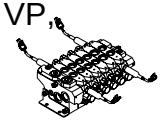
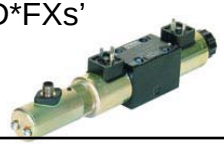
Introduction to Electro-hydraulic Proportional and Servo Valves

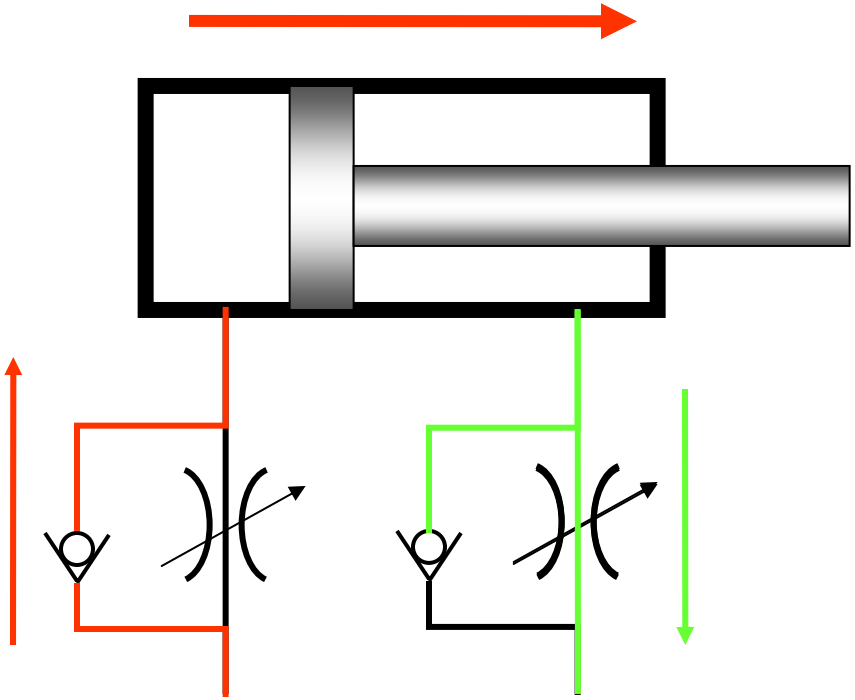
ENGINEERING YOUR SUCCESS.

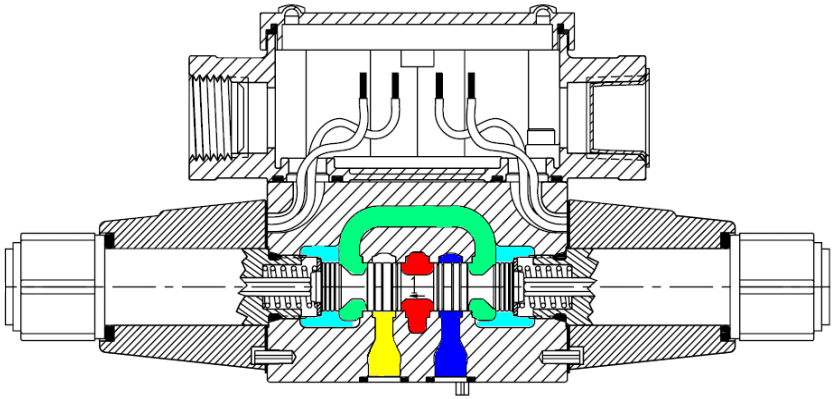
Proportional Valves

Servo Valves

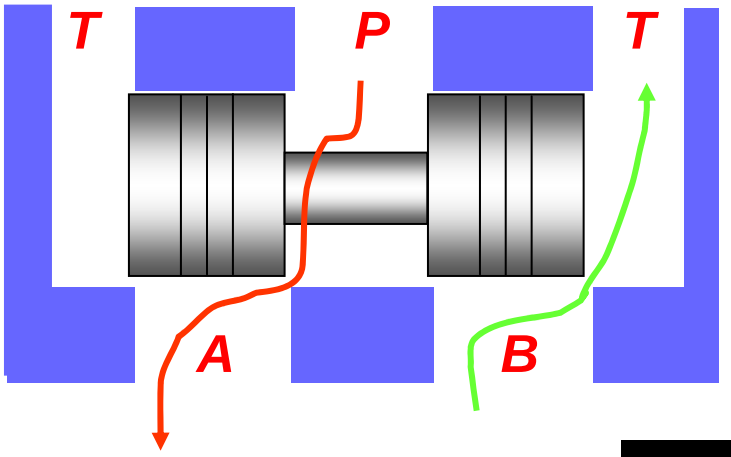
	Mobile bankable Style, Threaded Cartrdige Style	NFPA Mounting Without Spool Position Feedback	NFPA Mounting With Spool Position Feedback	Servo Performance, Closed Loop Valves with Spool Position Feedback	Servo Valves With either Mechanical or Electrical Feedback (spool position).
Parker Models	Pulsar VP, VPLs. 	D*FWs, D*FTs' 	D*FXs' 	D*FP D*FHs D*1FH 	BDs' DYs' SEs' 
Mechanical Construction (spool shift)	Electro-Hydraulic Pilot, Mechanical (spring) Return	Electromagnetic Force, Mechanical (spring) Return	Electromagnetic Force, Mechanical (spring) Return	Electromagnetic Force, Mechanical (spring) Return	Torque Motor Pilot Control Balance PSI spool Control
Hysteresis	3…..7%	3…7%	0.03…..1%	0.1….5%	0.1…..0.5%
Frequency Response	< 10 Hz	10…50 Hz	10….70 Hz	50...150 Hz	100…200 Hz
Center Lap Condition	Overlap 5…20%			Zero Overlap	Zero Overlap
Operating Pressures Limits (Drop across metering edge).	1000…2000 PSI			1000…3000 PSI	None
Applications	Open Loop Control		Low End Closed Loop Position	Closed Loop Position & Force	Closed Loop Position & Force

Meter Out Circuit



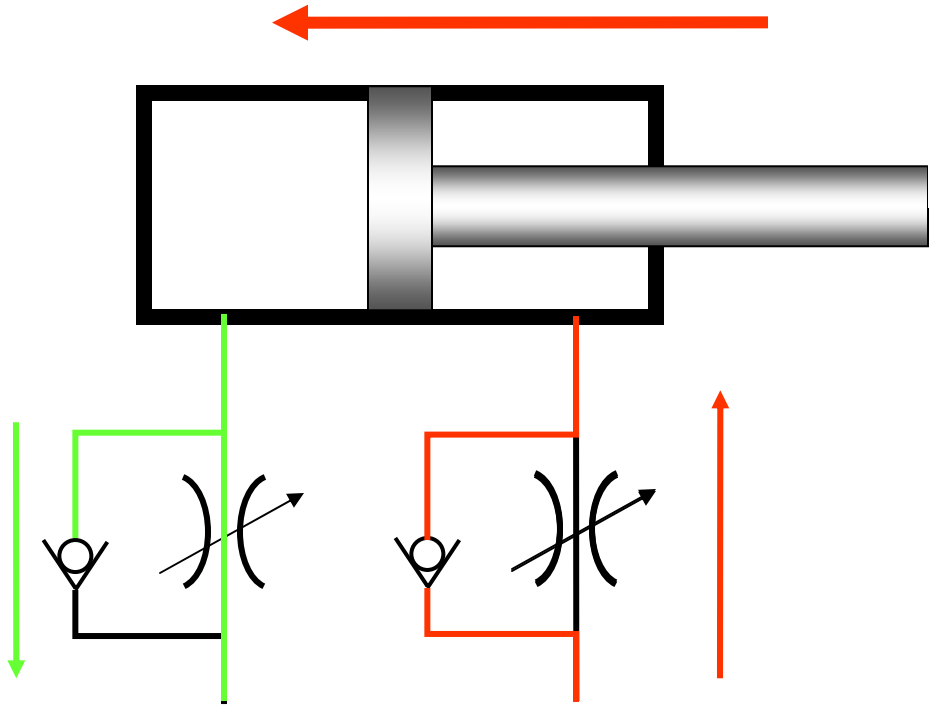


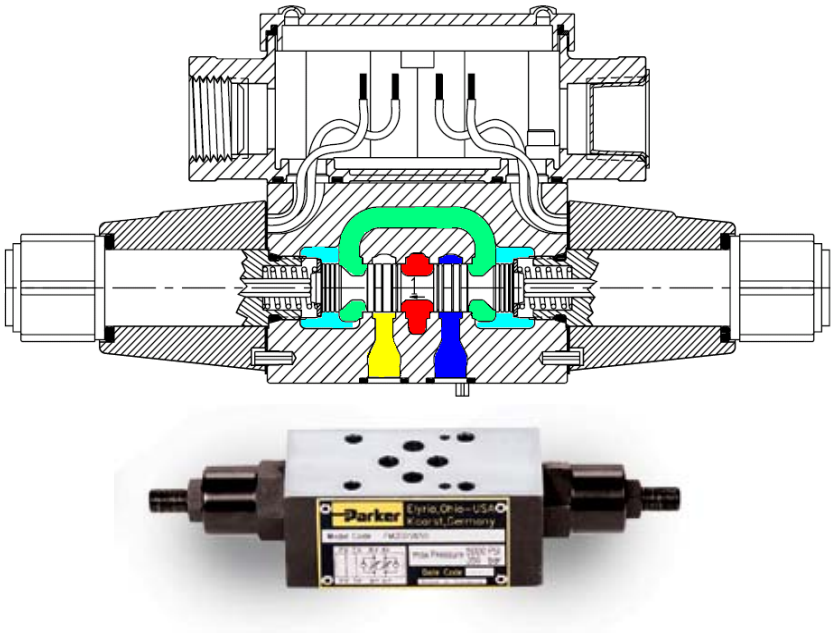
P to A
B to T



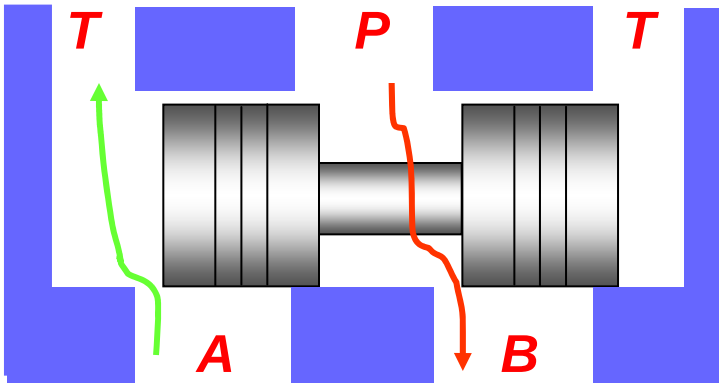
Free flow *into the "cap" end*
Metered Flow *out the "head" end.*

Meter Out Circuit



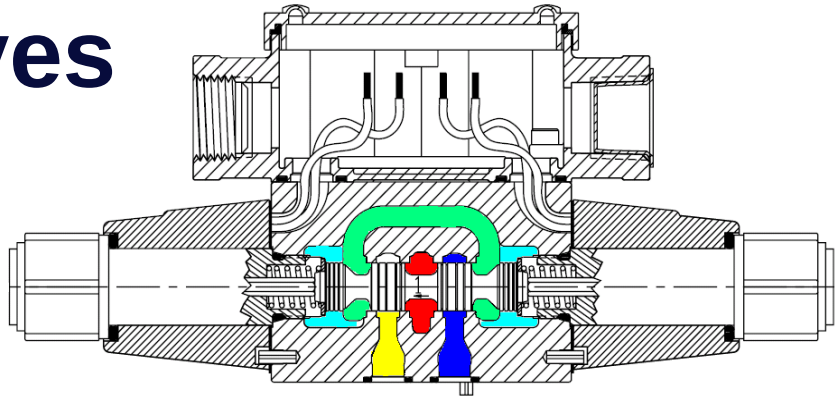


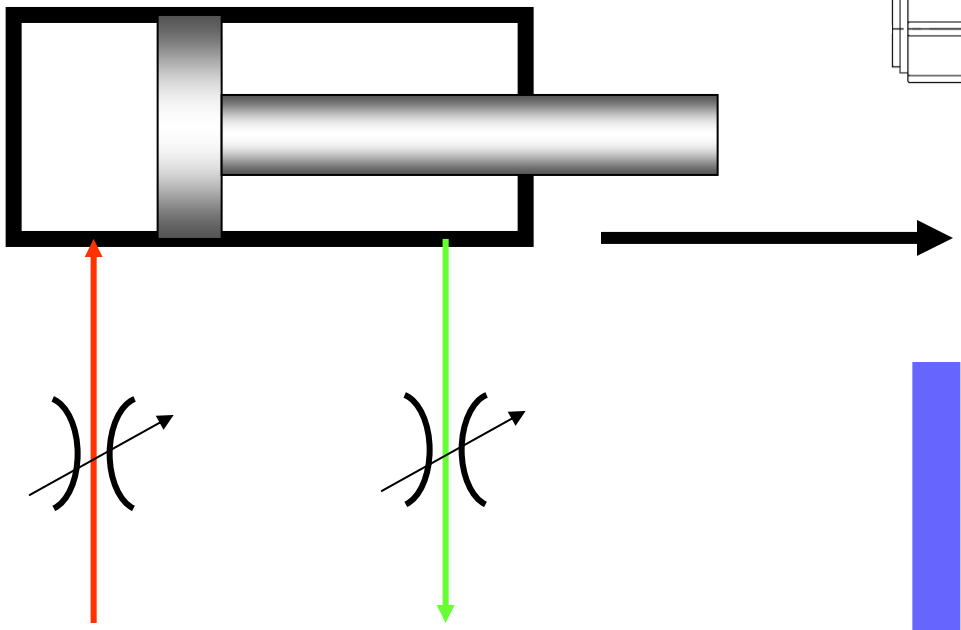
P to B
A to T



Free flow into the "cap" end
Metered Flow out the "head" end.

Electrohydraulic Valves





P to A
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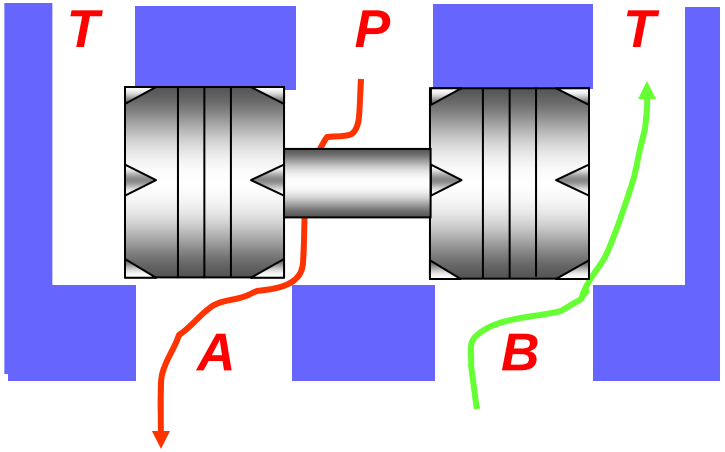
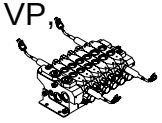
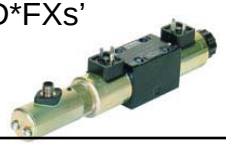


Shift Spool slightly to create metering Orifice

Proportional Valves

Servo Valves

	Mobile bankable Style, Threaded Cartridge Style	NFPA Mounting Without Spool Position Feedback	NFPA Mounting With Spool Position Feedback	Servo Performance, Closed Loop Valves with Spool Position Feedback	Servo Valves With either Mechanical or Electrical Feedback (spool position).
Parker Models	Pulsar VP, VPLs. 	D*FWs, D*FTs' 	D*FXs' 	D*FP D*FHs D*1FH 	BDs' DYs' SEs' 
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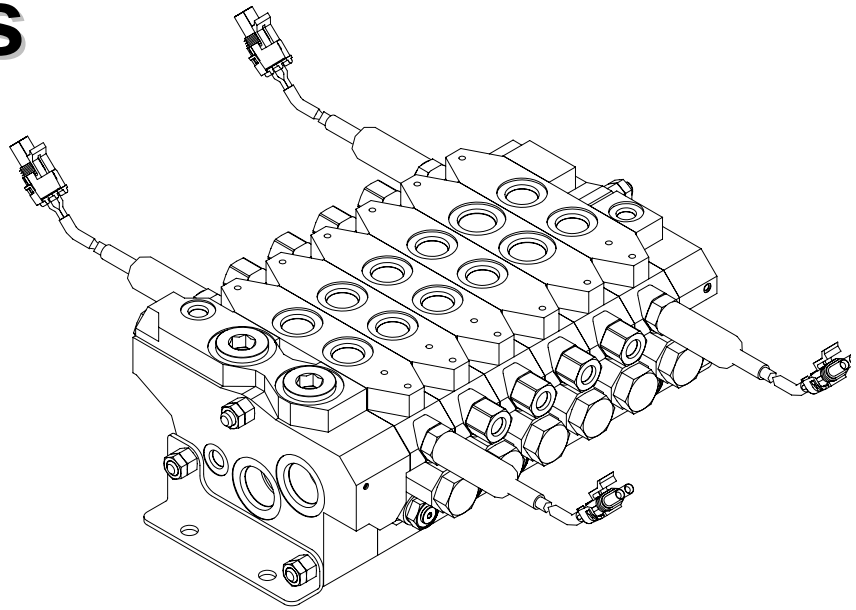
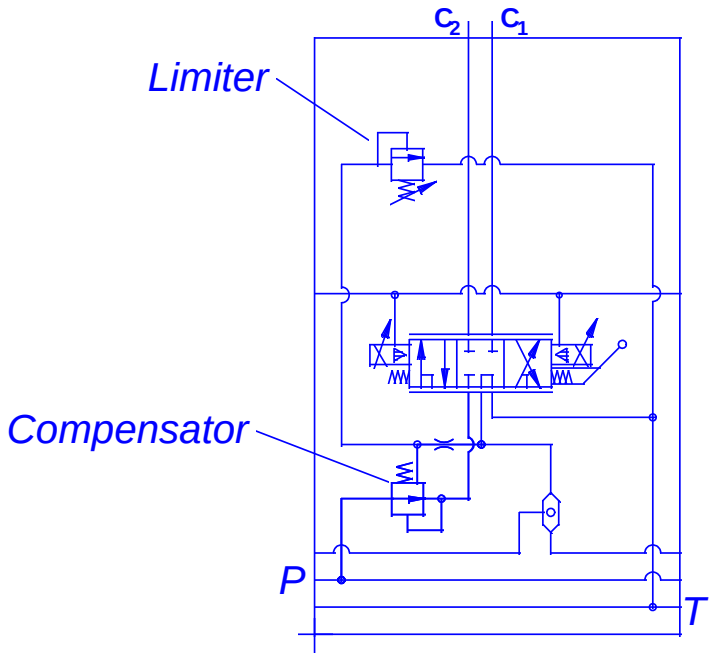
Sectional Valves

VPL Series





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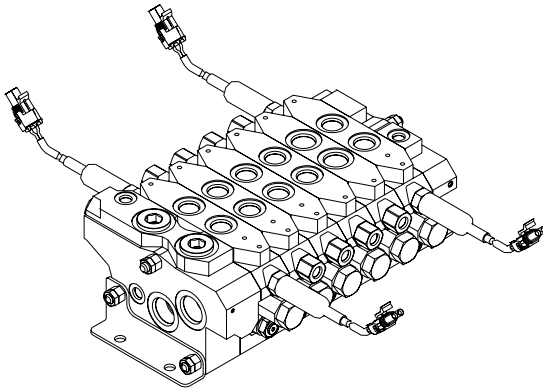
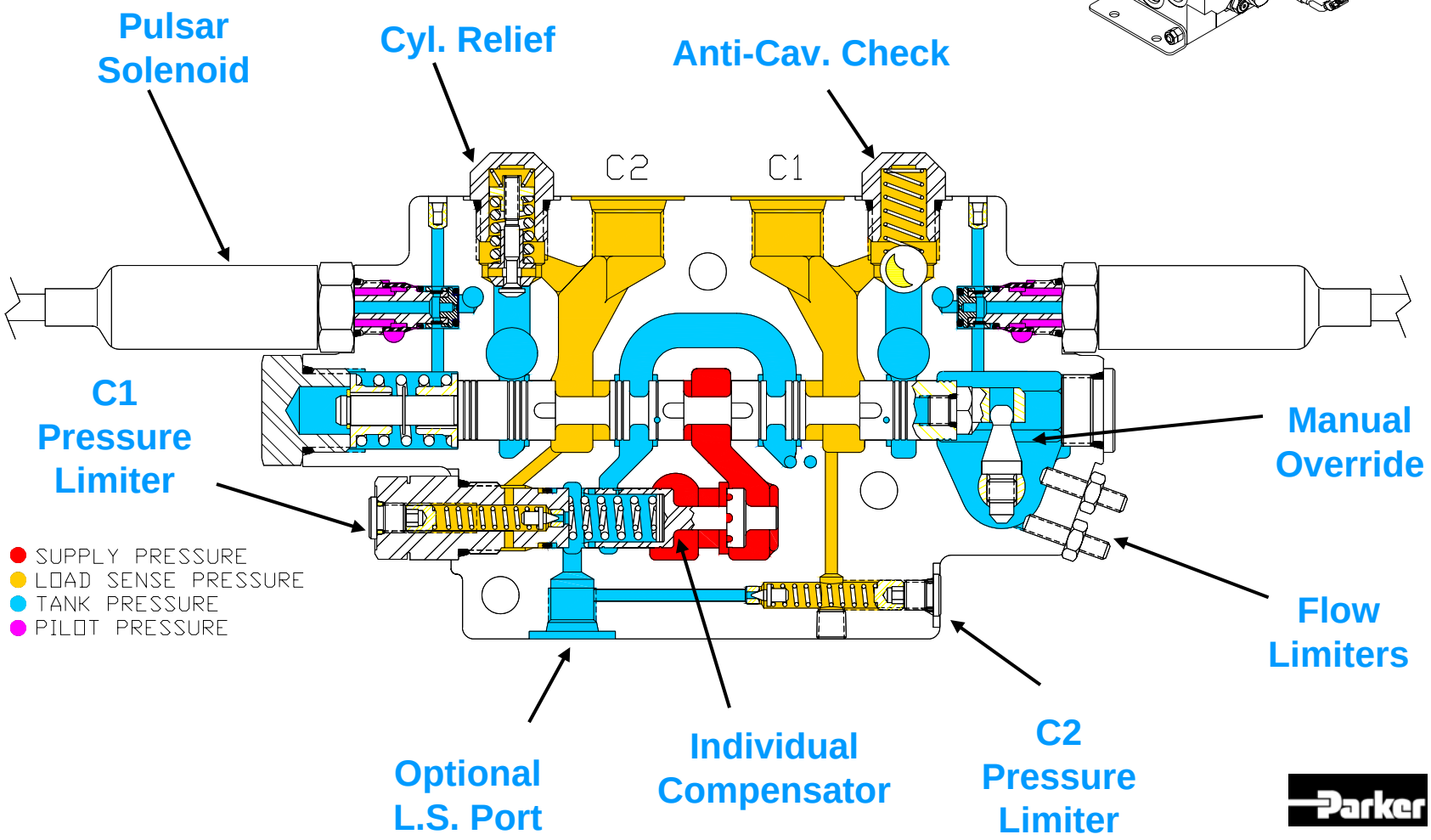
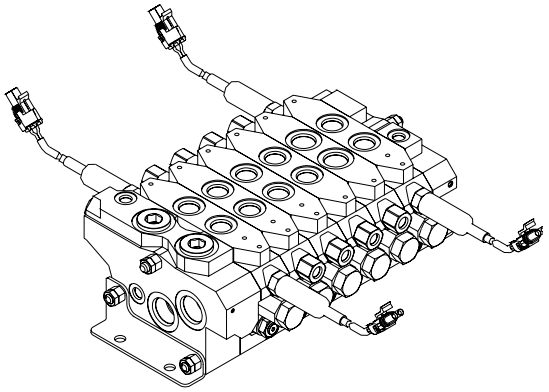
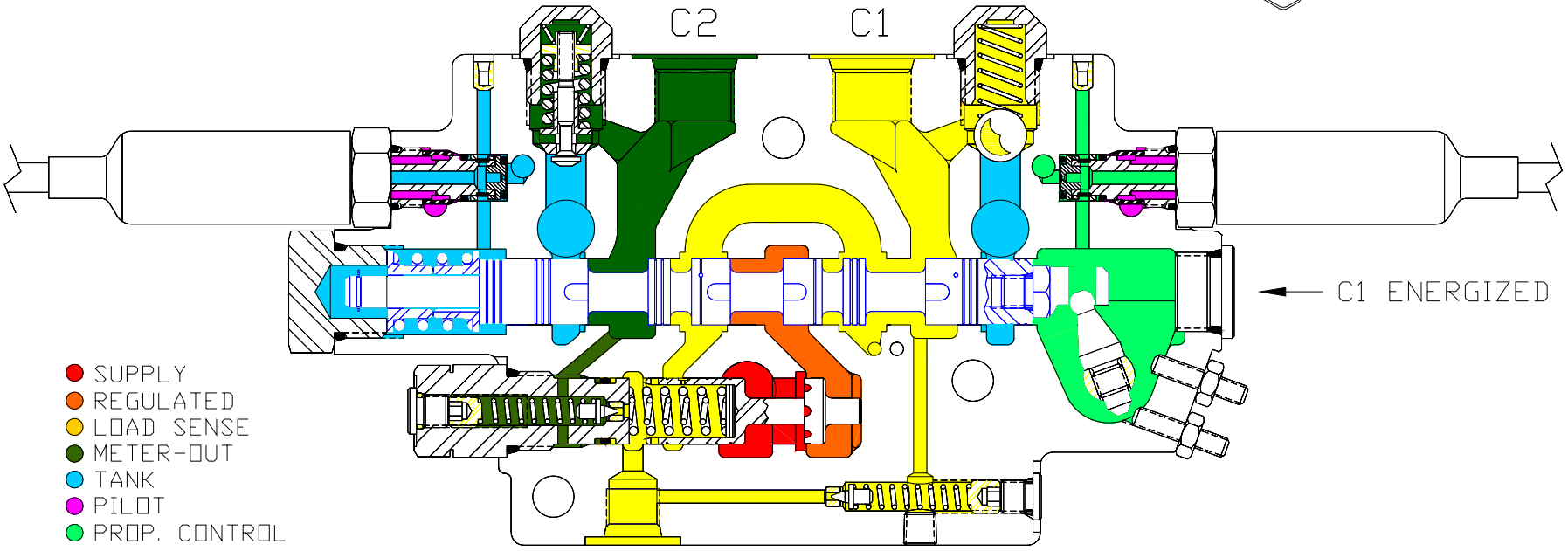




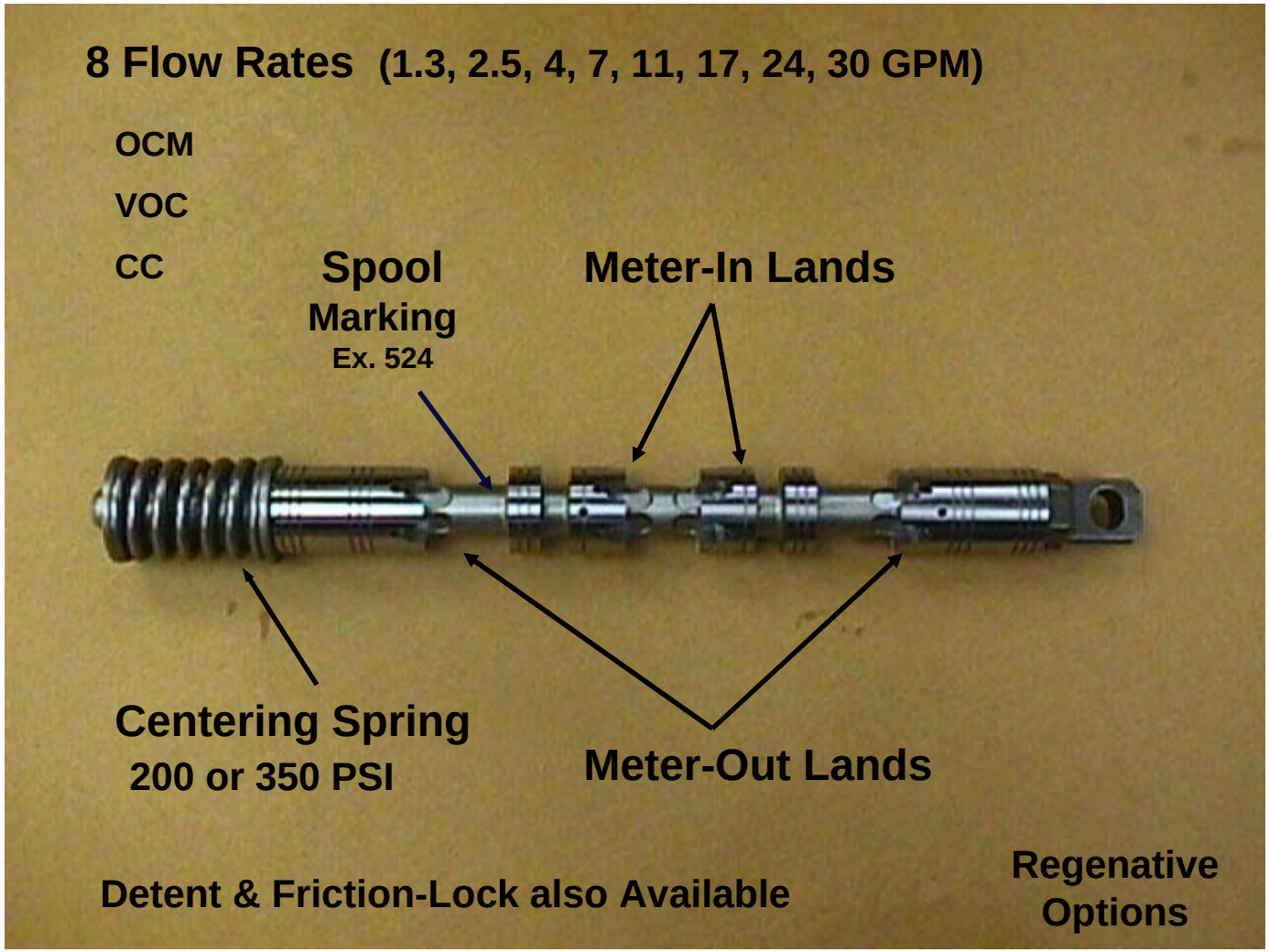
Sectional Valves

VPL Series (C1 Energized)



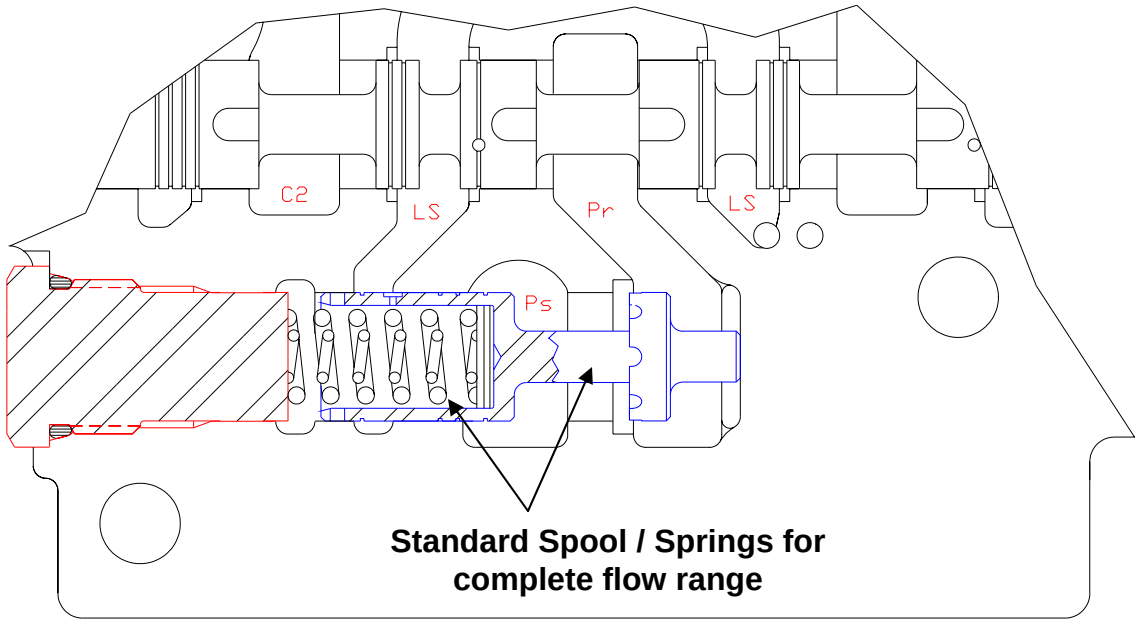


VPL Main Spool

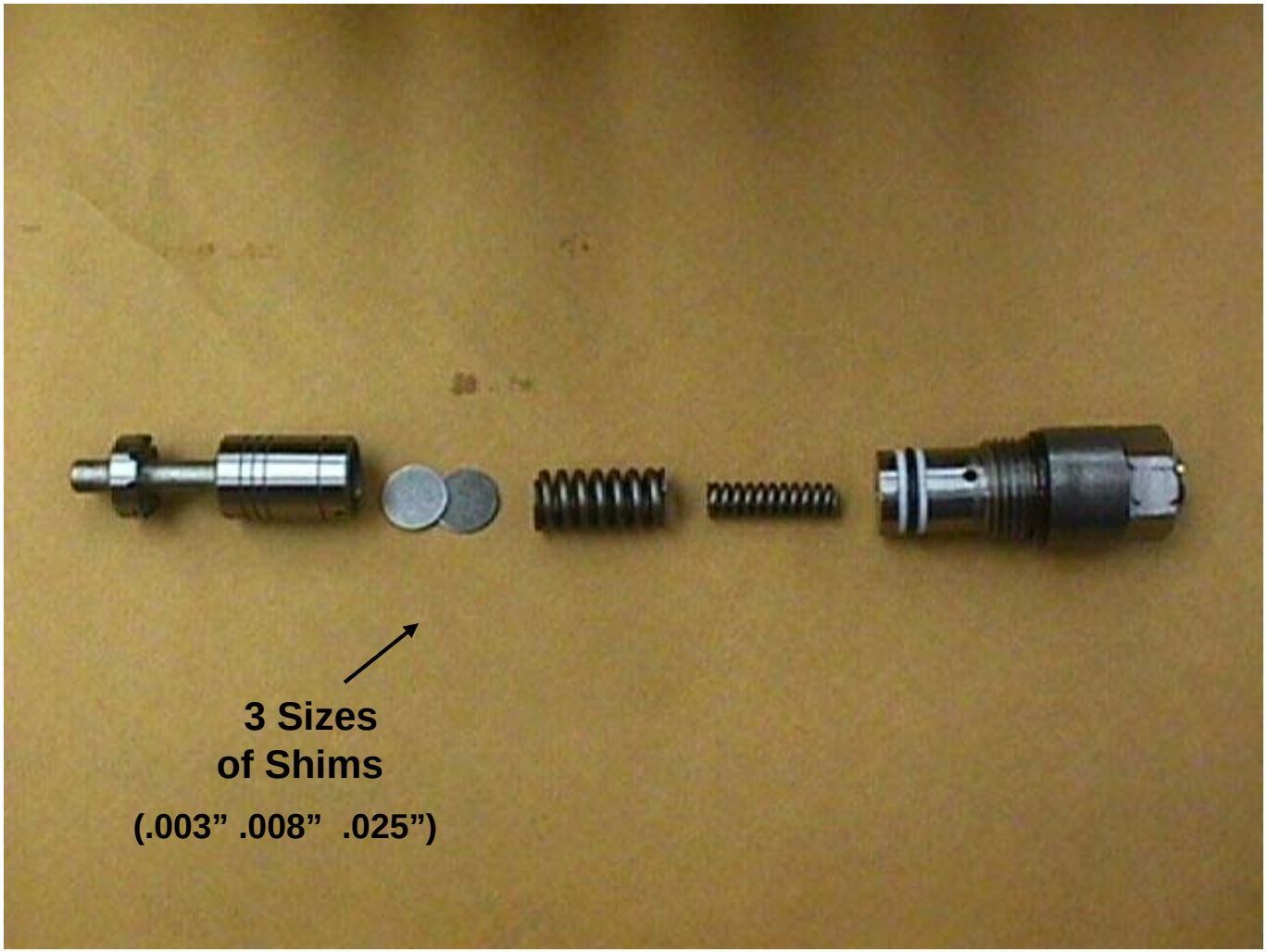


Compensation, VPL Series

- Pressure compensation maintains a constant flow regardless of pump pressure, load pressure, or any other load in the system
- This means when running multiple sections at the same time, there will be no change in speed



VPL Compensator Components



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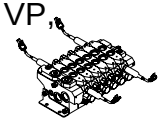
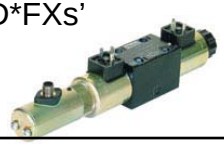
Parker Models	Pulsar VP, VPLs. 	D*FWs, D*FTs' 	D*FXs' 	D*FP D*FHs D*1FH 	BDs' DYs' SEs' 
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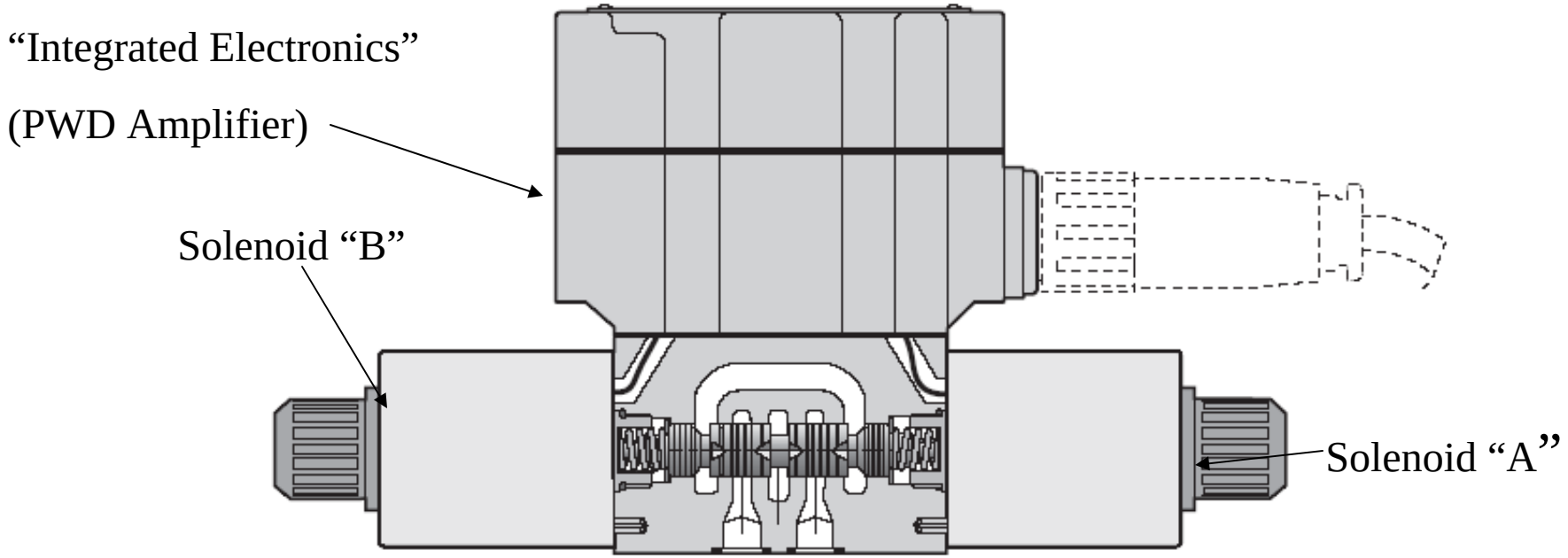
How does it Work? (No Spool Feedback)

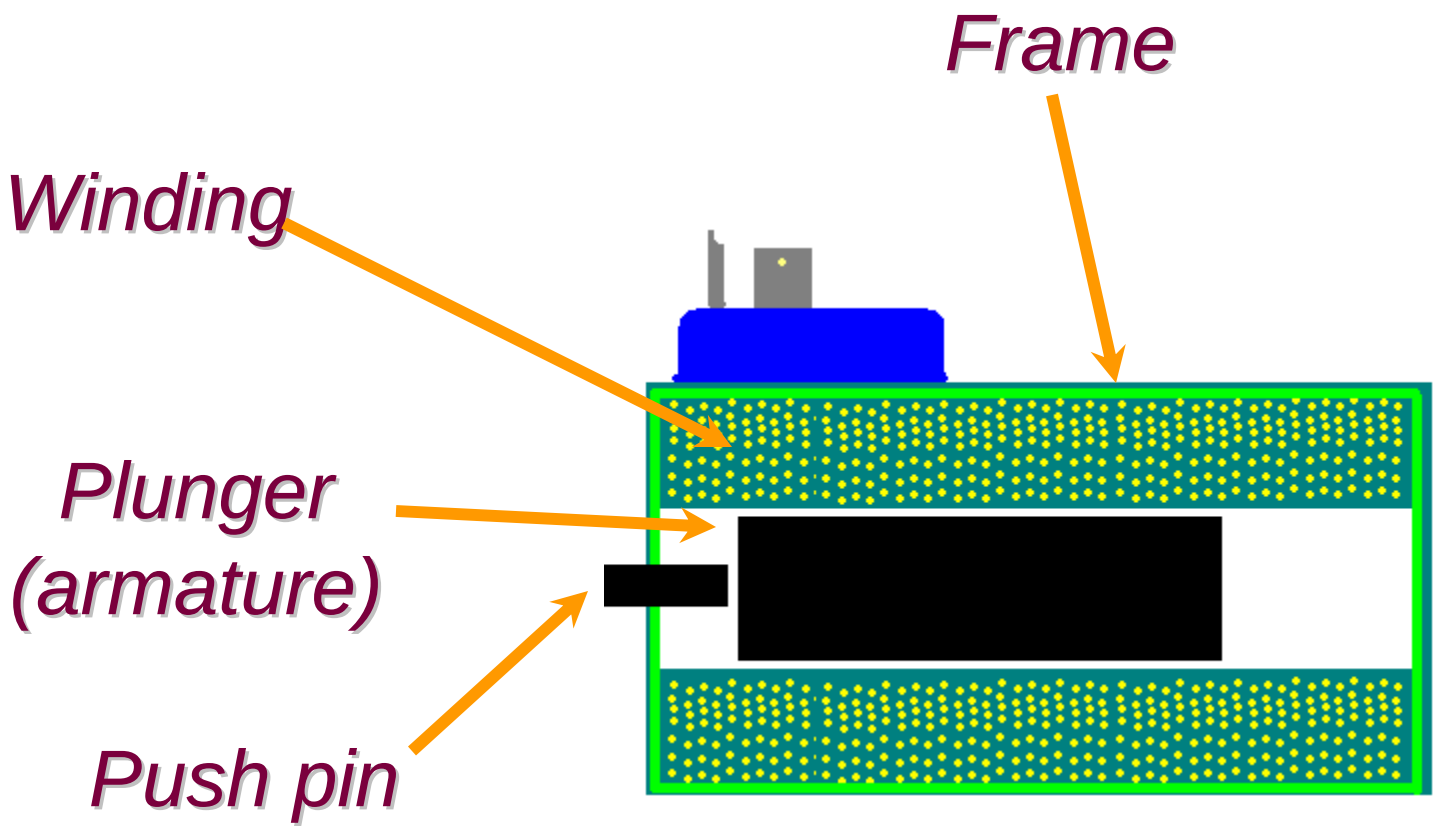


"Command Signal" based upon a % of Maximum. Typically 0 to +/- 10 VDC. Amplifier converts Voltage (Command) into proportional Current (Typically 0..2.1 Amps).

