Integrated Circuits, MOSFETs, OP-Amps and their Applications
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Lecture – 36
Analysis of Data Sheets of an Op-Amp Contd.

Welcome to this module in the last module what we have seen is the effect of the input offset voltage right. So, an earlier input offset current and before that we have seen input bias current, in this class we will see what are the few more characteristics of operational amplifier such as thermal drift.

So, what exactly is a thermal drift? So, let us see the slide.

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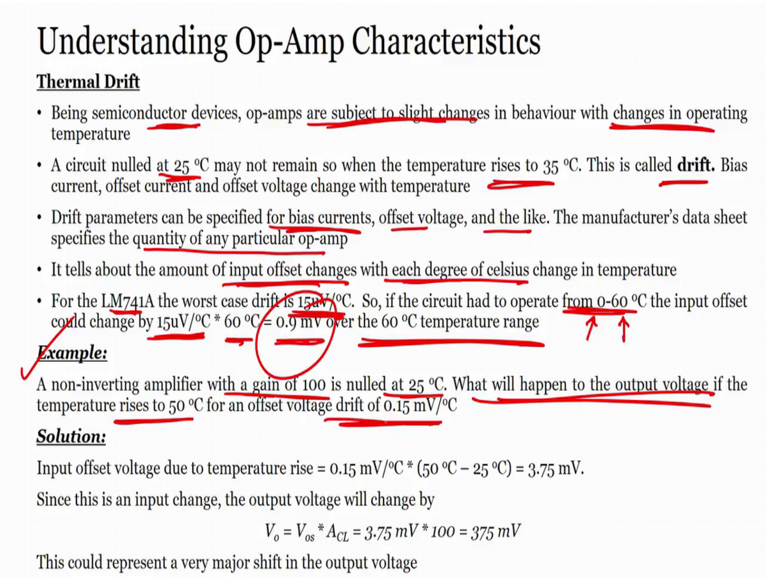

Thermal drift being a semiconductor devices Op Amps are subject to slight changes in behavior which changes in the operating temperature that we know right because Op Amps are made up out of semiconductor devices. So, as Op Amps are considered as semiconductor devices because we are using semiconductor material to design the Op Amp.

And when you are using semiconductor material it has air it will change, it will slightly change its behavior with change in the operating temperature. So, our circuit under 25 degree may not remain. So, when the temperature rises to 35 degree this is called the drift, this is called the drift, bias current offset current offset voltage change with temperature all right. So, we had understand that a different temperature if you have nulled for 1 temperature it may not be nulled for another temperature ok.

The drift parameters can be specified for the bias current offset voltage and the like the manufacturers datasheet specifies the quantity of any particular Op Amp. It tells about the amount of input offset changes with each degree of centigrade change in the temperature right. Now, for lm 741 the worst case drift is 15 micro volts per degree centigrade this is a worst case drift.

So, if the circuit has to be operated from 0 to 16 degree the input could change by 15 micro volts per degree centigrade in to 60 degree which is 0.9 volts over 16 degree temperature range; that means, from 0 to 60 there is a change of 0.9 millivolts right. So, it is very important to understand the thermal drift that what temperature you are nullifying your output voltage.

Now, let us see an example our non inverting amplifier with a gain of 100 is nulled at 25 degree, what will happen what will happen to the output voltage if the temperature rises to 50 degree for an offset drift off 0.15 millivolts per degree centigrade. This is a given problem right this is a given problem what is the problem that if for non inverting amplifier is there and it is a it has a gain of 100 and it is nulled at 25 degree centigrade.

So, our output voltage is 0 right everything is taken care of, but what happens through the output voltage if the temperature rises to 50 degree almost double to this right. Double to 50 for an offset voltage drift of drift of 0.15 milli volts per degree centigrade right. Let us see input voltage due to temperature rises 0.15 by degree centigrade into 50 minus 50 which is 50 which is equals to 3.75 millivolts.

