Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Introduction to Experiments in Flight

Lecture-09
Sensors Part-I

by
Prof. A.K.Ghosh
Dept. of Aerospace Engineering
IIT Kanpur

Hello friends, So far in this course you have seen how to measure different deflection of control surface, how to calculate centre of gravity and all this experiments require different sort of senses to be either calibrated or regarded the software which we use for lab view. Now for all this sensor data collection, we use the module an IDAC card can be used. Now today what we will be concentrating on, how this senses work and we collect data using this sensor.

Before this lecture we use an **IDAC,** but for illustration purpose or demonstration purpose we will be using a processor board that is ordinal you know and MEMS sensor that is micro electro mechanical systems and the code will be using a Drano ID or any other software such as C++ or Matlab, or any platform you want and write that code. So today is lecture will be basically on various types of sensors and their working principles and how do we collect data from them.

So the different sensors which we will be discussing are first pressure sensor now these pressure sensors usually used to calculate the altitude and air speed.

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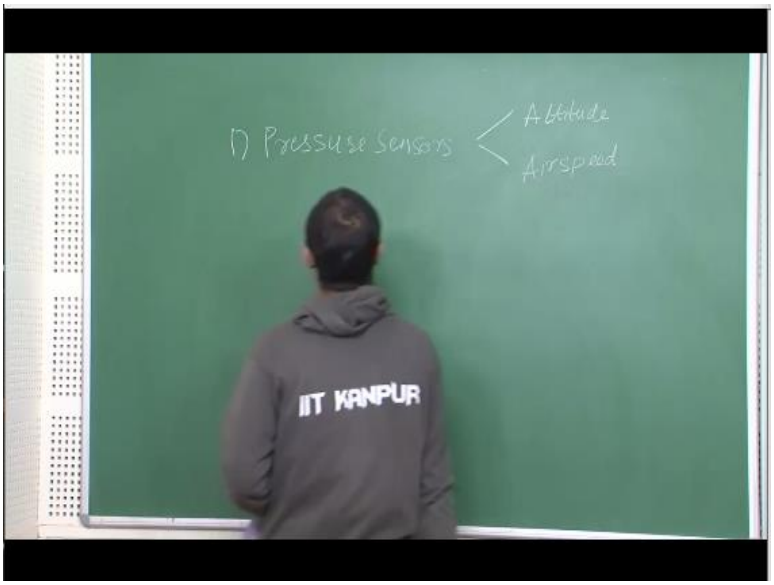

The second sensor which we will be concentrating on Accelerometer, third rate gyro we will be seen what the importance of magneto meter is then we will see how angle of sensor attack works and why it is needed. These were the sensors which was seen in the flight data recorder, while the data collection of the flight data recorder was showed it was seen the different total pressure and differential pressure, the acclimation in all three axis, what the role of your empitch will rate for different axis.

We did not mention this magnetometer, but instead of that we mention what was your role angle, your pitch angle and the joint angle were mentioned. And we mention angle of attack as well as side slip angle plus in FDR, we also saw the result of control surface deflection that is deflection of elevator deflection of celadon, deflection of weirdo were also mentioned.

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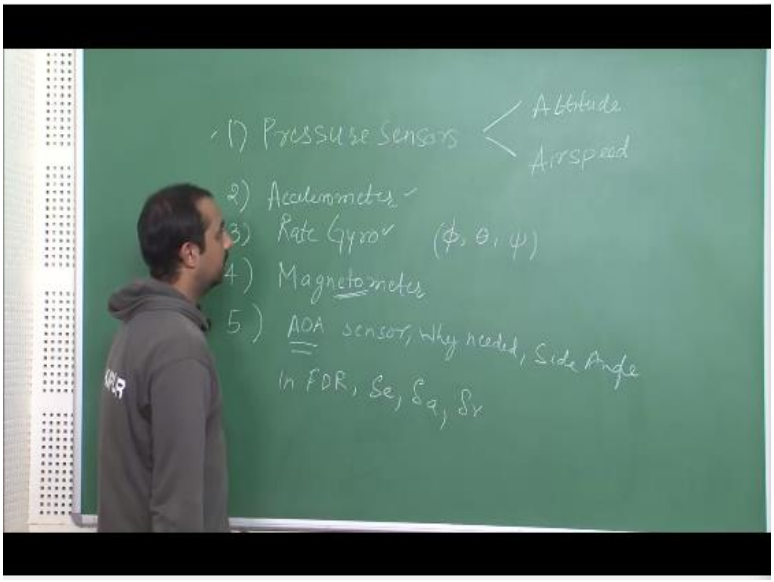

These were the data's we saw in flight data recorder, excluding your magnetometer, data and your GPS data, which will be the sixth sensor, which we will be concentrating on. Let us start with your first sensor that is your pressure sensor as I already told you that pressure sensor are used to calculate altitude as well as airspeed.