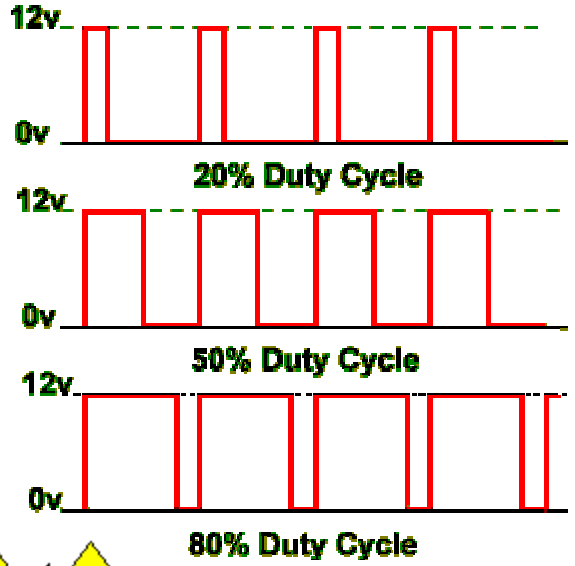
Variable DC current into solenoid assembly produces Electromagnetic Force, proportional to current applied.

By matching Opposition Spring Force to Solenoid Force, Proportional Spool Movement is obtained.

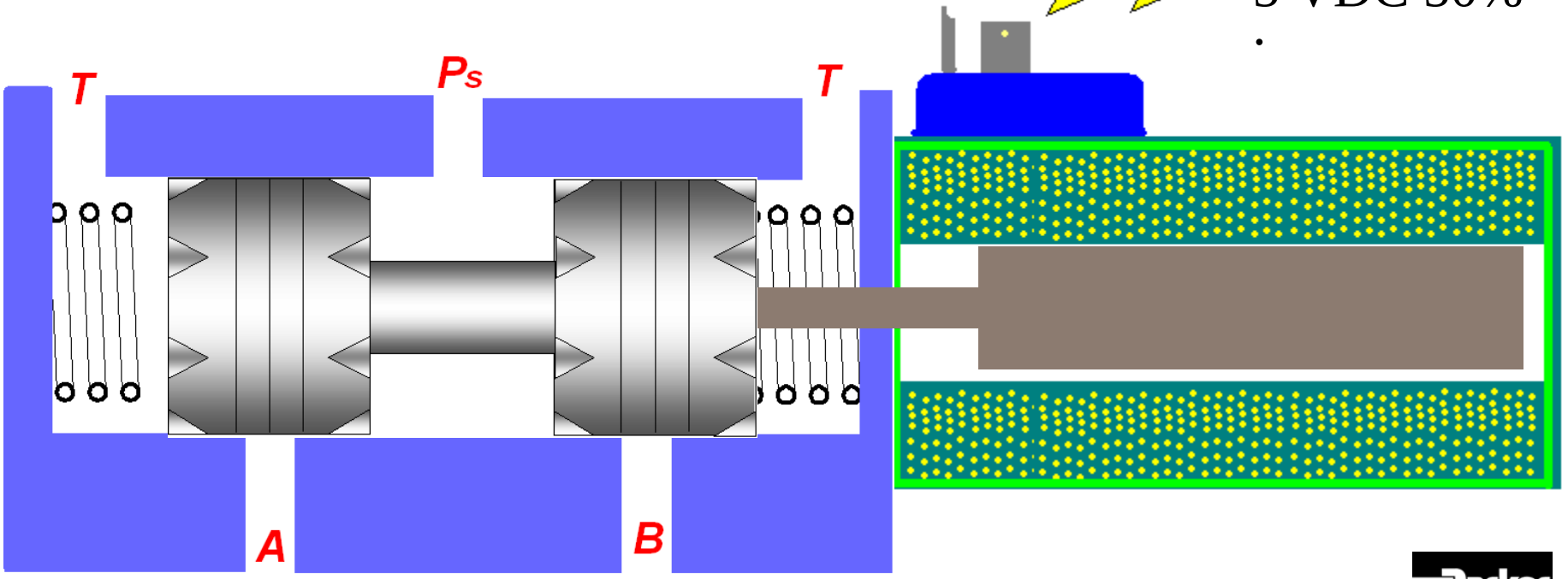
How does it Work?
Proportional Solenoid Construction



How does it Work?
Solenoid Operation

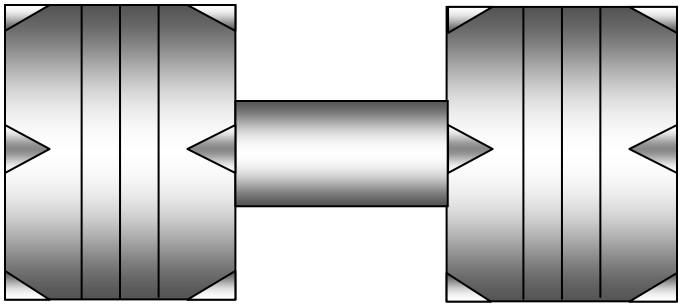


5 VDC 50%

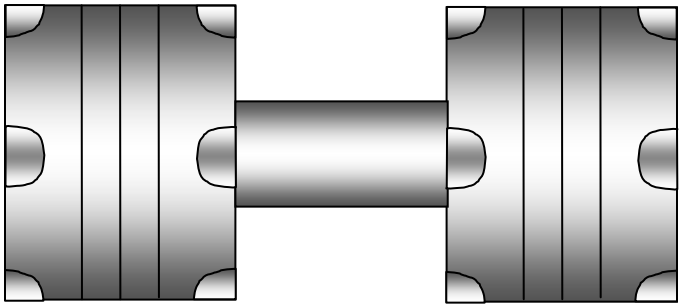


Proportional Valve Spool Designs

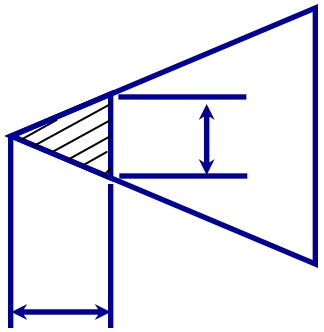
V-Notch Spool

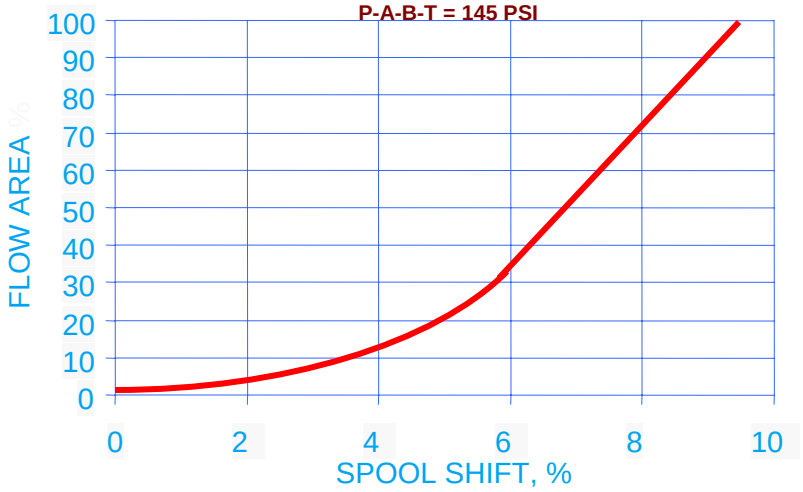


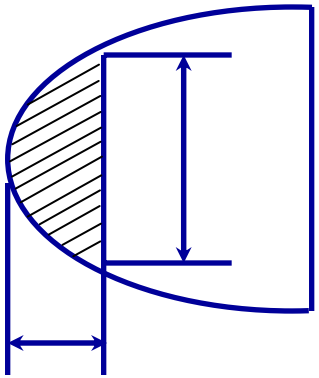
C-Notch Spool

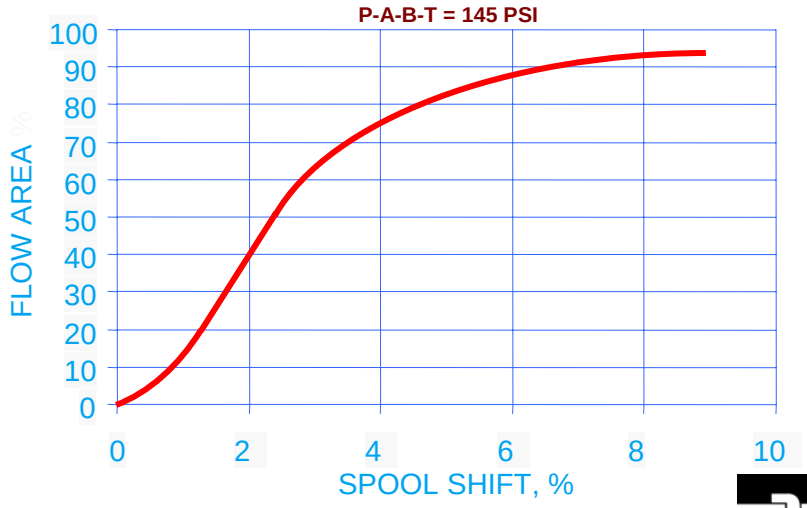


Proportional Valve Spool Designs

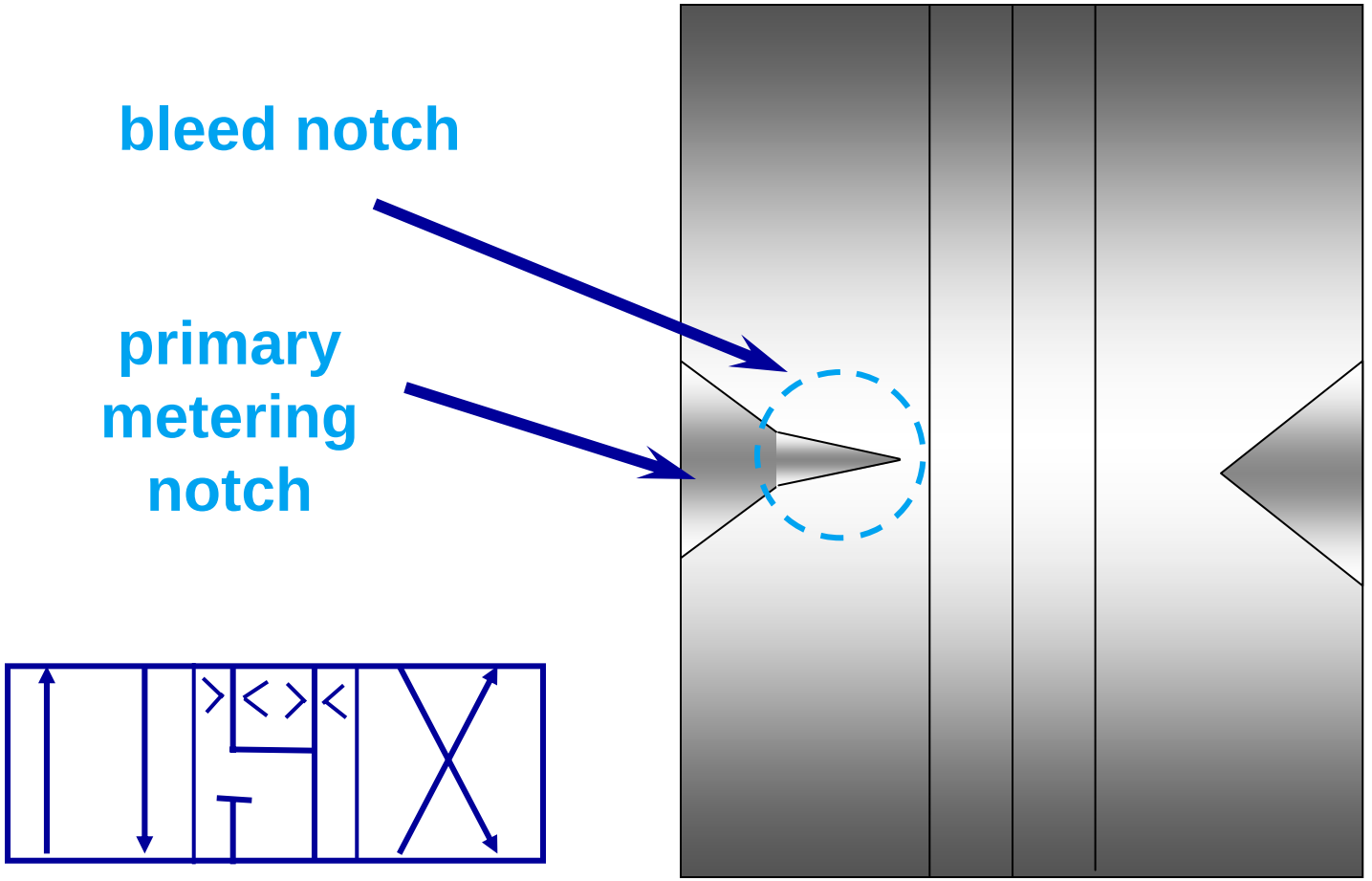




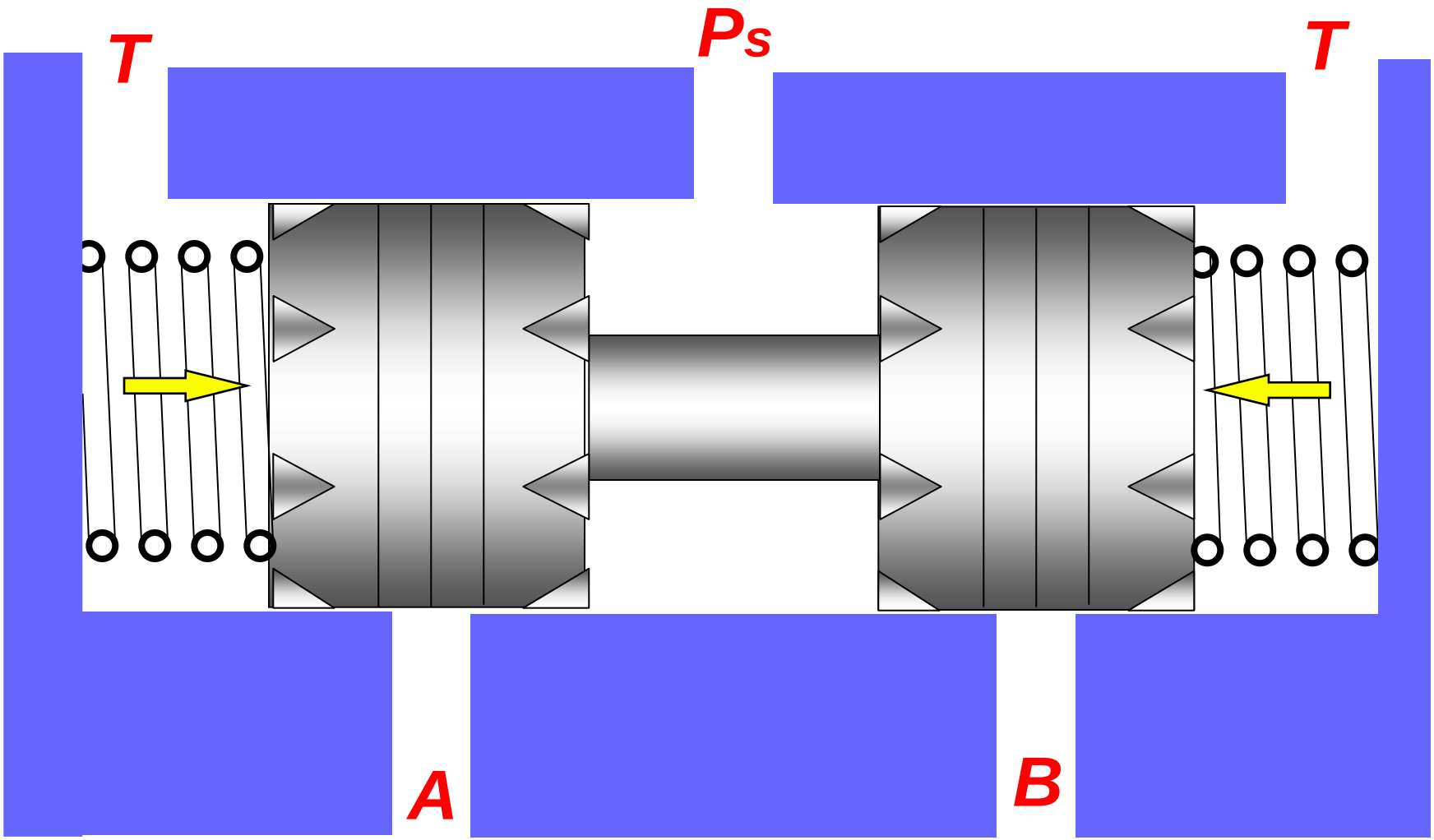




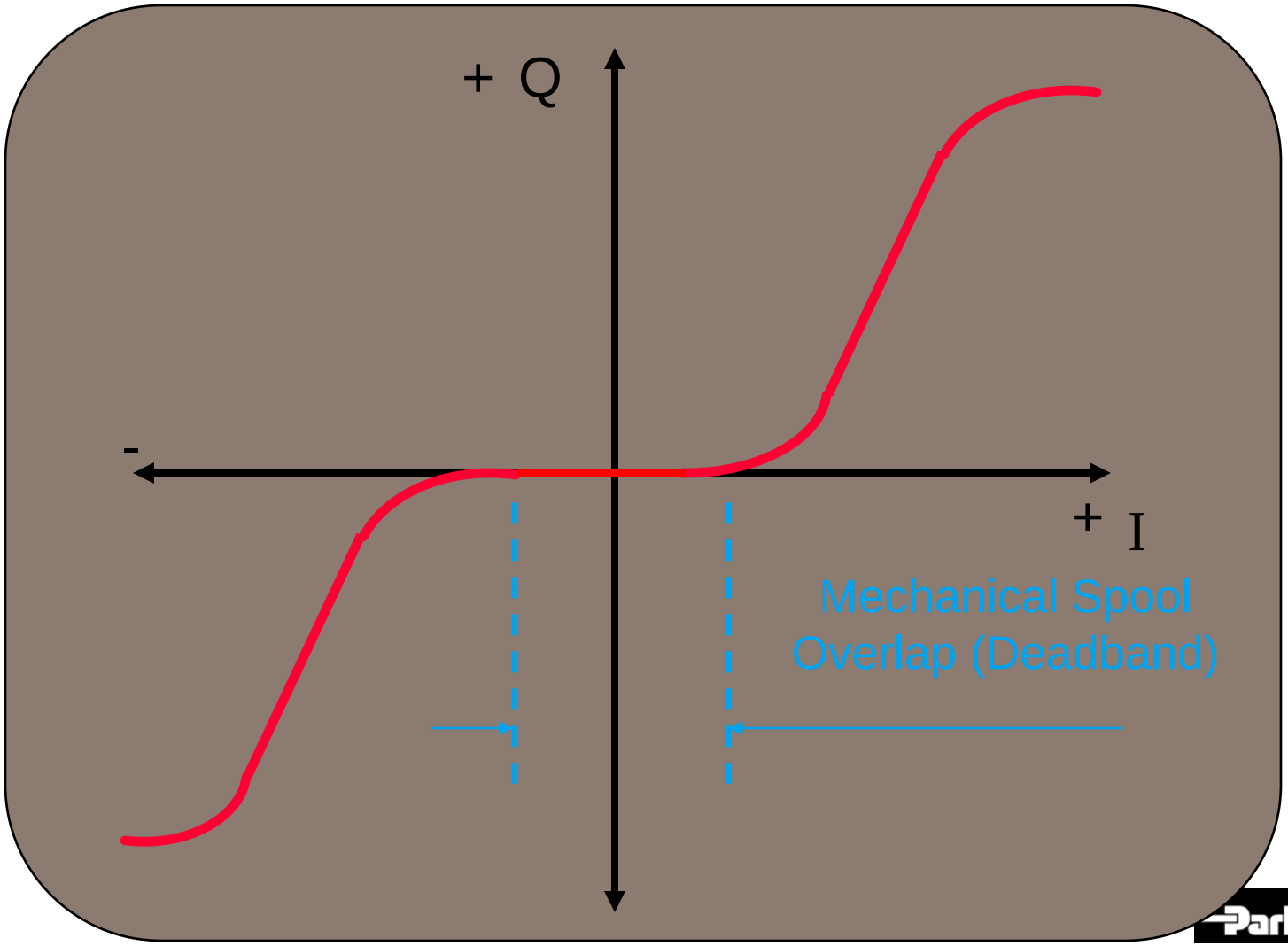
V-Notch - Bleed Center



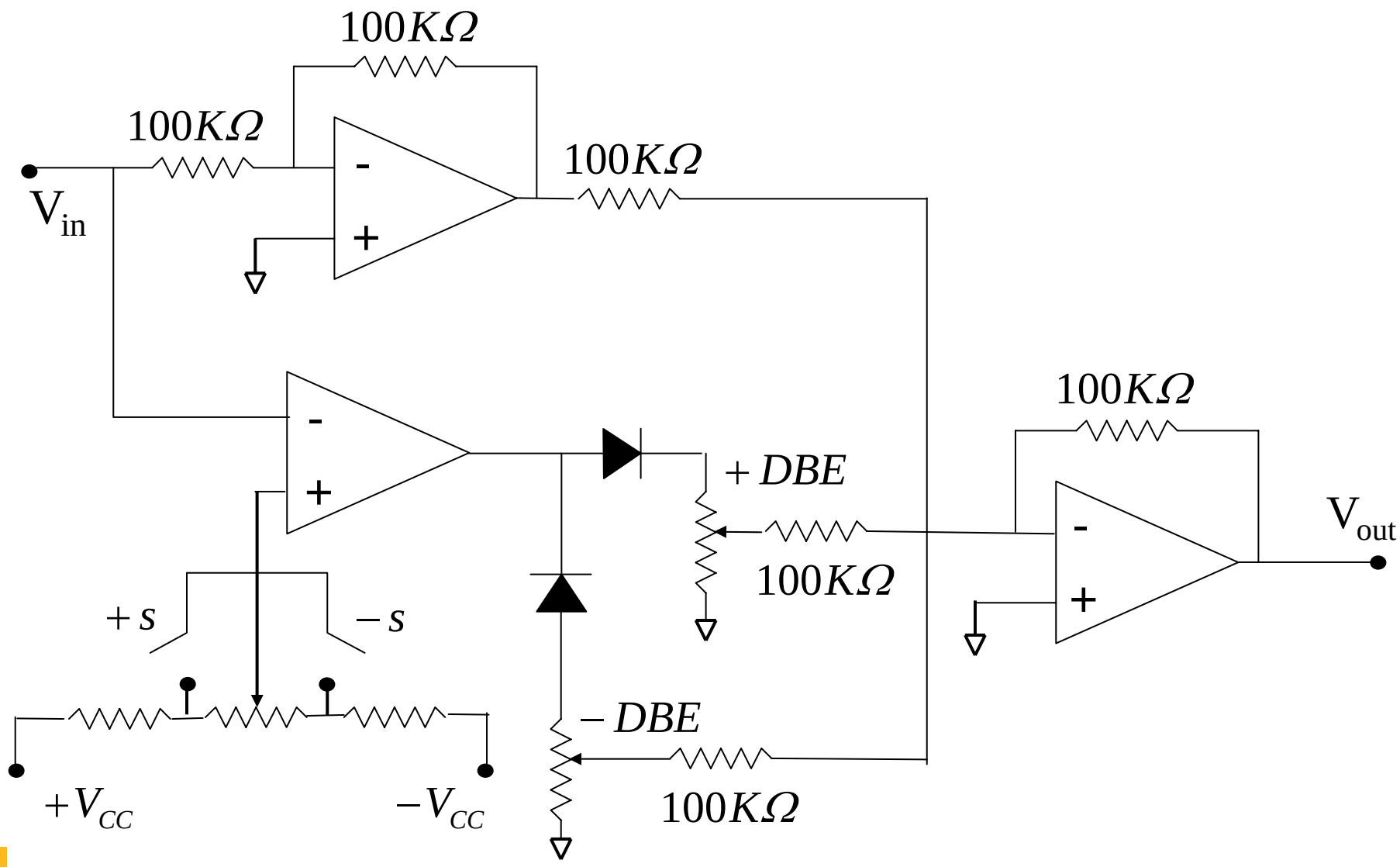
Proportional Valve Deadband



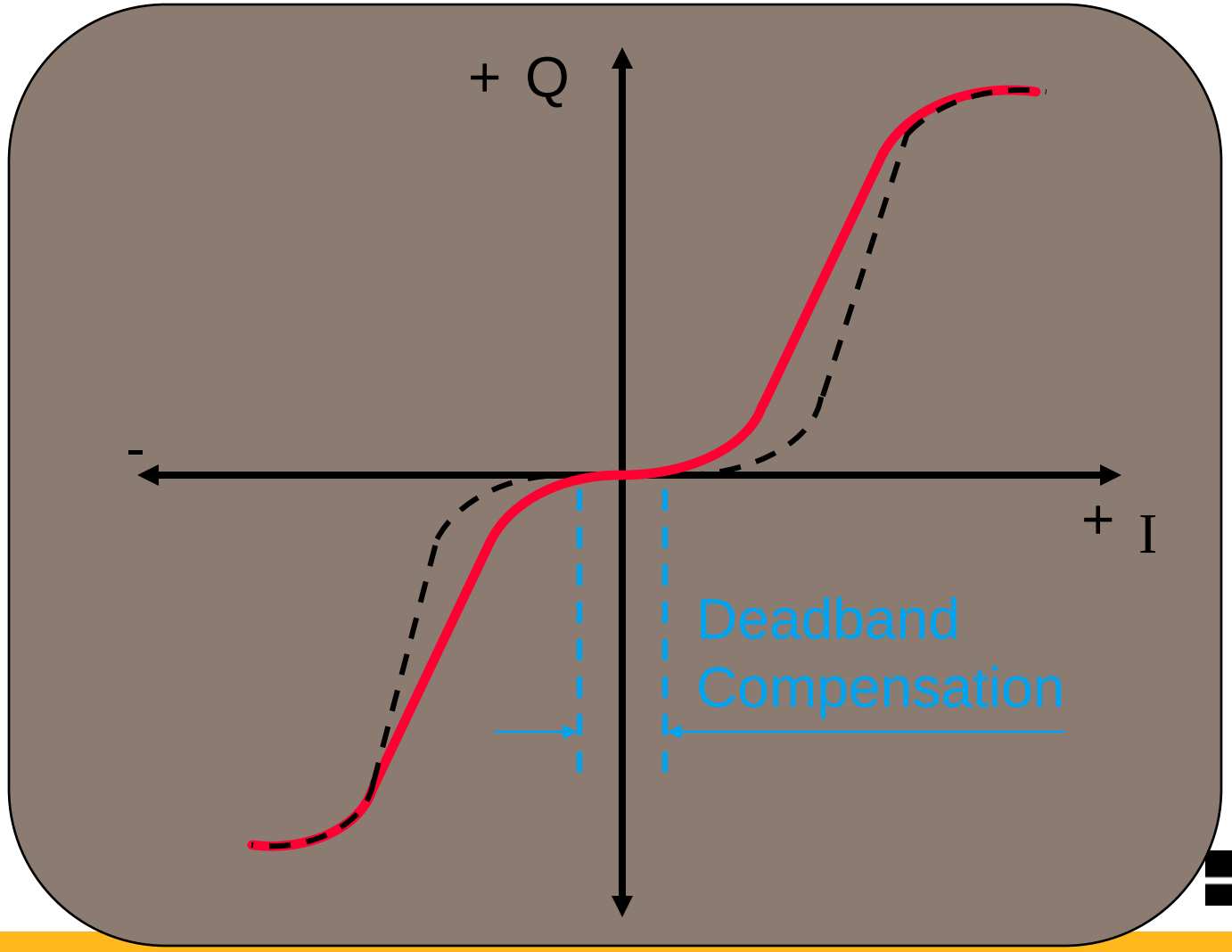
Positive Overlap + Spring Force



Deadband Eliminator



Deadband Compensation



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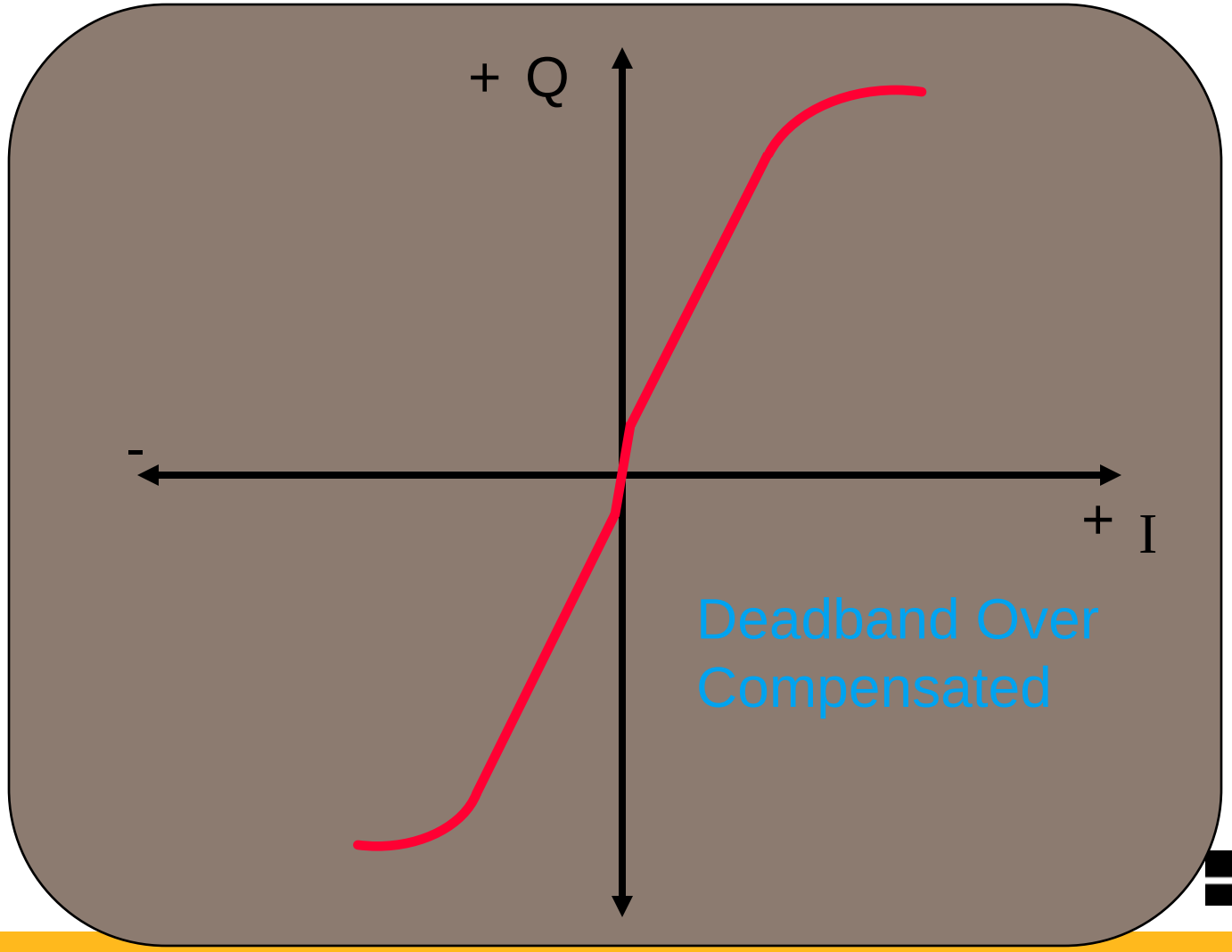
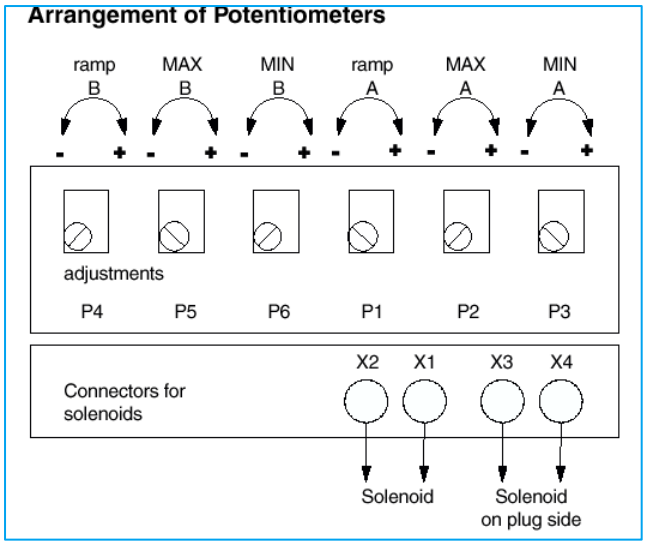
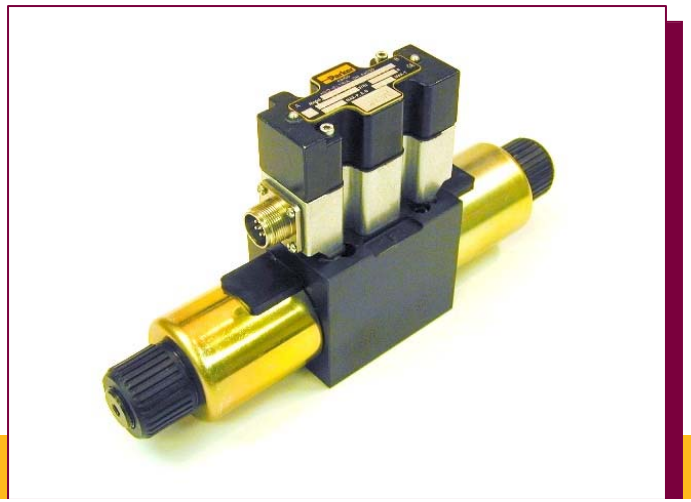
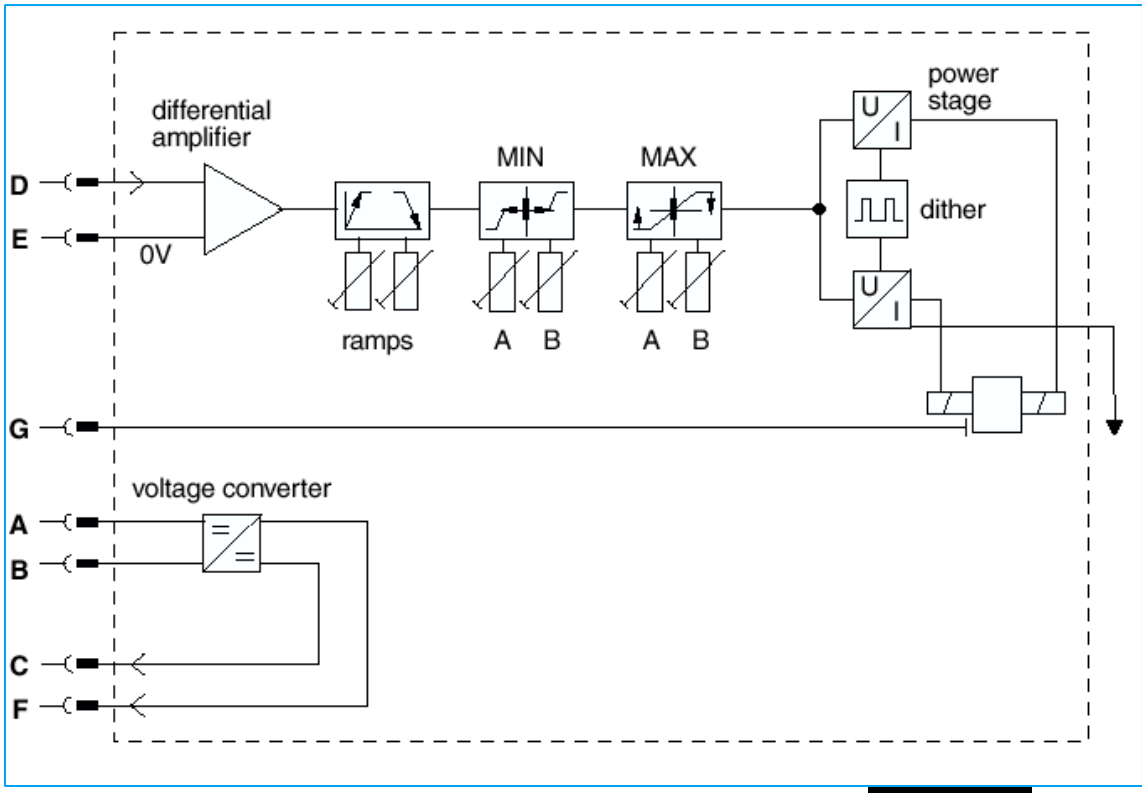


