Design for Internet of Things

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Lecture - 28
Actuators

Welcome back. Let us look at some actuators and understand some basic characteristics of the, basic types of actuators and what are the selection criteria's associated with these actuators. And of course, we will follow up with a small demo that will give you some idea of how to choose an actuator and for different applications. So, what is an actuator if you ask.

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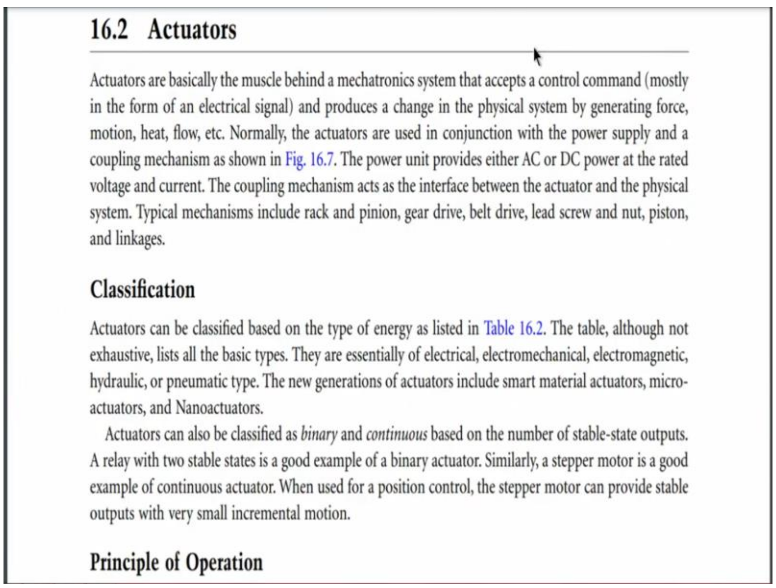

16.2 Actuators

Actuators are basically the muscle behind a mechatronics system that accepts a control command (mostly in the form of an electrical signal) and produces a change in the physical system by generating force, motion, heat, flow, etc. Normally, the actuators are used in conjunction with the power supply and a coupling mechanism as shown in Fig. 16.7. The power unit provides either AC or DC power at the rated voltage and current. The coupling mechanism acts as the interface between the actuator and the physical system. Typical mechanisms include rack and pinion, gear drive, belt drive, lead screw and nut, piston, and linkages.

Classification

Actuators can be classified based on the type of energy as listed in Table 16.2. The table, although not exhaustive, lists all the basic types. They are essentially of electrical, electromechanical, electromagnetic, hydraulic, or pneumatic type. The new generations of actuators include smart material actuators, micro-actuators, and Nanoactuators.

Actuators can also be classified as *binary* and *continuous* based on the number of stable-state outputs. A relay with two stable states is a good example of a binary actuator. Similarly, a stepper motor is a good example of continuous actuator. When used for a position control, the stepper motor can provide stable outputs with very small incremental motion.

Principle of Operation

Actually, this is a document which we found on the internet and you can download it yourself. Essentially, it is a muscle behind all mechatronic systems okay and basically it accepts a control command and it produces a change in the physical system. That is the key thing it generates a certain force, it can be in terms of motion, it can be a generating force, it can be motion, it can be heat, it can be flow etc.

If you if you actuate a heater, then it will produce heat if you actuate a valve, it may actually bring in certain flow, it may actuate a flow. If you connect it to a let us, say a robotic arm, it may generate a certain force and you have a force the robotic arm itself will generate a certain force and so on. So, these are all actuators essentially. Now, you can classify actuators of different types.

You can have actuators which can be under, basically under binary type of actuator, on off kind of actuators or you can be talking of continuous based actuators which are based on stable state outputs. A relay for instance has two stable states is a good example of a binary actuator. Even a solenoid valve for that matter can be regarded as a binary kind of actuator on, solenoid valve is on, solenoid valve is off.

