Analog Circuits
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Week – 04
Module - 05
Tutorial No.3

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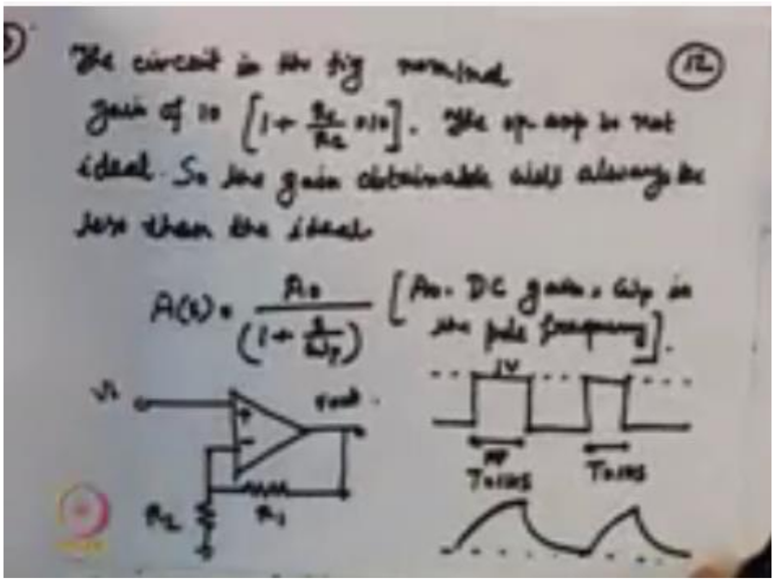

So, our third problem is, so we will have a circuit the circuit in the figure has nominal gain of 10, that is 1 + R1 by R2 = 10 and also it has been given that the op amp is not ideal I will go this point in more detail while discussing the solution, there is the op amp is not ideal so the gain obtainable will always be less than the ideal and we have been given the transfer function of the op amp is A0 by 1 + S by omega P and do you know that A0 is the DC gain of the op amp and omega P is the pole frequency.

So, the op amp is +, this is -, this is R2, R1 the input that we have given here this Vi the input is actually like this, this is a simple falls input uniformed amplitude this 1 volt and this also is sorry this is T scale this is 1 micro second and this is 1 volt this is 1 volt and here also it is repeating and the output is it is going like this it is touching then it is decaying and then it is going like this.

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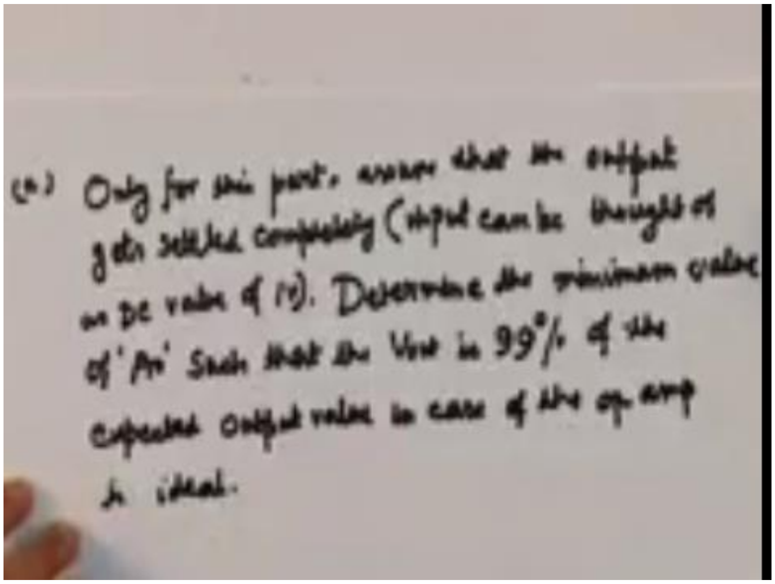

Now the problem is the first portion is only for this part assume that the output gets settled completely and input can be thought of as DC value of 1 volt, so what we have to find out, we have to find out determine the minimum value of A0 such that the Vout is 99% of the expected output value in case of the op amp is ideal, now look 1 by 1 so what we have to find out so solution for part A.

