Automatic Control
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Lecture – 04
Block Diagrams

So, welcome to the lecture on Automatic Control System. In this lecture we will discuss about block diagrams. So, in previous lecture, we saw that in the design process of a control system when we follow the frequency approach that is to represent a system through transfer functions. We use the block diagrams to represent the system or the individual components because the system is made of components and each component can be represented through block diagrams and therefore, a block diagram is made as a input output and transfer function.

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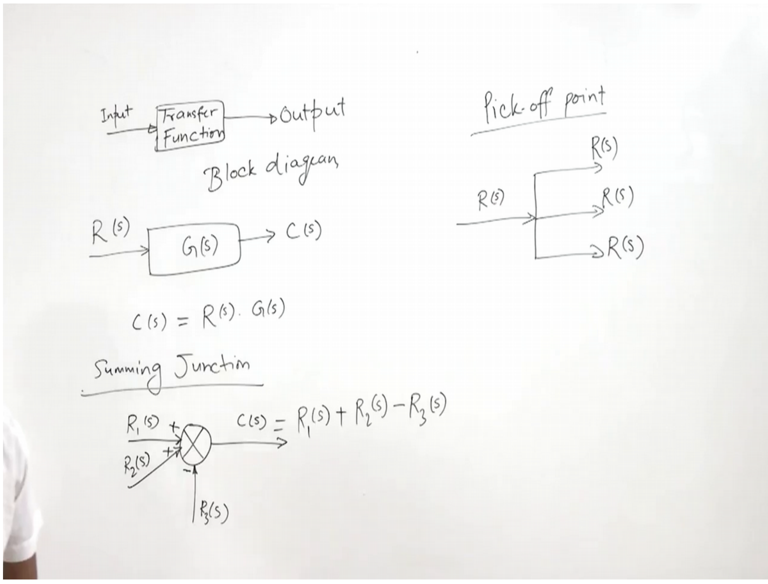

So, we can represent this block diagram as, so, this is the block, this is input, this is output and this is transfer function and this is we call the block diagram. So, let us say here is some input R s, this is the transfer function G s and this is the output C s. So, s is here the complex frequency domain or Laplace coefficient, s is the Laplace variable, s is a complex it is a complex variable. We will discuss more in the next lecture about this Laplace variable and Laplace transform and transfer function. But, here we will discuss more about block diagrams and we should understand that a input can be a function of time, but it can be converted to s domain using the Laplace transform and the output can also be a function of time and that could be a also converted into the s domain using the Laplace transform and G s is a transfer function and that is function of s.

So, this transfer function is the property of a system or subsystem. So, here we will in this lecture we will understand some operations on the block diagram means if the block diagrams because we know that in the design process we reduced to a single block diagram for a components block program. So, how to reduce to a single block diagram if we have a components block diagram and therefore, there are certain operations that we should know and we must know, these things will be discussed.

So, a block diagram has some input transfer function and output. So, here we can write C s equal to R s into G s. So, it is output is if you multiply input with transfer function of the block diagram this is the output. now, we understand the summing junction because we saw that summing junction there are several inputs, several signals comes and they are algebraic operation is going on either these signals are added or subtracted. So, what is the property of summing junction?

So, let us say we represent summing junction like a circle and a cross and there is suppose there is one signal R 1 s coming and this is plus sign. So, this is going to be added, then there is another signal R 2 s and this has also plus sign then there is some other signal R 3 s and it has minus sign, it is going to be subtracted. So, subtraction of the R 3 and addition of these; what will be the output of this summing junctions? What output will pass from this summing junction, if these three signals are coming at this point?

So, this R 1 C s will be equal to R 1 s plus R 2 s and minus R 3 s. So, we understand the operation of a summing junction and. So, when there are multiple signals entering at this we should know that what will be the output going on because usually summing junctions are used before the controller. So, the controller will get this part C s, that is, has this relationship with the input signals. Now, there is another operation that is pick-off point. So, here is pick-off point.

So, pick-off point there could be one signal coming and it might be entering into multiple signals. So, one signal is going to be divided into multiple signals and, this R s will be the same here this is also R s, this is R s and this is R s. So, whenever we have some another block in that block the input will be the same R s, the signal from the pick-off point is the same, how many branches it is going to be divided. So, these are a few points.

Now, we will discuss some more familiar parts they are that if the blocks are in series and the blocks are in parallel. So, the blocks in series are called the cascade form and blocks in parallel are called the parallel form. So, first we will discuss the cascade form.

