Electronic System for Cancer Diagnosis
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Lecture – 29
Basic building blocks of Electronics System: Amplifiers (contd..)

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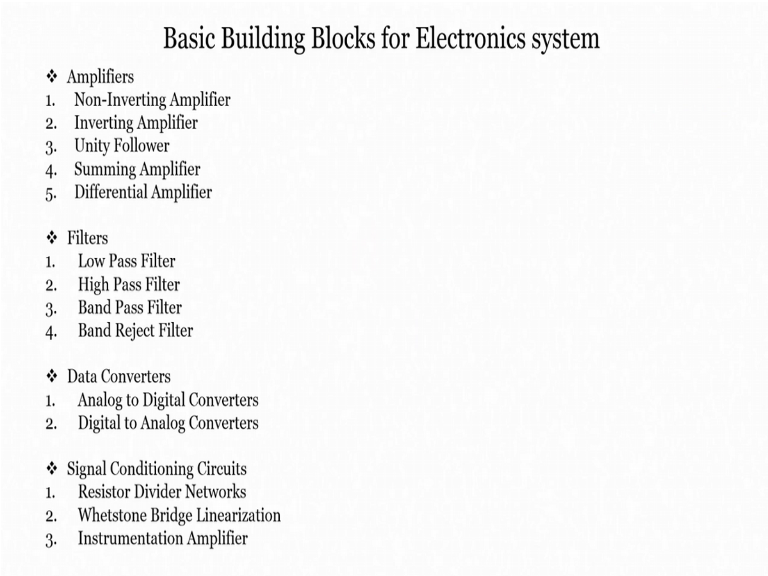

[FL] We should start understanding the first one which is the voltage follower circuit.

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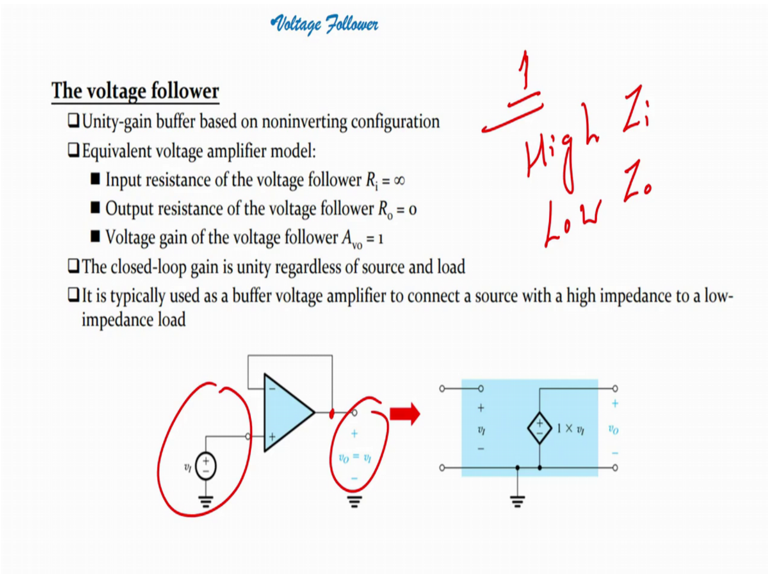

So, if you can see on the screen what we see is a unity gain buffer based on non-inverting configuration. What does that mean? That if I apply; if I apply a voltage at the non-inverting input; voltage at a non-inverting input, right and I have a feedback to the inverting, the output is fed back to the inverting here, right this is our, this becomes our unity gain buffer. This is unity gain buffer based on non-inverting configuration because we are applying voltage to the non-inverting amplifier, right.

We have seen this application earlier also, equivalent voltage amplifier model. So, if I make a equivalent voltage amplifier model how can I use it? You can see that the input resistance of the voltage follower, input resistance is infinite, right, output resistance is 0, output resistance is 0, voltage gain of the unity gain amplifier that is why this is called the unity gain. Unity gain means what? The gain is 1; gain is 1, right. So, have to have gain equal to 1, right we have A vo voltage k equal to 1, all right.

The closed loop gain is unity regardless of source or load, source or load. So, this is our indicate amplifier. It is also used as a buffer voltage amplifier to connect a source with high input impedance to a low input impedance load, right. Why? Because the indicate amplifier has a high input impedance, high input impedance and it has a low output impedance, it has a low output impedance. That means, that it can be connected to a source to a source, suppose the source is this one, right which has extremely high input impedance, then we can connect the we can connect the uniting amplifier. And the load, load will have extremely low output impedance, no out, no impedance load, no impedance load. Then we can connect the unity gain amplifier.

