Sensors and Actuators
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Lecture - 46
Basic of Pressure Sensor and Demonstration using Arduino Microcontoller

Hi, welcome to this is demonstration class. In this class we are not taking into the lab, but we will kind of give you an understanding about the pressure sensor and then how can you use pressure sensor with Arduino as a microcontroller ok. So if I want to use pressure sensor, if I press it then how can I change this pressure value or how can I see what is the pressure there were applying in terms of some digits. So, can I use a arduino as a controller in between as a interfacing module to measure the change in the pressure at the output signal.

So, this is the demonstration class we have thought a lot after, before putting this particular class to this course work. And it makes lot of sense because once you have pressure sensor how you will be using this in single condition module to use the pressure sensor. So, focus on this class and if you any question just you can feel free to ask me, I will just request some other teaching assistant to show it you how to use pressure sensor with arduino module as a demo class right. Till then you take care, have any question please ask me I will see you in the next class bye.

Hi, welcome to the Sensors and Actuator course. Today we will be discussing about a pressure sensor. So, I will be showing a demo with the pressure sensor called as BMP180 which is developed by Bosch. And also I will be explaining about the working principle of a pressure sensor ok. Professor Hardik must have already discussed with you regarding how a pressure sensor is fabricated, how a diaphragm is fabricated out of silicon and other things.

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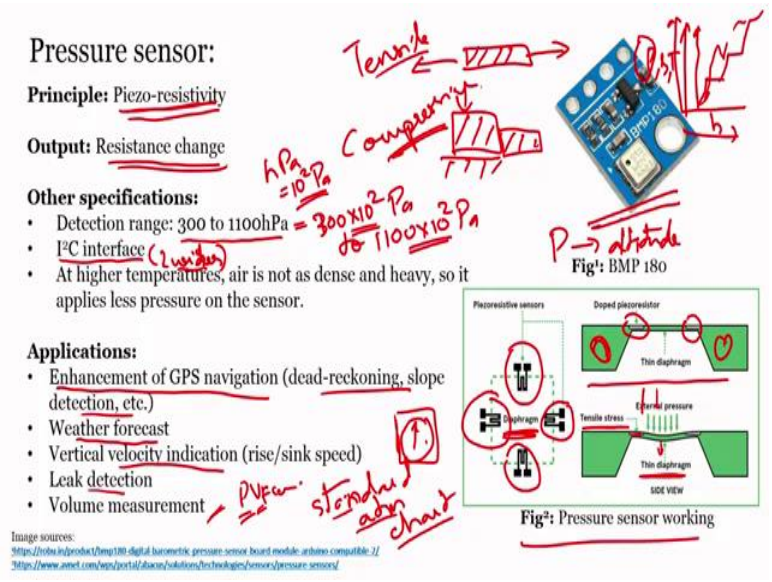

So, now I will be showing a practical example of pressure sensor like that. So, today we will be discussing about this BMP 180 sensor that you can see on this side ok. So, this is the pressure sensor that we are going to discuss today ok. So, BMPs like many other sensors that are working based on piezo resistivity. So, you must have also heard about piezo resistivity piezoelectric nature and so on.

So, it is basically like if it is a piezoelectric material then if you apply the pressure it will generate a potential. When a piezo resistive material will exhibit a change in resistance? So, what a pressure sensor over here will be using is, it's piezo resistive property. So, you can see here. So, this is the how the construction aspect of pressure sensor that we are going to use here, ok. So, you can see here that there are piezo resistors ok. And in the sender there is a diaphragm ok.

So, a diaphragm and in the four edges of the diaphragm there are piezo resistors. And the diaphragm over here this is the side view or a section view so you can see there is a piezo resistor here there will be a piezo resistor here on the both sides and the thin diaphragm is between it. So, this diaphragm is actually like hanging on this 4 piezo resistors ok.

So, that is how the construction of it is. So, this will be a solid region and by machining micro machining operation we have got a thin diaphragm and we have also build piezo resistors on it ok. Now before further more into this I will like to tell you about some more things regarding pressure ok.

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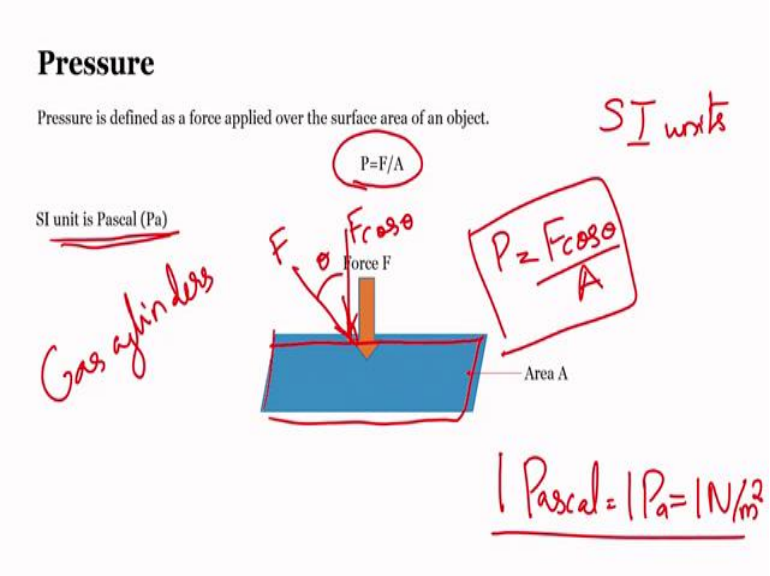

So, what is pressure actually? So, you must be aware of force what is force? Force is like, force is what do you apply on a object to move it. So, if I am moving a cart by pushing it, I am applying a force right. So, this is what force we know different kind of force gravitational force, electrostatic force, mechanical force such many of such stuffer there. And pressure is a concept that is related with force and it is the pressure is defined as the force applied per unit area or the pressure is the force applied over an area and the equation of pressure P is equal to F by A.

Where F is the force applied and A is the area on it is acting and pressure is always acting normal to the surface and this area is the surface area and the force acting on it is considered as the normal force acting on it ok. So, you can see here ok. So, this force over here is a normal force and not inline force. So, the pressure if it is an inline force like what I am going to show now so if it is an inline force then the normal component will be like this; over a theta if this is F then this is going to be F cos theta and then the pressure P acting on the surface will be F cos theta by area ok.

