Engineering Metrology
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Lecture - 20
Transducers (Part 1 of 2)

So, the next topic of discussion is going to be Transducers.

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These two figures are transducers. So, first of all, we will see what is the transducer and then we will try to see the transfer efficiency classifications of transducers.

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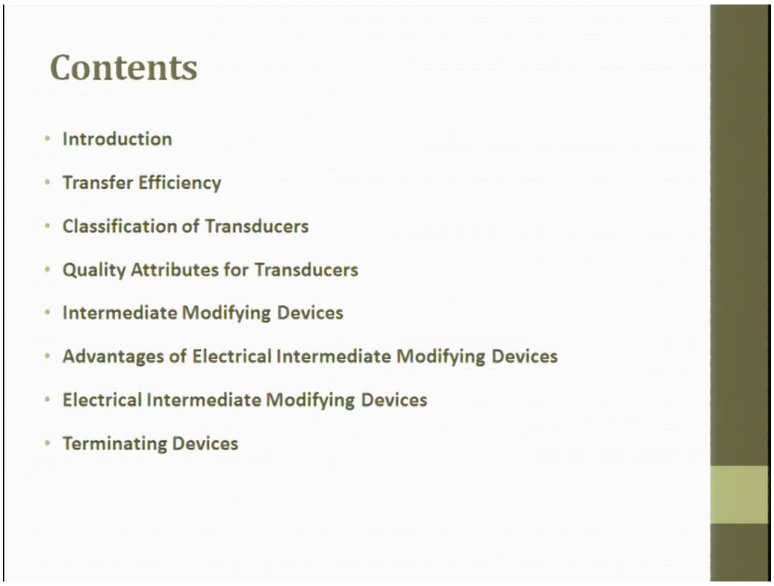

There are several types of transducers, then quality attributes for transducers, intermediate modifying the devices and then advantage of electrical intermediate modifying devices, then electrical intermediate modifying devices and terminating devices. These are the topics which we will be covering in this lecture.

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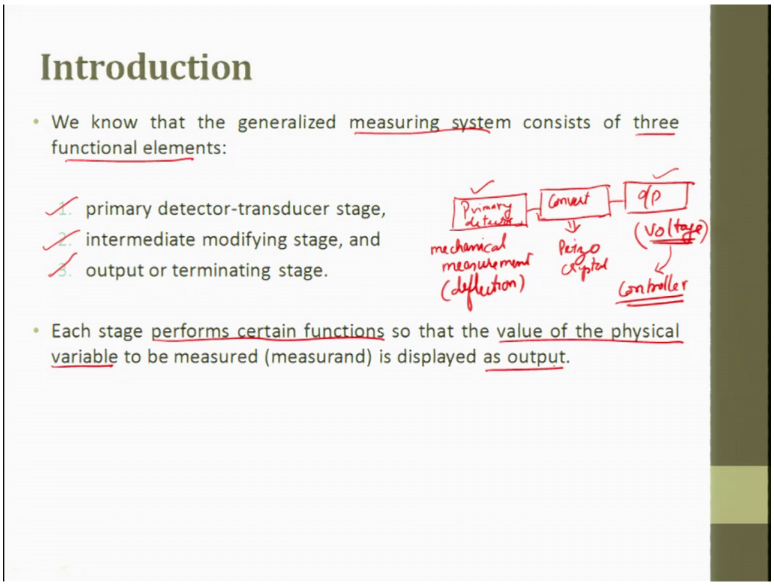

First we know that the generalised measuring system consist of three functional parts. First is primary detector-transducer stage, then intermediate modifying stage and then output stage. So, what we are predominantly trying to do is here is one device which tries to find out what is the response, we are supposed to take primary detector.

Once this primary detector detects, so, now, then this data has to be converted. So, suppose you has to be converted into a readable output. So, you have input, you want you decide; what is the output you want. So, then in between you try to have a stage where in which you convert the primary into a readable output. So, this is a convertible or intermediate modifying stage.

For example, here you can have a mechanical measurement done for a mechanical measurement. So, this can be in terms of deflection, this can be mechanical deflection dial gauge which measures and the output; what you want, you want it in terms of voltage.

So, now, you have to convert the mechanical measurement into a readable output, why it is in voltage because then it becomes easy for controlling. So, if you want to establish a controller or you want to have an online monitoring system and then controlling system; so, adopt to controlling system, then what we do is we always look for voltage or current as the output voltage it is easy to manage. So, we always look for voltage.

So, now this mechanical has to get converted into voltage just as an example, we can try to I put a Piezo crystal here. So, what is the Piezo crystal do? Piezo crystal converts the mechanical displacement into an electrical voltage. So, this is an intermediate modifying stage ok, here you can have circuits; I have just put a simple analogy for your understanding. So, basically there are three functional elements for a transducer or for a measuring system. So, one is primary, second is intermediate modifying stage and the third one is the output stage output or the terminating stage.

Each stage performs certain function so, that the value of the physical variable to be measured is displayed as output; please relook into it performs certain functions. So, that the value of the physical variable to be measured is displayed as output.

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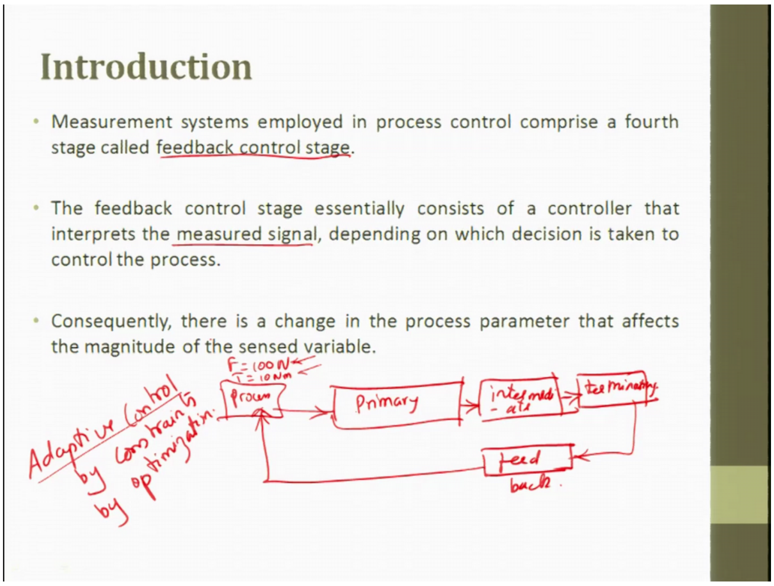

The measuring system employed in process control comprises a fourth stage called as feedback control system. So, what are we talking about primary then intermediate this is primary intermediate stage, then we have terminating stage terminating stage and from here, we try to take an feedback stage and this feedback, sorry, this feedback this feedback will be may be it will be to the process. So, here is the process happening and you have something like this. So, here is the process ok.

So, a feedback control system essentially controls that interprets the measured signal depending on which decision is taken to control the system. So, here you can have adaptive control by constraints or you can have by optimisation ok. So, here what we do is we give the feedback the process gets changed. So, the process becomes adaptable what is said the constrain is you fix a variable and you as a maximum limit, for example, the force cannot go more than 100 Newtons. So, this is a constraint.

Suppose, if there is force as well as a torque component of 10 Newton meter something like this is the two constraints are there. So, then what we do is we first one by constraints, we say do not cross 100 and the second one; you say do not cross 10. So, it is all 10 constraints are put, but when we talk about optimisation, it does not look at constraints, but it looks at intermediate value which is safer for the process to operate ok.

So, here if you want to do all these adaptive controls, we need to have a feedback control stage and that is takes an input from the terminating stage consequently, there is a change in process parameter that affects the magnitude of the sensing variable.

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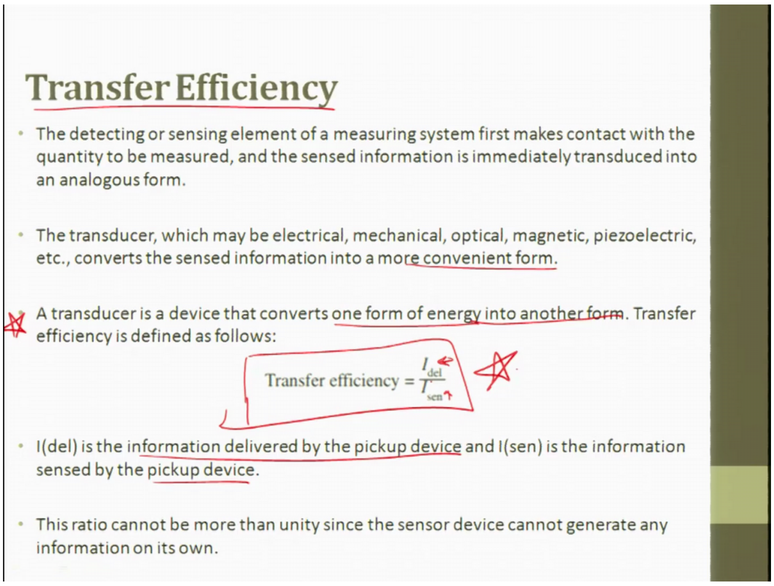

So, transfer efficiency like magnification, this is very important in terms of transducers the detecting or the sensing element of the measuring system first makes contact with the quality to be measured and the sensed information is immediately transduced into an analogous form ok, you are sensing the stage and you are converting the sensed stage into a data are the primary.

