Kyntronics
Innovation in Motion

TECHNICAL REPORT
TR-301
REV B

ACTUATOR GENERAL CONTROL GUIDLINES

Prepared By Title:	Scott Schmocker Sr. Electrical Engineer	Date:	02/22/2024
Checked By Title:		Date:	
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REVISION HISTORY

Revision	Description of Change	Date (MM-DD-YYYY)	Revised by
A	Created	02/22/2024	ss
B	Additions in section 10.1	06/19/2024	ss

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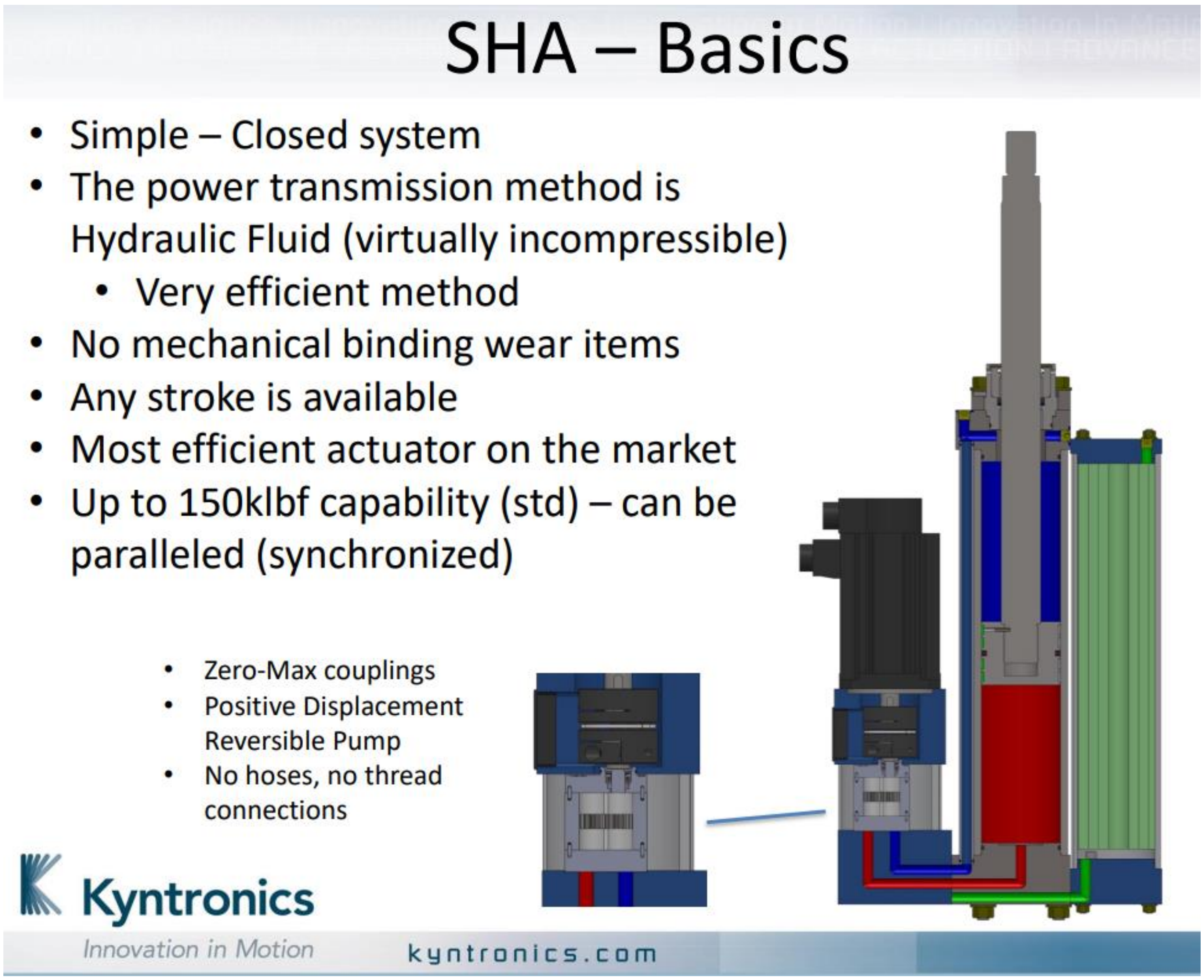
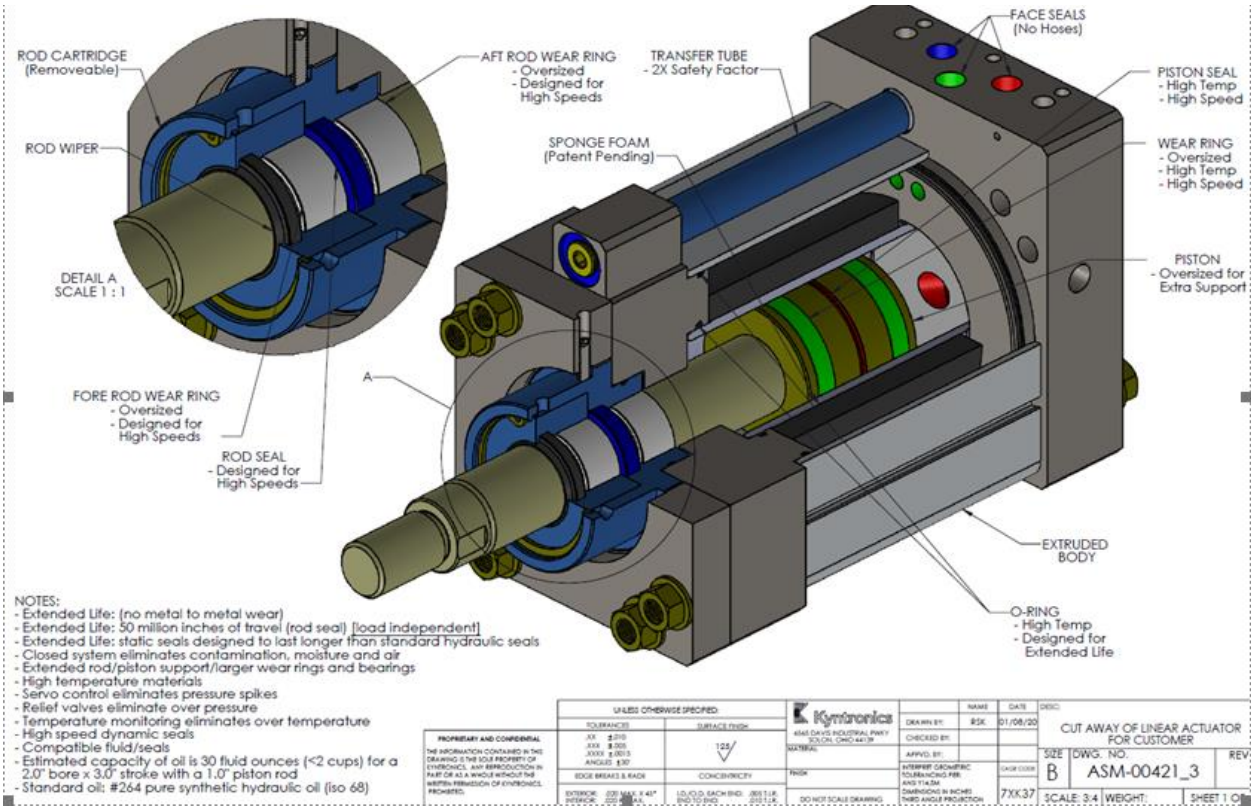
1 PURPOSE

To provide an overview and guidelines for interfacing a Kyntronics Smart Hydraulic Actuator (SHA) using custom controls, drives and I/O.

2 ACTUATOR DESCRIPTION



The Kyntronics actuator has a main rod and cylinder, dimensioned based on the force requirements, along with a reservoir, and with an oil pump which can be considered a positive displacement pump. The unit is sealed, and the relief valves and zero-leak fittings are marked with pink tamper-proof indicator seals and are not to be adjusted in the field.



