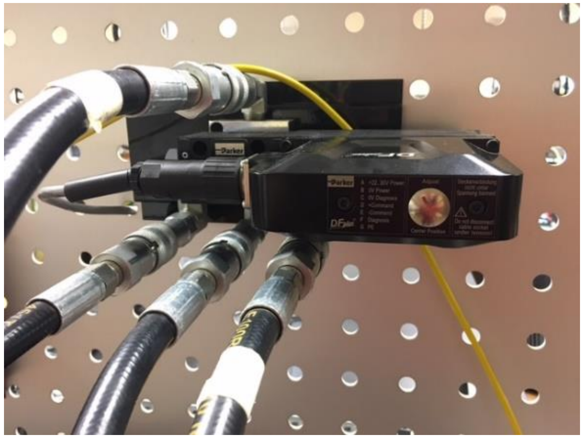
EH Valves in Electrohydraulic Systems



What is Electrohydraulics…?

Electrohydraulics is the use of electrical discharges to operate hydraulic mechanisms in a mechanically-oriented control system.

The Need for Electrohydraulic Systems

- Automatic control of hydraulic systems has evolved into an increasingly superior alternative for many industrial applications.

- Controlling the position, force, and pressure of hydraulic cylinder motion are the most widely demanding hydraulic motion control techniques.

- Electrohydraulic control systems remove the need for complex sequencing set-ups, and gives users the ability to remotely influence various motions (both dependent and independent of one another) with logic programs

Electrohydraulics Technology

- Electro-hydraulics is the use of electrical discharges to operate hydraulic mechanisms in a mechanically-oriented control system.
- An amplifier will receive a signal from a controller between (-)10 to (+)10. This command is then transferred into an electrical discharge, where its used to motivate the coils within a directional control valve, thus created spool movement.
- A positive command prompts the spool to shift in one direction, whereas a negative command will shift it in the opposite direction. When there is no signal transmitted to the valve amplifier the spool is in most instances automatically centered.

Electrohydraulics Valves

- **Traditional Solenoid Valve**
  - On/Off control
  - Referred to as “bang-bang” valves
- **Proportional Valve**
  - Coils will shift proportionally in either direction when exposed to variable amounts of amperes (amps), or current.
  - Allow for relatively limitless spool positioning.
  - Used for both open and closed loop applications
- **Servo Valve**
  - Utilize a magnetized torque motor for pressure imbalance, which is essentially the factor responsible for spool propulsion.
  - Low voltage used to position a valve accurately.
  - Have a means of receiving system feedback, usually via an internal spring.
  - Only used in closed loop systems

Proportional Valves

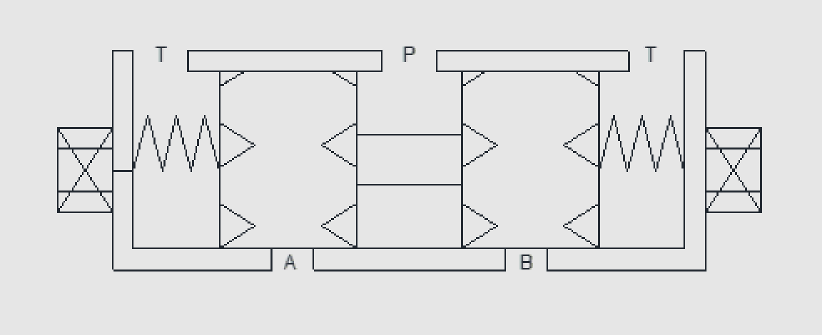
Overview

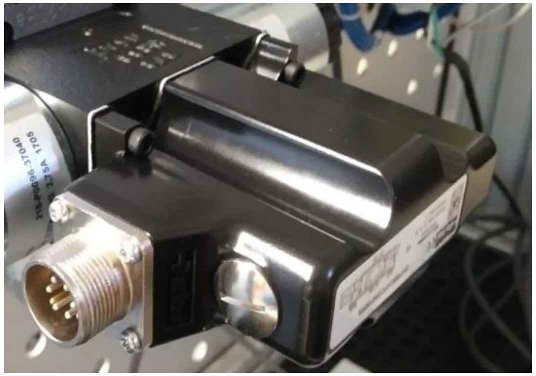
- Utilize DC coils for movement, coils will shift proportionally in either direction (movement based on available current)