The transducer which may be electrical mechanical optical magnetic Piezoelectric converts the sensed information into a more convenient form such that you can start correcting editing analysing the data a transducer is a device that converts one form of energy into another form, this is very important and this is what is the definition for a transducer a transducer is a device which converts one form of energy into another form and this one form is it can be mechanical, it can be electrical, it can be optical, but this is the energy which this is the thing which has to be sensed.

For example, a pneumatic converter using backpressure we used to check what is the deviation along around the whole something that. So, a transducer is a device that converts one form of energy into an another form the transfer efficiency is defined as this is very important which is nothing, but I del by I sen. So, I del is the information delivered by the pickup device and I sen is the information sensed by the pickup device, I del is the information delivered by the pickup device pickup device. So, this is in; so, in information delivered by the sense ok.

The ratio cannot be more than one since the sensing device cannot generate any information of its own, is it clear? So, I del by I sen is the transfer efficiency, this is very very important and this point is also very important, a transducer is a device that converts one form of energy into another form and the transfer efficiency is defined as I del by I sen and when efficiency can never be more than 1. So, I sen cannot generate its own signal which is making sense. So, this is the definition or this is the ratio for transfer efficiency.

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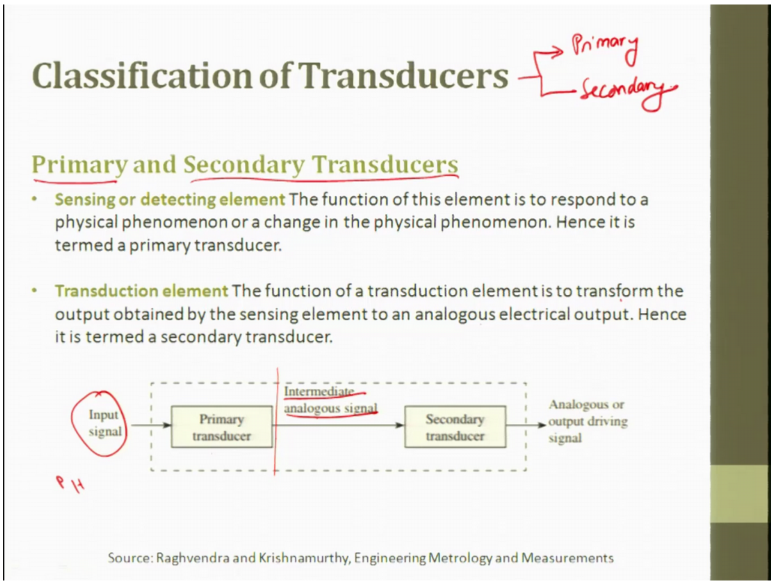

There are two types of transducers; one it is called as primary transducer, the other one is called as secondary transducer.

The sensing or detecting element; the function of the element is to respond to a physical phenomenon or a change in the physical phenomenon. Hence, it is termed as primary transducer. For example, if you take a (Refer Time: 09:41) and put it inside an acid or base the colour changes. So, the function of the element is to respond to the physical phenomenon or the change in the physical phenomenon as it is present colour changes, hence, it is called as primary transducer clear this is primary transducer.

The transduction element the function of a transduction element is to transform the output obtained by the sensing element to an analogous electrical output. Hence, it is called as sense secondary transducer. So, here you will have input for this example whatever we dealt I took a pH. So, it measures the pH and tries to give you a colour which tries to say whether it is acid or basic, but this data if you want it as voltage data or some continuous data, then we convert this data into secondary transducer.

So, what is the secondary transducer? A secondary transducer is the function of the transducer element is to transform the output obtained by the sensing element to an analogous electrical output. So, here it is something like digital pH meter, you have measured is digital. Now you convert this into an analogous form and give an analogous output that device is called as secondary transducer. So, classification of transducer can be primary and secondary, is it clear?

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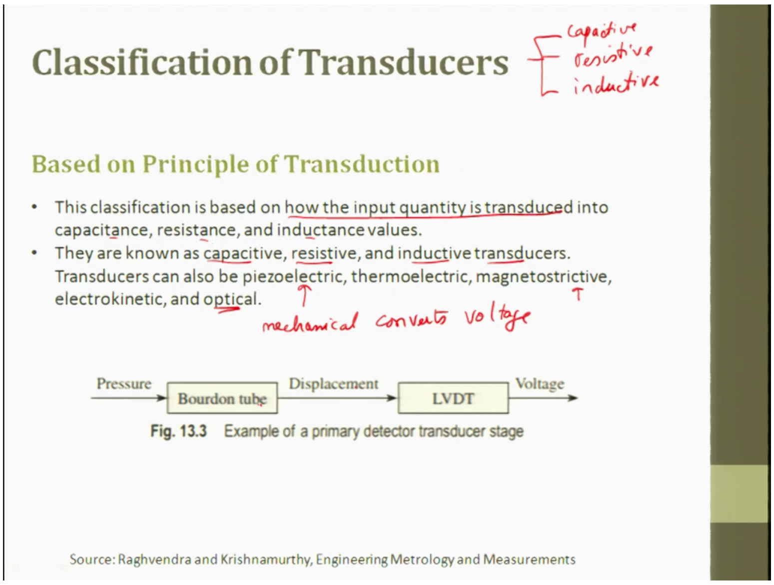

So, what are the based on the principles of transduction? The classification is based on how the input quantity is transduced into a capacitance resistance and inductance value ok. So, the based on the classification is of how the input quantity is transduced input can be mechanical how it is getting transduced; whether, it is the capacitance value, resistance value or and inductance value, they are known as capacitive transducer or resistive transducer or inductive transducers, the transducers can be Piezoelectric, I told you; what is Piezoelectric based upon mechanical displacement, it converts into voltage thermo electrical temperature based into electric magnetostrictive. So, based upon magnetostrictive is also with very similar to that of Piezo which gives you displacement by applying it.

Optical sensing is the other way doing, today, if the displacements are very small in nanometres optical techniques are used in a big way to find out this displacement. So, there are optical transducers also there. So, a pressure is given we have we have we have bourdon tube is used. So, bourdon tube gives me the displacement that I attach it to an LVDT. This LVDT in turn gives me voltage. So, that is taken for further processing. So, here the input quantity is transfused into capacitance; sensor capacitance transducer, resistance transducer or inductance transducer, the basic principle is using capacitance resistance or inductance.

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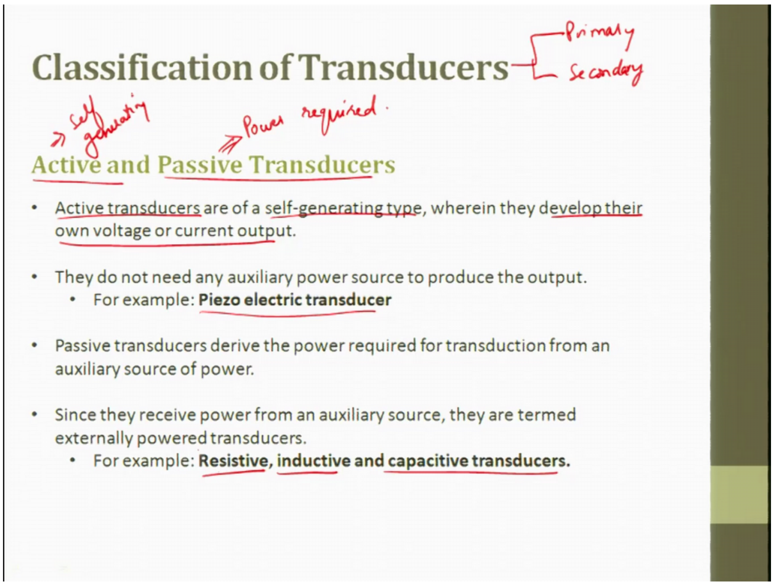

Transducers can also be classified into two which can be active or passive. So, you see several classifications; one it was primary-secondary, the other one is active and passive. So, before that we also saw based upon the principle, you can also classify it as capacitance sensor capacitive sensor, you can cell it as resistive sensor and you can also call it as inductive sensor you can call anyone of the sensor. So, classification active passive capacitive resistive inductive and then you can also have primary and secondary so on.

So, you can have active and passive active transducers are self generating type wherein they develop their own voltage or current output is active; active are self generating type they develop their own output, either, it can be voltage or it can be current predominantly, we use voltage they do not need any auxiliary power source to produce the output example Piezo crystal transducer mechanical displacement into voltage.

Passive transducer derive the power from required for transduction from an auxiliary source of power. So, here what we do is for working the final transducer to come out with the displacement or to come out with a display, they use of power since they receive power from the auxiliary source they are termed as externally powered transducer example resistive type inductive type and capacitive type transducers are called as passive transducers. Passive means power required active self generating.