2.1 Actuator Conventions

Typically, the pump will be turned using an electric motor, via a keyed coupler.

Kyntronics conventions are:

Positive motor rotation **must** extend the rod, and negative motor rotation **must** retract the rod. Invert polarity as needed to satisfy this requirement.

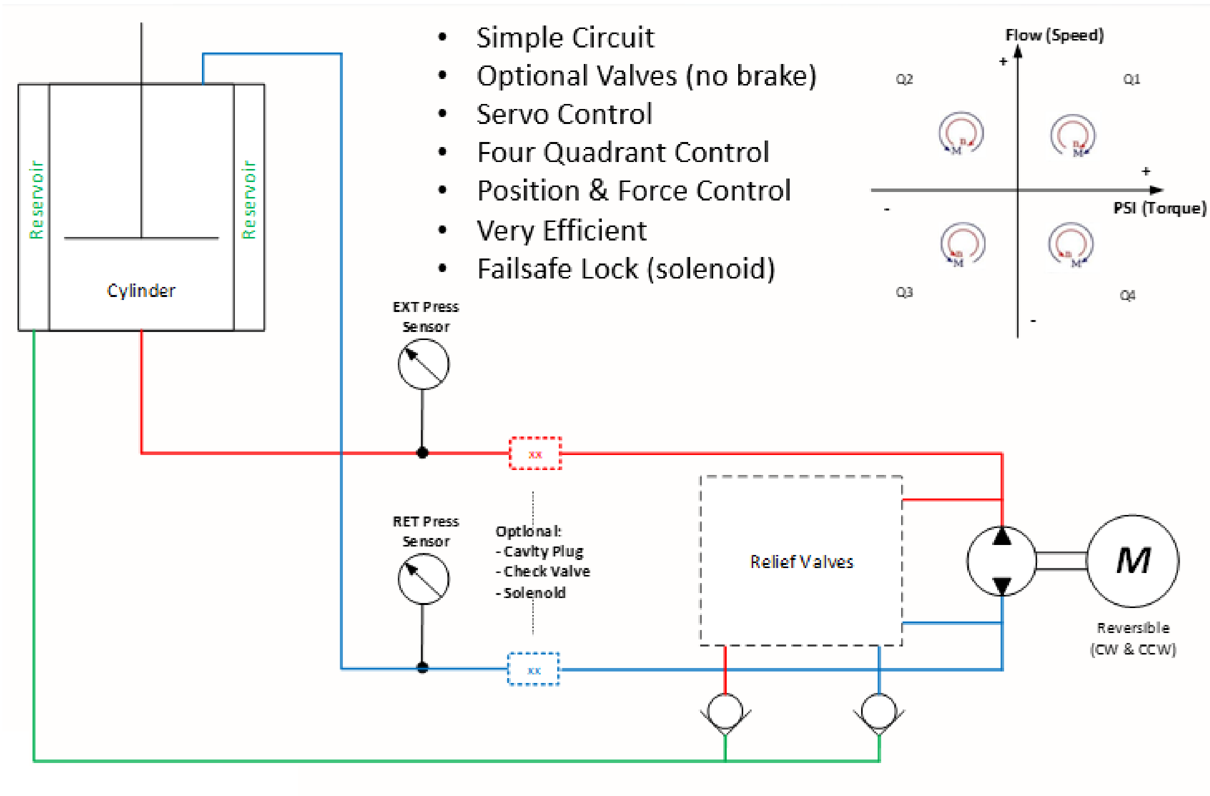
When pressure sensor(s) are used, they are typically providing 0 to +10V dc = 0 to 3000 psi. However, consult your documentation to confirm the sensor range.

The pressure sensor psi feedback value is multiplied by the Gain value (provided by Kyntronics) to determine the corresponding force value. The Gain typically provides LBF (pound force); convert to other units as needed.

