**Design of Mechatronic Systems**
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**Lecture 08**
**Scanner**

Let us begin with Scanner system. So, how scanner works.

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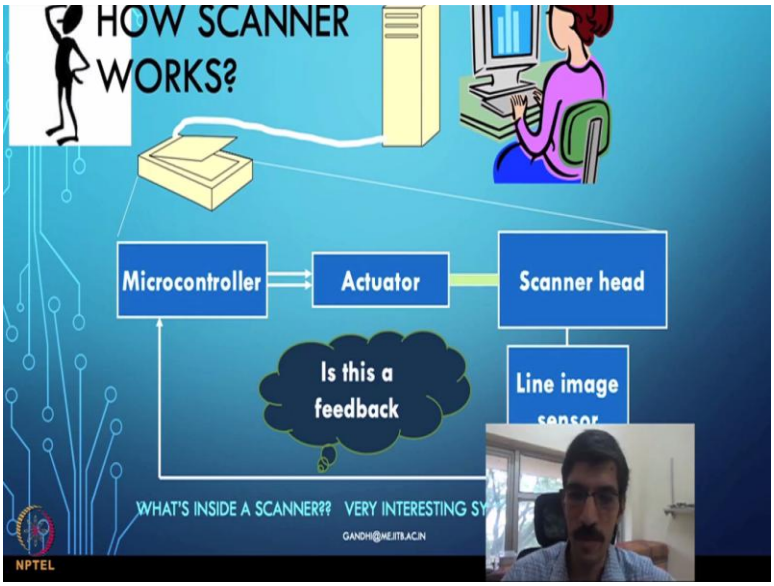


So, as you can see you will have a computer then you have a connected scanner to it and then the scanner will have a lot of this elements of mechatronics system that we have seen. So, there will be actuator, there will be a scanner head and then like as a plant then you get something from the scanner head which is that line scan image with the image sensor you get like the image of the page and that case goes to microcontroller.

But again here is this image a feedback probably not. So we will see what is, what is it is there any feedback or required in the first place or not? All those kind of things now, we will start looking at so it is also very interesting system for scanning with the color scan. Of course, nowadays you have your mobile phone you can directly use right now this scanner scanning application and like your scanning of the documents can be done with it simple mobile images anything like that, but for xeroxing purposes and for scanning purposes.

So, this now a lot of these sophisticated systems have come with much more automation than what you have in the scanner that we are going to see. So, what we are going to see is a simple scanner where you have let me see this picture here. So, let us see the picture first and then.

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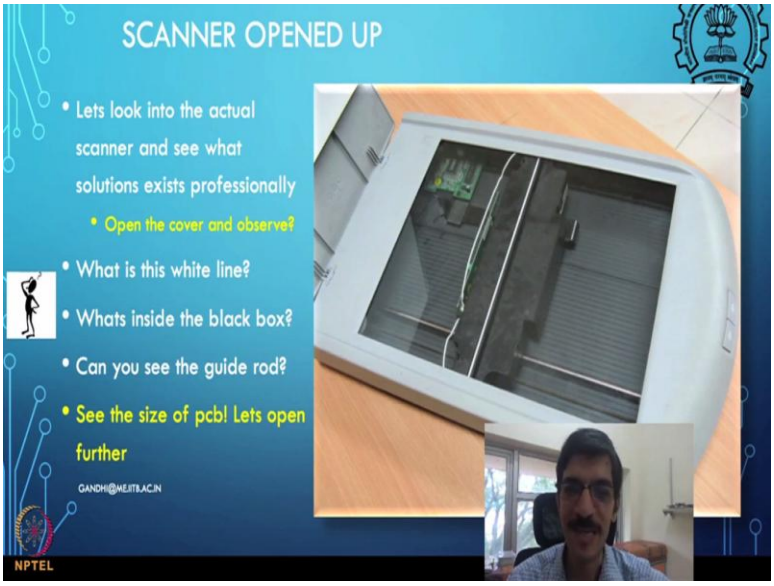


So, this is a kind of a scanner we are going to see, so it does not have any paper feeding system or auto kind of scan of any entire document kind of a stuff, which is there in lot of modern xeroxing and or photocopying to be precise and scanning systems.

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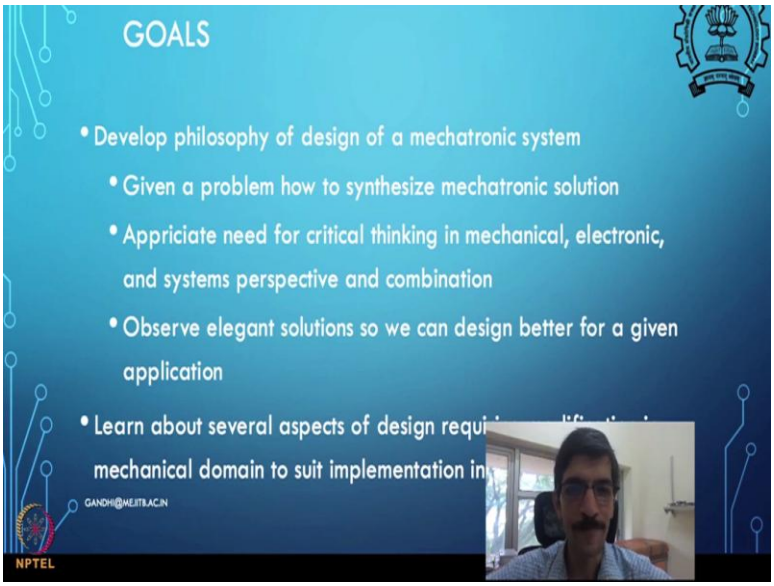

So, again our goals here are similar as we had for the CD ROM system given a problem how to synthesize mechatronics solution you need to have a thinking done now that we are equipped with really more the kind of knowledge based on the CD ROM drive one can think for the scanner kind of very easily probably.

