VICKERS

Application Notes for Electronic PID Controller Module type EHA-PID-201-A-10 Series

GB-B-9108

INDEX

This unit is one of a range of "Snap-on" control modules for cabinet-mounting on rails to DIN EN 50022 or DIN EN 50035. It is ideally suited for use in control systems using Vickers "KA" series proportional valves with integral amplifiers, where external ramp generation, conversion of current command signals to voltage, etc., may be required.

The PID module can be used for closed-loop pressure, velocity, position and p/Q controls. A selector switch on the front panel is used to set the internal configuration of the controller.

Parameters P, I, D and V of the controller, as well as ramp up and ramp down, are independently adjustable. Ramp function, integrator and output can be enabled independently via external 24V signals. The output signal level is ±10V, compatible with the input requirements of Vickers "KA" series valves.

The working range of the demand, feedback and feedforward signals is ±10V.

To facilitate startup and fault diagnostics, the integrator output signal is fed to a monitor point in the front panel, with ramp output and error signals available at terminal connections. The front panel mounted LEDs give the power supply and internal control voltage status, as well as providing ramp, controller and integrator "enabled" indications. All the potentiometers are mounted on the front panel.

Notes on use

The PID controller structure used in hydraulics is normally that of a slightly modified standard PID controller. The individual controller structures will therefore be described first. These structures are application-specific and can be selected via the mode switch. Some knowledge of PID controllers and their use is required.

It is also essential to use an oscilloscope for controller optimization. The adjustment instructions and notes always refer to this test instrument.

The safety measures that must be taken prior to switching on the hydraulics and electronics are naturally machine-specific. However, just remember that defective, incorrectly wired or poorly adjusted electronics usually tends to produce extreme reactions, (i.e. maximum velocities up to the end stop, maximum or minimum pressure).

Incorrect polarity of control direction: If the system has been completely installed, but the individual effective directions have not been correctly observed, the control direction may be reversed and the control circuit will act as a positive feedback loop. If this is the case, the actuator (valve) goes to the end stop (100% open or closed). This fault may be observed most easily at the integrator. In a positive feedback situation, the integrator is always at its limit (±10V).
In the case of position-controlled systems, the drive always moves in the wrong direction at maximum velocity. In this case the cylinder is the integrator.

The integrator is also used for pressure, force and velocity control systems. In these arrangements it is possible to measure at the monitor point on the PID module whether the integrator is at its limit (± 10V). This does not apply to P/Q mode, since reaching the correcting limit is a normal operating state for this type of controller. In this case the polarities must be carefully checked.

For **reproducing** the adjustment parameters determined for series applications, monitor points (V,P,I and D) are provided under the cover on the left-hand side. Controller settings can be measured with respect to ground using an ohmmeter. Consequently, when a replacement is supplied, the module can be set up in advance.

Hydraulic drive systems mainly employ two fundamentally different forms of control action.

On the one hand, there is the position control circuit with its integrating action and, on the other, the velocity, speed or force control circuit with its proportional action.

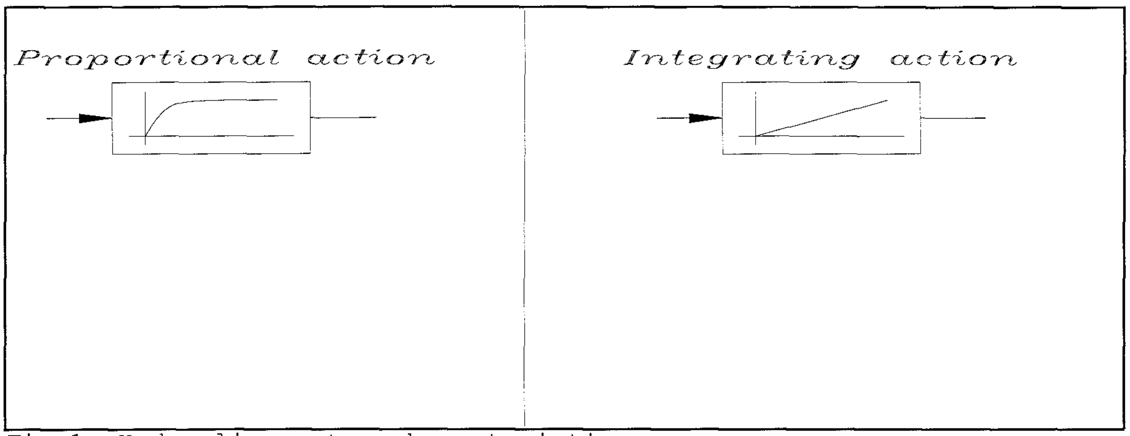

Fig.1 Hydraulic system characteristics

The basic characteristic of the proportional hydraulic system is that the output varies proportionally (but not necessarily linearly) with respect to the input signal. This means, for example, that if a 10V input voltage results in a pressure of 100 bar, a 5V input signal will produce a pressure of 50 bar (linearized).

