Process Control - Design, Analysis and Assessment
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Understanding PID Gains

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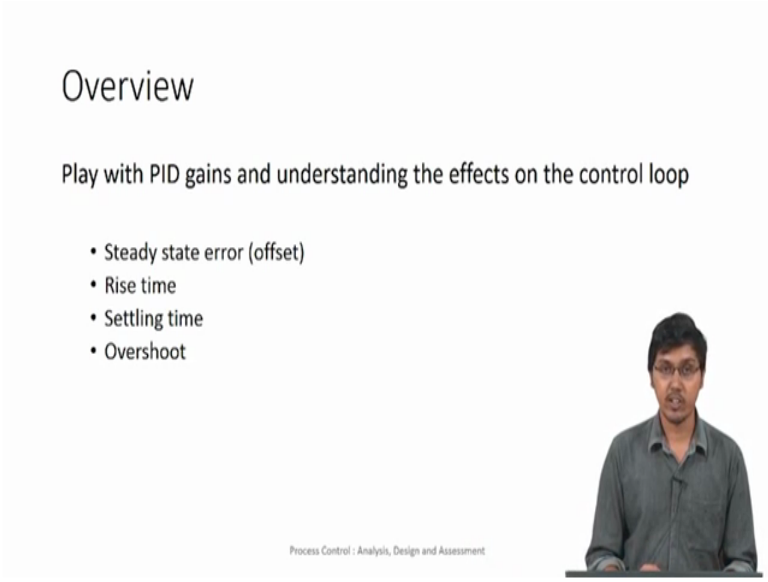

Welcome to the next lecture on process control and it is simulation, so in this lecture we are going to play around with PID gains and we are going to see like how each as an effect on the control loop behavior. So we are going to mostly use MATLAB for this particular lecture, so what we are going to basically see is like we are going to see the effect of PID gains for the steady state error which is the offset and their parameters like settling time, rise time and overshoot.

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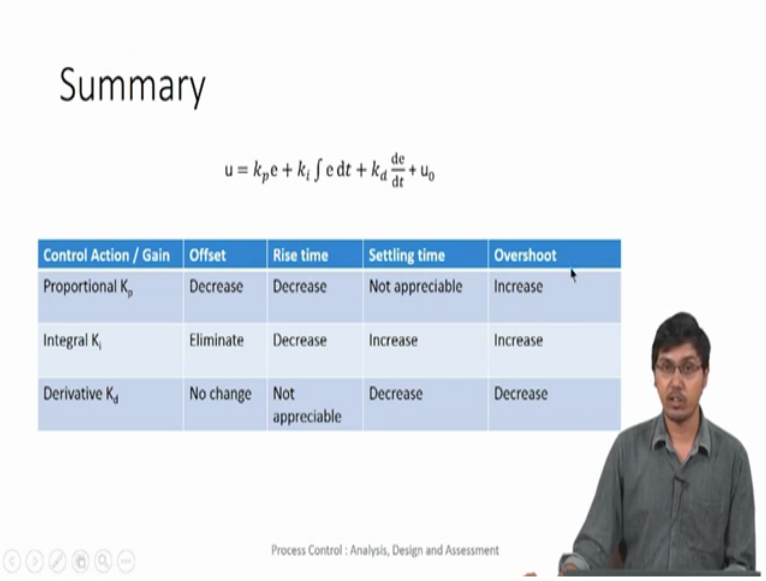

So and finally we are going to look at this table and see like a there we are able to observe all these relationship between whatever if we increase these values what will be the effect on a offset and what will be the effect on rise time, what will be the effect on settling time and what will be the effect on overshoot, to you switch out to matlab and we will see the effects.

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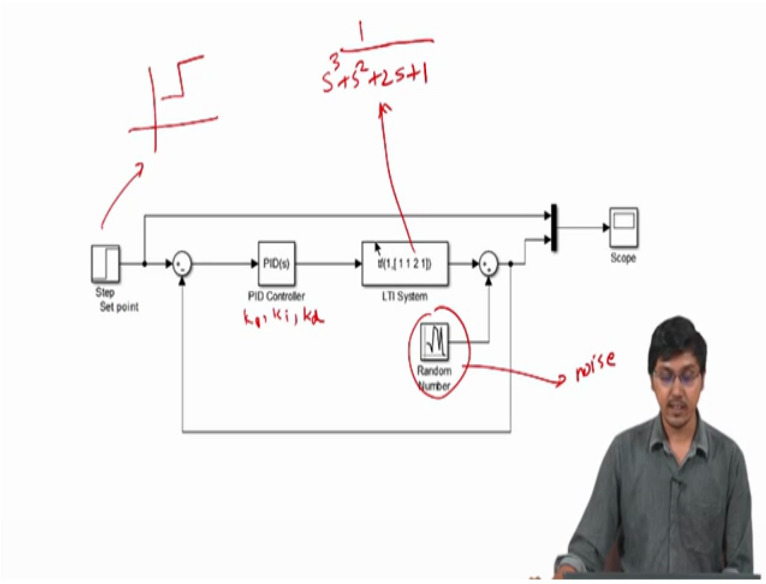

So if you could see here this is the Simulink that we are developed, so let us just go through the this control loop to understand what you are done, so if you can go to Simulink and find the blocks of step PID controller, LTI system you can get all this blocks and what we are trying to do is like we are going to we are having a system this is the system, system is nothing but 1 by S cube plus S square plus 2s plus 1, so that is what this transfer function says.

So the first one is the numerator and the these is actually correspond to coefficients in the denominator for the powers of s and then if you could see here like a register set point which is we are trying to give a step input we want it to change the value of the control variable by a step input and then we are going to see out system is behaving, so basically what we are trying to achieve is a servo response basically we are trying to change the set point and then we are going to see how the output is following the set point and the input signal we are giving for a set point is nothing but step input.

And there is a PID controller block that is inside inbuilt inside the MATLAB, so this is been going out k p, k i and k d and we are going to observe the (diff) the how output is going to change and also like towards the end of this we will use this particular thing which is now which is just going to generate a noise, so any measurement has some noise so we are trying to induce effect of the noise into the output and then see how this control is going to behave as well, so that is what if you want to do towards the end of this, so with that we are we will just starts simulating and seeing the responses.