You can also have a wall which is sort of continuously opening that means you control a solenoid valve control the power to it is in such a manner that you open it let us say half you open it 1/4th and so on. So, such valves are also existing such solenoids also may be available, but by and large solenoids will give you on off, on off. You can also have different types variants of the solenoid valve, which essentially are different types of valves, where you can have continuous change, that is also possible as I said, you want to open only a small orifice.

So, that small amount of flow goes then you open it a little bit and so on. So, that is also another possibility. Similarly, stepper motor, again, it goes back to another example of good example of continuous actuator. What happens in a step motor is? If you take a step motor, we typically step motors you will get as 200 step motors. You will have 200 steps, which the rotor can take, if you look at my hand motion, this is like a motor, this is like a shaft, the shaft goes cut, cut, cut, it goes like this, and each time it moves, it moves by 1.8 degrees.

That is why you get 200 steps when it completes one full rotation. Now, supposing for every pulse I feed it moves by 1.8 degrees. Now, if I start increasing the frequency of the pulse, then you will see that the shaft is rotating continuously, which means it is continuous actuation each pulse will give it an, which will move it by 1.8. And because the frequency of the pulse is high, it moves continuously.

So, what the eye sees is a continuous motion, but actually the actuation is in a step way in each for each pulse, it is moving in a step. Therefore, that can be regarded as something which is like a continuous actuator. But when you use it for position control, that means you want it to move by, let us say10 steps, that means you want to move it by 18 degrees, I am assuming that it is a 1.8 degree step motor, you give something give it a command.

It will go and settle down at the end of 10 steps which means it would have moved by 18 degrees, then you can think about it like a binary motion. That is in every 18 degrees it goes and halts itself there. So, the notion of continuous and binary depends also a little bit on what you want to do with that actuator like Solenoid as I mentioned. So; careful about the interpretation of continuous and binary actuators.

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TABLE 16.2 Type of Actuators and Their Features

Actuator			Features
		Electrical	
Diodes, thyristor, bipolar transistor, triacs, diacs, power MOSFET, solid state relay, etc.			Electronic type Very high frequency response Low power consumption
		Electromechanical	
DC motor	Wound field	Separately excited	Speed can be controlled either by the voltage across the armature winding or by varying the field current
		Shunt	Constant-speed application
		Series	High starting torque, high acceleration torque, high speed with light load
		Compound	Low starting torque, good speed regulation Instability at heavy loads
	Permanent magnet	Conventional PM motor	High efficiency, high peak power, and fast response
		Moving-coil PM motor	Higher efficiency and lower inductance than conventional DC motor
		Torque motor	Designed to run for a long periods in a stalled or a low rpm condition
	Electronic commutation (brushless motor)		Fast response High efficiency, often exceeding 75% Long life, high reliability, no maintenance needed

Now, when you talk about actuators you can be talking about electrical actuators you can be talking about electromechanical actuators, you can be talking about different types. So, let us see a nice table which talks about these actuators. So, diodes, thyristors, bipolar transistors, triacs, diacs, power MOSFET, solid state relay, these are all electrical type of actuators. But they are basically devices which are electronic devices.

So, they are basically electrical electronic type of devices. They have extremely good frequency response very high frequency response and sometimes they are very low power consumption. Now, DC motor, DC motor is a classic example of being an electromechanical actuator then you can have wound field or you can have permanent magnet kind of DC motors or Wound field Motors, where the way you excite the windings makes the huge difference.

And there are advantages and disadvantages of each one of them. In permanent magnet you have conventional permanent magnet, your moving coil and so on. So, again he talks about different types of motors, you can also have brushless motors, which gives you extremely fast response, highly efficient over 75%, very long life because there are no brushes the here it is brushless DC motor and so on.

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So, do have a look at it these are all also actuators a DC motor is a very good accurate. AC motor, AC motor we can think about synchronous motor and also induction motors several industrial plants use induction motors, most commonly used motor in industry simple rugged and very inexpensive. Starting with the flour mills, where we grind our grain to extremely important like toy making or any kind of factory you can think of you know.