The integrating system, the position control loop, behaves differently. If e.g. an input signal of 10V is selected, this produces a corresponding velocity which is proportional to the input signal. The position changes constantly with that velocity. This means that the position control system has no self-regulation and the travel is only limited by the mechanical end stop.

In order now to correct the error in a control circuit, an integrator (in the system or in the controller) is required.

In the case of a proportional system, a controller structure incorporating an integrator (I, PI or PID) must therefore be selected.

In the case of an integrating system (closed-loop position control), the integrator must already be provided in the system (cylinder) and a controller structure with no integrator (P or PD) must be selected. If in this system an integrator were to be additionally activated in the controller, the hydraulic system would be unstable and tend to oscillate.

The Ramp Function

In many applications of hydraulic drive engineering, overshooting of the position or the pressure is undesirable. As a step-change input to the control system is not normally acceptable, a linear operating ramp can be provided in the demand signal branch (**Fig. 2a**). As may be seen from **Fig. 2b**, a step change in the demand signals results in varying degrees of overshoot. To prevent this, the controller would have to exhibit considerable inertia. The ramp in the demand signal branch damps this response and generally allows a more dynamic controller adjustment and therefore better correction of control errors without overshoots (**Fig. 2c**). In position controls, the ramp settings determine the velocities, in velocity control arrangements they determine the accelerations and in pressure controls they determine the pressure build-up and relief times.

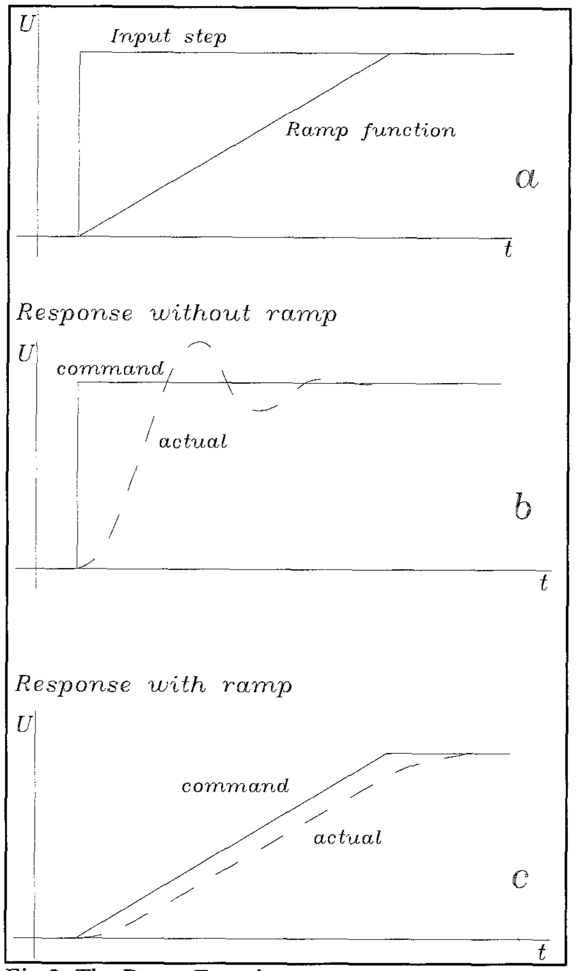

Fig.2 The Ramp Functions

Four different controller structures can be implemented via the mode switch. All these structures are derived from the basic structure of the standard PID controller and represent modifications for optimum matching to the relevant control tasks.

