Basics for proportional electrohydraulics

1 WHAT IS PROPORTIONAL ELECTROHYDRAULICS?

Electrohydraulic proportional controls modulate hydraulic parameters according to the electronic reference signals.
They are the ideal interface between hydraulic and electronic systems and are used in open or in closed-loop controls, see section 3, to achieve the fast, smooth and accurate motions required by today's modern machines and plants.
The electrohydraulic system is a section of the overall automation architecture unit where information, controls, alarms can be transmitted in a "transparent" way to the centralized electronic control unit and viceversa also via standard fieldbus, see tab. F002 for "Basics for digital electrohydraulics".
Proportional electrohydraulics provides the following advantages in comparison with the electromechanical systems; intrinsic overload protection, automatic force adaption, fast operating response, self lubrification of the system, simple stepless variation in speed, energy storage capability, high power density, forces and torques, long service life and high reliability.

2 WHAT IS A PROPORTIONAL VALVE?

The core of electrohydraulic controls is the proportional valve that regulates a pressure P or a flow Q according to the reference input signal (normally ±10 V_{DC}) supplied by the machine CNC. Particularly the proportional valve must be operated by an electronic driver (see tab. G001) which regulates a proper electrical current supplied to the valve's solenoid according to the reference signal. The solenoid converts the electrical current into a mechanical force acting the spool against a return spring: rising of the current produces a corresponding increasing in the output force and consequent compression of the return spring, thus the movement of the spool. The proportional valves can be single stage or piloted, with or without pressure/position transducer. Proportional valves with transducer provide better regulation accuracy.
In pilot operated executions the proportional pilot valve regulates flow and pressure acting on the main operated stage.
When electrical failure occurs, return springs restore the neutral position according to valve configuration, to ensure a fail-safe operation, i.e. to ensure that in case of absence of reference signal or, generally, in case of electric system breakdown, the system configuration does not cause damages. Fail-safe can be realized directly by the proportional valve (fail-safe operation intrinsic in valve configuration) or it can be realized by consequential operation of a group of valves.

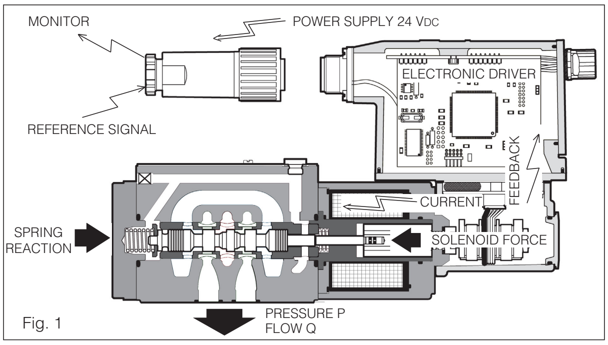


Fig. 1

3 CONTROL LOOPS

Today industrial machines are multi-axis machines, more and more electrohydraulically controlled by proportional devices. The axis motion can be operated in "open loop" or in "closed loop" control, depending to the accuracy level required in the application. In many applications the motion cycles do not require extreme accuracy, so they are performed in open loop, while each time the application requires the positioning of an actuator, a closed loop control must be provided.

OPEN LOOP MOTION CONTROL

Axis control is provided through the supply of a reference input signal to the driver of the proportional valve.
There is no feedback of the valve's regulated hydraulic parameter.
The accuracy of the open loop controls is strictly dependent of the good quality of the hydraulic system and particularly of the proportional valve and of the relevant driver.

CLOSED LOOP MOTION CONTROL

Axis control is provided through the supply of an input reference signal to a closed loop axis controller which receive the feedback signal from the actuator transducer. The controller compares the two signals and the resulting error is then processed to the proportional valve, in order to align its regulation to the PID control loop requirements.
The accuracy of the closed loop controls is much better respect to the open loop ones and it is less influenced by the external environmental disturbances, thanks to the presence of the feedback.
Anyway the best is the overall quality of the hydraulic system, the best is the accuracy of the axis control.