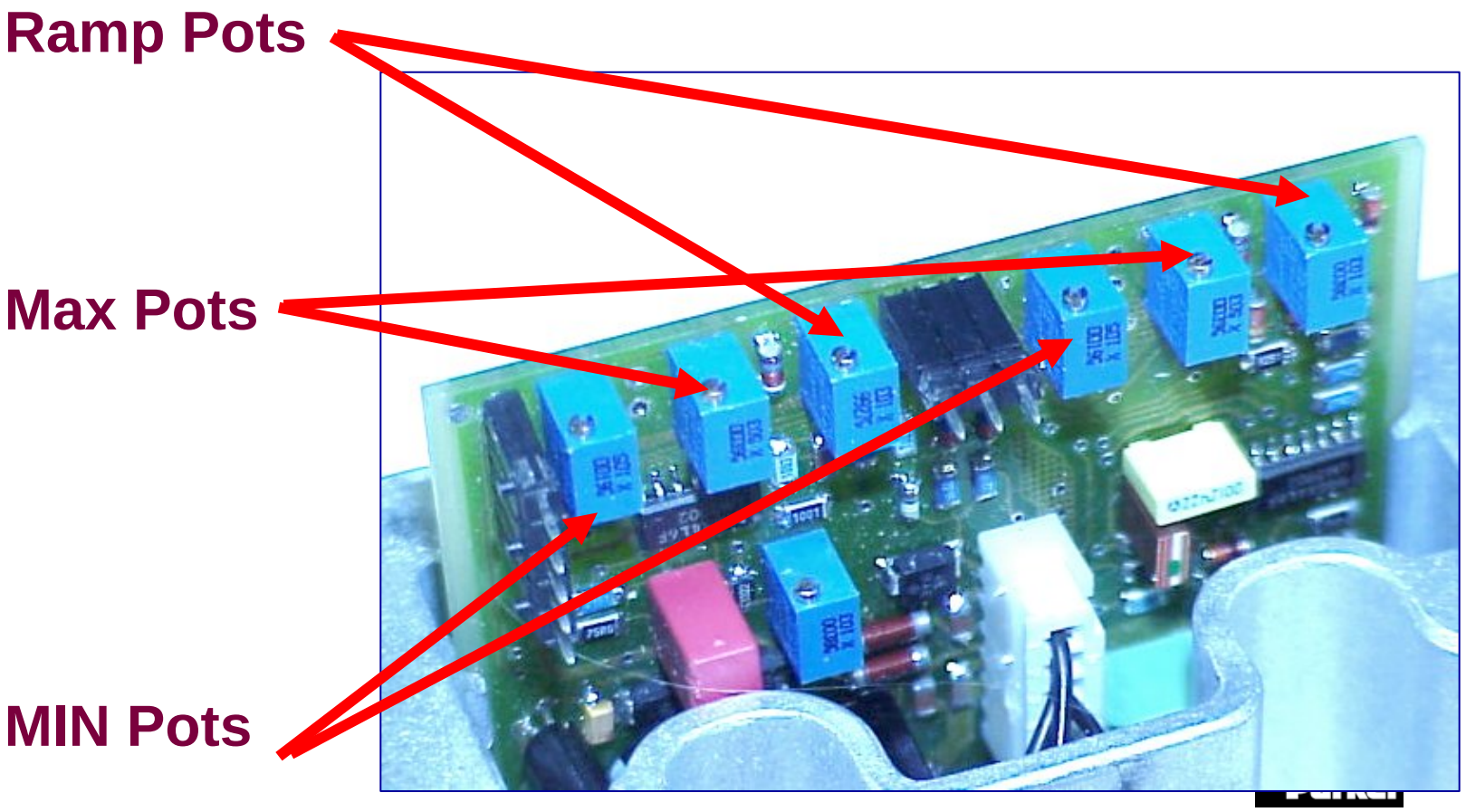
Valve Drivers (Open Loop) On Board Integrated Electronics





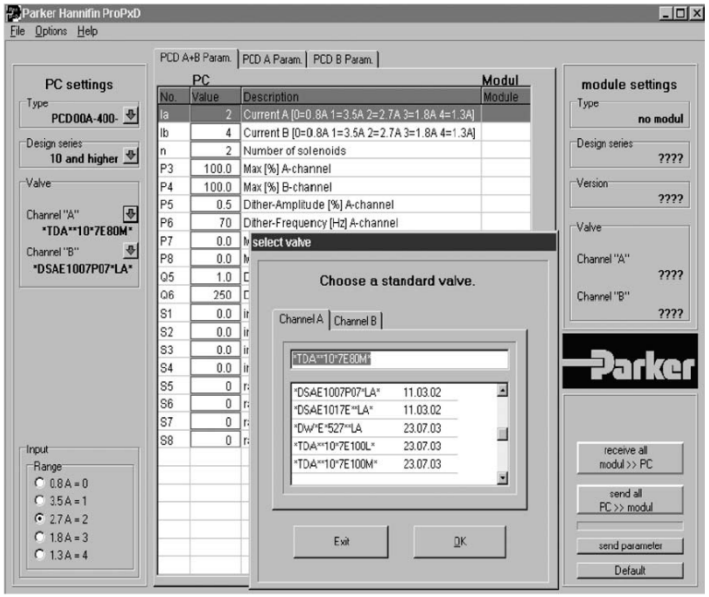


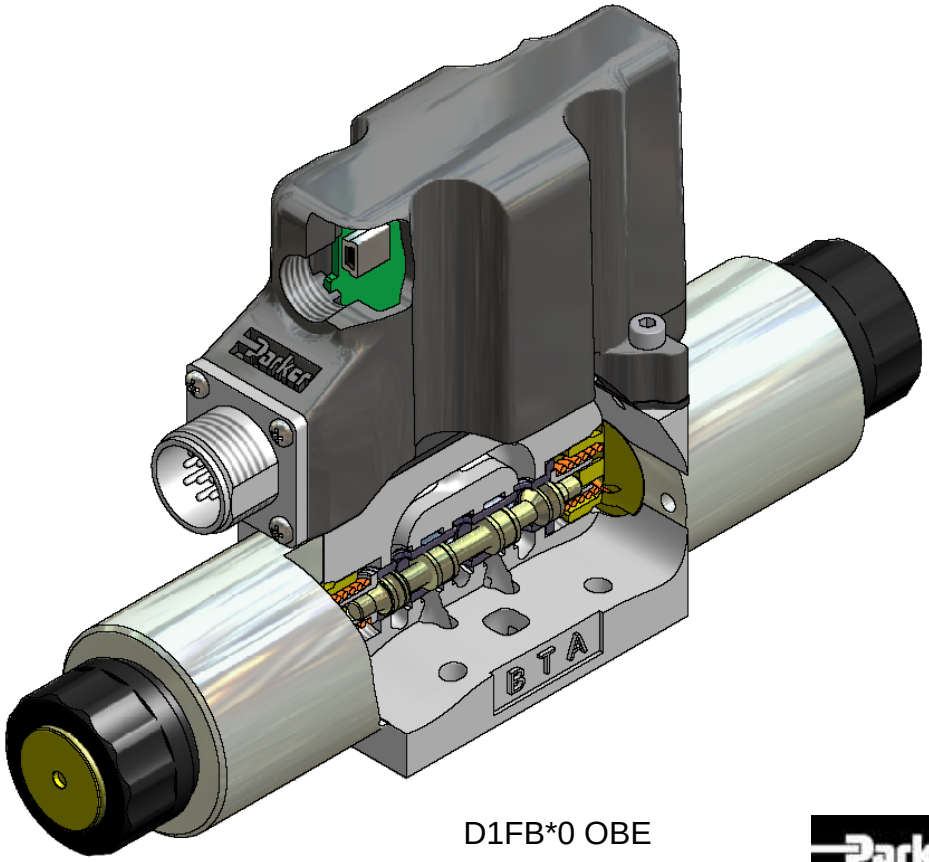
Valve Drivers (Open Loop) On Board Integrated Electronics (Pot adjustments)



Valve Drivers (Open Loop) On Board Integrated Electronics (PC Adjustments)

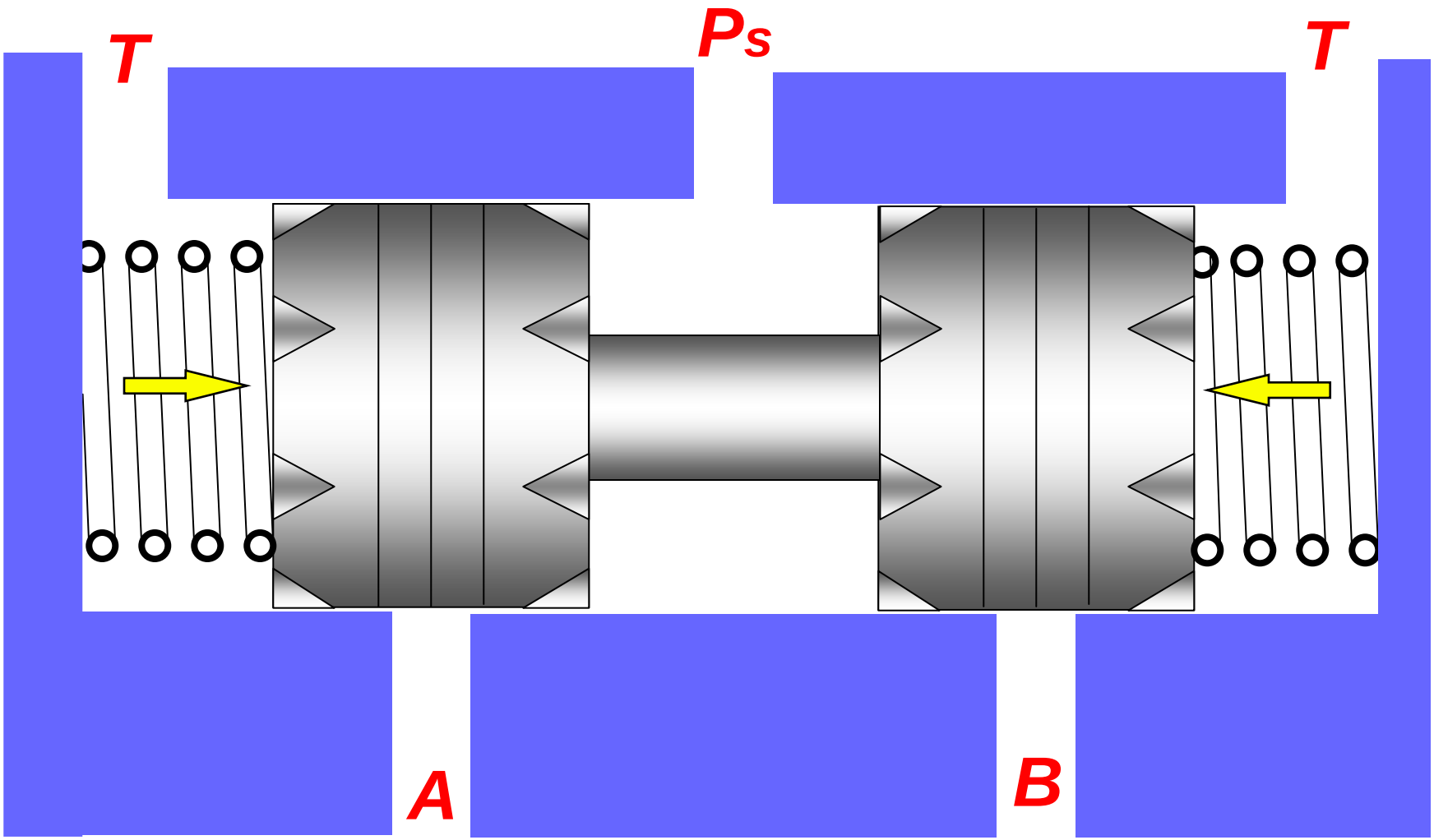
Digital Onboard Electronics



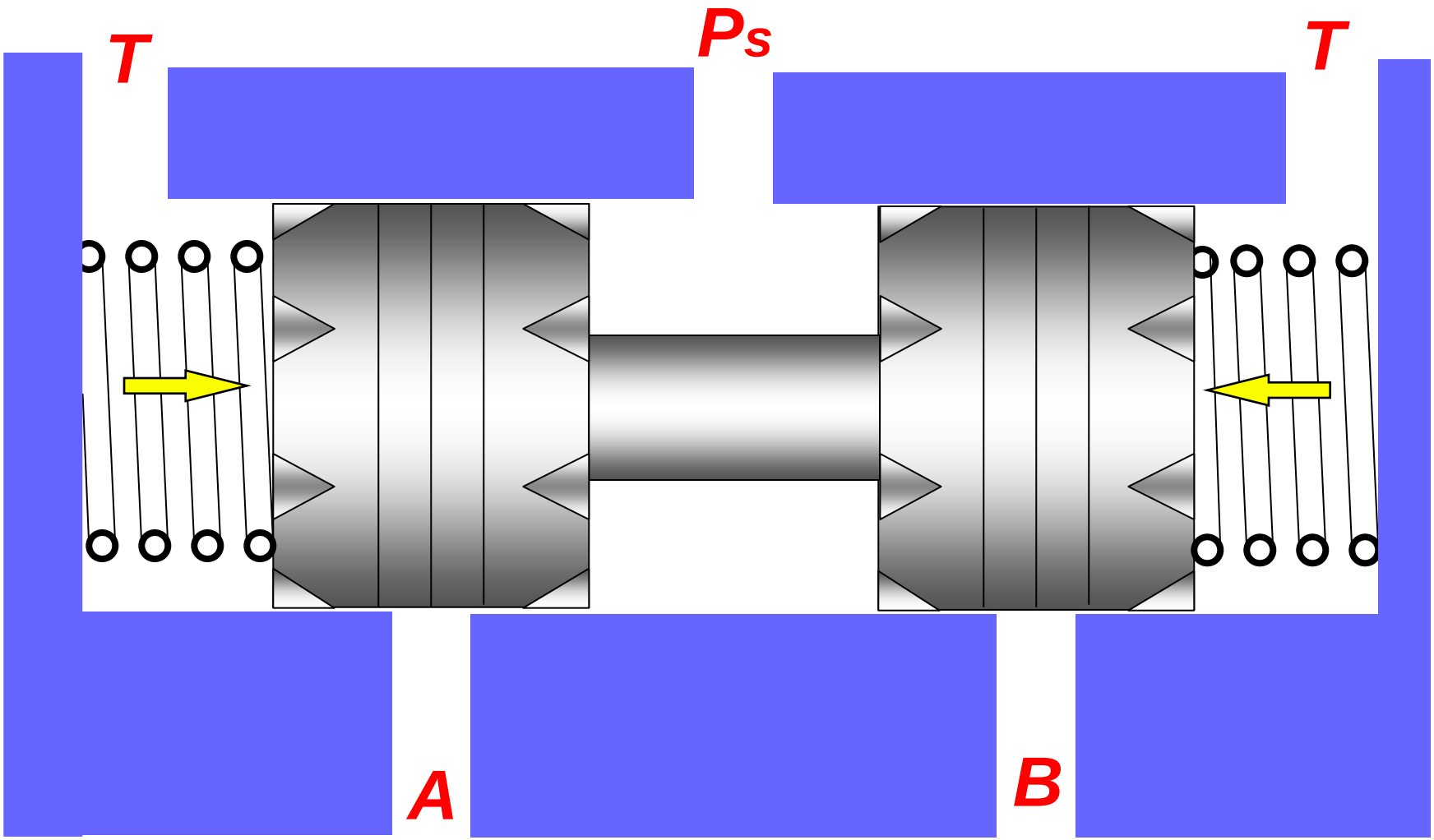


D1FB*0 OBE

Deadband Eliminator P to A flow Path



Deadband Eliminator (P to B flow Path)



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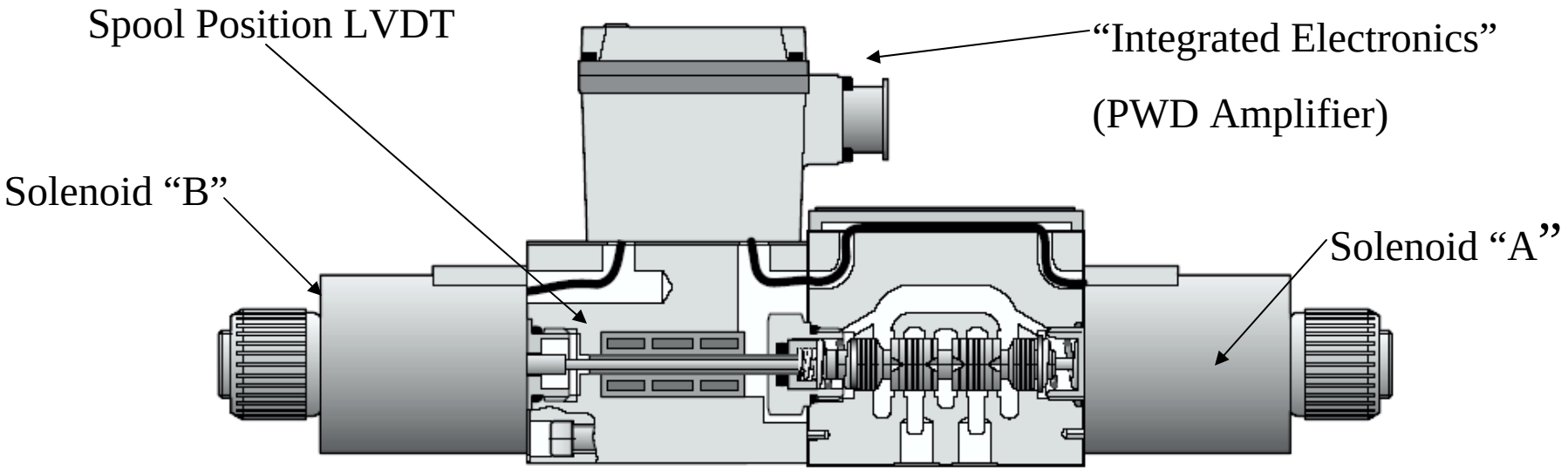
Center Lap Condition	Overlap 5…20%			Zero Overlap	Zero Overlap
Operating Pressures Limits (Drop across metering edge).	1000…2000 PSI			1000…3000 PSI	None
Applications	Open Loop Control		Low End Closed Loop Position	Closed Loop Position & Force	Closed Loop Position & Force

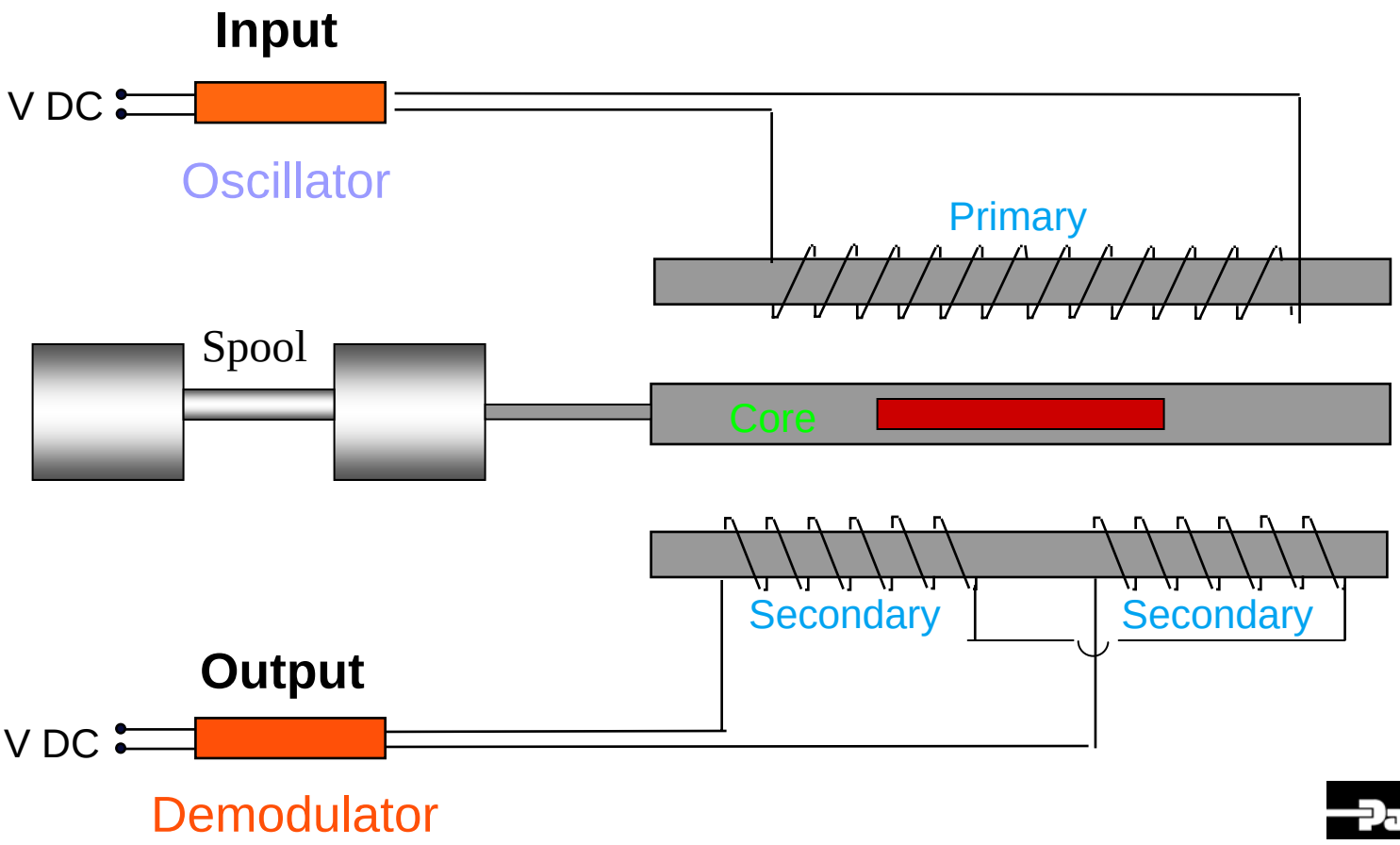
Spool Feedback, How does it Work?



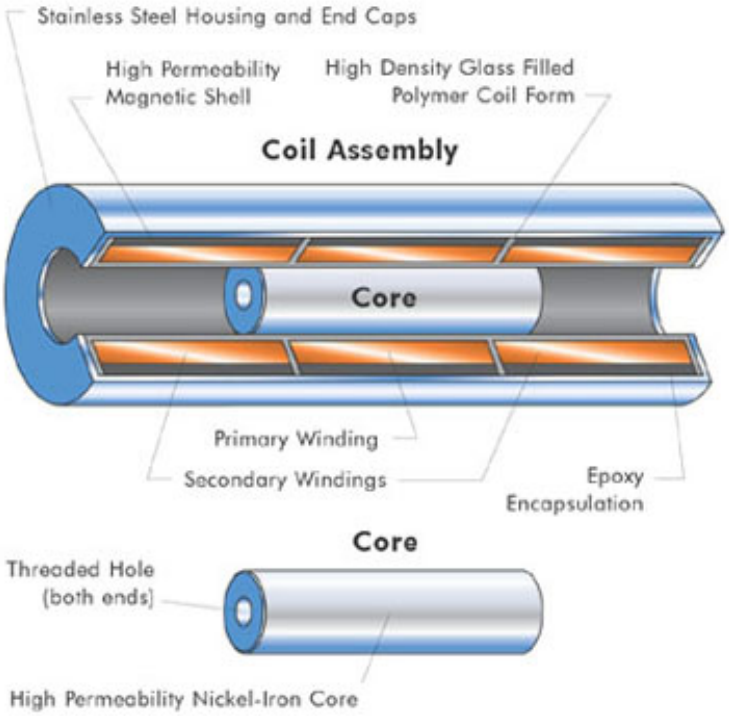
- Same basic operation as non-feedback valves, but "outcome" is measured and corrected to match desired result.
- "Closing the Loop".

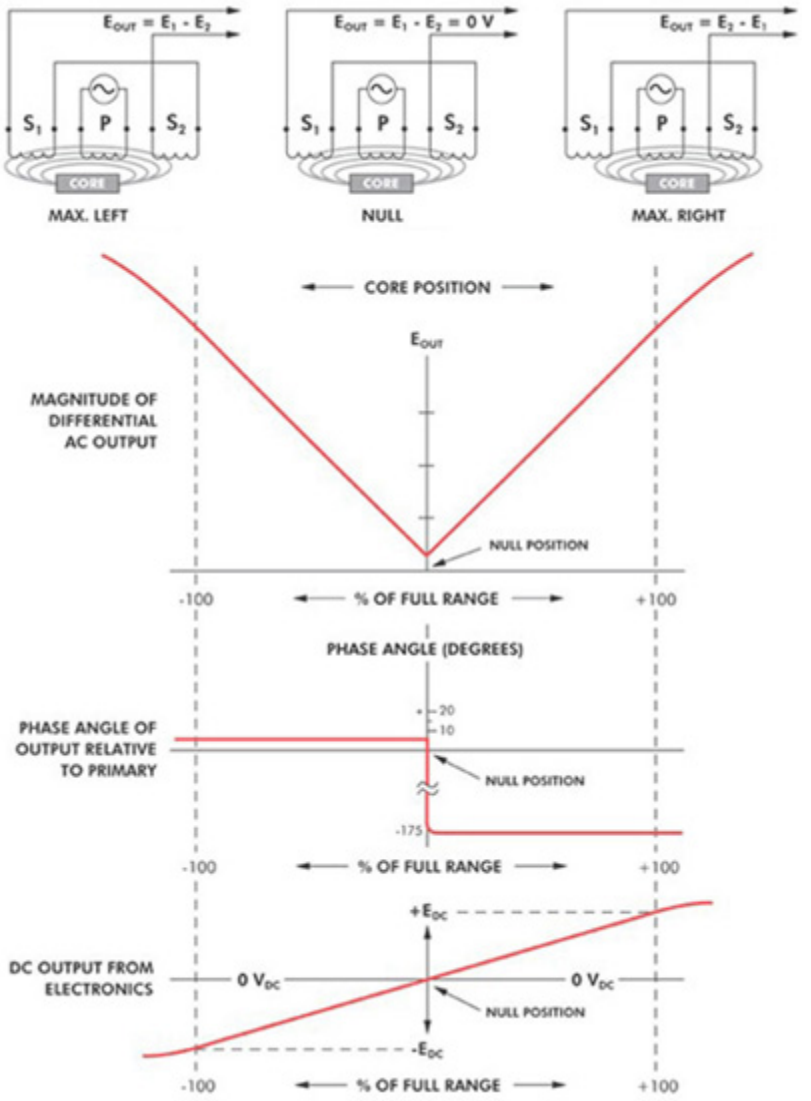
Spool Feedback Device

Linear Variable Differential Transformer

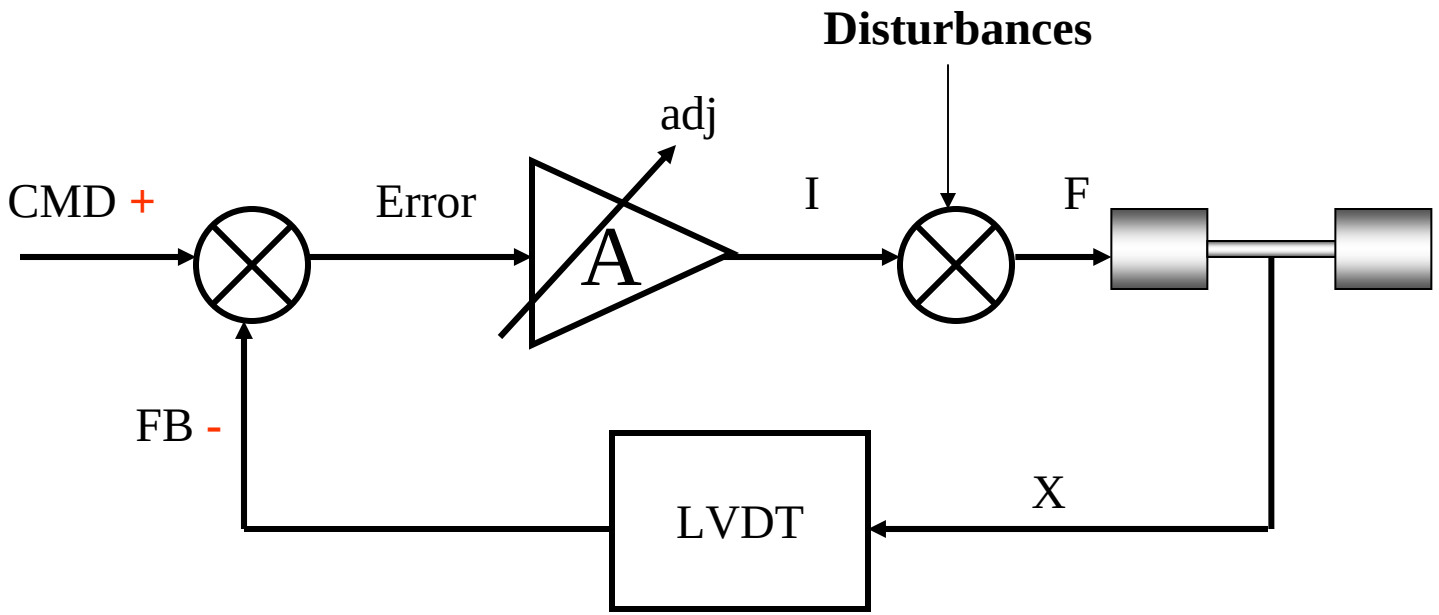


L.V.D.T.s

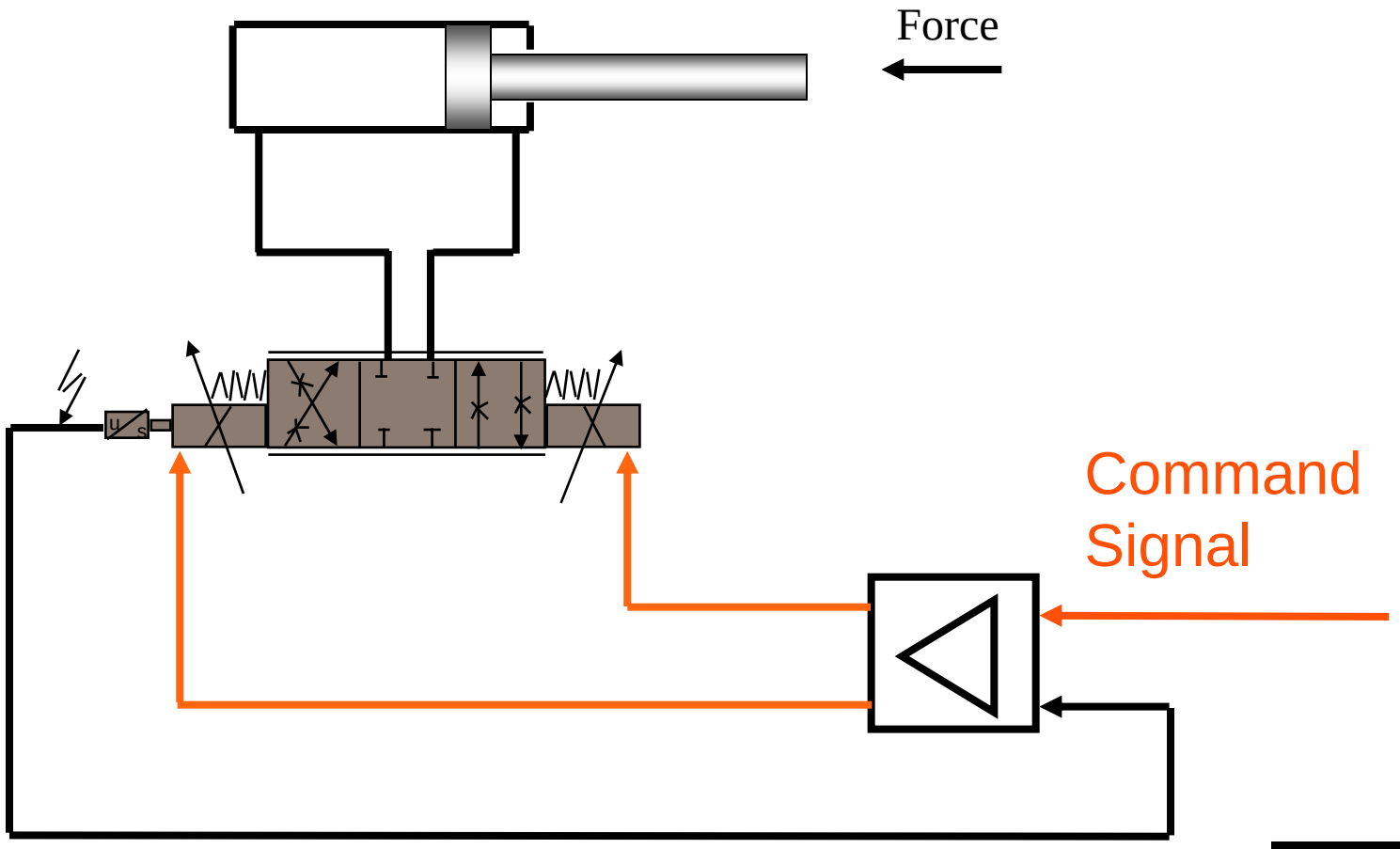

Stainless Steel Housing and End Caps
High Permeability Magnetic Shell
High Density Glass Filled Polymer Coil Form
Coil Assembly
Core
Primary Winding
Secondary Windings
Epoxy Encapsulation
Core
Threaded Hole (both ends)
High Permeability Nickel-Iron Core


$E_{OUT} = E_1 - E_2$
$E_{OUT} = E_1 - E_2 = 0$ V
$E_{OUT} = E_2 - E_1$
S1
P
S2
CORE
MAX. LEFT
NULL
MAX. RIGHT
CORE POSITION
E_{OUT}
MAGNITUDE OF DIFFERENTIAL AC OUTPUT
NULL POSITION
-100
% OF FULL RANGE
+100
PHASE ANGLE (DEGREES)
PHASE ANGLE OF OUTPUT RELATIVE TO PRIMARY
+20
+10
-175
DC OUTPUT FROM ELECTRONICS
$+E_{DC}$
0 V_{DC}
$-E_{DC}$

Spool Feedback Devices (Electrical Schematic-Integrated Electronics)