Applying force while extending (compressive force) is reported as a positive force value. Applying a force while retracting (tensile force) is reported as a negative force value. In other words, the Net Force is computed as: Net Force = Extend Force – Retract Force. So, if only an extend pressure sensor is present then the Net Force is always positive. Similarly, if only a retract pressure sensor is present, then the Net Force is always negative. Loadcell outputs should be set up to match this convention.

While the pumps are efficient, they have a small amount of leakage. When a force is being applied, the motor will continue to spin to compensate and maintain the force.

2.2 SHA Basics

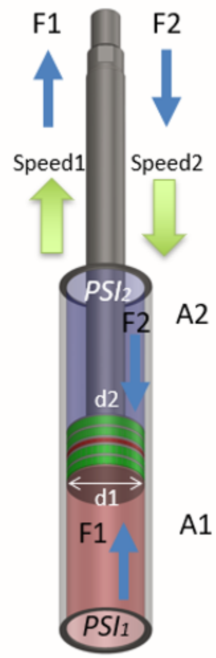


The Extend / Retract speeds & force (ratios) will be different with single-ended rod (usually provided). The retract direction has a smaller area (vs. the extend) which equates to a lower force and higher speed.

With a single-ended rod:

- Retract force is less than the extend force *(given the same pressure)*
- Retract speed is faster than the extend speed *(given the same flow)*

Dual Rods have identical force and speeds



$$F1 = \pi\left(\frac{d1}{2}\right)^2 * PSI1 - F2$$

$$F2 = \pi\left(\frac{(d1-d2)}{2}\right)^2 * PSI2 - F1$$

$$Speed1 = \frac{PumpFlow}{A1}$$

$$Speed2 = \frac{PumpFlow}{A2}$$

$A2 < A1$
$F2 < F1$
$Speed2 > Speed1$

Since the pump has a slight loss, a motor brake will **not** hold the actuator in position. Therefore, the motor used does not need a brake. Instead, the actuator will have lock valve(s) to hold the rod in place as needed, especially for vertical mount applications or if the lock valves will be used to hold a force (so that the motor can be turned off, until the force drops out of the desired deadband range).

The actuator can be equipped with extend and/or retract pressure sensors, which are usually analog output voltage devices. The pressure sensor value can be used to calculate the force in that direction. Loadcells may also be used; but don't forget to include a signal conditioner between the loadcell output and the host controller analog input.

An absolute position sensor is commonly used for position feedback, such as a Temposonics device. These can provide SSI or analog feedback and in varying resolutions. With larger diameter rods, it is also possible to install a position sensor inside the rod, instead of having an external mount.

In some applications, limit switches may be used, with or without a position sensor.

The actuator has internal relief valves in each direction, to prevent over-pressurizing and damaging the actuator. These valves are spring-loaded, and will need a couple hundred milliseconds to recover when tripped. The relief valve provides a "short circuit" fluid path to relieve the pressure, which can build up heat in a matter of seconds, so logic should be in place to react quickly if this happens. Typically the motor RPM will ramp up, and the motor torque will be high, but the target position would not be reached, and the force would drop off. Running the actuator rod into either internal hard end stop should be avoided.