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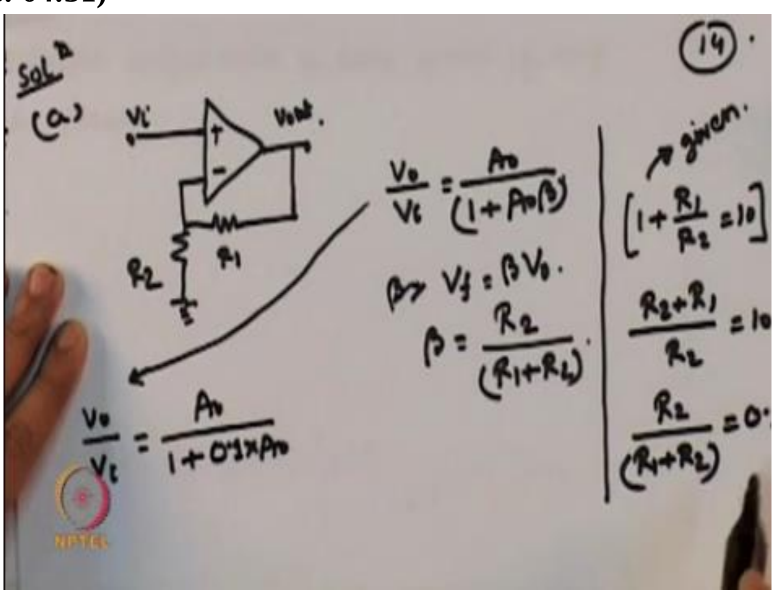

So, the circuit given is simple op amp circuit this is + this is - here we are giving Vi here it is R2, it is R1 it is Vout now assume that the output gets settled completely, so when in the input is being applied like this and we are telling output is gets settled which means that Ao for this problem Ao actually is a constant quantity it is not function up because we are considering in the steady state conditions where the output get settle means output we are getting a DC.

So, we can write that Vo by Vi = A0 + 1 by A0 beta, now A0 as we have already discussed it is a constant quantity, so now beta is what, for this circuit beta is the feedback factor so the feedback factor means how much portion of the output voltage is being sampled and its fed back to our input so beta is the amount of feedback generally beta will define Vf = beta V0 and in our case beta is R2 is potentially dividing and the output voltage and it is feeding back to the input, so the beta is from the potential divided and can find out beta is R2 by R1 + R2.

Now in the problem we have already know that 1 by R1 + R2 is = 10 this is given, so R2 + R1 by R2 = 10, so R2 by R1 + R2 its coming out to be 0.1 then from this one Vo by Vi = A0 by 1 + 0.1 A0 this beta value we are put which is A0, now let's see the problem so upper this determine the minimum value of A0 such that the Vout is this Vout is 99% of the expected output value in case of the op amp is ideal.

Now let's suppose if the op amp is ideal then what will be happen, if the op amp is ideal then for the ideal op amp Vo by Vi is A by 1 + A beta for ideal op amp the open loop gain is infinite, so 1 by 1 by A + beta now for ideal case SA tending to infinity we can write that it is coming out 1 by beta, so the Vo by VA for ideal op amp Vo by Vi is coming out the same value which is the open loop gain given in the problem that is 10 now we want that our minimum value of A0 such that determine that minimum value of A0 such that the Vout is 99% of the expected out value output value in case of the op amp is ideal.

So, it will be this tends 99% A0 1 + 0.1 into A0, so if we solve this one will get that A0 will come 990 this is all minimum value of A0 for which the output value will be the 99% of the ideal op amps output value, now let's have look out the second part of the problem this is the problem third only but this is the second part.