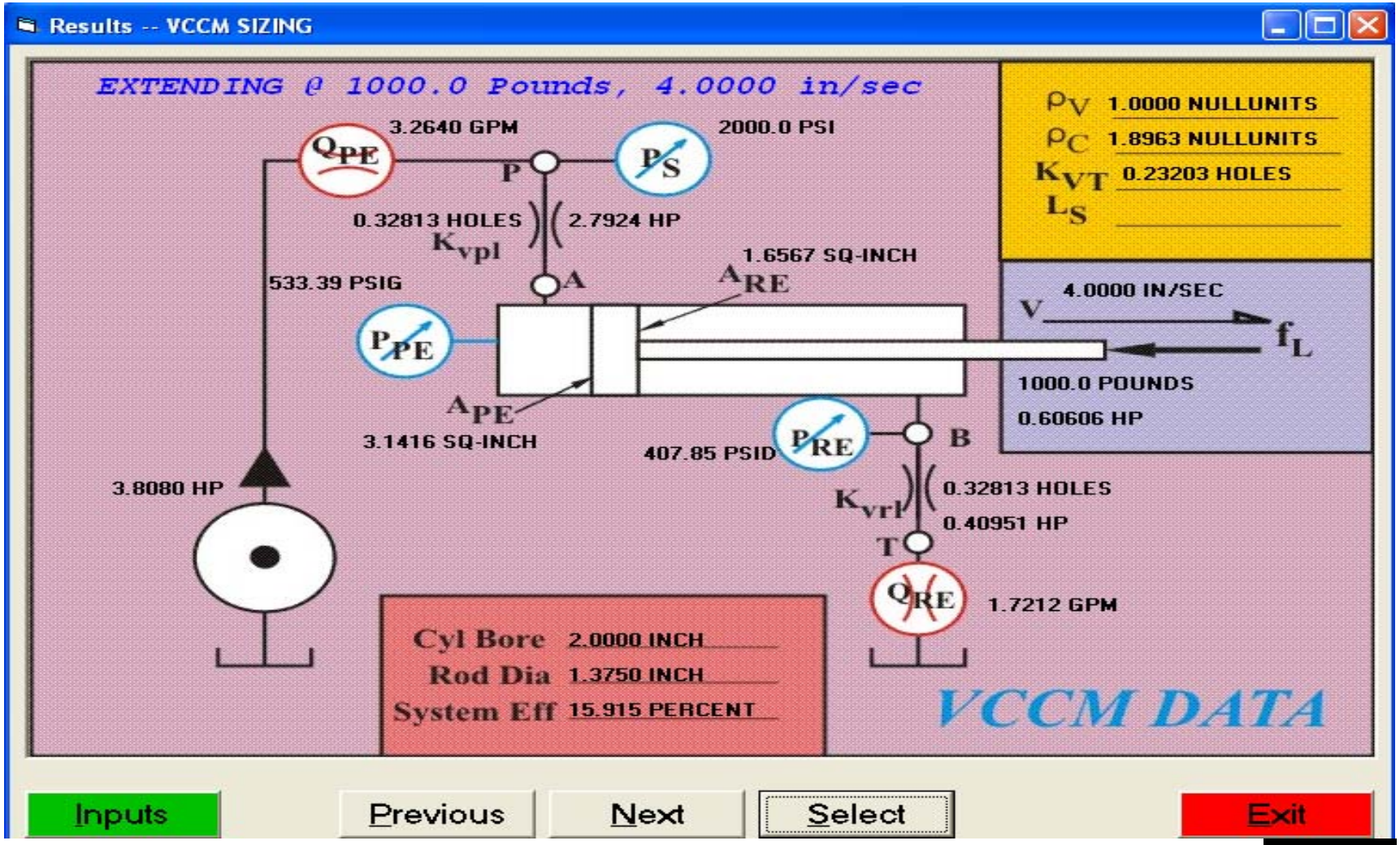


Internal Closed Loop

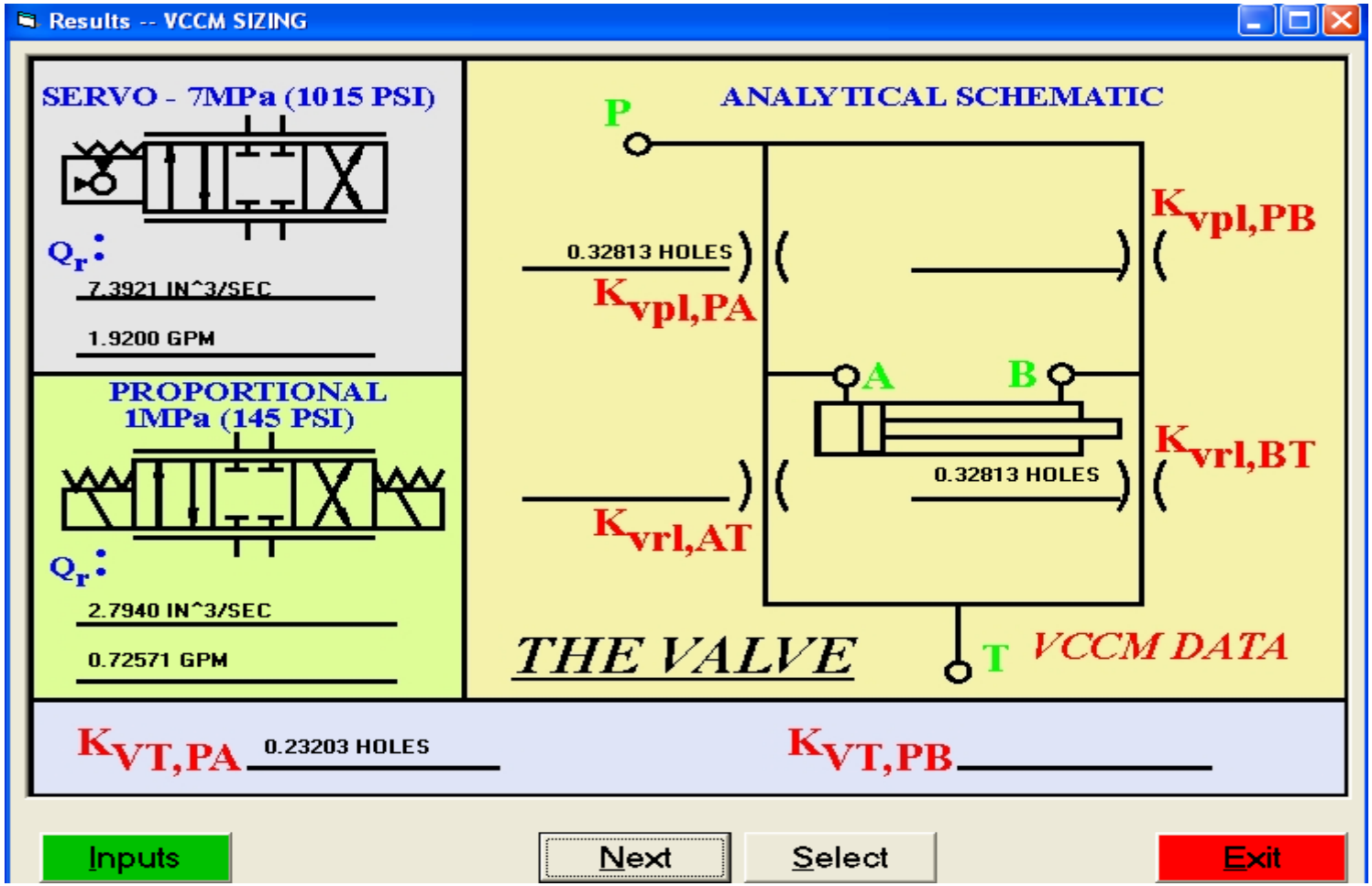


Valve position feedback

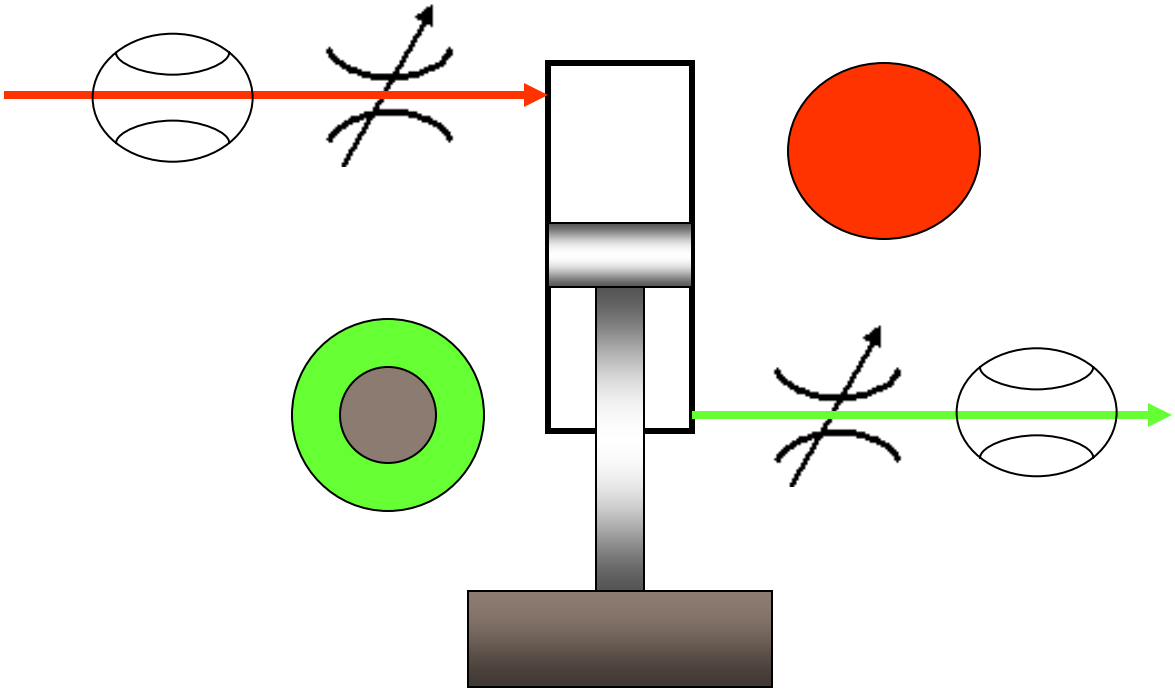
Sample Application

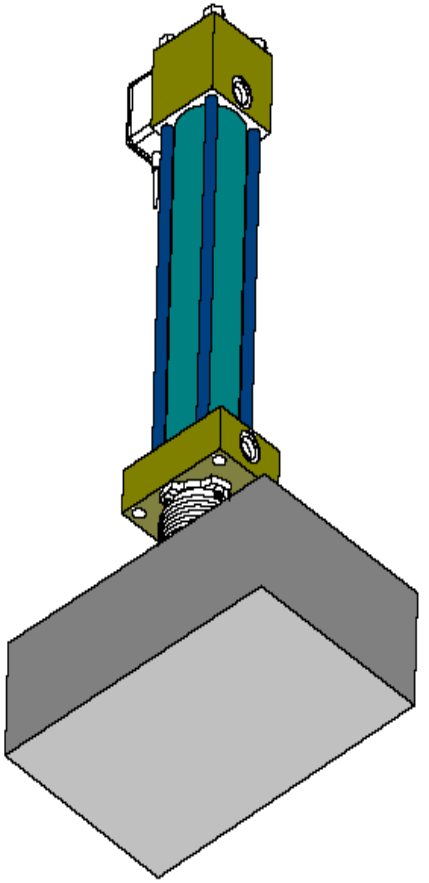


Kv Sizing

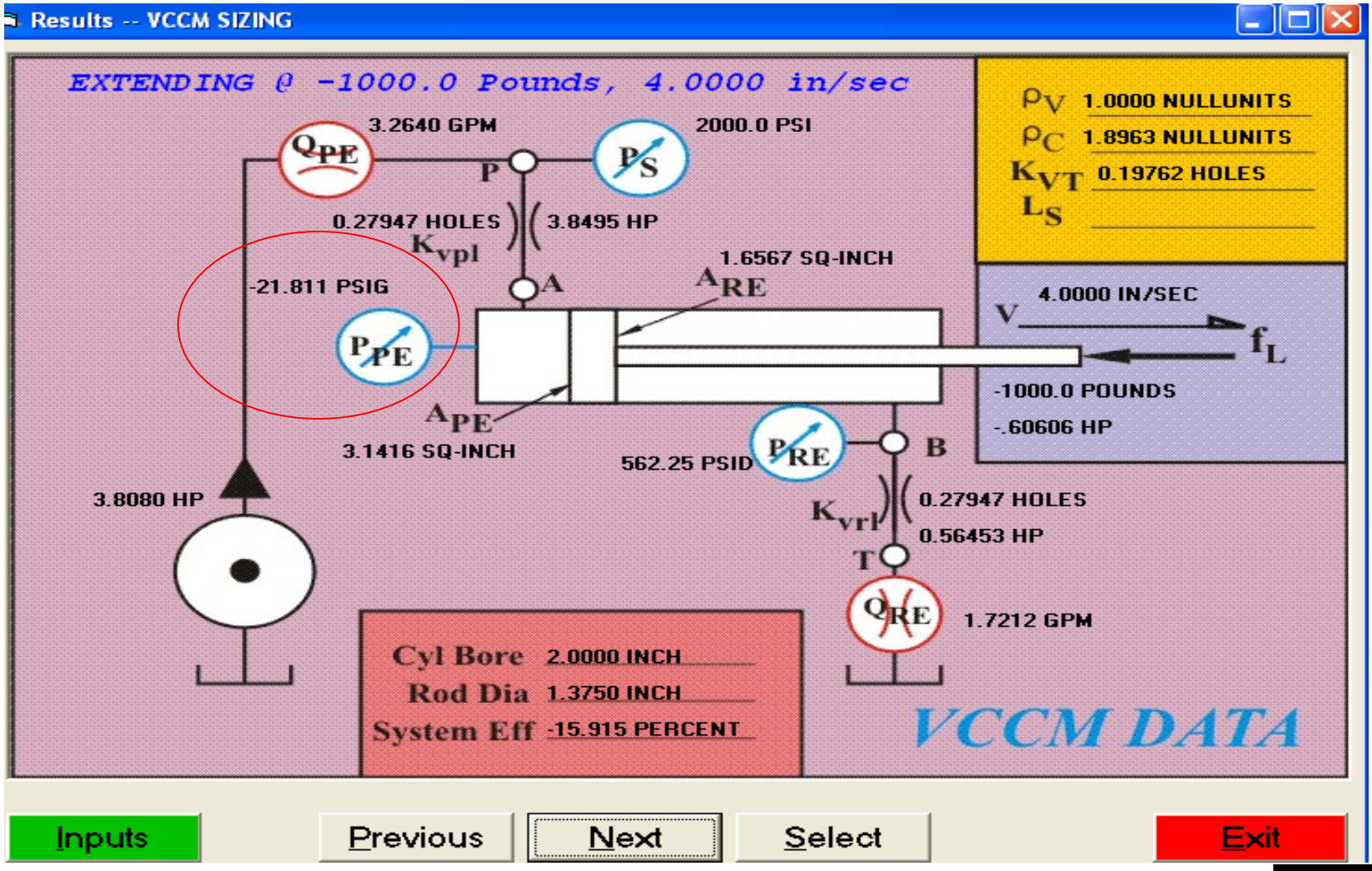

Results -- VCCM SIZING
SERVO - 7MPa (1015 PSI)
Qr:
7.3921 IN^3/SEC
1.9200 GPM
PROPORTIONAL
1MPa (145 PSI)
Qr:
2.7940 IN^3/SEC
0.72571 GPM
ANALYTICAL SCHEMATIC
P
A
B
T
0.32813 HOLES
KVpl,PA
KVpl,PB
KVrl,AT
KVrl,BT
0.32813 HOLES
THE VALVE
VCCM DATA
KVT,PA
0.23203 HOLES
KVT,PB
Inputs
Next
Select
Exit

Non-Symmetrical Spools

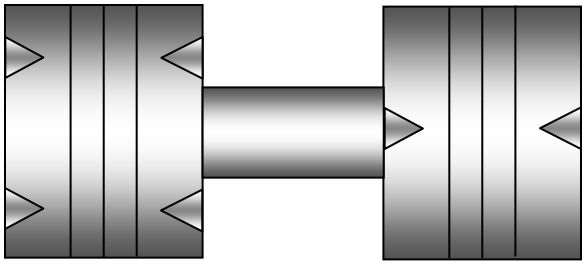


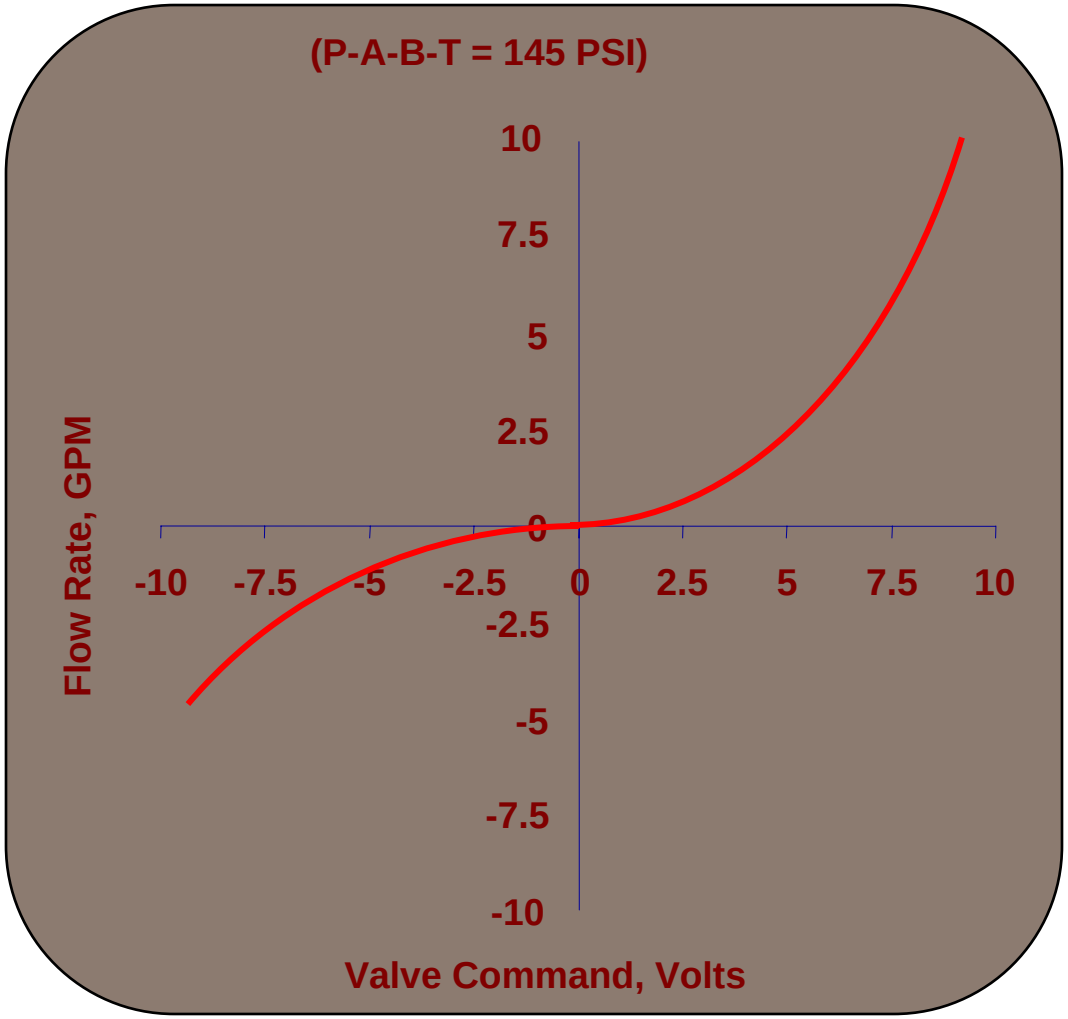


Sample Application, Number 2



Non-Symmetrical Spools

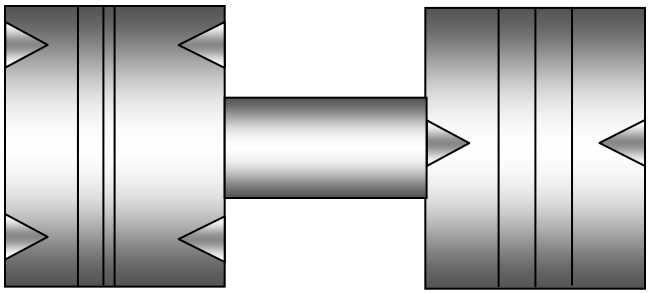




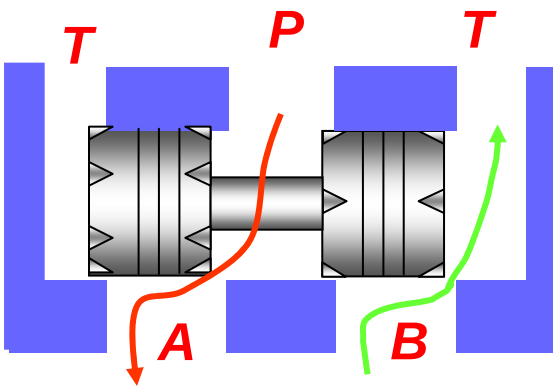
Common Procedure

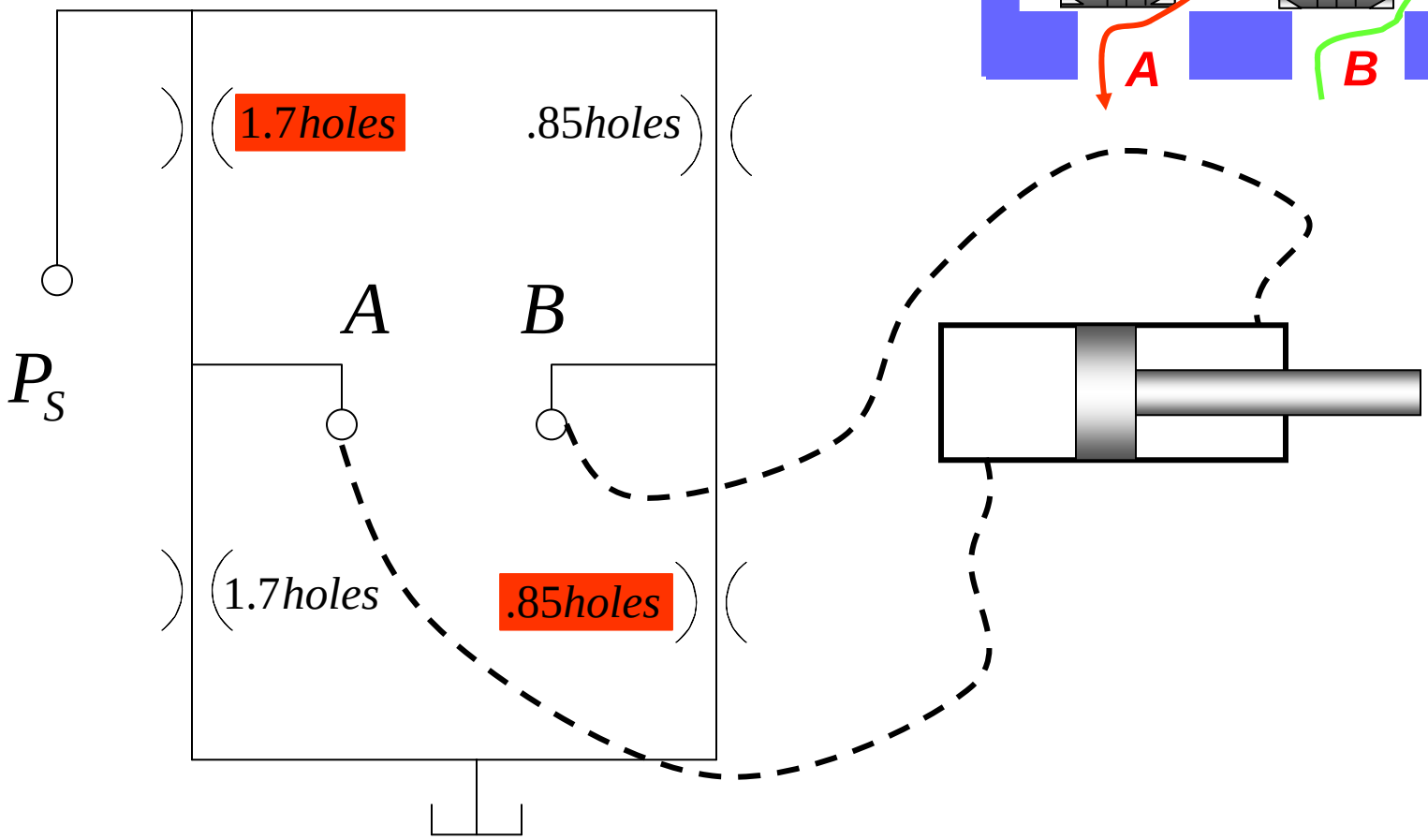
The manufacturer can choose to take a standard 10gpm valve with normally 4 notches on each land and only cut two notches in the land that will be connected to the small area of the cylinder.

3 notches instead of 4
4 notches instead of 6
2 notches instead of 6…

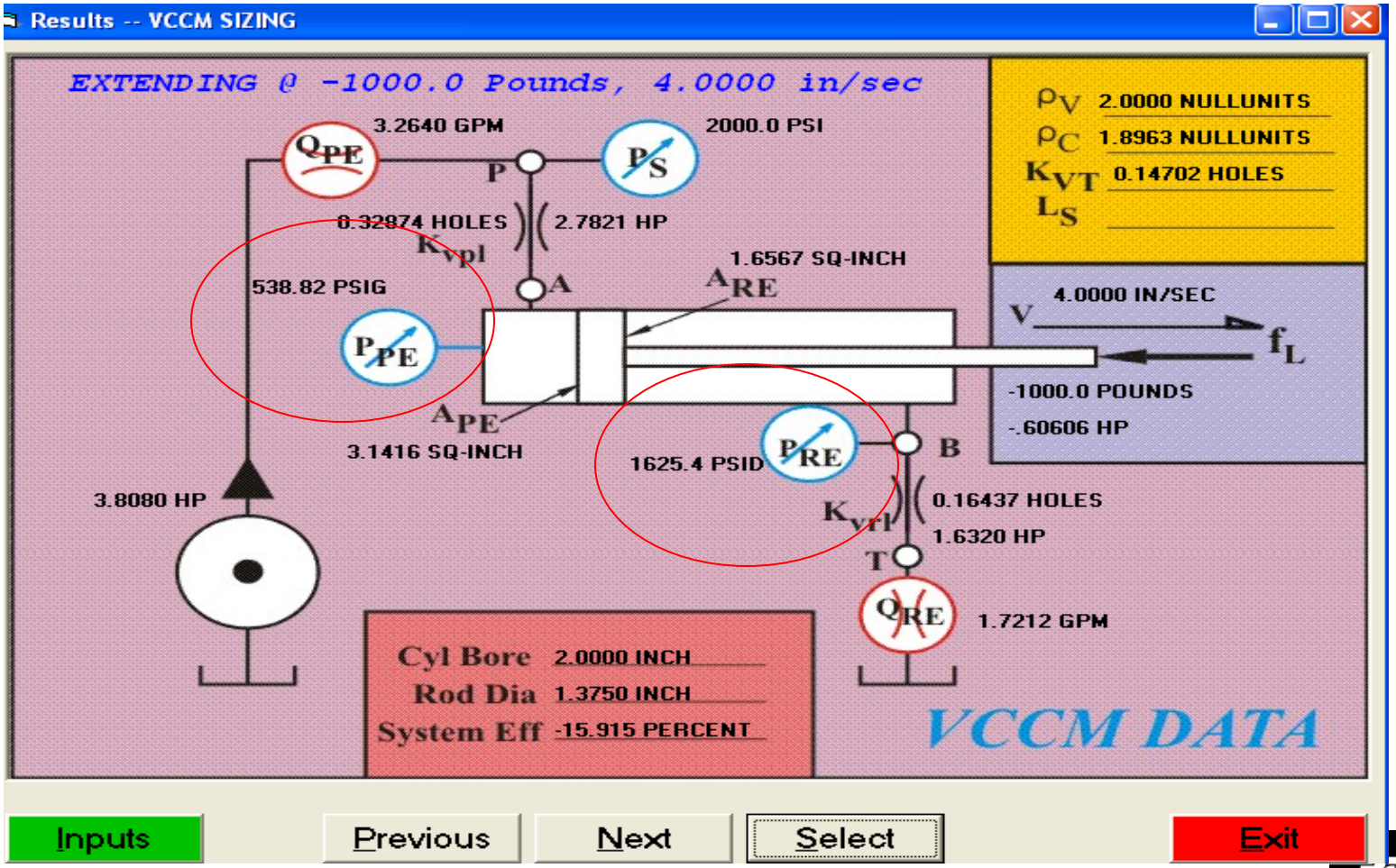


Non-symmetrical Spools

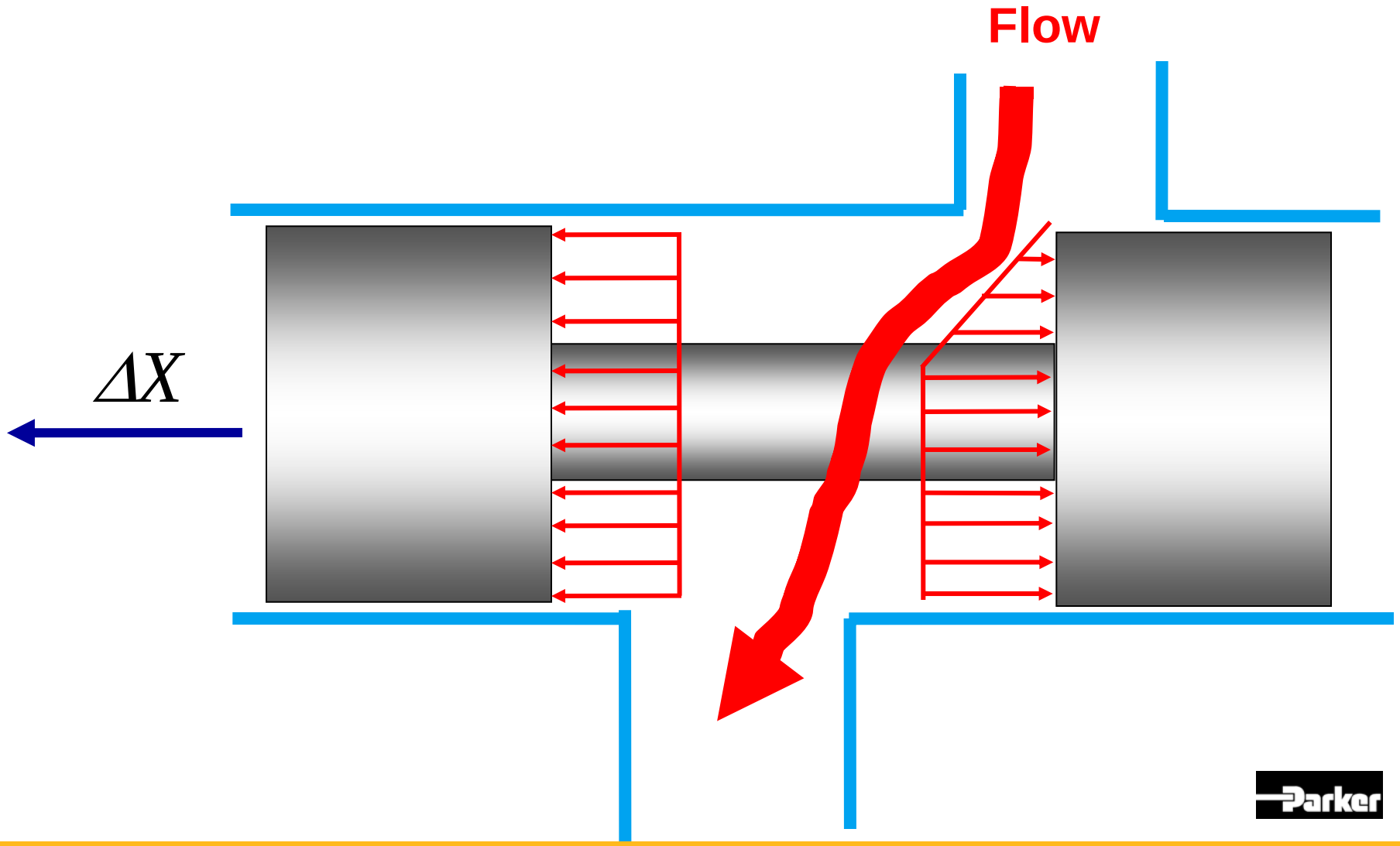




Sample Application No. 2 with Non-Symmetrical Spool

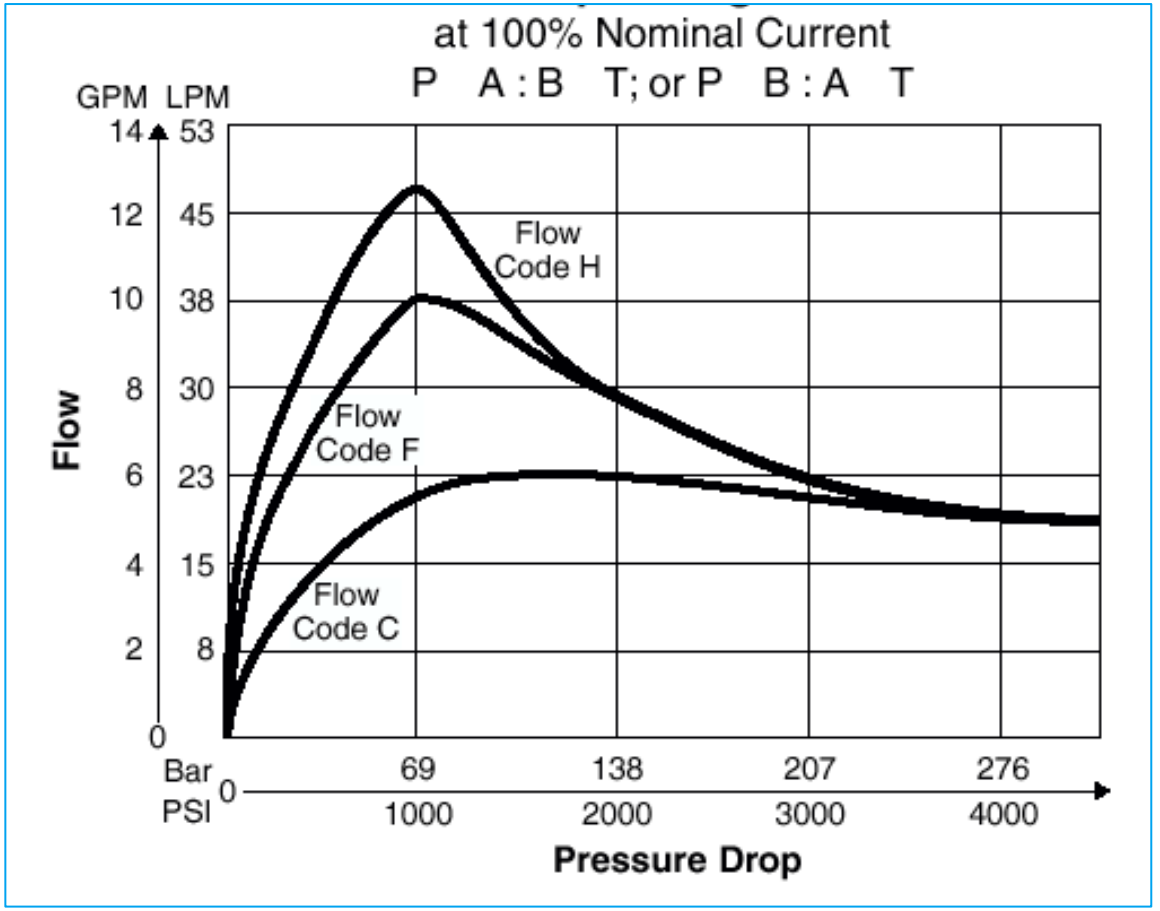


Flow Force Effects Proportional Valves



Flow Force Performance

Operating Limits Curves show Valve Performance over entire Pressure Range



Proportional Valves

Servo Valves

	Mobile bankable Style, Threaded Cartrdige Style	NFPA Mounting Without Spool Position Feedback	NFPA Mounting With Spool Position Feedback	Servo Performance. Closed Loop Valves with Spool Position Feedback	Servo Valves With either Mechanical or Electrical Feedback (spool position).
Parker Models	Pulsar VP, VPLs. DF**, ERVs	D*FWs, D*FTs' 	D*FXs' 	D*FH D*FMs D*1FH 	BDs' DYs' SEs' 
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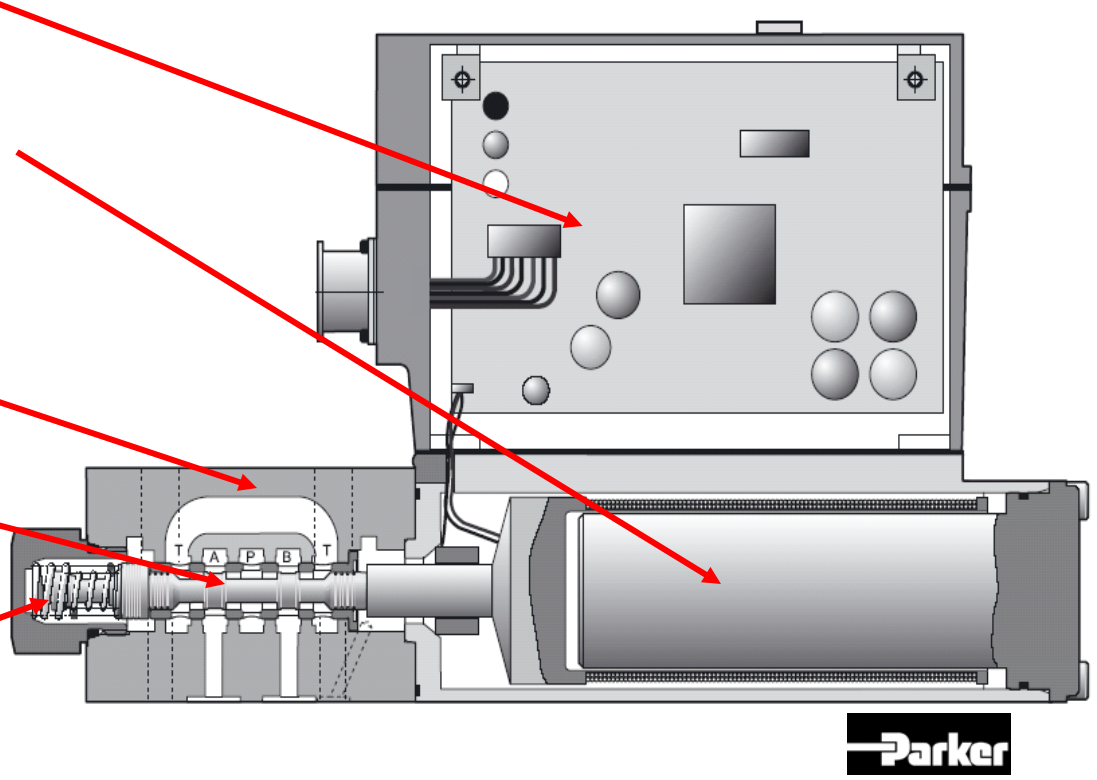
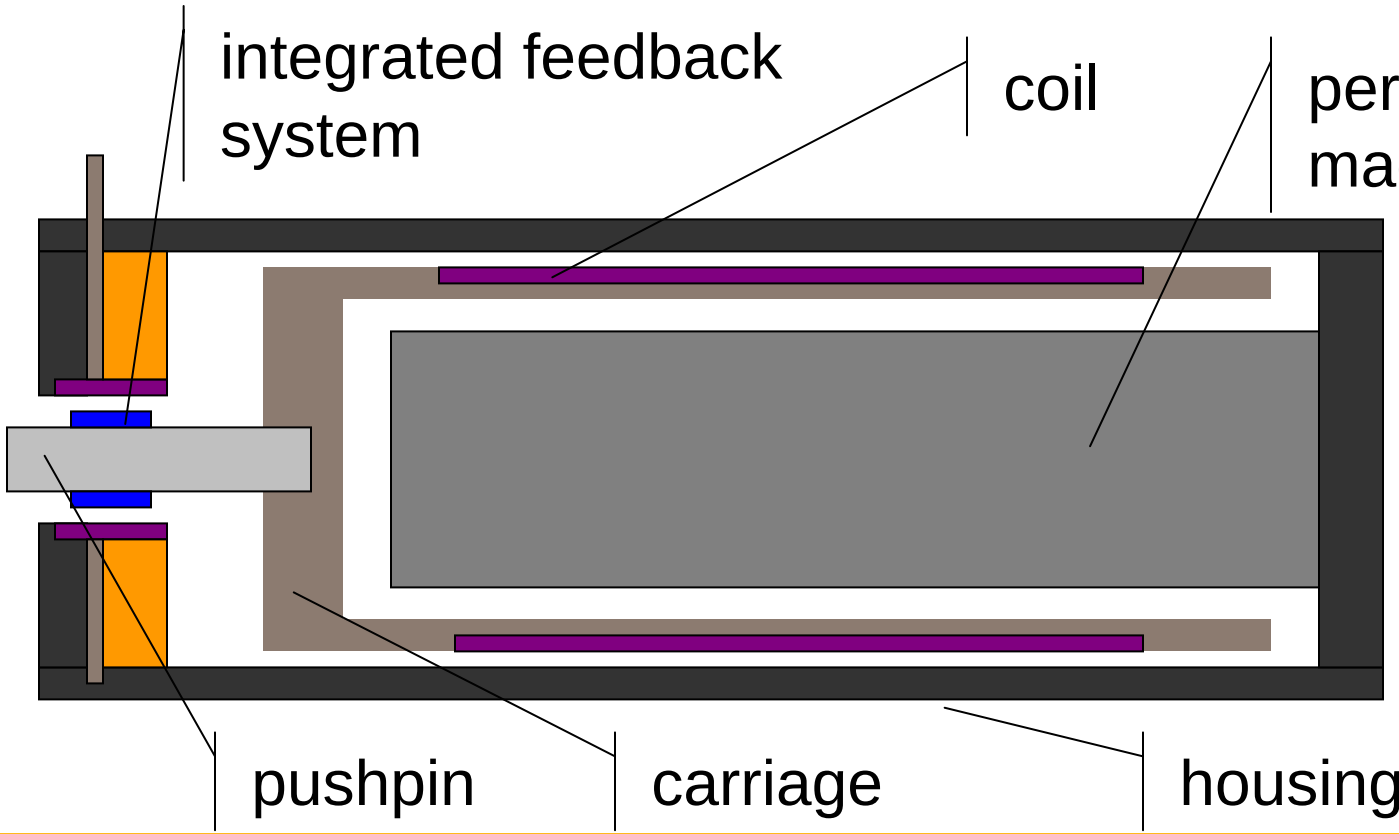
VCD®…Milestone for High Performance Valves

