Lecture 29 –
Design of Speed Control of a
DC Motor using Op-amp Controllers

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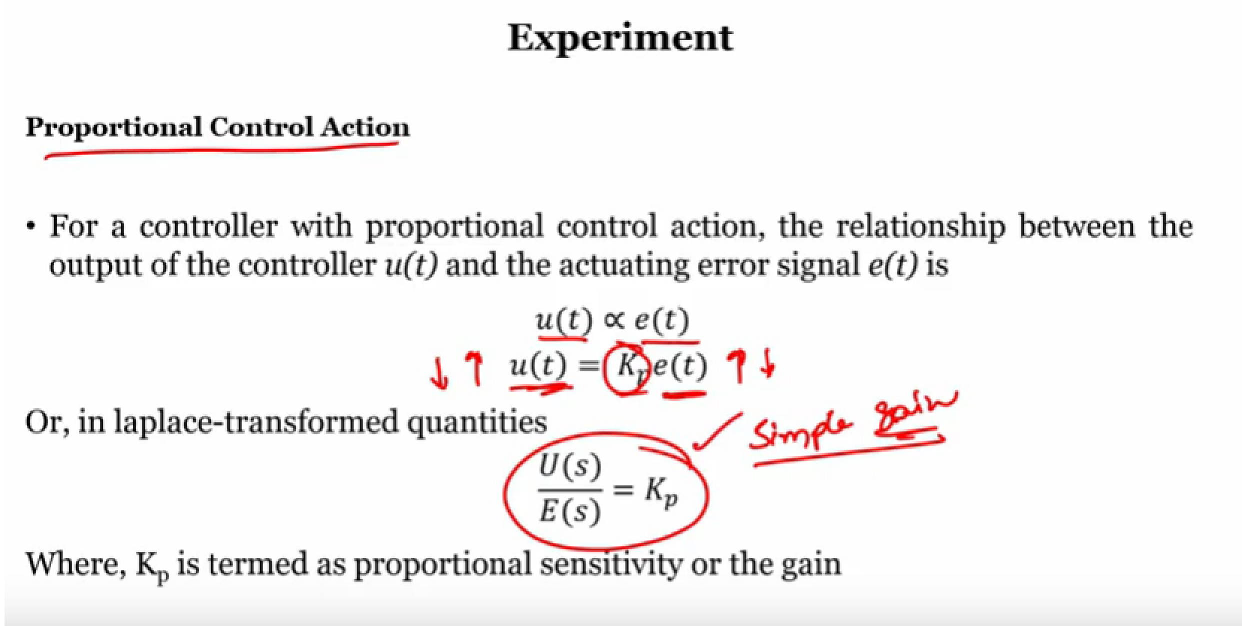

So now, we will see, how the Proportional Control Action will work, difference between that, on of control and the proportional controller and we will discuss and we will see how to implement the proportional controller, using, operational amplifier. So, in order to Implement that, one thing we have to understand, how exactly the proportional controller works, what is the relation between your input and output once we know the relation between the input or output, it is easy to develop, our to design the circuit using an op-amp. Now so, what is n proportional controller? So, the name itself says that, as we have also seen in that theory session, the proportional controller is nothing but, the proportionate, to that of here input. The input to the system is error and the output is always proportional to that of error. So, when we remove the proportional, parameter so that means the U of T is always equal to, the proportion aiding factor KP. Right? Which is also called, 'Proportional sensitivity' or the gain of the system, into error of T. So, when we see, when we convert into Laplace transform and if you observe it, it looks something like, the gain of the system. So, a proportional controller is nothing but, a simple gain, simple gain so proportional, so that means depends upon the error factor that will be always proportionally change, how much proportionate will change? Or what is the scaling factor? Internal depends upon the KP parameter that is a tuning parameter in this case. So, if your error is higher. Right? The input voltage applied to the system, to the plant, will also be higher. If the input is the error is low, then the into the output of the proportional control system, which is nothing but input to the plant, they'll always be low. So that is, entirely related to here error. Right? Error in this case input. So, that means how do you implements So, when we recall, we can either use an inverting, as well as a non rating amplifier, with proper gain. So, that gain we can set by using your feedback resistance. So, by using a part, as a feedback resistor, in inverting or non-wetting amplifier mode. So, this kind of, this kind of a proportional action, control action can be easily implemented using op-amp.

