

ELECTRO-HYDRAULIC ACTUATOR (EHA) MOTION CONTROL SIMPLE AND ACCURATE – NO MAGIC

This article will provide some basics regarding motion control in general and motion control for hydraulics compared to electrical mechanical actuators (EMA) and electro-hydraulic actuators (EHA).

Closed Loop Control Set-point...

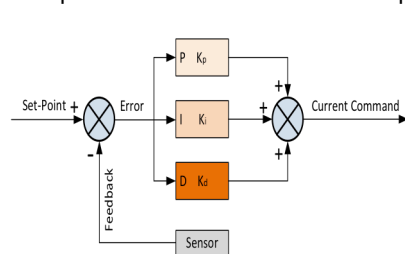
A set-point, which is your target position, can be provided through various sources including a 0-10Vdc signal, a 4-20ma signal or through a communications method (serial or fieldbus). A 4-20ma signal is usually more noise immune than the 0-10vdc signal and can travel a longer distance. Of course a shielded communications signal is the preferred choice but has a larger overall system expense. A simple example would be using a 0-10vdc reference which represents 10 inches of stroke. A 5vdc signal into the controller would tell the system to go to the 5 inch position.

Feedback...

The feedback is a signal from a device which you desire to control (e.g. position, load or current). The feedback signal is connected to the machine or actuator that provides a status response back to the controller. Using position for example... for a 10in actuator a 0-10vdc feedback device is used, a 3vdc signal would advise the controller the actuator is at the 3 inch position.

Error

Error is the difference between the set-point and the feedback. Keeping the example in the analog form for discussion purposes (BTW, in the old days all of this was done in the analog world & control engineers were electronic magicians - - no processors or software). In the above examples the set-point of 5vdc minus the feedback of 3vdc provides an error of



2vdc. The error of 2vdc then goes into a PID controller (Proportional, Integral and Derivative). The PID

sends a current command to the current loop to increase or decrease current to the motor until the error is at zero. Many applications can get by with a proportional only term, the integral assists with reducing steady-state error which the proportional term is unable to bring to zero (but could introduce instability), the derivative is for more complicated systems and rarely used.

A/D Conversions...

Depending on the controller, the analog signals are converted to a digital representation. These analog to digital (A/D) conversions are

Common Sense Control Rules...

- Apply the KISS mindset (keep it simple) - - the simpler the design the easier to control
- The set-point and feedback signals need to be noise-free and should not be routed with higher voltage cables
- The closer the feedback device to the control mechanism the better. E.g. placing a feedback device directly on the actuator rod is more accurate than a device on the motor going through a gear train.
- Size things properly (Motor, drive, valve, pump, pipes etc.)
- Minimize / eliminate all variables except for what is being controlled. I.e. flex hoses, poor mechanics, friction etc.
- Use higher resolution A/D controllers
- Understand the system, the dynamics and any mechanical interactions. Controlling a large arm or a large rotating inertia have different challenges.

important regarding system accuracy. Controllers have various resolutions and claim different accuracies. Many use 16 bit registers, which is 2 to the 16th power that equals 65536 counts which represents 10vdc and 10 inches. The controller performs motion control using these digital registers. Of course with more resolution (higher bits), more precise control is achievable.

Control Loops...

There are various control loops, inner loops and outer loops. The inner most control loop is the current loop (for motor control) which directly controls current flowing into (and out of) the motor (current command). For a proportional servo valve (in simple terms), it controls the valve's spool position (which controls flow or pressure) via a torque motor / LVDT. The outer loops usually control what is desired like actuator position or load.

Limits...

Maximum or minimum limits are used in control to limit a speed or force during a motion. For example, a press needs to run at maximum speed at no load while controlling position so a max speed can be set as the PID "winds-up" (with a large position error), a limit on the max output of the PID (or downstream prior to the current command) can be set to the max desired speed.

Synchronizing Motion...