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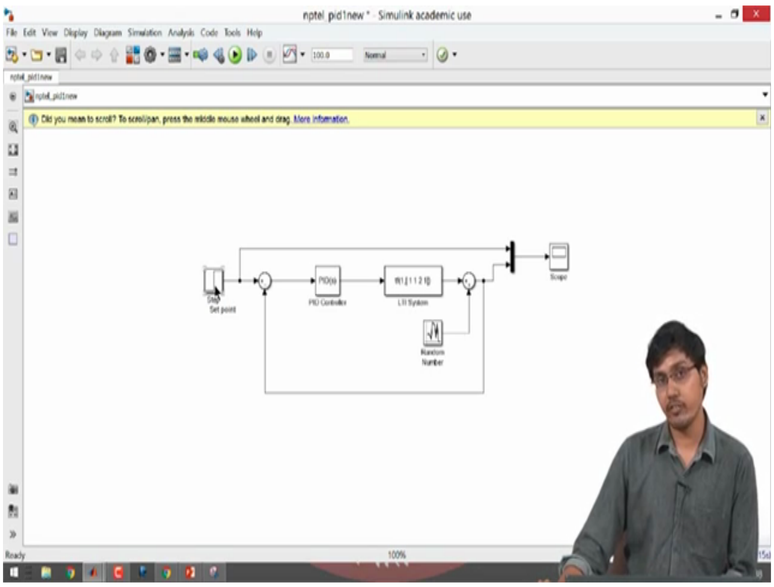

So if you see here like a I just open the blocks and show out what are the parameters inside it maybe you can or if you have any doubt you can also go to the website or like online matlab and then see that they are like could expressions available in the internet but just let us go through it quickly once.

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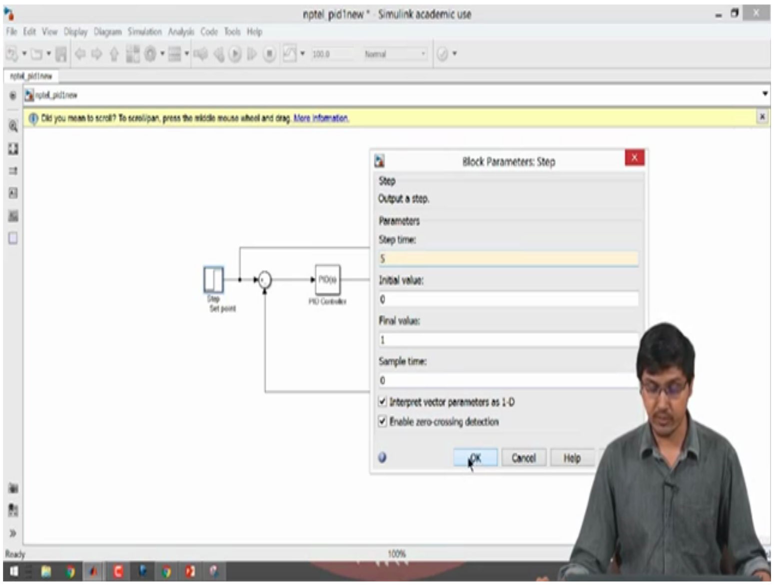

So statements put says like the initial value is 0, so it changes from 0 to the final value 1, so step time is like a at what time I want it to create the step for example let us say I monitor to change the (inp if inp) initial value from 0 to 1 after like 5 seconds or 5 steps of simulation, so that is what we are going to do here.

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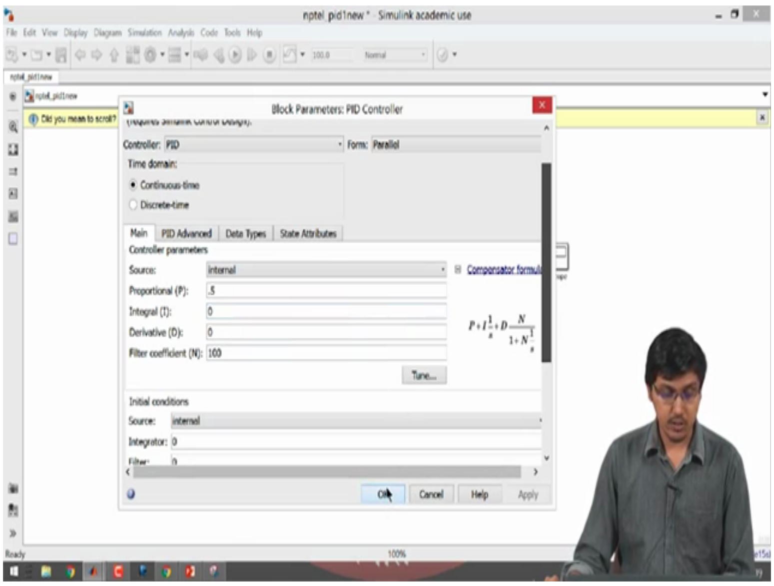

And if you open the PID controller block you can see here there is a proportional gain, integral gain and the derivative gain and what we have here and let us forget off for now about this filter coefficient it is the differentiation that we are implementing here, so it is forget for this for now and then we are thus going to change this PID value k p, k i and k d values and going to see how it is arriving the response.

And also there is a bios part if you could see here there is a option here call tune this is this will open the MATLAB's PID tune and blocks which is which you can use for automatically tuning the setting the getting the values of k p, k i and k d that is but for now we are now interested in tuning the controller and seeing that we are what we are going to do in this lecture is just go and change these values and then see like what are the things at changed to get an understanding of it is just like a gain that we are going to do now.

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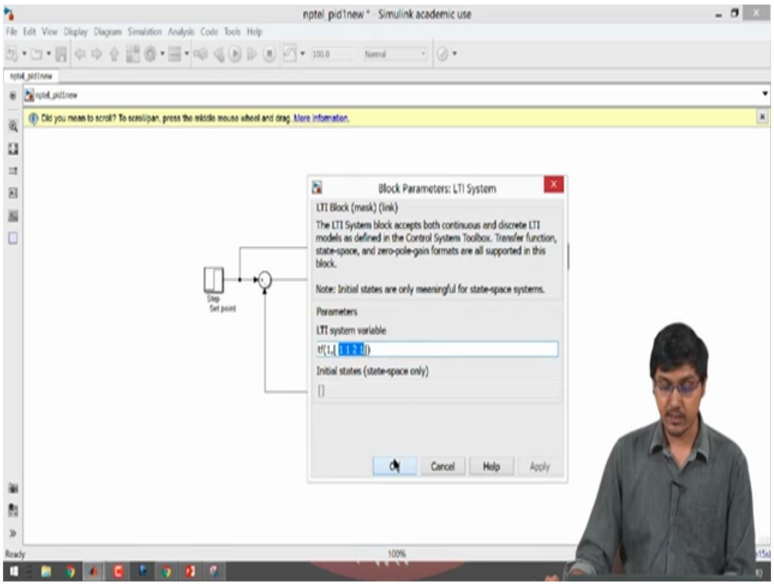

So let us now start with and this random and this transfer function block is nothing but as we already discussed this as a numerator and then this is power softer this is a coefficient of the power soft s in the denominator and the this is hammer block, so this has the signal with the noise.