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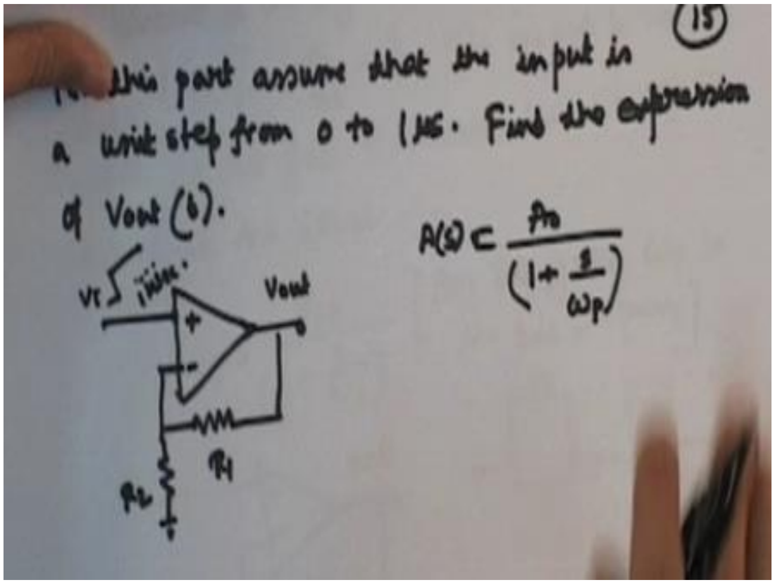

For this part assume that the input is a unit step from 0 to 1 micro second, find the expression of Vout t, for the same op amp now what is the problem for the same op amp , now at the input we are having the unit step from 0 to 1 micro second and the AS the same AS that I am writing A0 by 1 + S by omega P, so what will be the solution so we have to find out actually the expression in time domain at the V output when the excitation is an unit output and the stable is varying from 0 to 1 micro second.

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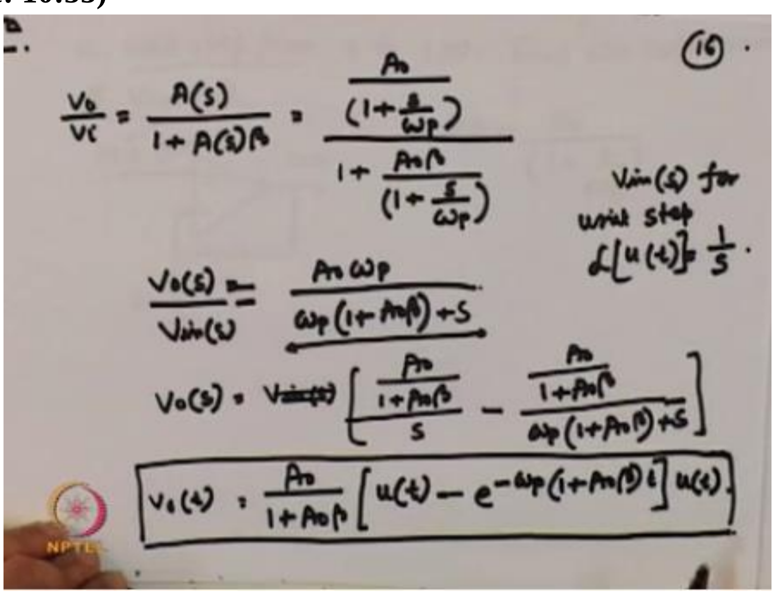

So, V0 by Vi AS + this case the output is not settling so we will assuming that AS is Ao by 1 + S by omega P divided by 1 + Ao beta 1 + S by omega P, so VoS by VinS if we simplify this one it is going to come Ao omega P omega P by into 1 + omega Ao beta + S, so VoS so now this portion we can separate it in partial fraction and we can write VoS = VinS Ao by 1 + Ao beta by S - A0 by 1 + Ao beta omega P + Ao beta + S, now we have applied what, we have applied an unit step so for an unit step function VinS for unit steps ut will be Laplacian of this 1 by S actually this is already multiplied.