- Relatively limitless spool positioning = infinite alternatives for volume flow

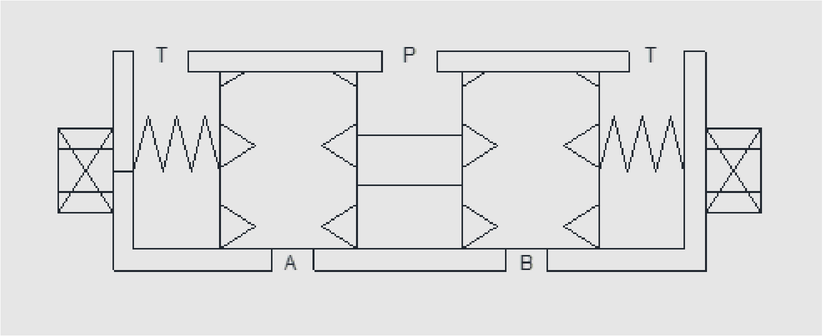
- Used for Open/Closed loop systems

- Internal spools are outfitted with machined notches for increased fluid control





Proportional Valves



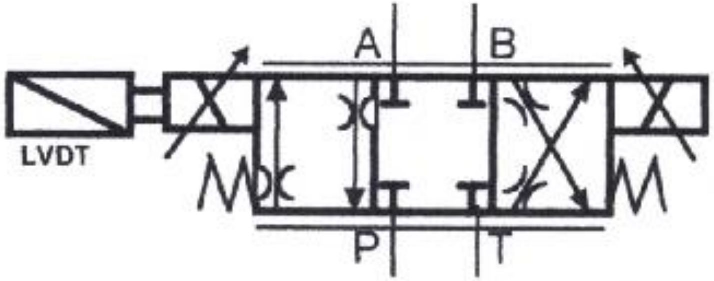
Valve Operation Principle

- The DC coils on both ends of the valve produce a variable amount of force in response to a variable amount of current.

- The force will motivate the valve spool a distance proportional to the magnitude of current.

- The proportional displacement of the spool allows the valve output flow to be continuously variable.

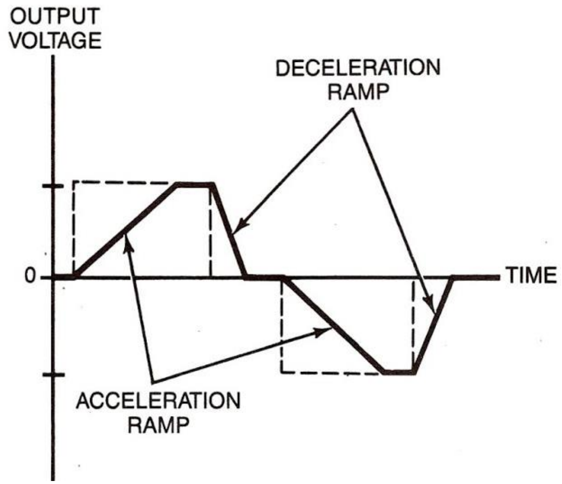
Proportional Valves



Proportional Valve Schematic

- The arrows at both ends symbolize the proportional relationship between the amount of current through the coils and the force exerted on the spool.
- The parallel lines on the top and the bottom denote an infinite range of spool displacement within the total stroke of the spool.
- The orifices represent metered flow through the valve when shifted in one direction or the other.

Proportional Valves



Proportional Valve Ramps

- Single Ramp Function: one setting for the slope of all four ramps
- Two Ramp Function: two independent settings for acceleration and deceleration in both directions.
- Four Ramp Function: all four ramps can be set independently.

Proportional Valves

Velocity Limiter

- Electronically limit the maximum speed of the actuator from the controller

- There are two types of velocity limiters:

  - The command signal range decreases with a decrease of the velocity limit.