They will definitely have an induction motor for sure. So, it is the most commonly used motor for any industry simple rugged, inexpensive, easy to service. Then you have AC synchronous motor rotor rotates at synchronous speed very high efficiency again and a wide range of speeds and loads. But the only thing is it needs some additional system to start and you also have what are known as universal motors.

They can operate on DC and AC very high horsepower, relatively short operating life and so on. Then you have stepper motors, several of the printers, old printers dot matrix printers that you know or floppy disk drives, which were being used in computer hardware. I am talking of 2 decades back, floppy disk drives or computer dot matrix printers, they all had stepper motor drives, and therefore step motors are quite common.

In fact, nowadays, if you look at 3D printers, 3D printers will have stepper motors inside them for very precise movement. Good thing about stepper motors is you can drive them in open loop. You just give a pulse it will move by whatever degree it is designed for typically it is 1.8, you can also do half stepping which means it will go by 0.9 degrees. So, all these possibilities are there. You can provide it will give you very good positioning without feedback.

That is the reason why I said you can do open loop operation of this and also there are other types of motors which is also called a variable reluctance motor. Variable reluctance in big sizes are very popular, they have extremely low maintenance, there are no magnets in a variable reluctance motor so that is a good thing. So, once dependence on magnets can be done away if you design good variable reluctance motors.

Then you come to solenoids. Solenoids are also electromagnetic by nature, unlike the other ones which are electro mechanical by nature.

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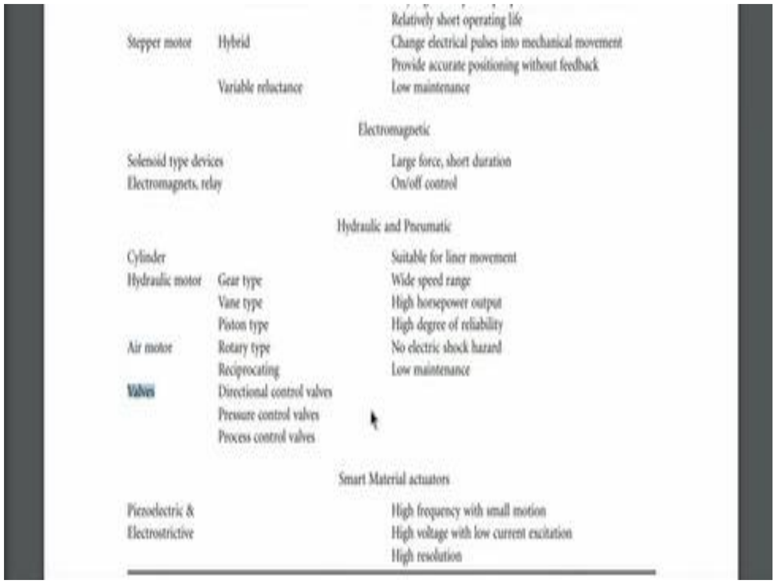

And you will have electromagnets relays all of them come into one class of electromagnetic large force, short duration on off something that you can be guaranteed. Then, we will do a demonstration of solenoid type of device which comes under the electromagnetic category. Then you can also have hydraulic and pneumatic you have hydraulic motor, then you have air motor then have walls which are also directional control walls, pressure control walls and so on.

They are all coming under the hydraulic and pneumatic kind of actuators. You can also have smart material actuators a really strong upcoming area piezo electric and electro strictive kind of actuators these are all for high frequency with small motion, high voltage and low excitation and high resolution kind of actuators.