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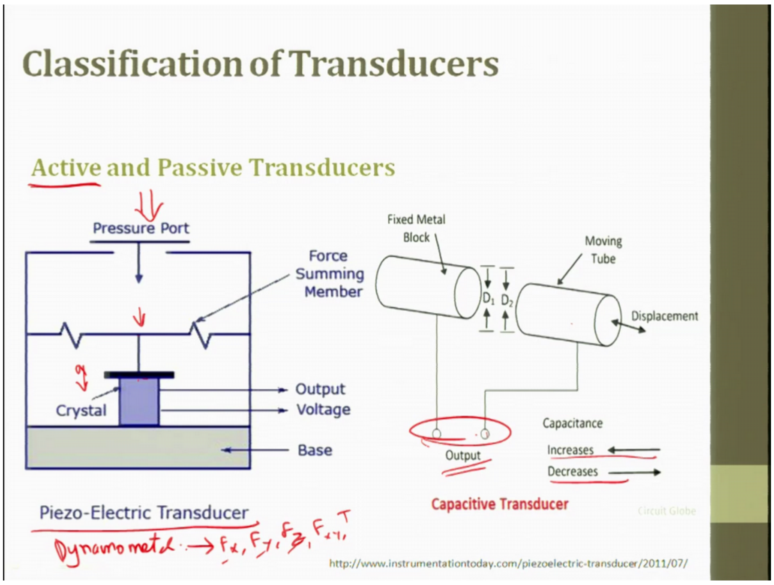

So, this is how a typical active and a passive transducer look like in active transducer you have a pressure port. So, when there is a pressure difference or pressure which comes and hits. So, this tries to push the diaphragm here or force summing member it tries to push up this member in turn pushes the Piezo pushes the top of a Piezo crystal then a Piezo crystal is moved. So, Piezo crystal will be moved to vibrate or based upon the displacement it, it can vibrate if it is sensitive, it will vibrate or it can just go passively and stay it can go just one side displacement and say and then we measure the output and this is the base ok; Piezo electric transducer is also used in dynamometers dynamometer all the force dynamometer uses use the Piezo crystal transducers.

So, pressure; so, in a force dynamometer here force is supplied based upon the force, there is a force summing member. So, this member in turn is attached to a Piezo crystal this Piezo crystal output is measured and you can do it and interestingly when we talk about dynamo meter where Piezo crystals are used they are they can record multiple direction forces. So, this is one direction force, you can have it in xy direction you can also have it as F Fx; force in x, force in y, force in z, you can also have combination forces you can also have torsional forces ok, all these things are possible, these type of sensors are called as active sensors when we talk about passive sensors there is a fixed block here of d and here is a moving tube. So, here what happens? So, this is the fixed metal blocks tries to move and the inside the moving tube or this moving tube gives a displacement.

So, then what happens based upon this movement there is a capacitance. So, can see the direction of increase and the direction of decrease; so, this fellow slides inside and what we get output is a capacitance type transducer. So, here we apply a power and get this capacitance value. So, that is why it is called as passive transducers.

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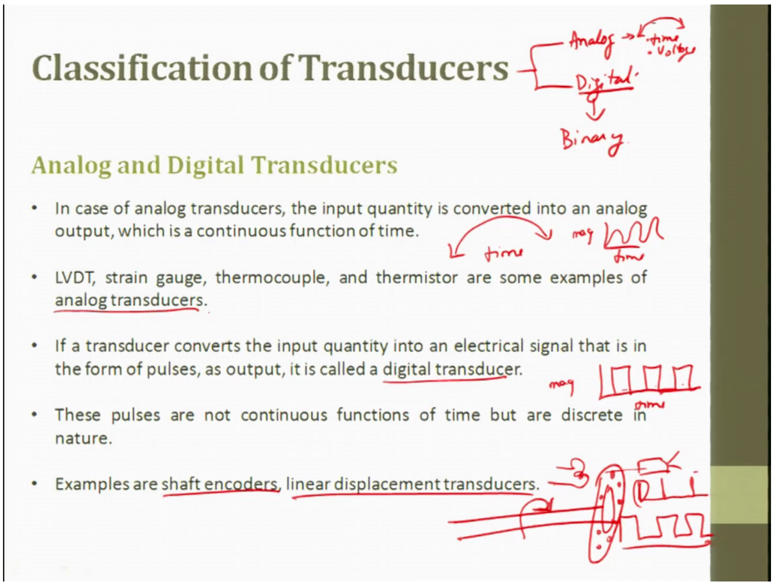

So, you also have analogous transducer and digital transducer analog and digital. Digital means it is binary. So, here you can have a variation analogous variation with respect to time or with respect to voltage whatever it is. So, it is continuously increase and decreasing analogous or digital transducers in case of analogous transducer, the input quantity is converted into an analogous output which is continuous function of time which continuously varies with time varying with time. So, so this is analogous or I can put it like this is magnitude whatever you take this is time. So, it can go something like this it is analogous ok.

Ah. So, LVDT strain gauge thermocouple thermistor are some of the example of analogous transducers, if the transducer converts the input quantity into an electrical signal that is in the form of pulse, then it is called as digital. So, it is magnitude versus time. So, I just say something like this. So, this is pulsed or digital transducer these forms are not continuous forms of time, but are discrete in nature example shaft code encoder a shaft encoder linear displacement transducer.

What is shaft encoder? You attach an encoder at the end of the shaft and it will have lot of slots and then what we do is we passed a bulb and then we have a photodiode which deducts. So, it passes through. So, once this rotates. So, once this rotates. So, the whole is there. So, you will have a light passing through and next you will have a blunt portion or a blind portion, then you will have a next hole which comes through. So, here if you see the signals are given one, then it will be 0, 1 up and down and then it will be 0, then 1 up and down to be 0 1 up down and then it will be 0.

So, if you zoom it, so, then it can be like this. So, these are digital transducers digital analogous transducer gives lot of freedom to play with the signal, you can you can enhance or you can enhance the signal put filters get to avoid lot of noise and then you can process the signal, but whereas, here when we get the signal itself we discretize the signal. So, when we try to discretize lot of noises get added to the basic data and when we do further processing, we miss lot of informations, then we try to do digitisation; however, digitisation is easy to communicate.

So, people prefer digitisation, but once the quality of the of the signal has to know improve; now people transfer analog signal and start working with the analogous transducer ok.

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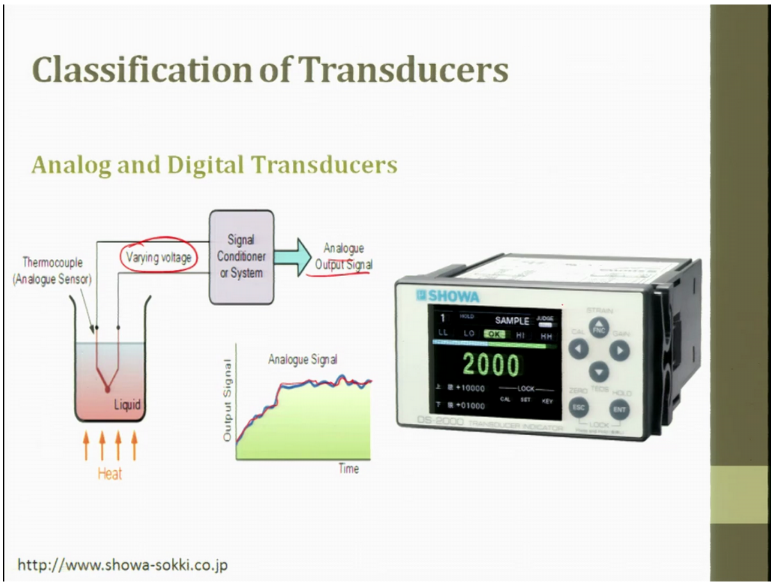

So, this is an analogous transducer; so, where heat is applied. So, you have a thermocouple hot junction cold junction the then it creates an EMF. So, there is a varying voltage which is created this signal is condition monitored and then we try to get an analogous output signal. So, this is the with respect to time this is the analogous. So, you can see the analogous signal continuously recorded with respect to time, this is a device wherein which this data can be recorded and it can also nowadays, it can also give a plot from the screen itself.