So, it is the normal component over the force by the area over which it is acting ok. So, in SI units you know SI units it is ok. In SI units the unit of pressure is Pascal. And 1 Pascal or 1 Pa that is how we denote it in short form is equal to 1 Newton per meter square ok. So, this is the unit of pressure ok. So, we told you that when we apply a force

it acts on an area and that force per unit area is called as pressure, and it should be normal the force taken here is the normal force ok.

So, as I have seen if we apply an inline force this is how the force is resolved and pressure is calculated. So, we have an idea about pressure when we you must have heard of a gas cylinder ok, you must have heard of gas cylinders and there will be prescribed maximum limit for the pressure that can be stored in a gas cylinder and such stuffer there ok. So, we will go in to that now ok.

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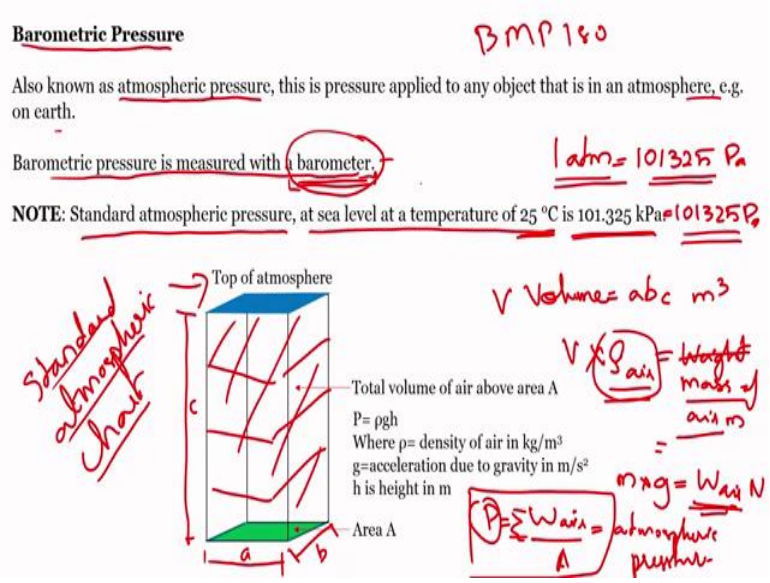

So, there is something called as barometric pressure ok what is called as barometric pressure you must have volume also heard of it as atmospheric pressure also. So, here I have a got a diagram here you can see this cuboid over here in its written the top of the atmosphere over here. So, consider this cuboid and this is the surface of earth. I am just giving an example; this is the surface of earth and consider a cuboid over like this.

And inside this cuboid there will be what air ok. This air also have its own density water has its density of like 1 gram per centimeter cube 1 gram per cc right. And similarly, metal have more density than gases and so on so you must have learned this basics before also. So, consider the atmosphere it has air ok. And I have considered this area of earth and this much air is over here inside this cuboid this is the top of the atmosphere.

So, whatever air is there in between the top of atmosphere to the surface of earth will be causing a weight this will have a weight. And in this case we could calculate it as; see if this is area length a and this is length b and say there is a height c then the volume of air will be a into b into c ok. Whatever unit may be it could be in meter or whatever it is. So, the volume can be a b c saying it is in meter cube though so we have the volume and if we multiply this volume V this volume V into the density of air.

I am writing rho. Rho is density of air then what we get is the what the weight of air right or mass of air actually it is the mass of air. And if I am multiplied with; so this is the mass of air say m and if I multiply this mass with the acceleration due to gravity then I get the weight of air ok. So, this much weight is equivalent to force and then Newton of the unit of weight is nothing but Newton. So, this much volume of air over here will cause a weight of W air and this will create a forcefully and this force acts on this area A.

So, the pressure acting over here P will be is equal to W air correct W air by this area. So, this much force is acting here. So, this is a very basic concept and then we call this pressure as atmospheric pressure atmospheric pressure. So, it should be understood that this is not exactly like the density of air is not a constant like; I assumed here as rho air it is not constant it varies with the altitude you know that there is different layer heights for atmosphere so it actually varies.

So, in the troposphere will be different stratosphere will be different and it depends on temperature and a lot of parameters and we have something called as standard atmospheric chart. So, this is not important for the course, but you should understand that there is something about standard atmospheric share chart, with which is not just a chart. It has the relation between temperature density and a lot of parameters related with atmosphere air its density a lot of thing.

It is actually a good thing to know it is like very passionating thing you can actually look into that anytime ok. So, even though I told this as symbol as this it is not like this so it does this pressure actually is not like this it is actually a sum up of the various densities and other things so at different layers we will have different densities, different weights all sum up to finally, this.

So, we can say the total weight the sigma of whatever weight of the area is the atmospheric pressure. And at sea level its being calculated that the standard atmospheric

pressure at sea level at a temperature of 25 degree Celsius. It is very important in to note that this pressure that is 101 325 kilo Pascal or is equal to 101 325 Pascal is the same just in the kilo Pascal.

So, this value of is called as standard atmospheric pressure and it is at 25 degree Celsius ok. It is a 25 Celsius if temperature changes pressure changes so it is very important ok. So, this is the standard atmospheric pressure. So, we also have given it as a term or a unit as 1 atmosphere atm is equal to 101325 Pascal ok. This is a standard value remember this is always; 1 atmosphere is equal to 10 32 101325 Pascal ok. And this is called as 1 atmospheric pressure.

So, if you are going near a sea; near a sea and then the pressure of air acting on you is equal to 1 atmosphere and is equal to 101325 Pascal ok. So, this is also called as barometric pressure ok. This is called as barometric pressure so it is right it is also known as atmospheric pressure. Is the pressure applied to any object that is in an atmosphere example; on earth ok. So, barometric pressure is measured using a instrument known as barometer. This must be being all you must have measures studied this during a small classes itself that what is the instrument used to measure pressure? It is barometer. So, this is also a sensor ok.

So, we are going to see how we are going to use the BMP180. That we discussed earlier as a to be used as a barometer how it barometer is mechanical in nature the conventional one, but this one is in an electronic barometer that we are going to do ok. So, this is the one thing why I said about barometer pressure? I will tell you. So, there is something as called as manometric pressure also ok.