2.2.1 PID MODE Switch Position 1

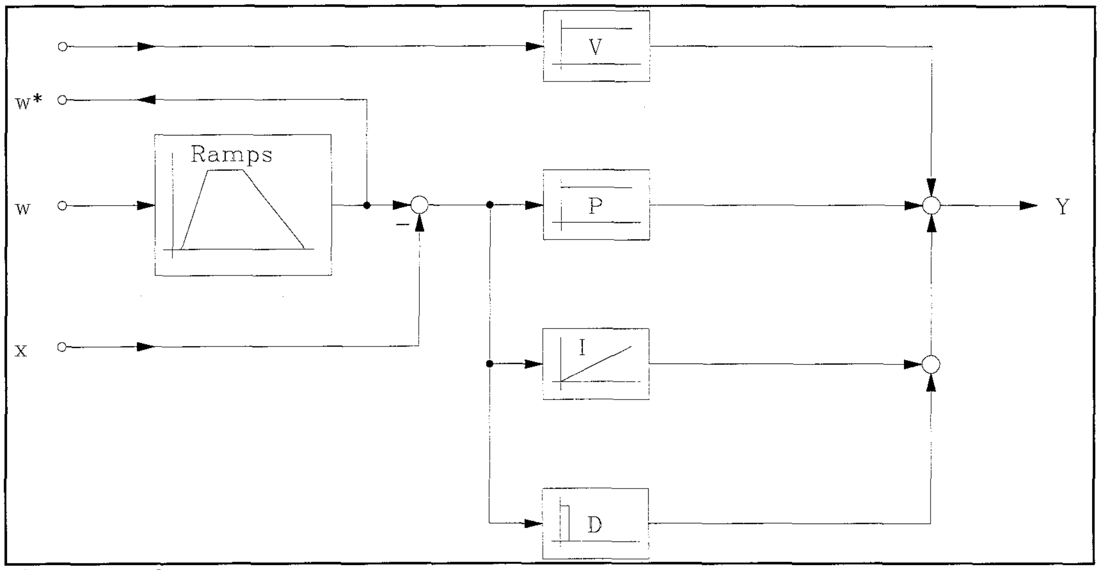

Fig.3 PID MODE

This mode corresponds to the standard PID controller, where the various signal components are added at the output. A rate of change can be superimposed on the demand signal via the ramp function. The demand signal can be directly supplemented at the controller output via the feedforward input. For control tasks where the system exhibits a proportional action, the dynamic response can be positively influenced using the feedforward input.

- Without I and V gain, this structure can be used for position controls.
- With PID and V gain, it is suitable for pressure control circuits with proportional pressure control valves and for velocity control circuits.
- With PID but without V gain, it is suitable for pressure and force control circuits incorporating control or servo valves.

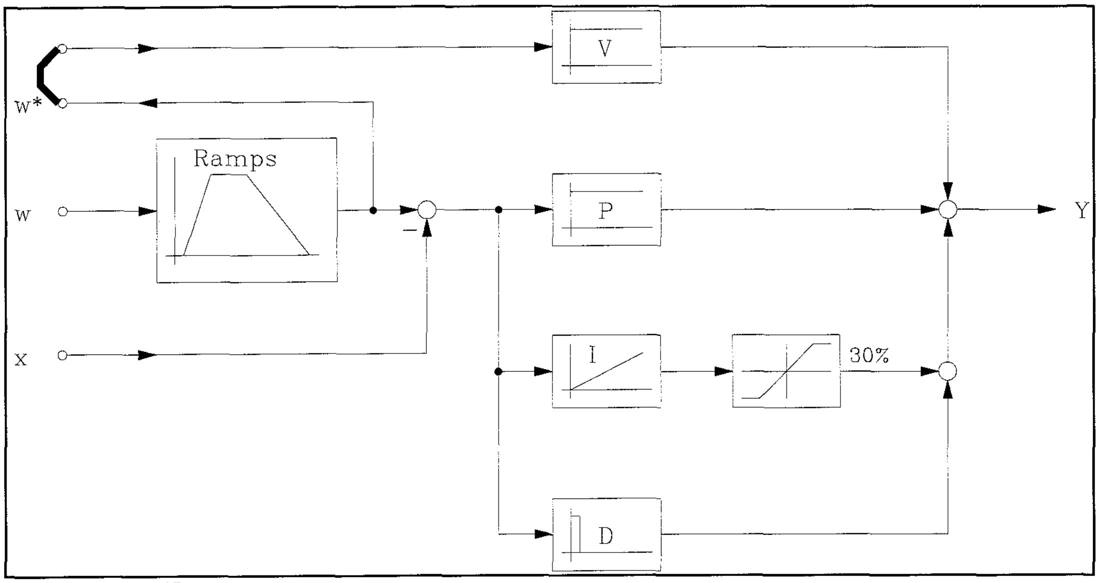

Fig.4 V-MODE

V-MODE is particularly suitable for velocity, speed, pressure and force controls (except pressure controls using proportional spool or servo valves). It differs from PID MODE in that the I gain is limited to 30% signal amplitude and the integrator time constant is reduced by a factor of 3. Since in the case of proportional control processes, the error can only be corrected via the I gain under steady-state conditions, the valve must be pre-opened via the feedforward input.

This has the advantage that, due to the piloting of the valve, the controller only needs to correct the error due to any nonlinearities. This allows the dynamic response and stability of the control circuit to be considerably improved.