So, I have VinS is already multiplied and this 1 by S which is coming because of this after partial separation, so we will calculate 1 + Ao beta ut - this is simply inverse Laplacian time domain we are taking omega P 1 + A0 beta t ut, so this is our final output in time domain when the signal at the input is an unit step function and it is varying from 1 micro second a step at that time the output it is in time domain will look like this you can see that it is an unit step from their again magnitude exponential function which is gradually decaying now let's have a look at third part the same problem.

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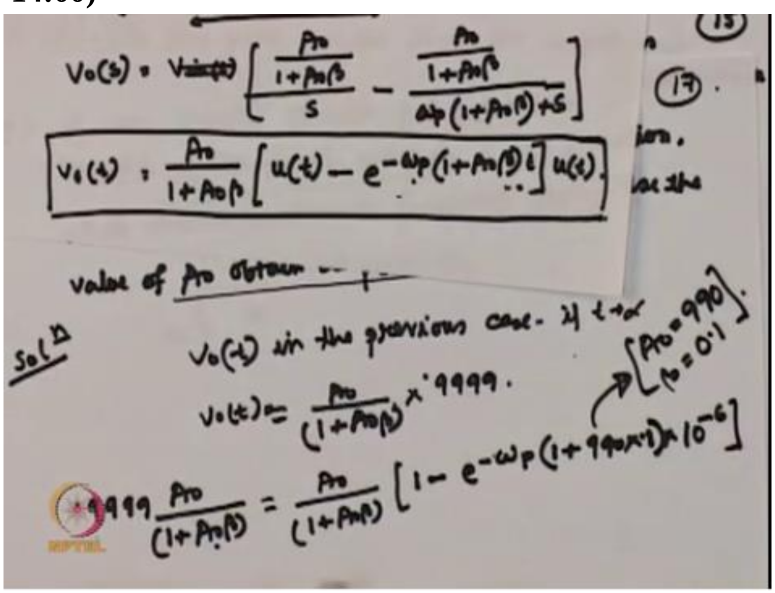

If the Vout t should get settled to 99.99 % of the final value in 1 micro second duration what should be the pole frequency omega p? Use the value of A0 obtain at part A, so what actually we have to see, if the Vout that we have found out in previous expression this is this one should get settled to 99 % of the final value in 1 micro second.

So, the final value of this one means if this case Vout t if t tends to infinity here we will get that the Vout t in the previous case if t tending to infinity Vot it is coming out so this t tending to infinity means this portion will go in to the power of - infinity 0 so final value is going to come A0 y 1 + Ao beta and we have 99% of the final value, so of these 99% so it will be looking like 0.99 so 0.9999 Ao by 1 + Ao beta is the final output voltage that is desired final output voltage that is desired and that we have to achieve t = micro second t = 1 micro second and we have to find out that what is the corresponding pole frequency.

So, we know that the output is this one 0.9999 of Ao by 1 + Ao beta and our beta value it is given in the problem Ao is actually with they are telling that use the value of Ao obtained in part A so Ao is also known to us, so we have to just find out what is the value of omega P. So, it is 1 - ut is 1 - omega P and if you can recollect Ao we have calculated in the first problem it’s 990 so it is 990 and beta is 0.1 that is already given t is 1 micro second t is 1 micro second.

So, it is coming to 10 to the power - 6 1 micro second, so I am writing here because this values we are taken from given problem set at 1 problem and 1 value we are determined that value we are using, so Ao it’s 990 and is beta is 0.1.

