Application Note

FESTO

Proportional Valve Technology

This file offers detailed technical information about the proportional valves.

MPYE,VPWP, VPCF, VPPX,VPPM,MPPES, VPPE,VPPL,MPPE, VEAA,VEAB

100276

Title ..... Proportional Valve Technology
Version 1.10
Document no. 100276
Original ..... en
Author ..... Festo

Last saved 05.06.2018

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Proportional Function	Type Code
Proportional direction control valve	MPYE,VPWP
Proportional flow control valve	VPCF
Proportional pressure regulator	VPPX,VPPM,MPPES,VPPE,VPPL,MPPE
Piezo Valve	VEAA,VEAB

Table 1.1: 1 Components/Software used

2 Introduction

2.1 Proportional Valve Technology

For modern applications, customers always trying to find a solution which can adjust the pressure or flow rate for applications.

The traditional solution is using the solenoid valve to switch on and off.

Now, the proportional valve can offer a proper regulation process for the pressure and flow rate dynamic changing.

Regulating process means that the changing of an input signal (action) must be followed by a very definite change in an output signal (reaction). Since the correlation of action and reaction occur within a given proportion, this is referred to as proportional technology (proportionality).

There are two control methods for the Proportional control technology

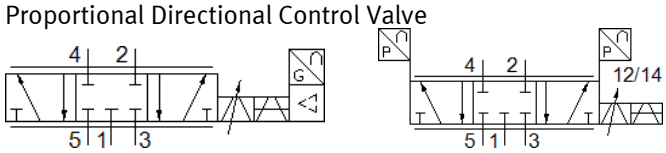
a. Open loop control system
b. Close loop control system

In the open-loop control system, the actual value is not feedback to the control process. We specify a set point and “target” for the right result. We cannot, however, influence the control process in any other way.

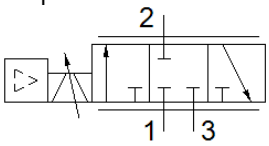
In the closed-loop control the set point and actual value are constantly compared with each other and compensation is made for deviations.

2.2 Types of proportional valves, offered by Festo

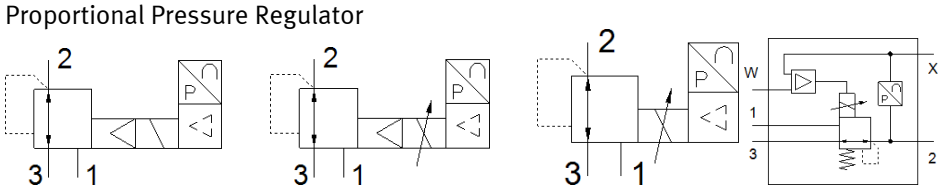
1. Regarding to the regulating target
   Festo can offer the:
   a. Proportional Directional Control Valve



