Integrated Circuits, MOSFETs, OP-Amps and their Applications

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Lecture - 35
Analysis of Data Sheets of an Op-Amp Contd.

Welcome to this module this module is a continuation of our last module in which you were looking at the Op Amp data sheet and then we were looking at the characteristics of Op Amp and we have seen what is input bias current and how we can remove the effect of input bias current on the output. This module we will see what exactly is an input, offset current and how does input offset current effects the amplifier operation right.

Now, we already have seen what is input offset current? we have seen in the earlier lectures, the formula also now we know very well. The formula of input offset current is nothing, but is nothing, but I o 1 or I B 1 minus I B 2 mode of I B 1 minus I B 2 right. Input bias current was I B 1 plus I B 2 by 2 input offset current is I B 1 mode of I B 1 minus I B 2 all right. Now, let us see how this is going to affect the amplifier operation. So, if I see the slide what can I find.

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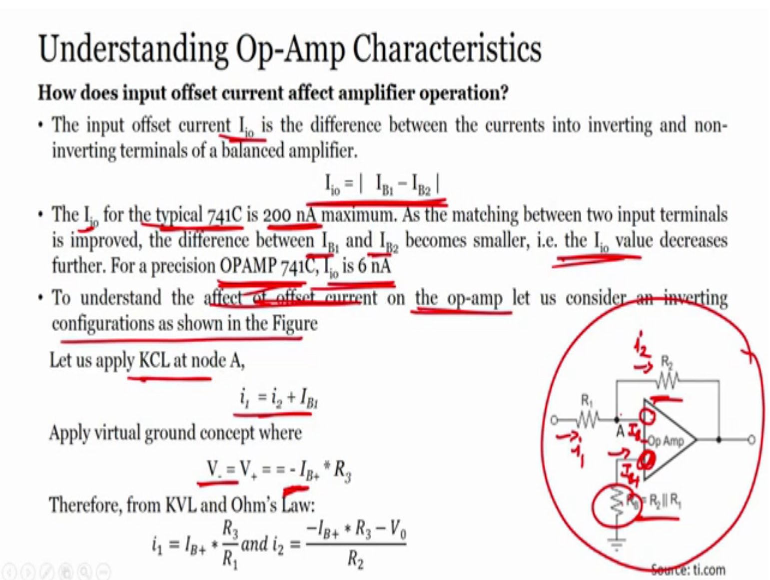

I find that input offset current definition which we already know right.

Then I see that the input offset current for typical 741 is 200 nano ampere maximum as the matching between into input terminals is improved the difference between I B 1 and I B 2 become smaller that is the input offset current value decreases further right. Now, for a precision of Op Amp 741 input offset current, input offset current is nothing, but 6 nano amperes ok.

So, input offset current is nothing, but 6 nano amperes for a precision Op Amp, to understand the effect of offset current on the Op Amp let us consider an inverting configuration as shown in this particular figure. So, what we find there is a R 1 there is R 2 inverting Op Amp and then we have R 3 which we already know which would be equal to R 2 parallel to R 1.

Now, if I apply Kirchhoff's current law at node a here i 1 will be nothing, but I 1 equals to i 2 plus I B 1 all right. So, applying virtual ground I will have V in equals to V plus equals to minus I B plus right I B plus will go here I B plus here will be I B minus right here will be i 1 i 2 right.

So, V minus which is voltage over here right. So, V minus V will be equal to V plus equals to minus I B plus right into R 3 into R 3 right from Kirchhoff current law I 1 is nothing, but I one is I B plus right I one would be nothing, but I B plus into R 3 by R 1 into R 3 by R 1 then 2 would be nothing, but minus I B plus into into R 3 minus V o divided by R 2 correct..