Unity gain amplifier is also used as a last stage, to the last stage of the of most of the amplifying circuit because it is a voltage follower and it will it can be connected to any load which will draw lot of current by the voltage at the voltage at the input will be same at the output. The voltage will follow the voltage whatever voltage is at input it will follow at the output. So, output voltage follows the input voltage, right. This files also called voltage follower, the gain is 1 that is why is it is also called unity gain amplifier unity gain amplifier ok. So, these are the characteristics of operation amplifier particularly this as a voltage follower. This is how we can use operation amplifier as a voltage follower.

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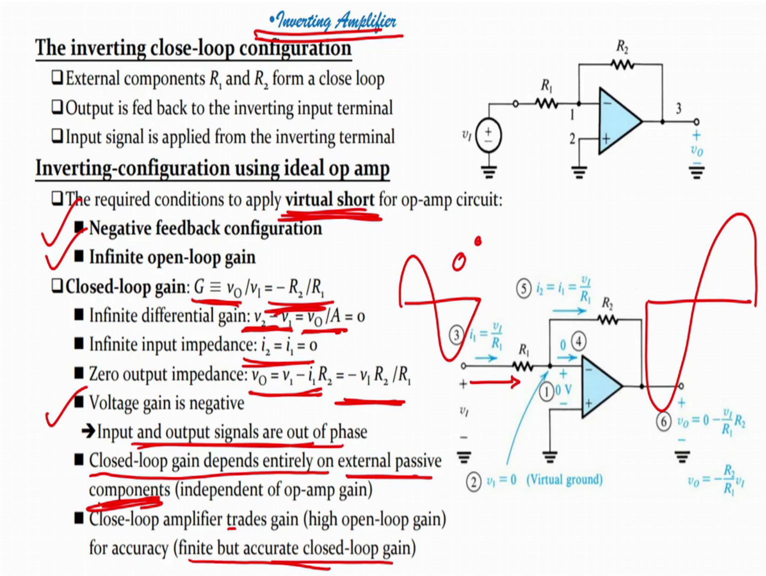

Now, let us see further let us see further the inverting amplifier, inverting amplifier. So, how we can how we can design a circuit of an inverting amplifier using a op amp, using an op amp? So, the inverting closed loop configuration external value components R 1 and R 2 follow closed loop here you can see R 1 and R 2, right. This forms a closed loop because with you are you are feeding back here see here um. And input signal is applied from the inverting terminal. So, we are applying the input to the inverting terminal ok. So, 3 things we have to understand, external components R 1 and R 2 they form closed loop, second output is fed back to the inverting input and for is that input signal is applied to the inverting terminal ok.

Now, the required condition to apply virtual short op amp circuit virtual short, right is negative fed feedback and infinite open loop gain these are the requirement, is not it. So, what if there is a closed loop gain what if there is a closed loop gain. So, closed loop gain G equals to v o by v i, right v o by v i which is nothing but which is nothing but minus R 2 by R 1. See if I if I see here you see at this point it will be virtual ground.

We have seen the concept of virtual ground, right because this terminal is grounded; our inverting terminal is grounded that is why the point at non-inverting terminal will also be considered as ground the virtual ground. So, if I have register R 1 I apply voltage v 1, then the current flowing through my register R 1 would be nothing but i equals to v by R

1. Similarly, if I want to measure the current frame through R 2 it will be nothing but i 2 equals to i 1 equals to v 1 by R 1.

So, what will be my output voltage? It is 0 here right, a here voltage is 0, because nothing will flow here it is a infinite input impedance and a very high input impedance. And the different voltage is also 0 volt. So, I if I want to measure v o; v o is nothing but 0 minus v 1 by v 1 by R 1 into R 2, right, v 1 by R 1 into R 2. So, what will be the v o? V o would be nothing but minus R 2 by R 1 correct, v o would be nothing but minus R 2 by R 1.

Now, if you see infinite differential gain, infinite differential gain is v 2 minus v 1 is nothing but v o by A is nothing but 0, right, infinite in differential gain would be 0 in because a infinite differential gain, right the when nuclear us 0, infinite input impedance, right we know that it is a it has infinite input impedance; that means, my i 1 equals to i 2 equals to 0.

Then you have 0 output impedance; that means, my output voltage will be nothing but v o equals to v 1 minus i 1 R 2 that is correct, v o equals what v 1 minus i 1 into R 2, right because you see here is same this is R 2. So, I have v o equals to nothing but v o equals to v 1 minus i 1 R 2, right. So, if I substitute the value what will I have? Output equals to minus v 1 R 2 by R 1, right.