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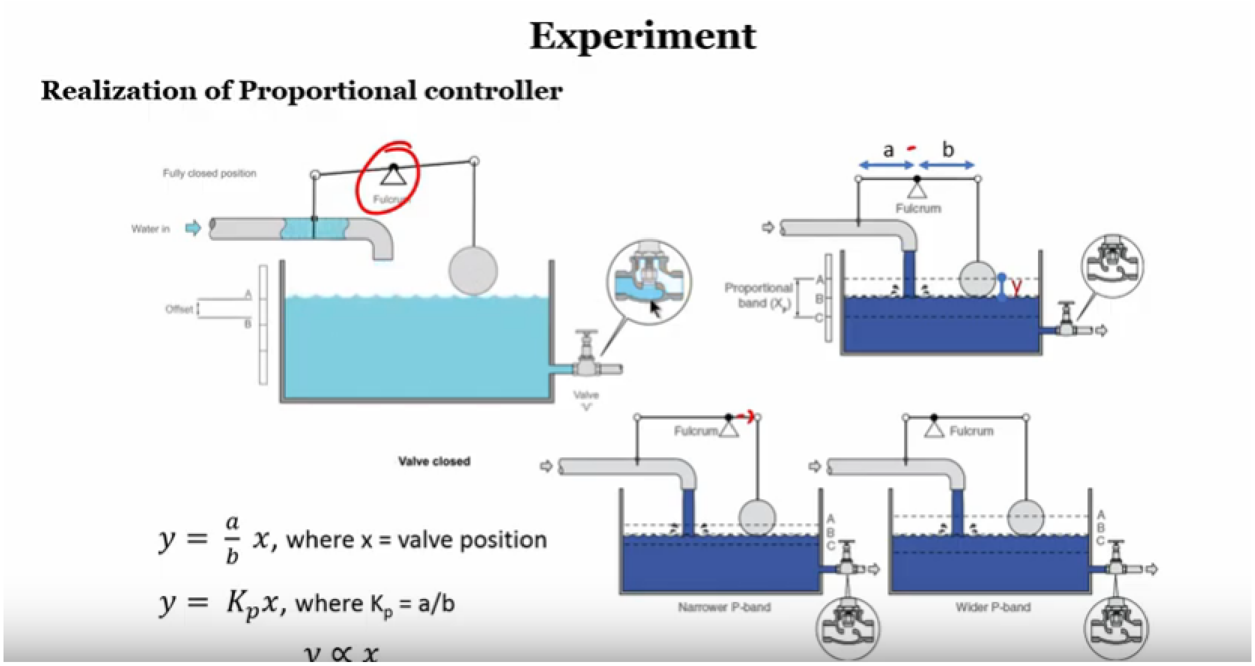

Now, when we see, in order to know realize how exactly the proportional controller works, this is a simple example, similar to the previous one, in a previous case, we have seen that, when the tank is almost at this position. Right? Then it will switch on, such off, if it is higher than this one little stuff and again, if it is lower than this value, then it will switch on, you have only option like, either completely on or completely off. But, in this case, it is entirely depends upon the level of your tank, if you see the animation very closely, so this is where we have connected our Bob and this is where the valve. Right? When the level is lower: that there will be some flow of water into the tank or some liquid into the tank and the amount of liquid flowing, until it depends upon the position of the Bob, if the position is at a higher position, the output the water in, in this case, will be literally smaller, into the tank is smaller. Right? So, that entirely how much, amount of water is being injected into the system, entirely depends upon, what is the level of your float. So that means if I want to change, the you know, the gain of the system in mechanical way, so the position of this fulcrum, decides. Right? Decides the band of your system. So for example, if a and B are equal. Right? The output this offset, it's nothing but a by B into X. Right? So, a by B is nothing but a gain. Now what if the fulcrum is in this position? So, if it is in this position the value of a is higher and the value is B is lower, as it is again is higher. Right? So that means if you want to understand, when the Bob is at a low position, more amount of input that means the valve will be completely at the open, completely open. Right? So, more flow, of water into the system. Right? The band if you see, it will be completely narrow, when, when, when the flow is keep on increasing. Right? It, it will suddenly, there you can see a sudden close, sudden stop of your input. Right? So that means this error band, until it depends upon, what is a gain? What is a gain? What where exactly you are using the fulcrum, whereas, if a is smaller and B is higher, the result the again is very smaller, it takes a longer duration, which means that the, the band, the proportionality band, will be even higher. Right? So the proportionality band and tell depends upon, what is the gain that you are using it or in order to understand, what is the current? The rate, at which the current flow, into our system, depends upon the gain, higher the gain, higher current initially and slowly, decreases lower gain slowly this. Right? This is the way to; just understand the mechanical, but, since in our case we have to understand about the electrical way. Right?