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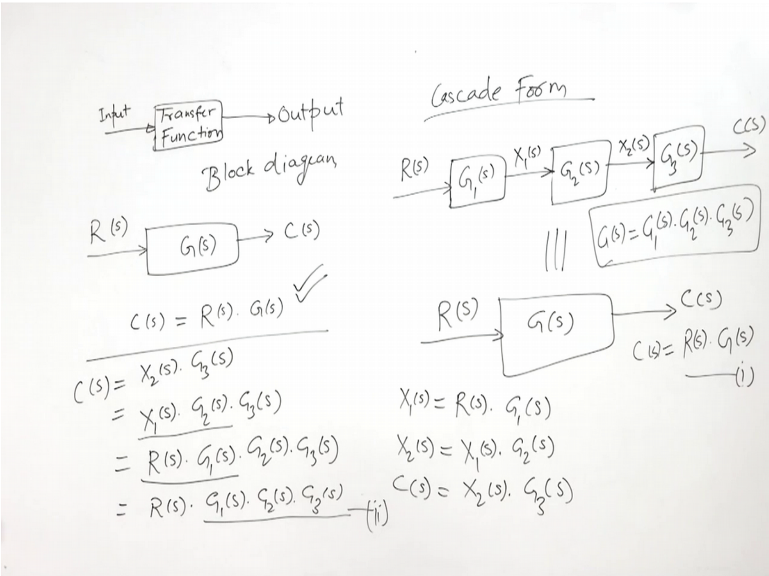

So, let us discuss the cascade form or series form. So, let us say if we have some input R s, there are blocks here and there is certain output C s and this block has a transfer function G 1 s, this has G 2 s and this has G 3 s. Now, we want to know if there are three blocks in series what will be the C s, because we can we want to represent this system into one block that is R s and C s. So, what will be the equivalent transfer function so that we can replace these three blocks to by one block, we can reduce these blocks to a single block.

Now, how, we will know. So, let us assume that if there is input there is a system transfer function there will be some output and that output will be input to this system and the output from this system will be input to the third system and let us say this output is X 1 s and this output is X 2 s. So, we apply this rule that if we have input R s transfer function G s. So, output C s can be expressed at R s into G s.

So, here X 1 s can be written as R s into G 1 s and X 2 s can be written as X 1 s because input is X 1 s into G 2 s and C s can be written as X 2 s into G 3 s. Now, here C s equal to X 2 s into G 3 s and X 2 is X 1 s into G 2 s into G 3 s and X 1 is equal to R s into, let us say this is G s, R s into G 1 s into G 2 s into G 3 s. So, you see what we are doing? So, here C s is equal to R s into G s. So, X 2 s we can write X 1 s into G 2 s; now, X 1 s we can write R s into G 1 s from these equations and so, finally, we are going to get R s into G 1 s into G 2 s into G 3 s. Now if we, so, this is equation 1, here C s is equal to R s into G s and this is equation 2, C s is equal to R s into G 1 s, G 2 s into G 3 s.

Now, if we compare the two, equation 1 and 2, we can see that G is equal to G 1 s into G 2 s into G 3 s. So, means we can replace these three blocks by one block and these blocks transfer function will be multiplied, multiplication of the individual blocks functions.

So, here a general conclusion we can draw is that if the blocks are in series we can replace them through a single block and the transfer function of that single block will be the multiplication of the individual blocks. So, that is the equivalent transfer function. Here G s is the equivalent transfer functions.

Now, we come to the parallel form, that is, the second form parallel form.

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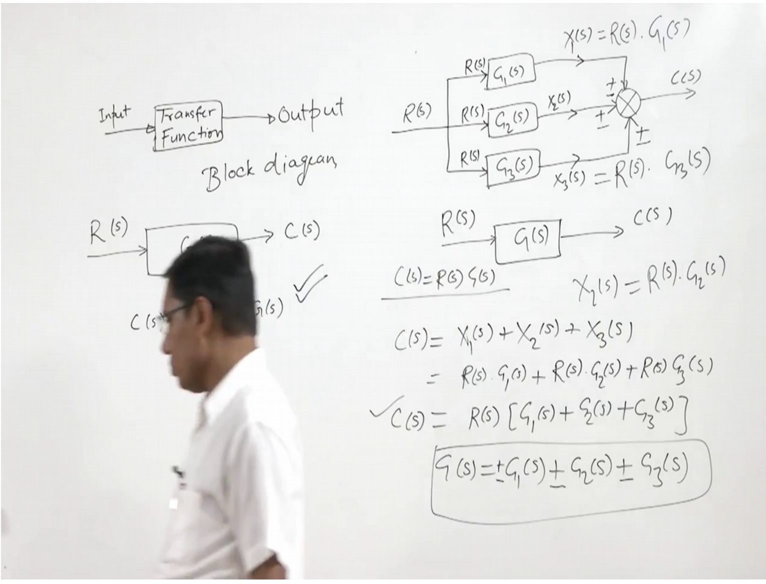

So, no parallel form let us have a input R s and there is a pick-off point. So, suppose we have these arrays and there is the three blocks in parallel and the blocks are going to be added here at the some junction, summation junction and we are going to get the output from these 3 blocks. So, we want to know that if we want to replace this block with a single block and that has a transfer function G s and this is C s and this is R s. So, what will be G s, as a function of G 1 s, G 2 s and G 3 s? Now, again we will apply the simple principle this one that we applied in the case of cascade form.