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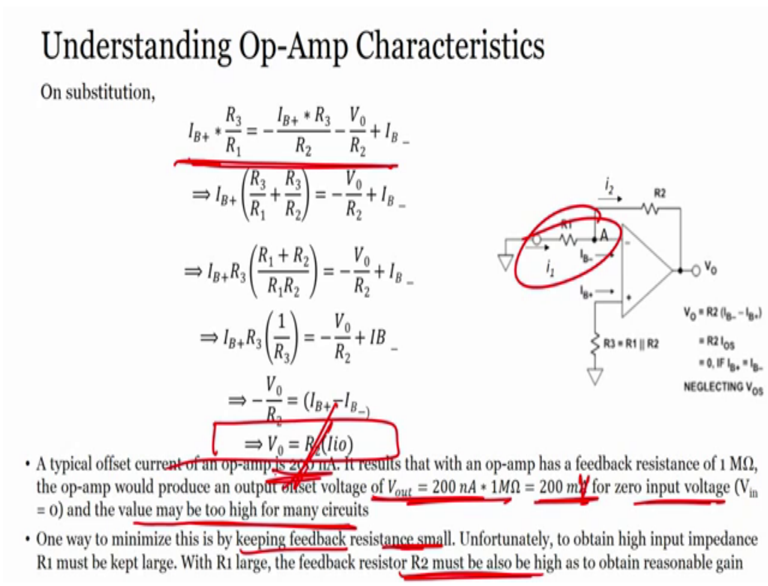

Now if you substitute on substituting the values we will have I B plus into R 3 by R 1 equals to minus of I B plus into R 3 by R 2 minus V o by R 2 plus I B minus. So, if I solve this equation further what I will have V o will be equal to R 2 into I I o right.

Now, a typical offset current of an Op Amp is 200 nano amperes it results that within Op Amp has a feedback resistance of one mega ohm, the Op Amp would produce an output voltage of 200 into 1 which is 200 milliampere for 0 input offset voltage this much is the change. Some 200 millivolts right that is generated at the output voltage and the value may be too high for many circuits right.

So, when the way to minimize this is by, is by keeping the feedback resistance small, unfortunately to obtain high input impedance R 1 must be kept large right R 1 should be large otherwise we will not have high input impedance and we know that in Op Amp we should have extremely high input impedance. So, we cannot do that.

Now, feedback resistor R 2 must also be high otherwise we cannot have gain same problem right, the idea is if I can reduce value of R 1 or if I am sorry if I can reduce the value of R 2 then I have a minimum effect, but I cannot have reduce a value of R 2 and that is why, that is why I do not have any solution till this point.

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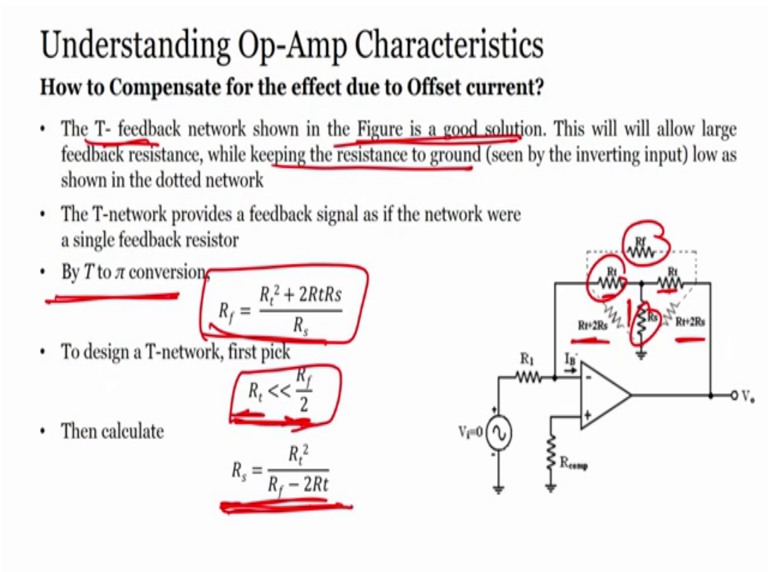

Now, let us see. So, if I want to compensate the effect of due to the offset current what should I do, then the feedback network right here you can see here it looks like a T right it looks like a T that is why we say t feedback network shown in the figure is a good solution.

How? A how is a good solution let us see this will allow large feedback resistance while keeping the resistance to the ground see by inverting input low as shown in the dotted network. So, if I have R t plus 2 R s R t plus 2 R s R t and R t and here will be by R s this configuration will help to compensate the effect of the offset current. So, by t 2 pi, by t 2 pi what we have R f is nothing, but R f is equal to nothing, but R t square right R t square plus 2 times R t R s divided by R s.