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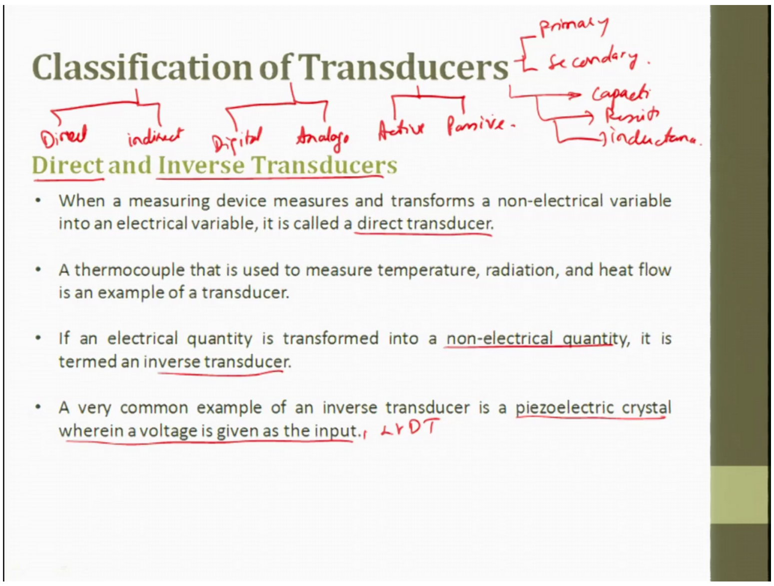

There is another classification which is called as direct and inverse transducer direct transducer and inverse transducer when the measuring device measures and transforms a non electrical variable into an electrical variable, it is called as direct transducer for example, displacement converted into an electrical form.

A thermocouple that is used to measure temperature radiation heat flow is an example for this transducer direct. So, EMF converted into voltage ok. So, that is a direct if the electrical quantity is transformed into a non electrical quantity it is called as inverse transform. So, wherein which suppose I apply a voltage and by applying of this voltage I want an LVDT to move the displacement is to be generated by the LVDT signal the core moves or the ion core which is there between the primary and the secondary coil moves. So, that is called as inverse.

For example a very common example for inverse transducer is a Piezo crystal where in the voltage is given as the input and displacement is taken as the output. So, LVDT can be one Piezo crystal can also be one. So, we have seen lot of classification. So, let me rewind and recollect.

So, one is primary, other one was secondary, one was active, the other one was passive, one was digital, the another one was analog, the next one was direct and it indirect I think, I have covered all the classifications direct indirect active passive and then oh I have not given the basic transducers. So, the other one is going to be capacitance base capacitive, then it is resistive then it is inductance. So, if you see that inductance, if you see that you can put this as passive and active. So, there it can come into that category. So, these are so many different types of classification of transducer.

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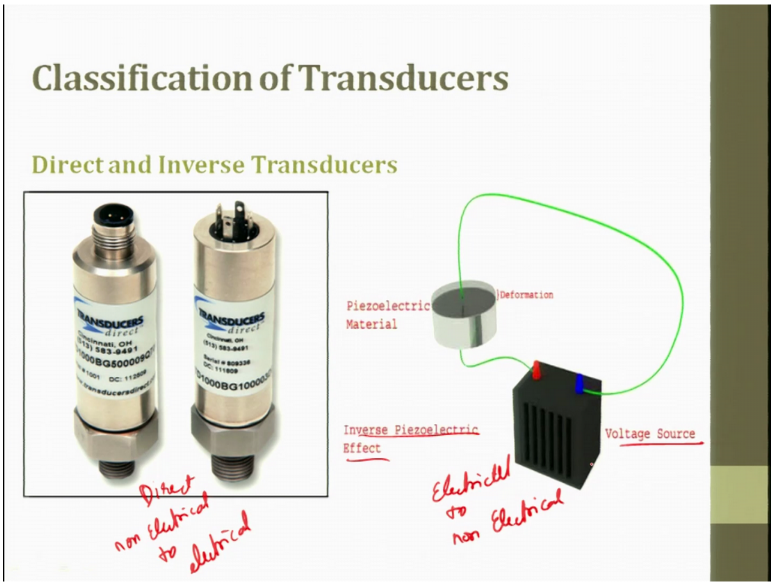

Let us see an example for direct transducer and indirect transducer what is the direct transducer wherein which electrical signal is converted when a measuring device measures and transforms a non electrical value into an electrical value it is direct when it is converting and an electrical signal into a non electrical quantity is called as inverse signal. So, here we can see an electrical Piezo crystal is given. So, then this Piezo crystal tries to move. So, here you have inverse effect which is given; so, voltage source. So, Piezo crystal moves ups and up and down.

So, what is an inverse? Inverse is an electrical quantity is transformed an electrical quantity is electrical quantity is transformed into displacement, it is called as inverse. So, a measuring device the transform non electrical values into electrical signal is direct. So, this is direct; so, non electrical to electrical. So, here it is electrical to non electrical displacement right. So, it is called as inverse transducer.

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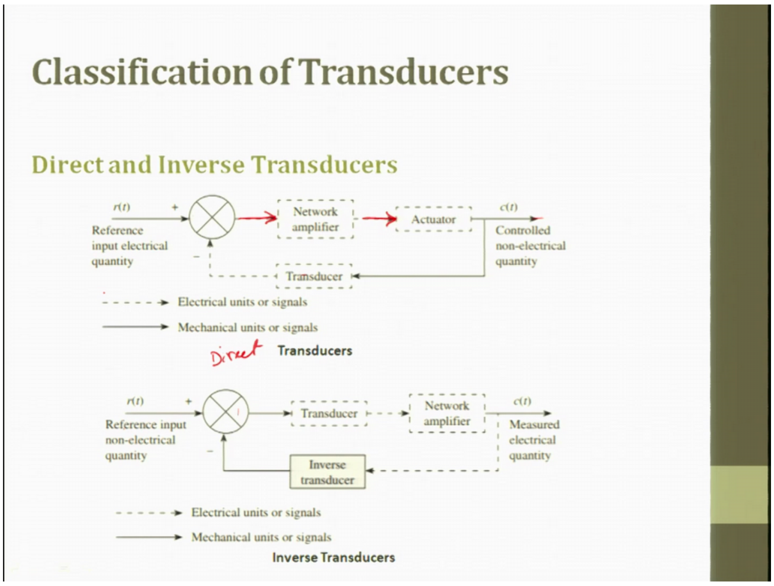

So, direct and inverse transducer let us see with the a schematic diagram. So, you have a reference signal which is given as a input ok, then you have you have a comparator. So, then you have a network amplifier. So, this amplifies and then it tries to actuate whatever it has recorded, it tries to actuate. So, then this actuation happens and then you have a controlled non electrical quantity signal, which is coming out. So, based upon the actuation, the I measure the displacement of the actuation is a transducer and this signal is fed in and then it is compared and the reference signal is given.

So, electrical unit or signal is going in this direction going in this direction mechanical comes in the reverse direction; so, after the transducer you have an electrical signal. So, that these electrical signals can be compared easily and then you can start doing. So, this is a direct transducer direct transducer; so, converts non electrical into electrical. So, if you take inverse the schematic diagram goes like this reference input non electrical quantity is given here displacement then transducer network getting amplified and then you get a measured quantity output from here, we get an electrical signal does inverse transducer this is transducer, this is inverse transducer and then you get a mechanical signal.

It is compared and the next set of signal goes on this is a beautiful schematic diagram which tries to talk about direct transducer and indirect or inverse transducer ok.

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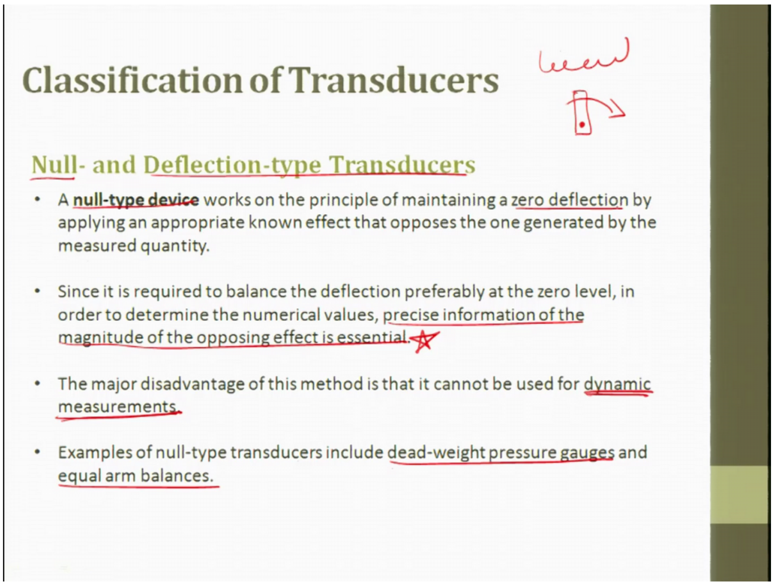

Then you have null and deflection type transducer we saw this null in comparators. So, you can also have a null type device working on the principle of maintaining a 0 deflection by applying an appropriate known effect that opposes the one generated by the measured quantity. So, it is always in 0; or you try to put a measured value. So, then it immediately shows the displacement and from the displacement, you try to apply some force and bring it to 0.

So, now you know how much have you applied such that brought it to 0. Now this quantity can be measured with that we try to get some information a null type device works on the principle of maintaining a 0. So, for example, if there is a pointer; so, this; so, this pointer while keeping it to in front of some device what happens it tries to deflect ok, then it tries to deflect.

Now, I try to apply force and re bring it to the center position and a find out what is the force I have applied to re bringing it to the central position and then this I converted into a known quantity and null type device works on the principle of maintaining a 0 deflection by applying an appropriate known effect that opposes the one generated by the measured quantity. Since, it is required to balance the deflection preferably at the 0 level in order of determining the numerical value precise information of the magnitude of the opposing effect is essential since, it has to bring back this point is very very important.