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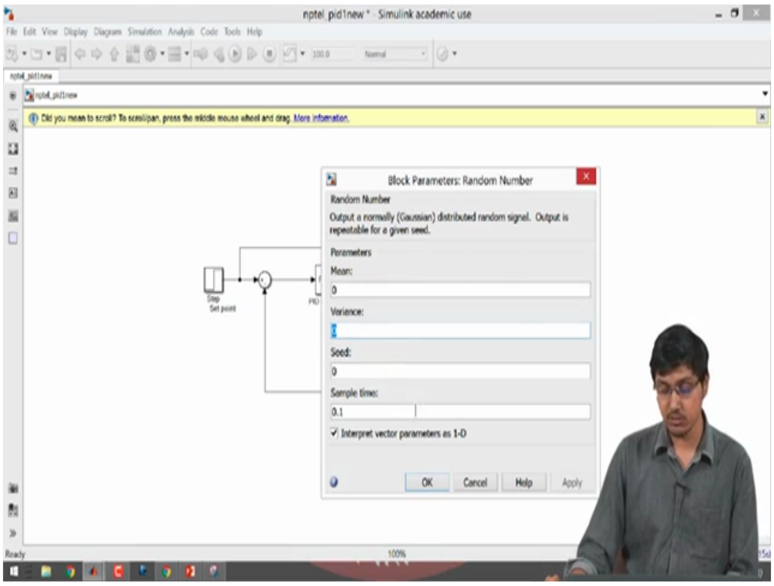

So if you just look if you could look through this signal then it just says like what will be the mean of the noise and then what will be the variance of the noise, so we are put both as 0 which means connectively there is known there is no noise now. So without noise we are going to simulate first and this is the scope and this is the multiplexer which will actually come show both the signals bios set point signal and also this particular signal onto the scope, so let us start simulating and seeing.

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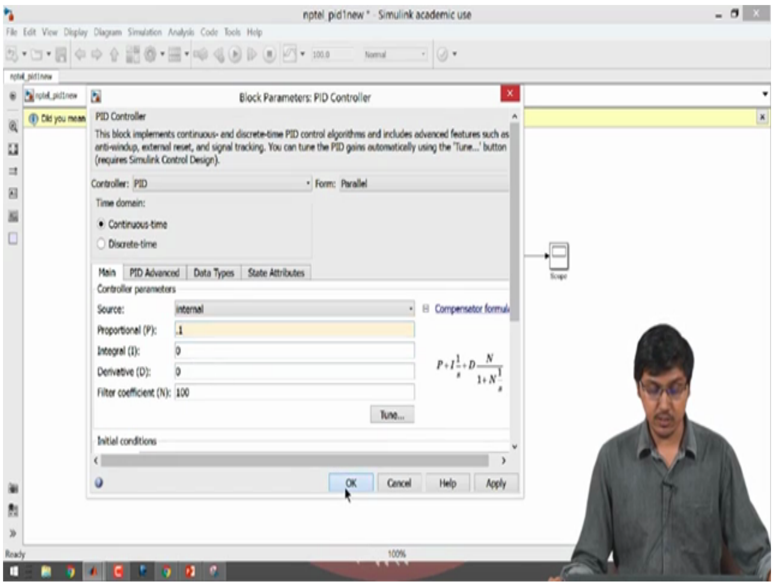

So now just remember the value of proportional gain k p be are is let us start with a small value, so point 1 and k i value is 0 and k d value is 0 again so we are just going to see how the system behaves.

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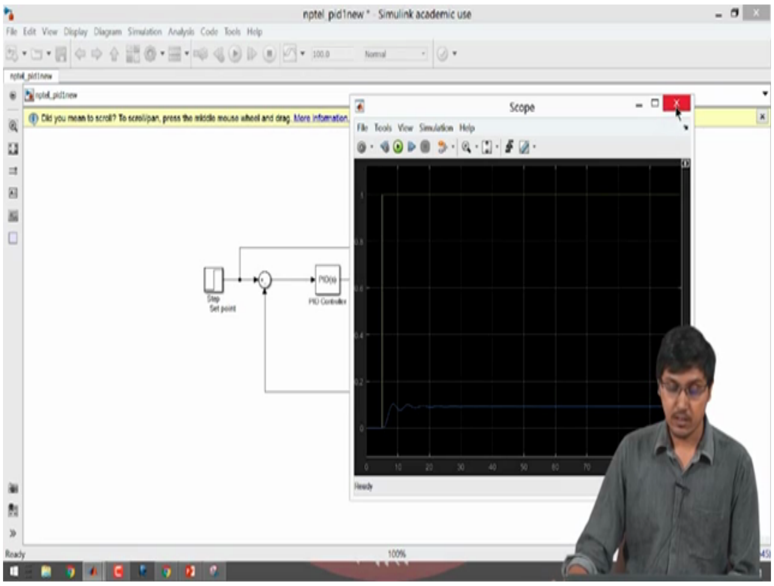

So now if you could see here the yellow line shows the set point change that is this is the how we wanted the output of the process to vary but what has happened this is basically the output has change from 0 it has increased but it has some error see if you could see here we want till the value of 1 here but it settles at the value of around say point 1, so this is called steady state error.

So at the steady state after everything like there is no transition where I have so it makes (()) (05:45) this level, right so at the steady state what is the error I have between whatever value I want and whatever value the control loop the output of the process is basically though that is like there is a constant error now so that this is called steady state error, steady state error is nothing but 1 minus point 1 it is point 9 and also let us now increase the value of k p and see what happens.

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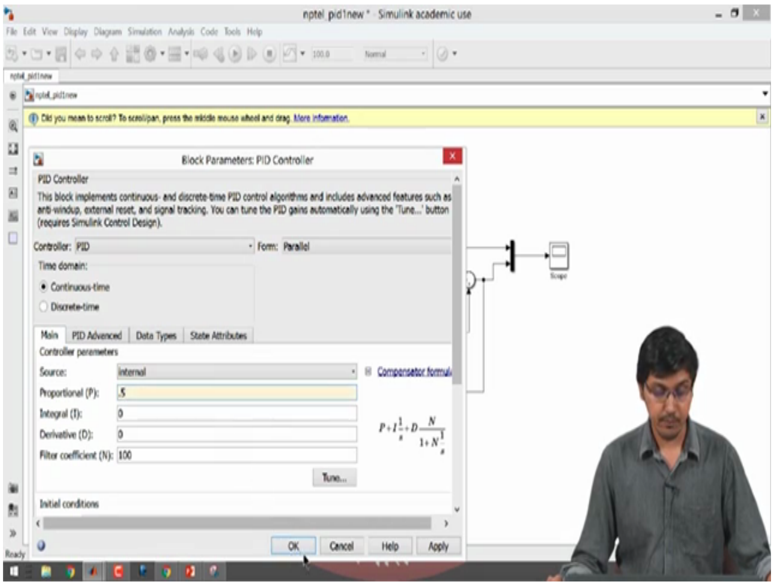

So basically what happen to now is basically increasing the value of k p let us say point 5 and then we are going to see what happen now.