    When velocity limit set to 50%, the command signal range will change from 0~10 volts to 0~5v.

  - The command signal range remains the same with a decrease of the velocity limit.

    When velocity limit set to 50%, the command signal range remains the same as 0~10v. The resolution will be increased.

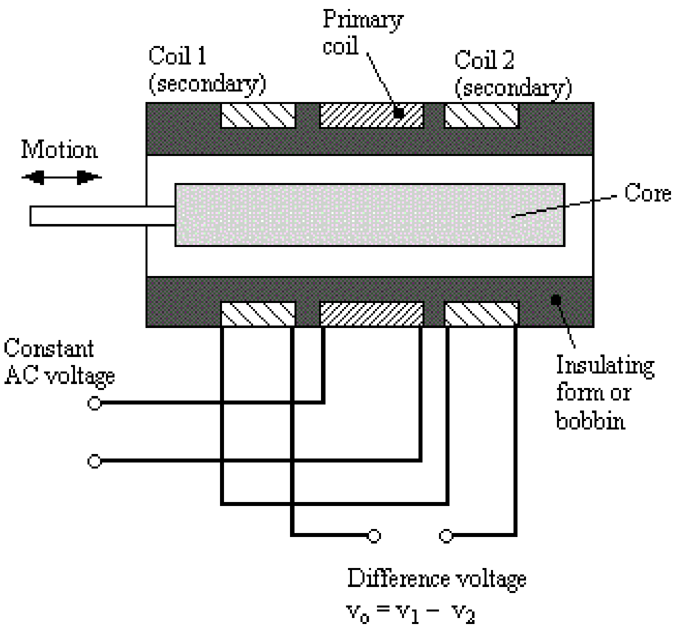
Proportional Valves

The Linear Variable Differential Transformer (LVDT)

- A transformer (sensor) that produces a voltage output proportional to a mechanical displacement.

- Proportional valves use an LVDT to provide feedback for closing the control loop.

Proportional Valves

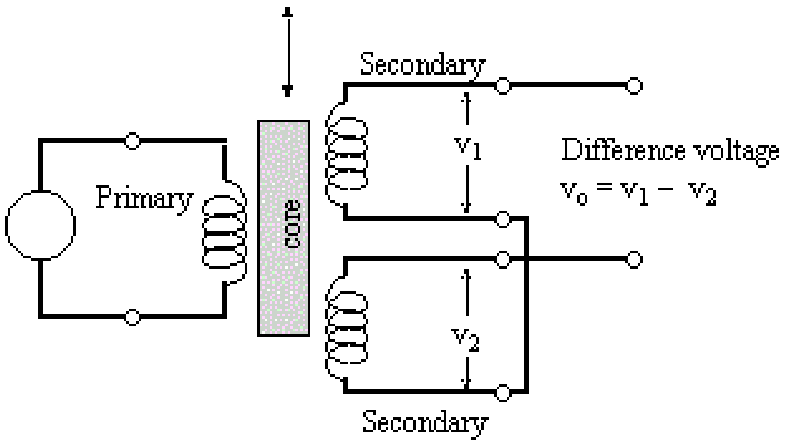


(a)

The Linear Variable Differential Transformer (LVDT)

- An LVDT has one primary coil with AC current, which generates magnetic flux.
- The motion of a movable iron core in the magnetic flux induces an alternating signal onto the secondary coils.
- One secondary coil produces a positive signal and the other produces a negative signal.
- When the spool is centered, the signals from two secondary coils are canceled to be zero.
- When the spool moves from center, the induced voltage is strengthened in one coil, and reduced in the other. The output signal will be demodulated to generate a DC voltage proportional to the amount of the displacement.