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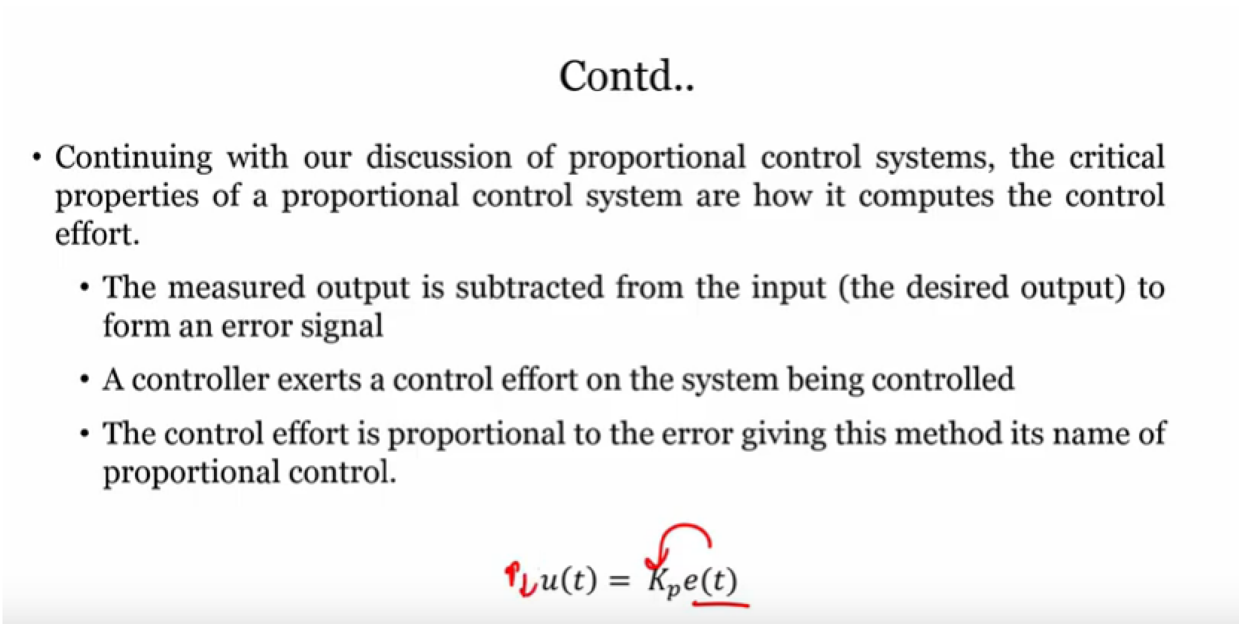

So, when we recall, the input to the plant, input to the system, the controller system is nothing but error. Right? Error signal which is the difference between years, measured input and here, desired output. Set point and that and the actual output. So, that difference input is connected to the KP, if the error is higher, higher input, will be pump, will be given as an input to the plant and there is a smaller, smaller input voltage will be given as an input to the plant. Right?