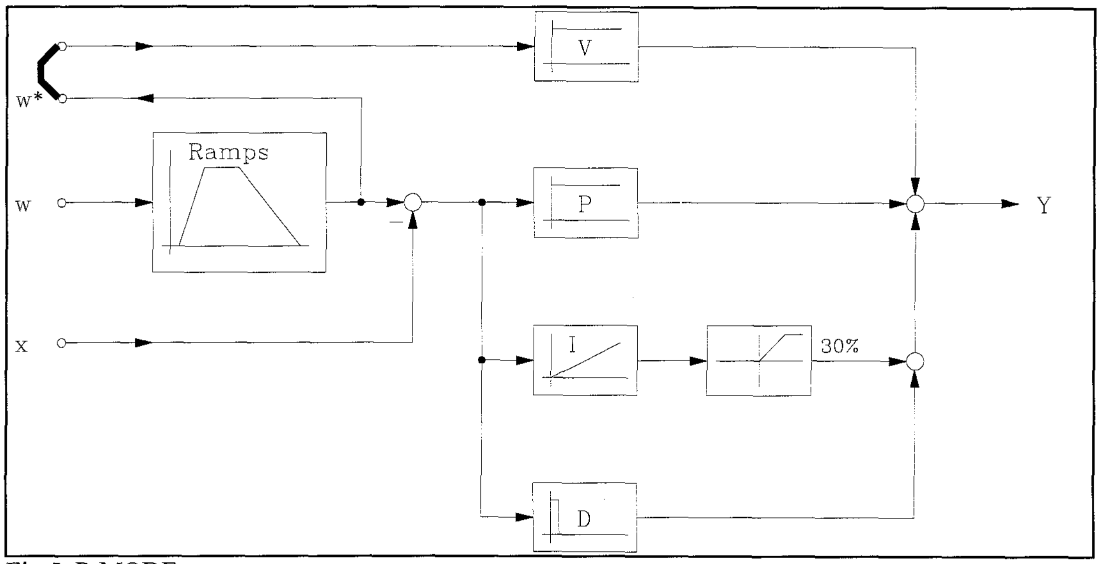

Fig.5 P-MODE

P MODE is employed for time-critical pressure controls incorporating proportional pressure valves where the I gain must not go into negative saturation. Unlike V MODE, in this case the I gain only operates in the positive range. This means that only positive errors can be corrected. Here the piloting must be adjusted such that the actual pressure is always lower than the required pressure during controlled operation. Only if this is the case can the regulator correct errors occurring during controlled operation.

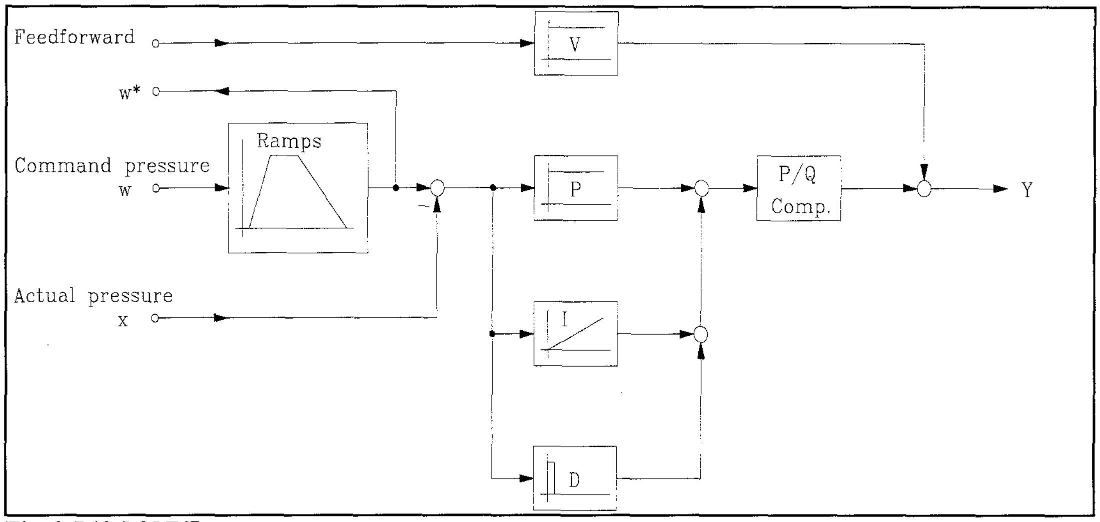

Fig.6 P/Q MODE

The P/Q or pressure limiting regulator is used where a flow rate is specified and a specified pressure (or pressure profile) must not be exceeded. The controller output signal is 0 as long as the actual pressure is lower than the required pressure. This means that the controller is only activated if the actual pressure signal is larger than the pressure demand signal. In this case, the limiting controller reduces the output signal, and therefore the rate, which was selected via the feedforward input, until the required and actual pressures are equalized. The drive can be reversed if necessary to maintain the pre-selected pressure. This controller structure can only be used with control or servo valves.