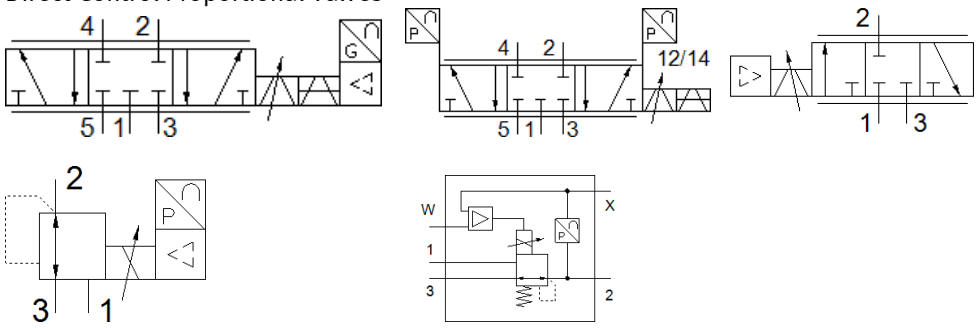
   b. Proportional Flow Control Valve



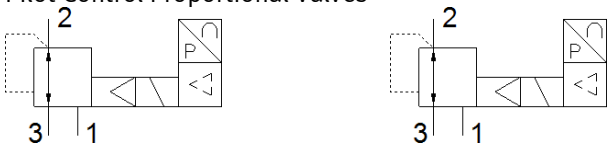
   c. Proportional Pressure Regulator



2. Regarding to the control principle
   Festo can offer:
   a. Direct Control Proportional Valves



   b. Pilot Control Proportional Valves

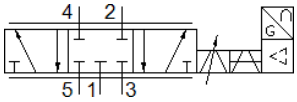


2.3 Proportional Valve working principles

3. For the proportional directional control valve, the solenoid coil directly operates the internal piston.

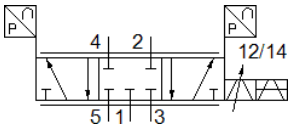
   The directly actuated proportional directional control valve MPYE-... has a position-controlled spool. This transforms an analogue input signal (voltage or current intensity) into a corresponding opening cross-section at the valve outputs. In combination with an external position controller and displacement encoder, a precise pneumatic positioning system can be created.

   The flow rate will be shut off when the electric power is down.



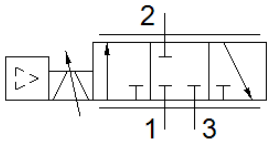
4. The 5/3-way proportional directional control valve VPWP, fully digitalised – with integrated pressure sensor with diagnostic functions. Combined with two sensors inside the valve.
   Pre-assembled cables guarantee faultless and fast connection with the controllers CPX-CMPX and CPX-CMAX.

   The flow rate will be shut off when the electric power is down.



5. The 3/3-way proportional direction control valve VPCF. With the fully digitalised control function and position control spool system. The valve flow rate is independent of fluctuations in the supply of the compressed Air. The integrated sensor monitors all the control circuit with high dynamic frequency and accuracy.

   The flow rate will be shut off when the electric power is down.



6. For the VPPM,VPPE,VPPX,MPPE-B

   All of them are pilot controlled proportional valves. There are double 2/2 NC pilot valves inside.

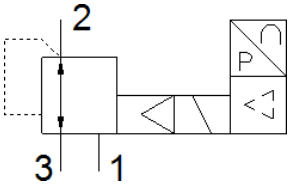
   One NC pilot valve(a) is used to increase the pressure and another pilot valve(b) is used to exhaust the pressure.

   During the pressure increasing process, the pilot valve opens, the diaphragm inside the proportional valve moves downwards and actuates the main piston inside the proportional valve.

   During the pressure exhausting process, the pilot valve b opens, the diaphragm inside the proportional valve moves upwards and actuate the exhaust function.

   The internal sensor will monitor all the pressure change process and give the feedback to the internal controller

   The pressure will be held when the electric power is down.



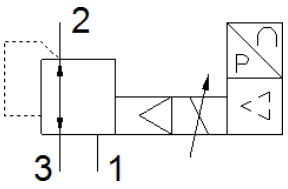
7. MPPE-S is a very special product type.

   The MPPES(except MPPES-3-1/8) is pilot controlled proportional valve. The pilot is actuated by a proportional solenoid.

   During the pressure increasing process, the pilot valve moves and actuate the main piston inside the proportional valve.

   During the pressure exhausting process, the pilot valve moves back and actuate the exhaust function.

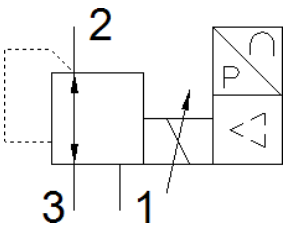
   The pressure will be exhausted when the electric power is down



   MPPES-3-1/8 is directly control piston regulator. The valve is direct actuated by the solenoid coil.

   MPPES-3-1/8 is double size bigger than the others.