So first altitude, now the general equation used to calculate altitude is a simple hydrostatic equation given by, P2 - P1= ρg (Z2-Z1), where Z2- Z1 here Z represents depth in case of units. ρ is your density, pressure with respective to position 2 and position one. Now in case of height instead of the this depth we have to substitute it with altitude so the equation will become P_{alt}- P_{ground} = ρg(h_{alt} - h_{ground}) . These values, that is h-altitude and h-ground, that is height above sea level, which will give me the ρ will be in minus sign because, in case of fluids the depth that is positive Z direction.

That is depth is downward direction this is known as positive Z, whereas, in case of height, we calculate that above sea level, this is negative Z. Hence, we get a negative Z. Also you can see that as altitude increases this value will decreases. So the overall equation will be positive. Do not get confused why we are using negative sign and

non negative sign here now in this all calculation, one thing we have approximated is that density remains constant for all height.

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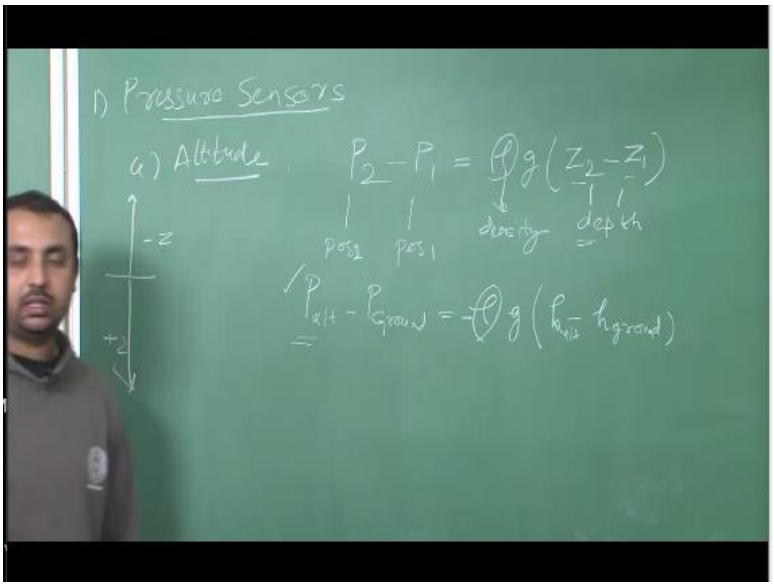

In case of water or any fluid, you can approximate that the density remains constant as you go beyond a certain depth. As height increases your density decreases. So if we want a more accurate result, you have to incorporate that the changing density as the height increases. So density with height is given as change of density that is $\rho_h=\rho_o$ that is at sea level $(T_h/T_o)^{-(n+1)}$ where n=go/aR that is g you know acceralation to gravity, a is your laps rate that is -0.0065 and that is your constant represented by R=237 and the temperature To at sea level is 288.6K.

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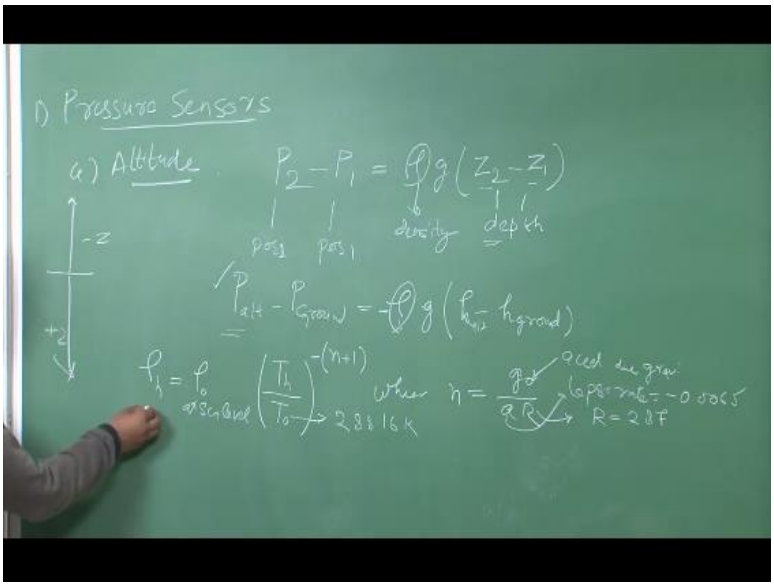

Now using this approximation you will get exact value of density that particular height. That you can substitute in this particular equation the output which we get from digital systems are always in terms of voltages or in terms of current that is why the output which will be getting will be something in terms of voltage that we have already seen in case of previous experiments were we calibrated your deflection of controls surface and the output, which were getting was in terms of voltage.