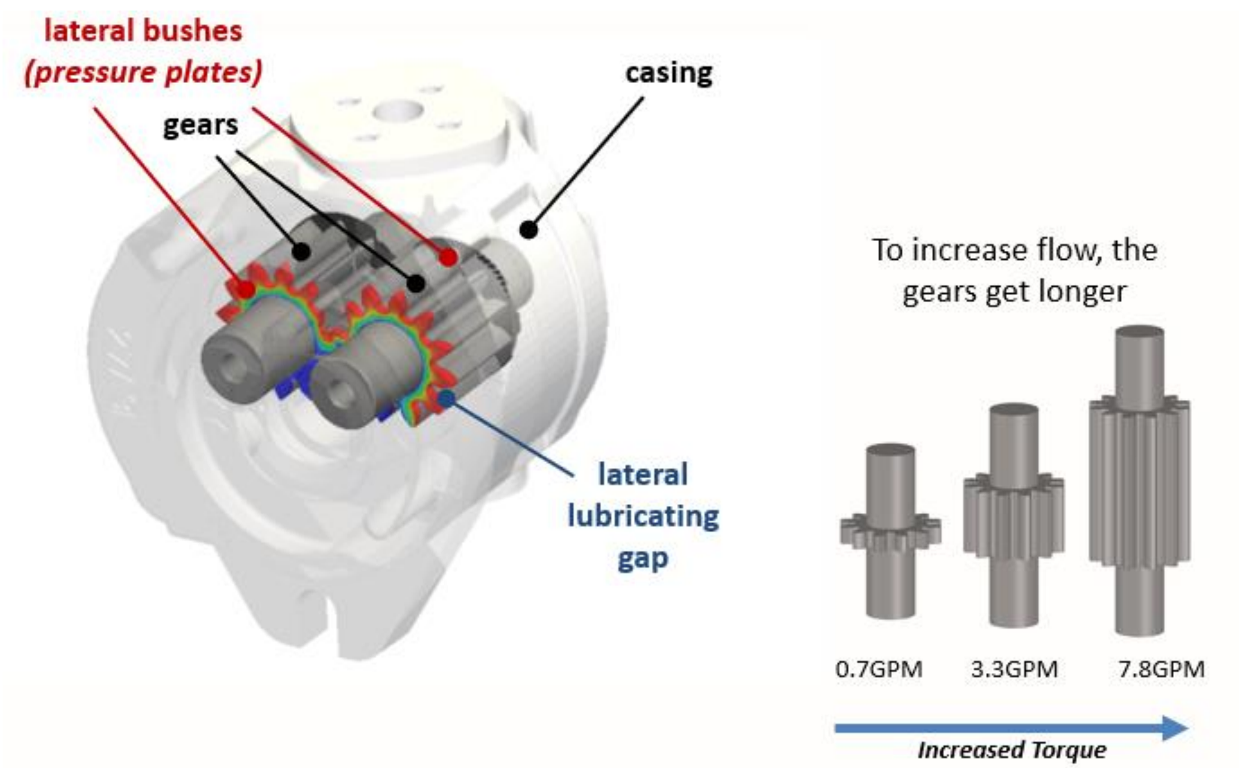
Float valves can be provided, if there is a requirement to reduce force or allow for manual activity when power is lost.

If emergency manual operation of the actuator is needed, then an additional pump can be included to provide this function—typically operated with a hand drill.

With High-Speed High-Force units, additional valving will be present to control the modes.

In certain harsh environments, such as having small metal chips flying into the rod, it is best to use a bellows cover over the rod. If a protective bellows may be needed, have this included in the initial specification of the actuator, as it is not always possible to add one to a unit in the field.

2.3 Pump Details



The size of the pump will determine the speed of the rod and will affect the amount of motor torque needed to reach the desired pressure and force. A smaller pump translates to slower rod speed, but then needs less motor torque to reach a given force. Higher flow (increased speeds) requires higher torques.

The largest pumps give the highest speed, but then they also move the largest amount of oil per revolution; so the position and force control can only be as fine as that "oil packet" allows.

The larger pumps have a thermal switch to prevent overheating. Heatsinks and fans may also be present.

2.4 Control and Lock Valves

Lock valves are the equivalent of hydraulic brakes. When locked, a vertical actuator should hold position, dropping a very small amount over a matter of days.

Typically, a solid state relay is used to control the valve. The valves are usually 25W (at 24Vdc), but some larger valves can be 45W.

Valves react in 20 to 50 milliseconds, typically.

In High-Speed, High-Force actuators, valves are used to select the modes.

2.5 Relief Valves

The actuator is equipped with extend and retract relief valves, which are spring-loaded, and are set to prevent internal over-pressure of the actuator. These are typically set for >3000 psi trip points, but consult your manual for special settings. >3000PSI requires higher torque values.