Since this is an input change the output voltage will change by Vo equals to Vos in to gain this is nothing, but V os is 3.75 into open loop gain or closed loop gain cacl is nothing, but 375. So, our output voltage Vo will be equal to 375 millivolts this could be represent a very major shift in the output voltage right, because this is the change in the output voltage is a very major drift.

So; that means, that there is the very significant effect of temperature on the performance of the operational amplifier.

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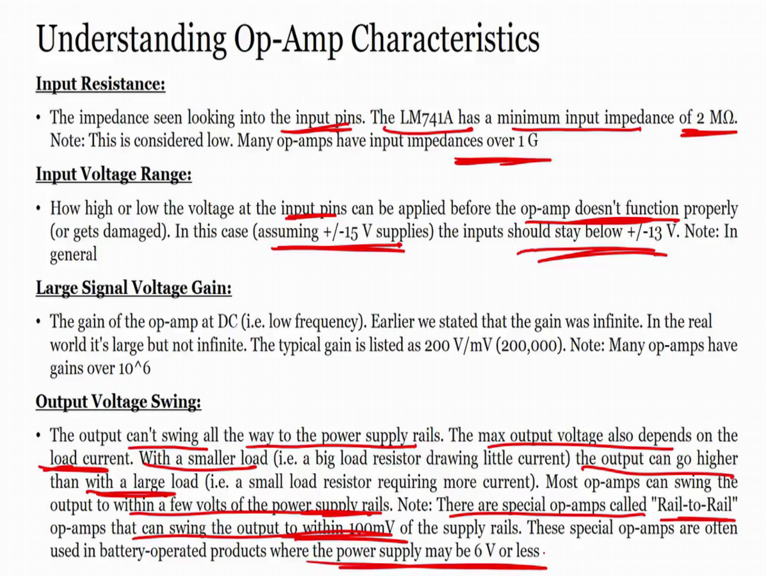

Let us see some more parameters some more characteristics how the characteristics is input impedance in looking into the input pins is input impedance LM 741 has a minimum input impedance of 2 mega ohms know that this is considered low many Op Amps have input impedance over 1 giga ohms ok.

Now, input voltage range high how high or low voltage the input pins can be applied before Op amp does not function properly there is called input offset voltage ranges. Does not function properly means it will get damaged, in this case assuming plus minus 15 volts apply the input should stay below plus minus 13 volts right. This is in general we are talking about in general if I apply plus minus 15 my input voltage range should be around plus minus 13 volts.

Large signal voltage gain the gain of the Op amp at dc right earlier we said and that again was infinite, in real world is it is large, but not infinite. Typical the gain is about 200 volts per milli watts or 200000 right. Now, output voltage swing the output voltage, output voltage swing how we can define, the output kind swing all the way to the power supply rails right, cannot go all the way to plus 5 plus 15 minus 15 or whatever power supply we have given.

The maximum output voltage also depends on the load current right, the smaller load the output can go higher then with a larger load right, most of the Op Amps can swing output to within a few volts to power supply rails. That means, that there are special Op Amps called a rail to rail Op Amps that can swing the output within 100 milli volts, these special Op Amps are offered used in a battery operated products where the power supply may be 6 volts or less got it that is what your output voltage swing.