- D1FP (NG6) valve as pilot valve for D*1FP
  - integrated drive electronics
  - Voice Coil Drive VCD®
  - valve body
  - spool-sleeve assembly
  - spring assembly fail-safe position



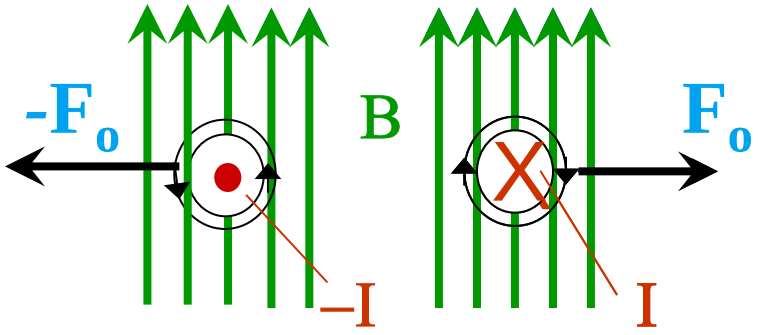
VCD®...Milestone for High Performance Valves

- Parker Voice Coil Drive (VCD®) technology for highest precision



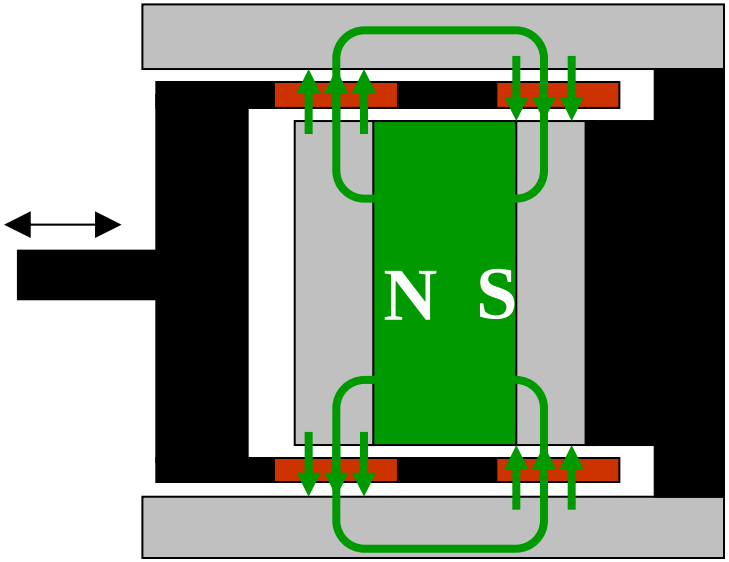
VCD®...Milestone for High Performance Valves

- VCD® principle, moved coil in magnetic field



$$F_o = B \cdot I \cdot l$$

B = magnetic flux density
I = electrical current
l = wire length (winding)



permanent magnet

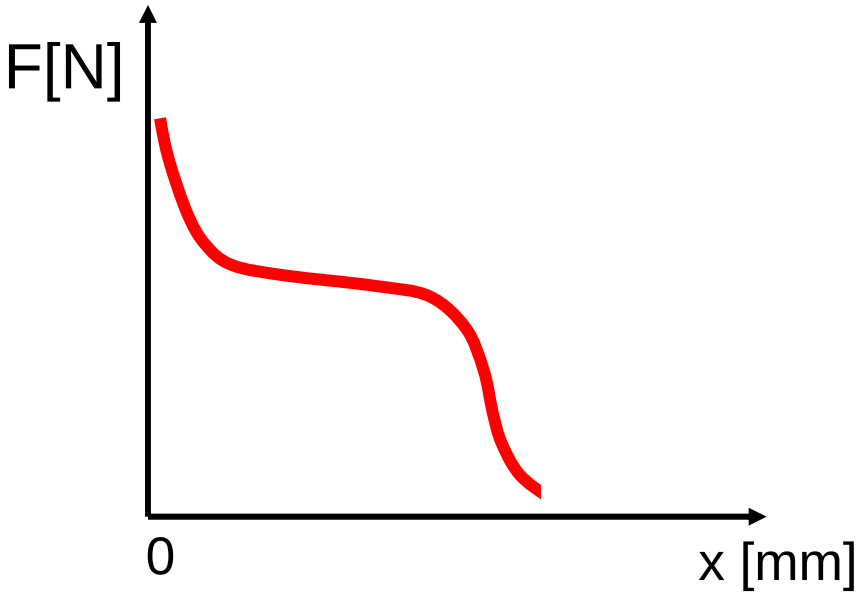
non-magnetic material

winding

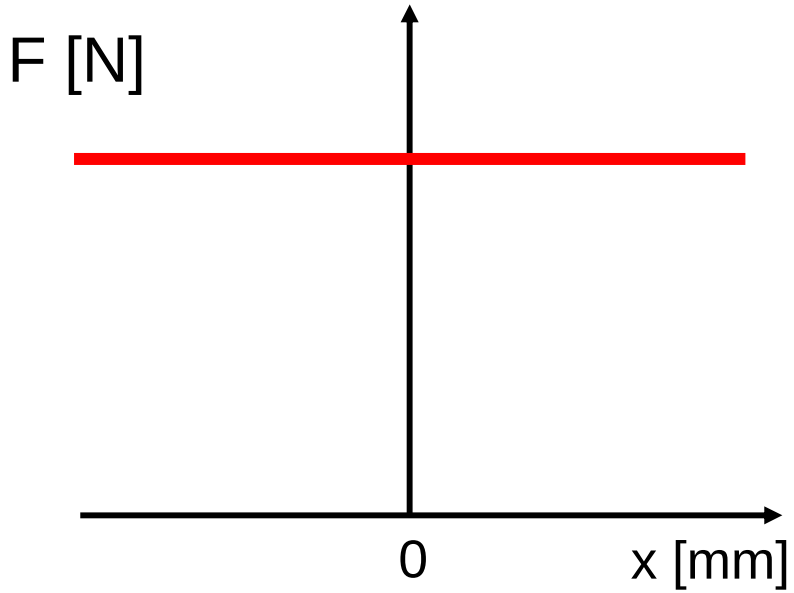
iron (magnetic)

VCD®…Milestone for High Performance Valves

- Characteristics of force in comparison



conventional solenoid
force dependent of stroke

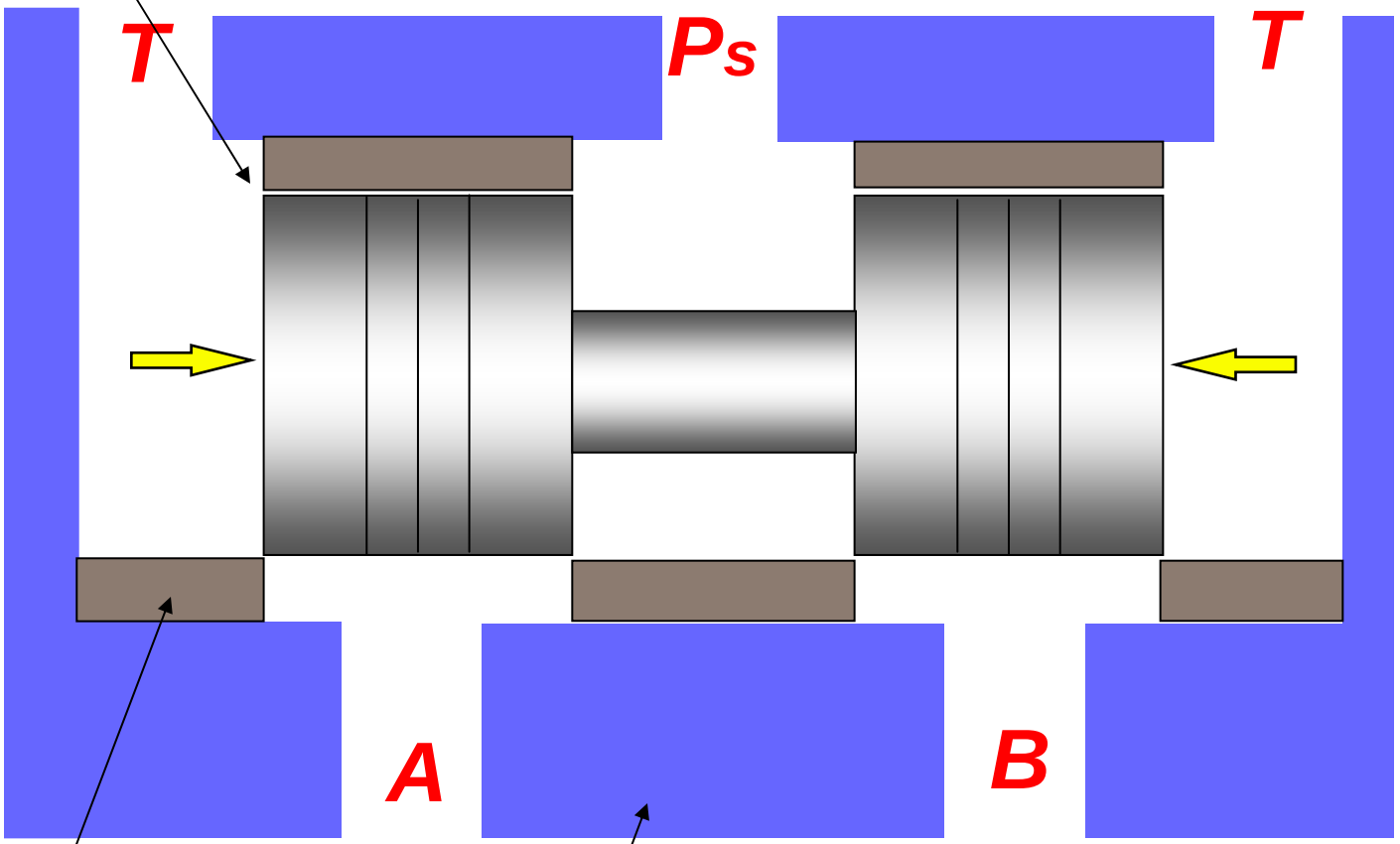


Voice Coil Drive
force independent of stroke

Servo Solenoid/Voice Coil Valves

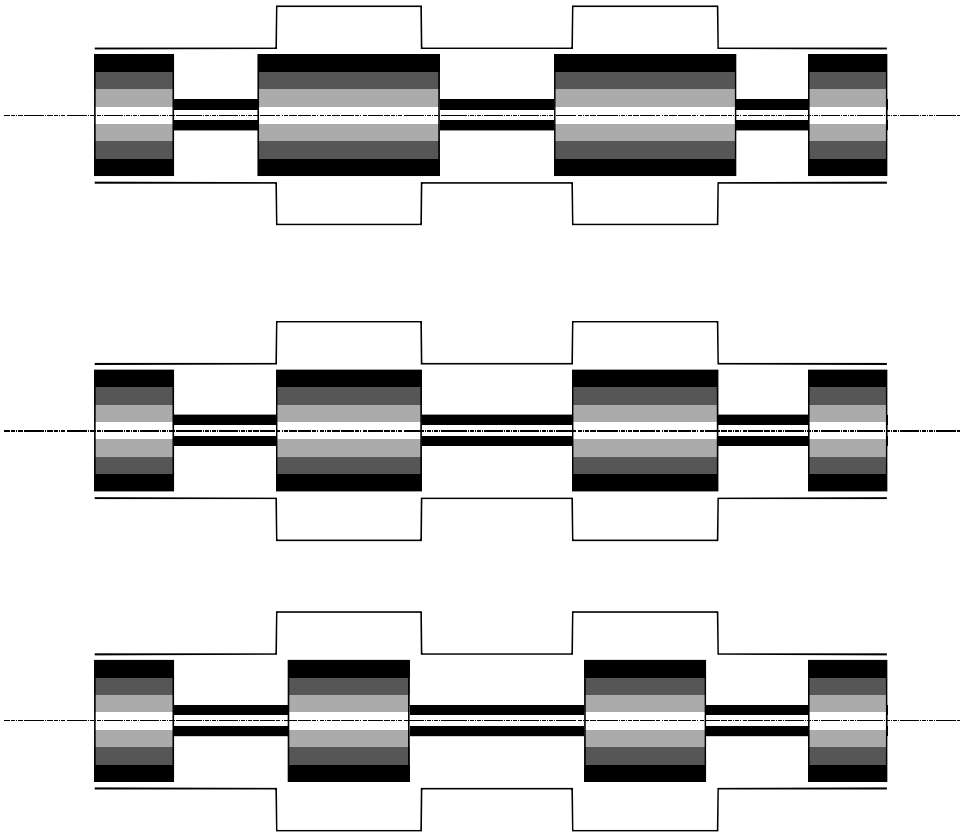
"Line to Line" Lap
Or "Axis Cut"

No Deadband



Spool and Sleeve Arrangement

Spool Lap Conditions

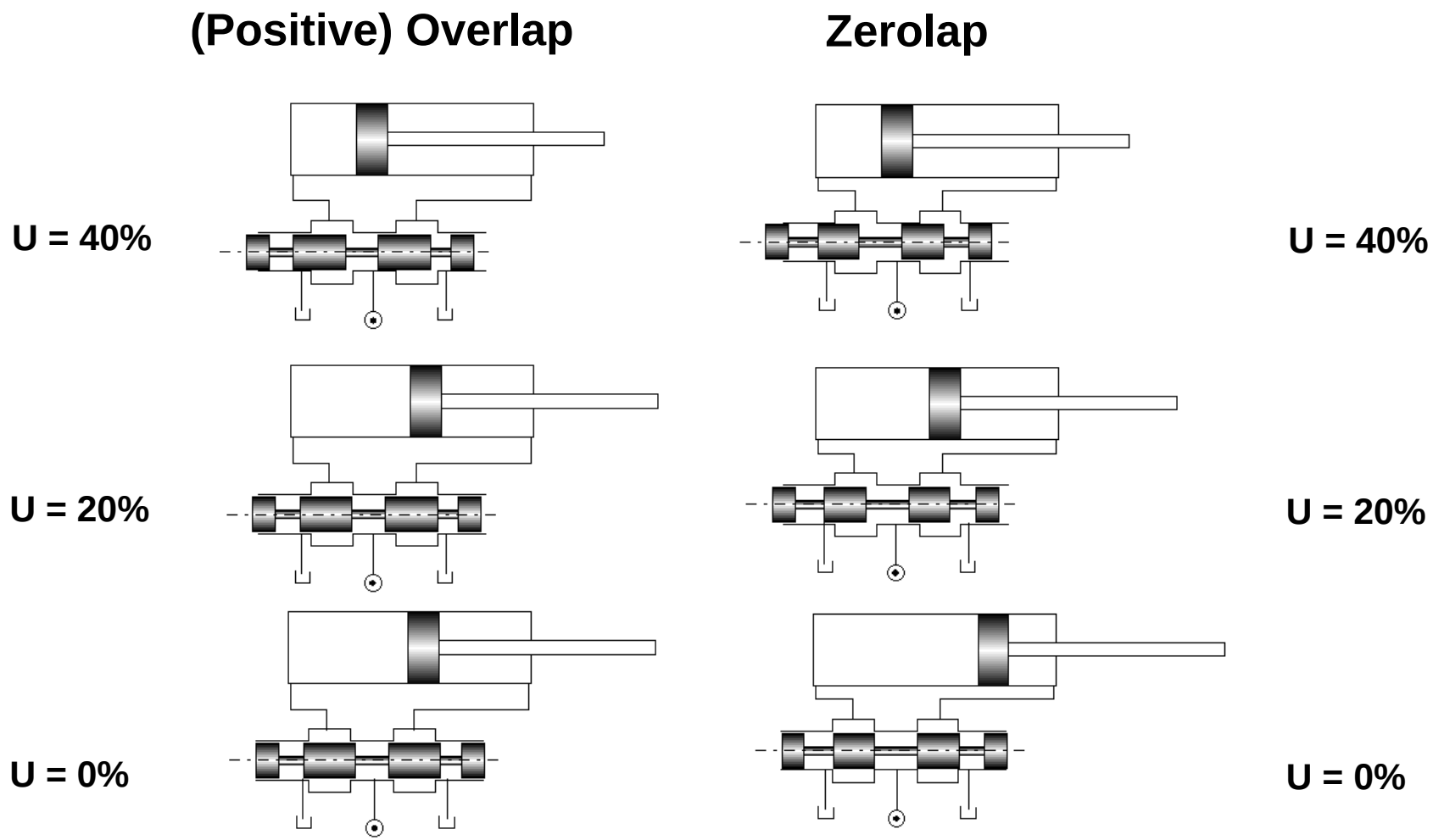


(Positive) Overlap

Zerolap

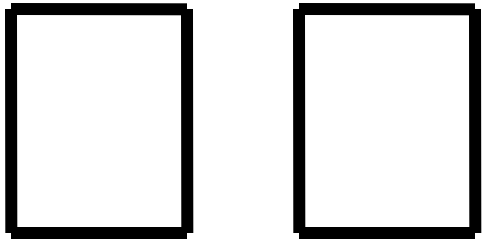
(Negative) Underlap

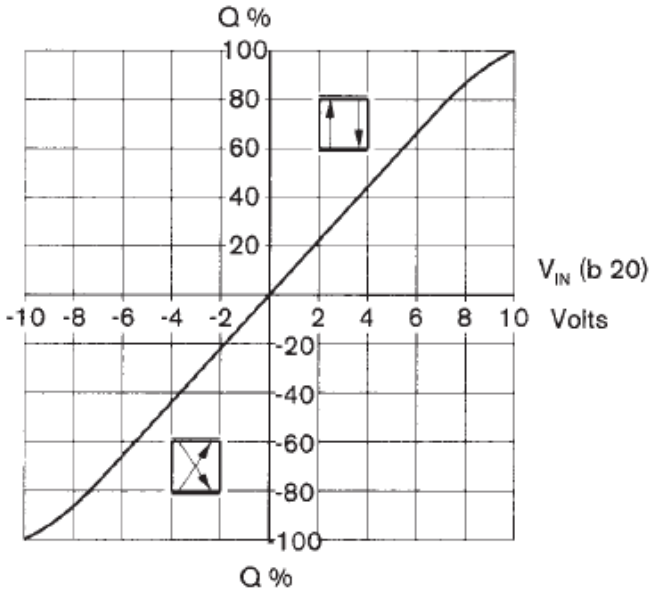
Spool Lap Conditions



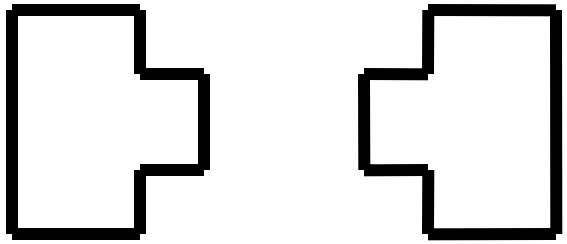
Flow windows

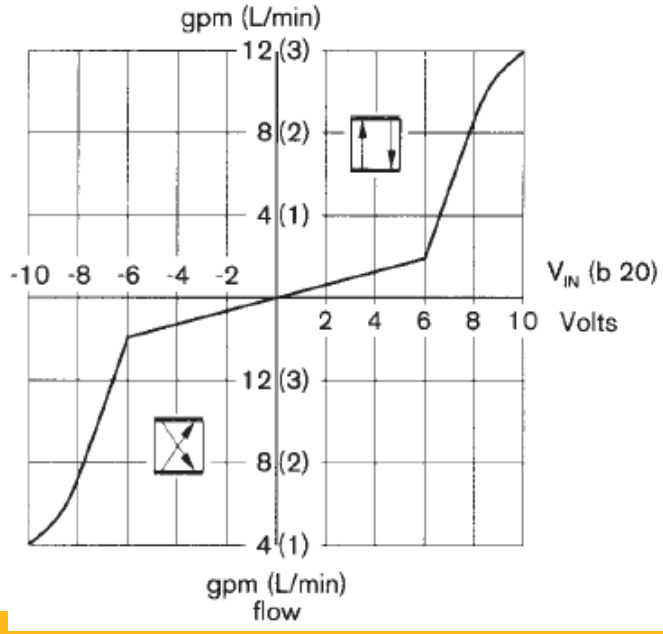
- Standard Symmetrical Laps





- "Knick Servo Cuts"





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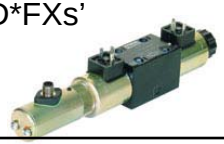
Parker Models	Pulsar VP, VPLs. DF**, ERVs	D*FWs, D*FTs' 	D*FXs' 	D*FH D*FMs D*1FH 	BDs' DYs' SEs' 
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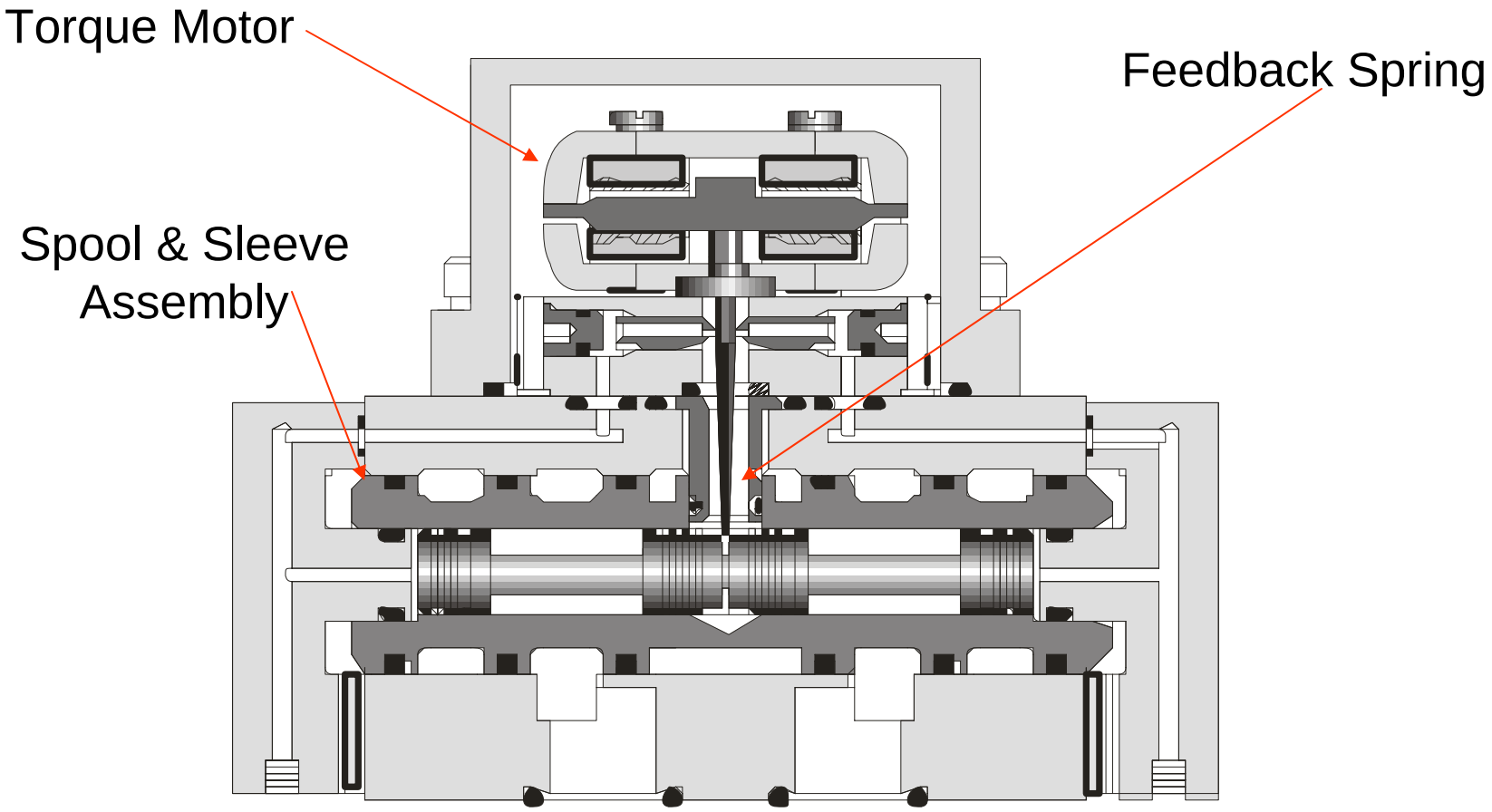
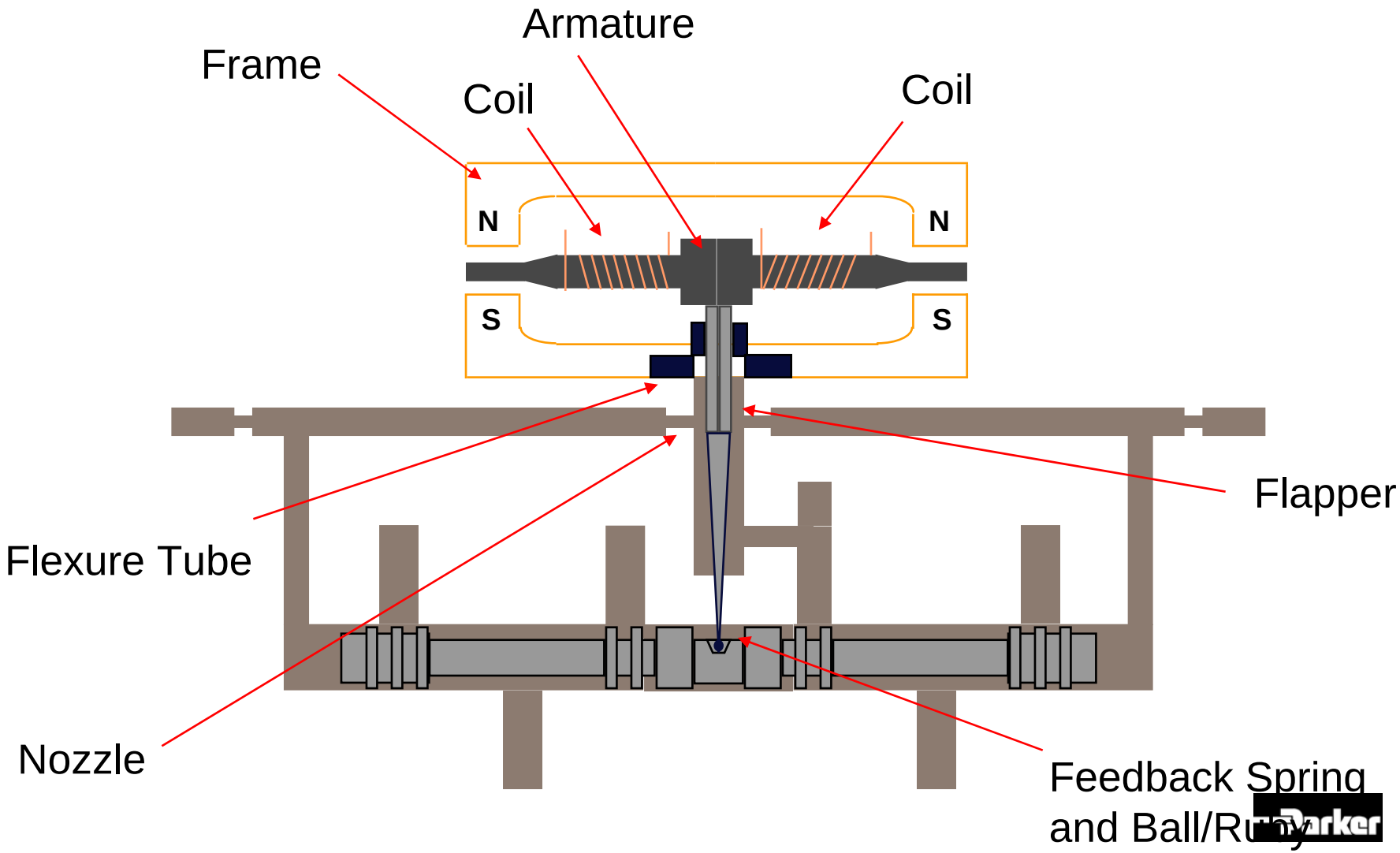
Servo Valve – Double Flapper Design

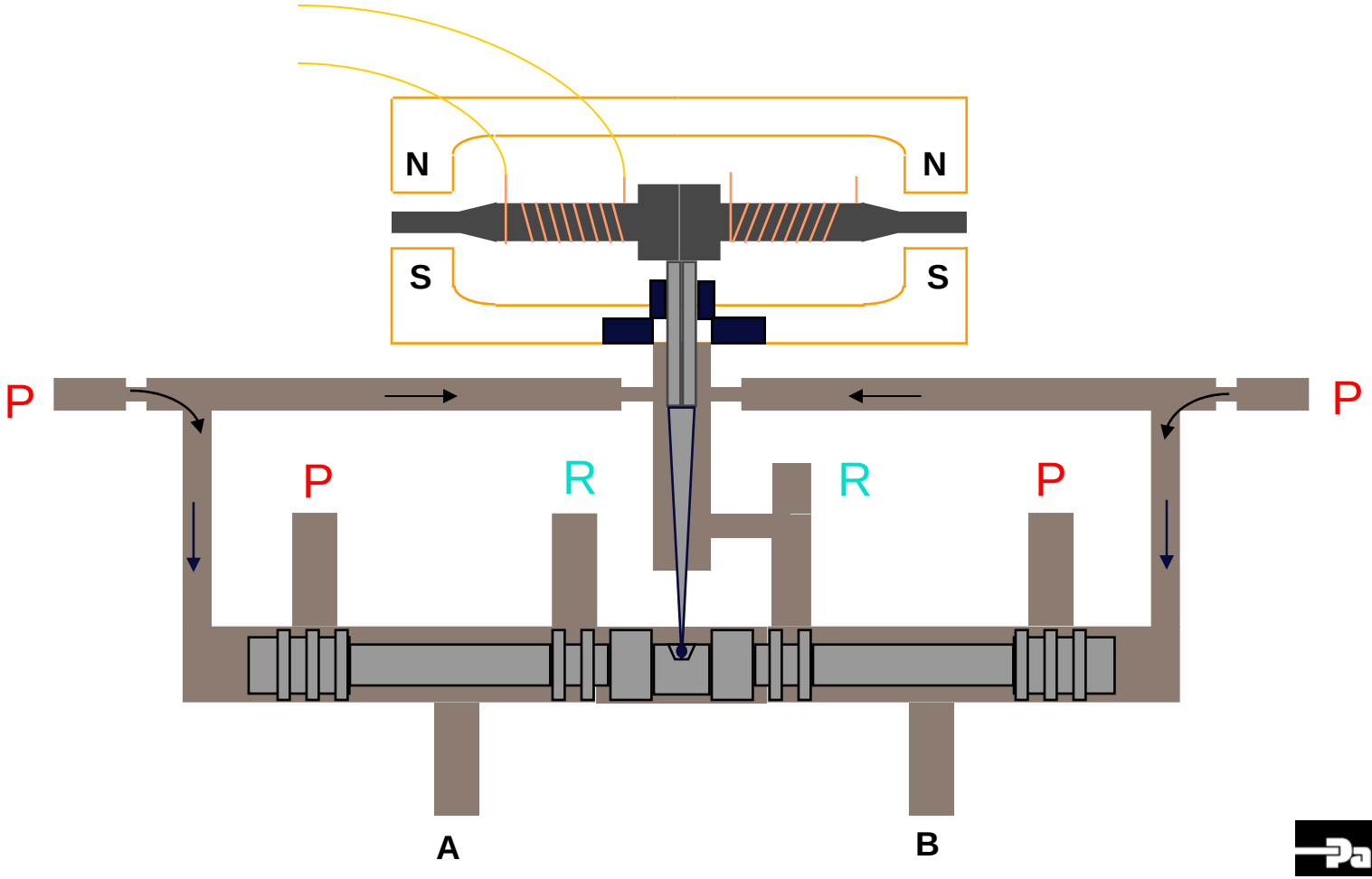


Servo Valve – Double Flapper Design



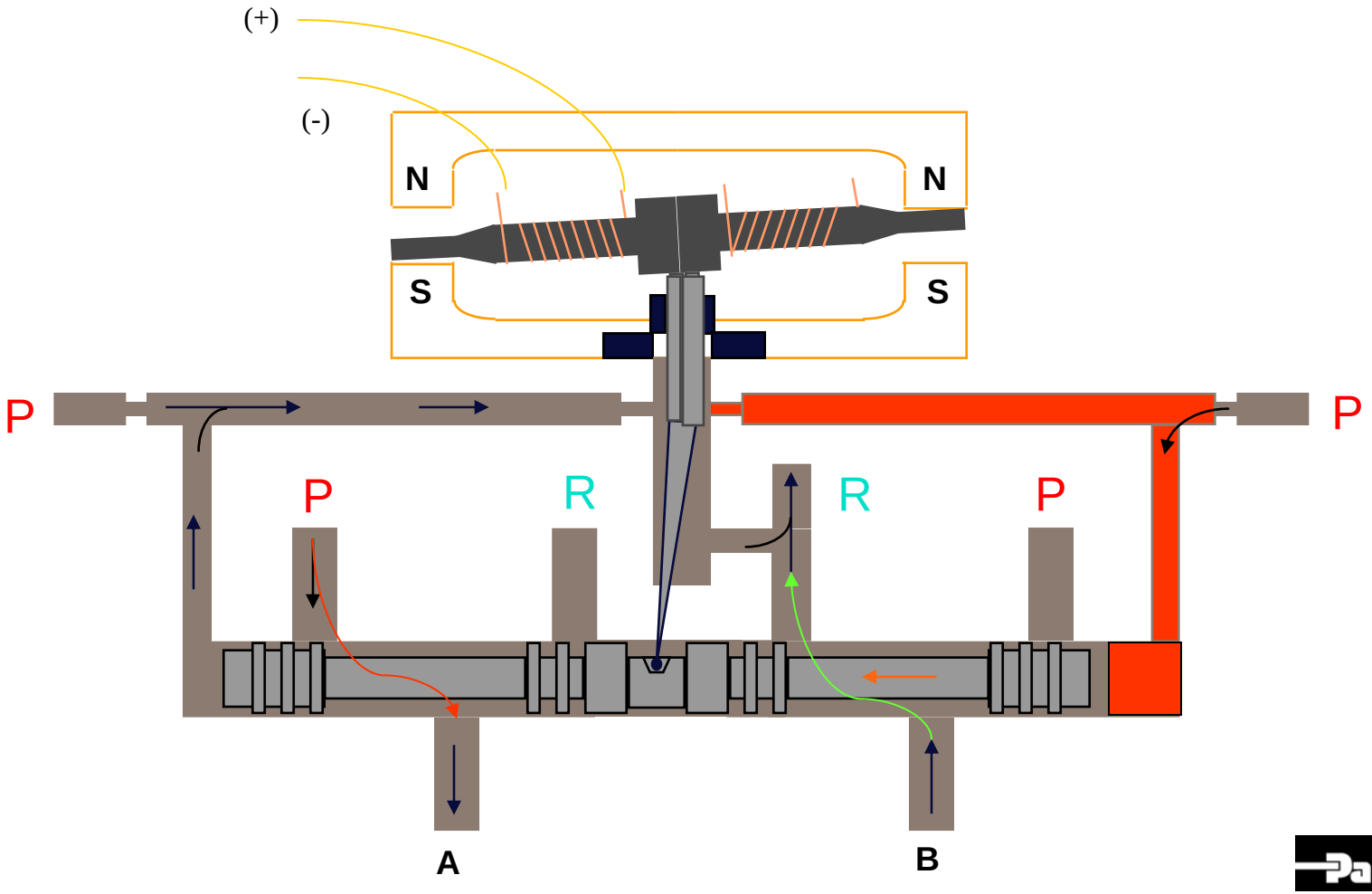
Servo Valve - Principles of Operation

Valve at "Null"