When a relief valve trips, they provide a "short-circuit" path for the oil to prevent over-pressure. However, the unit and pump can heat up VERY quickly if these open, and the motor and process should be stopped within a few seconds. Once tripped, the force must be reduced below the trip point for a couple hundred milliseconds to allow the valve to close. When tripped, the motor speed and torque will be high, but the force will drop. The position will not advance and may drop back some.

Proper logic to detect a relief valve tripping is recommended (high torque, minimal / no positional movement) and shut down in < 10 seconds, and prevent restarting. Then determine and clear the fault condition, which can be a machine or bad part issue.

2.6 Overriding Loads

2.6.1 Counter Balance Valves

Sometimes a counter balance valve may be used. These provide a resistance (load) to the flow of oil in a specific direction. In addition to providing a minimum load, they will also generate heat. In most situations, counter balance valves are not used as they do not allow 4 quadrant control; they are an inexpensive solution for overriding loads.

Another application for a counter balance is to control the rate of descent of a heavy load in an emergency or unpowered manual lowering operation.

2.6.2 Dynamic Braking Resistors

In most overriding load situations, DB (Dynamic Braking) resistors are properly sized to prevent a DC bus overvoltage and allow 4 quadrant control.

3 SENSOR FEEDBACK SIGNALS

Kyntronics provides total solutions with closed-loop position and force control motion planning. These systems update at rates of 0.5 to 1 milliseconds, and therefore they have analog inputs that can convert at these rates.

Other Kyntronics solutions have been run in the range of 4 to 6 milliseconds, either due to slower analog conversion time, or heavy PLC loading.

Therefore, high speed analog inputs are strongly recommended.

Make sure all sensor feedback cables are properly shielded and grounded and are properly separated from the high power (voltage) cables (following standard installation guidelines).

3.1 Analog Inputs

Fast analog inputs (those capable of conversion rates at 3 milliseconds or faster) are preferred. Often, filter settings need to be disabled, or set to extreme values to allow for fastest conversion. Check with the manufacturer specifications.

Some applications are not time (or speed) critical, and in those cases, slower analog I/O may be usable.

For analog cards with multiple channels/inputs, for fastest conversion rate, it is typical that ALL channels (or all enabled channels) must be set for the fastest conversion. If one channel is set slower, then often all channels will convert slower.

Consult the analog input module specifications to verify the configuration is set for the fastest conversion.

Some systems have an RPI (requested packet interval) for new data from the card; but this does NOT mean the actual analog input value will change with each update. For example, the RPI is set to 1.0 millisecond, but the actual analog input value only changes at 3 milliseconds because 4 channels are enabled.

One way to confirm the analog input value update rate is to capture the actual position (or pressure sensor value) on a graph while the actuator is moving/jogging (for position), or while applying a changing force (brief jog into a hard stop or hard object, so the pressure will be changing for a period of time). Ideally, run the graph at 1 millisecond updates, and then see how fast the analog input data is changing. If the input is slow to convert, the graph will show “stair-stepping” values, and the width of each step shows how fast the analog input is converting. Usually the motion/control logic does not need to run any faster than the analog input data changes. If the input only changes every 6 milliseconds, then that is as fast as the control process needs to run.

For actuators that need to be synchronized, for example master/slave dual actuators, it is best to have update rates (control scan rates) of 4 milliseconds or faster.

3.1.1 Analog Position Feedback

For analog position sensors, as the travel distance increases, the granularity of the feedback increases. For longer travel, there may need to be a deadband position tolerance setting to avoid reacting to positional changes smaller than the minimum feedback resolution.

On some controllers, it may be possible to use a virtual position axis to create a commanded position, and then use PI gain with the actual position feedback to follow the commanded position.

For closed loop control, Kyntronics supplied controllers run the motor in velocity mode and use the position (or force) feedback to close the loop.

Because the pumps have a slight leakage/loss, then when a force is being applied the motor will be spinning to maintain the force. To maintain a force setpoint, one could set the torque/current limit slightly above what is needed to reach that force, and then adjust the motor speed to maintain the force. Samples could be averaged to help maintain a smooth force.