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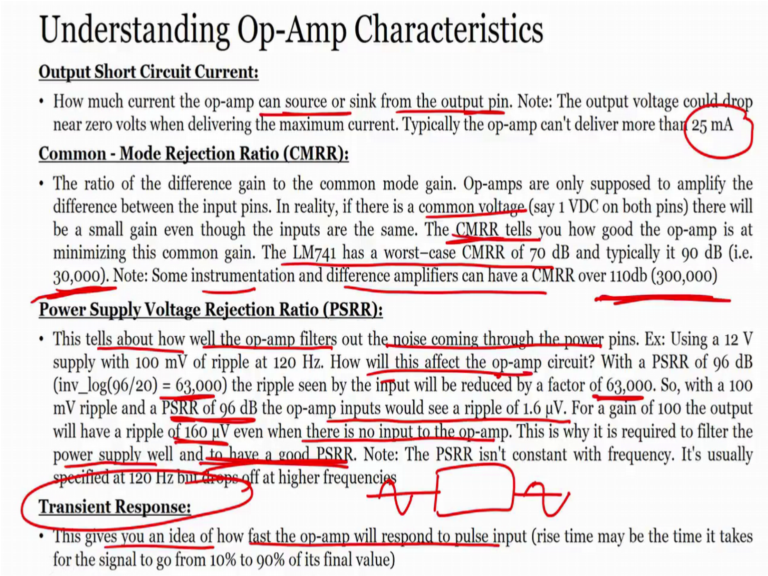

Let us see another parameter which is output short circuit current, what is that how much current the Op amp can source or saying from the output pin, the output voltage could drop near 0 volts when derived delivering the maximum current typically the Op amp cannot deliver more than 50 milli ampere. Then we have seen a favorite common mode rejection ratio, we know that the ratio of the difference gain to the common mode gain ad by a cm is our common mode rejection ratio, Op Amps are only supposed to amplify the difference and of the inputs and not the common mode gain.

But in reality that is a common mode voltage there will be a small gain even though the inputs are same the CMRR tells how good the Op amp is minimizing this common mode gain 741 has a worst case of CMRR of 70 dB and typically it is 90 dB that is 300000; however, some instrumentation and difference amplifier as CMRR over 300000 this is 30000 right this is 30000 for lm 7 4 1.

But in case of in case of some of the amplifiers, some of the instrumentation and difference amplifier this is about 300000 that is really great CMRR high our output will be close to ad in to vd we have seen the problems earlier, when we were looking at

CMRR right we have solved the problems. Now, let us see what is power supply rejection ratio, it is called PSRR.

If you know V in the datasheet there was a power supply rejection ratio the power supply voltage rejection ratio is nothing, but it will tell how about how well the Op amp filters out the noise coming to the power pins right, there is a noise generated in the power pins also. So, for example, a 12 volt supply with 100 milli volt of ripple at 120 hertz. How this effect of the Op amp circuit? How this will affect on the Op amp circuit, we had PSRR of 90 6 dB we will have was 63000.

So, the ripple seen by the input will be reduced by factor of 63000. So, with the 100 milli volts ripple and a PSRR of 96 dB the Op amp input would see a ripple of 1.6 micro volts right. Therefore, a gain of 100 the output will have ripple of 160 micro volts even when there is no input to the Op amp, this is why it is required to filter power supply well and to have a good PSRR you understand.

So, some in most of the circuit you will say that you have to use power supply which is having a very good power supply voltage detection ratio. So, that the noise coming to a power supply is taken care of right and now it is generally usually it is usually specified at 120 hertz, but it drops at the higher frequency this is about the power supply voltage rejection ratio. What is transient response? Transient response is nothing, but this gives you an idea of how fast the Op amp will response to the pulse input.

Right there is it transient; that means, that rise time might be the time it takes from signal to go from ten percent to 90 percent. How fast when I when I g, let us say these Op amp if I apply the input right, at the time of the input that I apply how fast may I see the change in the output right is the lag of 10 seconds lag of 1 second lag of few milliseconds that is your transient response that is a transient response right.

So, with this I should be continuous able to see the change in the output voltage if the transient response is faster.

