**Basic Electrical Circuits**
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**Lecture – 112**

We have discussed a number of circuits with the op amp and the ideal op amp, there is a crucial detail which we have omitted, the op amp is a device that needs power it has to be powered by some voltage source for it to operate. So, that aspect we have completely omitted in this lesson we will take a basic look at it.

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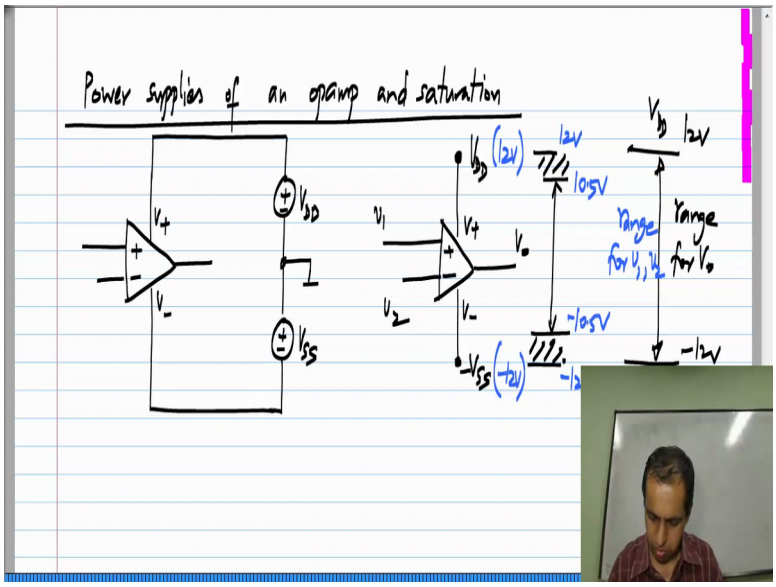


It turns out that the power supply voltages that you use set certain limits to how much the output voltage can be and still have the op amp operating as desired that is like a voltage controlled voltage source with a very large gain A naught or as an ideal op amp that is what is meant by saturation and we are going to discuss that in this lesson as well. So, far I have been using this symbol for the op amp with three terminals, non inverting terminal, inverting terminal and the output, this it turns out is incomplete and we need two more terminals to which we can attach the power supply.

So, typically this is leveled V plus and this is leveled V minus and you connect some power supplies to it and a typical scenario is to used to desperate voltages V D D and V S S to supply a positive voltage to the V plus terminal with respect to ground or a negative voltage to the V minus terminal with respect to ground. Now, this is not strictly necessary you could use a single voltage source.

But, in most of the standard op amp applications two power supplies are used, so we are going to stick to that and it is also quite usual to not show the power supply voltage sources like this, but to simply draw a picture of this sort. So, this is the V plus terminal that is the V minus terminal and it simply indicated here that it is V D D and V S S this means that there is a voltage source of value V D D connected between this terminal and ground and this means that there is a voltage source of value minus V S S connected between this terminal and ground, this should be minus V S S.

So, now, what is the effect of this on our amplifier or any circuit we built it turns out that the output voltage V naught of the op amp can swing between V D D and V S S, in fact it cannot go all the up to V D D or all the way down to V S S typically the allowable range for V naught is somewhere between V D D and V S S. So, let me take some typical values from old general purpose op amps, we did it could be 12 volts and minus V S S could be minus 12 volts.

So, we have 12 volts and minus 12 volts and the output could be swinging between let us say 10.5 volts and minus 10.5 volts, while still behaving like a voltage controlled voltage source for the op amp to behave like a voltage controlled voltage source some limits have to be placed on the output voltage V naught and that limit is set by the supply voltages which are connected to the op amp. In reality the limits on V naught will be a little less than the difference between the power supplies that is it cannot go all the way up to V D D nor can it go all the way down to V S S.

Now, in absence of any information about the details of the op amp frequently for solving problems we think of the range of V naught as being this entire range between 12 volts and minus 12 volts that is between V D D and minus V S S. So, this is the allowable range for V naught. Now, in addition to this if I call the input voltages as V 1 and V 2 each of V 1 and V 2 has to be also limited to some range and again in absence of any future details about the op amp, if you are not talking about the specific op amp, but we are solving problems in general then we can think of V 1 and V 2 also being limited to the same range. So, this is the range for V 1 and V 2.

Remember, when the op amp is placed in negative feedback this V 1 and V 2 will be very close to each other, but each of them can take on any value and that value is limited to this, when I say limited to this limited to between V D D and minus V S S what I mean is if V 1, V 2 and V naught are limited to these values, the op amp behaves like an ideal

voltage controlled voltage source with a very large gain and frequently it can be approximated by the ideal op amp in which we say that the gain is infinite.