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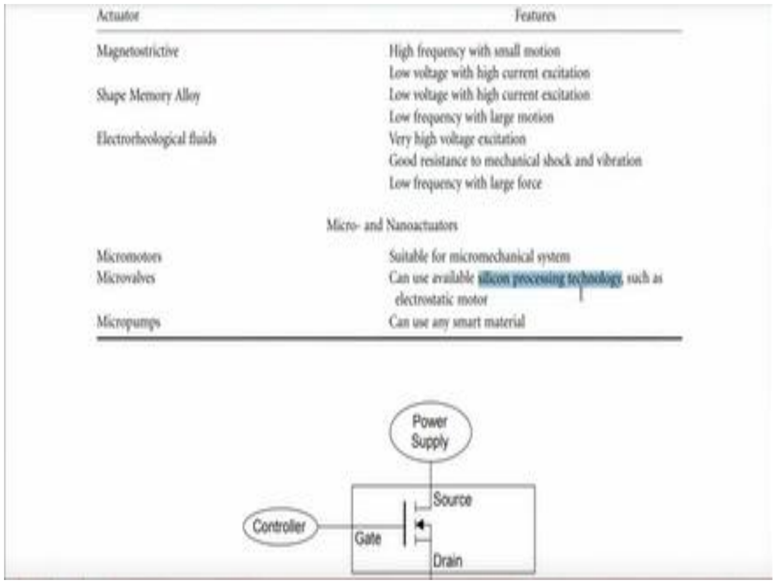

So, again, shape memory alloy is something that is very popular under this broad category of smart material based actuators, micro motors, micro valves, micro pumps all of them come under micro and nano actuators. They are all mostly PCB mounted kind of micro motors very small motors, suitable for micro mechanical systems and they can be available using silicon processing technology and it can be like a micro motor on a chip.

So, that is typical of what we talked about in micro motors and micro walls and they may have medical applications, several of them have medical applications. So, that is broadly what you have in terms of actuators that you will find and I hope if you read this document, you will get to know a lot more. The point is in terms of the selection of the different type of actuators, there is a requirement to know what are those technical parameters with which you; should select a particular type of actuator.

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dominates the power needs and the coupling mechanisms of the entire system. The coupling mechanism can sometimes be completely avoided if the actuator provides the output that can be directly interfaced to the physical system. For example, choosing a linear motor in place of a rotary motor can eliminate the need of a coupling mechanism to convert rotary motion to linear motion.

In general, the following performance parameters must be addressed before choosing an actuator for a specific need:

Continuous power output—The maximum force/torque attainable continuously without exceeding the temperature limits
Range of motion—The range of linear/rotary motion
Resolution—The minimum increment of force/torque attainable
Accuracy—Linearity of the relationship between the input and output
Peak force/torque—The force/torque at which the actuator stalls
Heat dissipation—Maximum wattage of heat dissipation in continuous operation
Speed characteristics—Force/torque versus speed relationship
No load speed—Typical operating speed/velocity with no external load
Frequency response—The range of frequency over which the output follows the input faithfully, applicable to linear actuators
Power requirement—Type of power (AC or DC), number of phases, voltage level, and current capacity

In addition to the above-referred criteria, many other factors become important depending upon the type of power and the coupling mechanism required. For example, if a rack- and-pinion coupling mechanism is chosen, the backlash and friction will affect the resolution of the actuating unit.

So, I have you know, these many points that you may want to look up I have it right on the table here. You have continuous power output range of motion, if it is linear or rotary kind of motion, what is the range? How many mm will it move how many centimetres will it move and so on. What is the maximum force if it is continuous power output or torque? Torque is usually measured in Newton meter. What is the kind of torque it provides.

Resolution: What is the minimum increment in force or torque? That you can see. What is the linearity? What is the accuracy of the system? Peak force or peak torque, heat dissipation in terms of maximum wattage of heat dissipation; speed characteristics, speed torque characteristics. When you plot any motor, you are interested in finding out at what speed you get the maximum amount of torque.

So, speed torque characteristics of the motor you may want to look at from the specifications of the manufacturer. And you may want to choose based on the speed you are likely to operate on for your application. So, all those matching will have to be done based on very important I keeps stressing it 100 times in this course data sheet will tell you what is the motor to choose if you are looking at the right speed and what is the torque requirement for your for that particular speed.