Now, if I take voltage gain is negative, voltage gain is negative that is correct because my inverting amplifier my voltage gain is minus R 2 by R 1, right, my gain is minus R 2 by R 1. Voltage gain then we can multiply by input. So, voltage gain is what? Negative, voltage gain is negative, right.

Input and output signals are out of phase, this is another concept. So, we have seen this concept or let us see when we talk about. Out of phase out of phase is nothing but when you apply the input to the inverting terminal which is right over here it is a like to the inverting terminal input is signal like this, output will be multiplied or amplified was in of the input output would be amplified was in of the input and that amplification depends on the value of R 2 by value of R 2 by R 1, right value of R 2 by R 1.

But the is it in phase or out of phase this is in phase signal. But in case of inverting in case of inverting amplifier we will see that the out output would be like amplified, but out of phase it will be magnified, but generally 180 degree out of phase if this is 0 degree, this is 180 degree out of phase ok. So, that is what is written here that input signals and output signals are out of phase ok.

Next closed loop gain depends entirely on external passive components, right, closed loop gain depends on external passive components why? Because we have R 2 and R 1, we have R 2 and R 1. So, this is external passive component R 1 is register, R 2 is register which are externally connected to the op amp that is why they are external, external, passive, passive components and our gain this is a closed loop. If you see this amplifier it is in closed loop configuration a closed loop gain depends on the value of R 2 and R 1 and that is why we can say that the closed loop depends entirely on external passive components, external passive components.

Closed loop amplifier played its gain for accuracy, right; that means, that here we do not have extremely high gain, but we can we can change the gain and we can have finite, but accurate closed loop gain. So, accuracy is better here, but we have finite closed loop gain, ok. But in case of no feedback you will have infinite gain, here in case of no feedback you have infinite gain. This is the inverting amplifier, it is the inverting amplifier.

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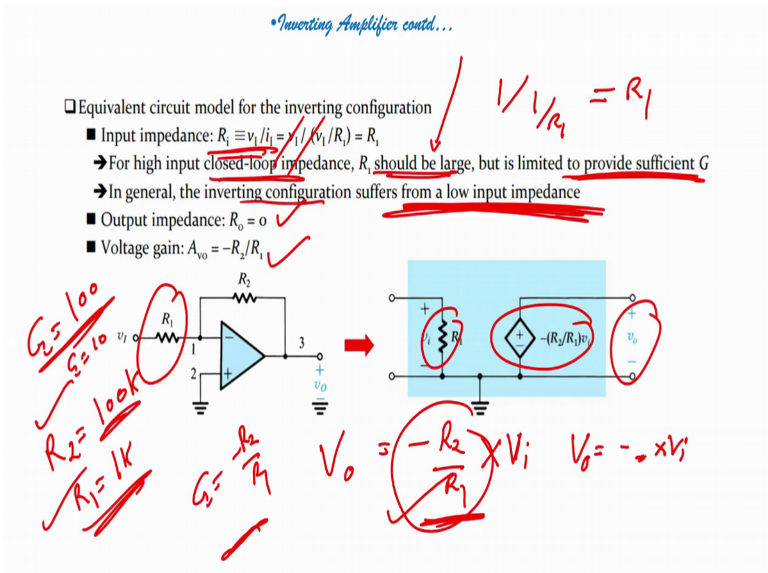

Now, if I draw equivalent circuit model of inverting configuration what will I have? I have R 1, my gain is minus R 2 by R 1 into v i I have two voltage v o input voltage v i, right. So, input impedance is nothing but R i equals to v i by ii or v i by i 1, right equals to v i divided by v 1 by R 1 that is correct, which is nothing but v v cancel this value will be cancelled. So, it nothing but 1 divide by 1 by R 1 which is equal to R 1, right that makes my input impedance; input impedance will depend on the value of resistor R 1.

For high input closed loop impedance R 1 should be large, but is limited to provide sufficient G. What is that mean? That if I have A v equals to, what is my gain here? R 2 by R 1 is not it, right and if I say output voltage; output voltage v o is nothing but R 2 by R 1 into input voltage V i, correct. Now, what we are; what are saying here? That for high input closed loop impedance, high input closed loop impedance what we should have? We should have R 1 extremely high, R 1 value should be extremely high. So, if I put R 1 extremely high what will happen; what will happen? My output would be similar to my input. Let us say if R 1 is infinite my out or closed infinite this R 2 value R 2 by R 1 will be extremely small, extremely small into v i into v i.