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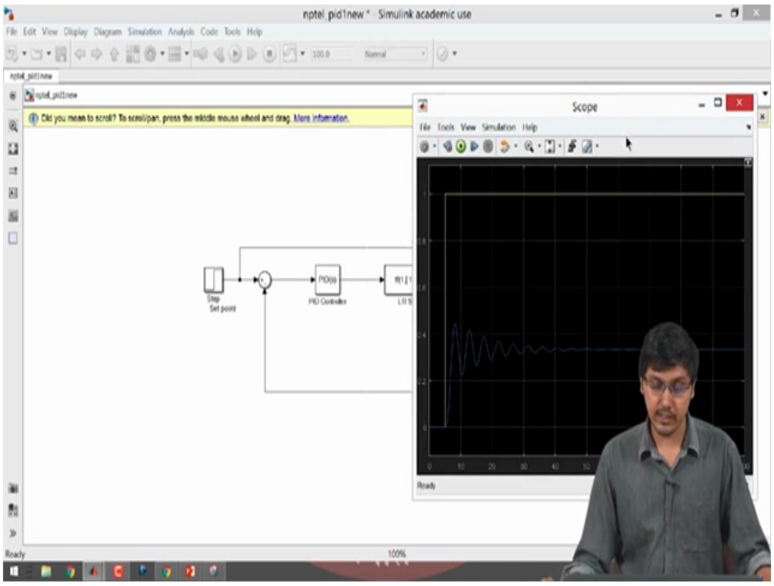

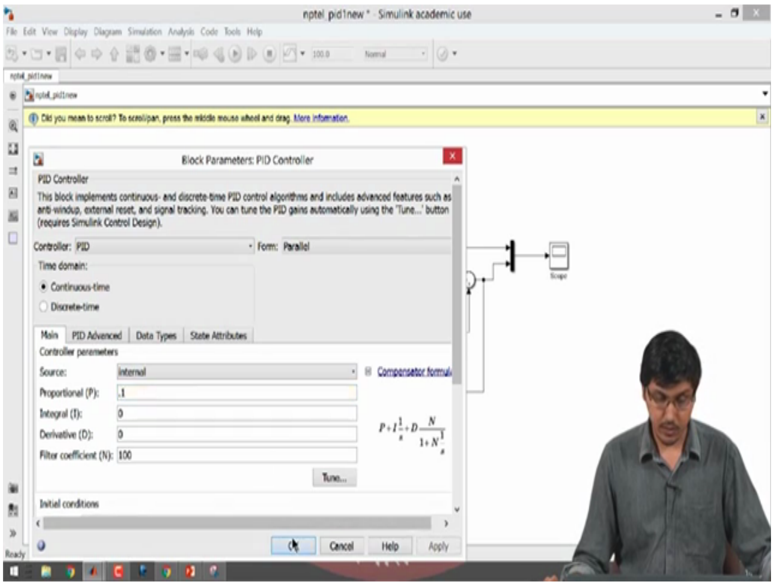

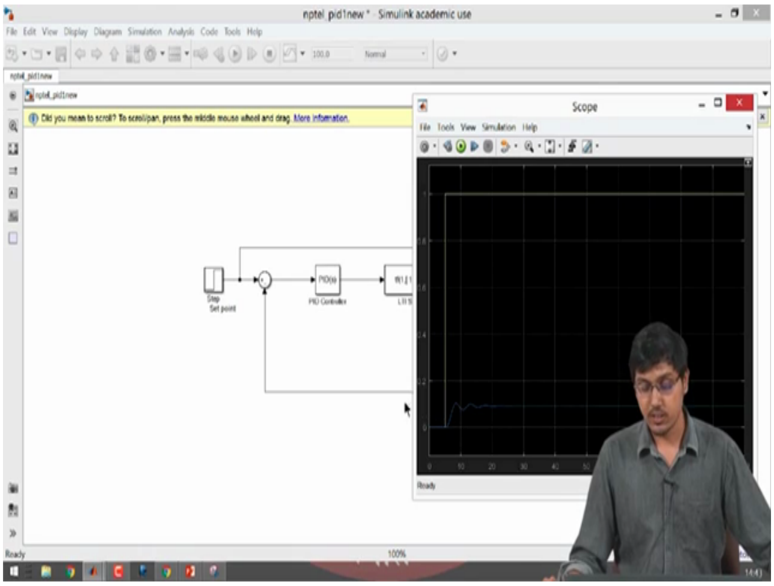

So as you could clearly see the offset has decreased so increasing the k p is decreasing the offset or offset is the steady state error so that is actually decreasing it was initially (po) it by hang value of this (cont) of this control variable was point 1 now it has become like around point 3, 5 or something, so basically the steady state error the difference between the value we this here and the value we are got us decreased.

So now there are two things we have observed right one is like increasing the increasing like proportional gain as decreased offset and also like it has also induce some (k i) actually it has if you could see the previous one we will compare both the things, so if you could see the parallel value and then if you could see now this is this has crossed like the final value by a very small amount, so if you could see the parallel value here it is around point 1, or something so but this is there if you could see in the initial starting portion it has crossed that final point and then decreased and then it has settle that point, so this value as also increased, so this we call as the overshoot.

What is overshoot? Is nothing but what is the (diff) what is the increase in this value that it has gone and come down and when we comparing to the final values, so now we have been increase in the proportional gain as I showed increase the overshoot.