Likewise, torque/current limits can be used to minimize the impact force (and/or use a slower speed). The force zone could be entered using a lower setting, and once the part is detected, the force could be ramped up by raising the current/torque limit.

3.1.2 Analog Pressure Sensors Feedback

The pressure sensors usually have 0 to +10Vdc representing 0 to 3000 psi; check the quotation/specifications to make sure. Then a gain multiplier setting is used to convert the pressure into a pounds-force value. This multiplier is based on the geometry of the actuator (the diameters/area of the cylinder and rod) and will be provided by Kyntronics.

3.2 SSI Position Feedback

Temposonics also makes SSI output position sensors. These normally run at a 250K to 300K baud rate. Sometimes an oversampling or averaging setting exists; if so, then minimize that to get faster response.
Position of the cylinder rod is measured by a non-contact linear transducer. It senses the absolute position of the rod as soon as powered, without a homing procedure or external reference or battery. The transducer output is digital, with a resolution of 50 steps per millimeter, typically.

The value increases as the rod extends. The transducer has no internal adjustments.
The transducer actual zero position is always inboard of the rod's fully retracted position. Therefore, a ZeroOffset can be defined and used to create a reachable position as "zero".

4 DRIVE CONSIDERATIONS

4.1 Brake Resistor Wiring

The system typically needs a brake resistor wired to the drive, to handle the regenerative energy created when the force is released.

If a brake resistor cage is used, make sure it is properly grounded.

4.2 Brake Thermal Switch Wiring

If the brake resistor has a thermal switch, make sure to wire it to an input and use it.

4.3 Safety Considerations

Provide proper safety around the actuator: E-Stop, Stop, Safe Torque Off, Two-Hand input, cages, etc., to protect the operator.

5 MOTOR CONSIDERATIONS

With Kyntronics controls, the motor is run in velocity mode, and the external linear position sensor is used to close the position loop.

For high-speed actuators used in punch type applications, low inertia servo motors are a good choice.

No motor brake is needed, as lock valve(s) in the hydraulic fluid path are used to hold the actuator in position, as needed.

5.1 Motor Tuning

Usually the motor can be run with “factory”/default tuning. If an auto-tune needs to be run, then typically this is run on the bare actuator, without any load. If lock valves are present, then these must be powered On during tuning, to allow the actuator to move if the motor will turn during the auto-tune.

6 CONTROL LOOP SPEEDS

Much of the control loop speed will depend on the needs of the application.

Kyntronics-provided complete control solutions typically run at rates of 0.5 to 1 millisecond for closed-loop motion, and therefore have analog inputs that can convert at these rates.

The update rate of any feedback I/O (position and/or force) will also limit the rate of the host control loop. If the position feedback only updates every 6 milli-seconds, then the main control loop would usually be run at that same rate.

7 ACTUATOR ROD SPEEDS, EXTEND AND RETRACT

During normal motion, when no appreciable force is being applied, then a given RPM speed of the motor and pump will result in a corresponding inches/second (mm/sec) EXTEND speed of the rod. Doubling the RPM will then double the EXTEND rod speed. When the actuator rod is extending, oil is being pumped into the cylinder to push out the rod.

When RETRACTING, however, oil is being pumped into the other side of the cylinder, where the rod occupies some of the volume. As a consequence, the rod will retract at a faster speed than it extends for a given RPM.

The maximum RPM is subject to the maximum RPM of the motor for the given torque requirements. 3000 RPM is a common upper limit; some larger motors may be limited to 2500 RPM.

The Kyntronics quote will typically show the maximum extend and retract speeds, and the associated RPMs for those speeds.

7.1 Direction and Force Conventions

The Kyntronics conventions for position and force are that extending the rod gives a more positive, increasing position, and a force applied by extending (compressive force) is a positive force.

Retracting the rod gives a decreasing position, and a force applied by retracting the rod (a tensile force) is considered a negative force.