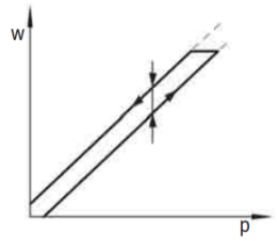
   The pressure will be exhausted when the electric power is down



3 Technical Explanations

Max. Pressure Hysteresis

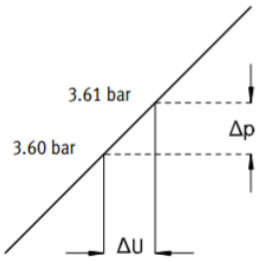
The value is the maximum spread or range if the control process has different starting conditions, namely coming from different directions. Hysteresis normally is a positive value (not ±) as is describes the bandwidth or span. Hysteresis is also a measure how good is the closed loop control. Normally the hysteresis is in the range of 2 times the repetition accuracy.



Response Sensitivity

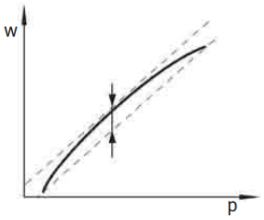
After an initial value set has been reached, the smallest set point difference, which led to a measurable change in the fluidic output signal.

The sensitivity is indicated in % of the maximum fluidic output signal



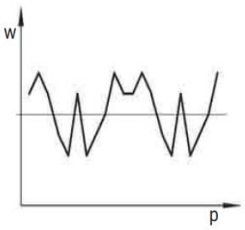
Linearity Error

This value is mainly caused by the pressure sensor. It is defined as the maximum absolute deviation from the ideal line (ideal linear behavior). Maximum deviation from this ideal line, expressed as a percentage, is known as linearity error. The percentage value is relative to maximum output pressure (full scale).



Repetition Accuracy

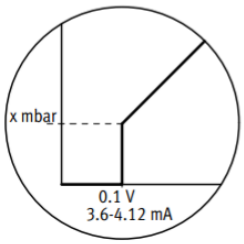
Repetition accuracy is the spread within which the fluidic output quantity is distributed when the same electrical signal, coming from the same direction, is repeatedly selected. Repetition accuracy is expressed as a percentage of the maximum fluidic output signal. It is the +/- deviation if we do the same control process again and again, e.g. demanding the same set pressure and starting from the same initial pressure.
For our proportional valves we can state that the repetition accuracy is better than half the hysteresis value. Repetition accuracy is mainly caused by the closed loop control.



Zero Point Suppression

In practice there exists the possibility of residual voltage or residual current at the setpoint input of the proportional valve (etc. VPPM) via the setpoint generator. Zero point suppression is used so that the valve is reliably vented at a setpoint value of zero.

Overall accuracy



This value can describe the absolute accuracy of the physical output (e.g. pressure) which can be reached. If a certain absolute pressure should be reached and we want to predict what can be actually expected (measured), then we need the overall accuracy. The overall accuracy is the sum of the two effects

The overall accuracy is the sum of the two effects

- measurement error of the sensor (Linearity and Offset error)
- control error of the closed loop controller (Repetition accuracy)

Overall accuracy = Sensor error + Repetition accuracy

After substituting

Sensor error = Linearity error + Offset error Repetition accuracy = 0.5 * Hysteresis

The result is:

Overall accuracy = Linearity error + Offset error + 0.5 * Hysteresis

The typical offset error is 0 at 20°C because the sensor is calibrated for this temperature.