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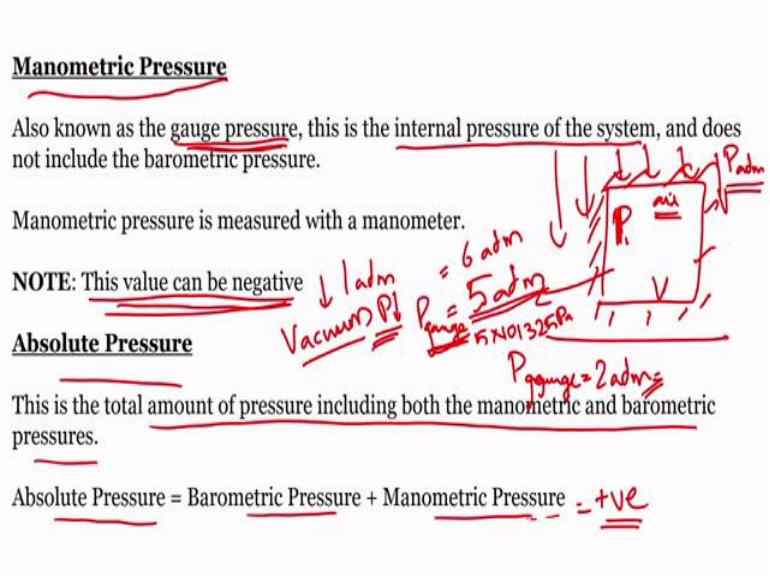

So, consider this is a cylinder this is a closed walled cylinder ok. In inside it there is air; air is there and the air is turned as a pressure ok; air is turned as a pressure P and the volume of the container fixed say volume V ok. So, there is P and V, I am just naming it as let will be P in see in this cylinder is on the surface of air so there will be atmospheric pressure acting on it right atmospheric pressure will be acting on it correct.

So, there is a term like; anyway there will be a pressure of around 1 atmosphere always on the surface of earth correct. So, we like; so it is already like 1 atmosphere is added to any pressure measure when we do; so we came up with a new term called as a manometric pressure ok. So, that we can get a value that starts from 0 so it is nothing, but it is the only pressure that is build up inside the system.

So, it is also known as a gauge pressure its known as a gauge pressure manometric pressure is also known as a gauge pressure. This is the internal pressure of the system; this is the internal pressure of the system and does not include barometric pressure. So, it is like a cylinder I say this cylinder this cylinder has a pressure inside is equal to 5 atmospheres. 5 atmosphere is nothing, but 5 into one atmosphere or 5 into 101325 Pascal.

That much pressure that is like higher pressure 5 times the atmospheric pressure is inside this then the gauge pressure is equal to 5 atmosphere. P gauge is or P manometric is equal to 5 atmospheres, but the real pressure or the absolute pressure that we will discuss

now is equal to 6 atmosphere. Because this 5 atmospheric pressure and pressure or the gauge pressure is devoid of the atmospheric pressure of the barometric pressure so this is like a new reference; a new reference that is devoid of the external pressure.

Anyway we know that there is an external pressure equivalent to P atmosphere. So, we will say that why we have to say again so keeping the atmospheric pressure as the reference point we will count from that. So, 2 gauge pressure of 2 P gauge of 2 atmosphere means nothing, but 1 atmospheric 2 atmospheric pressure greater than the normal atmospheric pressure that is it.

So, that is what a gauge pressure or manometric pressure is. So, very important to know that this value can be negative this value can be negative. Because see the atmospheric pressure that we discussed as 1 atmosphere; 1 atmosphere. We know that when we create a vacuum the pressure decreases, when we create vacuum pressure decreases correct pressure decreases. So, the pressure of the inside the cylinder if we create vacuum will decrease beyond 1atmosphere correct.

So, since 1 atmosphere was considered as the 0 for a gauge pressure calculation this value becomes negative now. This P gauge will be negative so the manometric pressure can be negative while the atmospheric pressure cannot be negative ok. And then we have the absolute pressure. So, it is nothing, but the total amount of pressure including both manometric and barometric pressure.

So, there is an absolute pressure that is equivalent to sum of barometric and manometric pressure and which will always be positive ok. Which will always be positive, because manometric pressure can reduce up to say if we create a lot of vacuum excellent vacuum then will be like be negative, but it does not go below barometric pressure a lot so the absolute pressure will always be positive ok. So, this is the concept that you need to know before we go into details of a pressure sensor ok.

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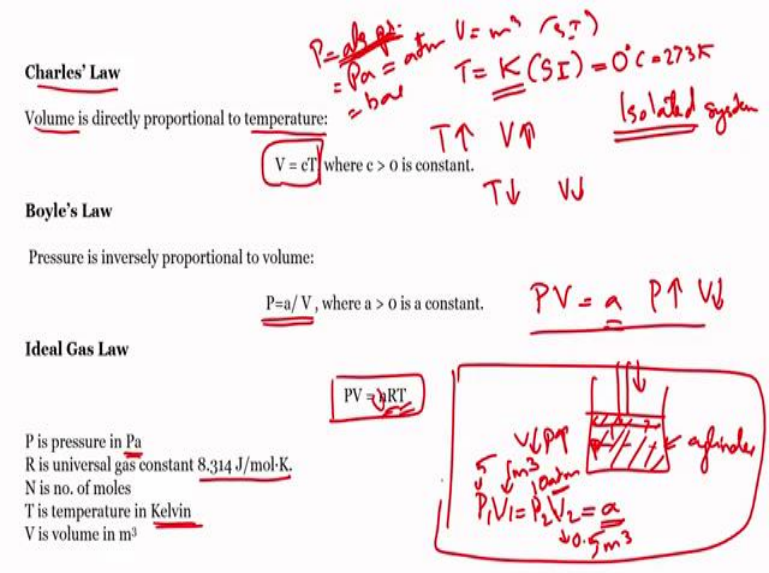

And one more thing that I think you should know is; some basics of thermodynamics that we must have known before ok. So, this is the it is the Charles law actually. So, Charles law is nothing, but volume is directly proportional to the temperature; volume is directly proportional to the temperature. So, when the temperature increases volume also increases. Then temperature increases volume increases or temperature decreases volume decreases.