So we have to calibrated that in output for instead for this something pressure absolute will be in terms of say the ground, altitude plus some noise $\gamma_{pabs}=P_{ground}-P_{alt}+$ noise which is equal to ρg both are sea levels we get $h_{asl}+$ noise this for calculation of altitude knows.

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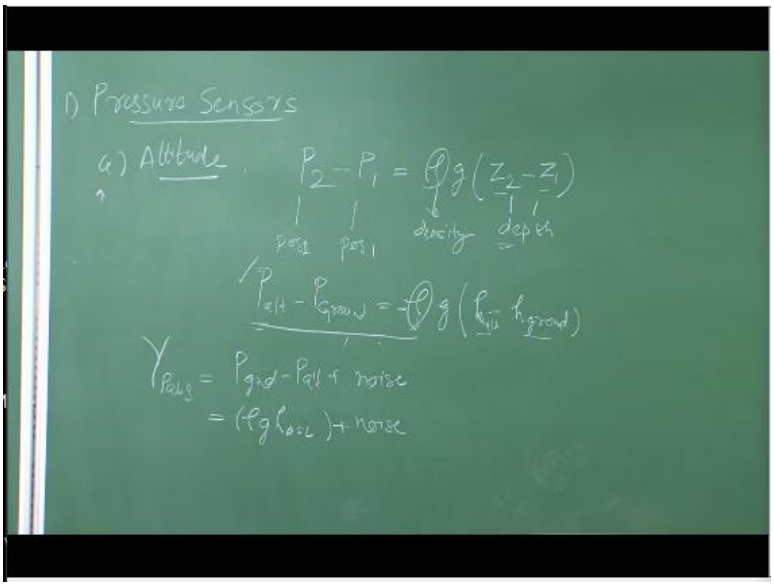

As the second application of pressure sensor is to calculate airspeed. Now the principle for calculating airspeed and altitude is same. The difference between them is for altitude block diagram is as follow.

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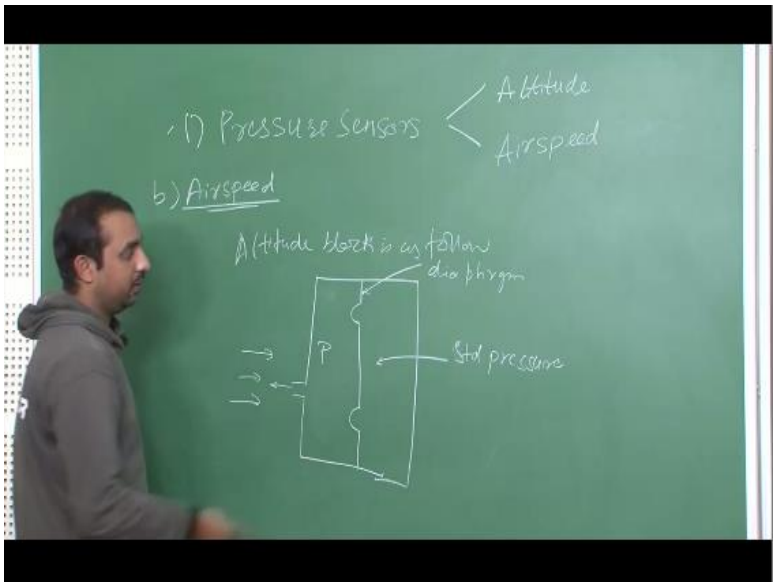

You have a chamber which is divided into two volumes by a small diaphrgram here you have a standard pressure some known pressure you are here and this vent is opened for air so the pressure difference P, pressure difference between this two volumes will be will cause deflection in this diaphrgram which will be again given to you in terms of voltages which can be calibrated and you get what will be your present altitude based on the pressure which you have got.

We have already shown you this will be your output something relation will be the difference between your pressure that round and particular altitude plus some noise part will be there. You can if instruments are quite accurate then noise can be neglected but we consider some noise part here and the difference between these, this was your altitude for air speed. You have a pivot P1 and P2 are the volumes chambers this is same diaphrgram now it has two outlet one is at the front this will be open to your air flow which will give you total pressure.