Per degree deviation from20°Cthe offset error for VPPM/VPPX is 0,04%/K

4 Technical Data

Valve	MPYE	VPWP	VPCF
Design Structure	Piston Slide	Piston Slide	Piston Slide
Valve Function	5/3 proportional directional control valve, closed	5/3 proportional directional control valve, closed	3/3 proportional direction control valve, closed
Sealing principle	Hard Sealing	Hard Sealing	Hard Sealing
Max. Leakage	MPYE-5-M5-...B 7 l/min MPYE-5-1/8-LF-...B 20 l/min MPYE-5-1/8-HF-...B 25 l/min MPYE-5-1/4-...B 30 l/min MPYE-5-3/8-...B 35 l/min	NW 4 20l/min NW 6 25l/min NW 8 30l/min NW 10 35l/min	4-8 l/min Typical 6 l/min
Dynamics(-3dB frequency)	MPYE-5-M5-...B 115 Hz (0–100 % stroke) MPYE-5-1/8-...B 95 Hz (0–100 % stroke) MPYE-5-1/4-...B 80 Hz (0–100 % stroke) MPYE-5-3/8-...B 70 Hz (0–100 % stroke) MPYE-5-M5-...B 150 Hz (20–80 % stroke) MPYE-5-1/8-...B 120 Hz (20–80 % stroke) MPYE-5-1/4-...B 105 Hz (20–80 % stroke) MPYE-5-3/8-...B 95 Hz (20–80 % stroke) MPYE-5-M5-...B 275 Hz (45–55 % stroke) MPYE-5-1/8-...B 230 Hz (45–55 % stroke) MPYE-5-1/4-...B 230 Hz (45–55 % stroke) MPYE-5-3/8-...B 200 Hz (45–55 % stroke)	NW 4 90 Hz (0–100 % stroke) NW 6 90 Hz (0–100 % stroke) NW 8 80 Hz (0–100 % stroke) NW 10 65 Hz (0–100 % stroke) NW 4 120 Hz (20–80 % stroke) NW 6 120 Hz (20–80 % stroke) NW 8 115 Hz (0–100 % stroke) NW 10 80 Hz (20–80 % stroke) NW 4 260 Hz (45–55 % stroke) NW 6 260 Hz (45–55 % stroke) NW 8 240 Hz (45–55 % stroke) NW 10 180 Hz (45–55 % stroke)	114 Hz (5–95 % stroke) 196 Hz (25–75 % stroke) 388 Hz (45–55 % stroke)
Input Pressure	0-10 Bar	0-10 Bar	1 - 10 Bar
Power Consumption	2.4 W Mid-position 26.4 W Full stroke	28.8 W	1.2 A
Repetition accuracy in ± %FS	0.50%	1.00%	1.00 %
Linearity error in (%FS)	0.004	1.50%	1.0%
Temperature coefficient	0.04 % / K	0.04 % / K	0.04 %/K
B10 Value	400 Mio	400 Mio	400 Mio
Continuously set point changes	Y	Y	Y