So, so design a t network first let us speak R t less than less than R f by 2 ok. So, first what we should do, we should pick a value of R t which is extremely less compared to R f by 2 then I calculate R s. So, R s would be nothing, but R t square R t square divided by R f minus 2 R t right.

Now, if there is there is a value then I can have value of R s and I can make value of R t. So, 2 things we have to know from this equations right, that we can design we can design a circuit that can be used as a good compensation circuit for the effect of to remove the effect of the offset current and how we can choose the value of R t and how we can choose the value of R s.

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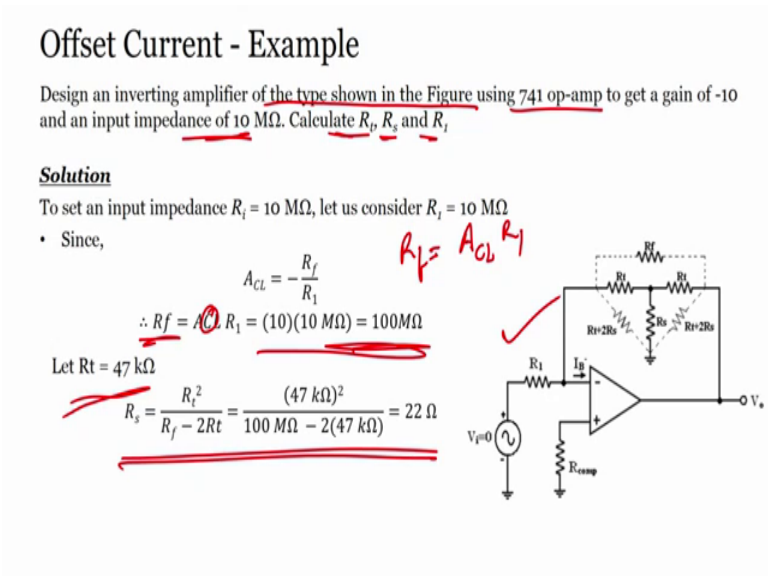

Now, let us take an example, let us take an example design an inverting amplifier of the type shown in figure using 741 to get a gain of minus 10 and input impedance of 10 mega ohms right also calculate R t R s and R 1 this are the this are this is the problem. So, let us find the solution since what we said gain is nothing, but minus R f by R 1 we have R f is equal to gain into R 1 this is c 1 should be subscript. So, we can say R f is nothing, but R f is nothing, but gain into R 1.

So, we have R f value 100 mega ohms now, let R t be 47 mega ohms right because we know that R 2 is nothing, but if we see less last slide R t is less than R f by 2 right. So, R f by 2 is 50 mega ohms we have less than 50 mega ohm let us very less than 50 mega ohms. Let us say R t equals to 47 kilo for that or R s value would be nothing, but 22 ohms R s should be nothing, but 22 ohms right.

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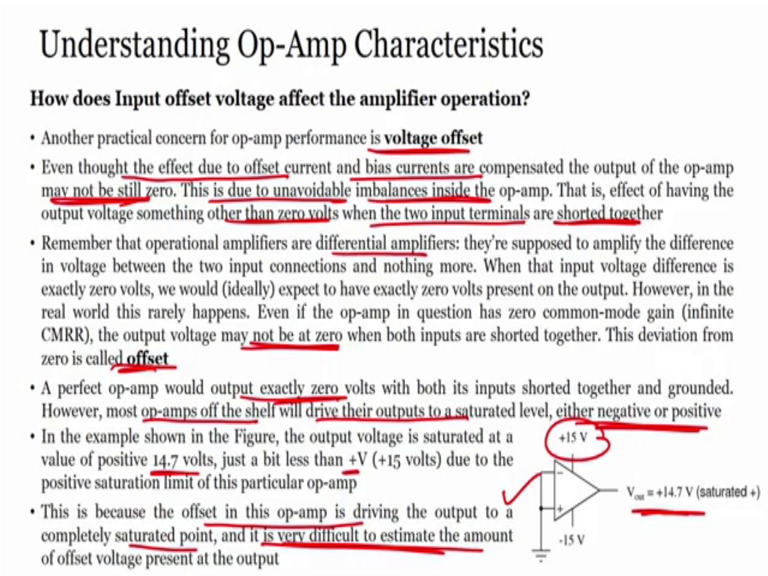

Now, let us see another point another point that is we have to understand the effect of input offset voltage on the amplifier operation, we will see now effect of input offset voltage on the amplifier operation. So, what is the input offset voltage, we already know right another practical concern Op Amp is voltage offset even though the effect due to the offset current and bias current are compensated.