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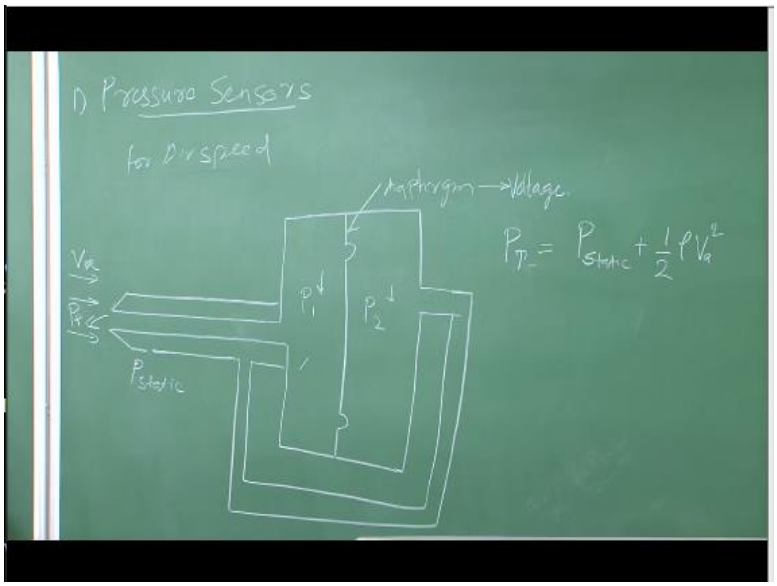

And this is a small vent here which will give you static pressure, now this will respect to the total pressure you will get a pressure P1 on left volume and due to static pressure you will get pressure on right volume. The difference between these two pressure will be re sultan giving a deflection to diaphrgram will again which again will give you a voltage compare to that deflection which can be again calibrated. And the difference between these two pressures can be noted in terms of voltage and the relation which goes with for the calculation of the airspeed is Ptotal=Pstatic + ½ ρVa^2 that is Va is a velocity. S this the basic difference between your pressure sensor for airspeed calculation and your altitude calculations. This is basic difference between the block diagrams.

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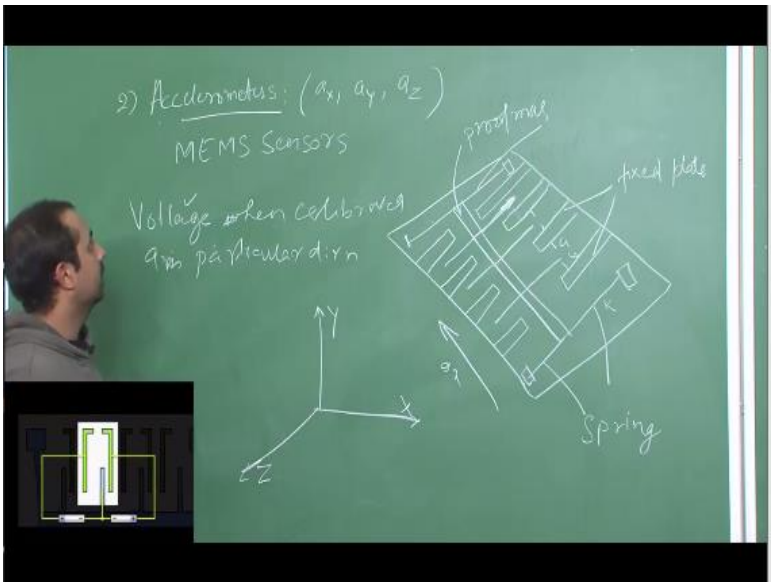

The second sensor which we talk about Accelerometer remembers when we showed to that flight required data recorded. You saw there were three times named as ax, ay, az these represent acceleration in X, Y and Z direction. Now Accelerometer the walking principle is this for MEMS sensors which use the schematic of them it will be these are your is you proof mass.

These are your springs and these are your springs these all are fixed plate. Now when the body is in acceleration this proof mass oxalates for suppose this the or acceleration experienced in this particular direction your proof mass will oxalate in particular direction these spring cause with constant K. So that capacity of between these plates will change and corresponding to that capacity tense you will get a voltage. This voltage is when calibrated will represent acceleration in particular direction.

Now since this proof mass can only acceleration in one particular direction so for three axis you have to have three different accelerometer for three different axis that is X, Y and Z each have a different accelerometer that can move only in particular direction this proof mass will move in only in X direction for Y will move only in Y direction, and for

Z it will move only in Z direction. And based on that change in capacitors c1 and c2 you can calibrate that to get what will be required the voltage and what will be the acceleration out that particular accelerometer.