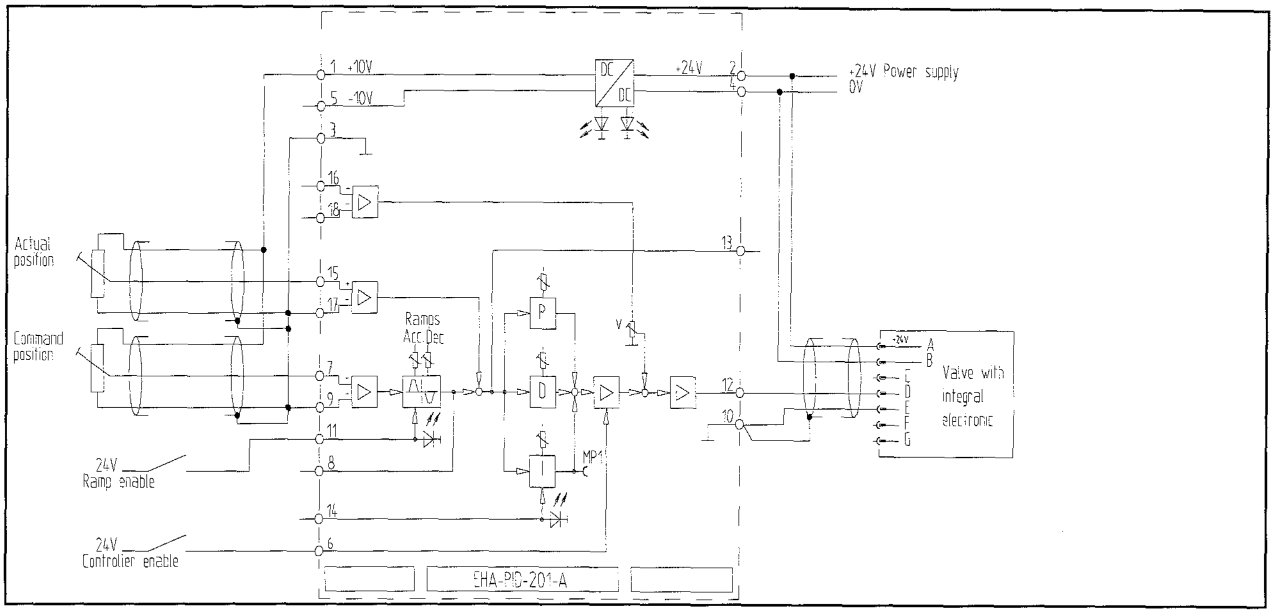

Fig.7 Position control circuit

Controller Configuration PID MODE:

Position controls are implemented using cylinder or motor drives. An analog position transducer signal (± 10V, + 10V) must be present. The controller output drives a proportional directional valve or a servo valve.

Depending on requirements, the demand position can be specified as a signal step change or using a speed ramp. The position controller is configured as a P or PD controller. The feedforward input must not be used for position controls.

- Rotate the P and D gain controls counterclockwise to minimum setting.
- The I gain is deactivated.
- If the ramp stage is to be used as a velocity limiter, the ramp time must be set using an oscilloscope by switching between two position demand values.
- Now switch on the hydraulics and enter two different wanted positions alternately.
- Using an oscilloscope, observe the output signal at terminal 12.
- Now increase the P gain until the drive follows the demand profile and the target positions are reached with the required accuracy.
- Observe the oscilloscope. The higher the P gain is set, the more rectangular the signal becomes.
- If the P gain is too high, the drive becomes unstable and overshooting of the target positions occurs.
- Fine optimization using the D gain can now be performed by increasing the P and D gain alternately. Caution! For many drives, the D gain may produce severe oscillation.
- Target positions can now be reached only with a defined tolerance.

  If a higher degree of accuracy is required, the complete system must be designed accordingly.