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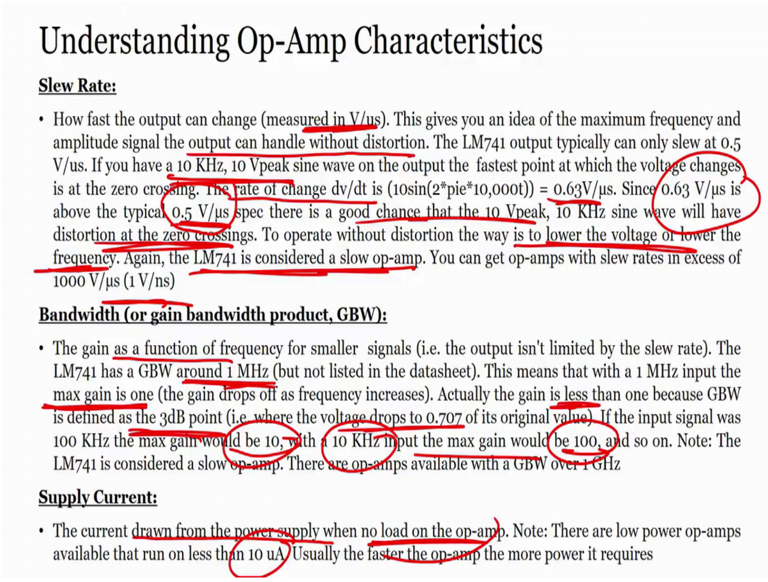

So, let us see few more things one is called slew rate, what is it the slew rate is how fast the Op amp can change and it is measure in volts per micro seconds right this will give you an idea of maximum frequency and amplitude signal the output can handle without distortion right. In case of 741 LM741 the typically slew rate is between about 0.5 volts per microsecond right.

So, if you have a 10 kilo hertz 10 will volt peak to peak sine wave right diff on the output the fastest point at which the voltage changes it as the 0 crossing, the rate of change dV by dt is nothing, but 0.63 volts per micro seconds. So, since 0.63 volts per microsecond is about the wall typical value of 0.5 volts specification right in the datasheet there is a good chance that 10 volts peak to peak sine wave will have a distortion at 0 crossings.

To operate the without distortion the way is to lower the voltage or lower the frequency you got it. So, if my output is 0.63 volts per microsecond, but my specification says that my slew rate should be 0.5 microsecond volts per microsecond, then there is a possibility that the output there will be distortion at the crossing of the 0 crossing and to operate the Op amp without any distortion what we require is to lower the voltage and lower the frequency.

Again LM741 is considered as low Op amp you can get an Op amp with a slew rate excess of 1 volts per nanosecond all right. Let us see the next one bandwidth or gain bandwidth product, very important characteristics of an Op amp the gain as a function of frequency for smaller signals right that is output is unlimited by slew rate the Lm741 has a gain bandwidth product of 1 megahertz ok.

This means that with a one mega hertz input maximum gain is 1, but actually this gain is less than 1 because gain by product is defined as three dB decibel 0.3 dB point right we have already seen what is 3 dB or what that is where the voltage drops about 0.707 of its original value right. We have seen that if in, if the input signal was 100 kilo watts the maximum gain would be 10, but it is 10 kilo hertz the input maximum gain would be 10 right.

So, this is about your band width or band gain bandwidth product supply current the current drawn from the power supply when no load of the, when no load on the Op amp is call your. So, there is a current that is drawn when there is no load to the Op amp. So, the this is your supply current, there are lower Op Amps available that run on less than 10 micro ampere usually the faster Op amp runs on more power, it is obvious it is obvious.

So, when you see these are the, see these are the some of the parameter that we are looking at in the datasheet. So, if we quickly go back and see that what exactly where the parameters in datasheet then it will be, that we will see that the data sheets that we were looking at whether now looking at these parameters understanding the characteristics, whether it makes sense to go back and see whether we are understanding the parameters or characteristics given in the data sheet.

Let us quickly see once again what are the day, what is what are the parameters or the characteristics given in the data sheet of LM741 and we will end up end of this particular module all right. So, let us see the slide once again, here what you see is here, what you see is.