The output of the Op Amp may not be still 0, this is due to unavoidable imbalances inside the Op Amp. There is the effect of having the output voltage something other than 0 volts when 2 input terminals are shorted together right.

So, we have seen what is a input offset voltage earlier also let us see remember that Op Amp are differential amplifier as supposed to amplify the difference in voltage between the 2 input connections and nothing more when the output input voltage difference is exactly 0 volts we would ideally except output to be 0 right.

However, in the real world this really happens even in the Op Amp in equation has 0 common mode gain the output voltage may not be 0 this deviation is nothing, but your offset, this deviation is your offset a perfect Op Amp would output exactly have 0 volts where both inputs are sorted right like here both inputs are sorted and output should be 0 volts right.

But most op amps of the self will drive their outputs to a saturated level either negative or positive right for example, in the given figure what we see the output voltage saturated at value 14.7 volts just a bit less than plus 15 volts.

So, the reason is this is because the offset in this Op Amp is driving the output to a completely saturated point it is very difficult to estimate the amount of offset present at the output right.

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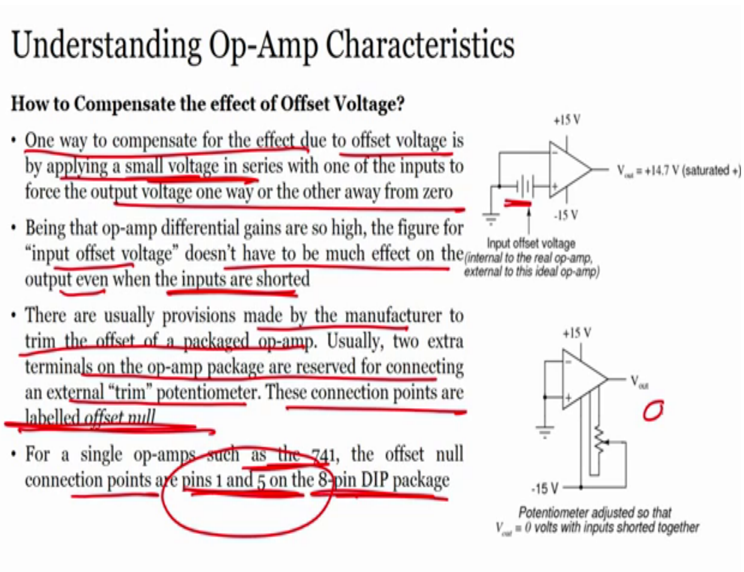

Now, how to compensate then this effect of offset voltage very important point, very important ok. So, these are all the important points that we are discussing because it is very important that we compensate the effect of offset voltage, we compensate the effect of input bias current, we compensate the effect of input offset current.

So, that when everything when the terminals are grounded our output should be 0, that is how we have offset we have our offset should be perfect such that our output voltage should be 0 it should be null right. So, so, understanding this parameters and understanding this characteristic would help us to design the amplifier accordingly right.

Now, if you go back to the slide what we see that how we can compensate the effect of offset voltage, to do that other way one way to compensate this for the effect due to the offset voltage is by applying small voltage in series by applying small voltages in series with one of the inputs to force the output voltage to become 0 right. This is one way of offset in the voltage be being that Op Amp differential gains are high the figure for input offset voltage does not have to be much affect on the output even though inputs are shorted right.

Since the differential gain is very high the effect of the input offset voltage is not really going to affect our output they are usually provisions made by manufacturer to trim the offset of the packaged Op Amp, how usually 2 extra terminals on the Op Amp package are reserved for connecting an external trim potentiometer these connection points are labeled as offset null. So, if you have seen the I c the terminal 1 and 5 are used for offset null right because single Op Amp such as 741 the effect of null connection points 1 and 5 right on the 8 pin d I p package are used for offset null.

So, we connect a potentiometer between 1 and 5 and we trim the voltage right trim the potentiometer such that our output voltage would be 0.