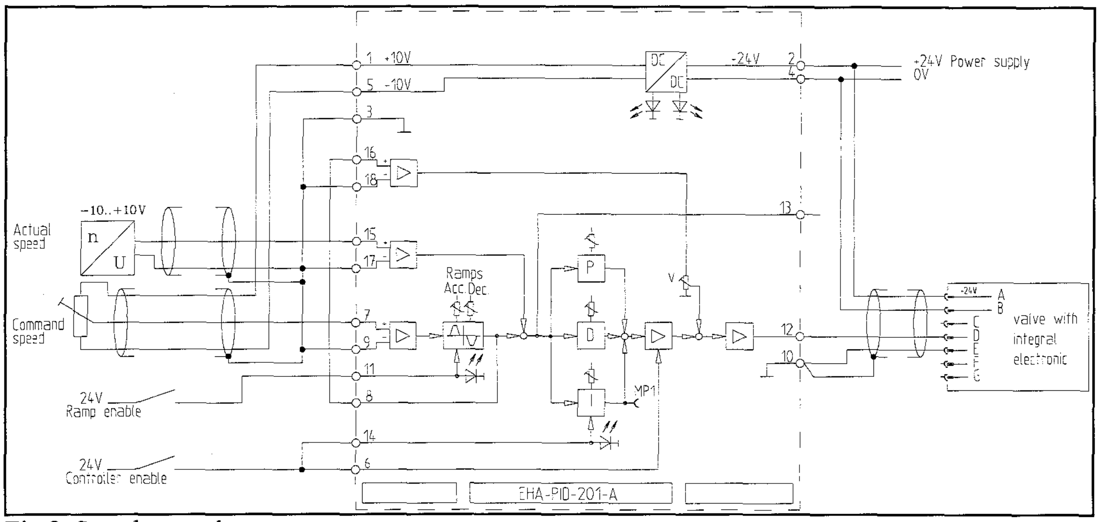

Fig.8 Speed control

Controller Configuration V MODE:

For velocity and speed controls, a motor drive is normally used. Velocity controls on the cylinder drive require expensive linear velocity transducers and are often difficult to incorporate into the machine. For motor drives, a tacho generator is mounted on the second shaft end, providing a simple, cost-effective solution. A proportional directional valve or servo valve is driven by the output signal of the module. Depending on requirements, the demand velocity can be selected as a signal step change or via an acceleration ramp.

The velocity controller is designed as a PID controller with limited I gain and pilot control.

- Rotate P, I and D potentiometers counterclockwise to minimum. V potentiometer to maximum.
- Controller enable and integrator are inactive.
- If the ramp is used to limit acceleration, the ramp time must be set with an oscilloscope by switching between the input signal for maximum velocity and zero.
- Now switch on the hydraulics and select an input signal (10V) for the maximum velocity required. The desired velocity is now set on the V potentiometer.
- The drive now moves under control with the velocity you have selected.
- Now switch on the controller and integrator.
- Cycle the drive between two velocities selected by you.
- Observe the error signal, terminal **13**, on the oscilloscope.
- Increase the I gain and continue to observe the error signal at terminal **13**. The error is now corrected via the I gain and the signal at terminal **13** must go to zero. If the I gain is excessively large, the control circuit tends to oscillate.
- The dynamic correction response is increased by the P gain.
- The transient response can be damped using the D gain.
- For fine optimization, the individual parameters can be further readjusted alternately.