This case is very tricky actually. So, this is in case of an isolated system actually; isolated system means in no energy is lost no energy or matter is lost outside then if we increase the temperature volume will increase for a isolated system ok. Then when we increase the temperature volume will also increase when we decrease the temperature volume will decrease. And then there is Boyle's law ok.

That is say that pressure P is inversely proportional to the volume or P V is a constant constant a or like that. So, if pressure increases volume decreases and one simple example is considered this is a cylinder then keeping a piston like in the SI engines and all ok. So, if I apply pressure here what happens is pressure inside the air is inside this cylinder when I applied a pressure here the cylinder is the piston is going to come down and the volume decreases correct volume decreases, when volume decreases what happens pressure increases.

You know this example; this example we will be showing you today that is why I am just telling you this basic example so that you will have the idea. And one more important

thing that you have to remember is when we use this equations you should remember that volume can be in meter cube or any other SI unit does not matter, but temperature should be in Kelvin; Kelvin is the SI unit of everything should be in a standard unit ok. Kelvin is the SI unit of temperature.

So, you know that 0 degree Celsius I mean 273 Kelvin right. So temperature should be in Kelvin and pressure should be in some standard unit and this standard unit should be in absolute pressure ok. We can use Pascal or atmosphere or bar these are all units of pressure only, but we should use the absolute pressure not the gauge pressure absolute pressure in the calculation.

For example, I would say according to this relation PV is a constant. We can say that P 1 V 1 equal to P 2 V 2 right. So, you understand that right, so initial pressure and initial volume the product of those two will be equal to P 2 V 2 will be is equal to a constant a correct. That is what according to Boyle's law happens. So, initially if the atmospheric pressure was 5 atmosphere and volume was 1 meter cube then if I increase the pressure to say 10 atmospheric absolute pressure then the volume will decrease actually, to how much to 0.5.

So, that this constant will remain same so this is how Boyle's law works ok. And then we also need not mention much, but ideal gas law is there that is PV is equal to nRT where n is the number of moles, R is the universal gas constant, which is equal to 8.314 Joule per mole Kelvin and T is the temperature in Kelvin. Remember always use the SI unit and SI units of pressure should also be in absolute pressure very important thing always remember this ok.

Now we will be going back to the pressure sensor ok. So, this is the BMP pressure sensor that we are going to demonstrate ok. Now I am going to apply some force here and external pressure will be acting over here ok. So, what happens is due to this external pressure that is going to act here like this; what happens is a tensile stress is going to reproduced, stress are of two type not two types more than two types are there, but I could simply say that you could pressure can be tensile; stress can be tensile stress and pressure are almost the same, but you know we are not mentioning that you will be confused. So, there is something means known as tensile stress.

For example, you tensile stress is that stress develop when you pull a block from this side and this side. So, it will stretch right like; a rubber band you stretched. So, that is the tensile force. And you take a sponge is keep it somewhere and you apply force then it compresses right and it reduces the size this is called as compressive force ok. And the stress is called as compressive stress or compression stress ok, tensile stress conversion that is the stress that is going to happen. So, be here tensile stress will be produced due to this external pressure over a here on the thin diaphragm.

So, the thin diaphragm will deform and when it deforms or it comes down, what happens is this since this piezo resistor does not stretch much there will be tensile stress and this will goes the change in resistance and that is why we are saying that this is piezo resistive sensor ok. So, the output is actually a resistance change so there are four piezo resistors here and we will be using an so we will be using a signal conditioning unit to get this output ok. So, this is how a pressure sensor works.

And this BMP180 ok, it has a detection range of 300 to 1100 hecto Pascal, that is equal to 300 into 10 power 2 Pascal. Hecto Pascal is equal to 10 power 2 Pascal; 10 power 2 Pascal. So, 300 into 10 power 2 Pascal to 1100 into 10 power 2 Pascal. This is the measurement range of this pressure sensor ok. So, and it uses something else called as I square C interface with arduino you know when I am going to show the example; I will tell you so this is a different mode of communication this is also serial mode of communication only, but it uses 2 wires ok; for the 2 wires for communication.

So, it is like; a serial communication only, but with very high speed. So, it is an I square C communication, we would not be going too much into it ok. And, so this is the main thing good. Then why we use this is? I told you initially about the standard atmospheric chart rate. We talked about standard atmospheric chart there the pressure variation as well as density variation everything will be plotted it is like a graph like this; various values will be shown.

So, it is like; so I will be plotting say pressure here, density here, temperature here on the y axis in different y axis. And we would be plotting altitude h on this thing and it will be like the temperature first increases, then draw its stay similar like this and the pressure actually increases then strokes something like this it is not exactly like this, but something like this.

Why we develop this standard atmospheric chart is? For mainly, because we need to do a fly aircrafts and rockets and everything, since over these things find the air, we need to exactly know the pressure variation so that we could adjust the thrust and everything in the aircraft. So, this pressure sensors are widely used in aircraft and other things to measure the pressure outside and do the calculation as well as and base this; since the atmospheric pressure at that height will be more or less they constant they even use pressure sensor to calculate the altitude ok.

So, they will measure pressure and predict the altitude. So, a lot of applications are there for a for pressure sensors. So, why it is written as enhancement of GPS navigation is that; when we get the pressure value we will be exactly able to know the height range and all ok. So, slope detection everything then we can do weather forecast ok. So, when temperature changes there will be change in pressure. So, we can use it for weather forecast and vertical velocity indication. So, this is for the aircraft they have a instrument inside it ok.

So, it is something called like this; with it is called as a vertical velocity indicator and all. So, what happens is when it moves fast when move fast based on the pressure variation it will show the velocity at which it is moving up and down ok. And leak detection; if we keep a process insert inside a cylinder if its leaking the pressure will drop gradually and we will be able to know that there is leak and for volume measurement, as I said PV is a constant ok.

If pressure decreases we know that the volume of air also the pressure, if pressure decreases then the volume actually increase ok. So, we can do a lot of things like this ok. So, this is about the pressure sensor. Now we will switch to the showing how it happens in arduino. So, you can see here I have connected the BMP pressure sensor to the arduino due ok. You can see here and there are four cables that is coming from the BMP pressure sensor it is the same that the pressure sensor is almost the same thing that I showed you in the presentation.

