Hello students.

Today, we will be discussing about the characteristics of an ideal and practical operational amplifier with regards to IC741-Part 2.

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The outline will be OPAMP characteristics (ideal and practical).

At the end of this particular module, the students will be able to, define various characteristics of operational amplifier and select an operational amplifier for a particular application.

We have already seen some of the characteristics like input resistance, output resistance, large signal voltage gain. Today, we will be going through some more OPAMP characteristics. One among them is output offset voltage. It is denoted as Voo and defined as the voltage that is measured at the output terminals of an OPAMP when both the input terminals are grounded. If you look at this particular figure, the inverting pin as well as non-inverting pin is grounded. That means V_1 and V_2, both the voltages are zero. Ideally, I should get zero output at this output terminal pin number 6 of IC741. But practically we do get some voltage here, and that voltage is called as offset voltage that is output offset voltage. The ideal value of this should be zero volts. But, practically for IC741, this value is 6 millivolts. The offset voltage, output offset voltage can be either a positive value or a negative value, and this output offset voltage is caused by mismatching between the two input terminals of the differential amplifier. At the input stage of OPAMP, we use a differential amplifier wherein, the two transistors are used and it has two input terminals. Though, this particular differential amplifier is manufactured using IC technology and since both the transistors are manufactured at the same time or in the same process. Actually, it is expected that the two transistors should match perfectly. But practically it doesn't happen. Practically, there will be some mismatch, and this mismatch basically generates the output offset voltage. For minimizing the effect of output offset voltage, in some cases, voltage compensation networks will be used wherever necessary.

The next characteristic is input offset voltage. Denoted as Vio, and it is the voltage that must be applied between the two input terminals of an OPAMP to null the output. Meaning, when you ground these two input terminals, you get some output offset voltage. To minimize or to nullify this output offset voltage, whatever voltage which we need to apply at the input terminals, either inverting or non-inverting, is called as input offset voltage. The ideal value of this input offset voltage should be zero, because, we expect that output offset voltage should be also zero. But practically, we do get a typical voltage of 6 millivolts maximum for IC741C or it is very low voltage that is around 150 microvolts for IC741C precision type of OPAMP. The input offset voltage also can be positive or negative depending on the magnitude of the output offset voltage. Smaller the value of input offset voltage, better is the matching between the two input terminals.

The next characteristic is input offset current, denoted as Iio. And is defined as the algebraic difference between the currents into the inverting and non-inverting terminals. So, when you ground these two terminals, you still get some currents. That is I_{B1} is the current flowing through inverting pin, I_{B2} is current flowing through non-inverting pin. So, the algebraic difference between these two, that is I_{B1} - I_{B2}, is called as input offset current. Now, when we ground these two terminals, it is expected that these two currents should be zero, but practically we do get some value. So, ideal value of input offset current will be zero nano amperes, whereas practically for IC741C the value is around 200 nano amperes maximum. But, in case of precision type of OPAMP IC741C, the current is as low as 6 nano amperes. Input offset current is the indicator of mismatching at the input stage, and this input offset current can be minimized by the use of FET OPAMPs. Generally, for the ordinary OPAMPs, we use the bipolar junction transistors at the input stage of differential amplifier. But in place of that, if we use FETs, since the FETs have very high input resistance, the input currents will be very low, because of which the input offset current can be as low as 0.3 nano amperes for μA740C type of FET OPAMPs.

The next OPAMP characteristic is input bias current. Also denoted as I_B, and it is nothing but the average of the currents that flow into the inverting and non-inverting terminals. So, if I_{B1} and I_{B2} are the current flowing through inverting and non-inverting terminals, then the bias current will be simply $(I_{B1}+I_{B2})/2$. The ideal value of this bias current input bias current is zero nano amperes, whereas, the practical value is 500 nano amperes for IC741C. Whereas, for precision type of OPAMP IC 741C, the current is as low as plus or minus 7 nano amperes. Remember that the input bias current is always higher than the input offset current.

The next OPAMP characteristic is Supply Voltage Rejection Ratio, also denoted as SVRR, and it is the ratio of change in offset voltage to change in supply voltage. So, SVRR = $\Delta V_{io}/ \Delta V$. Now, this supply voltage that is +Vcc and -Vss can change due to poor filtering or maybe because of the poor regulation. In such a case, the output offset voltage will also vary and that's why you get $\Delta V_{io}/ \Delta V$ as the SVRR. The ideal value of this SVRR is Infinity, whereas for practical OPAMPs the typical value is 150 micro volts per Volt and it is maximum value for μA 741. In some of the data sheets you will find the same SVRR or supply voltage rejection ratio, also denoted as power supply rejection ratio called as PSRR or in some cases you will find it as input offset voltage sensitivity or power supply sensitivity. All these terms are one and the same. This SVRR is also measured in decibels.

The next OPAMP characteristic is common mode rejection ratio, denoted as CMRR, and defined as the ratio of differential gain to common mode gain. So, if you see here, CMRR $=A_D/A_{cm}$, where A_D here is the differential gain and Acm is called as the common mode gain. Differential gain means you apply the two input voltages V_1 and V_2. And the ratio of output to this differential input voltage is differential gain. Whereas, in case of common mode gain we short the two terminals V_1 and V_2 that is inverting and non-inverting pins and we apply common input to this. So, that will be Vcm and the output which you get because of that is Vocm. Ratio of this output to input is called as common mode gain. The ideal value of CMRR is infinite, whereas practically the value is around 90 decibels for μA741C. Higher the value of CMRR, better is the matching between the two input terminals, thereby reducing the noise.

The next OPAMP characteristic is slew rate, denoted as SR and defined as the maximum rate of change of output voltage per unit time. Slew rate basically indicates how rapidly the output of an OPAMP can change with respect to changes in the input frequency. Basically, this slew rate comes in picture because of the capacitive effects, cumulative capacitive effects which are generated within this OPAMP. And slew rate is defined as dVo/dt, maximum and units are volts per micro seconds. The ideal value of slew rate is infinite, whereas, the practical value is 0.5 volts per microseconds for

IC741C. Whereas, the value is increased to around 70 volts per microsecond for special type of IC LM 318. Remember that slew rate is specified at unity gain.

To summarize, if you see here, in this particular column, you will find all the OPAMP parameters which we have discussed. Their ideal values are given in the next column, and the practical value for IC741 is mentioned in this column.

This is the reference.

Thank you.