2.5.1 Pressure or Force Control with Proportional Pressure Control Valves

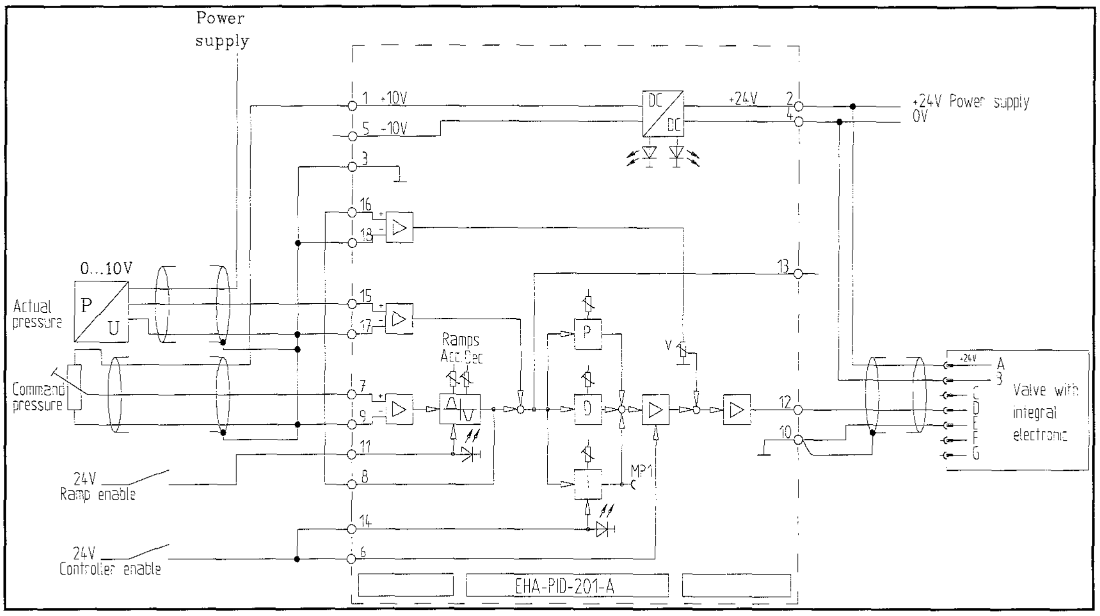

Fig.9 Pressure control using proportional pressure control valve in P/V MODE

Both proportional pressure reducing and relief valves and pumps with proportionally adjustable pressure controllers can be operated in a pressure control circuit. The hydraulic peculiarities of the circuit must be taken into account.

Note that in the above applications 0 pressure can never be attained. <u>The minimum pressure specified must be taken into account.</u>

In pressure control circuits, the operating pressure is measured by a pressure transducer; for force control, a force transducer is installed at a suitable point. These controls are implemented using P MODE or V MODE.

- Rotate P, I and D potentiometers counterclockwise to minimum. V potentiometer to maximum.
- Controller enable and integrator are disconnected.
- If the ramp stage for pressure build-up and relief is to be used, then set the ramp time using an oscilloscope by switching between the input signal for maximum pressure and zero.
- Now switch on the hydraulics and preselect an input signal for the maximum pressure required. Set the pressure on the V potentiometer.
- The drive now operates under control at the pressure you have selected.
- Now switch on the controller and integrator.
- Cycle the drive between two pressures you have selected.
- Observe the error signal, terminal **13**, on the oscilloscope.
- Increase the I gain and continue to observe the error signal at terminal **13**. The error is now corrected via the I gain and the signal at terminal **13** must go to zero. If the I gain is too high, the control circuit tends to oscillate.
- The dynamic correction response is increased by the P gain.
- The transient response can be damped by the D gain.
- For fine optimization, the individual parameters can be further adjusted alternately.

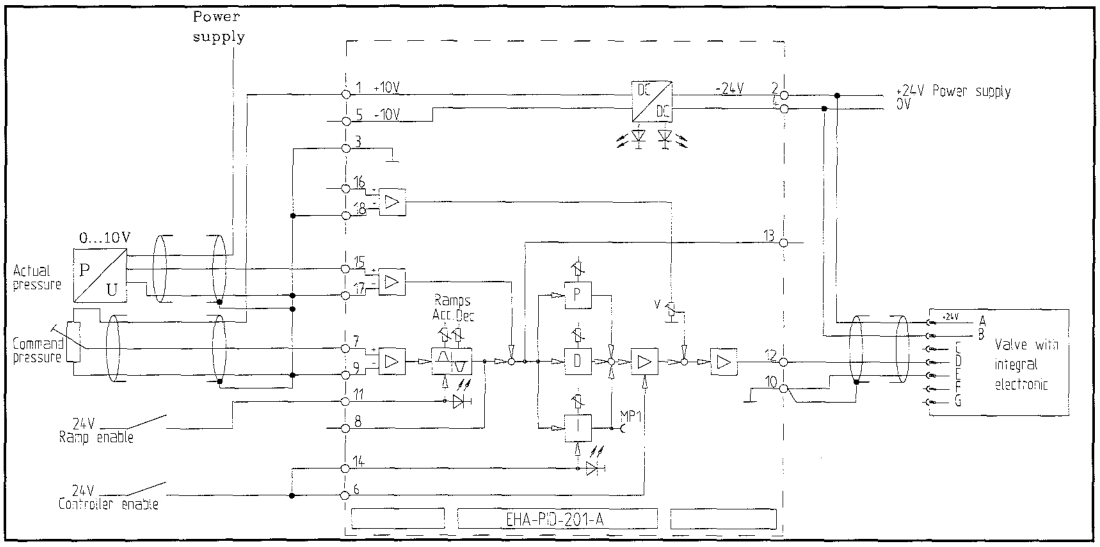

Fig.10 Pressure control using zero lapped valves in PID MODE

Pressure and force controls on the cylinder drive. The pressure is measured via pressure transducers in one of the two cylinder chambers, or the pressure in both cylinder chambers is determined and the differential pressure is calculated. A force transducer is required for the force control. The pressure or differential pressure control on the cylinder is an indirect force control due to the proportionality between force and pressure.