Then again, thinking in both multiple domains together and see whether there are any kind of solution that we can give mechatronically in this kind of a system. And again, observe other solutions that people have given in the product now these professional solutions that people have been given for such a system and learn from it, there is this kind of standard process that again, we will go through.

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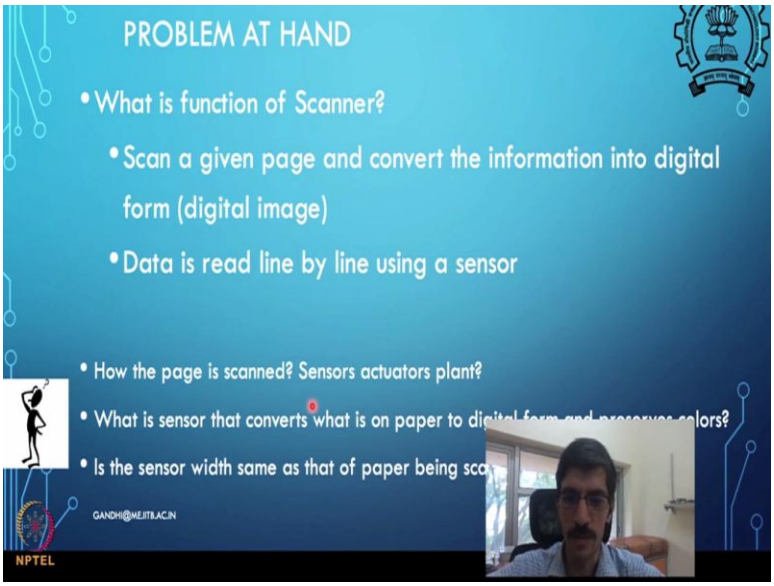

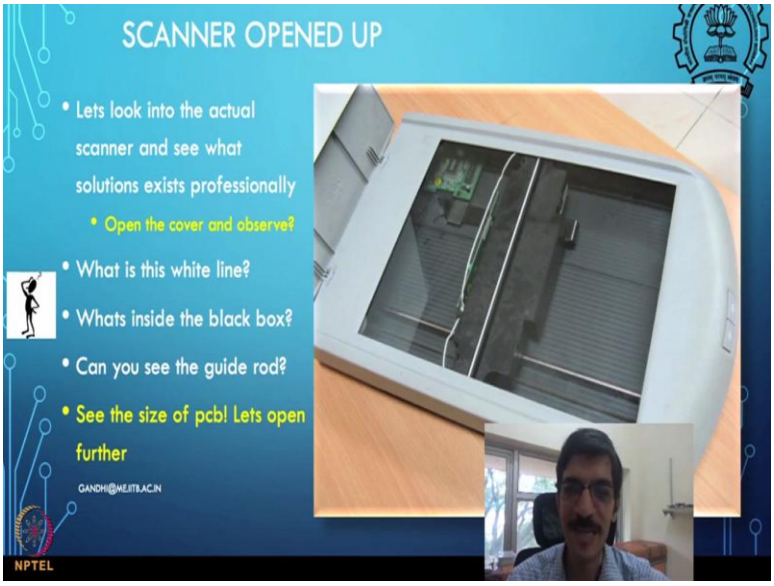


So, what is the problem at hand now so this problem is simple. So functional scanner you all you all know that, you have a page and page has some kind of color and maybe black image, black parts in the image and that image we want to kind of have scanned and converted into a digital format which can be displayed on your computer or you can be used for many other purposes. So, and typically the data in this is red line by line we are not taking a picture immediately and using that picture as a scan data.

So, this, this will have a much more higher resolution of image that can be possible with the scanner that is what we will do here. And to get that now can you think about, pause here and think about what solution comes to your mind, based on whatever scanner use that you had already done? What is the kind of a systems that this scanner needs to have? It is not very difficult to think like, one can know that, I need to scan a page with the some kind of a sensor.

So, the head should move across the paper in some way, that is clear that so there is some kind of a motion system should be there which can move the head of a scanner on the surface of a paper. And as it kind of moves the head of the scanner surface of paper, it should get a scan line by line the data should be getting line by line, the data should have come into the now what is this data? How do you kind of get this data? What kind of sensors you should have to get this data?

Can you think about? So, they need to be something like a light sensors. So, how this like light sensor will be doing the job of sensing and doing this kind of scan. So, this is what you need to think about and see what is the way this light sensors can be employed to kind of register the

data across one line in one go probably because you move this head on the surface of a paper and read one line next line next and keep on reading like that as the paper is moving.

So, the speed of motion of the head will be governed by how quickly you are able to kind of register the data for single line scan. So, let us start looking at it again. So, these are the questions that we raised, how the pages is scanned and what are the sensors actuators there, what is the sensor that converts the paper into digital kind of form output and preserves it preserves the color and the sensor width now needs to be same as paper width? No, think about this.

So, one can easily see like some kind of a solution can emerge for the head to move that we can use some stepper motor as we have seen the CD ROM drive. Now do we need what is the accuracy that is needed again here if you want to think about what is the accuracy that is needed for the motion here. So that is not as fine as you have seen in the CD ROM drives. So probably for this application you do not need to employ any compliant mechanisms.

Is that is that make common sense like the accuracy may not be so high. So, we will see how this accuracy can be see is whatever this kind of accuracy that is needed that is achieved, but it will not be definitely very high nanometric position it may be some 50 micron 100 micron kind of accuracy you can be okay with. In one particular kind of direction if you keep on scanning then that there is no direction reverse that is happening here that is other thing to note.