Synchronizing motion sounds complicated, but in reality applying the basic control outlined above allows the ability to coordinate motion as desired. For example, on a lift application with four actuators with an unbalanced load: This appears to be very challenging... all four actuators need to lift simultaneously while compensating for the unbalanced load. There are multiple ways to solve this... in general a simple method is to implement a master-slave follower. One actuator is determined to be the master and it receives the table's

target set-point, the position feedback from the master becomes the set-point for the remaining three actuators therefore all four lift together. With the unbalanced load the inner current loop will regulate its current to maintain the outer position loop, as one or two actuators see more load, the inner current error will increase (as the load is being more difficult to lift from one actuator to another), the inner current loop's PID will send a higher current command to the motor to compensate for the unbalanced load. So each actuator's current command will be different depending on friction and unbalanced table loads, but they all will start and stop together because of simple motion control techniques.

Open Loop Control

Open loop control is a simple method of moving a motor. However, it does not adjust for disturbances such as changing motor loads. E.g. with a 24Vdc motor, if one applies 24Vdc to the motor, it will run at its designed max RPM based on the no load characteristics. Varying the applied voltage higher/lower will proportionally increase/reduce the motor speed. For a fixed applied voltage, once a load is applied the speed will decrease as the current is used to overcome the load and reduces the speed -- current creates internal voltage drop in the motor due to the copper wire resistance. This drop effectively reduces the applied voltage to the motor and takes away from voltage available for creating speed.

Kyntronics EHA & Motion Control

Accurately controlling and synchronizing a hydraulic cylinder is common and is successfully performing its function in millions of locations around the world. Hydraulic motion control is semi-complex relative to an electrical motor driven cylinder / system. The hydraulic system has many individual parts/conditions that need to coordinate together including

the pump, cylinder, feedback transducer, standard valves, relief valves, servo valves, variable heat / pressures, contamination, leaks, hoses (flexible and fixed), connections etc. With the above, there are many variables that need to be accounted for to accurately and reliably perform the desired motion control. An electric motor/actuator eliminates most of the above regarding motion control variables. Along with being simpler, an electric actuator solution can easily communicate with a plant wide fieldbus providing diagnostics and status. Plant wide diagnostics and status communications with Hydraulics is challenging and expensive.

Kyntronics all-in-one Electro-Hydraulic Actuator (EHA) incorporates all the hydraulic advantages along with the motion control simplicity of the electric motor/actuator. With the rod having the position device directly connected, the controller will send the appropriate current signal to the motor (which is connected to the pump) to rotate and provide the desired amount of fluid to move the rod at the desired speed to the desired position. Some think a gear pump cannot be accurately controlled at slow speeds. This is true, the pump cannot by itself,... but the controller/motor/pump combination can. The controller compensates for slip and pump inefficiencies, the position error will advise the position PID to advise the motor's current loop to increase or decrease to satisfy the position error.

So the overall EHA system can go slow and can be accurately controlled (motion control 101). What if the system heats up and changes the condition of the oil and the performance of the pump you ask? The same applies... the motion controller will compensate for the error and will accurately control the EHA's rod position regardless of the conditions.

Kyntronics employed all the above common sense rules especially keeping the control design simple. With many years of motor/motion control experience the Kyntronics experts applied fundamental motion control techniques to the EHA to accurately control both position and pressure (lbf at the rod). Both the position and pressure loops are outer loops that work together running at max speed under no load (as a press) then quickly switch to force control to accurately control the force on the press. With the Kyntronics EHA, the

force on the rod is controlled via two pressure sensors, one on both sides of the piston. There is always pressure on both sides of the piston, so to accurately control force in the extend direction for example, the rod force calculation is $F_2 - F_1 = \text{Rod Force}$.

The above logic is an integral part of the EHA, no extra parts, no extra piping or connections. A mechanical actuator can “attempt” to control force via current but there are many variables and it cannot accurately control force at the load point at

variable speeds and variable conditions. To accurately control force, a mechanical actuator requires an expensive load cell and a custom program.

The Kyntronics all-in-one EHA is a simple cost effective design in a compact package that delivers accurate control of both position and force while providing synchronization of multiple actuators together.

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