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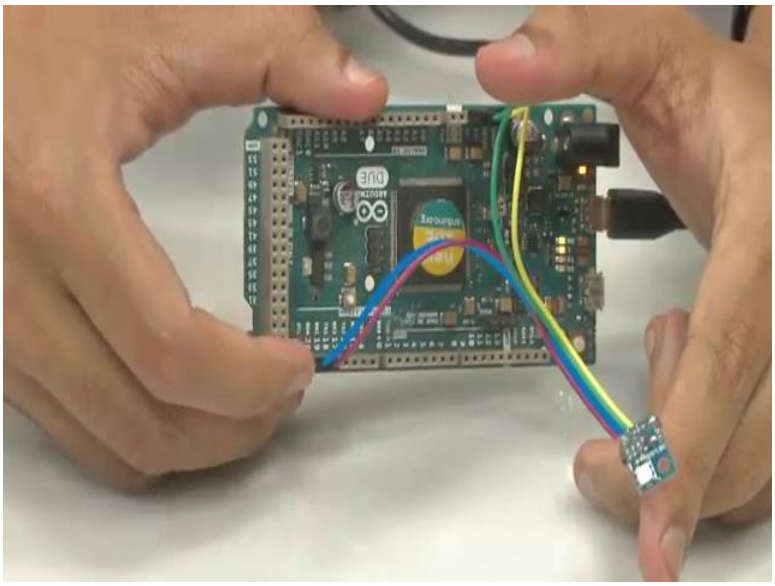

So, you have here the casing with the thin diaphragm inside and four cables come out of this out of which one is 5 volt one is ground and then there is SDA and SDA and SCL ok. These are the two connections that we use for I square C communication you can see here I have already connected it ok. Now we will move on to the arduino programming ok.

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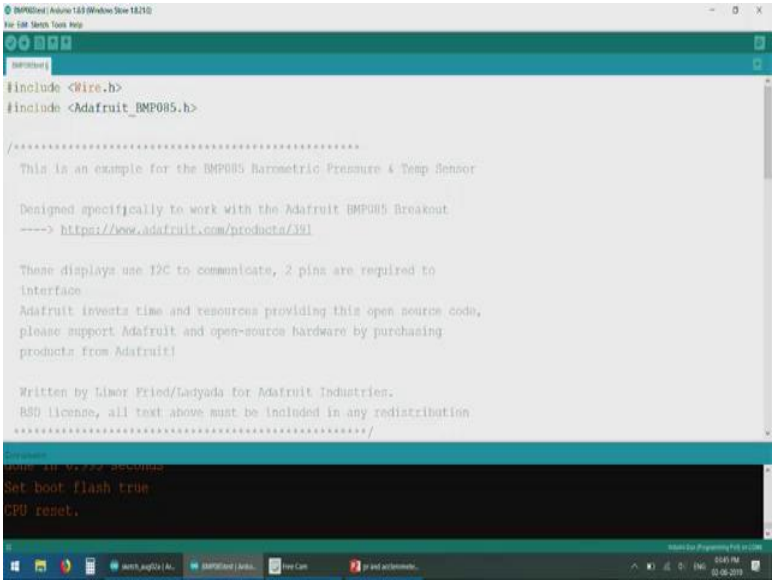

So, here it is the same thing that we always used to do ok, we can see that in the tools I have added a new library BMP180 ok.

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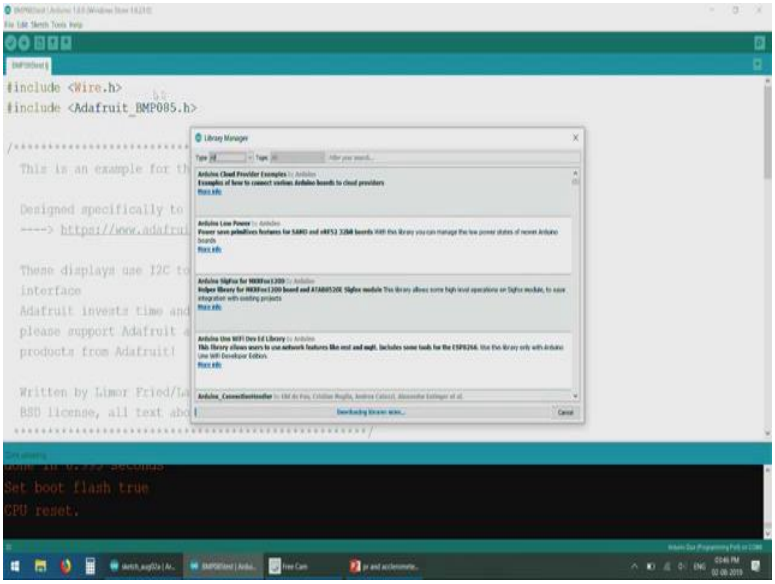

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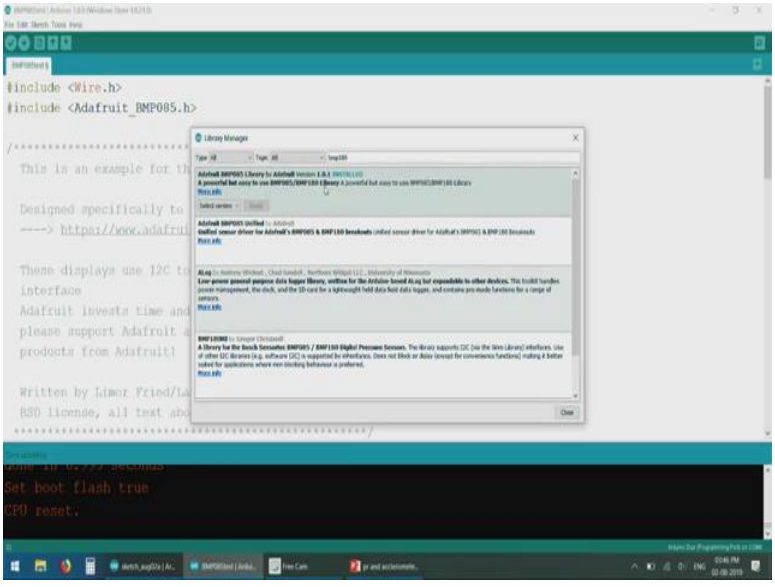

So, you can add it otherwise it is a bit of tricky to code the I square C communication by yourself, but so it is better to use it directly if you are not very experience. So, I have already installed in BMP c 085 or BMP180 library is available here. So, we you can just installed it. I have already installed it ok.