So, the I cannot do that R 1 can be extremely high this is not possible, right, otherwise this will not work properly. So, what is written? But is limited to provide sufficient gain that we have to use very high value of R 1, but we have to also understand what is a gain of our amplifier. For example, if I have if I want to have gain of amplifier to be 100, right there I can have R 2 which is 100, but R 1 I cannot have 100 I only I can only have 1, right. So, if I have gain enough, so I can have R 2 equal to 100 k, R 1 equal to 1 k you see. So, it is limited by this gain, it is limited by the gain. Even we want higher if I put like 10 k here, my gain will not be 100 my gain will become gain will become 10, right. Why gain will become 10? Because gain is nothing but minus R 2 by R 1, right. So, it is limited to provide sufficient gain, all right. This is an example which we have seen.

Now, in general the inverting configuration suffers from low input impedance. You see here why? Because you see here only R 2 by R 1, if I want to have gain of 100 my R 1 would be R 1 would be 1 k if I select R 2 equal to 100, now 1 k is extremely small, but in reality, we should have R 1 or in input impedance extremely high. So, in case of inverting in case of inverting amplifier the low input impedance low input impedance is a problem or in another terms inverting amplifier configuration suffers from a low input impedance, all right. Output impedance is 0, voltage gain is nothing but minus R 2 by R 1 easy, super easy, right.

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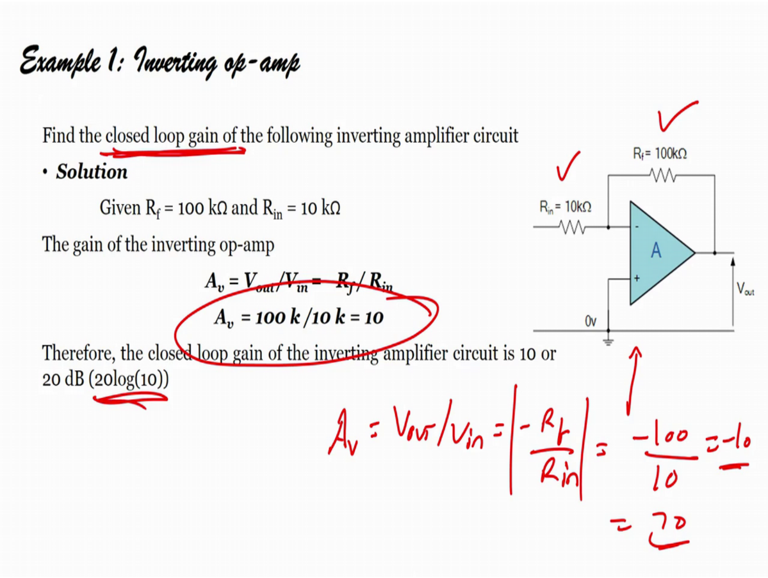

So, let us solve let us solve an example ok. Let us solve an example. So, find the closed loop gain of following inverting amplifier circuit. You have give, you are given a circuit and you are asked to find the closed loop, gain asked to find the closed loop gain ok.

Now, we are already given R in 10, R f 100, right then what is our A v? A v is nothing but V out by V in or we can write minute R f by R in 100 by 10 both is kilo ohms I am, I do not write it that is fine, right. So, what I have? Minus 10, but gain cannot be minus, right. So, we always write is equal to 10, gain is equal to 10. So, if I want to understand the closed loop gain, the closed loop gain of the inverting amplifier circuit is 10 or 20 dB or 20 log 10; 20 log 10, right. So, this is how I can understand my inverting amplifier; inverting amplifier.

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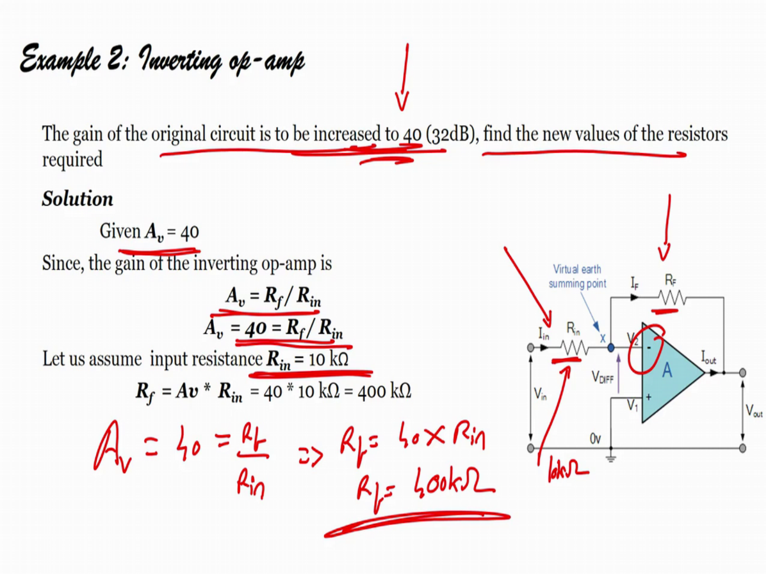