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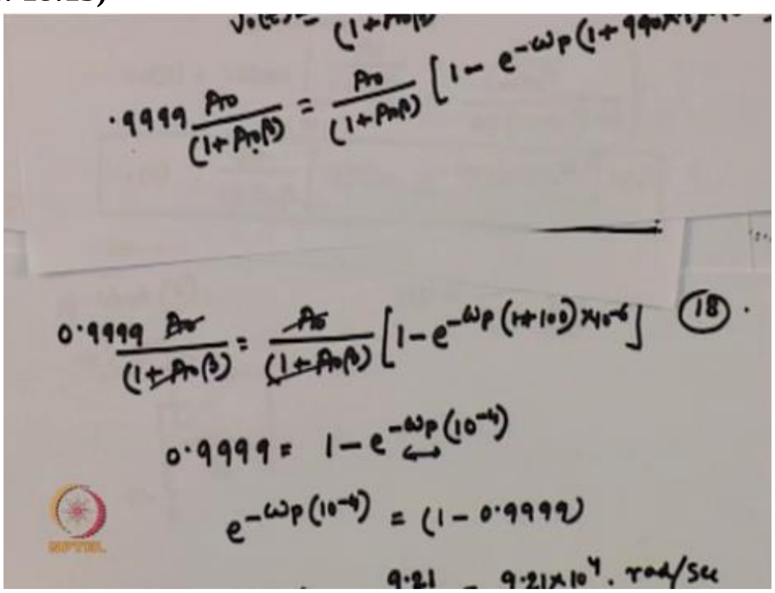

so let me take another sheet so let me write it, so this is going to come 100 in to 10 to the power - 6 because this is 990 in to 0.1 so it will come 1 + 99 100 ten to the power - 6, so this and this will go out so we will have 0.9999 this one 1 - e to the power - omega P into 10 to the power - 4 so all values are known only omega P we have to find out.

So, e to the power minus omega P 10 to the power - 4, 1 - of 0.9999 if we take the (()) (19:33) on both sides it will come ultimately omega P = 9.21 into the 10 to the power - 4 so it is 9.21 into 10 to the power 4 rad per second or it is 92.1 kilo rad per second, so this is our pole frequency.

So, that was the last part of the problem, so what we have seen we have seen that if any op amp problem is given we have been supplied only the open loop transfer function of this op amp that is AS and we know that what is the input applied and if the input is applied to the system known then we can easily find out from the output by using the illusion Vo by Vi Ai 1 + A beta and by using the Laplacian operator we can find out what is the time domain expression after applying the input and if ones we are getting the time domain expression just we can play with the values given and we can get any unknowns that is required to be find out.

Suppose in present case, if suppose we have to find out the pole frequency, so we have easily find out that pole frequency is coming, so we today I have covered 3 problems the first problem actually is 1 was in MOSFET's internal circuit and in that MOSFET internal circuit given just we have to see the output voltage and from that we have calculated the gain and from that gain we can easily see what will be the pole frequency and zero frequency for the first problem just we have stopped how to calculate the Vo by Vi and in the second problem its little bit get trickier one.

We have taken a op amp where the feedback is given by an RC or a combination of RC or any whatever combinations and the solving for the problem is the same way we have to find out the Vo by Vi and then we have to take it in the Laplacian domain or in a function of a omega then by splitting up low frequency or at the high frequency, we have to just can calculate or we can simplify the result that what will be the gain at the lower frequency, what may be the gain at the higher frequency and from the same expression eventually we can calculate the omega P and omega Z.

That is the pole frequency and the zero frequency and with this information's in hand we can easily draw the bode plot of any system or circuit that is given in the figure, so if you see that these problems that we have taken this problems are not a simpler one like the normal nodal analysis or KCL or KVL analysis that we come across in any general electric's electrical circuits book.

This is the one which is related to some concepts that we may have across in the exams and from how to proceed that one for any given circuit that is being described it and the same way we have described the these questions or these problems for any circuit given the approach should be the same and for the third problem.

We have just found out in the time domain expression and we have also seen that the expressions comes out in the time domain then how to find out the final value at t tends to infinity and how to calculate the omega p's and omega z's, in the next tutorial we will see some problems actually on gain margin and phase margin related to the op amps and we will discuss some problems filters like Butterworth filter and Chebyshev filter and also we will try to see that how the steps by step procedures how this filters can be designed, so that at any point of time if you are given any filter design exercise we can do that with the experience that we learned in next tutorials, thank you.