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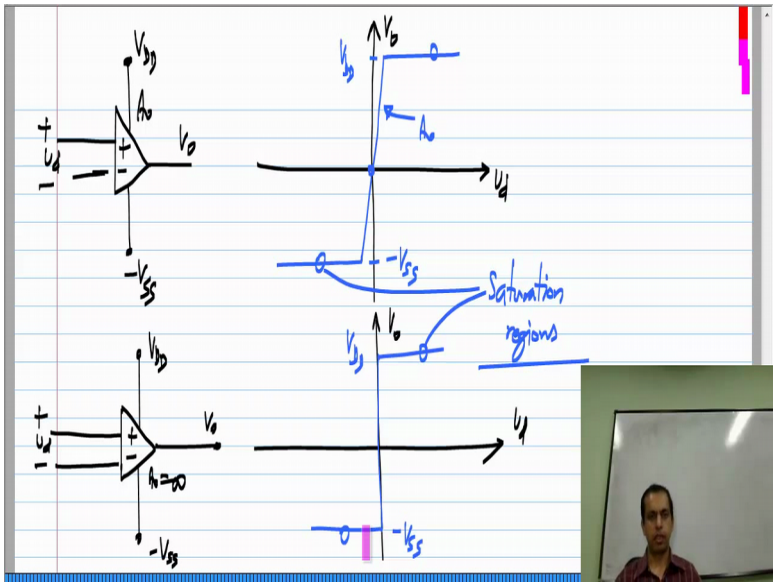


In other words if I take an op amp with gain A naught and plot V naught verses V d it will be a straight line, because we model it as a linear voltage controlled voltage source and the slop will be very large in fact if I use the same scale for x and y axis, then it will be pretty much of vertical line, but I want to show some slop. So, I will show it like that and the slop of this is nothing but, the gain A naught, but it will naught continue indefinitely like this assuming that supply voltage is V D D and the lower supply voltage is minus V S S on the upper side it will be limited to V D D and on the lower side it will be limited to minus V S S, so this is the characteristics of the op amp.

Now, if we are talking about an ideal op amp there are many cases in which we consider the slop here the gain of the op amp to be infinite, but still we want to judge the effect of having power supplies which are not infinitely large. So, I will show it like this with A naught equals infinity, in this case if I plot V naught verses V d I will get a straight vertical line, but it will saturated V D D and minus V S S. So, these regions here these are known as saturation regions.

Now, if you want the op amp circuit to behave in the way we analyzed it before that is when it is placed in negative feedback it is input voltage must be very small or even 0 if we consider the limiting case of A naught being infinity, the output voltage must not reach either of the limits. Similarly, the input voltages V 1 and V 2 individually must not

reach the limits. So, these are some limits on the input and output voltages for the op amps. So, that it behaves in the way we expect it to that is as a very high gain voltage controlled voltage source. Now, what is the effect of this one circuit?

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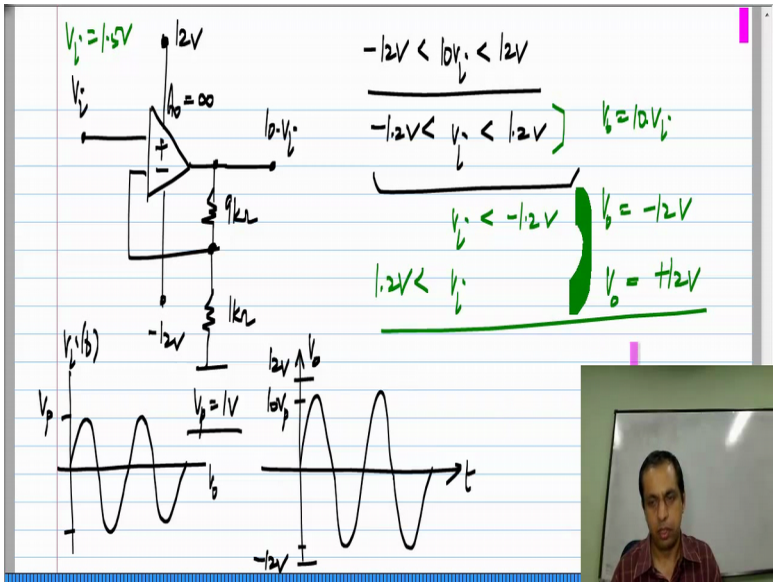

Let us take a circuit that is very familiar to us let us say I have 9 kilo ohm and 1 ohm kilo, this is the non inviting amplifier and let us say I assume that the op amp is ideal that is it is gain is very, very, very large tending to infinity. Now, I use supply voltages of 12 volts and minus 12 volts. So, if I have V i here I will have 10 times V i over there you can easily calculate that the gain of this amplifier is 10. Now, as I said 10 V i whatever the output voltages has to lie between the upper supply and the lower supply which is 12 volts and minus 12 volts; that means, that for this amplified work as expected for it to work like an amplifier of gain of 10 V i has to be limited to 1.2 and minus 1.2 volts.