When I start scanning I do not have to reverse the direction anytime you can see that unless unlike in CD ROM drives my head can go forward and backward as he scans like to the entire surface of this CD, so I need to be able to kind of move both backward and forward there but in the scanning I just moved only in one direction during the scan, once the scan is complete of course you come back to the normal position and continue whatever you know next scan.

So, let us kind of start with like seeing the scanner first and open up and see, see when you open up the scanner and see just cover opening and to the glass you can actually notice that you have this black kind of head here on that is white line, what is this white line for? What is there inside this box that is doing the job then you see that there is a flat kind of a connector which is running from here to here and as the head moves this flat connector kind of folds and does not gives too much of disturbance to the system or motion of this black head. And then there is a small little

kind of a circuit up here which gathers data and communicates it to the computer. So, let us open further and see what is that we get now.

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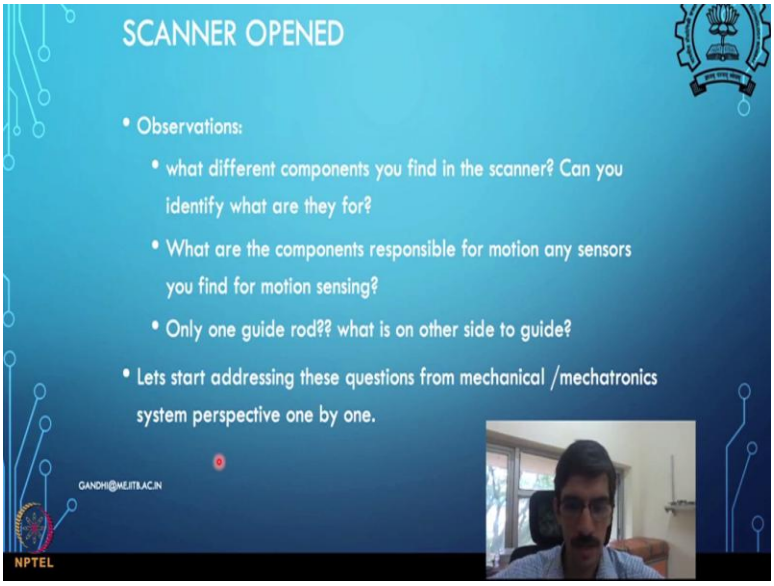


So, what we need to observe is what are the different components that you can find and identify what are they for. Out of that, these are the two system that we talked about one is motion system and other is sensing the sensor system. So, and then see the guide guiding in this case how these guiding in this case now can you connect relate is whatever guiding is happening in this case to what we saw in the CD ROM drive. So let us start looking at these questions here.

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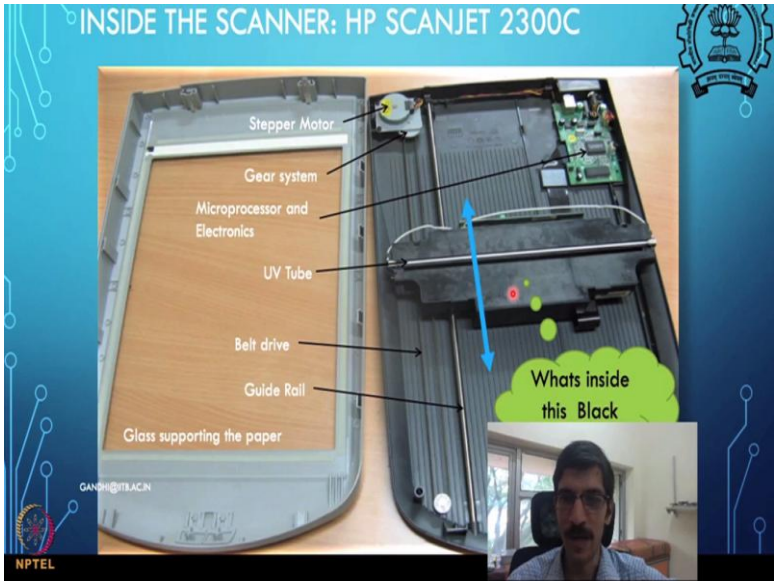


So, as you open up the top cover here, there are some screws, which have to be removed from the top cover here and here. And you will be and then some kind of mechanical interlocks will be there and you will be able to open this. Then you can observe there is some kind of a drive system here typically this has a stepper motor, why stepper motor because if you see on this motor also observe that are 4 terminals that are coming out.

Then there is some kind of a gear system we will open up that and check what is that gear system and then there is some kind of a drive here. So, this belt runs over the entire kind of the wheel up here and then there is some kind of idling wheel up here and then this head is guided by this guide rod, this is steel rod which will guide this head here and then where is the other guide there is only one guide here.

Let us think about where is the other guide what is acting as other guide? Can you notice something in the other side which will make sure that it is guided at two guides and it cannot have just one single kind of guide. So what is that guide on the other side is what you need to think about. Let us proceed further. So this is motion as you see is in this direction and then this is like a very bright mercury kind of lamp here.

Mercury tube here, very thin but very bright mercury lamp and then for this lamp to be driven there you need you need a good amount of current so that these wires if you see these white wires that are going to a circuit that are quite thick they are not very, very thin wires there. The

thick wires are needed for the higher currents that are to be carried with the tube. Now what is inside this black box it looks like a black box, it is really a black box to see and they are we see what is there in this box to kind of can you imagine what is there, what could be there inside?