Then there is frequency response and then there is also the power requirement which is an important thing. So, these are broadly what you want to look up the type of actuators which are out there and the selection criteria that you may have to apply. Basic principle of the actuators is mentioned in this document, which you can easily download. I really appreciate this document because it has covered the actuators in some detail.

And it is good for you to read up yourself. In fact, it also has something on sensors. So, if you go up and look up this document sensors and actuators you can easily download this chapter it is chapter 16 on introduction and actuators.

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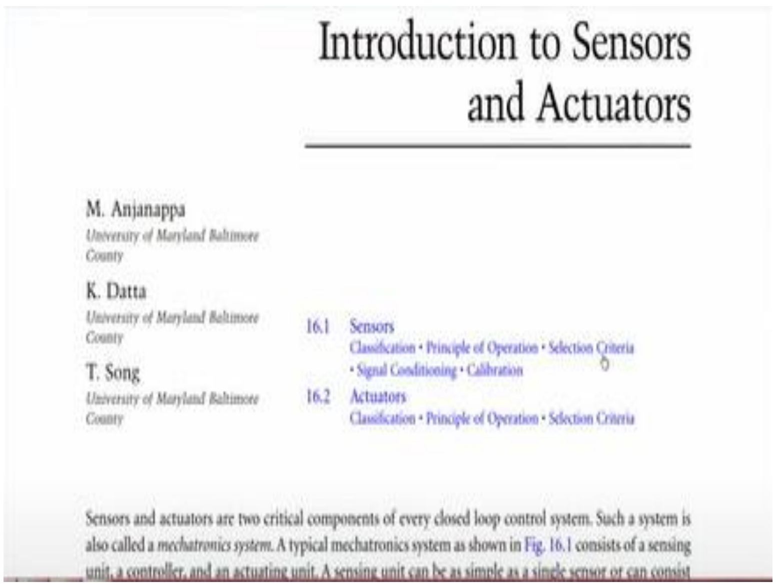

So, this is the paper introduction to sensors and actuators written by three people here three researchers and they have covered done a good job of it. Sensors also you can spend because sensing is an important thing. Please do look up the sensors also. And then of course, actuators you can directly use from whatever we discussed here. You can go through this file in great detail.

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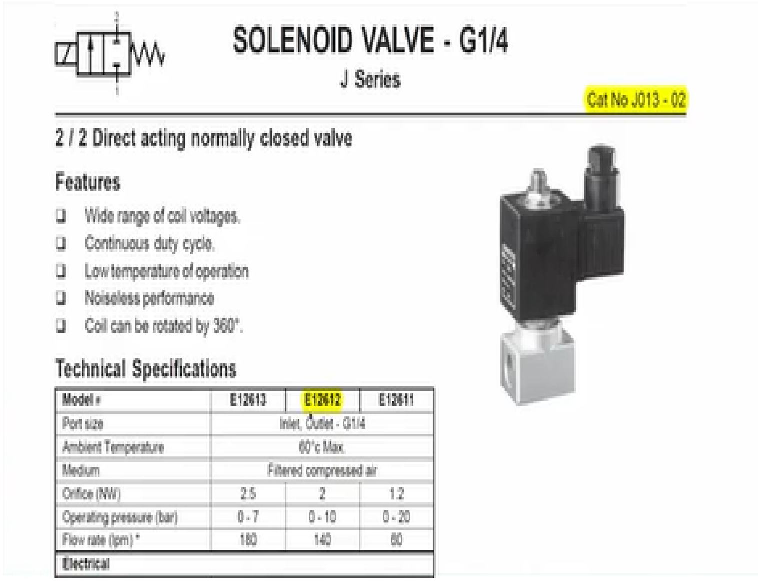

SOLENOID VALVE - G1/4

J Series

Cat No J013 - 02

2 / 2 Direct acting normally closed valve

Features

- Wide range of coil voltages.
- Continuous duty cycle.
- Low temperature of operation
- Noiseless performance
- Coil can be rotated by 360°.