Because, if you exceed these limits let us say you apply V i of 1.5 volts from the gain of 10 that you expect for this amplifier you would expect that the output would be 15 volts, but the output cannot be higher than this power supply. So, it will saturated 12 volts, so if the input voltages between these limits V naught will be 10 times V i and if V i happens to be smaller than minus 1.2 volts, the output will saturate to the negative saturation level of minus 12 volts and if V i happens to be more than plus 1.2 volts V naught will saturate to the positive saturation level which is plus 12 volts.

So, clearly in these cases it is naught behaving like an amplifier at all also let us say you apply a time varying signal the standard signal to analyze circuits with is sinusoid and

the let us say the peak value is V p at the output we expect that we will have a sinusoid of peak value 10 times V p, because the output is simply 10 times the input and this will happen if this 10 times V p is within the saturation limits. So, let us say V p is 1 volt then this 10 times V p is 10 volts and the saturation limits are really at plus 12 volts and minus 12 volts, the signal swings safely between that.

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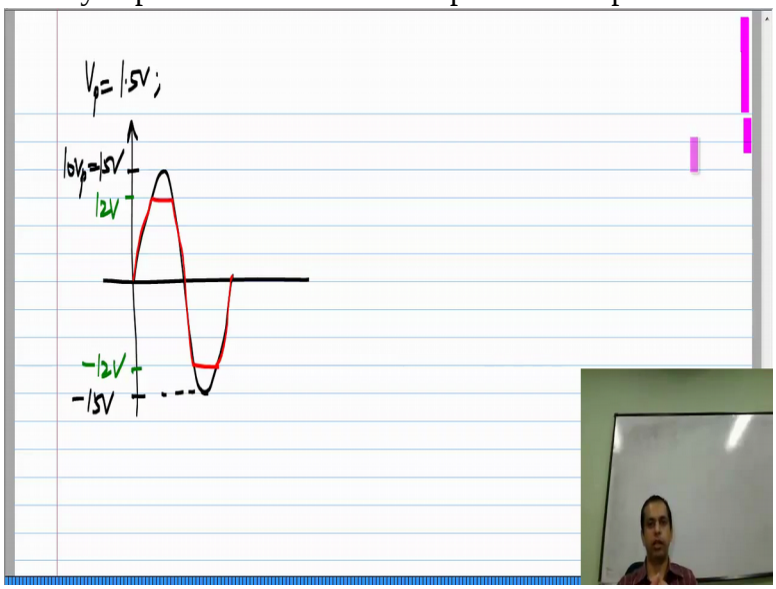
But instead, let us say V p is 1.5 volts and the output of an amplifier with the gain of 10 I




would expect sine wave like this whose amplitude is 10 times V p which is 15 volts and the sine wave is symmetrical. So, on the other side I would expect the peak to be minus 15 volts, but this is not going to happen what will happen is that, because the upper limit is 12 volts and the lower limit is minus 12 volts, the output will follow the expected one as long as it is within 12 volts and minus 12 volts and it will saturate there similarly it will come down it will saturate there and so on.

So, clearly this is not a good amplifier, because the output shape does not resemble the input shape anymore and it is naught the output is naught simply 10 times the input. So, whenever you use an op amp you have to also make sure that all the voltage levels the relevant voltage levels of the op amp, the individual input voltages V 1 and V 2 and the output voltage V naught are within the specified limits, in absence of information about a particular op amp you assume that the limits are equal to the supply voltage.

Now, I want discuss this in further details it is very common to use equal values of V D D and V S S that is use symmetrical supplies, where the upper supply voltage is 12 and the lower one is minus 12 as I showed in these examples. But, it is naught necessary for

them to be equal you could have plus 12 volts and minus 6 volts that will only change the limits you can have for V 1, V 2 and V naught.

Similarly, it is possible to eliminate the second supply voltage all together and have a single supply voltage that is the lower voltage will be 0 volts, you connect it to ground and the upper voltages whatever it can be, it could be 12 volts and 0 for instance. So, that is known as single supply operation of the op amps and that is perfectly possible all you have to make sure is that V 1, V 2 and V naught in your circuit fall only between 0 and 12 volts, you cannot go negative and it is quite easy to arrange that I won't going to those details here, but it is possible to operate op amps with the single power supply voltage as well.