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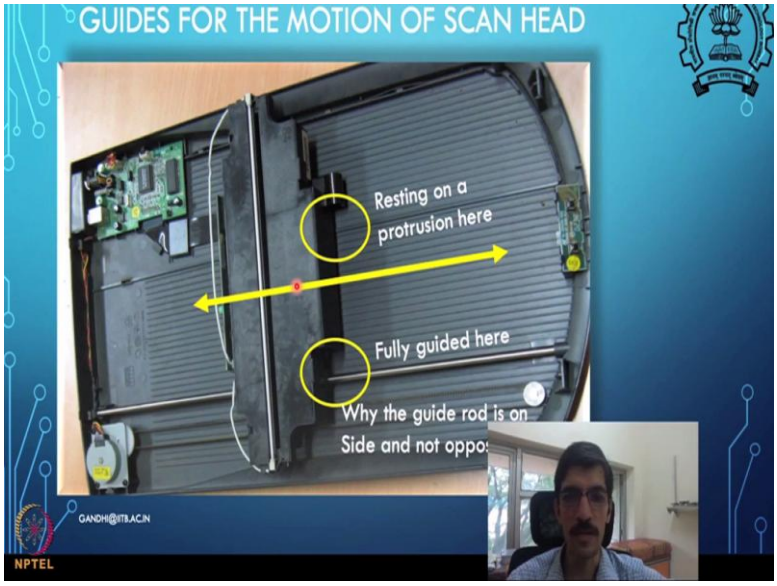


So, let us see. So this first we observe these guides. So these are the guide this is like one guide for the motion system this rod that we have seen so here you it goes inside but inside we will show later that it is actually guided by at two points. So two points it is going through as we have seen in the CD ROM drive system, on one side it goes to these two side suppose, why that is needed because think about that you think about why you needed two points even if it is guided here it will be these other points it will be guided.

So, observe carefully that it is some kind of a small protrusion coming out on the surface of this bottom. That protrusion **is actually guiding** like it is kind of resting the system is resting on this protrusion by gravity you do not have if you lift it, it will kind of get lifted up but I mean you know there is nobody to lift it when it is all packed and covered system. So then it will not have much of a problem.

So, so there is no like a rod kind of a guide, but it is just a small protrusion that is coming out I have saved the cost of the rod and assembly by means of this kind of protrusion which is sufficient to make sure that it is guided on the other side also very well. Now, this is fully guided

means it is having a rod fully covered on all the sides by a guiding slip and this is not on somewhere here it is on this side.

So, why this guide on this side not on the opposite side, you may say there is a circuit on this side no I can have I could have circuit on the other side on somewhere in the middle I mean there is a space up here whatever I can have circuit on whatever, wherever I want. But there is a specific reason for this rod to be on this side particularly close to this motor, close to this drive, think about that, think about a free body diagram when they when the motor starts operating and starts moving this head what are the forces and moments that are coming on the system? And then you may understand this part.

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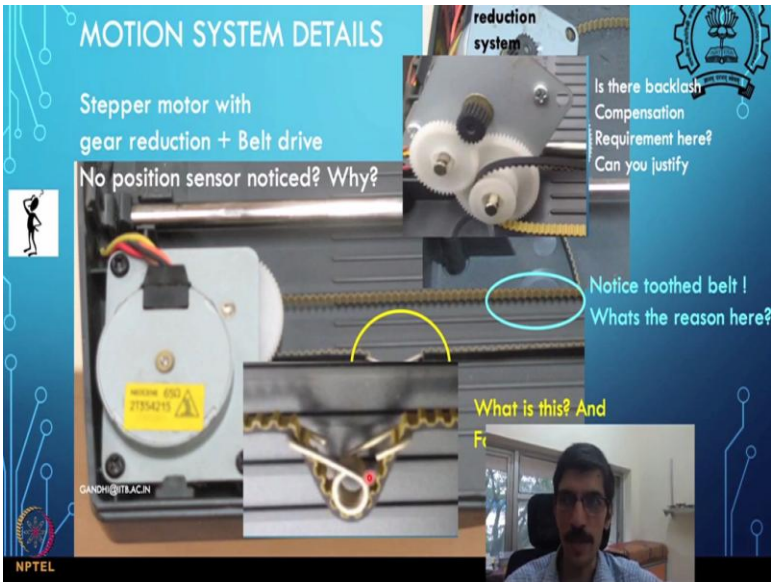


If you see this motion system little bit more in details you if you see this motor here you remove these three screws and you will see that there is upside down you can see there is a motor which is a diving gear pinion which is with a gear reduction driving this, this wheel which is on which this belt is going. So these are toothed wheel on which this toothed belt is mounted and that belt is running all across the drive and there is something like a spring here, what is this for?

So, think about this is if you see that this is this kind of spring and then like the belt goes inside that and it is when you straighten the belt it will have some kind of tension. So, these are questions that we need to kind of address here. Now, is there backlash compensation in the

system? You we do not see it here you cannot see let, there are two gears which are spring loaded or something like that. So is it really required there?

So, it is probably not can you think and justify why it is not? Because you do not have a very high precision positioning system here. First thing and second thing once you start driving in one direction, you are not going to reverse the direction at all. So you keep on driving in one direction. So then there is no backlash question come in, comes in there, even if there is a backlash in the system, it is not going to harm your application.

So, you see that it is very interesting way that this backlash does not bother for this application. So you do not have to kind of compensate for backlash for everything we only were you have to make sure that the application is requiring this need for compensated backlash then only you need to do that. So, another thing why is it toothed belt here? One could have used like he could have us here normal belt also. Why toothed belt? So, this belt will make sure that it will not slip this belt will not slip from the motor and it will be when the motor is driving it is a positive drive that will happen to the system with the stepper motor.

So, so, in case of trouble where the head gets struck in this particular case then what will happen is the stepper motor will start losing some steps and then might be some way electronically to detect that the stepper motor is doing some steps. Another thing you might notice here that in the entire system if you have opened up and seen like there is a motor here but on the motor there is no sensor.