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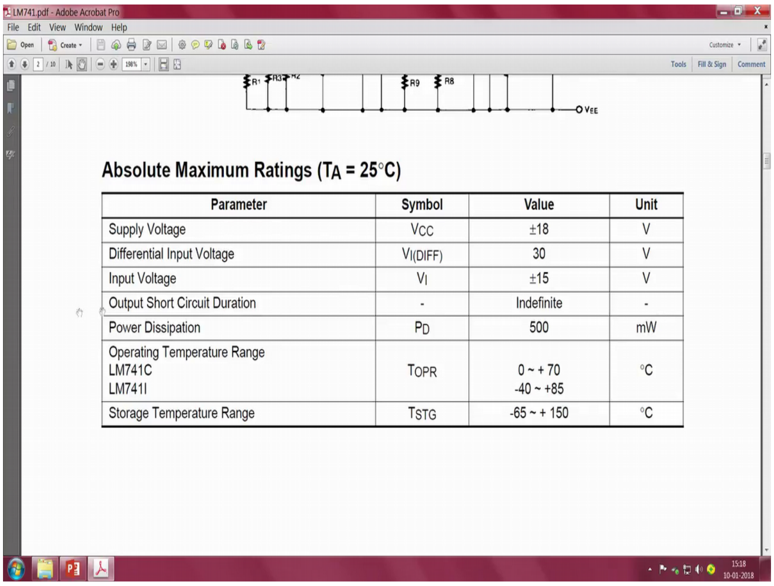

If you go to the characteristics supply voltage we have seen this output. So, have a duration we have seen power dissipation temperature range ok.

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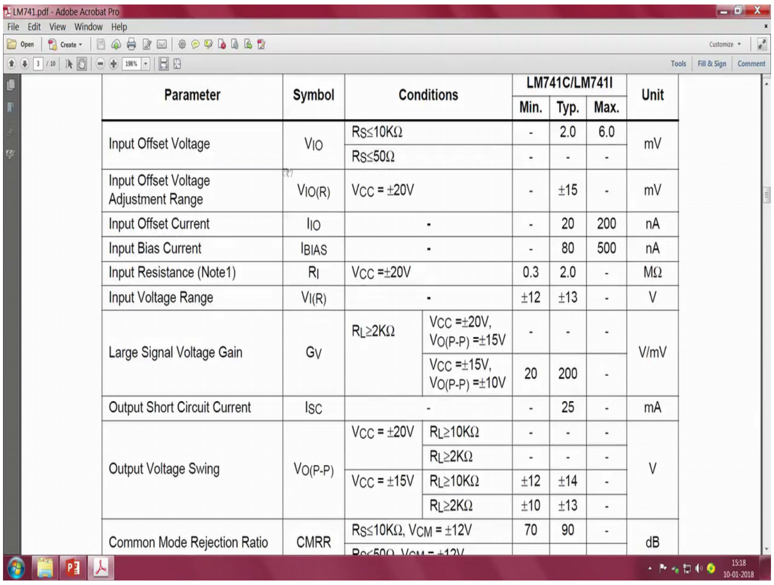

Parameter	Symbol	Conditions		LM741C/LM741I Min.	Typ.	Max.	Unit
Input Offset Voltage	V_{IO}	$R_S \le 10K\Omega$		-	2.0	6.0	mV
		$R_S \le 50\Omega$		-	-	-	
Input Offset Voltage Adjustment Range	$V_{IO(R)}$	$V_{CC} = \pm 20V$		-	±15	-	mV
Input Offset Current	I_{IO}	-		-	20	200	nA
Input Bias Current	I_{BIAS}	-		-	80	500	nA
Input Resistance (Note1)	R_I	$V_{CC} = \pm 20V$		0.3	2.0	-	MΩ
Input Voltage Range	$V_{I(R)}$	-		±12	±13	-	V
Large Signal Voltage Gain	G_V	$R_L \ge 2K\Omega$	$V_{CC} = \pm 20V$, $V_{O(P-P)} = \pm 15V$	-	-	-	V/mV
			$V_{CC} = \pm 15V$, $V_{O(P-P)} = \pm 10V$	20	200	-	
Output Short Circuit Current	I_{SC}	-		-	25	-	mA
Output Voltage Swing	$V_{O(P-P)}$	$V_{CC} = \pm 20V$	$R_L \ge 10K\Omega$	-	-	-	V
			$R_L \ge 2K\Omega$	-	-	-	
		$V_{CC} = \pm 15V$	$R_L \ge 10K\Omega$	±12	±14	-	
			$R_L \ge 2K\Omega$	±10	±13	-	
Common Mode Rejection Ratio	CMRR	$R_S \le 10K\Omega$, $V_{CM} = \pm 12V$		70	90	-	dB