Let us see one more example; let us see one more example ok. So, the inverting amplifier the gain of the original circuit is to be increased by 40 dB ok. Find then values of resistor. See we are not given the values of resistor ok. Now, what is given? That we have to; we have to increase the gain to 40 dB or 40 or 32 dB. So, what will be the value of resistors; what will be the value of this resistors? That is the question ok.

So, given A v equals to 40 right, it is already given gain is 40. Now, since it is an inverting op amp. Is it inverting op amp? Yes, because we are providing input to the inverting terminal. So, what will be my A v? A v will be nothing but the A v would be R f by R in A v would nothing but R f by R in.

So, 40 equals to R f by R in, right. 40 equals to R f by R in. So, if I assume that my R in let us say its 10 kilo ohm, is 10 kilo, ohm then my R f would be what? See I have a formula I have A v equals to 40, equals to R F by R in, all right, implies R f equals to 40 into R in. If I assume R in to be 10 kilo ohm my R f would be 400 kilo ohms, very easy, super easy, right. If I consider R in as 1 kilo ohm then my R f would be; my R f would be 40 kilo ohms R f would be 40 kilo ohms. If I assume my R in equals to 10 kilo ohm R f would be 100 kilo ohm, right. If I assume this is 10 kilo ohm, then R f equals to 1 kilo ohm. So, this is how we can solve the equation for that inverting amplifier, all right.

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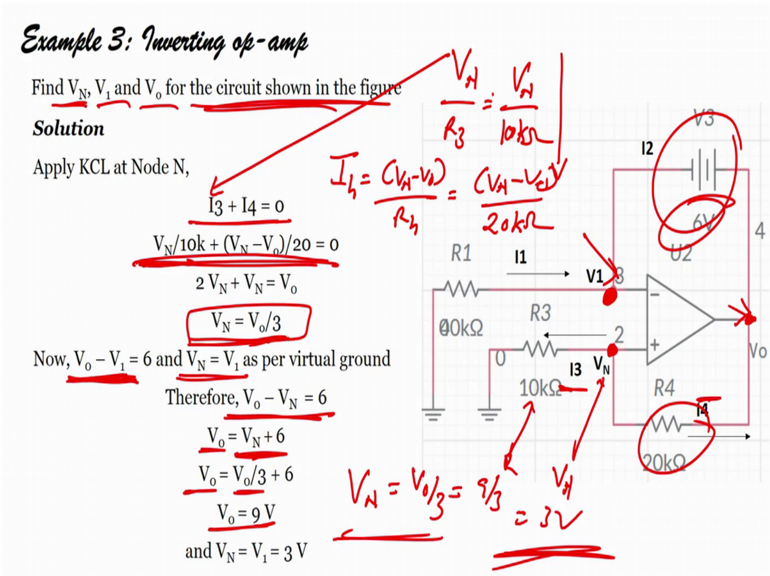

Let us see one more example, all right. I am giving you more example so that you can understand when you are given a circuit how can you solve the; how can you solve the problem ok. So, find V N, V 1, V 0 for the circuit shown here. For this particular circuit we have to find lot of things. So, let us see. So, if I use the circuit first at node N, right at node N I had to here. I had to find, so I will use Kirchhoff current law at lower end, and what will I have? I will have I 3; I will have I 3 and I have I 4 here, that will be I 3 I 3 plus I 4 equal to 0, correct. According to Kirchhoff current this will be I 3 I 4 equals 3 0.

Now, what is I 3? I 3 is nothing but V by R. What is V? V is my V N V is my V N. What is R? R is my 10 kilo ohm, right V N 10 kilo ohm. So, I substitute this value, correct, plus I 4. What is I 4? I 4 is here, I 4 is nothing but you see here, you see here, it is like V N minus V o divided by R 4, correct, V n. So, from here I 3 is what? I 3 will be my V N by 10 kilo ohm, right, which is my R 3. I 3 would be V N by R 3 which is V N by 10 kilo ohm, right and I 4 equals to V N minus V o by R 4 equals to V N minus V o divided by 20 kilo ohms, right. This is what I have written here. So, from here when we solve it you will find that V N equals to V o by 3 ok. V N equals to V o by 3.