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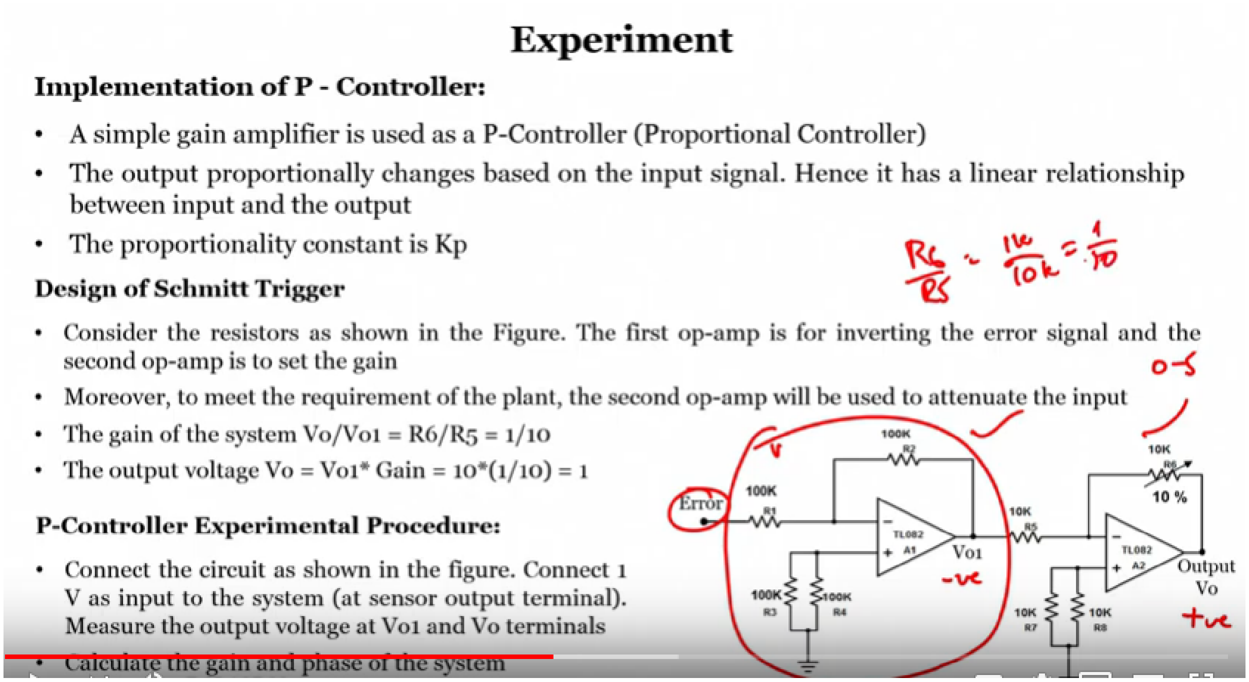

So that means we require to use, a simple gain amplifier. Right? So, if you see, this is a simple gain amplifier that we are using. Now, in this case, the first op-amp A 1 if you see, the gain of the plant, is 1 and whereas the second op-amp we see. Right? So, the input to the first op-amp is error signal, so the gain of the system is 1. So because of that, we will get a negative output voltage here, since we require the output to be in a positive condition, we require to use another operational amplifier configuration, such that the output will be always in faced, with your input signal to. So, in order to do that? Since we are using inverting, operational amplifier we have to go with the two op amps, either gain can be set here at this point or even at this point. Right? Because the plant input range is only between 0 to 5 volts. So, in order to do that? We require to do some attenuation factor to. Right? So, how do you understand this the gain, of the system entirely depends upon our 6 by our 5 in this case. Now, we have taken 10 percent of 10k which is nothing but 1k and R5 in this case, is 10k. So, the gain is 1 by 10.

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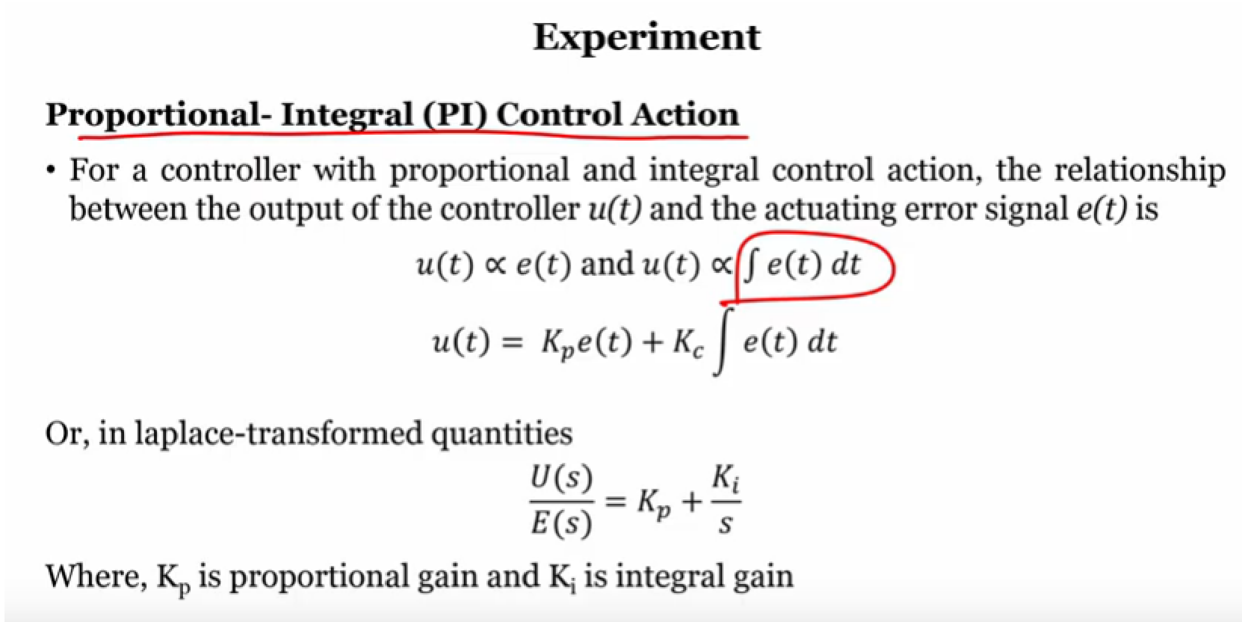