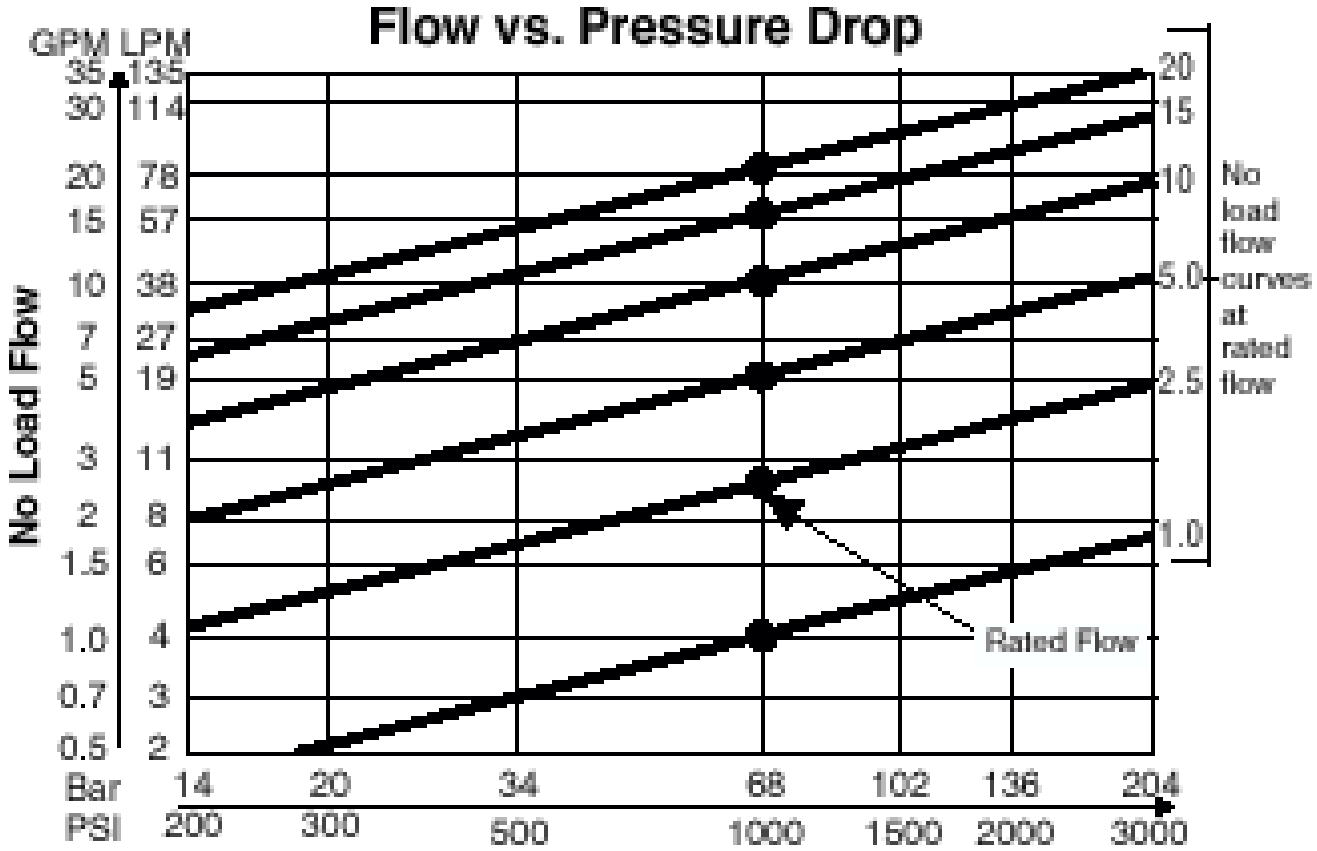


Servo Valve - Principles of Operation

Valve With Current Applied

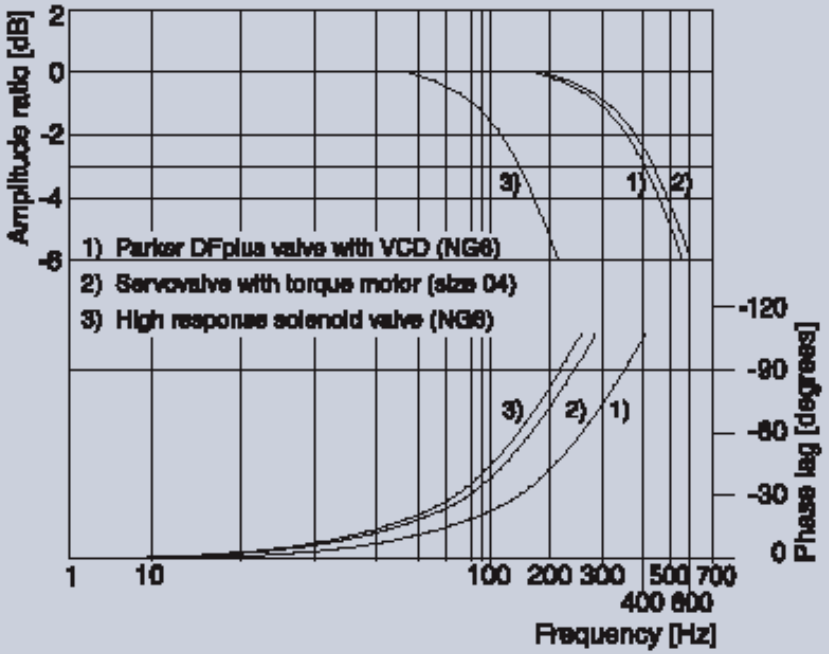


Flow Forces Not an Issue with Servo Valves

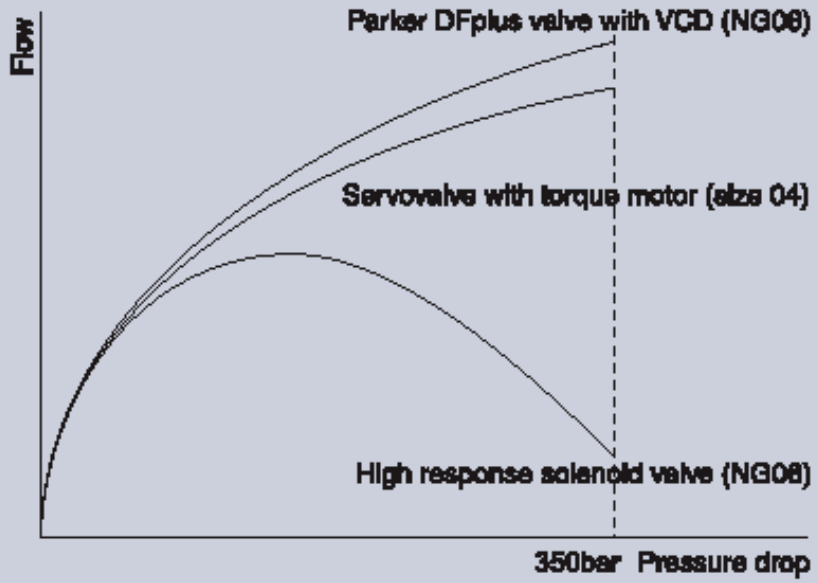


Servo ‘s Performances

Frequency response ±5% Command signal*



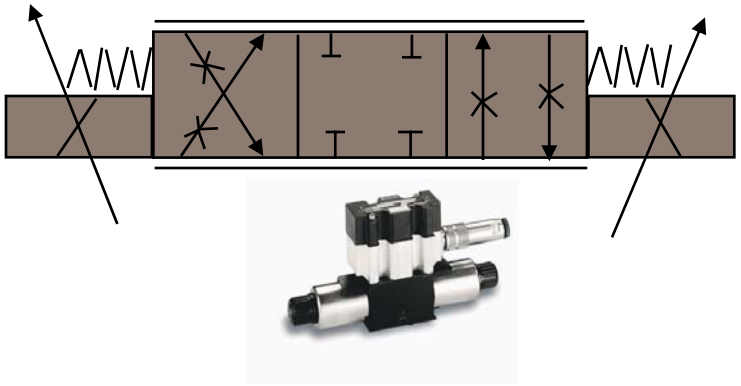
Flow limit*



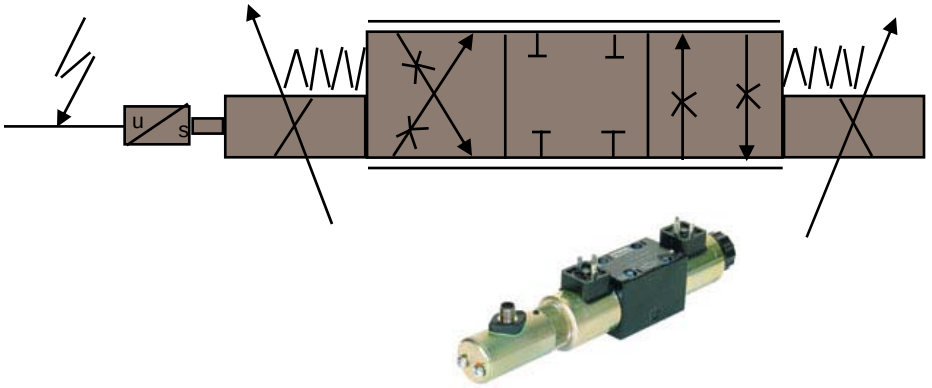
* schematics, all valves Q_{nom} = 40 l/min

Symbology

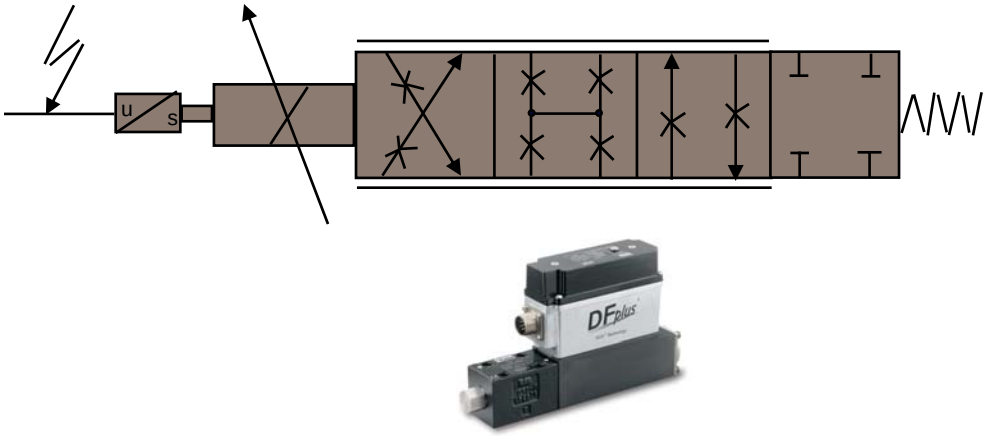
Proportional Directional Valve



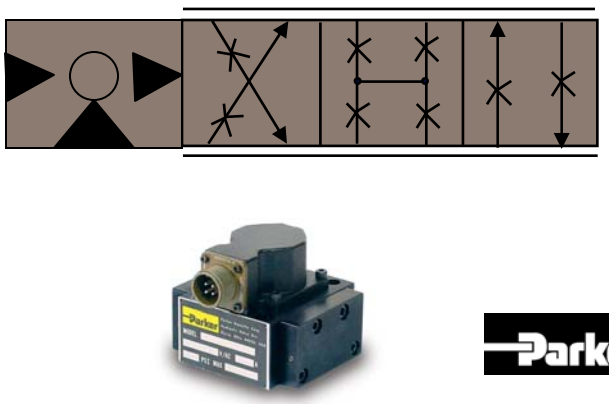
Proportional Valve with Spool Feedback



Servo Performance Proportional Valve

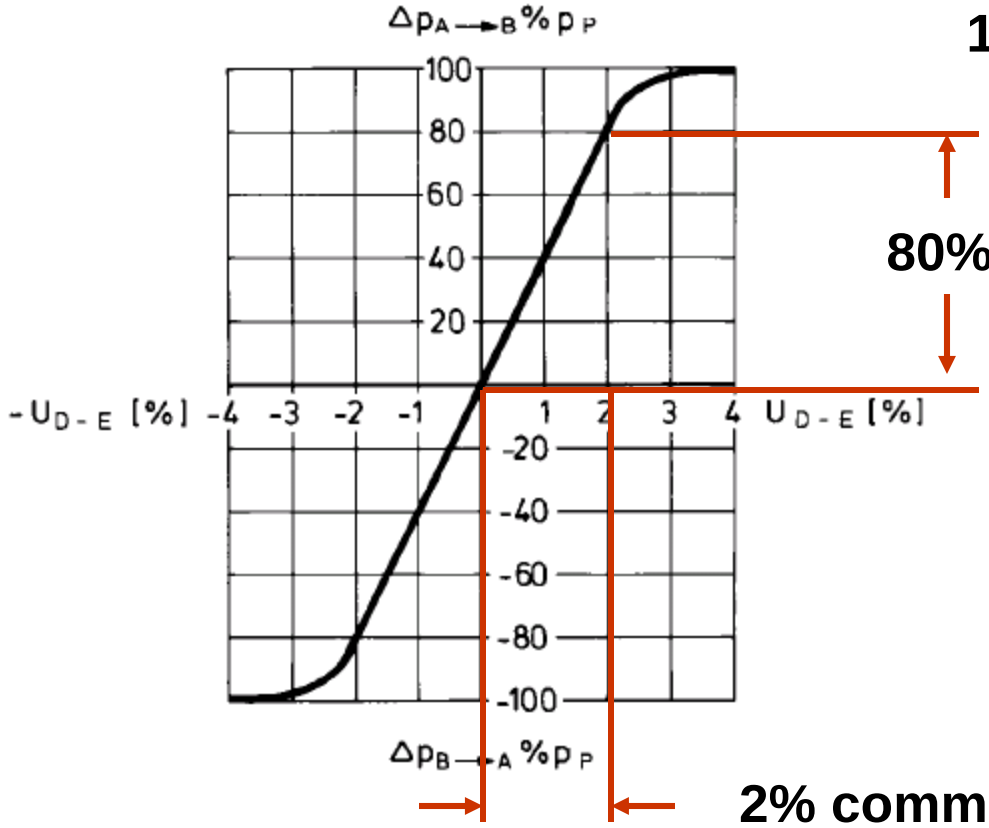


Servo Valve



Terminologies

Pressure Gain



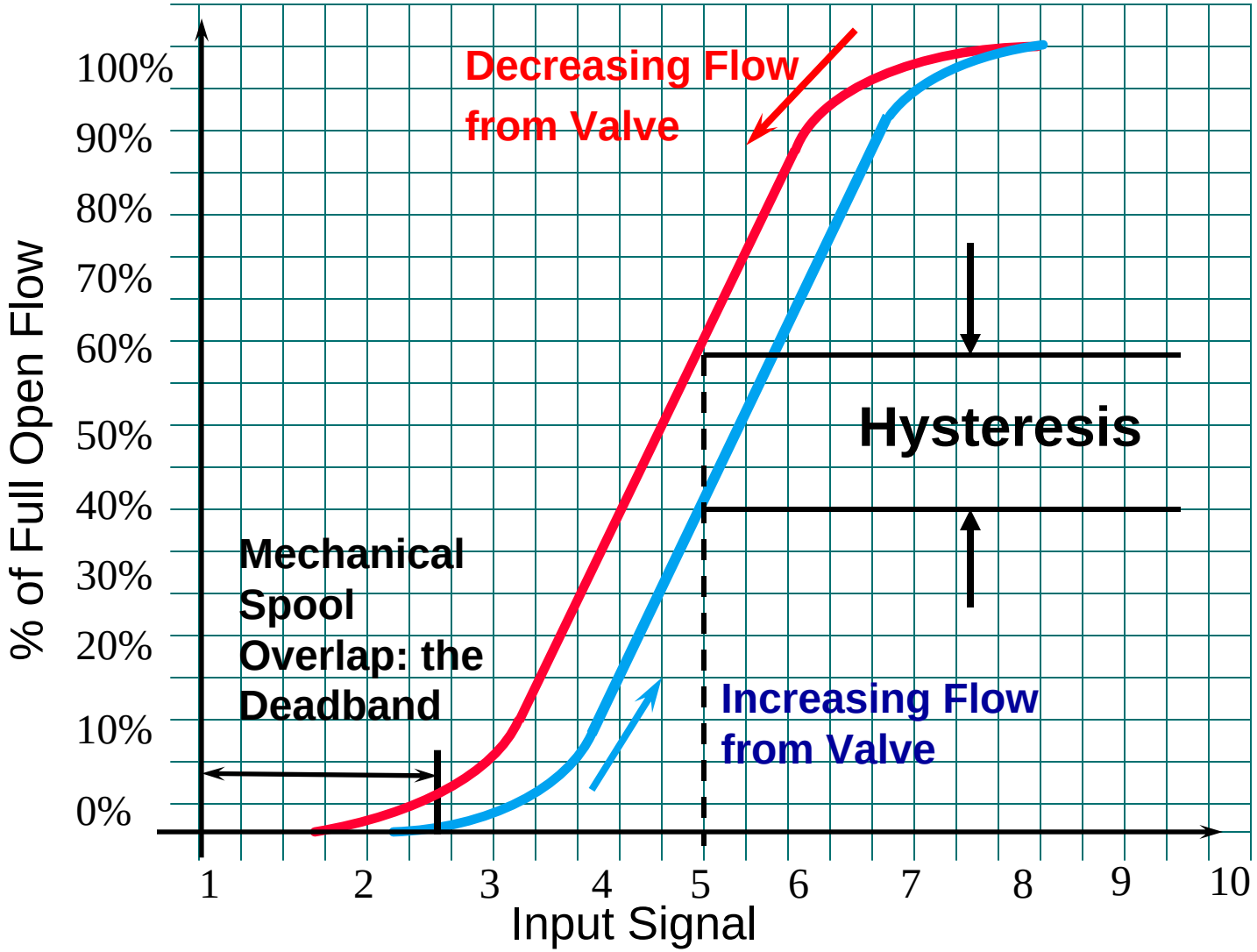
40% pressure change

1% command change

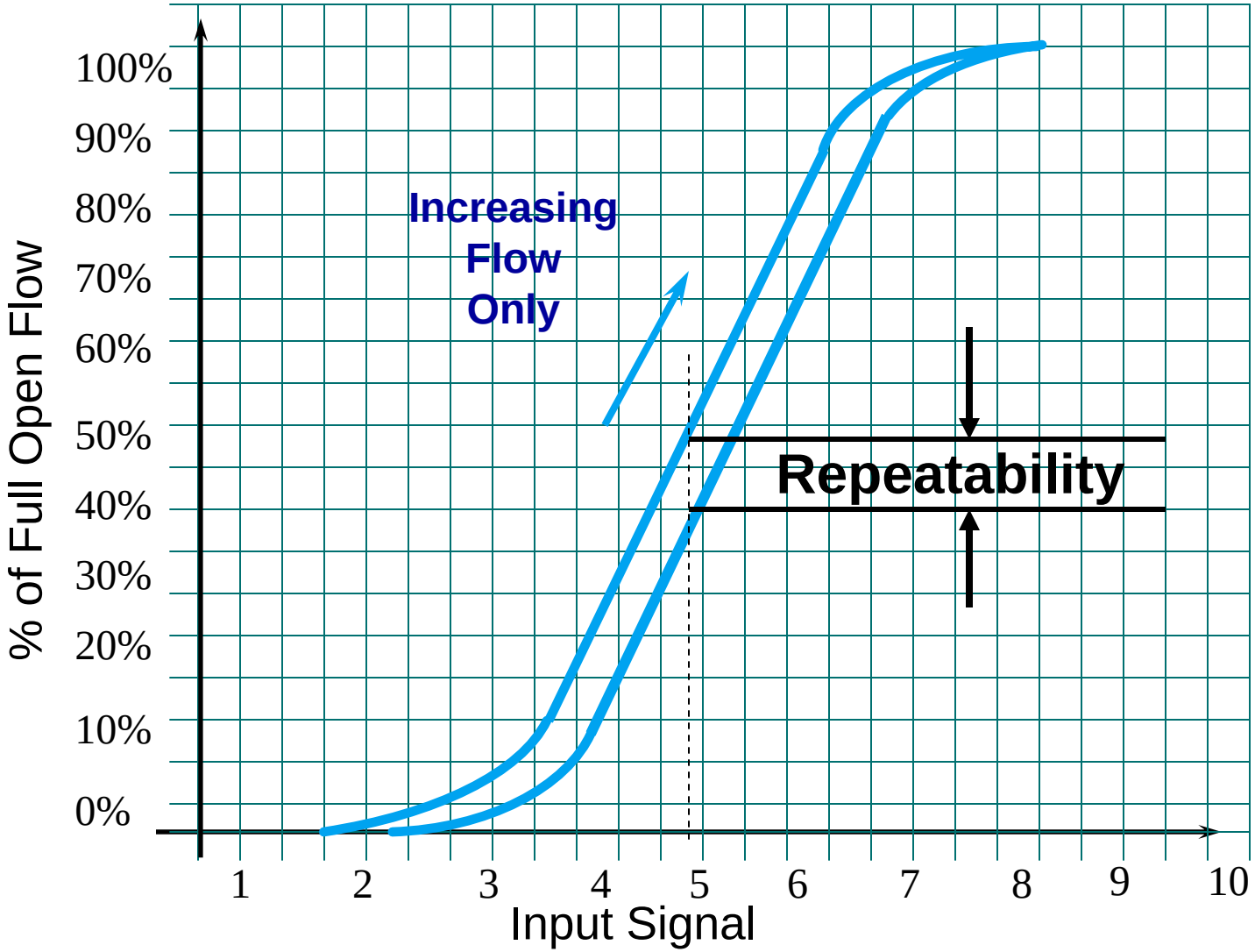
80% rise

2% command

Hysteresis


Decreasing Flow
from Valve
Hysteresis
Mechanical
Spool
Overlap: the
Deadband
Increasing Flow
from Valve
% of Full Open Flow
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1
2
3
4
5
6
7
8
9
10
Input Signal

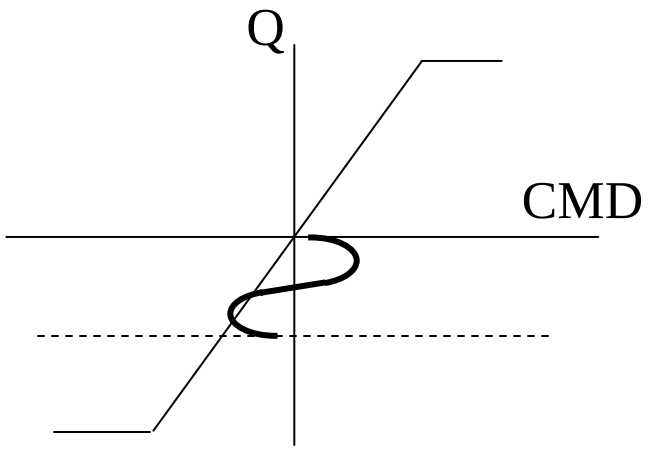
Repeatability



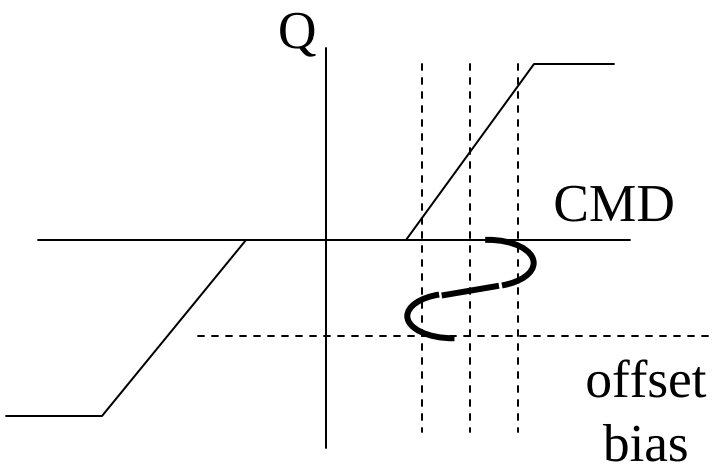
Valve Frequency

Two methods: frequency response, step response (we'll use frequency response)

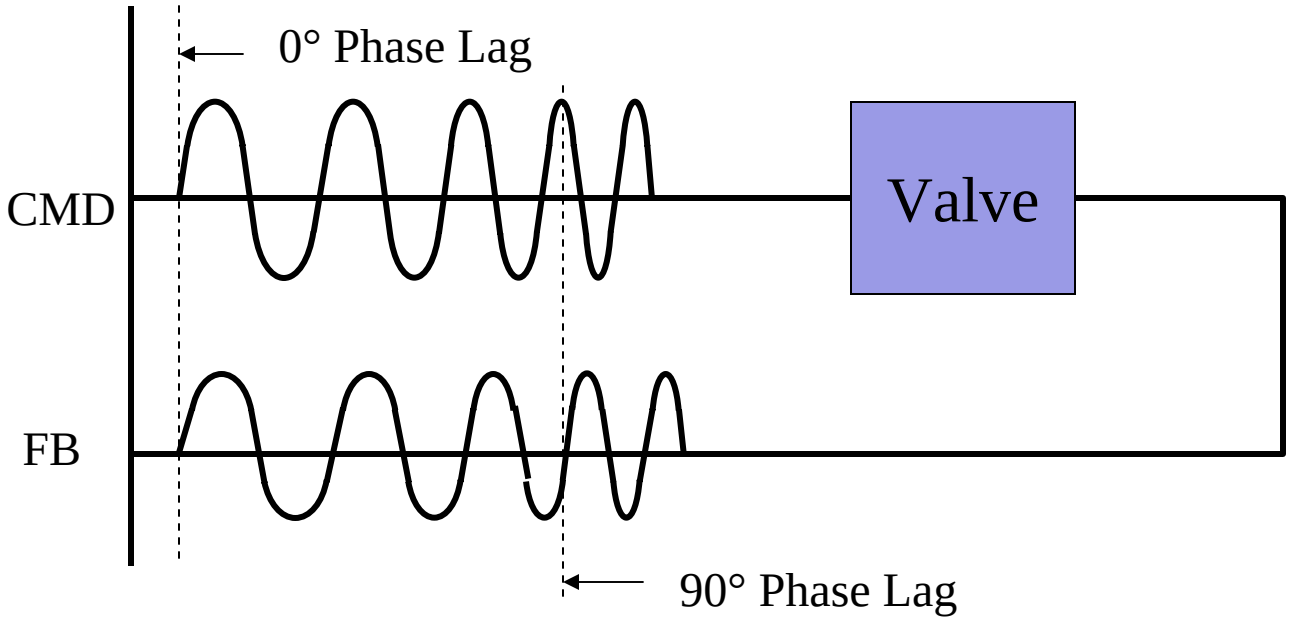
Thru center



Bias or one sided



Valve Frequency Response



90° Phase Lag = ¼ cycle

The input frequency which creates a phase lag of 90° is the defining characteristics of a valve and is referred to as bandwidth

Frequency Response

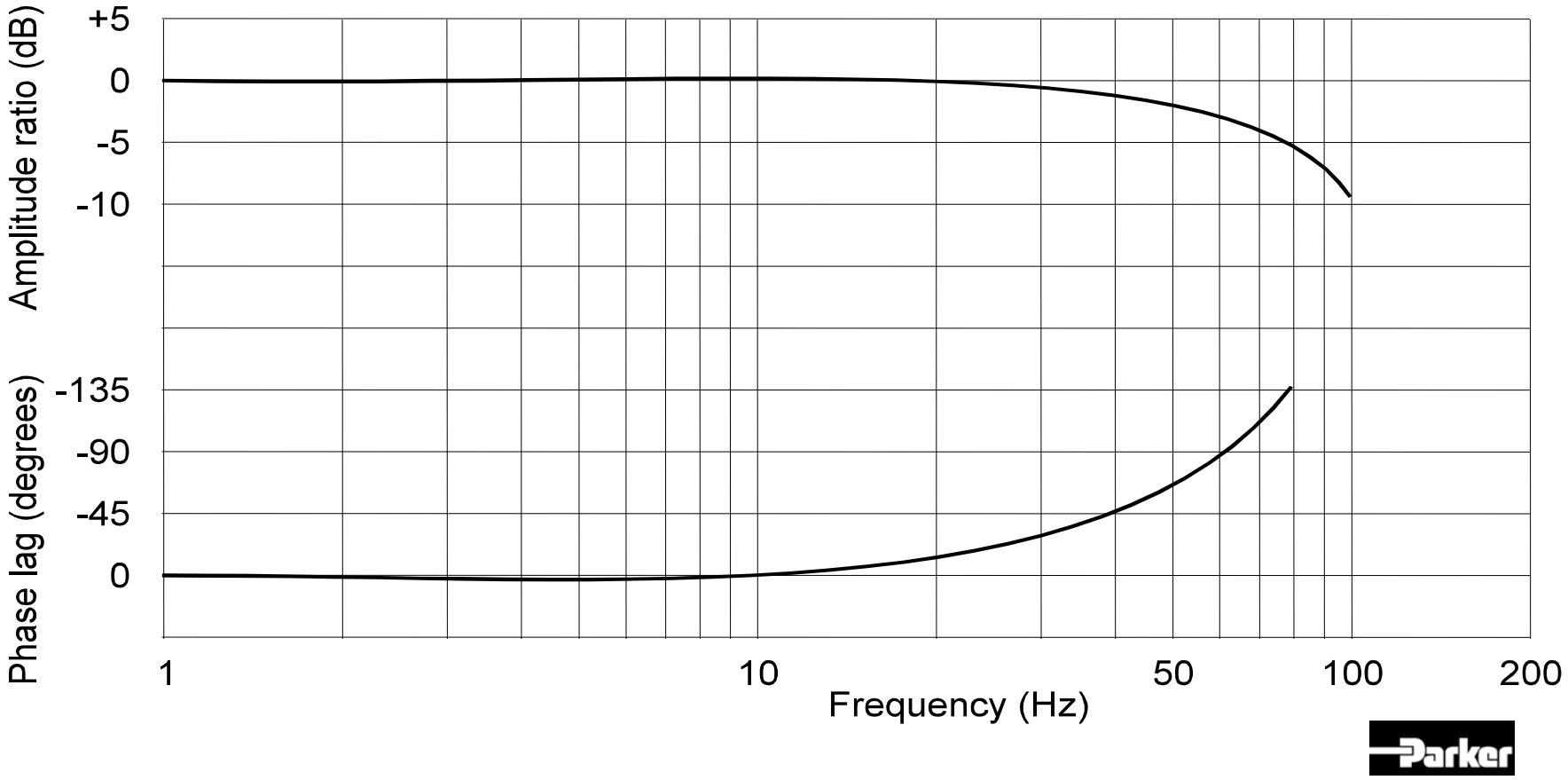
- To measure the response of a control valve, a sinusoidal varying input signal is applied, effectively switching the valve from one working position to the other
- At a very low frequency the valve is able to follow the demand signal closely
- As the frequency increases the valve becomes less able to follow the input signal precisely

Frequency Response

- The output starts to lag behind the input, then the valve is not able to reach the maximum output position before the input signal reverses
- The lag between the input and output is known as phase lag
- The reduced output apparent at higher frequencies is known as attenuation

Valve Frequency

Frequency response (sine wave) to make catalog data

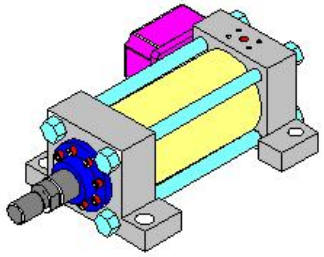


Proportional Valves

Servo Valves

	Mobile bankable Style, Threaded Cartrdige Style	NFPA Mounting Without Spool Position Feedback	NFPA Mounting With Spool Position Feedback	Servo Performance, Closed Loop Valves with Spool Position Feedback	Servo Valves With either Mechanical or Electrical Feedback (spool position).
Parker Models	Pulsar VP, VPLs. DF**, ERVs	D*FWs, D*FTs' 	D*FXs' 	D*FH D*FMs D*1FH 	BDs' DYs' SEs' 
Mechanical Construction (spool shift)	Electro-Hydraulic Pilot, Mechanical (spring) Return	Electromagnetic Force, Mechanical (spring) Return	Electromagnetic Force, Mechanical (spring) Return	Electromagnetic Force, Mechanical (spring) Return	Torque Motor Pilot Control Balance PSI spool Control
Hysteresis	3…..7%	3…7%	0.03…..1%	0.1….5%	0.1…..0.5%
Frequency Response	< 10 Hz	10…50 Hz	10….70 Hz	50...150 Hz	100…200 Hz
Center Lap Condition	Overlap 5…20%			Zero Overlap	Zero Overlap
Operating Pressures Limits (Drop across metering edge).	1000…2000 PSI			1000…3000 PSI	None
Applications	Open Loop Control		Low End Closed Loop Position	Closed Loop Position & Force	Closed Position & Force

Actuators

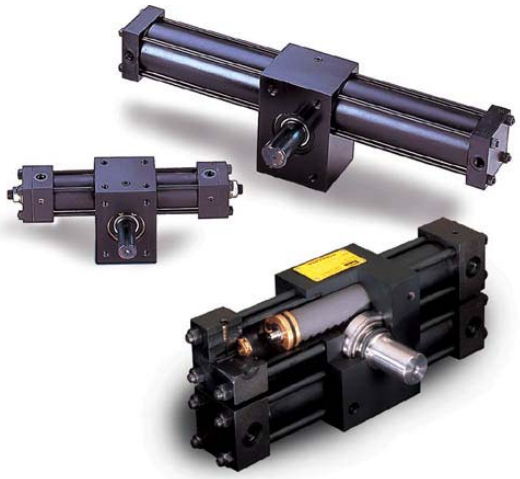


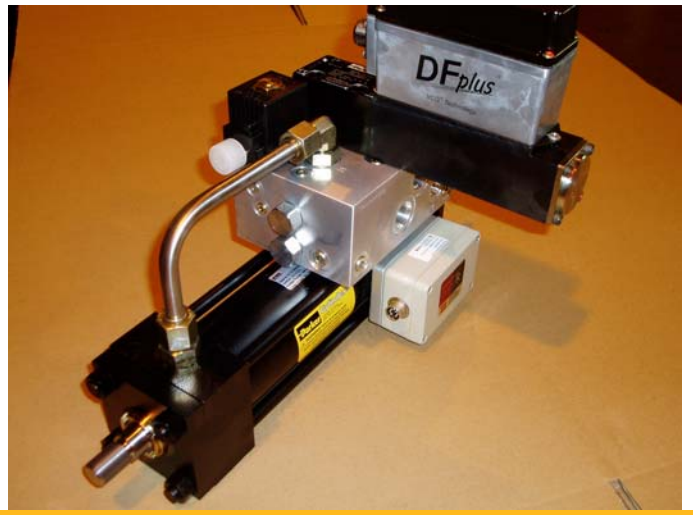
Rotary Motion

- Position Control (Angle)
- Velocity
- Torque

Linear Motion

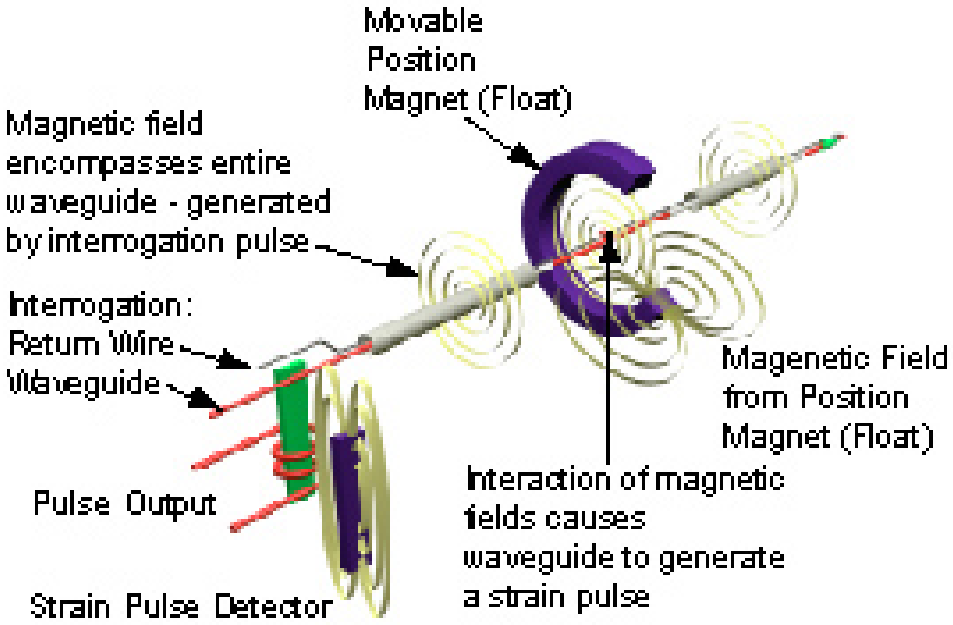
- Position Control
- Velocity
- Force

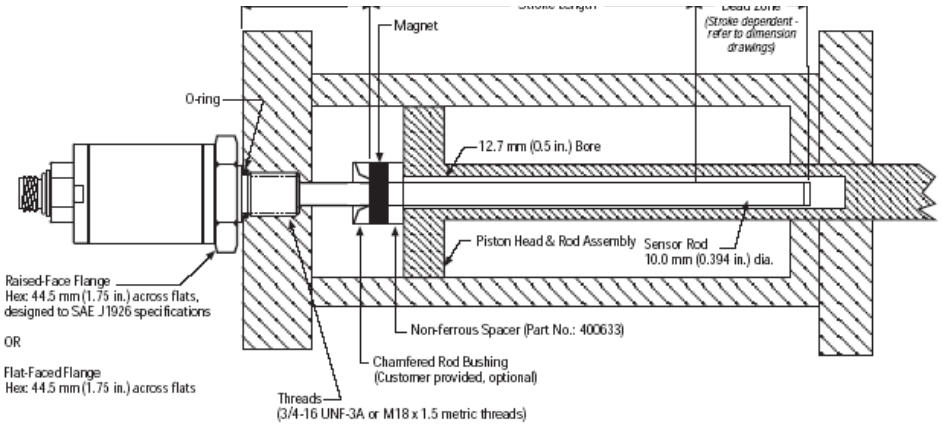




Actuators Linear Feedback Types

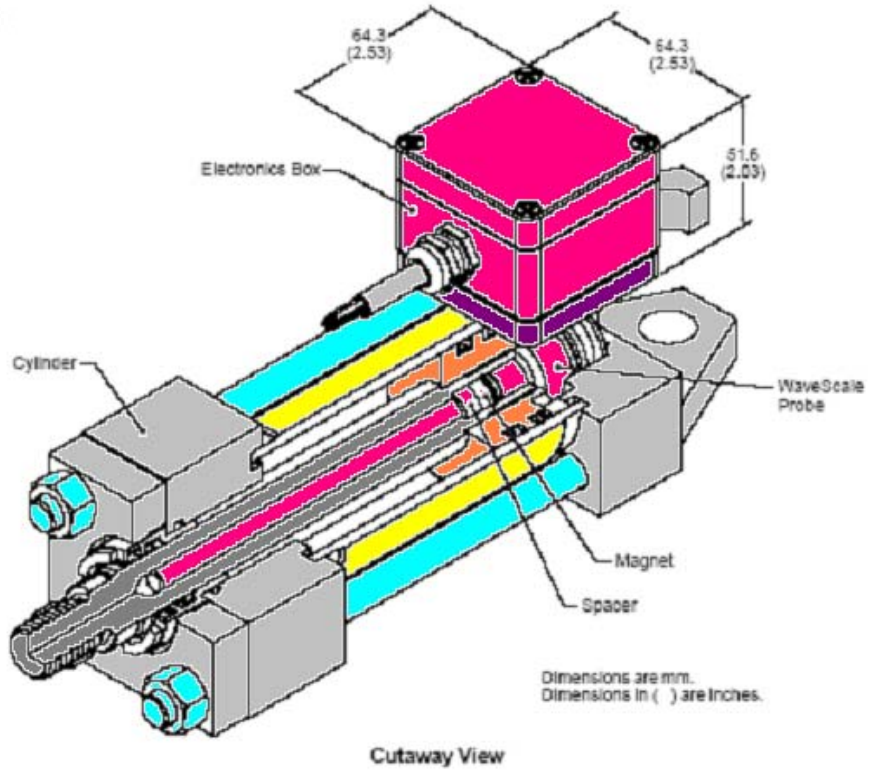
Magnetostrictive (M.D.T.s)





Pulse is sent down waveguide, when hits magnet, “twist” is sensed. Time between pulse sent to twist measured dictates distance.