Now, V o minus V 1 equals to 6, V o minus V 1 equals to 6 and V N equals to V 1 as per virtual ground correct, V o minus V 1 equals to 6 because here. See, what we have out what is the bias voltage? 6 volt this is applied across the 3 and V o, right. If I say V o minus V 1, V o this voltage minus this voltage is nothing but 6 volts, right and V N, this

V N this voltage V n, right should be equal to V 1 sorry V N is here. V N should be equal to this voltage V 1, right because by the concept of virtual ground by the virtual ground.

So, what we have? V o minus V 1 equals to 6 and V N equals to V 1. So, therefore, V o minus V N equals to 6. So, V o will be V N plus 6. So, V o will be V N plus 6. V N means what? V N is V o by 3, right. So, I will put V o by 3 plus 6. So, V o would be nothing but 9 volts. Now, I know that V N equals to V 1 equals to 3 volts how? Because I know V N equals to V o by 3 equals to 9 by 3 equals to 3 volts, correct. V o equals to V o by 3 V N equals to V o by 3 right.

This is 3 equals to what is V o? V o is 9 volts. So, 9 volts by 3 which is nothing but my 3 volts, right, so, this is how this is how I can find this is how I can find what is the V N, V 1 and V o for a given circuit. This is how I can find what is V N, V 1 and V o for the given circuit when you are given a circuit of an inverting amplifier, guys.

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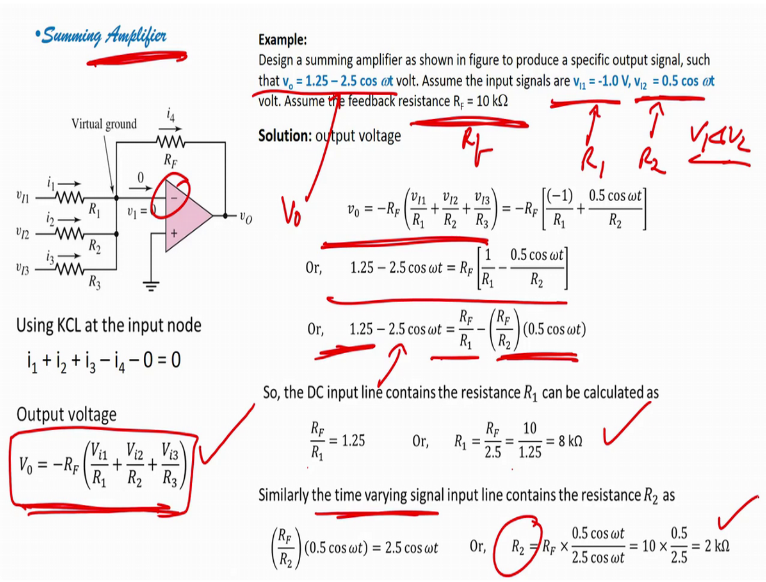

Now, let us see an example, let us see an example of a summing amplifier. So, what is summing amplifier? Let us see the circuit ok. So, when you see the circuit what do you find is that you when you use inverting amplifier if you come back on the screen you will see that you will see that we are using a inverting amplifier we have a feedback register, but instead of one input register you have 3, you can have n also, you can have n input resisters ok. So, n inputs and the output will be summation of all the inputs ok. So, how can we do that? You can it is written over here is given.

You are given the circuit then using Kirchhoff current law, using Kirchhoff current law what we can find we can find i 1 these values, i 1, i 2, i 3, 3 values are here. So, I 1 plus i 2 plus i 3 minus i 4 here and here, right you will see this configuration minus 0 equals to 0, right. So, output voltage will be what V o equals to minus R f, right. Why? Because it is inverting amplifier this is a inverting amplifier. So, inverting amplifier our formula is R F by input resistance R in, right. Here first is V 1 by R 1.

Why? Because R F into V 1 here, V 1 by R 1 thus V 2 by R 2 thus V 3 by R 3, right; that means, output voltage which is the, summation of the input voltage is summation of the input voltages and you can and you can change the gain with the help of R F and input resistors. That means, it is not only providing a summation it is also providing the amplification, it is also providing the amplification, and that is why what we say is this is a summing amplifier, right.