The major disadvantage of this method is it cannot be used for dynamic measurement why dynamic measurement there is something called a static measurement and dynamic measurement static measurement is you try to record the maximum value note it down dynamic means how does the response change with respect to time. So, then you have to have a device, which is very sensitive which can measure all the deflections all the responses, right.

So, the major disadvantage of this null type is it cannot be used for dynamic measurement when I do force measurement I will always try to do dynamic measurement olden days when we used to do with that dial gauge, it was only maximum force measurement used to measure, but now when we have this dynamic measurement during the process of machining we are able to find out different insights what is the interaction between the tool and the workpiece.

So, dynamic measurement is very vital example for null type transducer induces dead weight pressure gauges and arm and equal arm balances. So, these are some of the devices which work on null type device null type device works on the principle of maintaining a 0 deflection ok.

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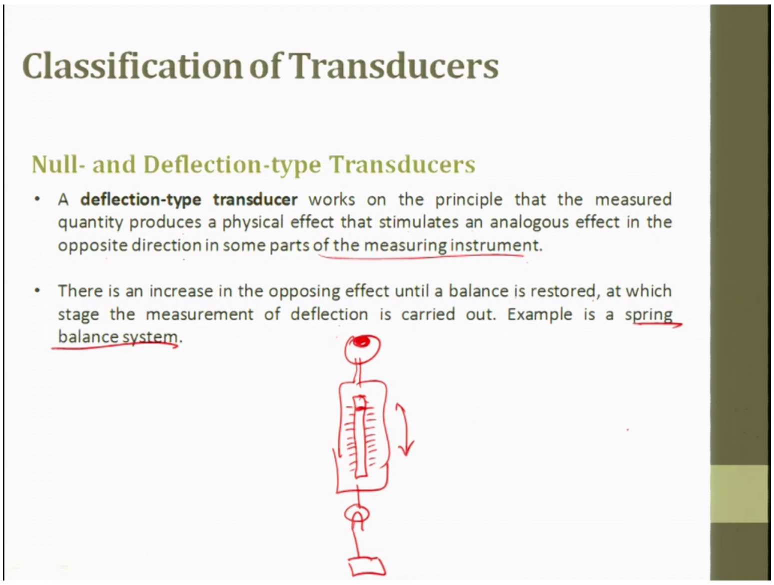

So, the deflection type transducer works on the principle that a measured quantity produced a physical effect that stimulates an analogous effect in the opposite direction in some part of the measuring instrument I repeat works on the principle that the measured quantity produces a physical effect measured quantity is displacement quantity produces a physical effect that stimulates an analogous effect in the opposite direction in some part of the measuring instrument.

So, principle of measured quantity is temperature produces a typical effect on stimulated an analogous effects like putting a thermocouple and measuring it in the opposite direction in some part of the measured instrument, there is an increase in the opposing effect until a balance is restored at which the stage the measurement of deflection is carried out example a spring balance.

So, what happens in a spring balance is the spring balance always it is in 0 position. So, what we do is, we try to put a weight on it the; so, movement you put a weight on it the spring tries to stretch ok. So, it tries to stretch. So, there is an increase in the opposing effect because normally it will be in a compressed position once you put a weight it is in an extended position opposite effect until a balance is restored at which stage the measurement of defection is carried out. So, the load whatever you apply you see maximum displacement happening. So, the work this deflection type transducer the simple example is spring balance.

Spring balance is nothing, but a hook is there. So, you have a spring and then you have a hook this hook is grouted and then you have a reading you have a pointer here. So, when you apply weight, you apply weight, this fellow moves up and down. So, there is an increase in the opposing effect until a balance is restored at which stage the measurement of the deflection is carried out and the simple example is the spring gauge. So, we saw null type and deflection type null type is it brings it to 0 and this is the other thing.

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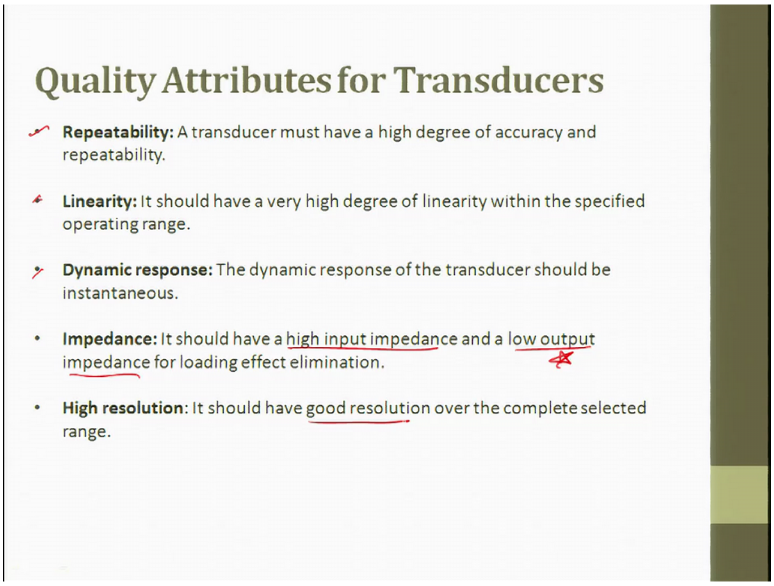

The quality attributes for transducer are like for any sensor, it is repeatability the transducer must have a high degree of accuracy then linearity it should have very high degree of linearity in the specific operating range, then it has to be dynamic it to; that means, to say any response, it has to take instantaneously, it the impedance it should have a high input impedance and the low output impedance for loading effect elimination this part is also very important, it would have very high input impedance and low output impedance such that, it does not take the loading effect, then high resolutions are required so, that it tries to give very close accuracy.

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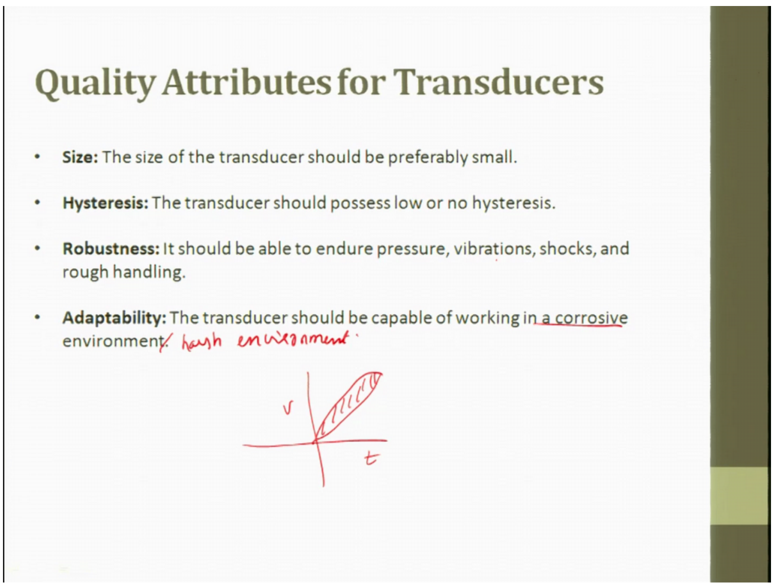

And then size the transducer size should be as small as possible hysteresis possess should possess low or no what is hysteresis for example, this is voltage versus time. So, you load when you try to unload it tries to take a different path. So, this is called as hysteresis loop. So, this should be as minimum as possible. So, then robustness, it should be able to ensure endure pressure vibration shock and rough handling robustness should be there as one quality and adaptability the transducer should be capable of working in a corrosive; corrosive environment or in harsh environment ok, these are some of the attributes which are which transducer should have.

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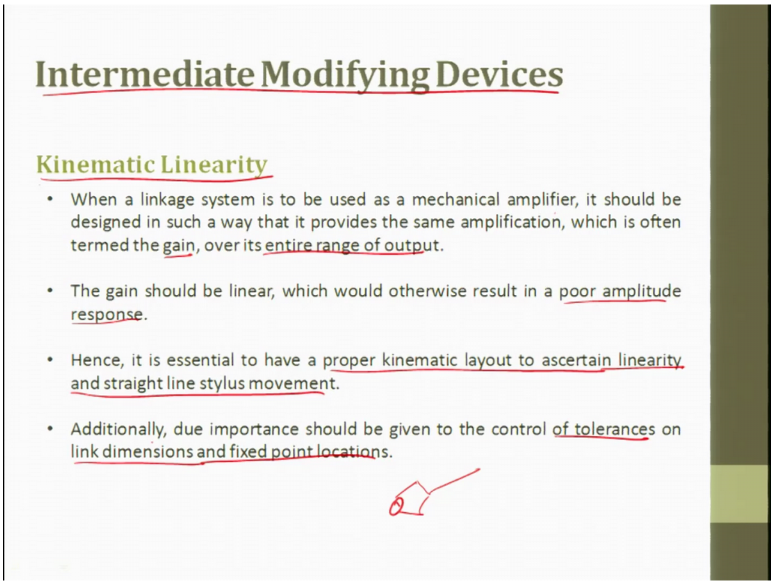

So, now we have seen the primary part now we will move to the next part which is the intermediate modifying device. So, here kinematic linearity is very important when a linkage system is to be used as a mechanical amplifier, it should be designed in such a way that it provides the small amplification which is often termed as gain over its entire range of output ok.