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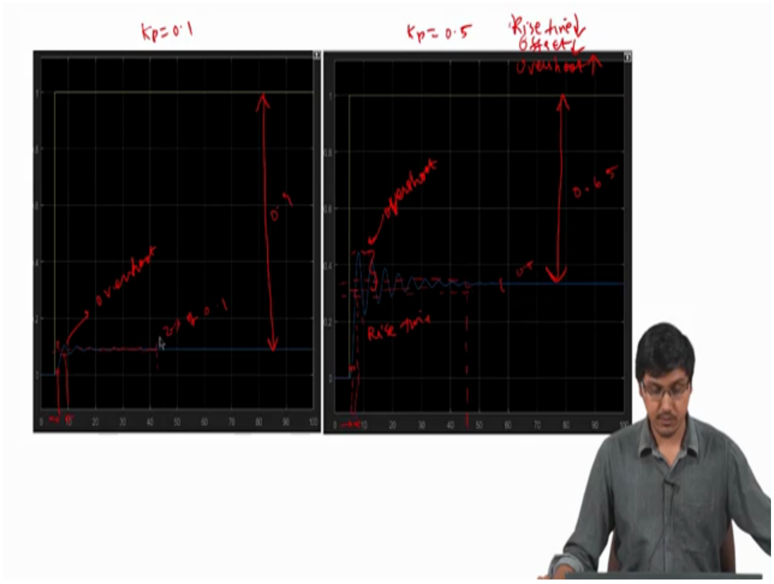

So now we can so we add the both the values of k p in this particulars slides. So this is nothing but what we are assume let it for k p equal to point 1 and this is what we assume let it for k p equal to point 5, so we will compare both the things so first thing we can (abh) initially see we can easily see is like this is the offset here and this is the offset, so increasing the proportional gain as actually decrease the offset so this is some same value around point 9 approximately and this is something around point 6 something point 65 or something maybe lesser than that but yeah it is just qualitatively this what we have to understand is increasing the proportional gain as decrease the offset, ok.

And another thing that we can see here is like if this is the final value see this is the final value and this has crossed a final value by this particular (quanti) this particular value here and this is the final value by it is (())(08:59) and this is the value by which it has cause initially so this is called this initial peaking is called value that it peaks is called like how it shoots the final value, it goes over it and comes down so this has also increase if this here the value of overshoot is like a very less is very small increase and near the value of overshoot is very high.

So this two things we can very easily observed from this pictures and also like if you could see here we can also define another entity call settling time, settling time is nothing but the final the time taken for this value to go between the two ranges for example like here let us say this is the final point 5 is the final value, so to reach to be within point 2 percentage of this particular value is what we call settling time and this has like become like somewhere around here and this is like this is even here you can see like it is going here and then so like big thinks it is as smaller value the 2 percentage is also smaller.

So basically this is again 2 percentage of the final value here, so this is around 2 percentage of point 1 and this is like 2 percentage of point 3 or something so more or less this is settling like this 2 percentage comes around here so there make me some effect but it is not like a very appreciable effect as we can see from overshoot or the offset, so this is what we observe on like what happens when we increase the proportional gain.

So the main thing that you can carry out carry with and like one more thing you can see is like there is a thing called like from 10 percent of the final value to 19 percent of the final value what is the time taken, so that is called time to rise there is a 10 percent of the final value to the 20 percent of the final value how long it takes to go and if you can see here this is like a slower thing, right so to from 10 percent of this to 10 percent of this is may take some time and this is like too short.

So if you can see it this time is longer than this time, so this when you increase the gain we can see two things one is the rise time is decreasing, ok and offset is decreasing so these are a two things that we can clearly make out from this and also we can see another thing is like overshoot is (decrea) increasing, so these are the observation that we have on increasing the proportional gain what happens.

So you can also like play with different transfer functions and observe that these things are right and one more thing is talked about but we or it do not observe anything significant settling time, settling time actually did not have any great impact or we cannot make anything about settling time. Now next thing will go to the integral controller and see like what happens to the integral controller.

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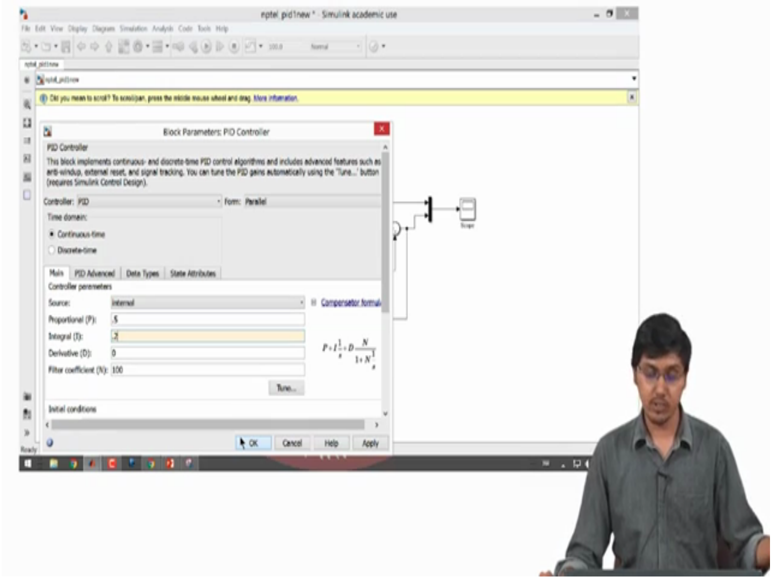

So coming to the MATLAB again and we are going to change the integral controller, so let us say we are going to have the integral controller by point 2 just we are giving some small value to start with you can give some other value and see how it behaves, let us see how it response now.

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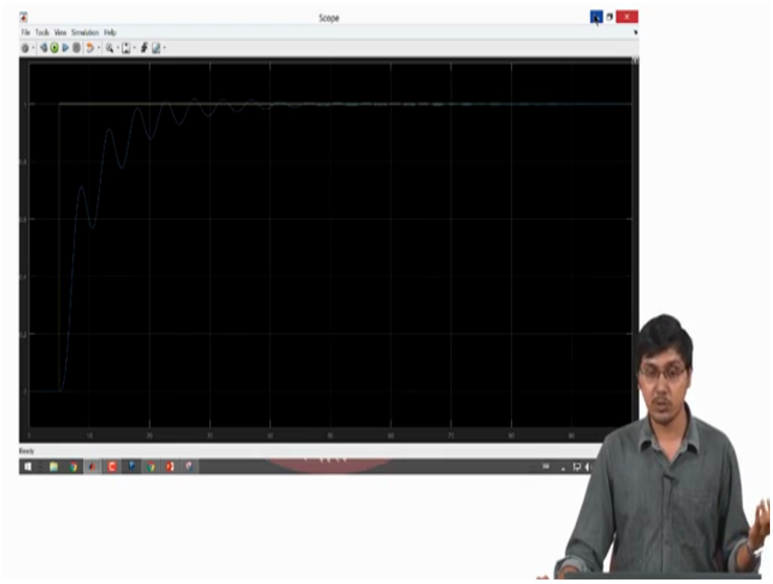

So the most interesting thing about this one is like there is no steady state error basically it the value is reaching the set point, so there is that is the very good thing about integral controller, so that is the reason why we most of the controllers that are that we are used in the (())(12:44) industries are p i controllers proportional and the integral controller, so integral action is very good thing to have from the perspective of it eliminates the steady state error.