Now, here you can see very easily that the concept of virtue is around will come here, here and here this is nothing but because the inverting terminal non-inverting terminal is grounded, the voltage at the inverting terminal is also considered as 0 which is your virtual ground which is your virtual ground.

Now, if you are given an example which is the right over here in front of you this example the design a summing amplifier as shown in figure to produce the specific voltage such that V o equals to this assume that V 1 is this, V 2 is this and feedback register R F phase value, R F phase of 10 kilo ohm value, right. Now, if you see closely you are given v in 1, you are given this voltage which is v in 1, right here you are given v in 2, but you are not given anything about v i 3 here. Are you given anything about v i 3? So, v you do not have to assume that is v i 3 or v i 3, v i 3 equals to 0 v i 3 equals to 0.

Now, we can just we know this formula, right we know this formula which is similar to here, the formula for summing amplifier. We will substitute the value, so minus R F remains as it is here. What is v i 1? V i 1 is minus 1 volt divided by R 1. Plus, what is v i 2? v i 2 is nothing but 0.5 cos omega t by R 2, right. Now, what is v o? V o is given as 1.25 minus 2.5 cos omega t equals to R F into this value. So, if I further solve it, we further solve it what will I have 1.25 minus 2.5 cos omega t equals to R F by R 1 minus R F by R 2 into 0.5 cos omega t, right 0.5 cos omega t.

So, the DC input line contains resistance R 1 and that can be calculated as nothing but R F by R 1 equals to 1.25, correct, 1.25. This is very easy, right here. How see this value R F by R 1 or R 1 equals to R 1 equals to R F by 2.5. What is R F? R f is given 10 kilo ohm, so R 1 equals to 8 kilo ohm. Similarly, time varying signal input line contains R 2, right you can see here. This is, the point is the point here you have to understand is when you are considering DC input line, then you can see DC input line, right it contains this value.

But point varying signal this contains this value, right, point varying signal which is this one will have 2.5 cos omega t. So, I can write R F by R 2 into 0.5 cos omega t is nothing but this particular equation or R 2 is nothing but this value or further if I solve it R 2 would be 2 kilo ohms.

Thus, I have find the value of; I have found the value of R 1m I have found the value of R 2 and now I can put this value and design and design a summing amplifier and design a summing amplifier, all right. It is very easy.

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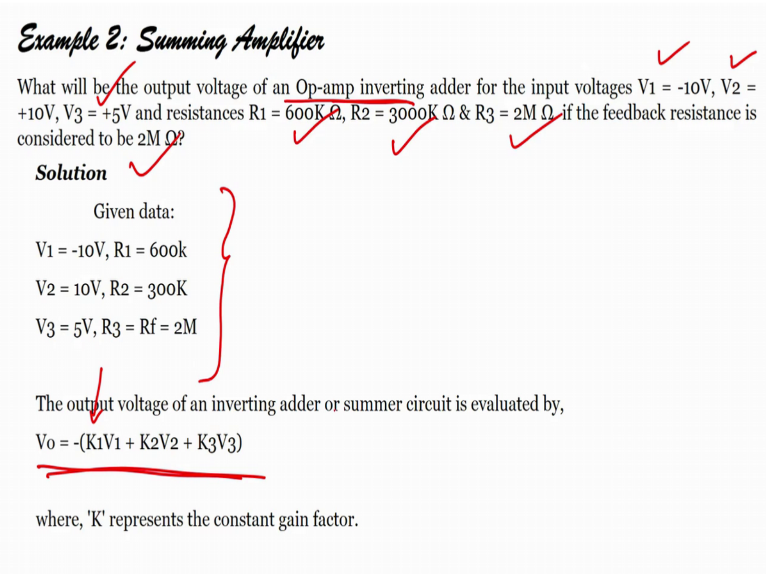

Let us quickly once again see was how what we have done with summing amplifier. Summing amplifier is nothing but an inverting amplifier corrected in a way that you have lot of input voltages more than, more than 1 voltage, now here you can see such that, you can take a summation of those input voltages can be n numbers, like this it can be until n ok, this R n in v i n, all right, n n times ok. So, point is that the formula is very easy v o equals to feedback resistor R F since this is inverting, so minus R F by R 1 we have seen, right; v o equals to minus R F by R 1 into v 1 then the inverting amplifier, right.