Valve	VPPM	VPPX	MPPES	MPPES-3-1/8	VPPL	MPPE	VPPE	VPPE Display
Design Structure	Pilot actuated dia-phragm regulator	Pilot actuated dia-phragm regulator	Piloted piston regulator	directly-controlled piston regulator	Directly actuated control valve	Piloted piston regulator	Pilot actuated dia-phragm regulator	Pilot actuated Dia-phragm regulator
Valve Function	3-way proportional-pressure regulator	3-way proportional-pressure regulator	3-way closed proportional-pressure regulator	3-way closed proportional-pressure regulator	3-way closed proportional pressure regulator	3-way closed proportional-pressure regulator	3-way propor-tional-pressure regulator	3-way proportional-pressure regulator
Sealing principle	Soft Sealing	Soft Sealing	Soft Sealing	Soft Sealing	Soft Sealing	Soft Sealing	Soft Sealing	Soft Sealing
Max. Leakage	5 l/h	5 l/h	5 l/h	5 l/h	20 l/h	5 l/h	5 l/h	5 l/h
Input Pressure	0-11Bar	0-11Bar	0-12Bar	0-12Bar	0 – 50 Bar	0-11 Bar	7Bar	0 – 11 Bar
Control Range	0-2 Bar 0-6 Bar 0-10 Bar	0-10 Bar	0-2 Bar 0-6 Bar 0-10 Bar	0-2 Bar 0-6 Bar 0-10 Bar	0,2 – 20 Bar 0,4 – 40 Bar	0-1 Bar 0-2.5 Bar 0-6 Bar 0-10 Bar	0-6Bar	0 – 2 Bar 0 – 6 Bar 0 – 10 Bar
Dynamics (-3dB frequency)	NW 6: 3 Hz NW 8: 2.5 Hz NW 12: 1,7 Hz	NW 6: 3 Hz NW 8: 2.5 Hz NW 12: 1,7 Hz	G1/8: 4.5 Hz G1/4: 3.3 Hz G1/2: 3 Hz	G1/8: 4.5 Hz G1/4: 3.3 Hz G1/2: 3 Hz	NW 2.5: >1.5Hz (20–80 % stroke)		x	3 Hz
Max. Pressure Hysteresis	0.05 Bar	0.05 Bar	0.05 Bar	0.05 Bar	0.3Bar	0.05 Bar	0.15Bar	2 Bar-type: 0.02 Bar 6 Bar-type: 0.03 Bar 10 Bar-type 0.05 Bar
Power Consumption	7W(-LCD, -LED) 11W(-IO)	7W(G1/8,G1/4) 11W(G1/2)	20W	20W	27 W	3.6W	3.6W	4.2W
Repetition accuracy in ± %FS	0.50%	0.50%	0.20%	0.20%	0.50%	0.50%	0.50%	0,70 %
Linearity error in (%FS)	1.00%	1.00%	0.50%	0.50%	0.5 %	1.00%	0.7%	0.7%
Resolution of actual value output	10Bit	10Bit	8Bit	8Bit	x	8Bit	Pure Analog	12Bit
Temperature coefficient	0.04 % / K	0.04 % / K	0.04 % / K	0.04 % / K	0.04 %/K	0.04 % / K	0.04 % / K	0.04 % / K
B10 Value	100 Mio VPPM 6/8 50 Mio VPPM 12	100 Mio VPPX 6/8 50 Mio VPPX 12	78 Mio	78 Mio	50 Mio	30 Mio	60 Mio	60 Mio

5 Power failure Function

If, due to an EMERGENCY OFF, the electrical supply of the proportional-pressure regulator is interrupted, the valve displays different characteristics depending on the type.

Valve type EMERGENCY OFF characteristics

VPPM -... on interruption of the electrical power supply, the output pressure is maintained but unregulated
VPPX-... on interruption of the electrical power supply, the output pressure is maintained but unregulated
VPPE-... on interruption of the electrical power supply, the output pressure is maintained but unregulated
MPPE-... on interruption of the electrical power supply, the output pressure is maintained but unregulated
MPPES-... on interruption of the electrical power supply, the output pressure is not maintained
MPYE... on interruption of the electrical power supply, the output flow is not maintained
VPWP... on interruption of the electrical power supply, the output flow is not maintained
VPCF... on interruption of the electrical power supply, the output flow is not maintained
VPPL-... in case of a wire break, the output pressure is lowered to 0 bar

6 Set point failure Function

VPPM -... on interruption of the set point, the output pressure is hold for the current type, and exhaust for the voltage type

VPPX-... on interruption of the set point, the output pressure is hold for the current type, and exhaust for the voltage type

VPPE-... on interruption of the set point, the output pressure is hold for the current type, and exhaust for the voltage type·

MPPE-... on interruption of the set point, the output pressure is hold for the current type, and exhaust for the voltage type

MPPES-... on interruption of the set point, the output pressure is exhaust for the current and voltage type.

MPYE... on interruption of the set point, the output flow rate is switched off

VPWP... on interruption of the set point, the output flow rate is switched off

VPCF... on interruption of the set point, the output flow rate is switched off

7 General Notes

Note

The proportional pressure regulator which has been designed for a maximum pressure of 10 Bar can also be adjusted to a pressure range of 0.8 Bar, but more accurate results are achieved using a proportional-pressure regulator designed for a maximum pressure of 1 Bar.