So when we say I want it to go say 90 degree Celsius if we have a just proportional controller we may not go to 90 degree Celsius you may have you may stay somewhere at 80 degree Celsius we can never go to 90 degree Celsius when we give a step change in the set point etcetera and but this integral controller actually solves that problem it is goes to the it touches 90 degree Celsius.

So we now we will try changing the values of integral gains and see like what happens when you change the integral gains, so one thing is whenever we have integral controller it is going to remove the offset or remove the steady state error, so the next question is ok what will happen if I change the integral gain what will be the output, so that is how the output is going to vary.

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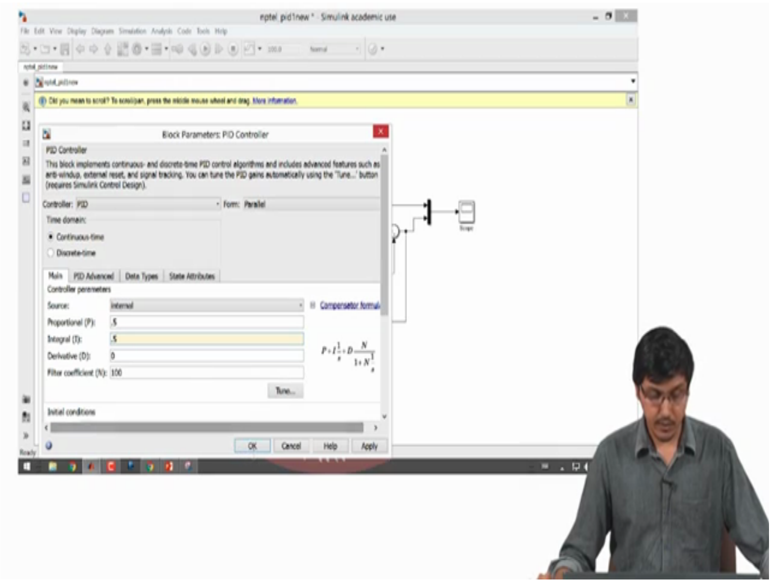

So that is what we are going to see now, so let us say let us take like ok we will go to point 5 and see what happens.

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Yeah, so basically if you can see here this is looking different from that is now let us put both these things together in a single page and compare the both the values, both the charge.

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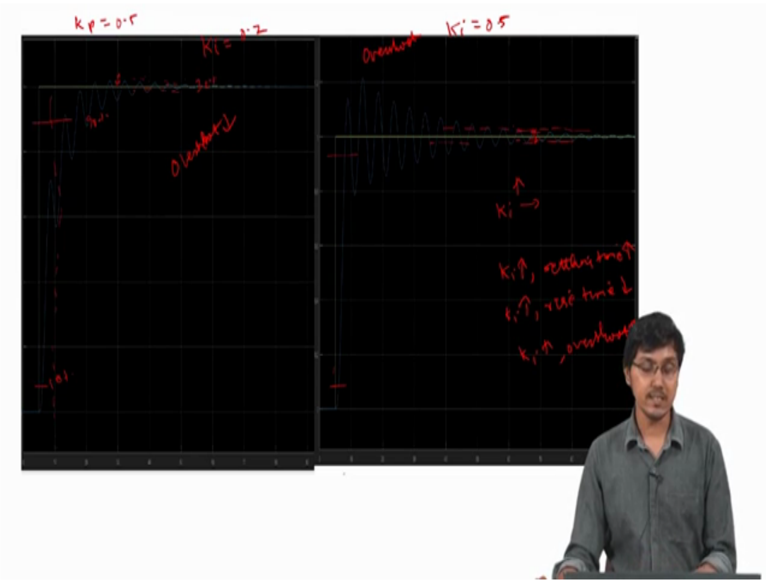

So what we are done is we put both the figures in the same page so we can compare them so this is nothing but k i is having a value of point 2 and this is nothing but the k i is having a value of point 5 and the k p in both the cases it is the same, so it is point 5. So what are the things we can see here first thing is like for this particular first graph like if when k i was lesser that time the it went in to a particular say two let us say this is 2 percent it is assumes 2 percent it went into that quite sooner than this, so if you can draw the same 2 percent here because it is the same value 2 percent of the final value and in both the cases the final value is nothing but 1 because it is going to eliminate the steady state error so there is no offset, so the final value is same.

So within this particular 2 percent range this goes faster than this one, so when you increase The k i settling time is actually getting higher, so it takes longer for me to go and stay within a particular ends, so it is so it takes a longer time to go and stay within this because it error it goes outside of this range again so here probably somewhere here it goes between this range and stays within there.

So settling time increases when k i increases unlike as take this one this is like I said this is like a 10 percent and this is 90 percent so the time taken to rise from 10 percent to 90 percent here is actually longer than here, so when I increase the k i the rise time is decreasing because here it is faster, see the here within 10 minute within 10 seconds it came but here if you can see here it took more than 10 seconds.

So that is again something we can evidently see from this and also like see increasing the k i values does not have any effect on steady state error whenever you have some value for k i whenever it is integral action steady state error is going to go to 0 so going to reaching 0 like steady state error reaching 0 as no impact on k i because for any value of k i it will if there is a steady state error is going to eliminated, so that is something that we will not worry much about, you know.

And the other thing that we will see is like we are talking about another thing called o how much it shoots over, so if you could see here, here it the final after the final value it has crossed only or very small levels, so here overshoot is very less like a percentage like a after this is the final value, so how much above the final value this has gone that is very less here but here how much above the final value it is gone is very high, so increasing the k i actually increases the overshoot value, so this is something that we can remember, so these are the sponsors that we have for a integral gain.

Now next thing we will go again is to do is changes for a derivative gain and see what happens and.