A linkage system is used as a mechanical amplifier see before this electrical could come people were trying to use only mechanical amplifiers if you go back and see the dial gauge if you see that there will be lot of gears, these gears these gears are basically used to for amplification. So, mechanical amplification; it should be designed in such a way that it provides the same amplification, which is often termed as gain and over an entire range of output, the gain should be linear which would otherwise results in poor amplification.

So, that is why you see in all the sensors are transducer is a the working range; why we do this specify the working range because in that working range, where is a linear response basically when you have linear response, you can try to write a mathematical equation and cross correlate y and x parameter without any error term.

Hence, it is essential to know a proper kinematic layout to ascertain linearity and straight line stylus movement additional due important should be given to control of tolerance on link dimension and fixed point location. So, this I was talking to an example of gears if you want to have a fixed link movement that is also possible.

Pivoted at a point and then what you do is you try to magnify. So, example like a pentagram in a pentagram the dimensions the linked by changing the link dimensions you can magnify the displacement.

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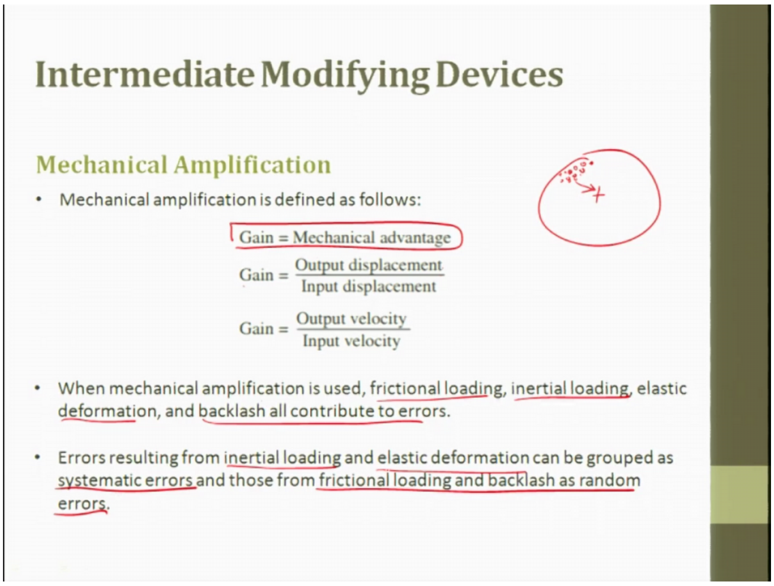

So, mechanical amplification is defined as the following; a gain is nothing, but a mechanical advantage gain is otherwise declared as output displacement by input displacement or it can be output voltage to input voltage. So, displacement the first derivative of it is velocity you can have the next derivative also as acceleration. So, x dx by dt, then next will be dx square by dt square. So, output displacement by input displacement output velocity by input velocity when mechanical amplification is used frictional loading inertial loading elastic deformation and backlashes are contributed to error.

Error resulting from inertial loading and the elastic deformation can be grouped as systemic error what is systemic error these errors are consistent and by mechanical wear and tear the systemic error happens. So, if we can try to figure out the response over a period of time then accordingly the correction factor can be given. So, systemic error are nothing, but if you go back to precision and accuracy somebody trying to hit all the or fire all the bullets at this point they are very accurate, but they are displaced from a the center point.

So, you can put a correction systemic correction and then move this to this point ok. So, the resulting error with forum inertial loading the elastic deformation can be grouped as systemic error and those from friction loading and backlash are random error frictional loading and backlash are random error this happens over a period of time, but it is very hard to predict the friction loading and backlash error.

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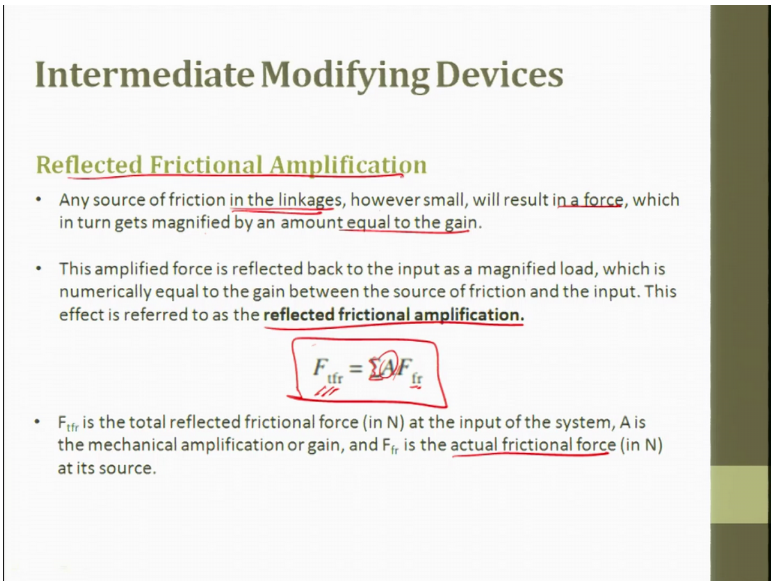

The reflected frictional amplification any source of friction in the linkage; however, small. So, that is why today what we are doing is we are trying to replace all these linkages with Piezo crystals. So, here there is a, in Piezo crystal the displacement happens you can stack the Piezo crystal you can amplify the displacement. So, we are moving out of mechanical amplification to electrical amplification any source of friction in the linkage; however, small will result in a force which turns gets magnified by an amount equal to their gain ok.

So, small movement in linkage gets magnified that is what we are trying to say here, this amplified force is reflected back to the input as magnified load which is numerically equal to the gain between the source of friction and the input. So, this effect is called as reflected frictional amplification reflected frictional amplification can be recorded as F to the suffix t f r, which is nothing nothing, but total reflected frictional force in Newton as the as the input to the system a is the mechanical amplification F is the actual frictional force at its source right frictional force at its source.

So, t total reflected frictional force can be written as summation of a is nothing, but the mechanical amplification in to F actual friction force for individual components. So, that is why we have given a summation ok. So, this is what is reflected frictional amplification; amplification of backlash and elastic deformation.

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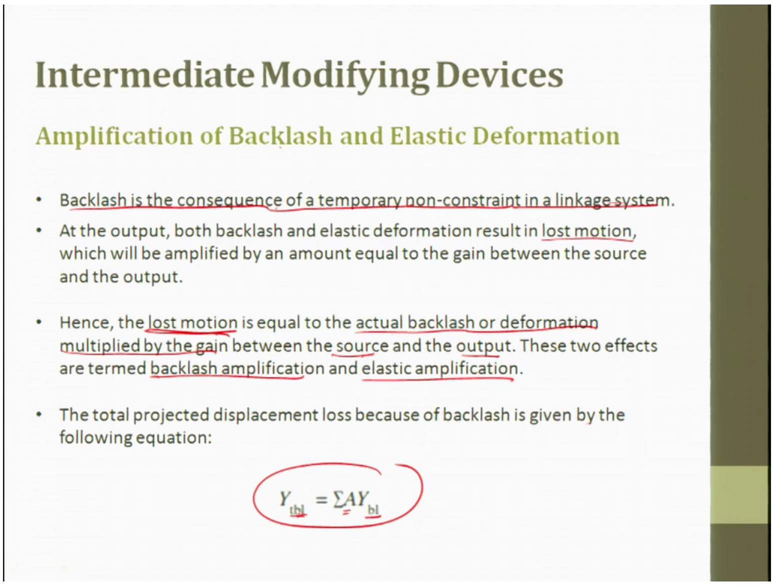

So, this is also very important backlash is the consequences of a temporary non constrained in the linkage system backlash is the consequence of a temporary non constrained in linkage system for example, it if you have two gears they are mixing with each other over a period of time this gears get worn out. So, when you move in the forward direction it will move when you go 10 rounds it might move to 10 millimeter when you come in the reverse direction 10 round, it might go only 9.5 millimeter. So, the difference whatever there is called a backlash.

So, same way this backlash also happens if we have in these linkages. So, the backlash is the consequences of a temporary non constrained in the linkage system at the output both backlash and the elastic deformation results in lost motion which will be amplified by an amount equal to the gain between the source in the output. So, this also will get amplified.

Hence, lost motion is equal to actual backlash or deformation multiplied by the gain between the source and the output. So, these two effects are termed as backlash amplification and elastic amplification. So, you have understood the lost motion is equal to actual backlash or deformation multiplied by gain will be the lost motion between the source and the output will be the lost motion.

The total projected displacement loss between because of backlash is given by the equation Y tb is equal to summation of A into Y bl backlash a is the area tbl is the total total backlash loss.