So, another way of implementing a system is by using proportional and integral. So, if you understand, we are adding one more component into the system, which is nothing but, integration. So, what is an advantage of having an integration? We have seen that, with respect to the proportional controller, the output will be proportionately changes based upon the error input, if there are is higher, it will always higher, if the error is lower, the output will also be lower. But, if the error is constant, as long as there is constant, it will always, mind another constant. Right? But, some cases we require, some intelligence into the system. Meaning even though if I am applying some input voltage, but there are the voltage the output temperature is always constant. Right? So, such a cases, such a cases we require some intelligence saying that yes, since there is no response change in the output, I have to add little higher value, input voltage. So, such an intelligence, humans will always have, but, when it comes to a system, how can you make that intelligence? So that intelligence can be created, by using an integration. So if you recall, your mathematics, what is an integration? How does an integration does? So, integration is nothing but, area under curve. So in this case, it not only depends upon, what is the present error? It depends upon the summation, of your previous error the accumulation of error. Right? That decides, the that decides the manipulated variable in this case, whereas in case of a proportional controller, you do not have such an intelligence. It completely proportionate, input changing, error values changing, output I will change. Right? What factor it is changing? What is the gain that F said to the proportional controller, the same factor the output will change? But, if the, if there is an error, between your input and output and if the error is always constant, it cannot either pump, a higher value or lower value, of the input voltage, to the plan in order to reach to the required set point. So, because it doesn't have any intelligence. So, whereas in this case, it will always count, it will always add some, if there are is constant, the accumulation, of error will be keep on increasing, as a result it changes here output voltage.

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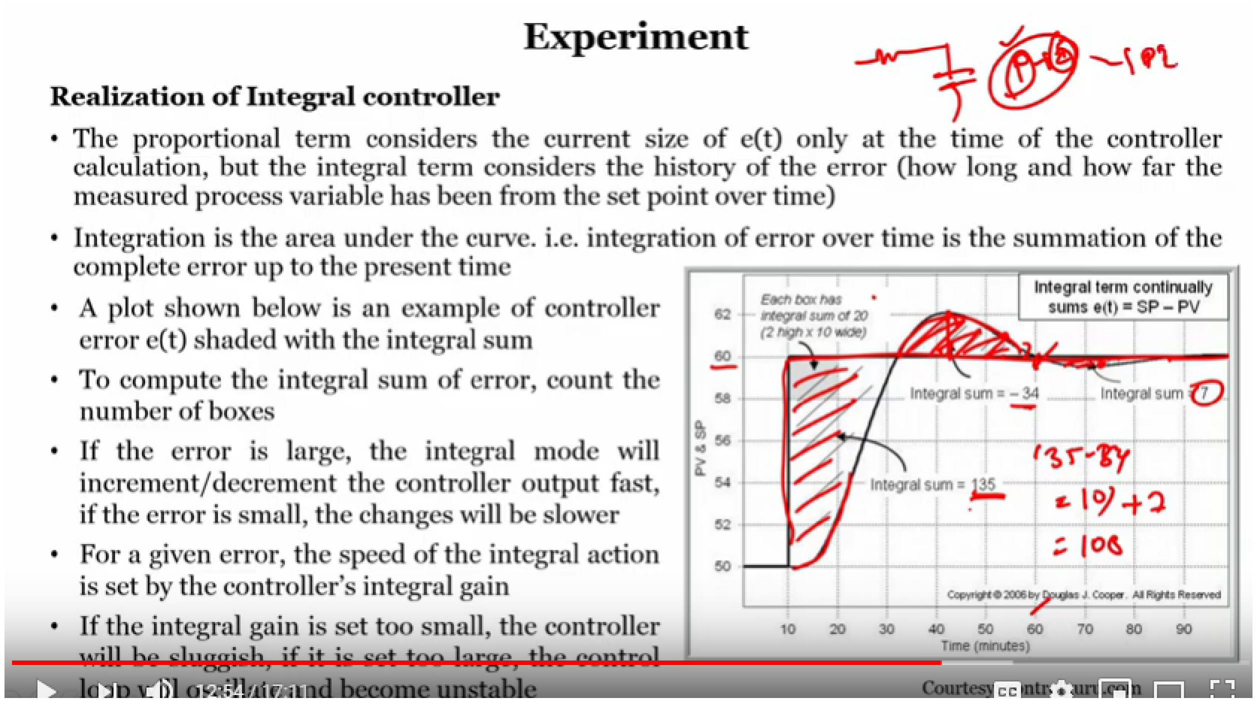