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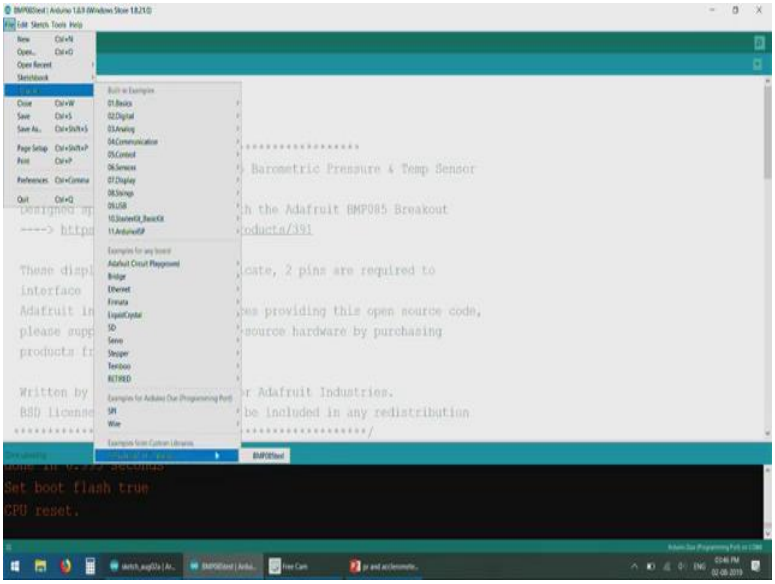

Now, you can see that from the file examples, I have selected this code Adafruit BMP library here, this is the code over here and there is a header that we have to call for wire dot h that is used for the I square C communication. So, wire dot h is popularly used for communication protocols and it has a function inside it and we also added the Adafruit BMP085 library in do it.

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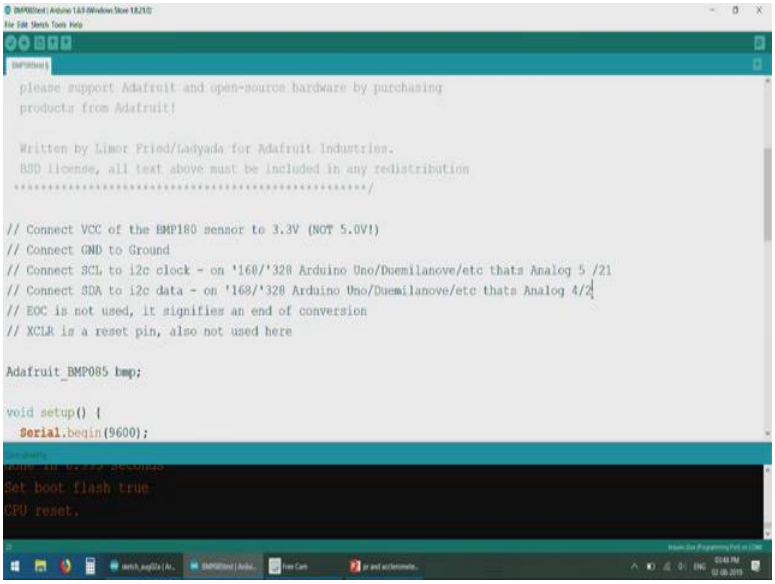

Then we already since we have connected the VCC of the BMP180 sensor here it is 085, but in our case it is 180 it does not matter any way it is command ok. And it should work

at 3.3 volt it is working level is 3.3 volt and not 5 volts. So, you should remember that connect the ground to ground of the arduino and the SCL pin from the SCL or the clock pin from the sensor to the clock on the arduino. And in case since we have use the arduino due ok the SCL pin is pin number 21 digital 21 and the other pin is pin number 20 SDA pin in due is pin number 20 ok. So, we have connected it like this.

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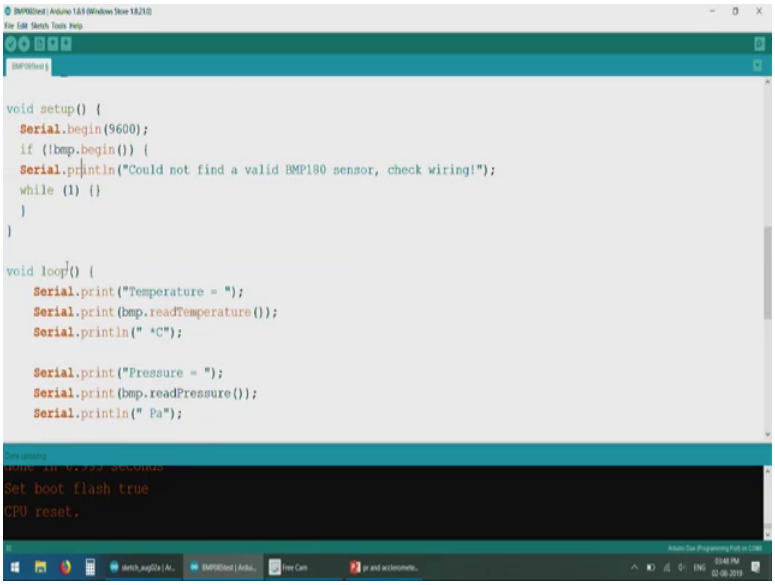

Then there is a bit of code over here. So, its bmp dot begin it is like the communication we have used before also the serial dot begin similarly, we have used bmp dot begin here; that means, a serial communication is starting between bmp sensor and the arduino board ok. Then inside the void loop we are using a set of functions like bmp dot readTemperature and other things and we have bring it on the serial monitor.