Proportional Valves



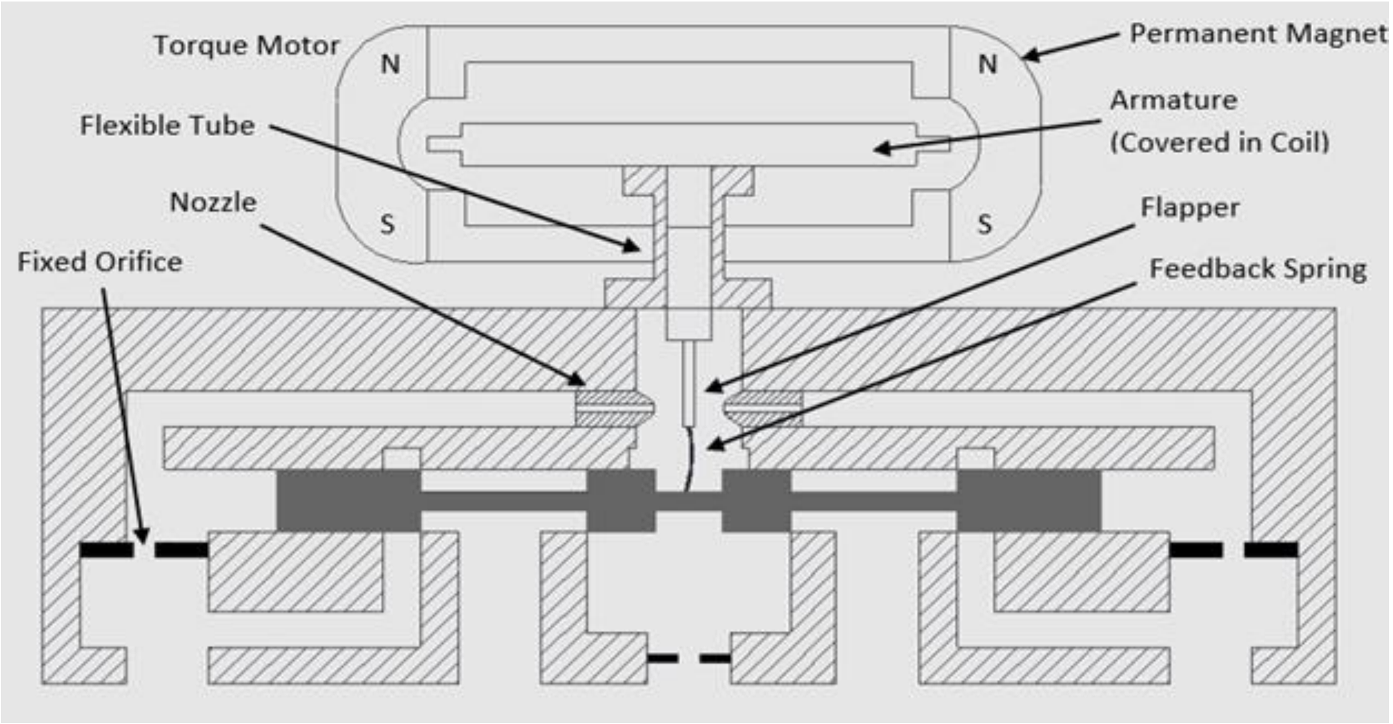
The Linear Variable Differential Transformer (LVDT)

- An LVDT outputs a feedback voltage proportional to the spool shift
- The feedback voltage is compared to the command and the error between the two is amplified.
- The amplified error powers the valve coil to drive the spool to its commanded position.

Servo Valves

- Infinite spool positioning capabilities
- Utilizes a magnetized torque motor for pressure imbalance, which is responsible for spool propulsion
- Used only for closed loop systems
- More accurate and better performing than their proportional counterparts
  - Relies on electronics for communication
  - Torque motors do not experience large amounts of inertia (resistance)