Approximately 9 microseconds = 1”

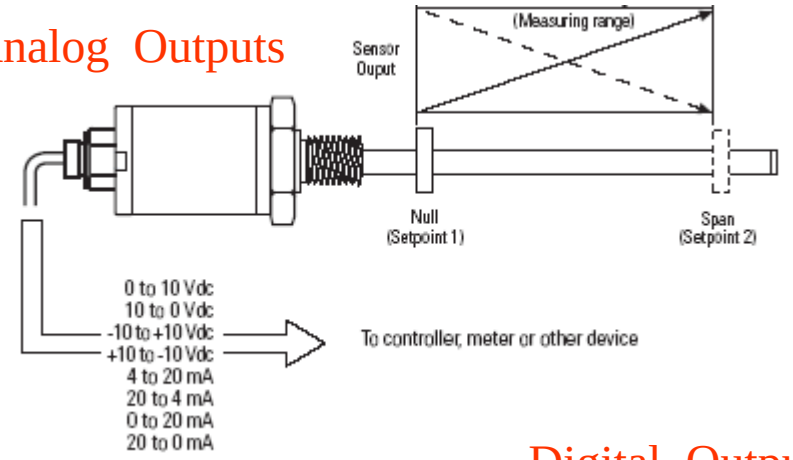


Cutaway View

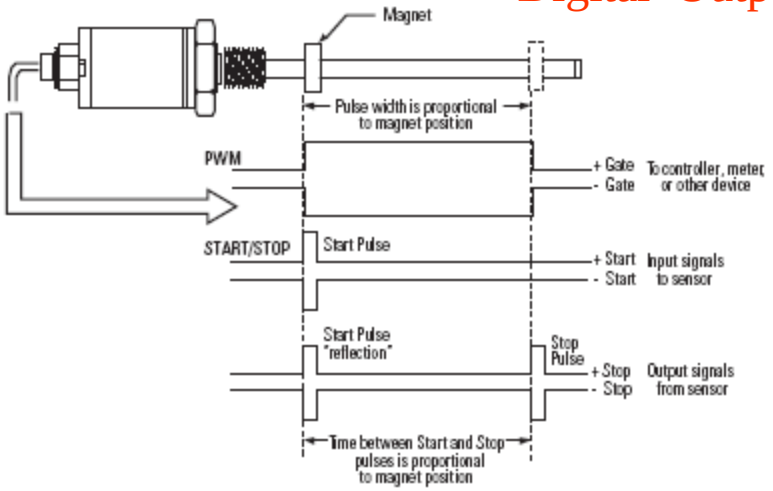
Actuators Linear Feedback Types

Magnetostrictive (M.D.T.s)

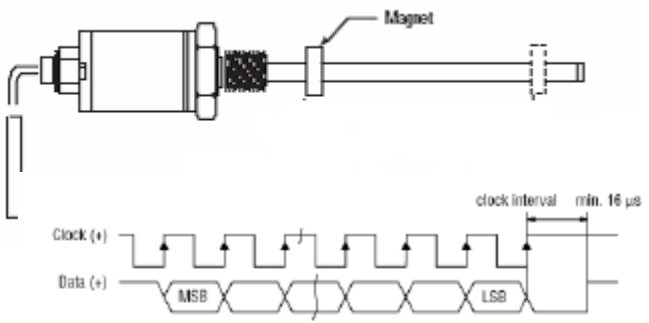
Analog Outputs



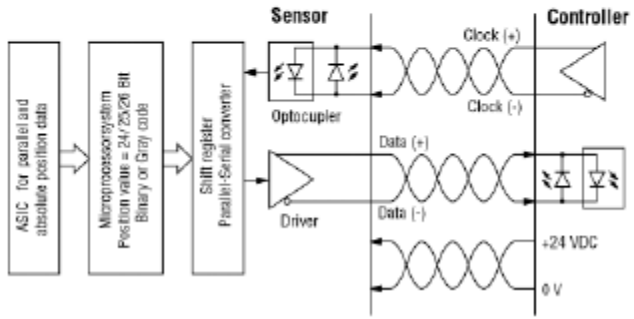
Digital Outputs



SSI Output



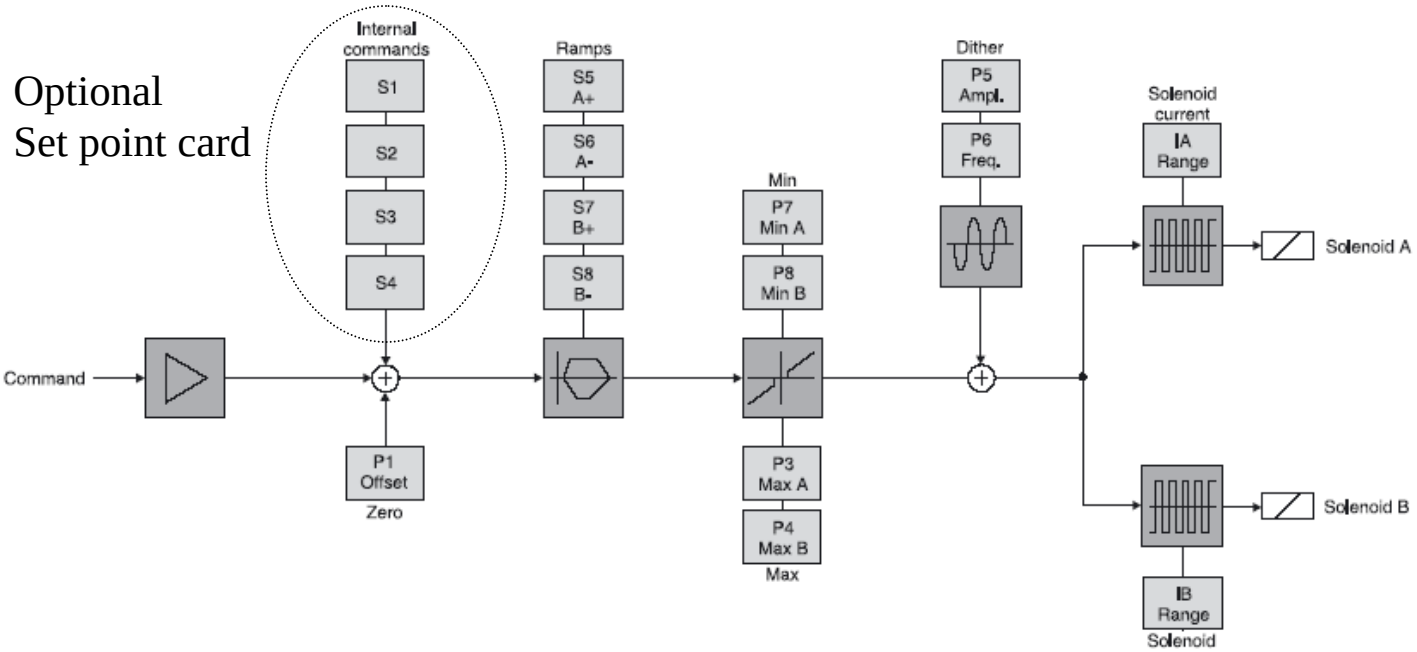
Logic diagram



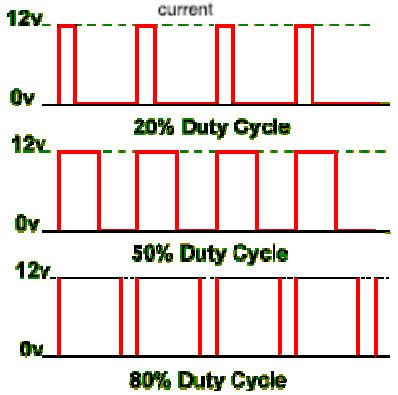
Valve Drivers and Motion Controllers

Valve Drivers (Open Loop) Off Board Elec

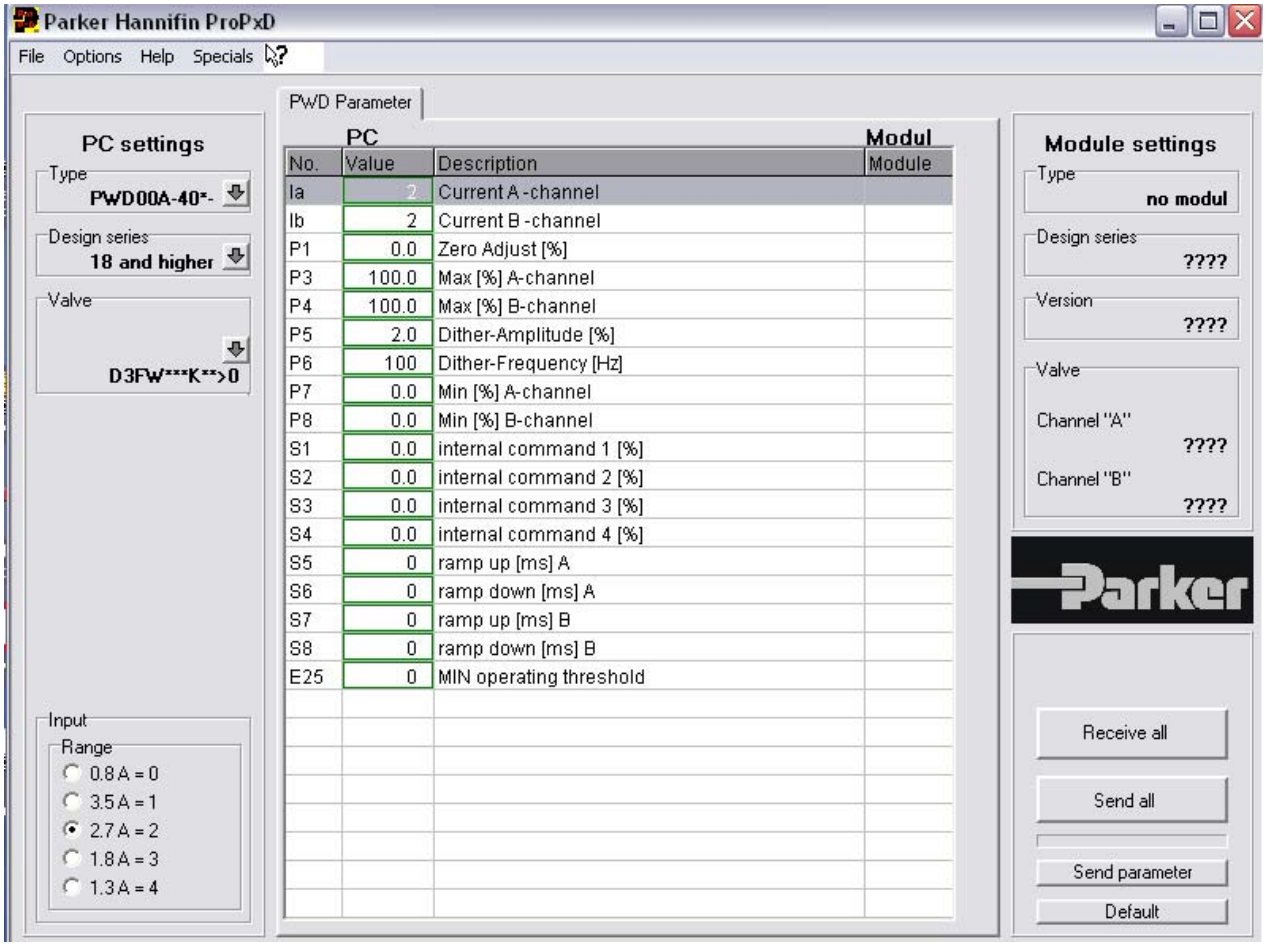
Optional
Set point card



- Converts “Command Signal” to PWM signal to drive Coil.
- Digital Versions (shown) incorporate a microprocessor with numeric settings.
- Analog Versions incorporate Trim pots for



Valve Drivers (Open Loop) Off Board Elec



Valve Drivers (Closed Loop)

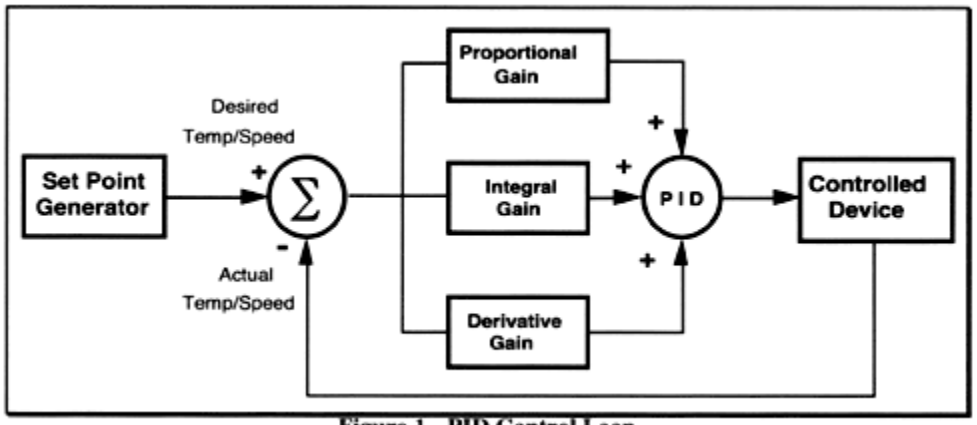
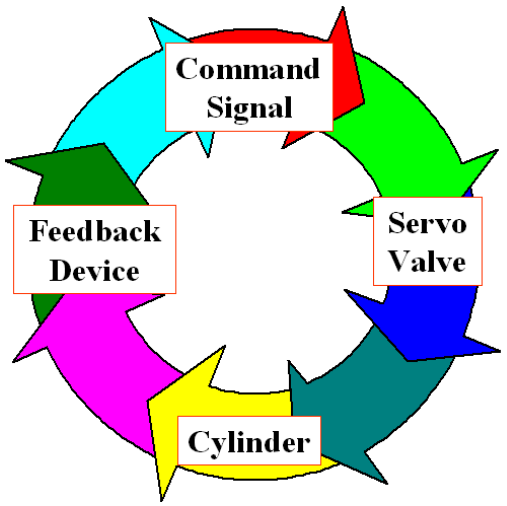
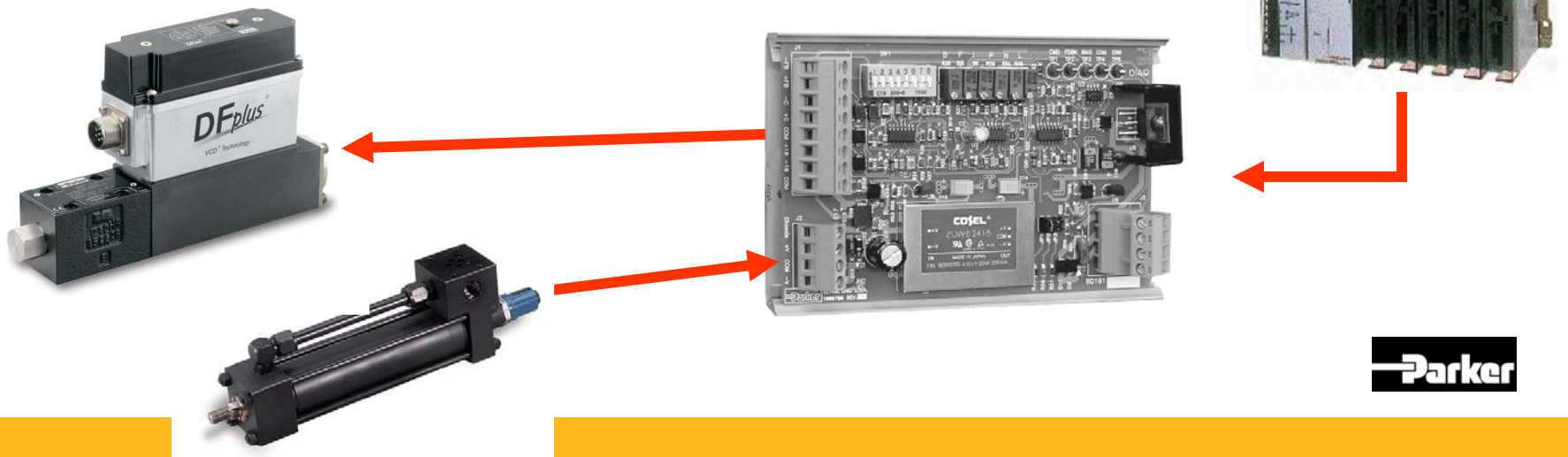


Figure 1 - PID Control Loop





Valve Drivers (Closed Loop)

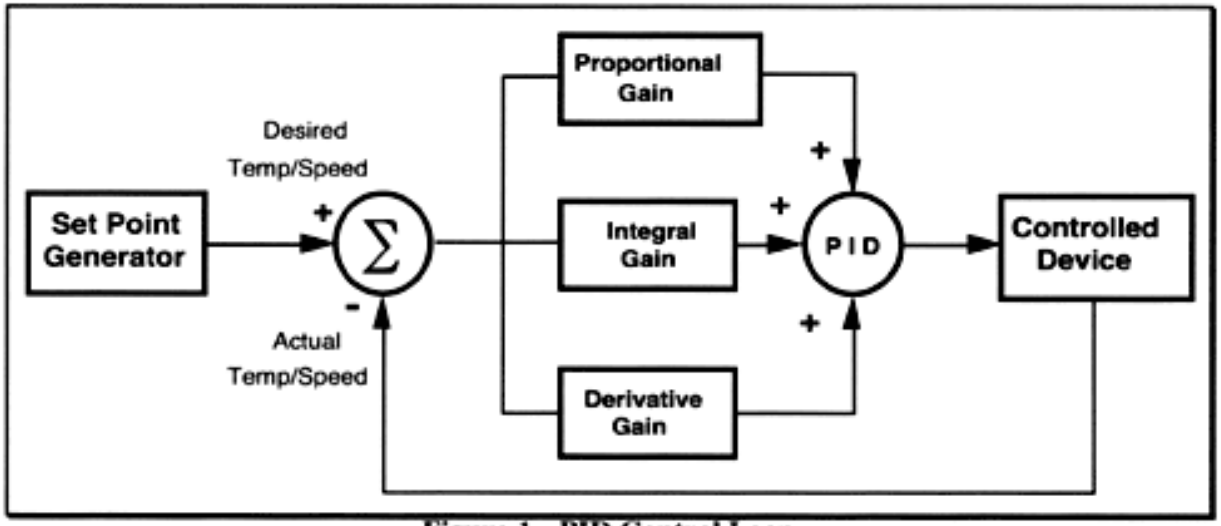
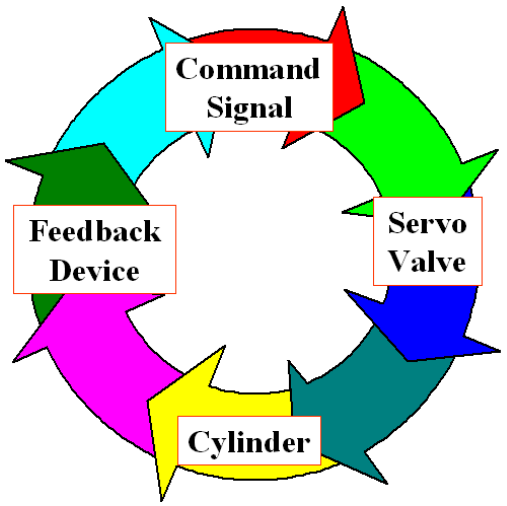
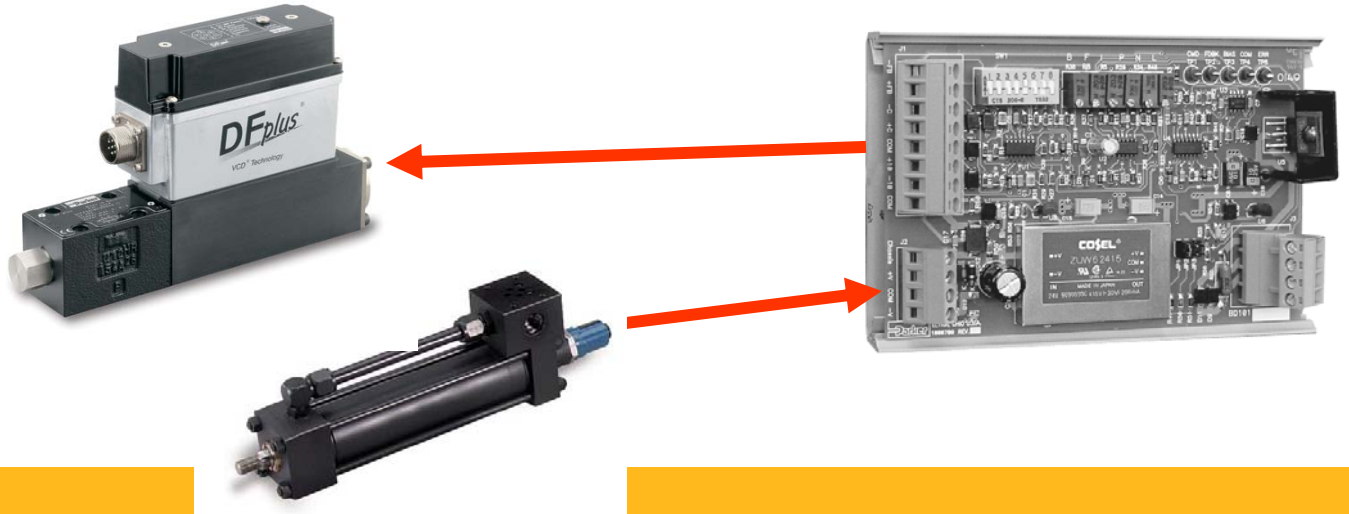
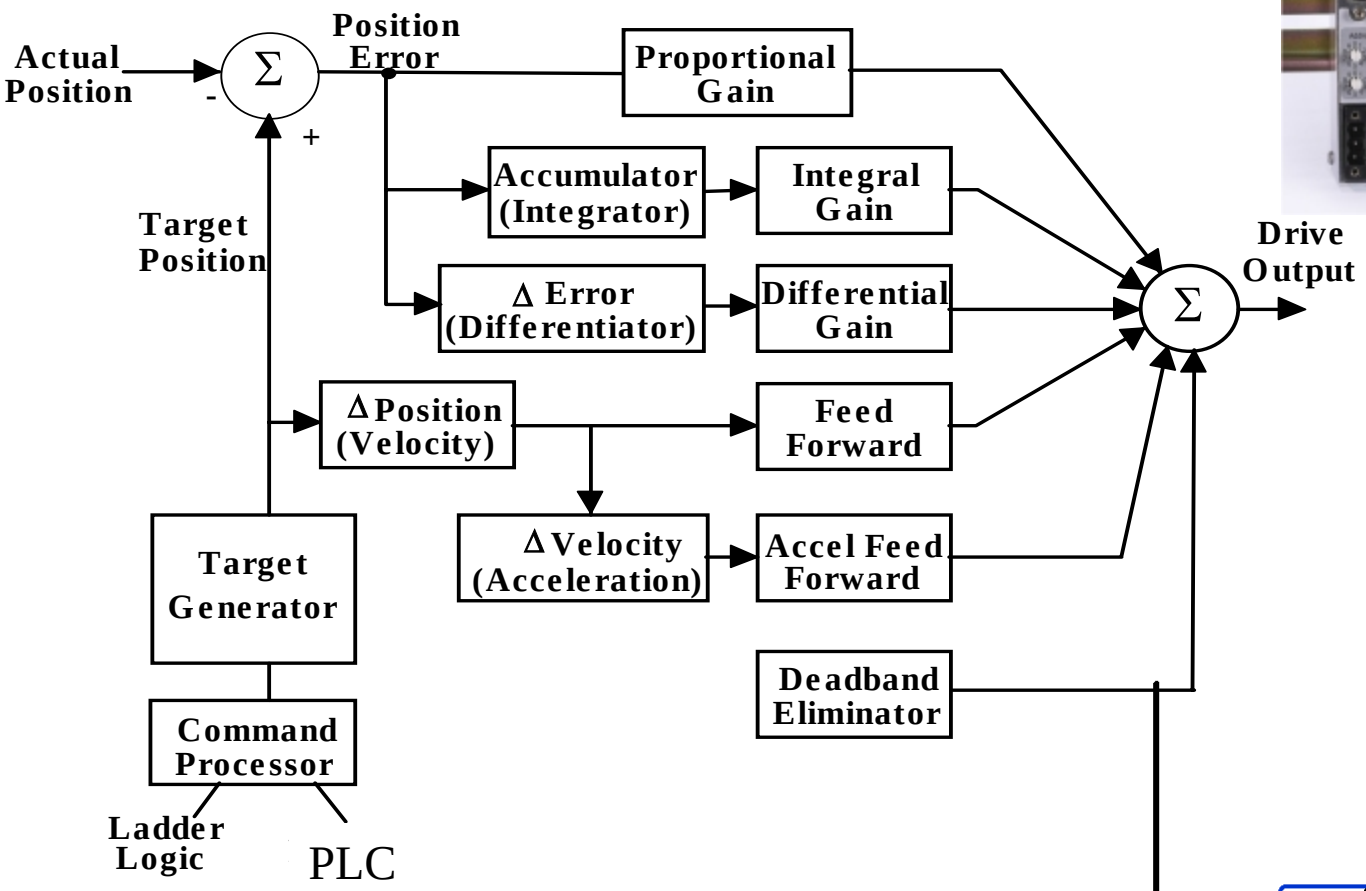


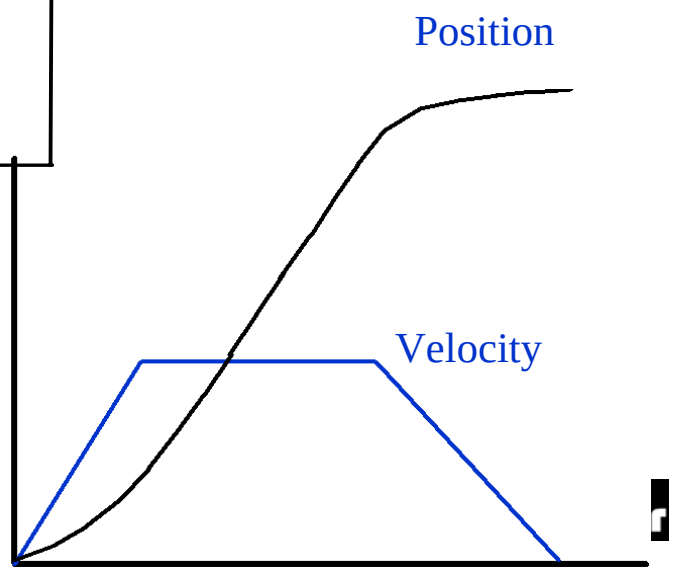
Figure 1 - PID Control Loop





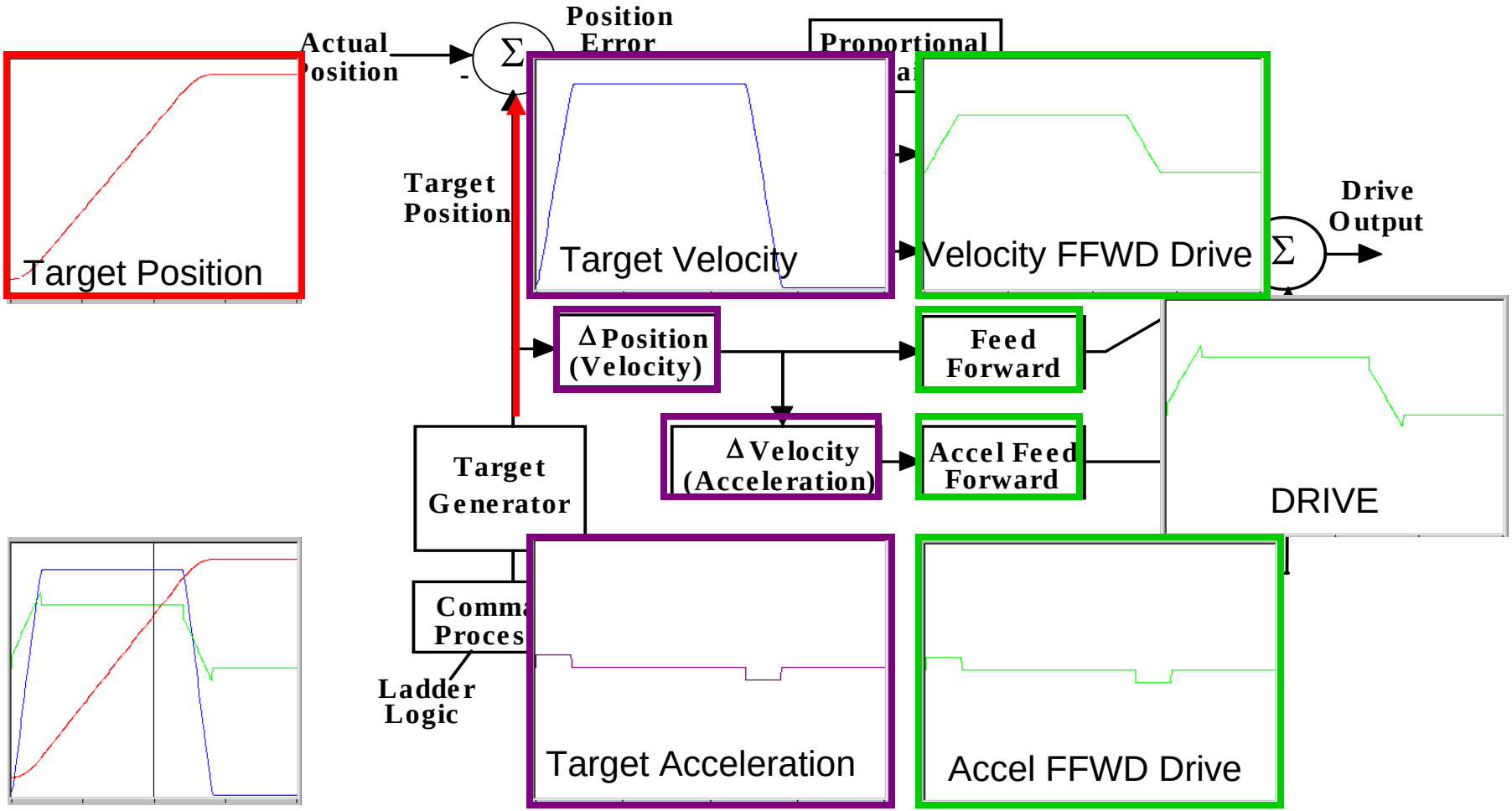
Motion Controllers



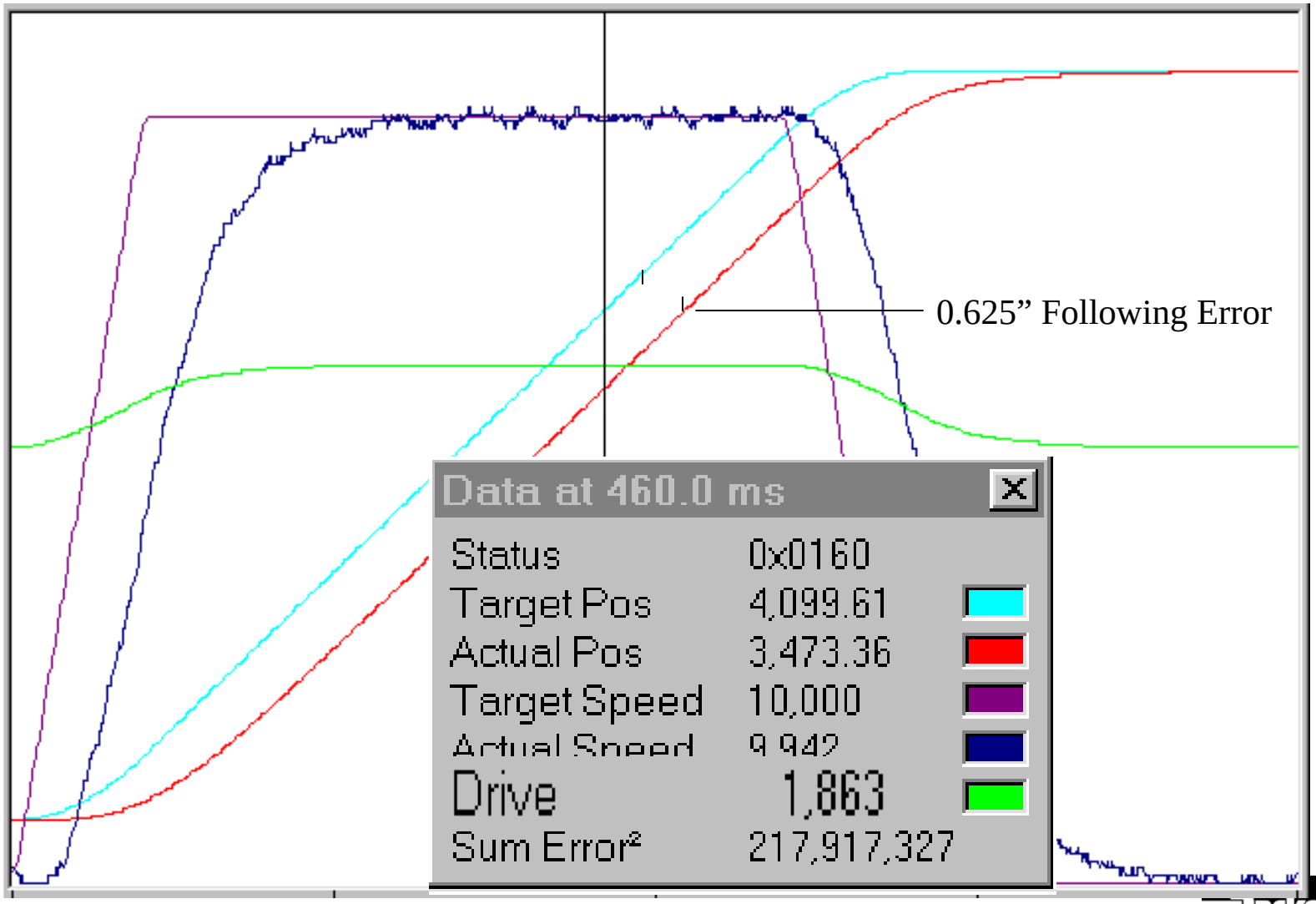


"Generate A Target Profile"

