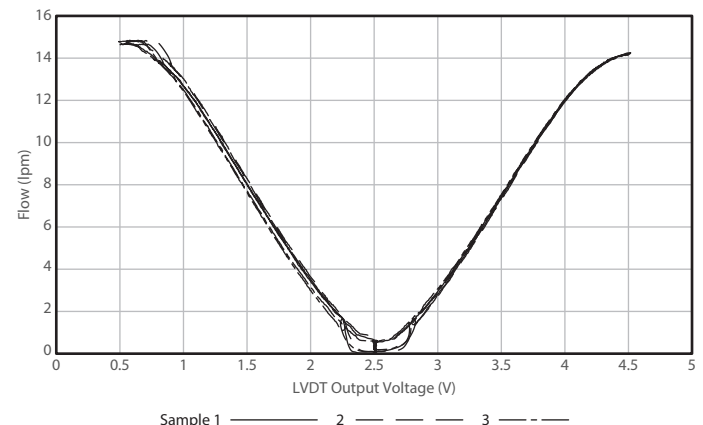
The digital proportional control is currently built on the existing SP10-58FL platform. This directional flow control features a minimum lap spool and has already been optimized for a responsive profile. In addition, HydraForce engineers designed and optimized the PID control for best-in-class response. The result is a 45 to 75 % improvement in step response (S1 shown).



The graph demonstrates the improvement in pull-in response (S1) between closed loop control and open loop control.

Ultra-Repeatable

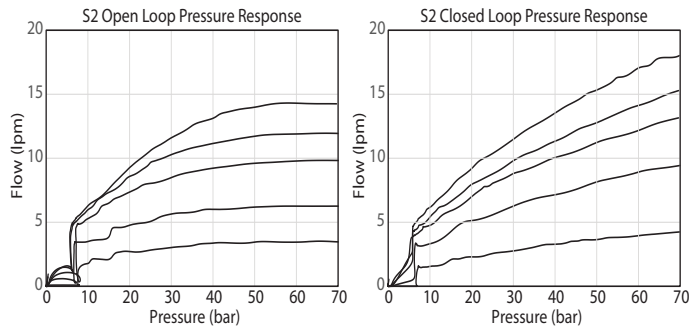
Common wisdom dictates: what we can measure, we can manage. With position feedback, the control system is always aware of the valve position and therefore it is easy to manage. The result is steadfast repeatability from valve to valve and in all operating conditions. Traditional directional flow control valves can have a tolerance profile that allows variation in threshold. For accurate operation this must be adjusted for and controlled. The digital proportional control, because it controls to a given position, eliminates the need to perform threshold adjustments and will control for threshold variation naturally. Also, it compensates for temperature changes that cause an increase in coil resistance and reduce maximum flow.



The graph shows an overlay of 3 separate valves. The control demonstrates an excellent ability to compensate for valve to valve variability, eliminating the need to tune each valve individually.

Overcomes Hydrodynamic Flow Forces

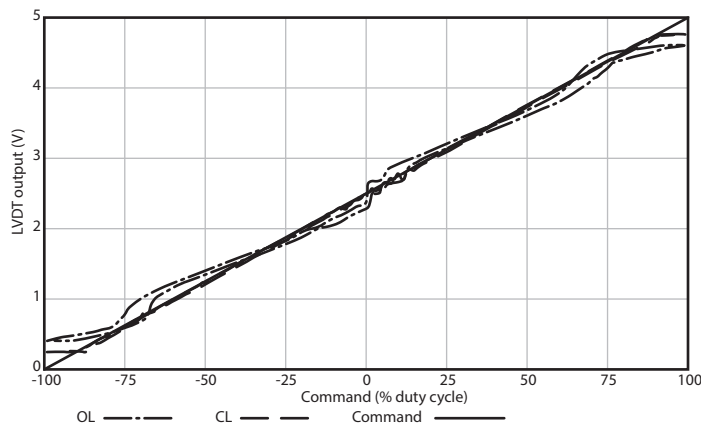
While HydraForce flow control designs are informed by the latest CFD analysis tools and practices, hydrodynamics can still affect performance under certain conditions. A spool valve can begin to washout or self-shift as these forces overcome the actuator force, restricting flow. A major advantage of the digital proportional control is that it can increase the coil current to maintain the setpoint if feedback indicates washout.



As pressure increases, flow forces tend to close the valve and the left graph indicates. The right graph indicates the control's ability to counteract washout.

Superb Linearity

Because of position feedback in the PID control loop, the digital proportional control is able to achieve a perfectly linear flow profile: a feature that just is not possible with open-loop control. This is true plug-n-play operation and it means the vehicle controller only has to manage the requested valve opening, it does not need to provide scaling profiles, perform current correction, or manage hysteresis.



The OL trace stays near the command line, but varies as much as 5 to 6% throughout the operating range. The CL trace follows the command exactly, demonstrating excellent linearity.

Applications

Cartridge valves with closed-loop position feedback control have many potential applications. The improved performance positions these valves competitively in precision applications where other bulky and more costly technologies such as D03 and stack valves have been required. This prepares the way for adoption in applications such as:

- Autosteering applications on agricultural tractors and earthmoving/grading equipment
- Semi and fully autonomous municipal vehicles like sweepers, salt spreaders, and refuse trucks
- Specialized harvesting equipment
- Precision application of agricultural chemicals
- Precision paving and roadmilling machines
- Railroad maintenance equipment

Digital proportional controls are perfect for applications where precision and response are key. With a fast-acting, repeatable directional flow control, one can achieve more stable autonomous functions like automatic steering, or precise placement of cargo in a narrow storage bay. More control-by-wire applications can open the use of rental machines to a broader range of less experienced operators. New possibilities are emerging every day. What will you build using digital proportional controls from Hydraforce?