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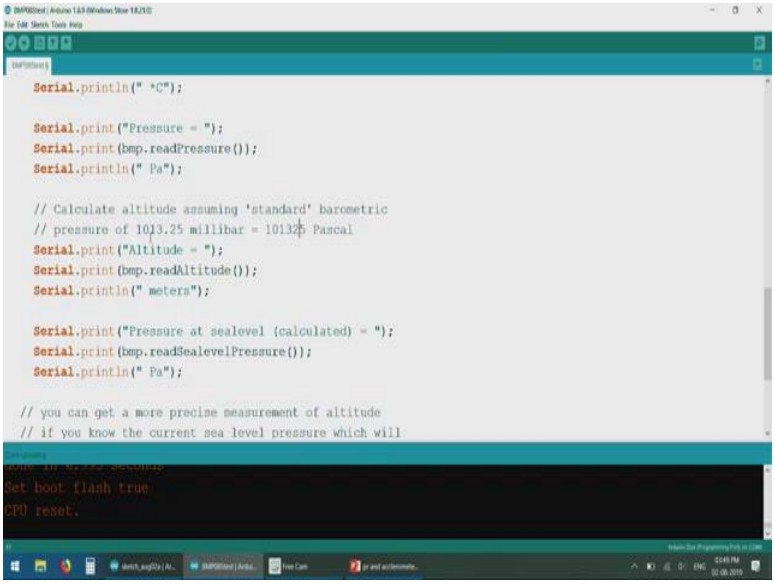

Why we are doing this system we can easily use the sensor without much coding, so that you can easily understand ok. So, what it will show is Temperature; there will be Temperature feedback from the pressure sensor. So, these Pressure sensor also have Temperature measurement inside it. So, we can read the Temperature, then also we can read the Pressure ok. And based on the assumption that standard barometric pressure is 101325 millibar over 101325 Pascal. We can calculate altitude.

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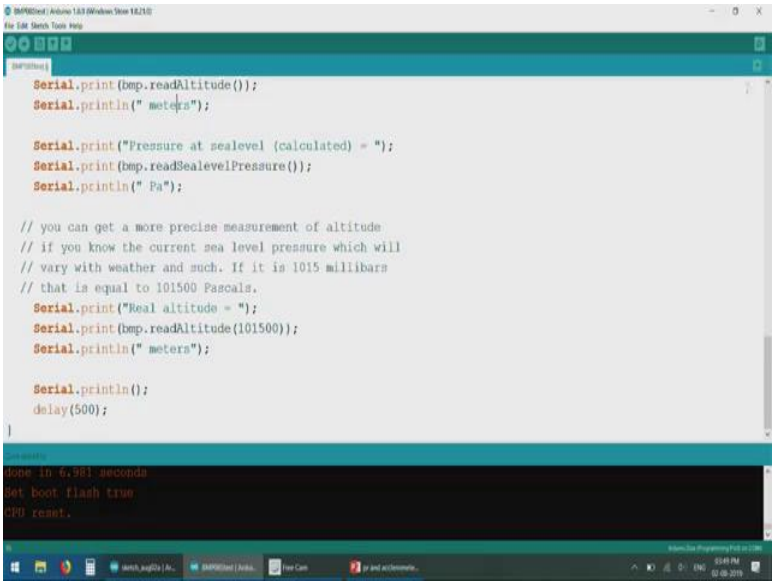

As I already said aircraft use this method to of like; the measurement of Pressure will be converted to the measurement of Altitude. So, you can see that Altitude can be measured, pressure at sealevel can be measured and lot of things are possible the real Altitude everything so I am just going to select the borders arduino due when programming port its already selected and the comp port and I am going to verifying the code now and I am uploading the sketch now.

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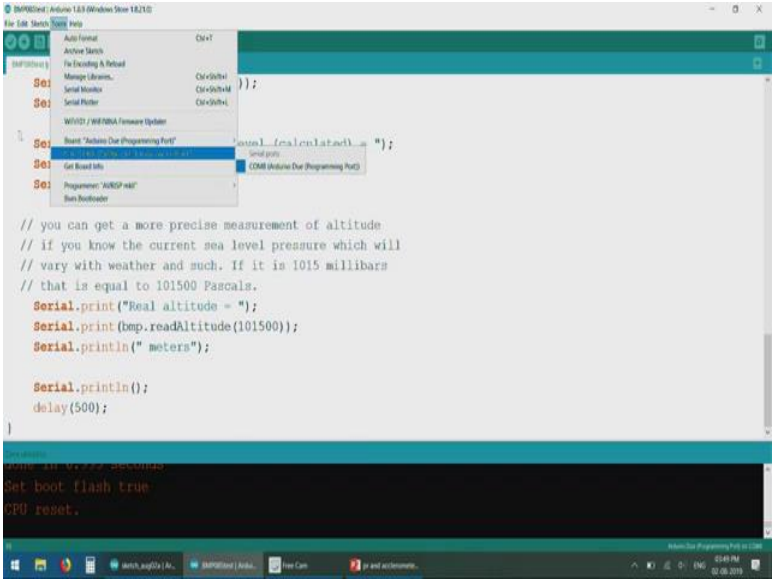

So, this code will be uploaded into the Pressure sensor now ok. Now if I select the serial mode drafter uploading here the blue progress bar is here, it is just getting uploaded only it is done uploading I am selecting this see I can see the temperature and other things ok.

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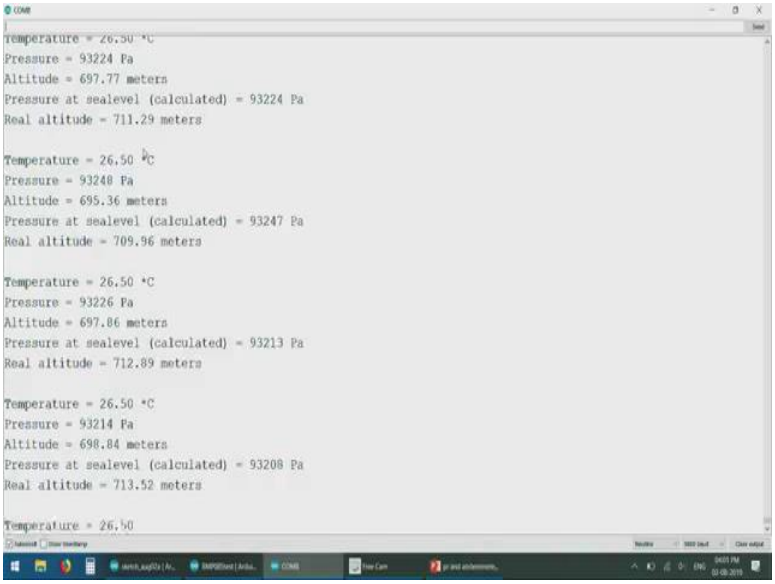

Its showing the Temperature as 23.5 degrees Celsius; 23.5 degrees Celsius and the Pressure as, 9054 90539 Pascal and then Altitude of 939 meters ok. So, I am sitting in Bangalore right now. So, Bangalore is at an elevation of around us according to the sensor it says that, 939 meters you can actually check how high is Bangalore from the sealevel to cross verified? I do not know exactly, but, let us see and also you can see that the pressure is this Pressure is the absolute Pressure right.