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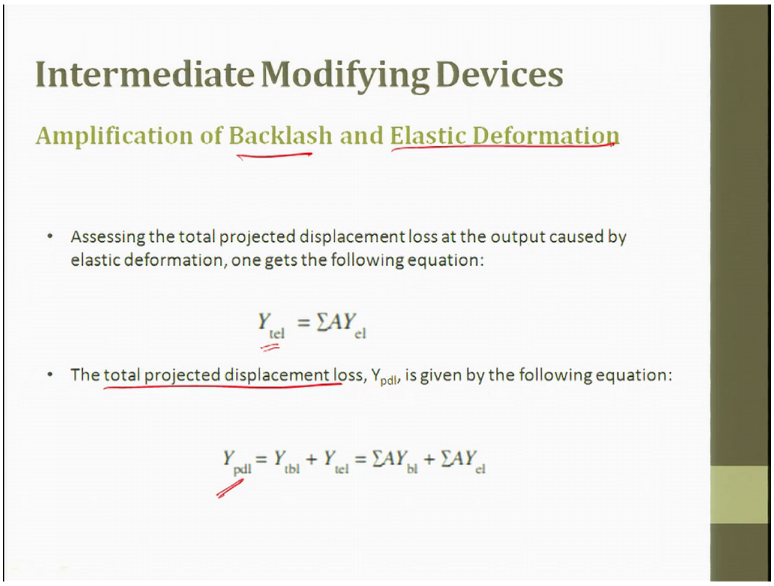

So, assuming that the total projected displacement loss at the output caused by the elastic deformation one can write the equation Y tel is equal to summation of A Y el elastic. So, the total projected displacement loss Y pdl will be equal to first one tbl plus Y tel, which is nothing, but these two summations what we get is the total projected displacement loss.

So, these are all the losses because of backlash and elastic and here there is also a gain which comes into influence. So, that is why we are trying to find out what is the influence.

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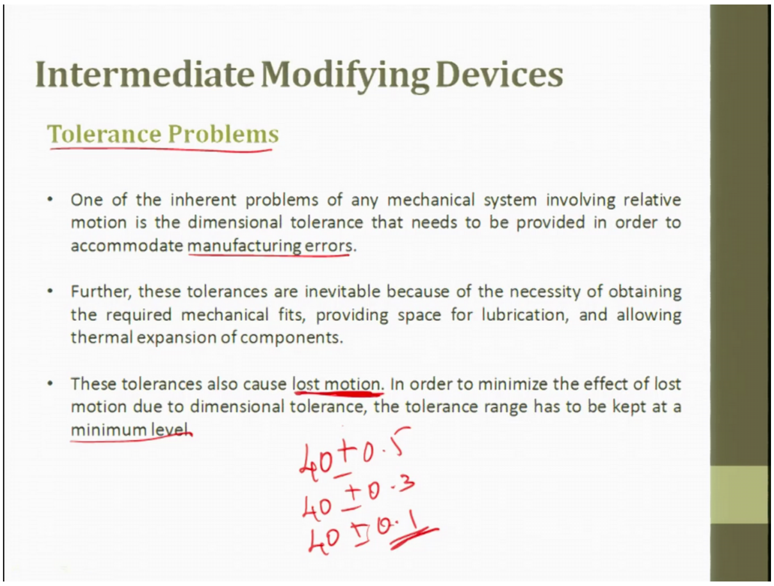

The other thing in the intermediate modifying device, we will have tolerance problem. So, one of the inherent problem of any mechanical system involves relative motion in dimensional tolerance that needs to be provided in order to accommodate manufacturing error. So, we are just trying to say why is tolerance given.

Further, these tolerance are inevitable because the necessity of obtaining the required mechanical fit providing space for lubricant and allowing thermal expansion of the component we need to give the tolerance. So, these tolerance also cause lost motion in order to minimise the effect of lost motion due to dimensional tolerance the tolerance range has to be kept at as minimum level as possible 40 plus or minus 0.5, 40 plus or minus 0.3, 40 plus or minus 0.1.

So, the tolerance level has to be kept as minimum as possible such that the lost motion is reduced ok, I understand when the tolerance level goes smaller and smaller and smaller. So, the cost goes higher the number of possess involved is high, but you should also understand when the tolerance becomes very liberal and when you have an a fit, then it becomes a completely different response and there is a lot of lost motion.

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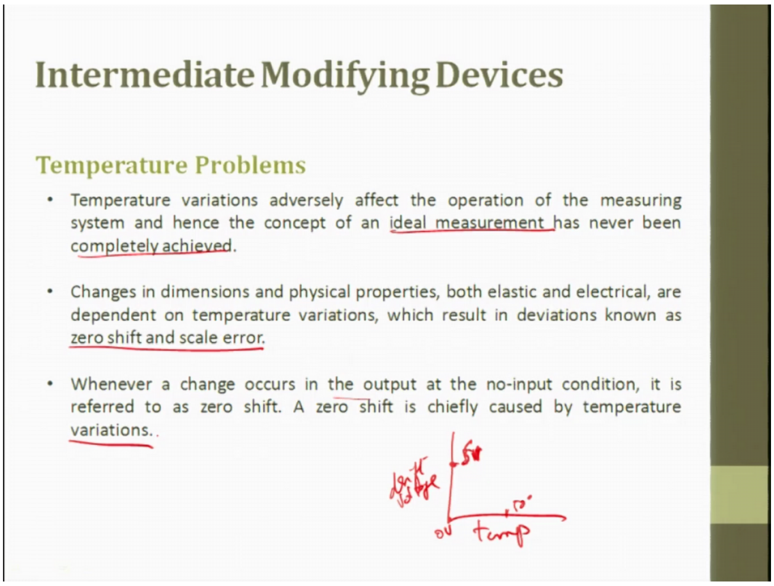

The temperature also leads to a lot of problems in this intermediate modifying as the temperature goes high the system starts malfunctioning; for example, there can be a thermal expansion of the cable and the coil. So, it gives you a different reason.

The temperature variation adversely affect the operation of the measuring system and hence the concept of ideal measurement has never been completely achieved with respect to temperature change in the dimension and physical properties both elastic and electrical are dependent on temperature variation. So, increase in length when you talk about increase in length happens, because of temperature when the current passes through it.

So, you completely get a different electrical response with results in a deviation known as 0 drift or scale and scale error when the change occurs in the output at the no input condition; that means, to say at a as the drift happens say for example, temperature then with respect to drift voltage when the temperature is 0 the drift voltage when the temperature goes high maybe 50 degree Celsius, you see the drift voltage might go here. So, there is a drift may be this might be 5, this is 0 volts, this is 5 volts, ok. So, this is a 0 drift is chiefly dependent on the temperature variation, we saw elastic deviation, we saw backlash deviation, we are now seeing temperature based problems for the drift.

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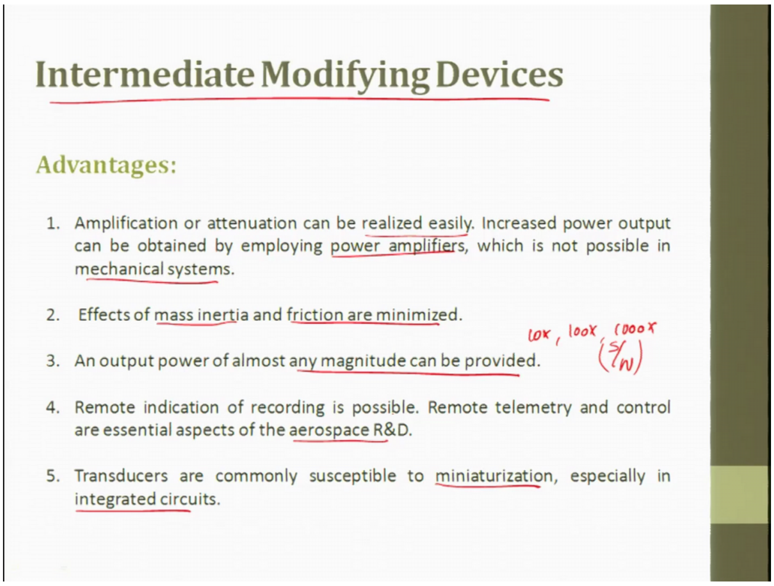

So, next we will start looking intermediate modification devices advantages. So, the first major advantages amplification or attenuation; so, amplification means increased attenuation is decreased amplification or attenuation can be realised very easily increased power output can be obtained by employing power amplifiers which is not possible. So, easily in mechanical systems, of course, you can use a levers and then you can a gears and you can magnified, but there is always a wear and tear loss. So, power amplifiers can be used such that you can amplify the signal.

The effect of mass inertia and friction are minimised to a large extent in the intermediate modified devices and output power of almost any magnitude can be provided. So, just by varying the electronic circuit, you can try to magnify it may be 10 times hundred times may be 1000 x also can be done very easily, of course, when you keep amplifying you will also try to have there is a factor called a signal to noise ratio the noise has to be reduced as an when you go high remote indication of the recording is possible remote telemetry and control are essential aspects of aerospace and R and D..