When setting up a loadcell, we recommend following these conventions.

8 DEFENSIVE CONTROLS

If the host controller is programmable, make sure to provide defensive measures to help prevent damage or the unexpected. For example, run a reasonable timeout against each step, and stop if the timeout occurs. If force sensing is present, make sure the reported force does not exceed the actuator's quote maximum force (other than possible short duration—less than 1 second—force spikes at impact).

If an absolute position sensor is present, then it can be used to prevent reaching either physical hard stop. Also, realize the actuator operates within the sensor's absolute range, so likely a "zero offset" will be used to create a zero-based position for the operator.

Make sure any thermal inputs, like the pump thermal switch, and/or a thermal switch on the brake resistor, do stop the process with an appropriate notification. After an over-heat, the actuator should remain off for 5 minutes, minimum, to cool. Try to determine and prevent the cause of the excessive temperature.

9 CONTROL MODES

Kyntronics-provided complete solutions usually support three closed-loop control modes; Position, Position with force limit, and Force (Force modes require pressure sensor(s) or load cells).
By closed-loop we mean that the pump is controlled to achieve a target force or position using feedback. Typically there are PI gains and PID control is used.

Jogging, which spins the pump at a constant speed, is not a closed-loop mode.

Position is measured with an absolute encoder, hence there is no requirement to "home" the system at startup or ever. Extending the rod is considered more positive.

Force is deduced by measuring the pressure on the extend side of the piston, which is considered positive, and then measuring the pressure on the retract side of the piston, which is considered negative, and then computing the net force.

10 STARTUP / INSTALLATION BEST PRACTICES

10.1 Developing the Application Control Sequence

Before the initial running of the system, it is a good practice to reduce the speeds and torques in the drive and operate the machine at slower rates to prove out the mechanics and logic. This helps minimize breaking or stressing anything unexpectedly, and gives more time to react and stop the process when needed.

If linear position sensor feedback is present, use it to monitor the position and limit the retract and extend range of the actuator.

Once the sequence is established and tested, then the speeds and forces can be raised up toward the desired target values. Optimizing the cycle time is typically one of the last steps to be done.

When the normal maximum torque levels are established for the process, the drive torque levels could be set to that value, plus 10 to 20%, to allow some overhead. For example, if the actuator is starting cold or in a cold environment, then more torque will be needed until the unit warms up. Limiting the maximum torque helps prevent overheating the pump and can reduce the impact force. The force itself—if pressure sensor(s) or a loadcell are present, should also be monitored, to prevent applying more than the quoted force for the unit; again, allow some overhead, as the force may overshoot on impact and for a second or so after impact.

IMPORTANT:

Capturing and storing “golden” graphical profiles (of positions, force, motor speed, motor torque) after tuning is a best practice. Then one can review and compare after machine wear of different parts, or if issues later arise.

While debugging, use graphs showing:

- Motor RPM
- Motor Torque
- Position (target & actual)
- Force (target & actual)

The above parameters provide the appropriate data to assist with analyzing an actuator issue versus a machine or part issue.

10.2 Initial Actuator Moves to Install Tooling/Fixturing

Often it is necessary to move the actuator rod to connect tooling, or to install the actuator into a fixture. This is best done with slow jogs, and with the motor torque kept low. Verify the jog directions and speeds first, before fixturing.

11 FAULTS

Over temperature conditions of the pump and/or brake resistor should be announced to the operator.

When the pump is commanded to reverse direction, it is possible for the motor to momentarily ramp up to a very high speed, until the fluid pressure reverses and provides a load on the pump. On some drives this may cause an “overspeed” error. If such an error occurs, then ignore it if possible, or adjust drive settings to prevent it.

If a thermal trip occurs, it is recommended to wait at least 5 minutes for cooling, before continuing operation. Also, investigate the cause of the over temperature condition.

The Kyntronics actuator is quoted with maximum speeds, forces, and duty cycles. Make sure the control implementation respects those values. The process should be setup and/or monitored to ensure those values are not exceeded.