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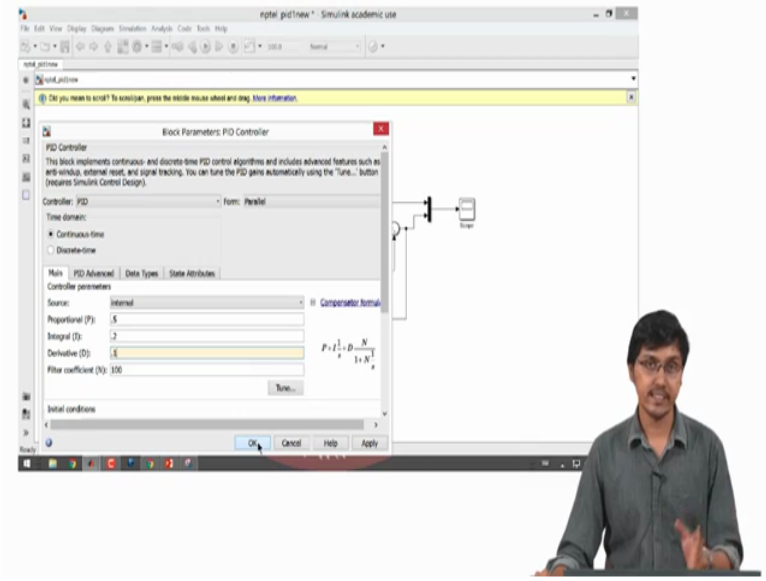

So coming to MATLAB again and let us put some value for the derivative gain now and for let us start with point 1 may be that you can put another value this is like are trying to see what happens basically so we are not going by any rules or something we are just going to change again and see what is happening and basically for qualitatively comparing or is k i difference gain behavior.

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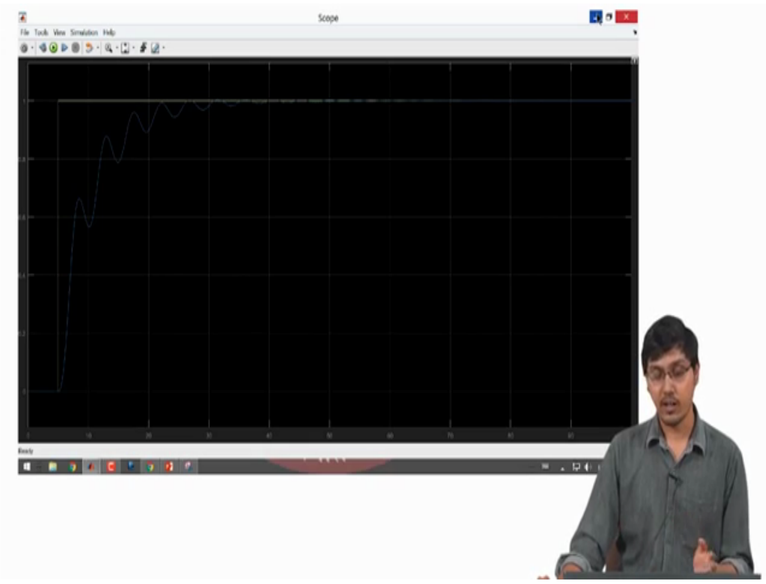

So coming to this, so here we have to compare this with basically we are what are you basically using this like k p is a same k i is point 2 and we have I had a derivative gain and this is this as behavior like one thing we can vary as easy as like previously we add some in some places it went above this and then came down but here it is very insignificant it is not going so much above this finally but let us do the same kind of exercise like we will change the k d again like a derivative gain again and then see like between what happens when you increase the derivative gain.

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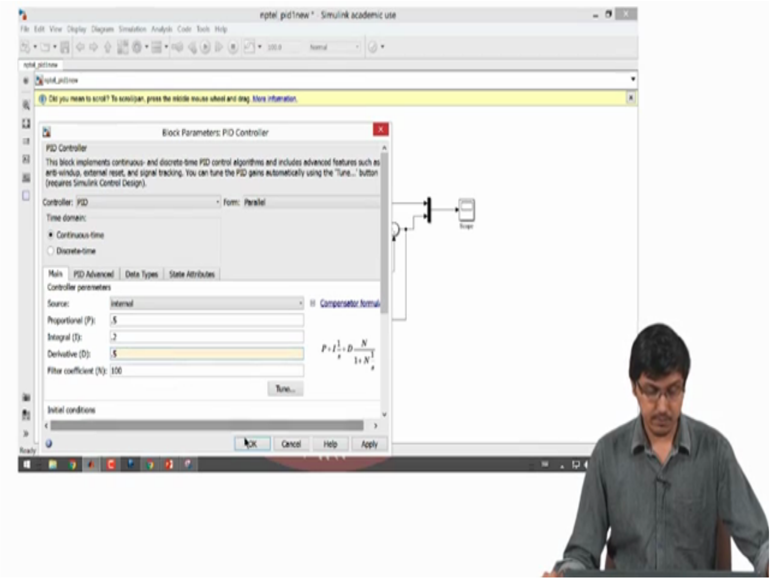

And the we will now choose are different value of derivative gain and we will say probably will take point 5 or something.

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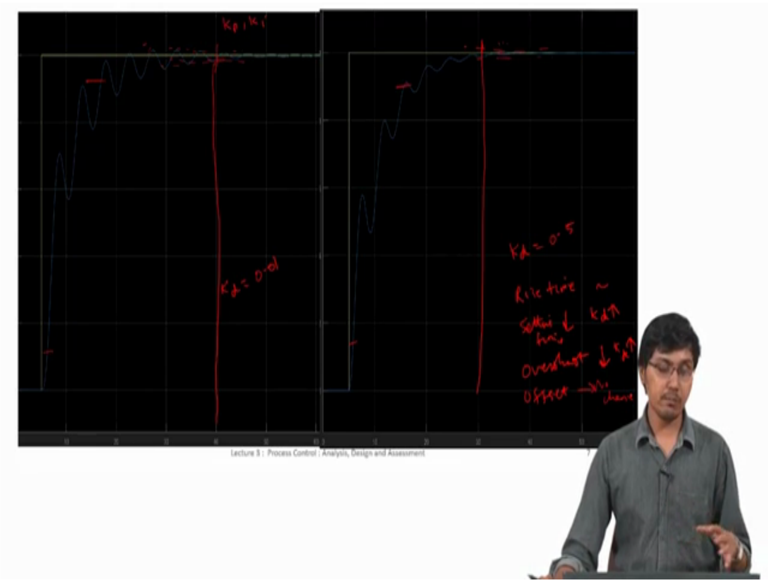

So now we have put a reboot the pictures in the same place where we can compile this two, so in both this cases the k p and k i or the same so what need parameter that we are going to change and the experiment is the k d value is the derivative gain so here we add derivative gain to be like let us we need took point 1 or I think this was simulated point 01 and this k d value was point 5 or something.

So now with level it is just qualitatively comparisons so you can took any smaller value of k d here and then any bigger value of k d here so we can compare this two qualitatively like what happens exactly. So these values do not really matter for this exercise for now what we are more concerned about is what will happen when the change the k d when we increase the k d what is effect it is going to happen on the controllers point or the performance of the control loop.