Technical Specifications

Model #	E12613	E12612	E12611
Port size	Inlet, Outlet - G1/4		
Ambient Temperature	60°c Max.		
Medium	Filtered compressed air		
Orifice (NW)	2.5	2	1.2
Operating pressure (bar)	0 - 7	0 - 10	0 - 20
Flow rate (lpm) *	180	140	60
Electrical			

Strain gauges are important from my sensor perspective do read up strain gauges, the corresponding circuits for strain gauges then there is acceleration sensor, flow sensor, temperature sensor, proximity, light, smart material sensors, micro and nano sensors like actuators also, micro and nano sensors then associated selection criteria. So, you see range resolution, accuracy, precision, sensitivity, zero offset, linearity.

Zero drift response time, bandwidth, resonance operating temperature, dead band, signal to noise ratio all important parameters; for choosing a sensor of interest and what kind of signal processing the kind of calibration that is required for these sensors. Particularly, if you look at air quality, you must look up the sensor manufacturer for the calibration curves. So, all of that will have to come again from the datasheet very, very important.

Then of course, what we discussed now is about the actuators now, let us move on to an actuator of interest to us. And I will point you to the actuator that we would like to show you and that comes from this company it is called genetics. This is a solenoid valve and the solenoid valve of interest that we would like to demonstrate is this model E12612W and again as we just discussed, it is important to know the technical specifications of this valve, solenoid valve.

So, you have to go there and look up the specifications in great detail. So, there you are, this is the wall of interest category number is J013-2, you can see features are wide range of coil voltages, continuous duty cycle and low temperature of operation, noiseless performance, coil can be rotated by 360. Why should you see a picture like this when I have this in my hand?

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So, let us look at my hand now, see this is the same wall that we have here same thing that you saw in the picture, this is operating at 24 volts and these are the two wires you apply a voltage. This is a binary solenoid valve will open you give a command; it will open you give another command it will close. And this is mainly used for air applications. It is air that it is trying to allow or disallow or block. So, that is essentially the function of this actuator there is a nice specification here.

It says this is DC, 8-Watt solenoid valve it consumes 8 watts of power and its duty cycle of operation is 100%. That means it is giving you either on or off, on or off that is what it is trying to tell you there is nothing like you can keep it in the middle position. So, essentially that is its operation.

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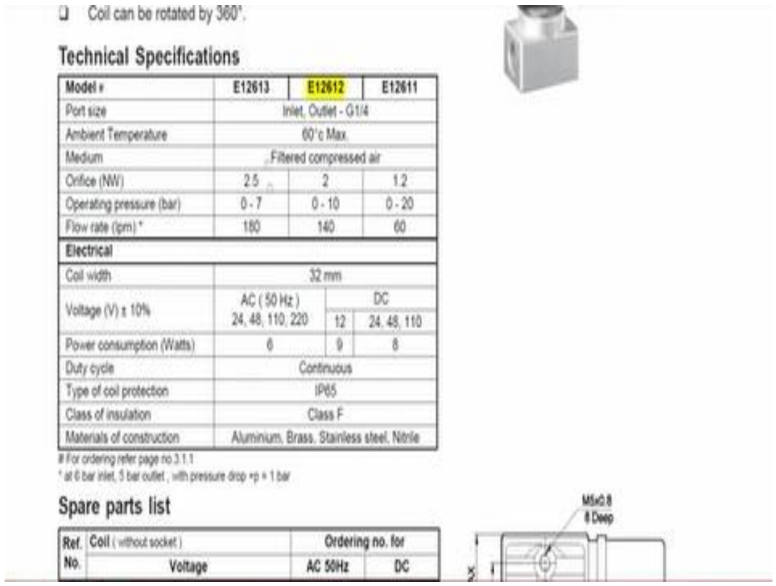

❑ Coil can be rotated by 360°.