So, as we have already seen, in the theoretical explanation by professor. So just recall, so if I say, this is my threshold sorry, this is my set point and this is how the output is keep on changing. Right? Keep on changing; when you do an integration, what it does is that? It will adds up, the error factor. So this is, this the dashed lines is nothing but, the error output. Right? So, it adds up, at this particular point, what is an error that I have? So that sum is 135. Now, if it is keep on continuing. Right? So, the error will be keep on accumulating, as a result output will change, suppose if it is at 60. So, the integration sum will be minus 34 here and this is 135. So, the error is so, because in this case, it is little higher, compared to the set point. Right? So, with 135 value, the quantity of 135. So, it is going to you know, more than, the required set point that means, one that if I is not an actual value. So, I have to decrease it, how much amount it is to be decreased? Internal depends upon, how much variation that we can observe here. So, as a result the value that will be applied is 135 minus 134 sorry, 34 which is somewhere around 1 not 1. But, if I apply this one not one, again there will be some understood, there is some overshoot here, there is an understood and if you calculate there are is seven, so one add one plus seven. So, application of one at eight, quantity it will maintain constant. Right? In case of a proportional if you realize, if the error is higher, the output will also higher. Right? That means if I say that error is this output also, this error is smaller output is smaller. It doesn't depends upon, the accumulation of errors in case of our integration. Right? So, so that is, that is the intelligence of the we are creating. So, since we are using integrated in the system, the complexity of the system is also increasing. But, how do we design, how do we design using an op-amp. So, one thing we have to understand, using an op amps, any kind of operations that we can do. So, integration we can do, differentiation we can do, if you recall, the way of doing integration, by simply using coffee a resistor and a capacitor, it does an integration operation. And it is a combination of integration as well as proportional, we have to take an adder, which adds you the proportional controller and which adds to the integral controller, the addition of these two, is nothing but my PA controller.