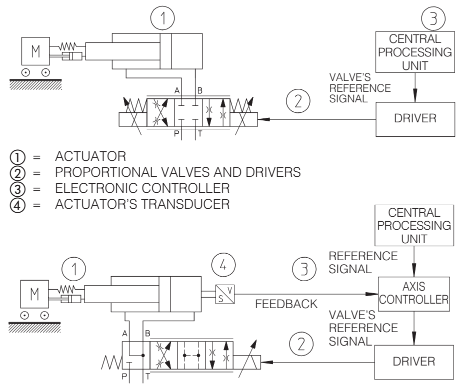


Fig 2: Electrohydraulic axes: a basic block diagrams

4 PROPORTIONAL VALVES AND DRIVERS

Atos valves may be spool type or cartridge execution and can be grouped in three different functional families:

- **pressure control valves: relief valves** and **reducing valves** regulate the hydraulic system pressure proportionally to the reference input signal;
- **4-way directional control valves:** direct and modulate the flow to an actuator proportionally to the reference input signal. These valves can be used in open or closed loop control system to determine the direction, speed and acceleration of actuators;
- **flow control valves:** 2 or 3-way, pressure compensated, to modulate the flow independently to the user loads.

Atos proportional valves are equipped with **ZO** and **ZOR**, efficient solenoids (30 W and 40 W) respectively designed for direct-acting valves of ISO 4401 size 06 and 10 and they are assembled in different options as follows:

ZO(R)-A: without integral transducer, open loop;
ZO(R)-AE, AES: as ZO-A plus integral electronic driver, analog or digital;
ZO(R)-T, -L: with integral LVDT single/double position transducer, closed loop, featuring high static and dynamic performances;
ZO(R)-TE, -LE, -LES: as ZO-T, -L plus integral electronic driver, analog or digital

In the new generation of -AE, -TE, -LE valves, the electronic driver is integral to the proportional valves and it is factory preset to ensure fine functionality plus valve-to-valve interchangeability and to simplify installation wiring and system set-up. Electronics are housed and resin encapsulated in a metal box to IP67, ensuring antivibration, antishock and weather-proof features; coils are fully plastic encapsulated.
For detailed information on Electronic drivers, see tab. G001

5 TYPICAL ELECTROHYDRAULIC TERMS

Repeatability: The maximum difference in the valve's hydraulic regulation repeating the same input reference signal. Repeatability is measured in percentage of the maximum value of the regulated hydraulic parameter.

Overlap: Percentage of spool stroke, starting from the central position, in which the valve remain closed.

Fail safe: spool's safety hydraulic configuration in absence of electrical power supply

Linear spool: provides linear correspondence between valves regulation and reference input signal

Progressive spool: provides progressive regulation for finest low flow control

Differential spool: as progressive but with P-B = 50% of P-A

Leakage: The flow passing through port P to tank port T with the valve spool in central position. It is directly connected with the quality of the valve's mechanical execution.

Reference input signal: The electric signal sent from machine CNC to the valve electronic driver to obtain the required regulation value.

Driving current: The current sent from the electronic driver to the valve's solenoid.

Bias current: Static offset added to the reference input signal required to compensate positive overlap spools.

Dither: The pulse frequency of the driver regulation used to minimize the valve hysteresis.

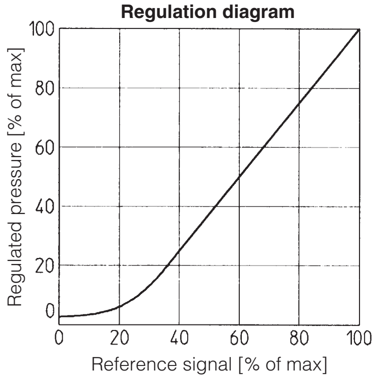
Regulation scale: Setting of the valve regulation with the max reference signal.

Ramp time: Time (in sec.) required to smoothly operate the valve in front of a step reference input signal.