Typically you find otherwise that additional kind of sensor sitting on top of your motor and neither there is a sensor in this belt or any other place for the motion sensor. So, why there is no need for the sensor position sensor here. If you ponder over little bit you will find it, this is there is no need for the motion sensor because as you start saying operating motor in one direction it starts scanning and then as its continuous its motion with we know the number of steps that are given will be proportional to the position of the head in one particular direction.

If I keep on driving the same direction exactly that number of steps are that are given will be. Now, when I reverse the direction then my count may not match because of the backlash in the system. So that is where, this is elegant kind of a way they have eliminated the like there is no sensor in the system. I keep driving in one direction and I get to know. Now where to start this is

starting there is a first starting to know where to start, there is a small limit switch inside the thing.

So, that limit switch, I do not think I have a photograph of it, but there is a limit switch inside the head somewhere which keeps on doing the sensing of the data. Now so this little thing here that you see with the spring loaded it is for the tensioning of the belt.

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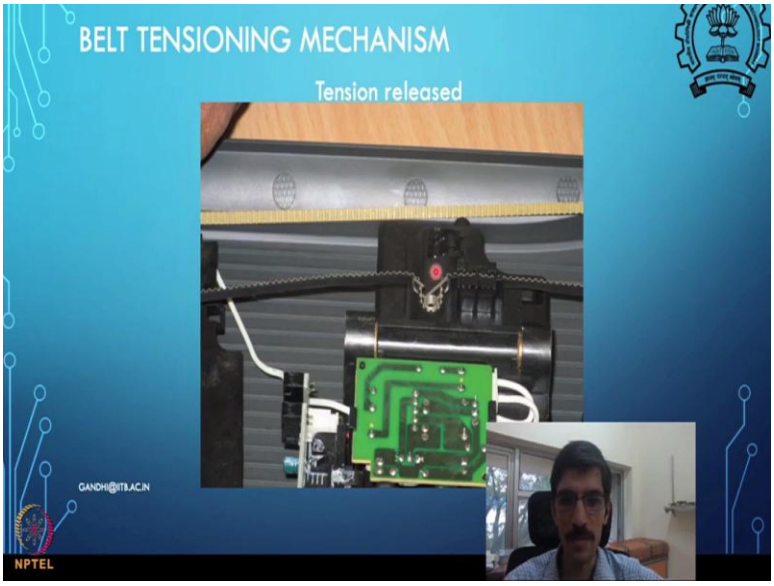


So, you can see the tensioning of the belt here, when this tension is released, this spring kind of gets no tension inside.

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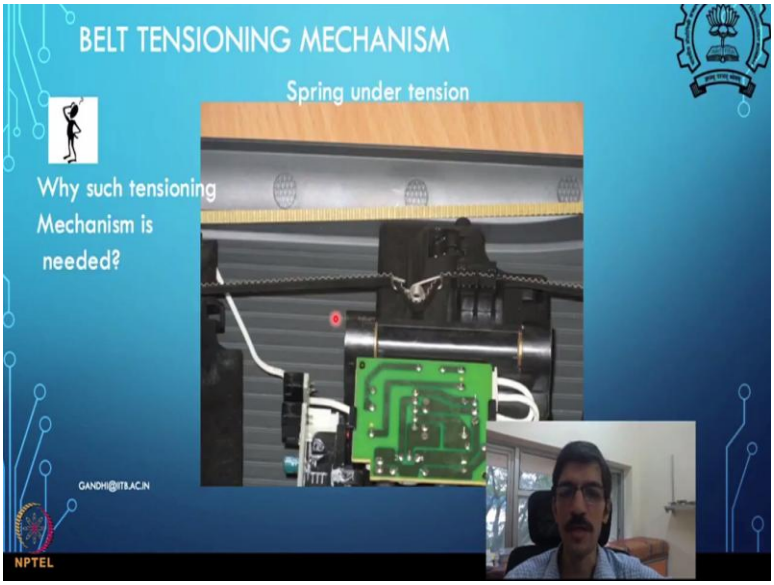


But if you see this stretch belt is stretched spring will be under tension here. So this is the thing that you can observe here. So interesting kind of a mechanism to kind of make sure the belt is tight. So that like a small amount of backlash, at least will be taken care of in the dry in the belt. It is not of backlash it is just slack in the belt. So, otherwise, a belt being so long it will have a tendency to slack and then also if you see this is a very interesting way the manufacturing errors in the assembly would be taken care of.

Say for example, if the motor is mounted little bit here and there in position the belt will not get slacked, the belt tension will be maintained by using the spring and this will be very nicely kind of operate and belt is kind of firmly held to the head in this particular place here and next to it is a spring so, the spring will not come into the, it will not go a ever over the pulley the spring part of the portion of the belt will not ever go over the pulley.

So then so, you have this one continuous belt and it is spring loaded here. So is spring tightening here and even if you have some errors in the assembly of your motor, they are not going to be, your belt is not going to go slack that we that is what is made sure because of this kind of interesting way of doing things. So, the accuracy or the skill that is required in assembly is avoided here.