Next sensor which we will discuss will be rate gyro in rate gyro the force which you experience is due to carioles acceleration. That is suppose you have a body which is moving with its velocity V and when it is subjected to an external rotation are you considered angular velocity. It will experience of force which will you perpendicular to your axis of rotation and velocity, that is, it will experience force in this particular direction. You name it as force or in this particular direction. Suppose this is X direction then this will be force experienced in X directions.

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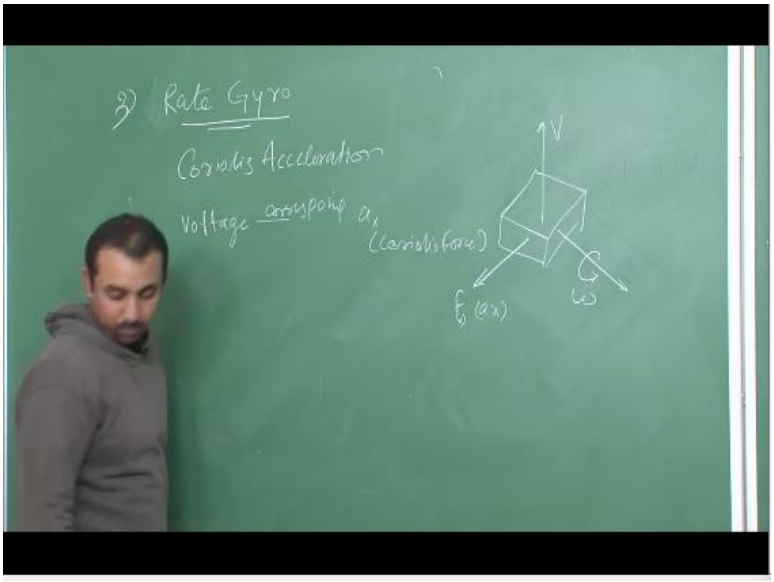

Once this force is experienced, the circuit will be the phenomena or the principle behind calculating what will be the voltage corresponding to this angular motion what will be the force that you can calibrate, the principle will be same, acceleration experience will move the proof mass and proof mass will vary the capacitance and according to the capacitance we will get a voltage.

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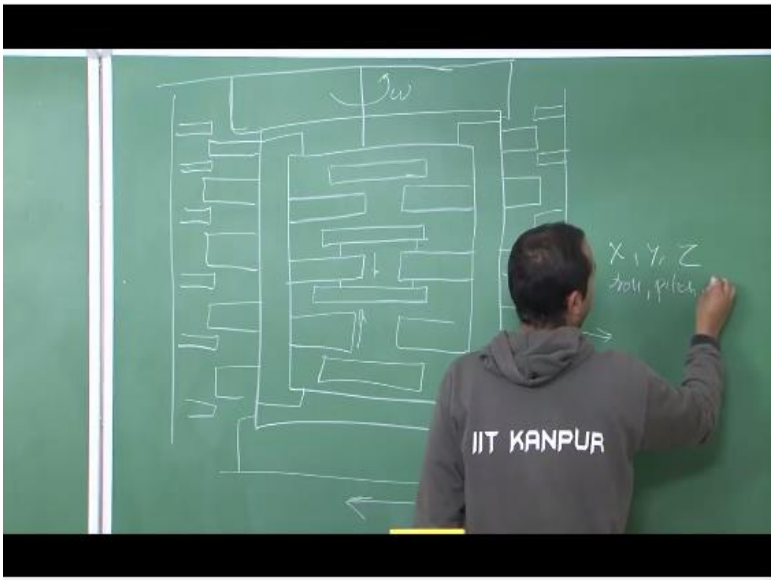

The block diagram for this is a little bit complex corresponding to axe ration, here axe ration is different because this is due to carioles force. The block diagram for this is axiomatic for rather I can say or redgarois. This is , these are fixed plates this is mounted for inside a casing, which is and singularly this will be asymmetrically about this axis and this is all mounted on the working of this is axiomatic of redgarois.

Now when the body is not rotating or it does not experience any angle of velocity. This the movement will be with this suppose you are bodies moving in its particular direction so this outer casing will be moving in that particular direction that is osculation with be in this particular direction either this or this outer case will be moving. Once it experience our angle of velocity say about this axis it experience some angle of velocity.

Now this particular inner casing will be moving, but these are fixed plate as you move so this will be moving in this particular direction or osculating in this particular direction. This will result in change of capacitor between these plates and say I already told due to change of capacitance you will get a respective voltage and that you can calibrate to get what ever it is in XYZ that is role which in your place.

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