For pressure control using a control or servo valve, the general mode of operation is similar to a pressure reducing valve. The control valve can operate like a three-way pressure reducing valve. This means that the oil can flow out of the cylinder chambers through the valve and back into the tank. Very small minimum pressures can be controlled. For this purpose PID MODE without piloting is used.

- Rotate P, I and D potentiometers counterclockwise to minimum. V potentiometer to maximum.
- Controller enable and integrator are disconnected.
- If the ramp stage for pressure build-up and relief is to be used, then set the ramp time using an oscilloscope by switching between the input signal for maximum pressure and zero.
- Now switch on the hydraulics and select an input signal for the maximum pressure required.
- Now switch on the controller and integrator.
- Cycle the drive between two pressures you have selected.
- Observe the error signal, terminal **13**, on the oscilloscope.
- Increase the I gain and continue to observe the error signal at terminal **13**. The error is now corrected via the I gain and the signal at terminal **13** must go to zero. If the I gain is too high, the control circuit tends to oscillate.
- The dynamic correction response is increased by the P gain.
- The transient response can be damped by the D gain.
- For fine optimization, the individual parameters can be further readjusted alternately.

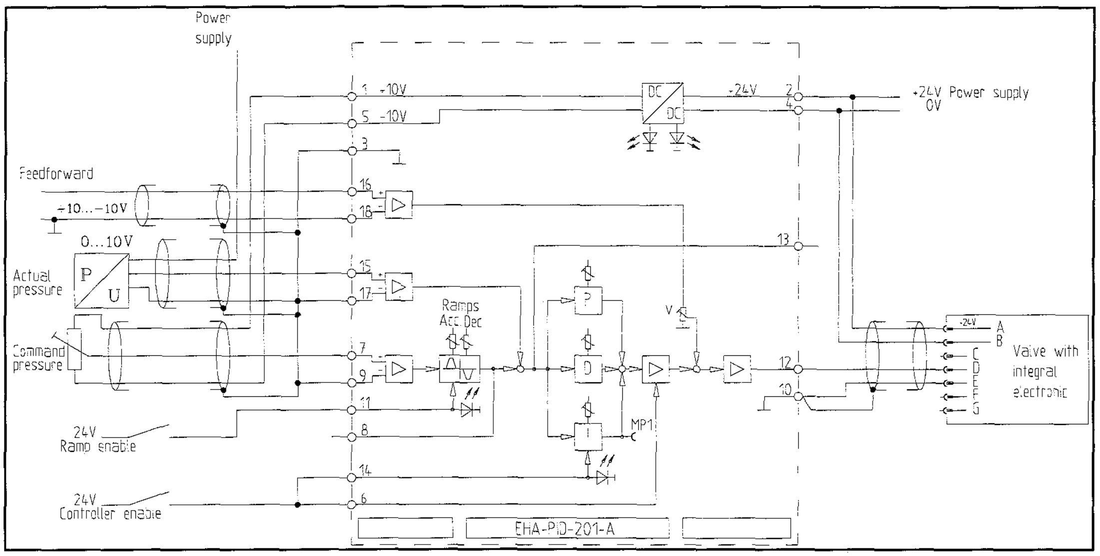

Fig.11 P/Q control

P/Q control employs control or servo valves or so-called P/Q valves for which the spool has been modified for a precisely specified pressure gain.

The pressure is measured in one of the two cylinder chambers, or the differential pressure is determined.

The travel velocity is preselected via the feedforward input by an external controller (e.g. EEA-POS-431-A-10).

- Rotate P, I and D potentiometers counterclockwise to minimum. V potentiometer to maximum.
- Controller enable and integrator are disconnected.
- If the ramp stage for pressure build-up and relief is to be used, now set the ramp time using an oscilloscope by switching between the input signal for maximum pressure and zero.
- Switch on the hydraulics.
- For a controlled system, now set the desired velocity using the V potentiometer.
- Then select the input signal for the maximum pressure required for moving the drive.
- Now switch on the controller and integrator.
- The drive moves under control at the velocity you have specified until the pressure builds up.
- Cycle the drive.
- Observe the error signal, terminal **13**, on the oscilloscope.
- Increase the I gain and continue to observe the error signal at terminal **13**. The error is now corrected via the I gain and the signal at terminal **13** must go to zero. If the I gain is too high, the control circuit tends to oscillate.
- The dynamic correction response is increased by the P gain.
- The transient response can be damped by the D gain.
- For fine optimization, the individual parameters can be further adjusted alternately.