So, you know that this is a pick-off point. So, a pick of point here input is R s. So, each of these branches will have the same input R s. So, means here is R s input and so, here will be some output, let us say X 1 s, X 2 s, X 3 s. Now, we know that X 1 s is equal to R s into G 1 s because the output is equal to input into the transfer function. Here, X 2 s is equal to R s into G 2 s and X 3 s equal to R s into G 3 s. Now, you see is there is all plus. So, summing junctions, C s is equal to summation of the three outputs.

So, summation of the three outputs we have X 1 s plus X 2 s plus X 3 s. So, we have R s into G 1 s plus R s into G 2 s plus R s into G 3 s. Now, we can take R s outside and we can have G 1 s plus G 2 s plus G 3 s. So, we can see here C s is equal to R s into G s and if we compare this equation with this equation. So, we get that G s is equal to G 1 s plus G 2 s plus G 3 s.

So, we can see that in this case when we have three parallel in parallel block diagrams and we are going to add these three block diagrams and then we want the output of the these block diagrams. It is the summation of the three block transfer function of the three block diagrams. So, the equivalent transfer function is summation of the individual block diagram. Now, remember that if in spite of plus here is minus, minus, minus there will be minus, minus, and minus. Any of if one is here plus, then there will be plus if minus this will be minus.

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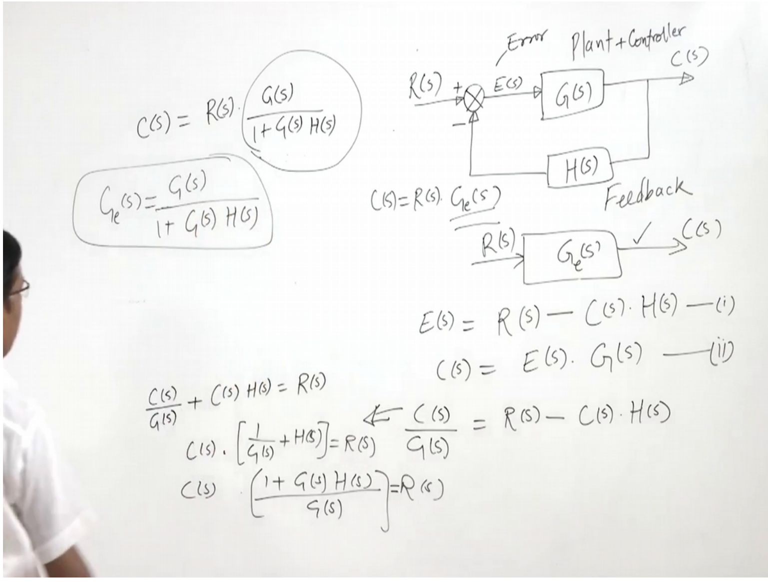

Now, another most important form that we will discuss is the feedback form because we know that feedback form is the most useful form for the closed loop system and therefore, in the automatic control system. So, we will discuss the feedback form.

So, here this is the error or activating signal E s, that the transfer function of these, G 1 s is the plant and controller transfer function, this is the feedback transfer function, this is the input. Now, we will try to replace this system as an equivalent system let us say G e s, that is, the equivalent transfer function. So, now here we can use something like, what is E s? E s is error a function that is R s minus it is summing junction R s minus H s into C s because what will reach here will be C s is this point C s. So, C s into H s will reach here, so, C s into H s, this is the equation number 1.

Now, what is C s? So, C s equal to E s, because this is an input to this block, so, E s into G s, this is equation number 2. Now, we can replace this E s to from this equation. So, E s can be written as C s by G s. So, C s by G s equal to R s minus C s in to H s. So, from here we take these terms which separate because we want this. So, we have to separate C s terms and R s terms, so, C s by G s plus C s, H s equal to R s we can take out C s here.

So, C s equal to 1 by G s plus H s equal to R s. So, this is 1 plus G s H s by G s, R s; so, this is C s . So, now, we can write that C s equal to R s into, here C s into this term equal to R s, so, C s equal to R s into G s upon 1 plus G s H s. So, if we compare this with here because here C s equal to R s into G e s this equation for this transfer function. So, we can see G e s is this part. So, G e s equal to G e s upon 1 plus G s, H s.