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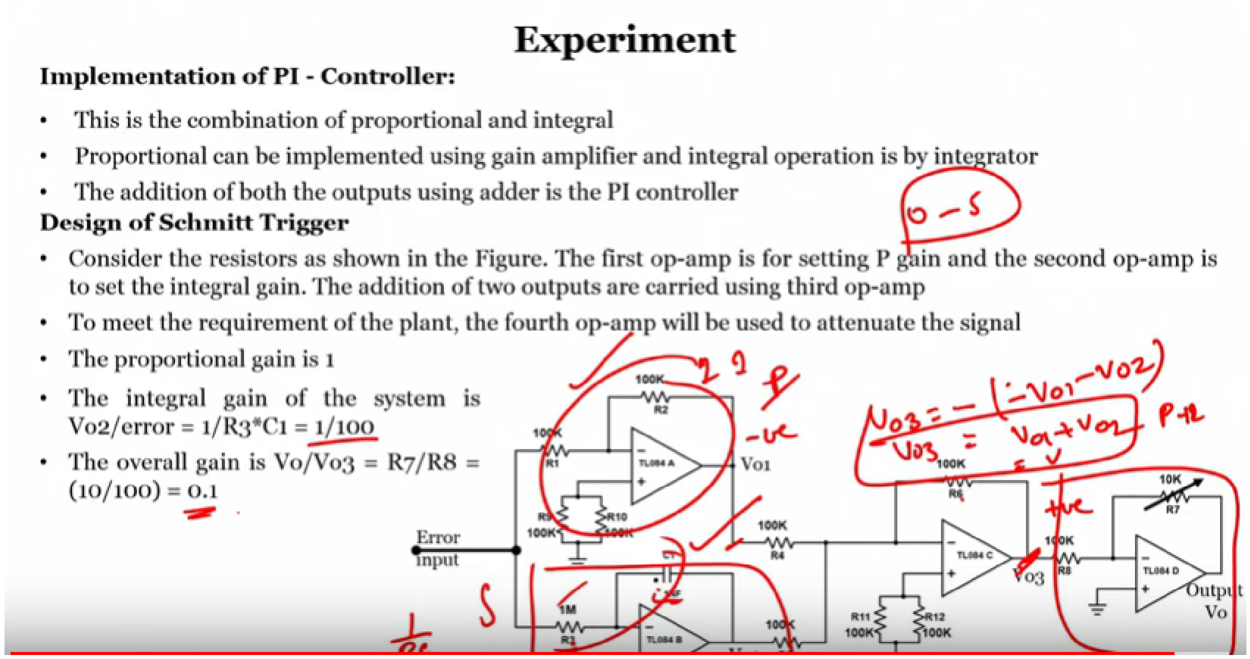

If I see the complete system, if you observe that, the A, A portion of TL 0 8 4. So, TL 0 8 4 is a Quad op amp. So, it has a 4 op amps inside, the a position of TL 0 8 4 first op amp, has a gain of 1. So, which is acting as a P and if you see this, B portion of TL 0 8 4, a resistor and a capacitor, it acts as an integrator. Right? I got P, with a gain of 1 and I got integrator and the factor: that the time factor, entirely depends upon, what is a resistor that we have chosen? Right? Which C is nothing but 1 by RC. Right? So one by, one by RC is the kg, which is nothing but, K I proposed integration gain. Right? So, I have implemented using the operational amplifier, the proportional controller, implementation of integrator, using operational amplifier, is m. But, proportional controller this addition of P and I. So, we need to have an adder. So, this will have a negative phase shift, this will also have a negative phase shift, so no problem. So I am, taking a negative adder. Right? I am taking a negative adder, so the output will be, positive. So, what it does? If I say this is V 1 V o2, V both 3, will be minus of r 6 by, r4 since both are same resistance all it will be the gain is 1, minus of, minus Vo 1, minus V 2. So, which is nothing but, V 1 plus V 2. So, we are getting a gain, we are getting Vo 3 as the required PA controller output. But, what is the value it will be? The value will be, entirely depends upon, what is the gain that we are setting here? What is the value of this? Right? Right? So, so the addition of these two will be some other value. But, if this voltage, is good enough to pump my, give us an input to the plant, may not be, sometimes the output will be even at more than 10 volts. But, I require the voltage, the range of the input voltage to be given as 0 to 5 volts, for the plant. So in order to, maintain that range, we are using one more operational amplifier, one more operational amplifier. Right? Which attenuates, when you see the gain of the system is 1 by 100 in this case. Okay? So, which will attenuate that. Right? So the, the proportional gain is 1, the integral gain is 1 by 100. Right? So, the overall gain of the system is, 10 by hundred which is 0.1, because so, overall again if I want to calculate, V not by V o three. Right? So, this gain is 0.1 so, compared to the voltage whatever we get, it will always, multiply with a factor of 0.1.So that, even if the input voltage somewhere under 10 volts, it will be at 1 volt. So, which will match to the plant requirement, what about the face?