Now, if you see here input offset voltage that we know right, how we can how we can compensate the effect of input offset voltage. We can compensate the effect of offset current, may compensate the effect of bias current, what is input resistance? What is the input voltage range? What is output short circuit current? What is voltage swing? What is common mode rejection ratio? What is power supply rejection ratio right, what is slew rate, what is bandwidth?

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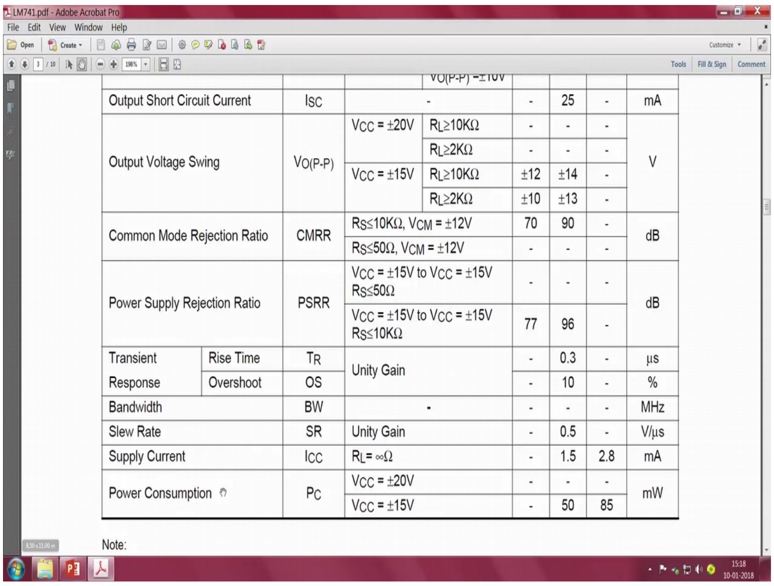

Parameter		Symbol	Conditions		Min.	Typ.	Max.	Unit
Output Short Circuit Current		I_{SC}	-		-	25	-	mA
Output Voltage Swing		$V_{O(P-P)}$	$V_{CC} = \pm 20V$	$R_L \ge 10K\Omega$	-	-	-	V
				$R_L \ge 2K\Omega$	-	-	-	
			$V_{CC} = \pm 15V$	$R_L \ge 10K\Omega$	±12	±14	-	
				$R_L \ge 2K\Omega$	±10	±13	-	
Common Mode Rejection Ratio		CMRR	$R_S \le 10K\Omega$, $V_{CM} = \pm 12V$		70	90	-	dB
			$R_S \le 50\Omega$, $V_{CM} = \pm 12V$		-	-	-	
Power Supply Rejection Ratio		PSRR	$V_{CC} = \pm 15V$ to $V_{CC} = \pm 15V$ $R_S \le 50\Omega$		-	-	-	dB
			$V_{CC} = \pm 15V$ to $V_{CC} = \pm 15V$ $R_S \le 10K\Omega$		77	96	-	
Transient Response	Rise Time	TR	Unity Gain		-	0.3	-	μs
	Overshoot	OS			-	10	-	%
Bandwidth		BW	-		-	-	-	MHz
Slew Rate		SR	Unity Gain		-	0.5	-	V/μs
Supply Current		I_{CC}	$R_L = \infty\Omega$		-	1.5	2.8	mA
Power Consumption		P_C	$V_{CC} = \pm 20V$		-	-	-	mW
			$V_{CC} = \pm 15V$		-	50	85	

Note:

What is the power consumption? What is the supply current? Now, we can see everything we have seen in the in the slides right, we have seen everything in the slides. Same way input offset voltage, voltage drift right CMRR because in CMRR ps in power supply rejection ratio output source of coverage circuit current.