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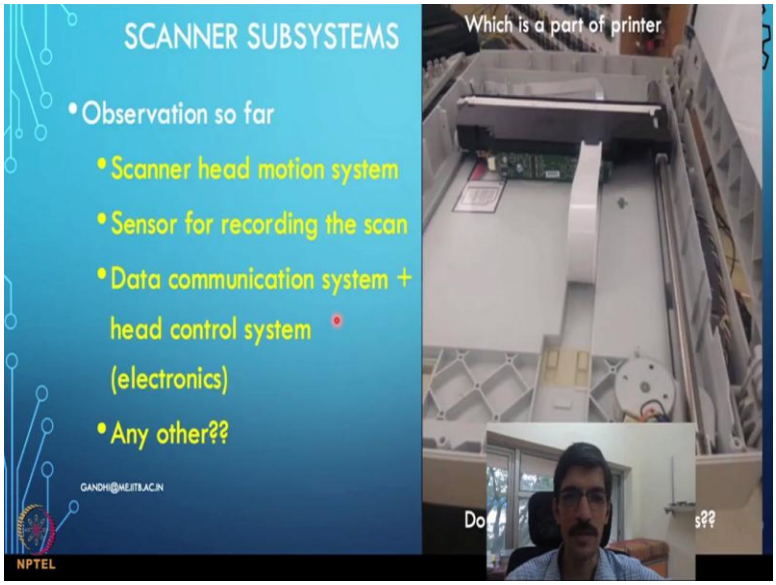


Now, this is another kind of see the similar subsystem for scanning this is in the printer, if you see a printer on the top there are some printers with the scanner combined system is there so, in that system, we will have this kind of arrangement and this another kind of a scanner open that will say. So, we have seen this are the service subsystem so far scanning head subsystem and sensor for recording the scan and then you will have data communication plus head and control systems and things like that. So, now let us move on to this second system which is Sensor system.

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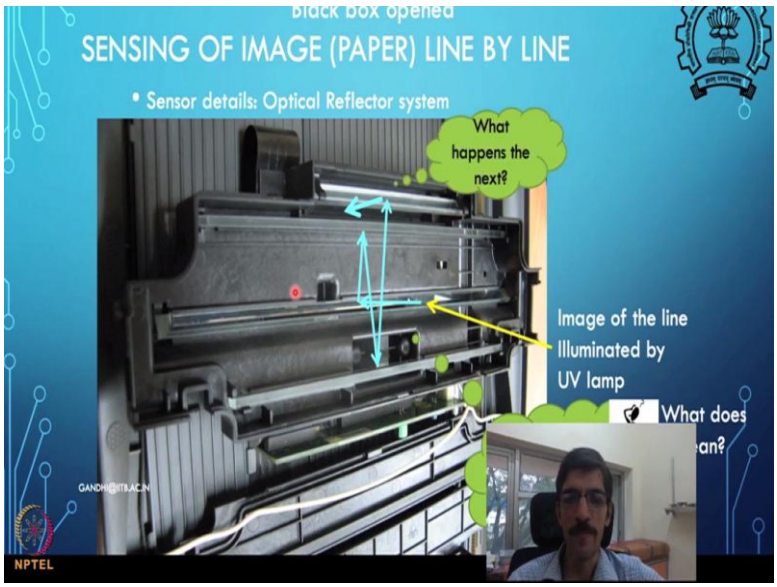

So, if you see this black box opened you will observe all these kind of elements, can this make sense? So, you see that there is a there is this big size something glass kind of thing here and then there is some other kind of a glass kind of a thing here some other kind of thing here then similar kind of a thing here and how do we kind of make sense of all these things. So, if you see carefully these are if these are not just glass, but they are kind of mirrors here if you carefully observe them they will be able to see that they are actually mirrors.

And this is the first mirror which is the length of the paper size mirror, then there are subsequent mirrors where which sizes are smaller and smaller, this is smaller mirror then this is smaller mirror like that there are smaller and smaller size mirrors that are happening. So, if you see that the angles at which they are placed then you see that the one mirror reflects on the surface of other and so and so forth.

So, so, image is full length of a paper image which coming on the top surface of the it is a image there is a glass we have removed that glass, so, from the glass the whatever is written on the paper will come as a reflection on the surface here and this mirror is at some angle such that this reflection comes on the surface here first from the top illuminated by UV then that mercury lamp and then it will get reflected on this surface.

So, this angle such that the mirror this reflection of this image of the paper goes here, then from here it goes to the next mirror here this so, you see this is smaller mirror than this mirror. Then you will have further smaller size here and then from here further smaller size, it will go on this mirror and from here this is about in 45 degree angle, so it goes down from here. Like that now we will see what happens when it goes down.

So, there is some other kind of a system that is expected down there. So, this is what is there in this kind of a black kind of a box that you have a black head that you are seeing for this system. So this is a reflector system for the optics. And you can notice that every time it getting reflected, there is a reduction in the size happening. That means are we losing the image here. No, no, no, we are not losing the image. What these mirrors are, they are not like a normal mirror they are like a concave kind of mirrors.

So, they will kind of make no sense the larger size and focus it in on the next mirror in a smaller kind of size because they are a concave kind of mirrors. So that is what is important here to see

that is what it means that every mirror is a concave mirror every time the reflection happens the size of the what is whatever is reflected keeps on reducing. Why would the size reduce or why it is needed to be designed that way we will see. So, what happens to the system next.

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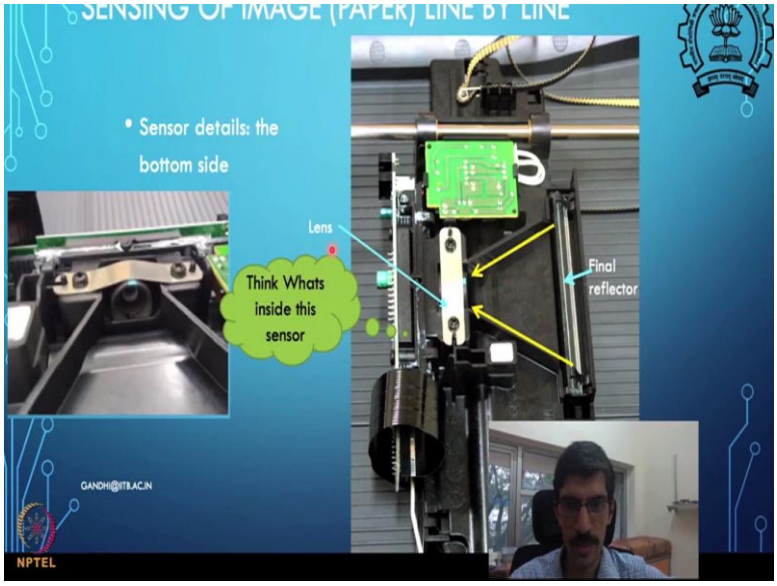


You go come down, this is now upside down here, when you see upside down like this is a mirror which is receiving the input from what the arrow that pointed down there so it is coming up here, because it is like no image taken from the bottom side. And now there is a final kind of a concave focusing happening into this system, this is a lens here, this lens would look something like that.