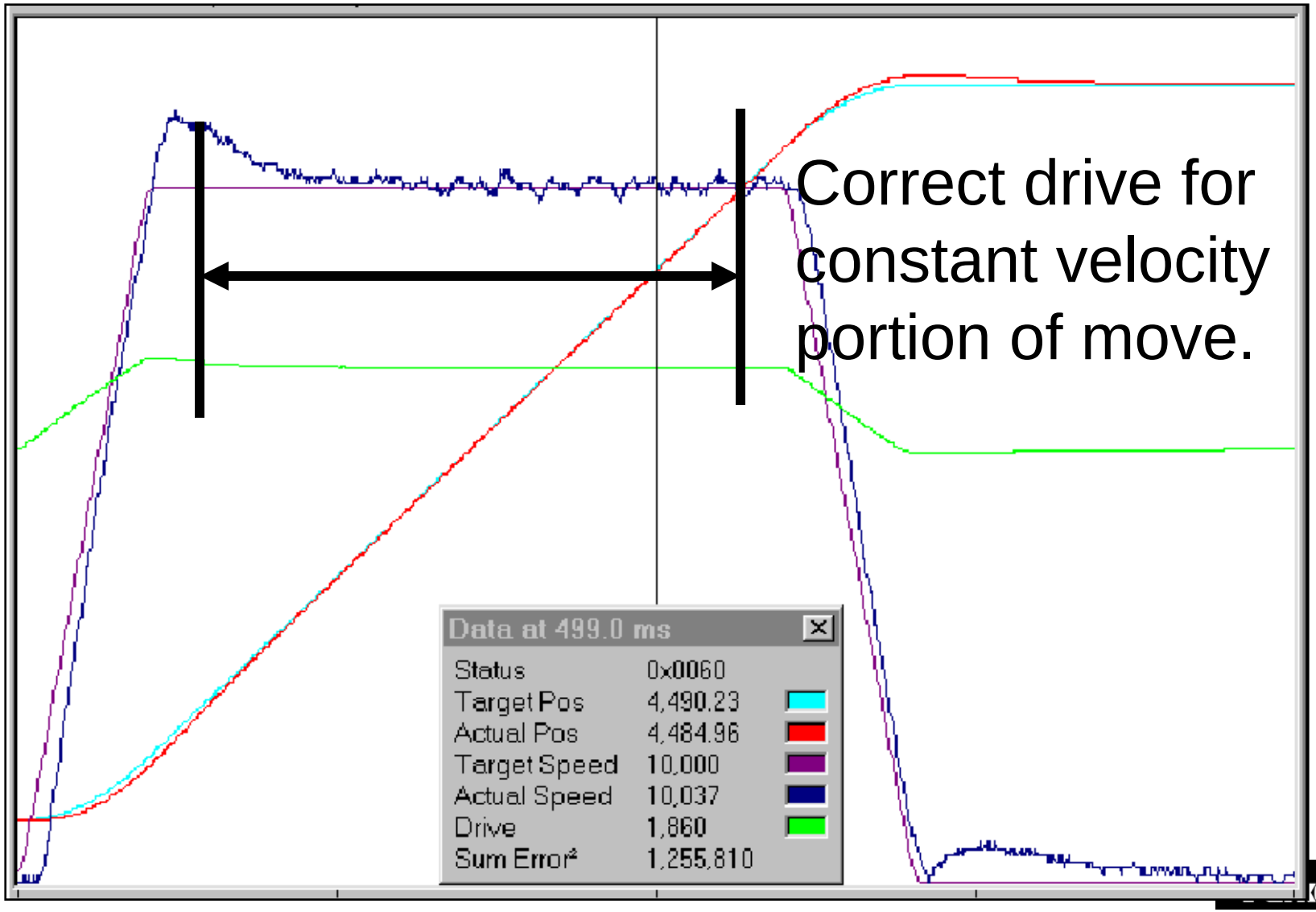
Velocity and Accel Feed Forward



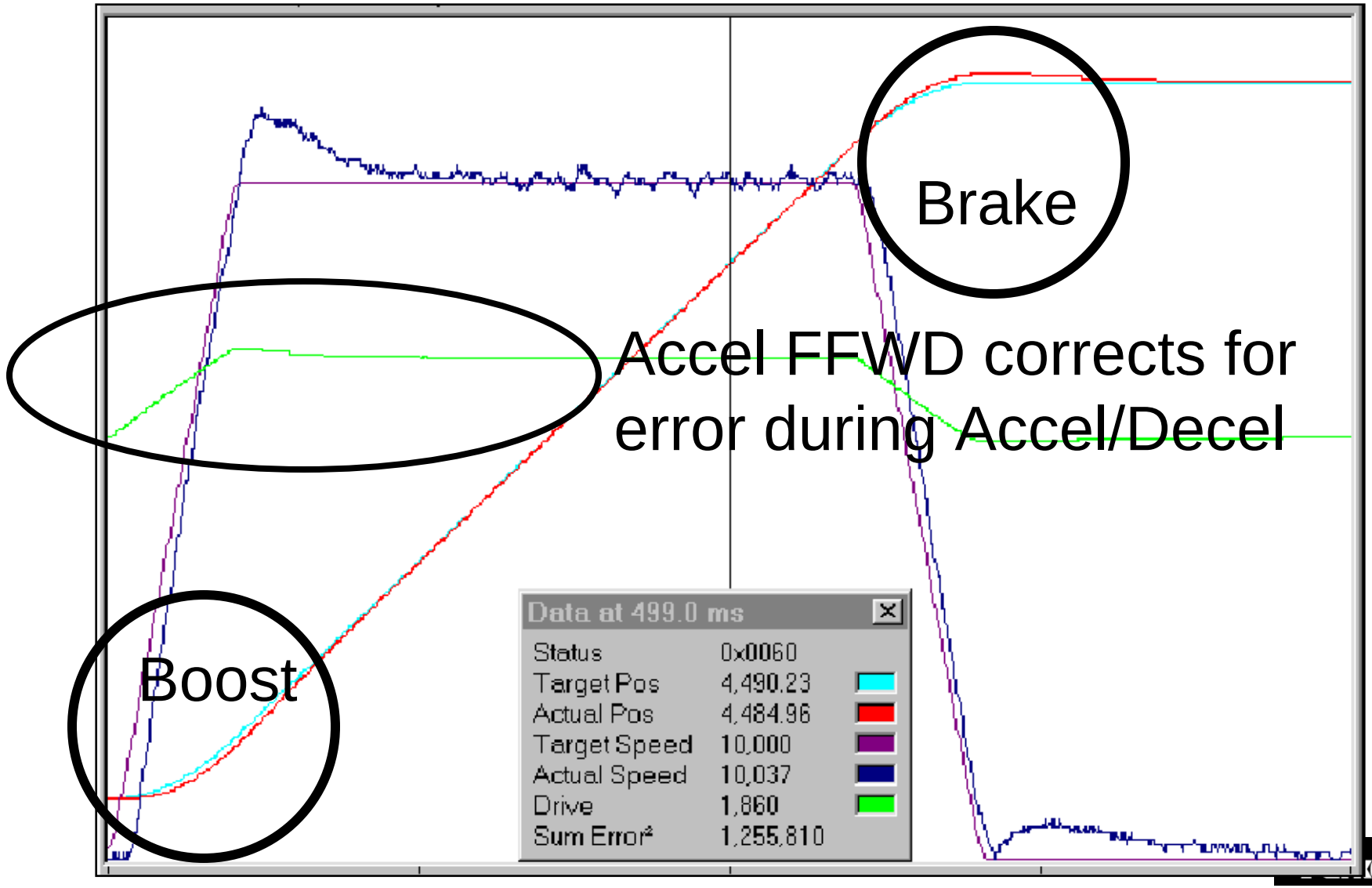
Proportional Gain ONLY



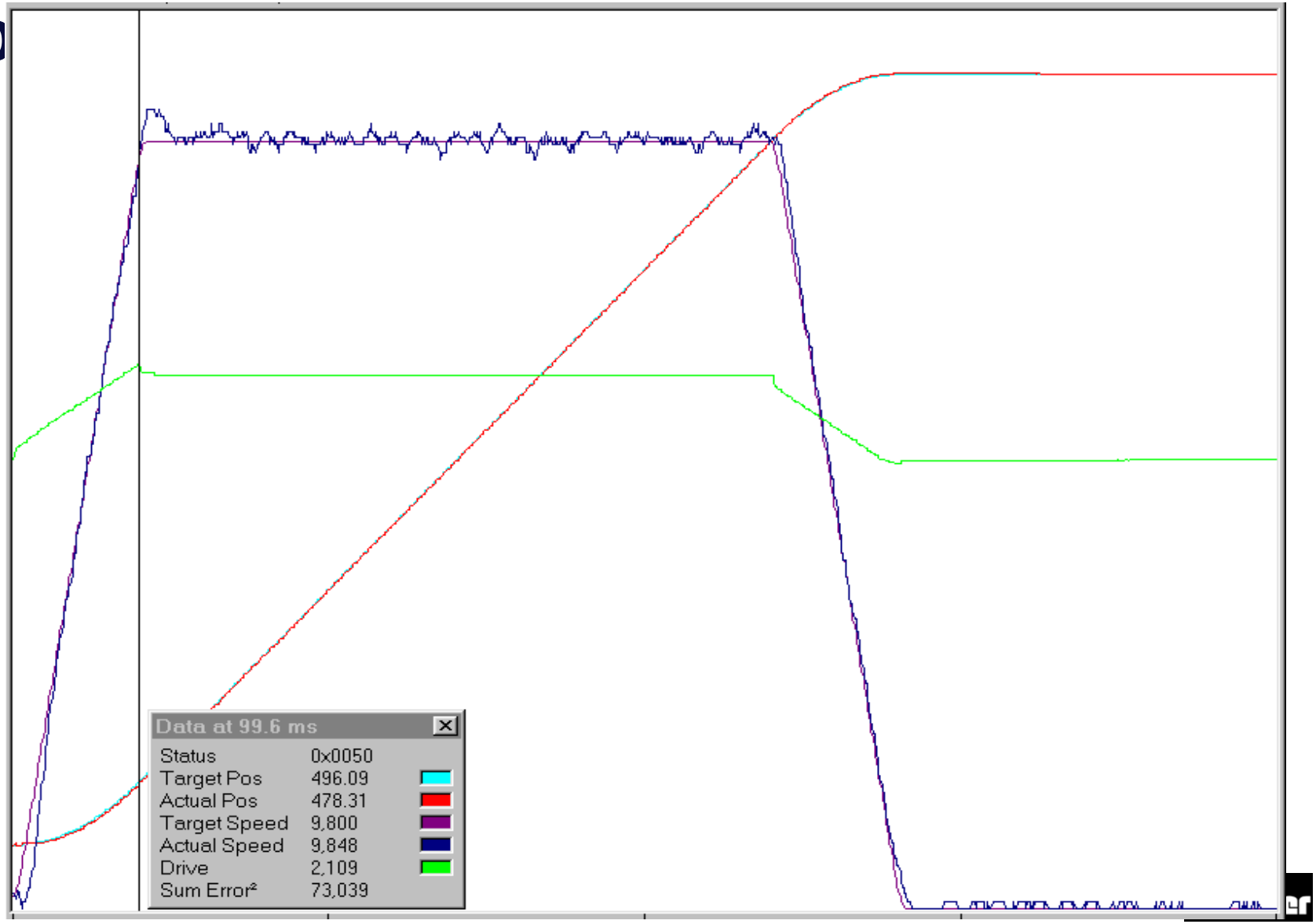
Feed Forward Adjust "F" Cmd



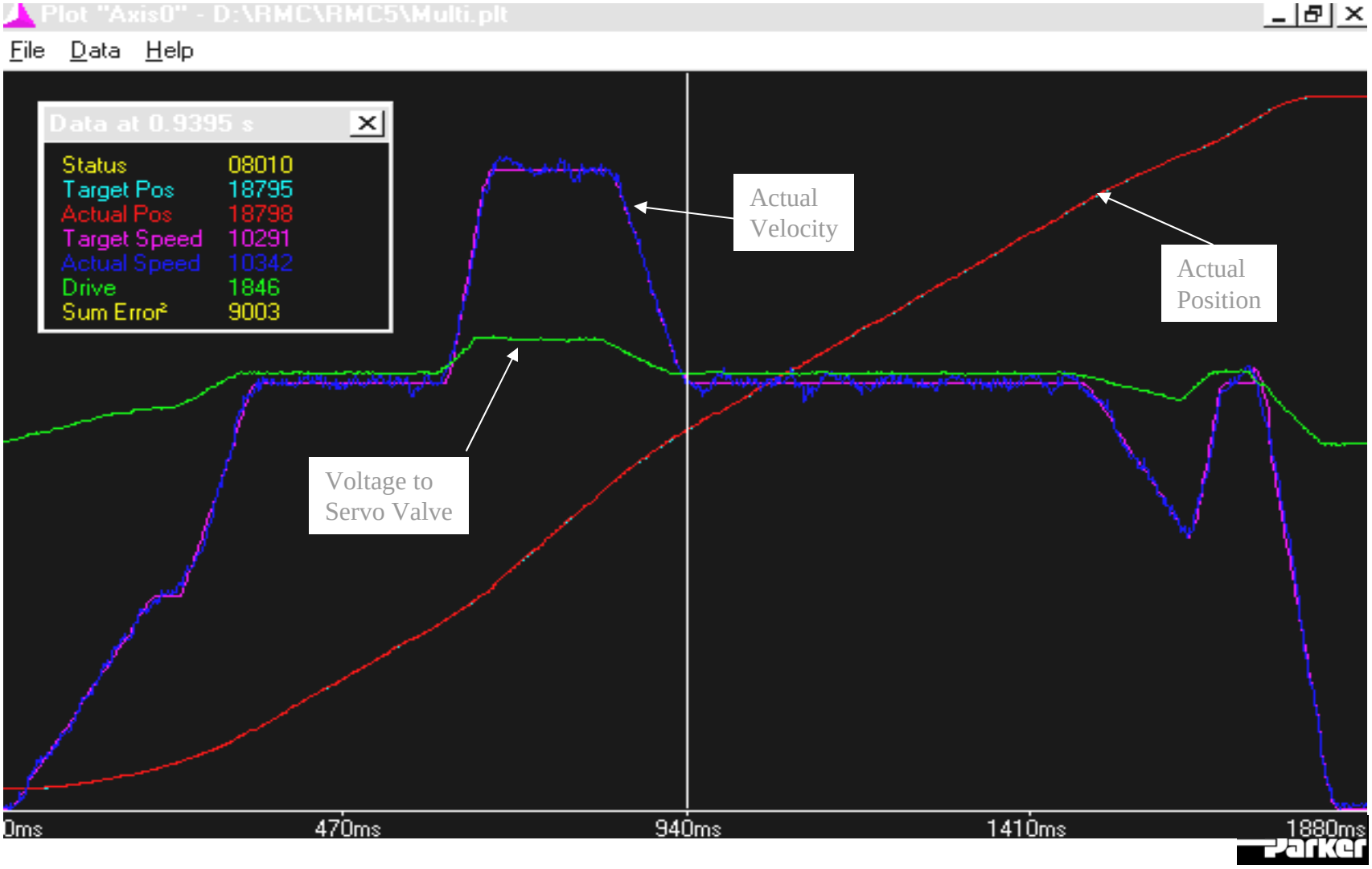
Position Error during



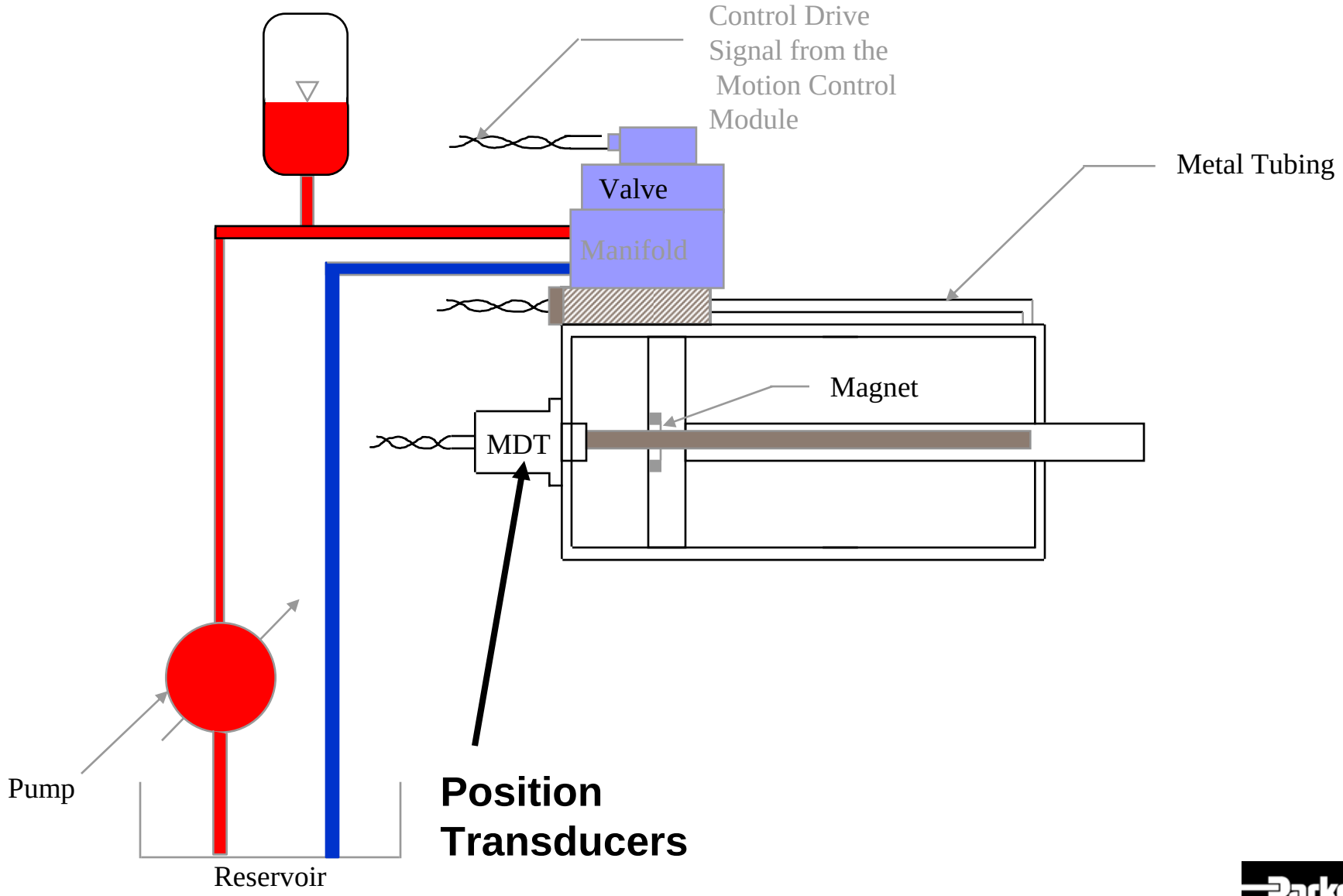
Proper Velocity and Accel Feed fo



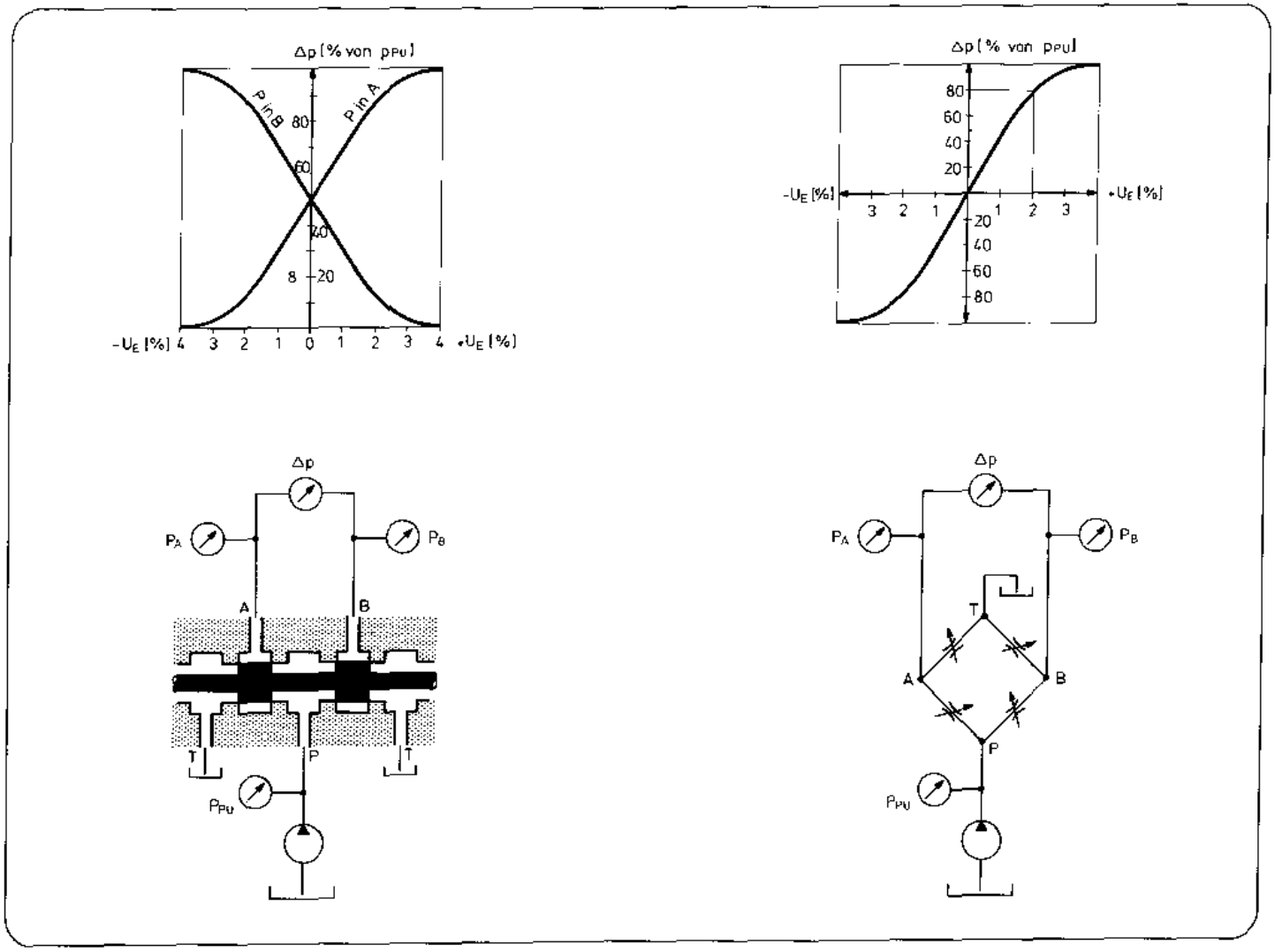
Real Time Plot Data



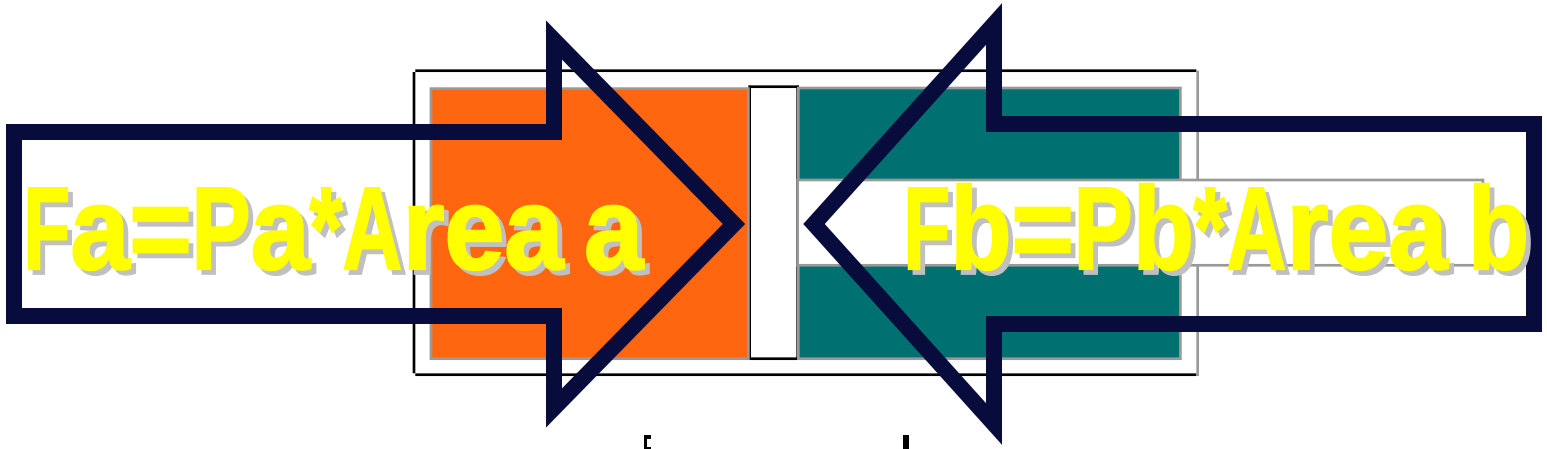
Closed Loop Position System

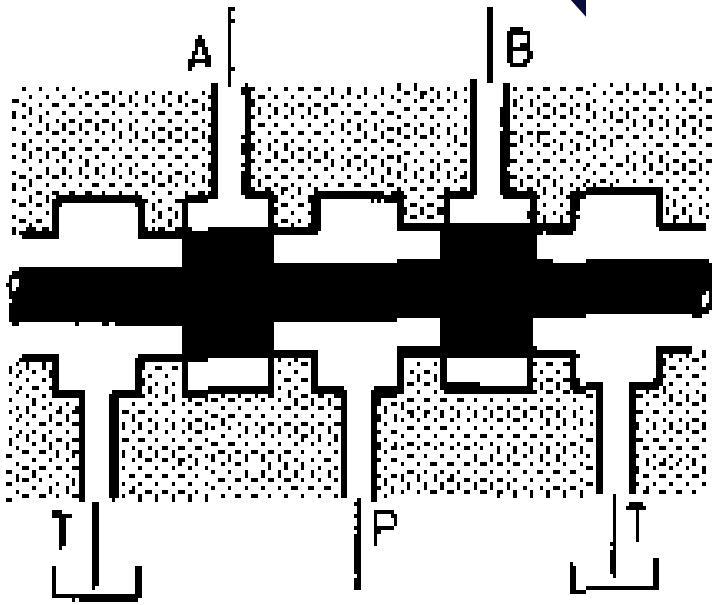


Principle of Operation Force Balance



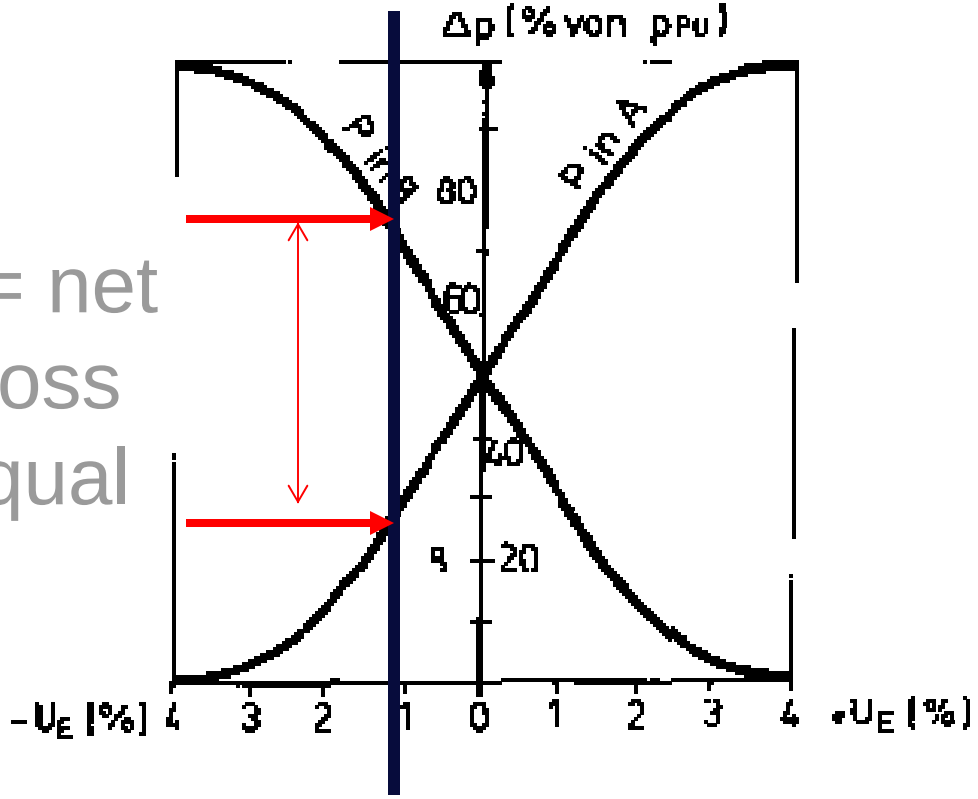
Balanced Force



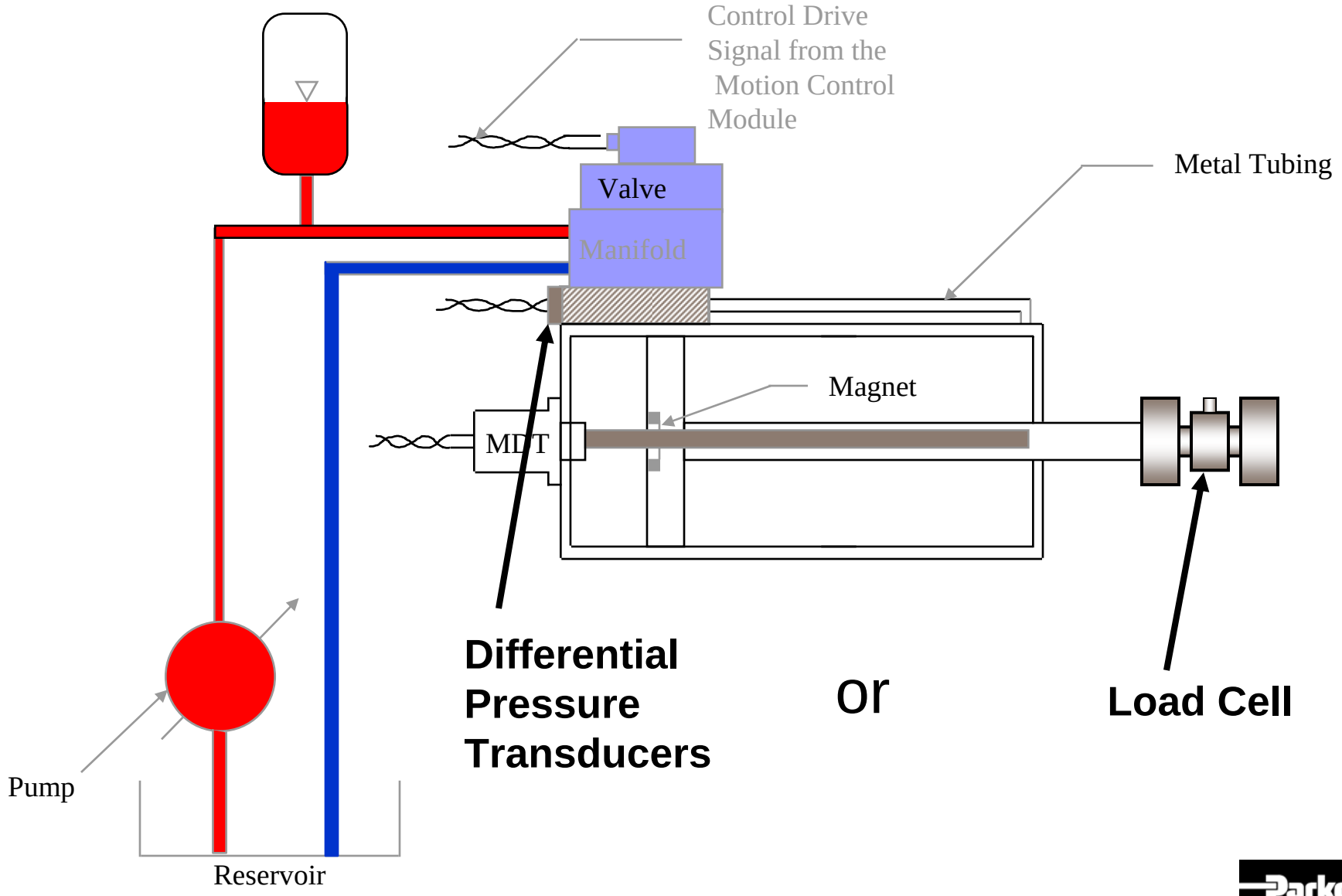


Principle of operation (cont)

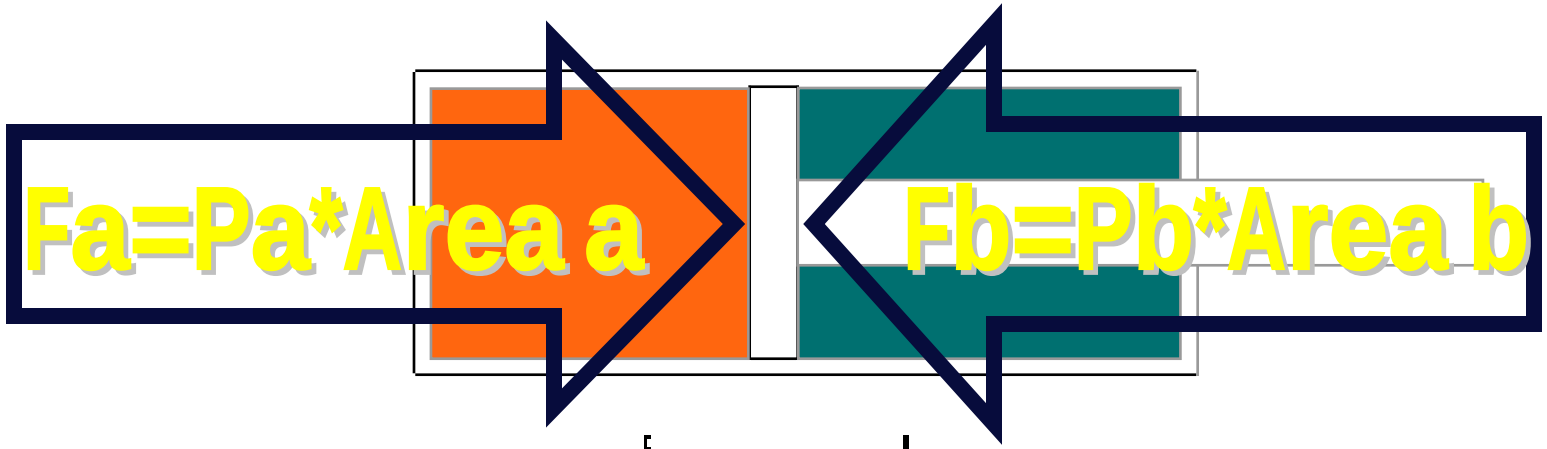
Valve null = net forces across cylinder equal zero

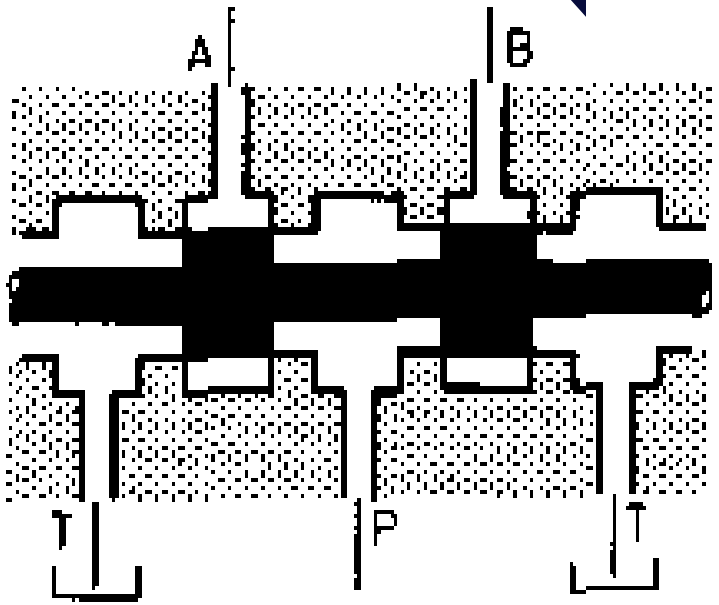


Closed Loop Force Control

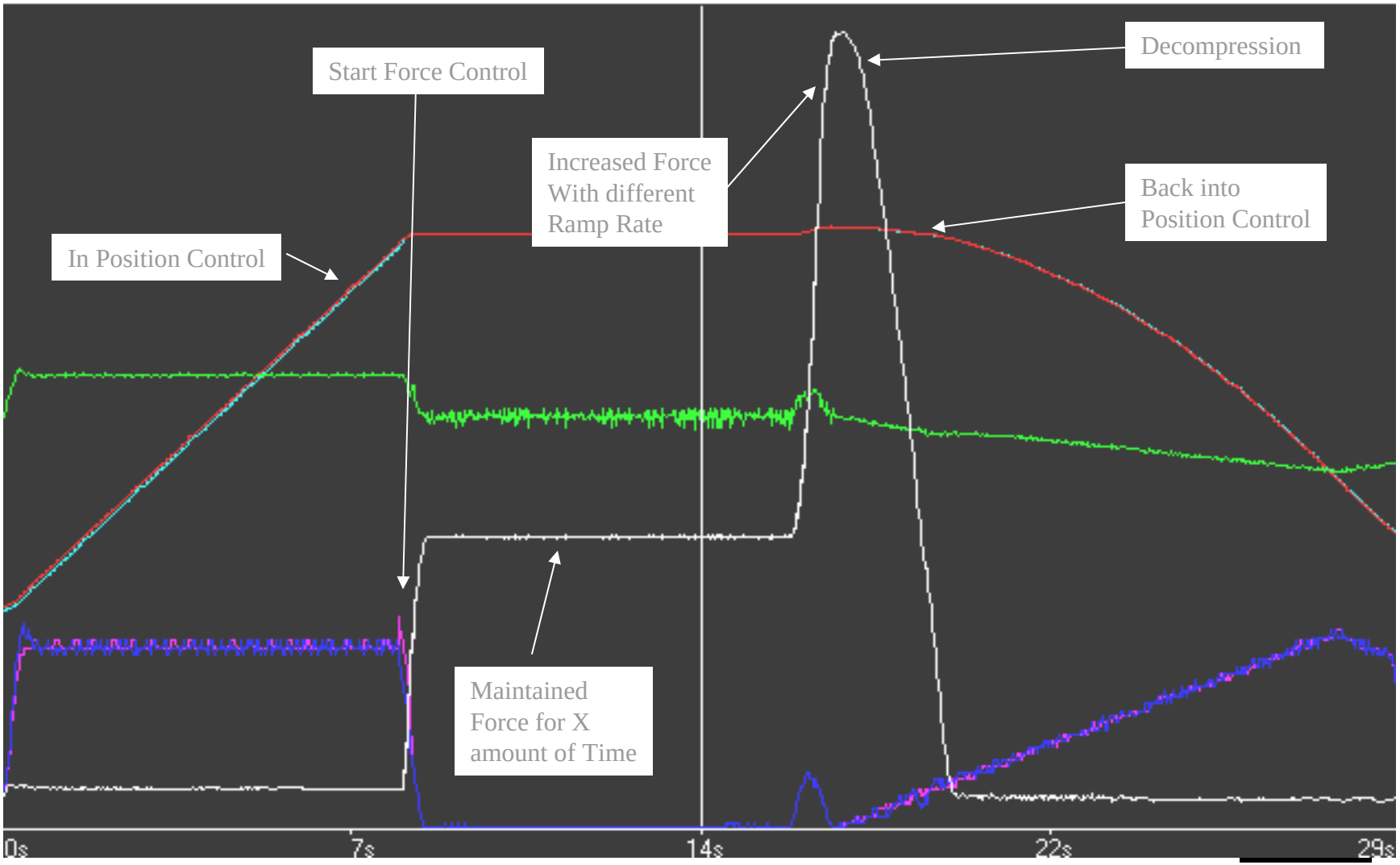


Balanced Force





Force Control



Thank you!