Also important is the operating pressure: the pressure applied to the primary side of the proportional-pressure regulator should be at least 1 Bar higher than the maximum value which is set with the proportional-pressure regulator.

Type Code	Allowed Operation Medium			
	Compressed Air	Neutral Gasses	Lubricated Gas	Unlubricated Gas
MPPE	Y	Y	Y	Y
MPPE-S	Y	Y	Y	Y
VPPE	Y	Y	N	Y
VPPM	Y	Y	N	Y
VPPX	Y	Y	N	Y
VPPL	Y	Y	N	Y
VPWP	Y	Y	N	Y
VPCF	Y	Y	N	Y
MPYE	Y	Y	N	Y

VPWP, VPCF and MPYE require max. particle size 5µm

8 Common Questions

For which application which type of proportional pressure valve can be recommended?

MPPES has the better service life in pilot stage, so it is recommended for the continuous pressure set point changing (e.g. ramp or sinus) application

VPPM is quite universal, fits for most application and offers a wide range of sizes and settings, two different linearity classes and also analogue monitoring and digital output is possible.

VPPE – just size 1/8 available - is for cost sensitive application with less demands.

MPPE-B is quite cheap but old-fashioned and is in phase out process already.

VPPL is a special valve for high pressure range.

VPPX is based on VPPM and is quite flexible due to an open sensor input.

VEAA/B is piezo valves with low flowrate up to 20 l/min mainly used for special application in medicine technics or laboratory automation.

What is the difference regarding fail save behavior between valves with switching valves and proportional magnet in the pilot stage?

The valves MPPES with proportional magnet will exhaust if supply voltage is switched off. In case of a setpoint signal but no supply pressure the proportion magnet can overheat.

The valves with switching valves in the pilot stage keep the output pressure even if supply voltage is switched off but due to leakage of the pilot valves the pressure can decrease of increase within long term.

How can the time for a pressure change be calculated?

The dynamic change of the output pressure over time depends on the starting pressure, set point pressure (= end pressure), volume, supply pressure, tubing and fittings and an eventually existing Air consumption or leakages. Within the datasheets or testing reports we can find some exhausting or venting time (often t90) for some sample configurations.

Only VPPM-6 currently can be calculated within simulation tool CACOS – but only for venting and with zero Bar start pressure.

Do all proportional pressure valves have zero-point suppression?

Yes, all proportional pressure valves have zero-point suppression below 1% of the input signal. This means for small input signal the output pressure is zero / fully exhausted. If the lower pressure value was shifted (range adaption) then no zero-point suppression is active.

What is the smallest set-point change which leads to a pressure change at the valve output?

This is the response sensitivity. For MPPES the response sensitivity is stated in the internal datasheet.

For all other proportional pressure valves, we must take the hysteresis value as worst case estimation.

Which types of pressure valves are available with range adaption and how far can the upper and lower pressure be changed?

VPPM and VPPE can be ordered with different lower and upper pressure range. For VPPM with display the range can be adjusted flexible by the user. Maximum range adaption for VPPM is 90% for lower pressure, 10% for upper pressure but minimum 10% range must remain.

What is the recommended sequence for switching on and off the supply voltage, supply pressure and set point signal?

Recommended switch on sequence is:

1. supply voltage,
2. supply pressure,
3. set point signal.

Switching off sequence should be in reversed order: 3 –> 2 –> 1

What are typical user or application errors?

Oversizing, (too big) valve size, too small tubing and fittings, wrong sequence for switching on or off.

Is there anything which can be repaired?

In general, no repair service is available. Except for old VPPE **repair service is** possible and for some MPPES repair and wearing part kit is available. But exchange makes more sense than repair.

VPPM with I/O Link supports Version 1.1 and I-Port. Is Versions 1.0 possible as well?

IODD for can be provided on demand but this was only tested with Siemens ET200S.

As we already have the SA proportion valve for the vacuum(SA21551) will it be one of our standard product in the future?