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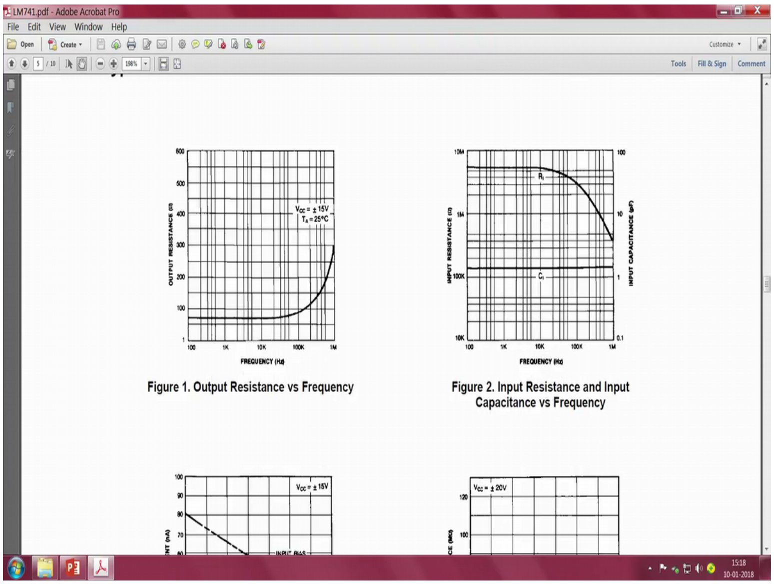

Now, with for a given data sheet for a given datasheet you guys would be able to understand how the things, how the things work right. That was the idea that at least at least some of the parameters on the datasheet, when you open the datasheet you will be able to know.

At the same time what are the ordering information for that particular ic is also given in the data sheet. So, what we have seen until now, we have we have seen how the datasheet when we open the datasheet what are the parameters of characteristics given in the data sheet and can we understand how to use these characteristics for our for compensating our output right, for getting our output to be 0 or to make the output null right.

So, we have to understand how we can deal with input bias current, input offset voltage, input offset current right. We have to understand how we can nullify the output voltage when both the terminals are the input are ground, we have to understand how the change in the output voltage would happen even the offset is nulled at particular temperature if I change the temperature right.

We had to understand how the plots or how the frequency will affect the overall performance right. So, there are a lot of things to understand, lot of things to learn and we have taken few things from that lot to understand this particular amplifier called operational amplifier right. So, I hope that if you go through the entire series of lectures for this particular course, for this particular theory class then you will know how the how the things works particularly in the area of operational amplifiers.

How you will know how the things works when you are given an indicator circuit and if you are asked that what are the process flow or how you can fabricate a indicator circuit or an indicator circuit or a device you will be able to at least tell that, now we know how the process flow works. We know what how we can grow silicon dioxide, we know how we can deposit a metal, we know how we can do lithography, we know how a MODFET is fabricated, we can fabricate n channel, we can fabricate a p channel, we know the depletion MOSFET.

We know and n MOSFET we knows the application of MOSFETs right, it is drain characteristics we know the transfer characteristics, we know the current mirror, we know how CMOS works at least as a not gate right. So, lot of things if you really think we have tried to cover in this short duration of 30 hours apart from this theory like I said we will also do few experiments. So, that you get the idea of how to use the circuit and how to perform experiments.

So, that we also understand that how the theory is there, we do some simulations and we will do some experiments on the breadboard all right. With that I will see you in the next class till then you take care, bye.