6 TYPICAL DIAGRAMS OF PROPORTIONAL CONTROLS

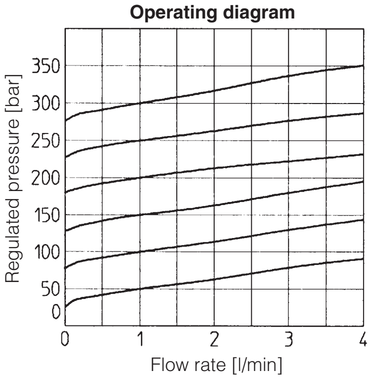
6.1 PRESSURE CONTROL VALVES

Regulation diagram



Valve's-regulated pressure variation according to the reference signal

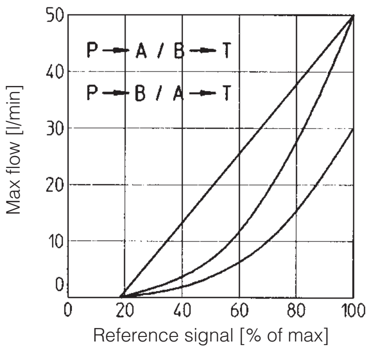
Operating diagram



Valve's-regulated pressure variation according to the flow passing through the valve

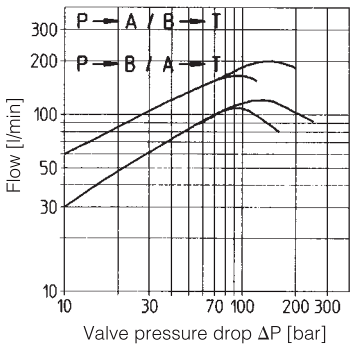
6.2 DIRECTIONAL AND FLOW CONTROL VALVES

Regulation diagram at characteristic Δp



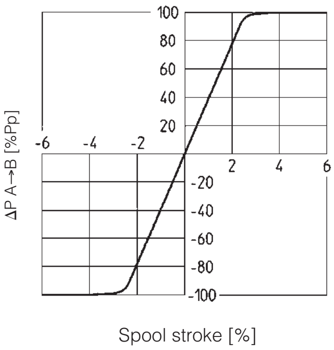
Valve's-regulated flow variation according to the reference input signal

Regulation diagram at max reference signal



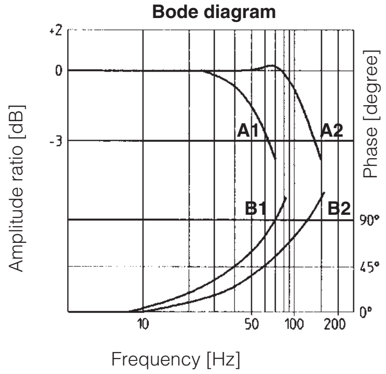
Regulated flow vs. functional Δp at max reference input signal

Pressure gain diagram



Pressure variation on use ports depending to the spool stroke (only for valves with zero overlapping in rest position).

Bode diagram

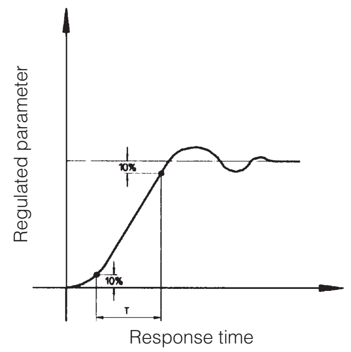


The curve shows for typical regulation ranges (±5% and ± 90%) at different sinusoidal reference input signal frequency:

A) amplitude ratio variation, between reference input signal and the regulated spool position output signal;

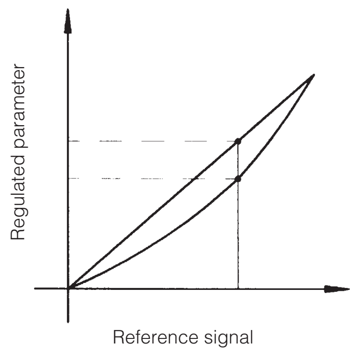
B) phase lag between reference input signal and the regulated spool position signal.

Response time - step input



The time lag required by the valve to reach the requested hydraulic ragulation in front of a step change in the reference input signal (usually 0÷100%).
Response time is measured in millisecond [ms] from 10 to 90 % of the step valve.

Hysteresis



The maximum difference in the valve regulation between reference input signal from 0 to maximum and than from maximum to zero.
Hysteresis is measured in percentage of the maximum value of the regulated hydraulic parameter.