Servo Valves

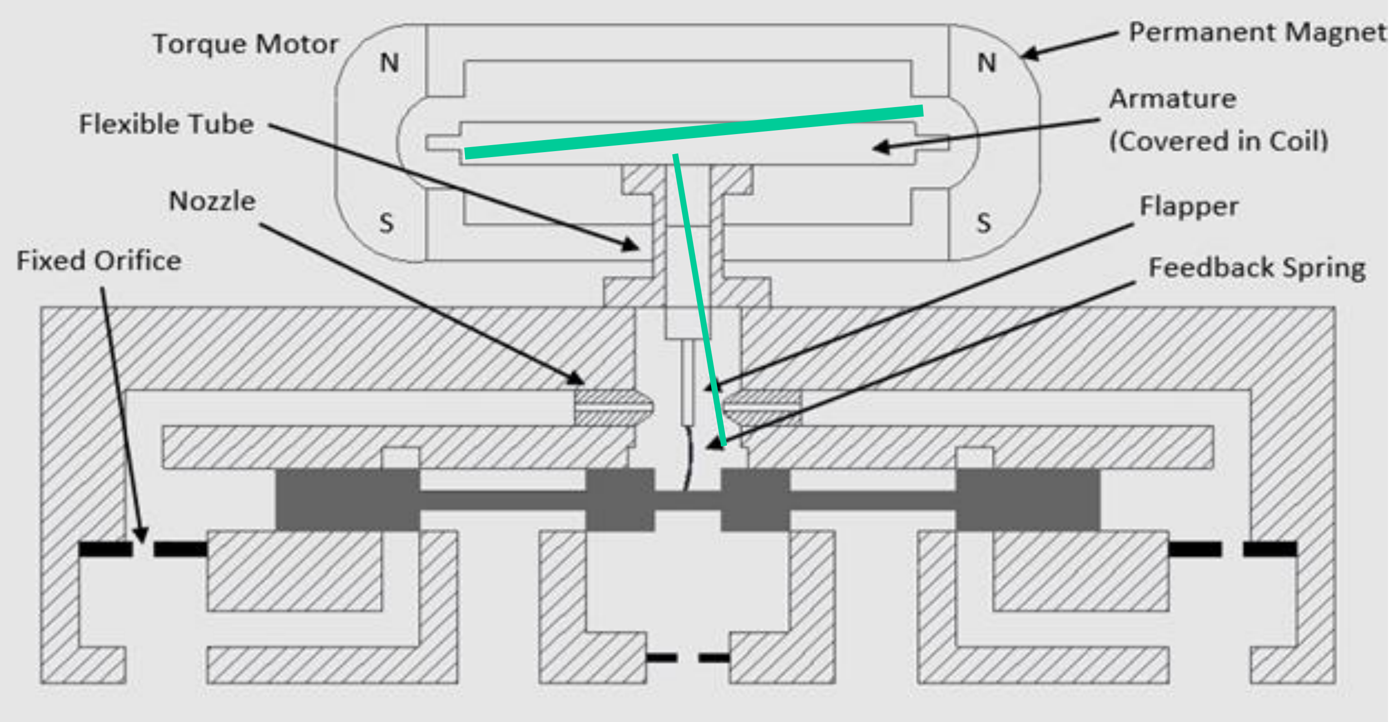


Flapper Nozzle Servo Valve in the Center Position:

At the center position, the flapper is in the center, the pressures on either end of the spool are equal and the spool remains stationary.

Connected to the flapper is a mechanical feedback wire that extends down and rides in the center of the spool.