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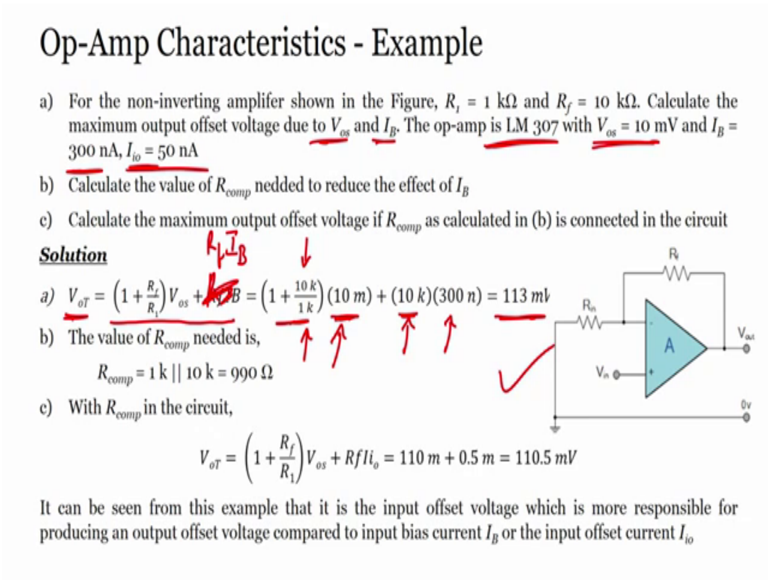

So, let us see an example. So, Op Amp characteristic we are looking at as an example first is for the non inverting amplifier shown in figure this one, R 1 is one kilo ohm R f equals to ten kilo ohm calculate the maximum output offset voltage due to V o s in I B. The Op Amp is l m seven l m 307 where V o s is ten millivolts and I B 300 nano ampere I I o V is 50 nano ampere right. So, the first thing is we have to calculate the maximum offset voltage.

The maximum offset voltage V o t is nothing but 1 plus R f by R 1 into R f into I B right this is R f into I B ok. So, if I substitute the value 1 plus 10 by 1 into 10 milli ampere right, 10 as see this is this is 10 right. So, it is a 10 millivolts plus 10 kilo ohms right because R f this is V o s right V o s here this is R f this is R 1 and here we have again R f and then we have I B what is I B I B is nothing, but 300 nano amperes. So, what will be my answer, my answer would be 113 millivolts very easy you just substitute the values of substitute the values of R f I B R f and R 1 to obtain the value of V o t let us see the second problem, second problem is calculate the R comp needed to reduce the effect of I b.

So, the value of R comp needed is R compensation is 1 k parallel to 10 k we are known right if I have to R compensation resistor R 3 would be R in parallel to R f. So, 1 k parallel to R f is nothing, but 990 ohms third thing with R compensation in circuit what we have V o t. So, calculate the maximum output offset voltage if R compensation is calculated in B right is connected in the circuit. So, assume that R compensation is connected in the circuit now we calculate the V o t. So, in this case we have one plus R f by R 1 V o s plus R f I into I o. So, we will have 1 plus R f by R 1 into V o s right which is this value plus R f into I I o which is this value.

So, our output voltage V o t would be 110.5 millivolts (Refer Time: 14:24) you can be seen from this example that it is the input offset voltage which is more responsible right. Input offset voltage which is more responsible for producing an offset voltage compared to input bias current I B right. So, you can see that what is the more responsible for the output for producing the output offset voltage; input bias current is what? What is input bias current and what is input offset voltage and what is output offset voltage the the from this example what we have seen.

We have seen that that it is the input offset voltage which is more responsible for producing the output offset voltage rather than the input bias current right. So, when you see a problem you understand that; what is the role of this problem and how you can what are the parameters that are responsible for the resulting for the final result that we are designing for right. In this case what we are desired thing is the output should be at 0 when we are grounding both the input terminal, that is only one thing that we want to understand right.

Now, we will see if you more characteristic of Op Amp in the next module until here what we have seen is what is the role of the input offset voltage how we can compensate input offset voltage and how we can compensate the input offset current. In the next module which is the last module of this particular lecture, we will see further few further characteristics of Op Amp there are already mentioned in the data sheet all right.

Till then you take care I will see you in the next module bye.