Basic Electrical Circuits
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Lecture - 113

One of the things many of you may have observed while looking at these op amp circuits which we have been discussing so far is that, if you take the op amp as a whole it does not seem to obey Kirchhoff's current law. Here is what I mean.

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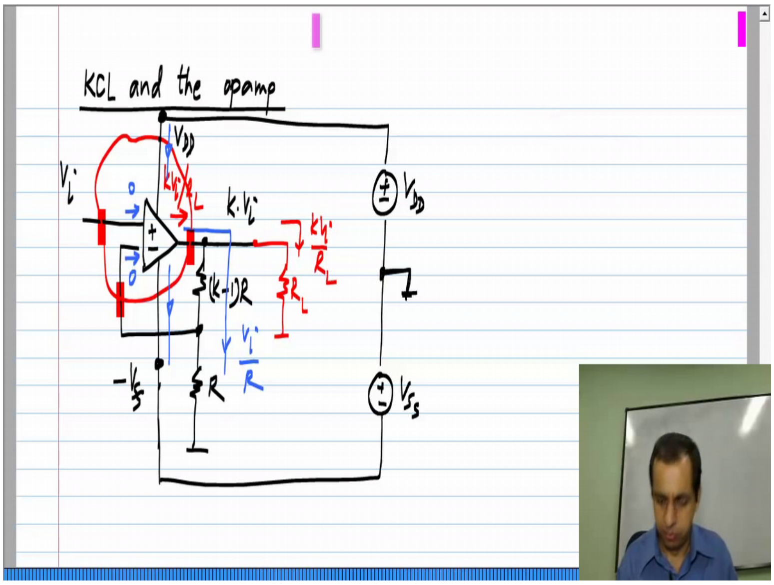

Let me take our usual amplifier circuit, if I have an input voltage V i and this is k minus 1 R and R, the output will be k times V i with an ideal op amp and with a real op amp for the finite, but very large gain, it will be close to this. Now, the current flowing through these resistors is V i by R, it is k V i divided by the sum of these which is V i by R. Alternatively V i appears here also, so the current through this is V i by R which also flows through that resistor.

Now, obviously, this current comes out of the op amp, but the input of the op amp both inverting and non inverting draw 0 current, the op amp draws no input current at all. So, if I think of the op amp as a whole, we know that any close surface should have the total current entering it or leaving it to be 0 and clearly here it is not 0. The current coming out of the op amp is V i by R, in fact I could add a load to it, then I current k V i by R L will flow that way. So, the total current coming out would also include k V i by R L, it will be V i by R plus k times V i by R L and these are 0.

So, if you sum the currents there, there and there let us say coming out of this close surface, it is clearly not 0. So, this seems to violate KCL which of course, cannot be violated at all, but the resolution to this is pretty simple. In this picture, as in most op amp pictures we have omitted the power supply connections. So, if we do include the power supply connections, this is V D D and this is V S S. So, the positive supply is connected to V D D, the negative supply to minus V S S with respect to this ground.

So, the currents through these are clearly not 0, so the current flows through the supply terminals. So, that is how the sum of these currents will get balanced, so essentially the current that is coming out of the op amp is coming out of the supply terminals of the op amp. Now, exactly how much current flows through the supplies depends on the internal details of the op amp, but there is a pretty simple model that we can use which I will discuss now.

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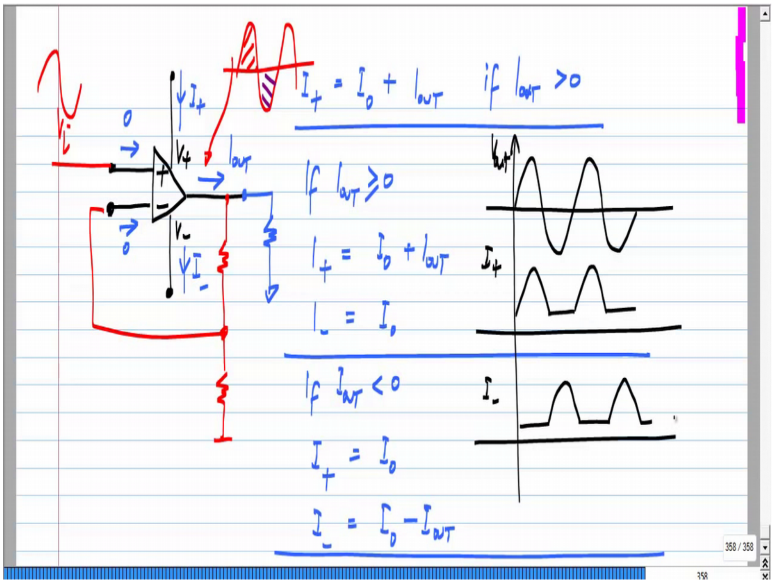

So, I have the positive and the negative supply and the currents into the input terminal of the op amp are 0 and let us say the current that is coming out it is called I out and the current that is going into the positive supply terminal I call it I plus, the current that is coming out of the negative supply terminal I call that I minus. Now, a very simple model for this I plus and I minus is that, I plus is some fixed value I naught plus I out, if I out is greater than 0. Rather let me first put this condition, if I out is greater than 0 that is a positive current is coming out of the op amp, then I plus is I naught plus I out and I minus is just I naught.

If I out is smaller than 0, then I plus is just equal to I naught and I minus will be I naught minus I out. So, this first of all satisfies Kirchhoff's current law and in fact this is a sort of a simple model and not every op amp may obey this model, it could be that the currents through the supply is exactly a constant and so on. But, usually there is a constant part and there is a part that is dependent on how much current is being driven out. At least for general purpose op amps that you can buy of the shelves such as this 741 or 347 or those op amps, this model is followed.

Clearly, if I out exactly equals 0 then I plus and I minus will be the same and equal to I naught, this is the pretty simple model that we can use. So, for instance let us make an amplifier out of this, I will not work out the presides details, so let us say that the input is a sinusoidal, the output voltage here also will be a sinusoidal. So, during these parts I out will be positive and during those parts I out will be negative.

So, what happens is that in such a case is, let say V out showing positive and negative and positive and negative, then I plus will be following the sinusoidal current. Because, the voltage is sinusoidal, the current is also sinusoidal, I plus will be following this current and when the output current is negative it will just the fixed value I naught and then it will follow this and so on.

Similarly, I minus will be please note that direction of I plus and I minus I have chosen I plus to be flowing into the terminal and I minus would be flowing out of the terminal, this is not the kind of convention I normally used, but these values are positive that is why I use them like this and I minus will do the opposite, when the output voltage and hence the output current is negative it will be a constant; otherwise, it will follow the signal and it does that.

So, first of all KCL cannot be violated and it is not violated in case of the op amp, the output current of the op amp comes from the supply terminals. Now, given any op amp circuit from the circuit analysis, you know how much current is flowing out of the op amp. Now, if you want to get an estimate of, how much current is flowing in the power supplies you can use this model and if the value of I naught is not given to you, you can even assume that to be 0 just to get a feel for, how the currents in the supply terminals vary.