No, this will remain a SA solution because this is only for very special applications.

We can configure the VPPM via the online xDki, but if we select the working range by ourselves, e.g. VPPM-8F-L-1-F-2L4.5H-V1P. What about the technical data (accuracy, Hy. , response time, etc.) and which is the right FS value to use?

The technical data is always the specification of the standard valve with the next bigger upper supply pressure. So, for the mentioned VPPM-8F-L-1-F-2L4.5H the technical data of VPPM-8F-L-1-F-0L6H is valid. This means that for technical data related to a FS value also the FS value of the next bigger upper supply pressure must be used.

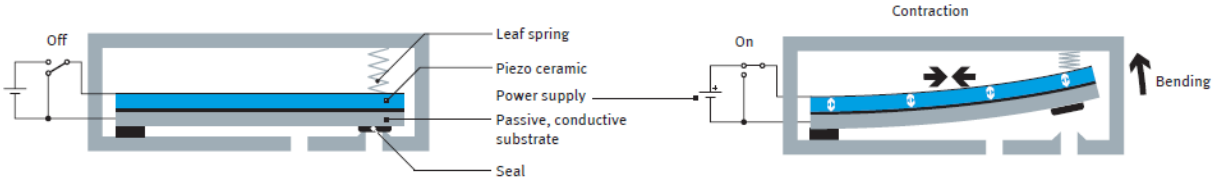
If the supply pressure exceed the operation range for the proportional valve, what will happen?

There will be not directly a damage on the pilot or the main stage and it can work. Control behavior will become more aggressive. Anyhow we have to dis-advise, because if the high supply pressure comes to the pressure sensor then the sensor accuracy can be affected or at double nominal pressure the sensor can be destroyed. During normal operation this will not happen but as we cannot fully exclude this in special situation we never recommend doing this.

9 Piezo Technology

a. What is Piezo technology?

Piezoelectric materials, usually special ceramic objects with surfaces which have been rendered conductive, convert electrical energy into mechanical energy and vice versa. The lattice structure of the molecules in these piezo-ceramics is asymmetrical below the Curie temperature Tc, and is thus a dipole. Under the influence of strong electric fields, it is possible to permanently polarize piezo-ceramics, or in other words give them a preferred direction. The ceramic material then has piezoelectric properties and changes shape when a voltage is applied. 3D deformation takes place along the field lines. Since the ceramic materials have a constant volume, shrinkage occurs in the material at right angles to the field lines. The advantage of piezo-based drives lies in the fact that they can be energized with almost zero power. In electrical terms, a piezo element is a capacitor consisting of two electrically conductive plates and the ceramic piezo material which functions as a dielectric. Current only flows while the capacitor is charging, and the flow drops to zero when charging is complete. Since electrical power is calculated as voltage x current, the power will be zero if no more current flows. In applications that need to be extremely energy-efficient it is even possible to recover the charging energy when the drive is reset. This can then be used again for the next charging operation.



Function of the bender actuator in the piezo valve: when a voltage is applied, the piezo element bends due to a reduction in longitudinal direction.

b. What kind of Piezo valve can be offered by Festo?

Festo can offer 2 kinds of Piezo Valve VEAA/VEAB.

Type	VEAA	VEAB
Design Structure	Piezo Valve	Valve
Valve Function	2/2 valve	2 2/2 valves
Sealing principle	Soft sealing	Soft sealing
Max. Input Pressure	11 Bar	-1 ... 6.5 Bar
Control Range	0.01...10 Bar	-1...6 Bar
Max. Pressure Hysteresis	0.25%	0.25%,0.5% for D12 type
Power Consumption	11.6W	11.6W
Repetition accuracy in ± %FS	0.4%	0.4%
Linearity error in (%FS)	0.5%	0.5%,0.8% for D12 type
Analog output accuracy(%FS)	2%	2%
B10 Value	100 Mio	100 Mio
Continuously set point changes	Y	Y