Servo Valves

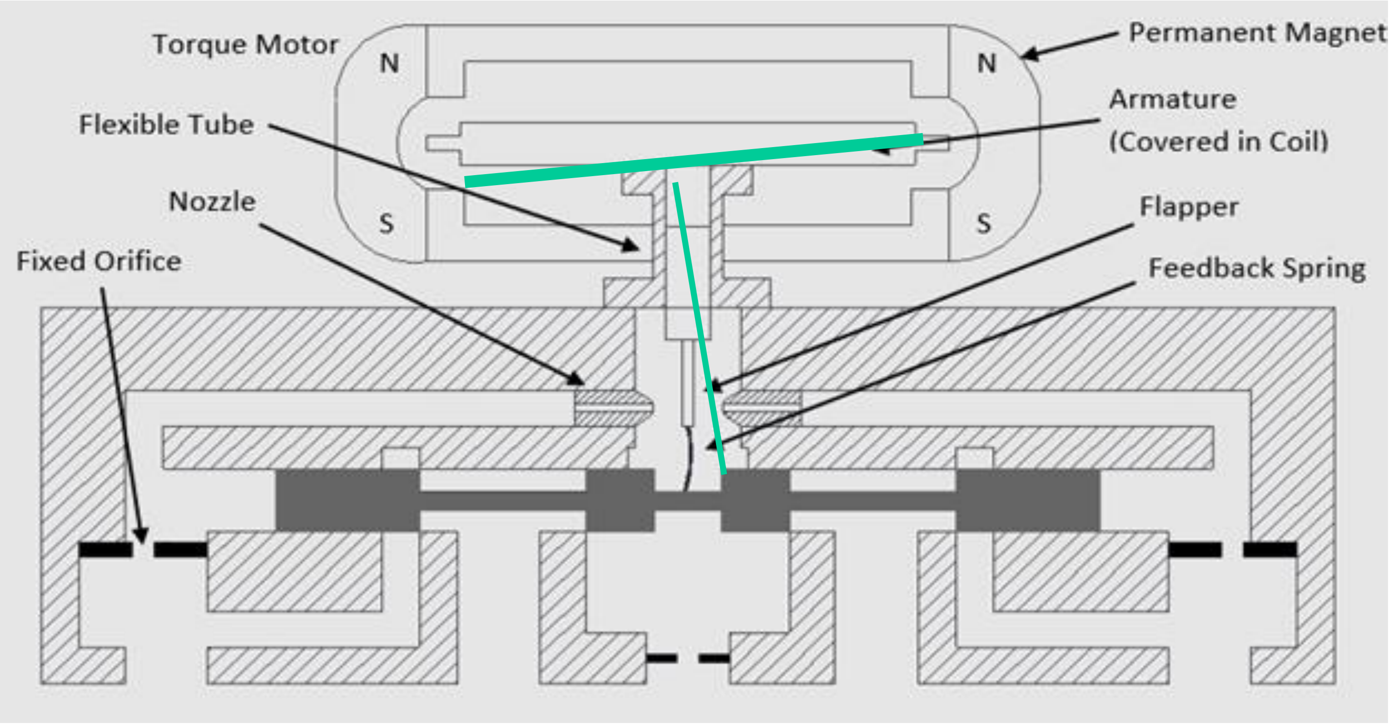


Flapper Nozzle Servo Valve Transitioning to a New Position:

When the current signal applies on the torque motor (15 to 100 mA), the motor shifts to one side blocking off one nozzle.

The imbalance in pilot pressures acting on either side of the spool has caused the spool to shift. The feedback wire is pulled in the opposite direction of the flapper movement.

Servo Valves



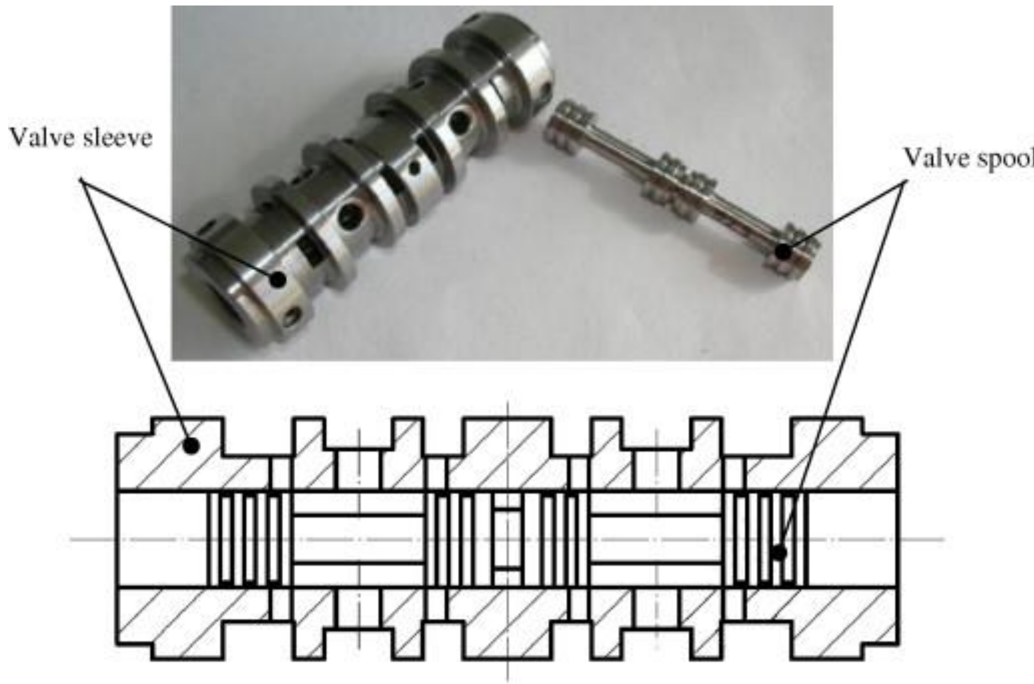
Flapper Nozzle Servo Valve Transitioning to a New Position:

When the mechanical feedback wire pulls the flapper to the center position, the pressures will balance and the spool will stop moving.

The feedback wire acts like LVDT for the proportional valve to the flapper.

When the current signal is removed, the flapper will no longer have the force to oppose the wire, the wire will pull the flapper back causing the spool to move back to the center position.

Servo Valves



Servo Valve Spool Designs

When controlling an actuator in a critical position control circuit, it is important that any change in position be corrected very quickly and valves need a high pressure gain for that purpose.

The assembly shown above has large windows machined which produce a linear flow gain.

Terms for EH Valve Configurations (1)

- **Saturation Flow**
  - The flow which issues from the valve's work ports when the spool is fully shifted.
- **Saturation Current**
  - The current that causes full shift of the valve.
- **Saturation Region**
  - The region of control current wherein further increases in control current result in no further increases in output flow.
- **Active Region**
  - The region of control current wherein changing current results in a changing output flow.

Terms for EH Valve Configurations (2)

- **Deadband (dead zone, overlap, null zone, or null region)**
  - The region near valve center where the flow is less than 1% of saturation flow.
  - The extra land area that overlaps the port openings is the deadband of the valve.
  - The current to the valve must be sufficient enough to travel past the dead zone and also overcome any resisting spring forces acting on the spool before the valve will produce output flow.

- **Deadband Compensation**
  - Compensate circuit that automatically adds additional voltage to shift the valve to the point where flow can begin when it senses a command signal of 50 mV.
  - Zero lap spools for position and velocity control
  - Overlap spools for velocity control and noncritical position control

Terms for EH Valve Configurations (3)

- **Threshold Current**
  - The current required to open the valve enough to cause an output flow which is 1% of the saturation flow, also called the cracking current.
- **Flow Gain**
  - The slope of the output flow curve versus control current at a specified operating point. (G_Q= ($\Delta Q/\Delta I$) It is a property of the valve.
- **Hysteresis**
  - A measure of the degree to which the output of a device with increasing input disagrees with the output with decreasing input. It is expressed as a percent of total change in input between positive and negative saturation areas.
- **Hysteresis Buster**
  - A feature which electronically adds a little nudge to internal CMD signal and comes back to the original command signal from the opposite direction.

Terms for EH Valve Configurations (4)

- **Repeatability**
  - The difference in flow when the command for flow is approached from the same direction. It is a random error.
- **Threshold**
  - The amount of current that must be given to a valve to create a change in output flow.
- **Linearity**
  - Maximum deviation between a measured input/output curve at a given point and the best fit mathematical straight line, expressed as a percent of the saturation value.
- **The Differential Port Pressure Gain (Gp)**
  - The rate of change in pressure of one port relative to the other versus control current. The differential port pressure gain is twice the magnitude of the port pressure gain slopes.

Terms for EH Valve Configurations (5)

- **Repeatability**
  - The difference in flow when the command for flow is approached from the same direction. It is a random error.
- **Threshold**
  - The amount of current that must be given to a valve to create a change in output flow.
- **Linearity**
  - Maximum deviation between a measured input/output curve at a given point and the best fit mathematical straight line, expressed as a percent of the saturation value.
- **The Differential Port Pressure Gain (Gp)**
  - The rate of change in pressure of one port relative to the other versus control current. The differential port pressure gain is twice the magnitude of the port pressure gain slopes.