So what we can observe here is the time to taken to rise from 10 percentage to 19 here 10 percentage to 19 somewhere here it is parallel the same it is not it might be little different but it is parallel the same so we cannot significantly see any difference between these two values, so the rise time value it is not going to change much it is approximately equal and what if you can see here the settling time, settling time is like this has like more a kind of like goes ups and downs more, right so it is take some value like if this is 2 percent within this is the 2 percent range and this is the 2 percent range and this actually goes within 2 percent range somewhere really here, right or somewhere really even here but this core between the 2 percent range somewhere later here.

So basically you can see that the settling time actually decreases when you increase the k d value, ok so settling time actually decreases when you increase the k d value and also you can see here the value of o how much like after the final value the final value is here again this the final value is here again the set point value because we have an integral controller but with even without integral controller even with the proportional and derivative controller you can observe all this things which is in exercise for you, you can just play put k i equal to 0 and then you can observe what happens when k d is increasing when you fix some k p value.

So now you could see here there is a it goes above the set point by some value and then it decreases, right so but here it is very negligible may have already does not even go above any time come soon but may be it goes very small amount of, we can see that the overshoot also value of overshoot decreases the value above by which it goes over the final value and then comes down is decreasing when an I increase the k d.

So and the steady state error value that offset it is not going to have any effect, so this there is not final whenever you are integral controller the offset is 0, so that is where not going to affect anything even at the proportional and derivative controller without integrating action when you set k i equal to 0 and use only k p and k d when you do this exercise you will show you will see that final offset steady state error value that is not really depend on the k d, so here there is no change.

So let us put everything in a table we saw the table and then.

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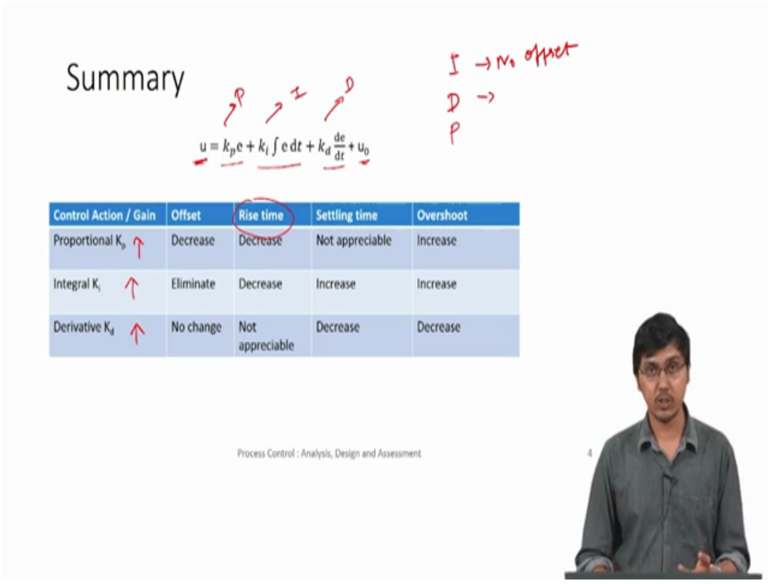

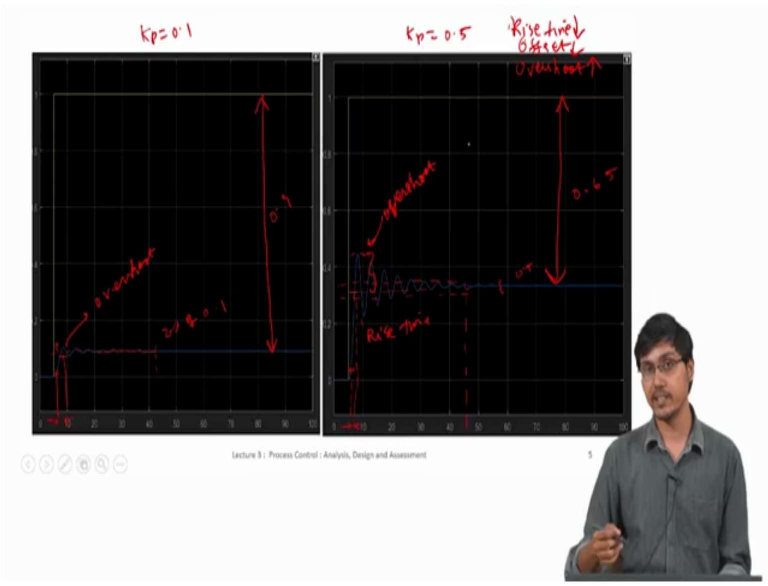

So this is the table that we are putting it everything together, this is the control equation which is that the value of the output of the controller is nothing but k p into the error which is a proportional part of that controller and k i into integral e dt which is the integral part of the controller and k d into de by dt which is the derivative part of the controller and we also saw that the MATLAB where did not use this exact representation it has due some in and that thing but that the I we told like we will forget for now, so and this is the bios that we initially start the system.

So this and we have seen that proportional controller when we increase the gain of proportional controller whenever k p increases offset decreases, rise time decreases, settling time does not change appreciably and overshoot also increases and when you increase the integral k i gain integral gain then offset is eliminated not only increasing the k i even when you have a small k i the offset will be eliminated and the rise time is decreasing, settling time increases and overshoot increases, so derivative again offset does not change and if you increase the k (())(23:28) of k d rise time does not change appreciably and settling time decreases and overshoot decreases.

So with this knowledge so this knowledge will be very useful, so if you can have this within your mind like then actually it will be very helpful when you are going to the when you are looking at the response for controllers and then saying what if the permit that I have to tweak to get a better response what I expected, so there is some very basic thing that you have to remember maybe not the entire thing if you have remember the entire thing is very good but if you not at least base very basic thing that you have to remember is increasing the whenever you have integral action there will be no offset.

Integral controller removing offset is something that you have to remember that and also one more thing about a derivative controller is if you increase the derivative gain then what happens is that the value of overshoot decreases and the settling time also decreases, so that is what you have to remember and then if you want to decrease the time to rise then proportional if you just increase the proportional time proportional gain the rise time also decreases.

In the next lecture what we are going to do basically is like go through some formal methodologies like how to get these values of k p, k i and k d, so today we are just qualitatively seen thorough these values but there are certain rules to how to get these k p, k i and k d, actually there are lot of rules based on it is basically there have will be pre proportional methods.

So we will just go to some very standards methods and then we will see how the system responses and the also we will briefly visit MATLAB’s peritoneal block like how the

MATLAB automatically tunes the PID controller itself and it can also provide the values of k p, k i, k d, so that will be the topic for the next lecture, thank you.