And this absolute pressure is less than the atmospheric Pressure it is because at a higher altitude at a higher altitude this Pressure actually decreases the atmospheric Pressure actually decreases so it is below 101325 Pascal. And if we measured the gauge Pressure using a gauge pressure sensor over here then what will happens is we will get a negative gauge Pressure right we will get a negative gauge Pressure. Because the gauge pressure is equal to the absolute Pressure minus atmospheric Pressure or barometric Pressure.

So, which is equal to this pressure 90538 Pascal minus 101325 Pascal which will give you a negative gauge value ok. So, this is how we connected between absolute Pressure and gauge Pressure ok, you should understand that and similarly, you must also remember the Charles equation Boyle's equation and everything ok. Now that you have seen this I will show you the variation in the pressure also. So, will put the gas sensor inside gas sensor inside a balloon inside balloon over here ok and I will inflate the balloon and seal it ok.

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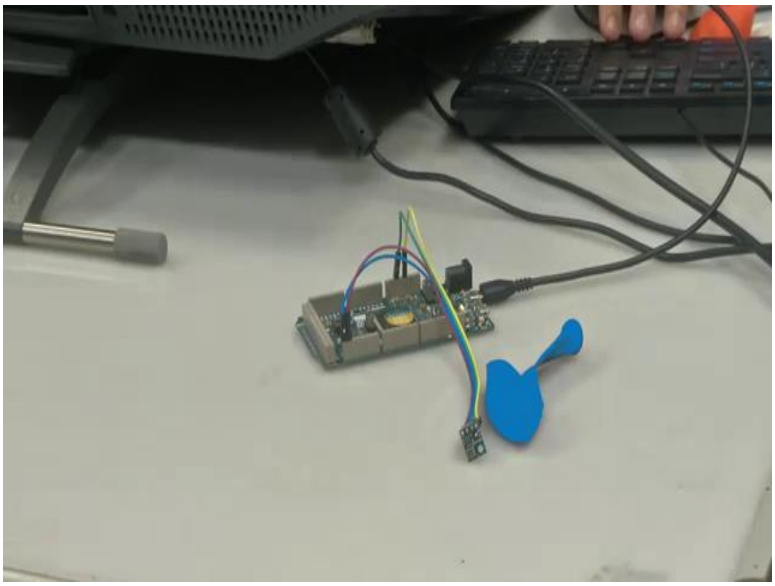

So, when I do that what happens is the volume of the air within the balloon will be like concentrate, because one size seal it off the air cannot go out correct air cannot go out. So, if I compress the balloon what happens is the pressure will build up according to which equation; the equation over here that we have seen which one that see it is the Boyle's law.

According to the Boyle's law what happens is when we decrease volume pressure will increase ok. So, according to the Boyle's low what happens is if we compress the balloon the pressure will go up and we will see that on the serial monitor ok. Now, we will do that once.

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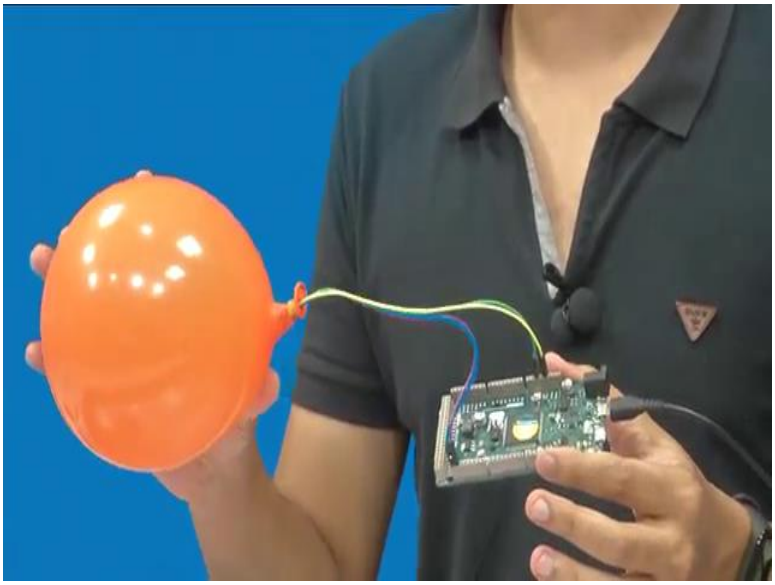

So, I have put the pressure sensor inside the balloon ok. So, it is like this now you can see that the pressure sensor is within this and I have connected everything. So, theoretically what should happen is when I compress this the volume decreases and the pressure should increase, but since this is a balloon can deform it can deform. So, if the pressure in change would not be so visible, but still you can see a pressure change in the serial monitor ok.

Now, you just look at the serial monitor now so the value of pressure is around 92000 Pascal 92000 600 or 680 Pascal. So, if I am going to compress it now compress the balloon see I am going to compress the balloon. And you can see that the pressure has increased to 93347. So, the there is a increase of pressure of around 500 Pascal correct I am leaving the hand now again back to normal see the pressure has even drop back to the normal 92600. Again I am compressing it; see the pressure has increased correct.

So, you can see that it is calculating the pressure accordingly, but you can see also something else that when I increase the pressure you can see the values that the altitude has what decrease. So, it is the calculation actually an error, because when the pressure increases accordingly the altitude should also decrease correct. So this is how the BMP180 pressure sensor works ok. I hope you understood how the BMP180 pressure sensor works and I think the concept is clear you can also know how micro fabricated sensors using thin as well as thick film sensors are widely used ok. So, that is it

Thank you.