If you see this is the image of deflection from this final mirror, we will get onto the lens and it will create an image on the sensor. So these are virtual image that will get created on the surface of a sensor, the sensor is located up here. So, this is a sensor in which on which this mirror the image gets virtual image will get formed on the surface of the sensor. So far so good. What you see here is this little circuit which actually drives the mercury tube that we have seen that white light kind of a tube there. Now, we further open up this, as you open up this lens and open up the sensor, things will look like this.

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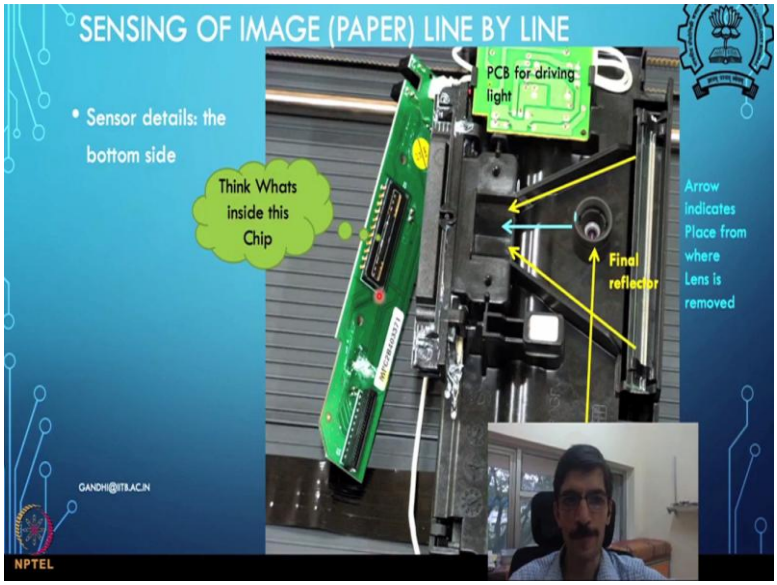


So, this is a lens up here, this was a PCB that I was talking about for the light I think they are in this is wires are kind of thick wires, which are a for high carrying current carrying capacity to so this wire one goes on the side and other goes on this side to connect to the mercury lamp. Now, what is there inside this chip? Can you imagine now, what could be there inside this chip? So, think about it.

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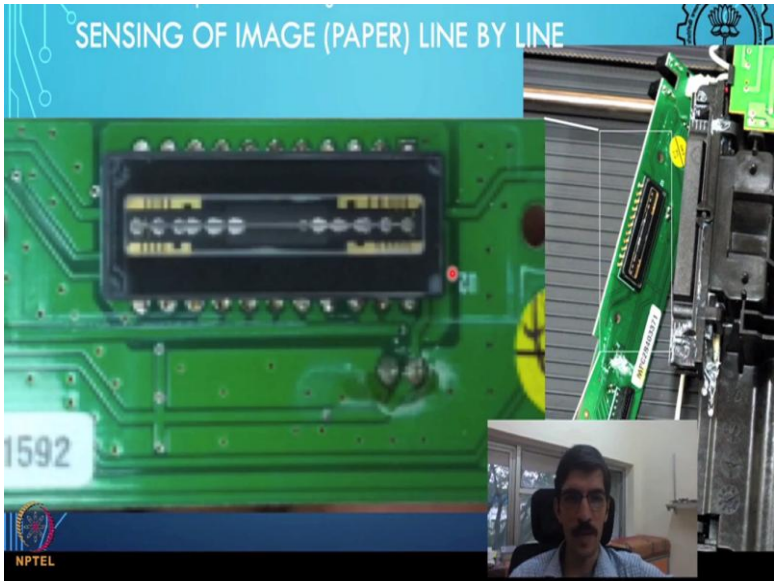


If you observe under microscope, this is a first kind of image or this is not like a microscopic but this is like a zoomed image of the sensor. You see some kind of a big line here and then there are

some wires that are connected and there are some golden pads are basically the points where the wires are connected from these points the chip carrier this package has these pins. So, these pins will be connected finally to this small, small little pads that you see there. Under microscope we need to observe the sensor to kind of really make sense what is happening there, let us kind of do that.

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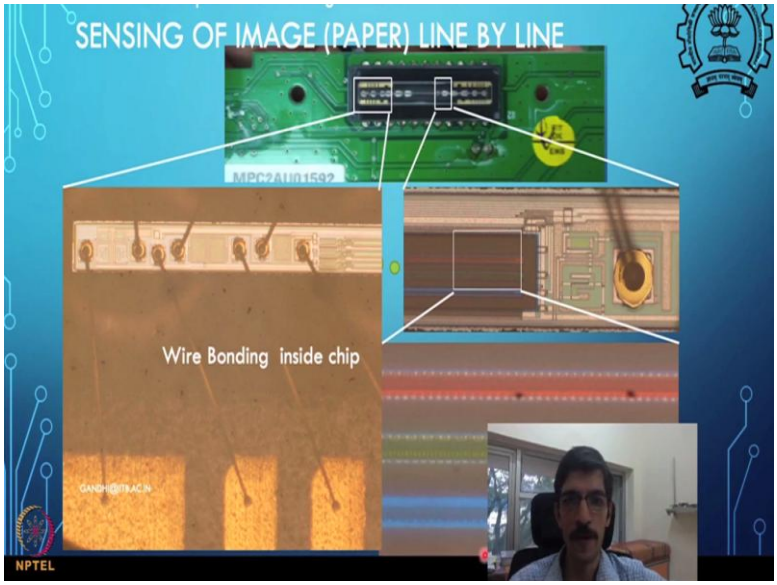


If you see this image under microscope, you will see that you know these are the golden pads which are seen up here on one side only these other golden side pads are not in this zoomed microscopic image and you will see these are the wires that are coming to golden pads from these different parts of this main sensor strip this is like a main sensor strip, on which like you see there are some sensors elements start up here.