Now, here we have minus R F by R 1 into v 1 plus we have or minus plus we can also write minus R F by R 1 into v 2 plus again we have minus R F by R 3, this is R 2 into v 3. So, if I solve this I will have this equation, right. Once I know this equation if I am given a problem if I am given a problem which is shown here that for the output voltage, given output voltage. If you have two signals input signals and you have feedback resisters then we can solve the value of R 1 and R 2, because there are only two voltages v 1 and v 2. So, we have to find R 1 and R 2. We are given the value of R F, we are given the value of v o, right we are value given the value of v 1 and v 2 everything is given.

So, this becomes, life becomes very easy because we have to just substitute the value and solve it and then we know that this is the DC input line, this is the resistance R 1, that is that is there the if input line contains. And then we see the time varying signal, this is the time varying signal and the it is related with this particular signal. So, then you can find the value of R 2. Thus R 1 and R 2 is very easy to find easy to find, all right.

So, let us see one more example of summing amplifier; one more example ok. So, what will be output voltage of op amp, inverting error, inverting error, it is also called inverting error for input voltage is V 1 is given, V 2 is given, V 3 is given, R 1 is given, R 2 is given, R 3 is given and feedback resistance consider to be 2 mega ohms, R F is also given. You see life is so easy, it is so easy question. Everything is given V 1, R 1, V 2, R 2, V 3, R 3, R F everything is given, right.

Now, now output voltage is what? Output voltage is V o equals to minus K, so K is nothing but, this is nothing but gain factor, this is nothing but gain factor, right. R F by R 1 that is the K ok, R F by R 2 K 2, R F by R 3 K 3. So, minus bracket K 1 V 1 plus K 2 V 2 plus K 3 V 3. So, if I substitute the values, if I substitute the values then what will happen? K 1 is nothing but R F by R 1.

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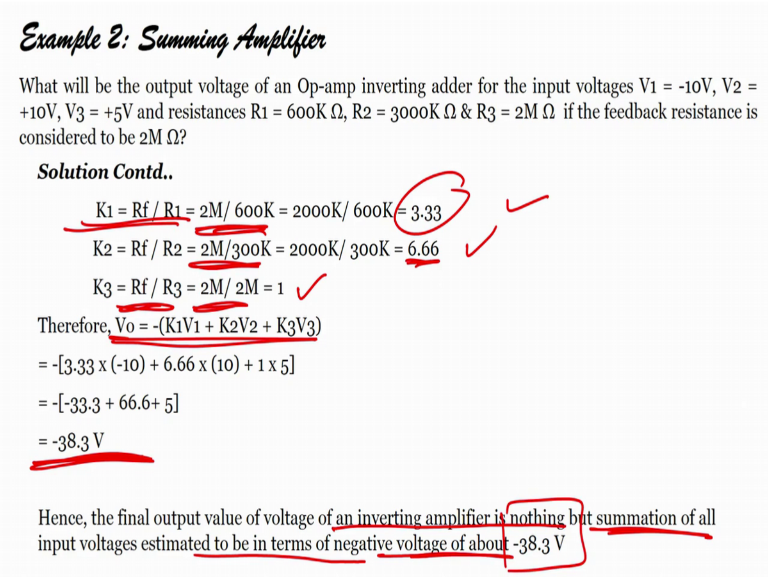

So, if I have seen the values 2 mega ohm will be a 600 kilo ohm and have 3.33 which is my R F by R 1 or K 1, same way if I substitute value for K 2 that is R F by R 2 2 mega ohm divided by 300 kilo ohm, I will have 6.66, right and then finally, for K 3 R F by R 3 2 mega ohm by 2 mega ohm is 1. So, I have now 3 values. If I substitute those values in this equation what will I have v o equals to minus 38.3, volts minus 38.3 volts.

Hence, the final output voltage of a inverting amplifier is nothing but the summation of all the input voltages estimated to be in terms of negative voltage of about 38.3 volts, about minus 38.3 volts finally, voltage is minus 38.3 volts ok, very easy. This is how the summing amplifier can be solved.

So, what we have seen in this particular module is that we have seen that we can use the operation amplifier as an inverting amplifier and then we have solved few problems. Then we have also seen the operation amplifier as a non-inverting amp as a summing amplifier and we have seen a problem how it can be use as a adder or as a summer, right, as a summing amplifier.

Now, in the next module let us see how we can use operation amplifier as the non-inverting amplifier ok. So, there are several applications like we have seen the slide one, that the op amp can be used as a inverting, non-inverting, differentiator, integrator, summer, right. So, we will see few other circuits in the next module. Till then you just look at what I have taught in this particular module and I will see you in the next module. Bye, take care.