So, this is the equivalent transfer function of the feedback closed loop system. So, you can see that this system we can represent 2 equivalent single block system having the transfer function G s upon 1 plus G s H s. Now, if here we have taken this minus if it is plus then there will be a minus sign here.

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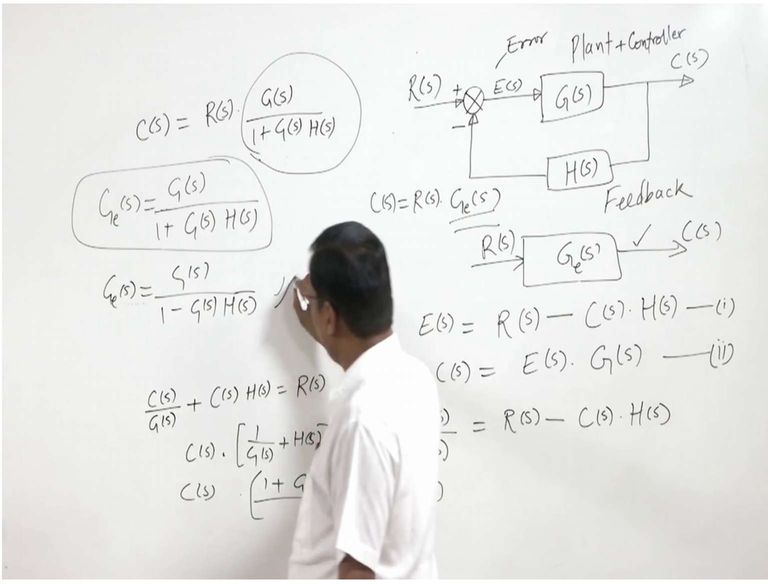

So, G e s equal to G e s upon 1 minus G s H s, if in spite of minus sign here something and say it is plus sign this transfer function we will get.

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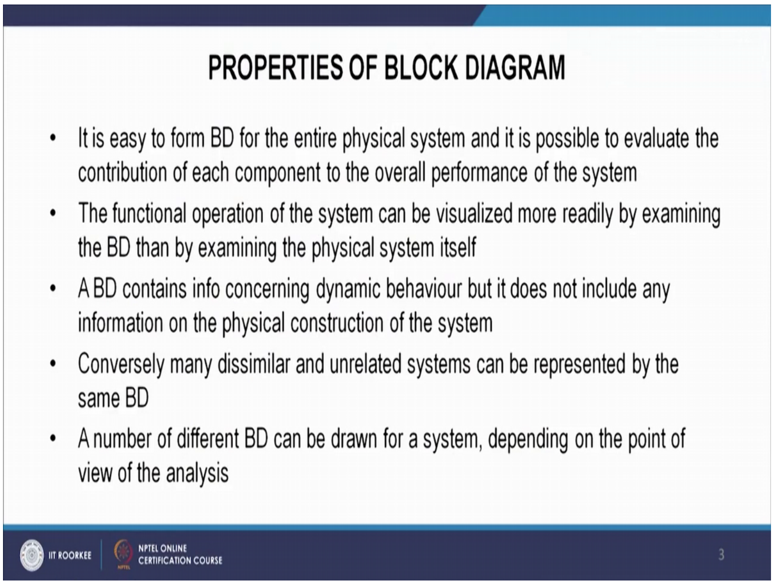

So, now we can discuss some properties of block diagram. So, what we see from this that it is easier to make a block diagram for a physical system and we can evaluate the contribution of each component to overall performance of the system and by examining the block diagram, we can examine the parameters of that system because block diagram consists a transfer function that consists the properties of the system.

Once we are may we have made the block diagram it is, if I give you a block diagram it is a difficult to tell that what actually the physical systems looks like, because physical system which transferred to the block diagram as a parameter consisting the parameters of the system. It could be a similar block diagram can be achieved for a mechanical system or electrical system or some other system. So, from just seeing the block diagram we cannot tell that what actually the physical system is. So, block diagram takes the property of a system where the physical features are not important, but what are important is the properties of the system that govern the performance of that system.

The last point is that we can make several block diagrams for the same system. It depends on that how much detail we are going to include in that block diagram, whether we are going to include some parameters or we are going to leave that parameter, whether we are going to consider that system as a first order or second order. So, this will change the block diagram the transfer function. So, therefore, it is possible to make several block diagrams for the same system depending on our consideration of the characteristics of the system.

So, here we stop and I thank you for your attention and let us see in the next lecture.

Thanks.