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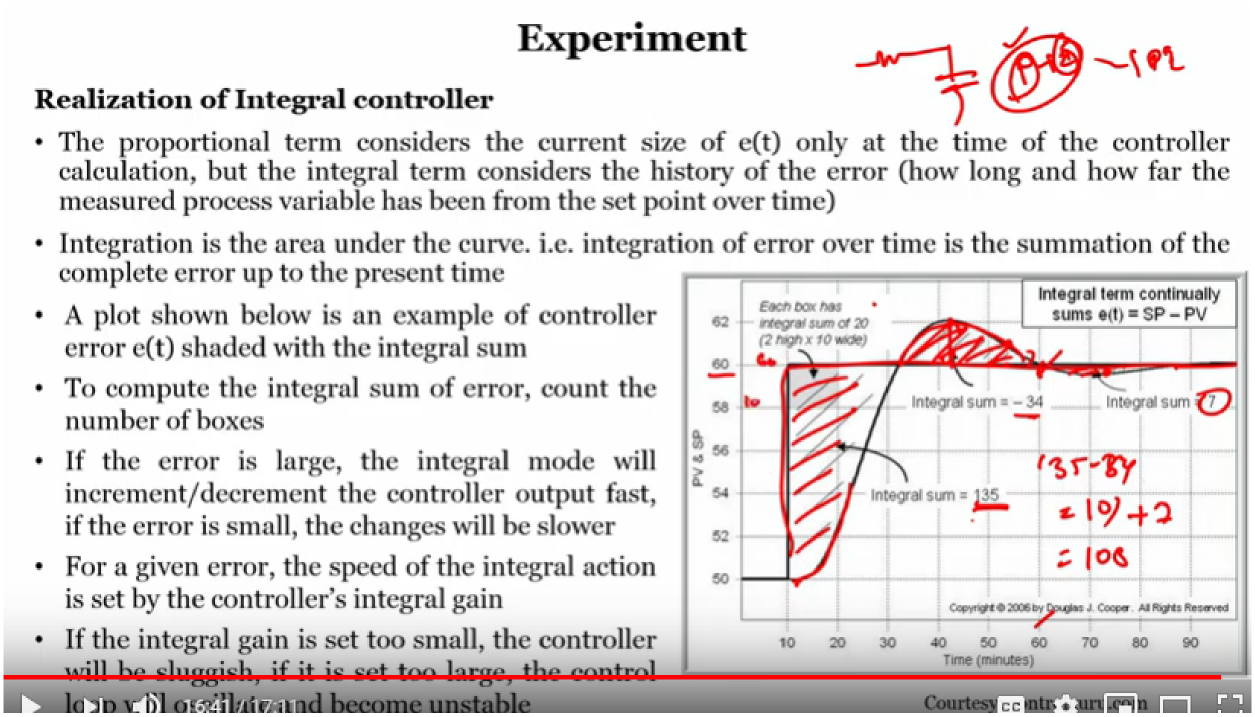

If you see, when you observe the error. Right? That an error will be always, so let us take, this is the input, this is set point sixty, sixty minus 50, 10. Right? When the input is 10.

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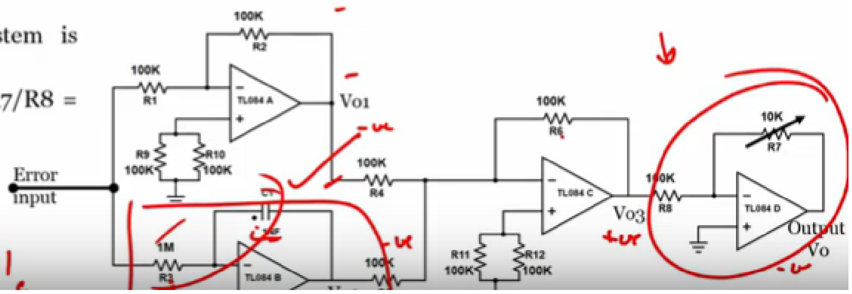
Experiment

Implementation of PI - Controller:

- This is the combination of proportional and integral
- Proportional can be implemented using gain amplifier and integral operation is by integrator
- The addition of both the outputs using adder is the PI controller

Design of Schmitt Trigger

- Consider the resistors as shown in the Figure. The first op-amp is for setting P gain and the second op-amp is to set the integral gain. The addition of two outputs are carried using third op-amp
- To meet the requirement of the plant, the fourth op-amp will be used to attenuate the signal
- The proportional gain is 1
- The integral gain of the system is Vo2/error = 1/R3*C1 = 1/100
- The overall gain is Vo/Vo3 = R7/R8 = (10/100) = 0.1



This will give minus, this is give, give minus, this will give positive, but, again this gives negative, but we require a positive: that means we have to use one more, operational amplifier, which converts, which will always maintain the same phase or rather than using, a simple inverting configuration, we have to go within non-wetting configuration, with the same r7 as a part. So that, the required gain can be, set by using our similar system.