So, this is a part where the connections or contacts are made for electrical elements and then there is a sensor pad that is up here and other end of the sensor pad we can see here and is under microscope like in like there is one wire that might be multiple wires connected on the other side. But there are some circuits up here which are doing some local processing of the signal before it is taken out of the sensor from these wires to the PC.

Now, if you zoom in this area further you will find there are these red, green and blue parts here. Can you imagine what are they? Why there are red, green and blue parts and below that there will be probably the sensors elements. We see this small, small the lines here or dots there. They

are like a sensor element and a sensor element is covered by this red kind of a patch. And then there is a green patch and there is a blue patch. So, these three sensing tracks.

We will get from the image these three R G and B parts of the image. So, the big eliminated image is falling on this surface here of the street tags and these are the three filters which are filtering the image to kind of get R G and B parts of the image saved. So that we can reproduce the color for the image in the nice way. So, this is arrangement for getting like the colored image very nicely done. So, so, this is what is making the colored image sensing possible.

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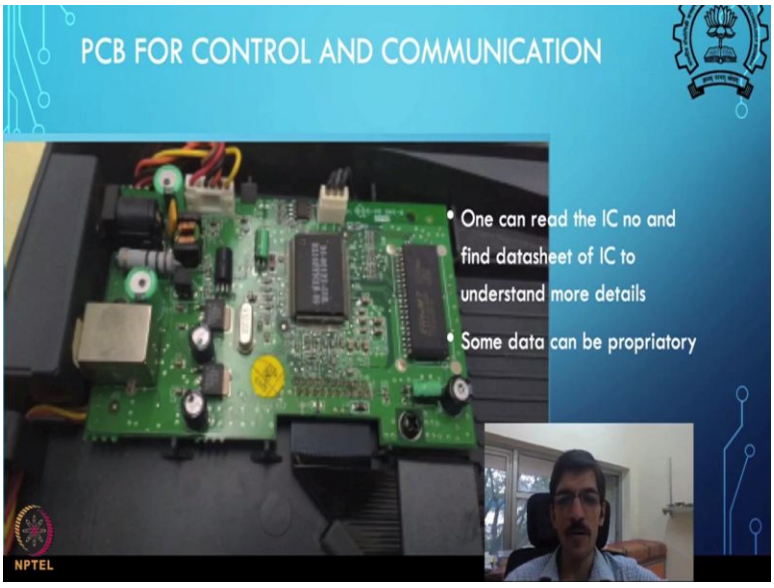


So, then finally you will have this PCB for control and like no communication, now control in this case is not really a closed loop control is like open to control us just keep on sending these steps of drive to the stepper motor and stepper motor keeps on going till until the end is hit until the paper end is hit.

So, you have seen, you might have seen in this kind of scanner even if your page is half the scan is still made full, you cannot control that, I want to scan only some part of the page, what is the reason because they do not have a sensor to kind of sense where the page is ending, can you see that?

So, that is the reason you do not kind of have a scanner to typically have scanning for this, this is kind of a simple scanner might be something sophisticated scanners which might have little more

kind of flexibility to kind of control where you want to have exactly the scan. But typically you will find that even if you are scanning you say your passport, you will need to keep typically run this full scan.

And then like once a scanned image is there in the computer, then you kind of crop that image and then you remove the part that you do not want. But as a scanner has no smartness to kind of register that only this part of the image is to be scanned and given to you. So that is how the scanner works.

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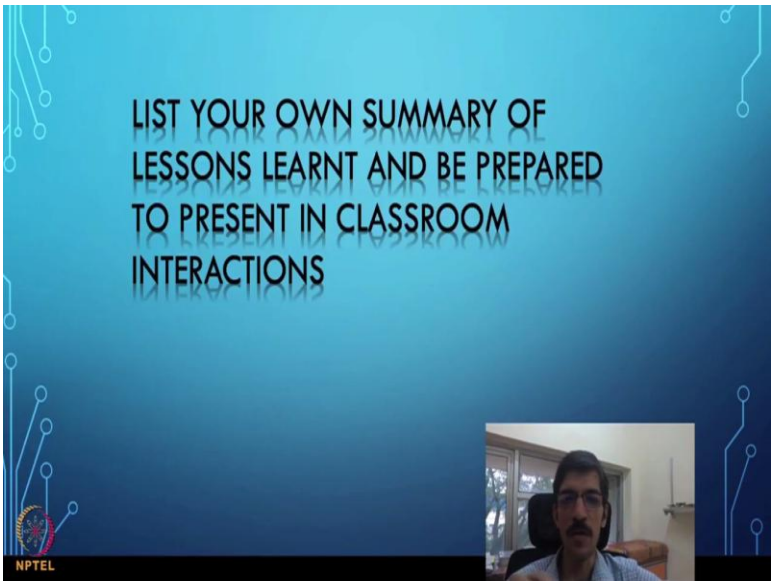


So again here, you can list down your summary lessons here.