Technical Specifications

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Orifice (NW)	2.5	2	1.2
Operating pressure (bar)	0 - 7	0 - 10	0 - 20
Flow rate (lpm) *	180	140	60
Electrical			
Coil width	32 mm		
Voltage (V) ± 10%	AC (50 Hz) 24, 48, 110, 220	DC 12	DC 24, 48, 110
Power consumption (Watts)	6	9	8
Duty cycle	Continuous		
Type of coil protection	IP65		
Class of insulation	Class F		
Materials of construction	Aluminium, Brass, Stainless steel, Nitrile		

For ordering refer page no 3.1.1
* at 6 bar inlet, 5 bar outlet , with pressure drop +p = 1 bar

Spare parts list

Ref. No.	Coil (without socket) Voltage	Ordering no. for AC 50Hz	Ordering no. for DC

So, you look up the technical specification, maximum temperature remember we did talk about the selection criteria and the technical specifications. Ambient temperature is mentioned here it is 60 degrees, medium is filtered air, compressed air and orifice is shown operating pressure is shown. And 0 to 10 bar is the maximum it can control and flow rate is 140 litres per minute. And coil width is mentioned the electrical parts are also mentioned.

And it is meant for outdoor applications, that is why it is IP65 protection and the class of installation is mentioned and so on. So, let us now shift to demonstration and I will explain the demonstration setup for you.

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What you see is power supply here and this power supply will essentially you will see the current consumption change. And I let you locate the change in the current consumption. What you have here is a source which generates a certain amount of pressure. And It tries to fill up this cylinder let me take this. So, this is the source which is generating some amount of air and this air with a certain pressure is filled up in this cylinder small little cylinder and this is measured by this sensor.

This sensor will measure the pressure inside and switch this off. Moment this pressure is reached this pressure be sufficient to open this valve. This is the solenoid valve of interest is a very basic demo where sensing and actuation both of them are together. You will hear a peculiar sound whenever the actuator goes on. And whenever the actuator goes on you should also be able to find out what is the current consumption.

I must tell you the operating voltage is 24 volts. So, what should be the current consumption that you expect? So, that the specification of the wall is 8 watts, roughly 8 watts. So, you should be able to see that about roughly 8 watts of power is actually consumed every time there is a solenoid operation. So, this is the demo setup. So, let us see what actually happens. Let us start it and then let us see what happens.

See, now, you hear that sound. This is coming from the solenoid. Every time the solenoid is on look at the current consumption on the screen, you get roughly 0.32 amps you can see that it is 0.33, 0.32. It may even go up to 0.37 and sometimes it may be fluctuating for you can see now it is zero it is off, solenoid it is off. Now, you can again see it will go on there you are there you are. The current consumption is not measured cannot be measured directly like this.

But if you keep it on you will see it steady state current. Let us keep it on in steady state. There you are, see, 0.38. So, now you can calculate what it is, voltages and that is about it this demo. You saw that there was a nice source which generated certain air with a certain pressure it was filling up this tank, small little tank cylinder and that the pressure was being measured by this pressure sensor.

And moment that pressure reached this source was turning off at the same instant in time this actuator turned on. So, that is the basic demo of sensing and actuation.

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This is something which is familiar for you the one in my hand. This is used for water; it is also a solenoid valve. But it is used for water applications what I showed you there was for air. This is for water inlet and outlet and this is what is typically used in all the water filters. Solenoid valve operating at 24 volts. Remember, solenoid valves industrial applications, they are mostly 24 volts be very clear about it, that is one this is one type.

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Then this is a pump. This is used to measure this is used to maintain a certain flow of air. Suppose you are making air quality measurement and your air quality sensors have to be maintained had to be measured at a fixed flow.

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And that time you use a pump like this and this is also an actuator, the second one. Then you have a fan, a simple fan. This is also an actuator. So, you have different type of actuators which you can put up in an IoT system and start looking up, and start designing your experiments around these sensors and actuators. Thank you very much.

(Video Ends: 23:32)