So that means, to say here what we are trying to do is based upon the sensing signals these signals can be wireless communicated. So, you can start receiving it and start possessing, it transducers are commonly susceptible to miniaturisation especially in integrated circuits where this in intermediate modified devices place a very very important role.

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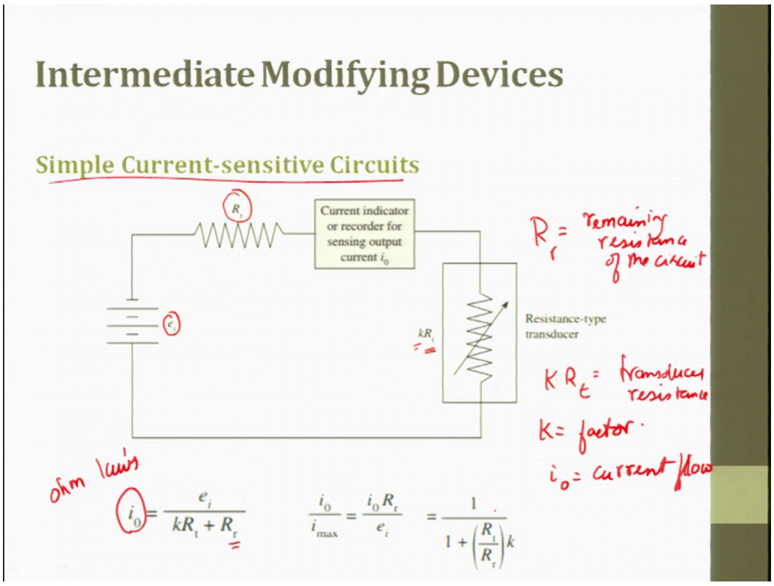

Next we will move into simple current sensitive circuits. So, here we see that this is the applied energy input energy this is the resistance R to the suffix r, then the current indicator or recorder of sensing output of current i naught, then you have R t, which is resistance type transducer where k is the magnitude which or a factor which can be multiplied with the current in term the i naught is expressed in terms of ei by k R t by R r by R suffix r

So, I just wanted to convert this into i naught by I max and then I get i naught into R r divided by e i, this can be reiterated and written like this. So, k R t is the transducer resistance trans where k is a factor R r; R suffix r represents the remaining resistance of the circuit and i naught, I have already given here i naught will be the flow of current, i naught will be the current flow. So, this is by using Ohm's law; Ohm's law; we get this. So, then what we write? We rewrite the equation in this form and then we finally, bring it to a ratio which can be used.

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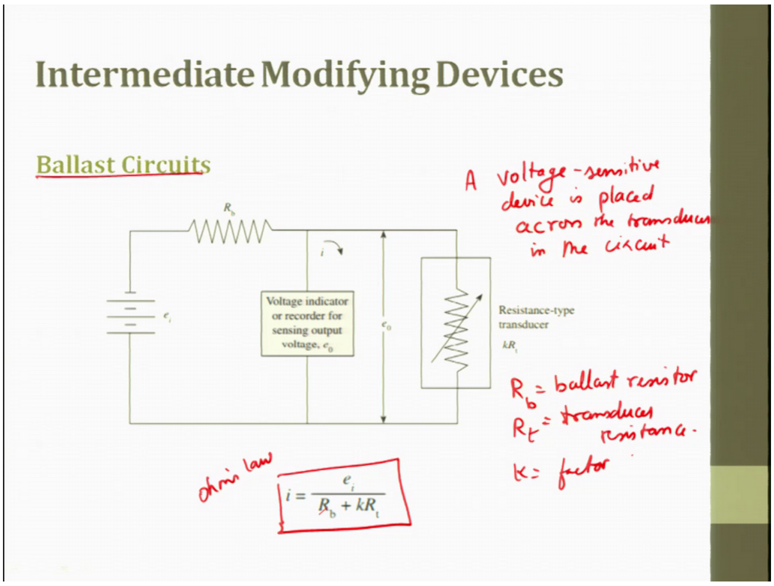

So, the next one is going to be Ballast, Ballast circuit. So, here we will have e i which is an applied voltage. So, this basically this is a small variation here a voltage here a voltage sensitive device is placed across the transducer across the transducer in the circuit this is small variation to the simple circuit. So, it is placed here. So, that we try to get the current variation. So, it is important to note that that in the absence of R b.

So, let me first write down what is R a. R b, R t; so that you will be able to understand. So, R b is the ballast resistor and R t is the resistance of the transducer; R t is the resistance of the resist transistor transducer sorry transducer resistance. So, again here by applying Ohm’s law Ohm’s law, you get this circuit, i current is nothing, but the voltage applied by R b plus k R t if ballast resistor is 0, then i is nothing, but e i by k R t where k is the factor k is the factor.

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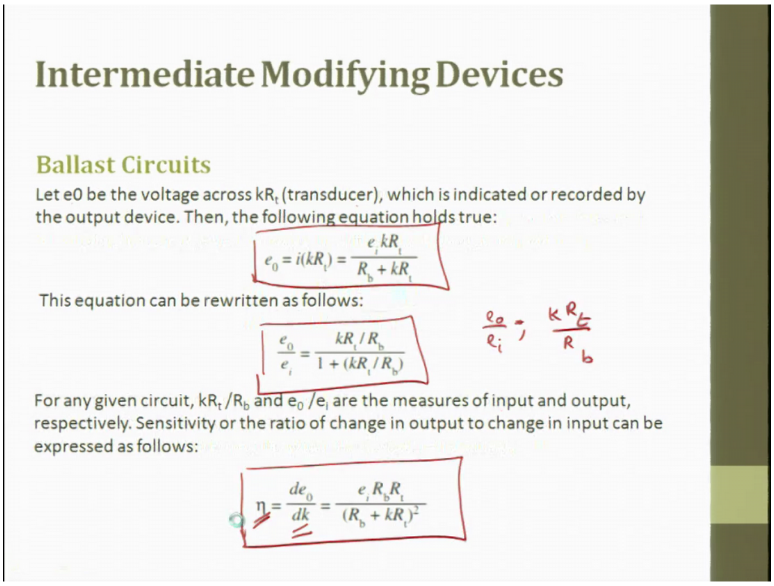

So, if e naught be the voltage across k t k R t which is indicated or recorded by the output device then the following equation holds good. So, this is going back and tracing from the previous equation. So, this equation can be rewritten like this and for any given circuit k R t divided by R b and e 0 by e i are measured input and output. So, e 0 by e i are. So, this and k R t by R b. So, these two are input and output, which are measured. So, the sensitivity ratio is given by the change in the output to the change in the input. So, you differentiate this with respect to k and this is what is the final equation you get this is to find out the sensitivity in the equation.

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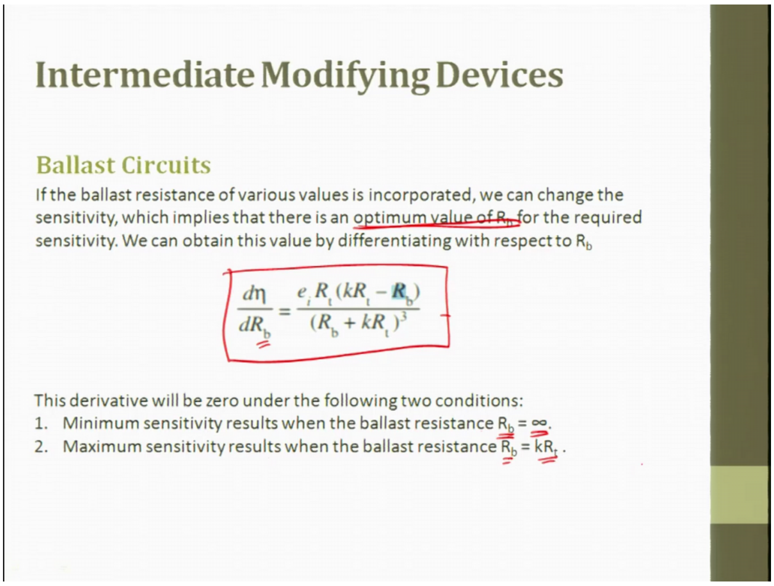

So, if the ballast resistance of various values is incorporated. So, what are the various values? So, here we have taken this and we have replaced it with n. So, if we start replacing it with differentiating it with R b. So, we can change the sensitivity which implies that that there is an optimum value of R b for the required sensitivity. So, when we differentiate this with respect to R b, we get this equation changed right we get this equation changed with respect to they are differentiating with respect to R b. So, dou n by dou r ok. So, that is with R b that is expressed in this form

So, what are we finally, saying we are trying to say that there is an optimum value for R b for the required sensitivity. So, this is an important equation where you have to understand sensitivity analysis and the optimum value of R b this derivative will be 0 the derivative will be 0 for the following two conditions, when the minimum sensitivity results for the ballast resistance, R b is equal to infinity or the maximum sensitivity results when the ballast R b equal to k times R t ok. So, this is about the ballast circuit.

Thank you very much.