

Integrated Circuits, MOSFETs, OP-Amps and their Applications
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Lecture - 50
Experiment: To study op-amp based comparator

Welcome to this module in this module we will see the other applications of operational amplifier. Until now what we have seen we have seen the characterization of op-amp, like some characteristics of op-amp and then we have seen a few functions of the op-amp right a function of an op-amp like summing amplifier, a function of an op-amp like differential amplifier, a function of an op-amp yeah that we saw yesterday or in the previous module which was the instrumentation amplifier correct.

So, see it is good to understand different applications of op-amp right it can be integrator, it can be differentiator, it can be filter, and as and when I told you that I will start from the basic and slowly may show you the complex circuits so that is very important part and we will see how we can make the complex circuits.

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Integrated Circuits, MOSFETs, Op-Amps and their Applications
Experiments on Understanding
Basic Op-Amp Circuits: Comparators, Differentiator, Integrator, Filters

Instructor: Hardik J. Pandya

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So, let us see on the screen let us see on the screen the integrated circuits MOSFET's op-amps and their applications that is the title of our course right and today's experiment in today's module we will see several application of the operational amplifier which are comparators, differentiator, integrator, and filters.

So, we will discuss each of those examples in detail and I have already taught you this thing in the theory classes and we will see today how can we actually implement the op-amps as comparator and then we will follow for differentiator indicators and filters.

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Op-Amp Based Comparators

- A comparator is a device that compares two input voltages and provides a digital output either high or low level signal based on the input signal
- It is a simple 1-bit analog to digital converter circuit
- It has two analog input terminals and one binary digital output
- A comparator is operated in an open loop configuration thus acts as a specialized high-gain differential amplifier
- They are commonly used in devices that measure and digitize analog signals, such as analog-to-digital converters (ADCs) and controlling applications
- A typical op-amp as comparator is as shown in the Figure 1.a aside

Figure 1.a
Ref: <http://www.electronics-tutorials.ws/>

So, if we go to the first slide of this module we want to use op-amp based comparators. So, we should first understand and we have already understood in the theory class what is a comparator. Let us refresh a comparator is a device that compares 2 input voltage and provides a digital output either high or low signal based on the input signal so what does that mean it will compare right.

So, it is very easy if I give you 2 signals and if I ask you V signal is high V signal is low you can use the comparator and you can tell which one high and which one is low suppose the signal a is high that is you see we are applying the signal to the comparator, but the way we use comparator is in different way we apply a constant voltage which we called a reference voltage and with respect to this reference voltage.

We apply another voltage and compared to this reference voltage; that means, that suppose this V IN right this is my analog input voltage and this is my reference voltage this reference voltage is constant is constant and this will change whatever input signal is there.

Suppose I have kept reference voltages 3 volts all right. Now, if my input voltage if my input voltage is 2 volts; 2 volts. Then my output would be output would be 0, alright and or we can also say minus V_{CC} 0 or minus V_{CC} go to the negative saturation region.

So, we can say 0 or minus V_{CC} same way if my input voltage the input signal is 3.1 volts then there is difference of 0.1 volt right, 3.1 volts here, 3 volts here. So, there is a difference of 0.1 volt this difference will cause the output to go to the positive saturation or positive plus 5 volts.

So, if I apply plus 5 volts here minus 5 volts here compared to the signal I get the output. Here what we can see now let us see what we have written this is I have a shown in example and it is a 1, it is a simple 1 bit analog to digital converter.

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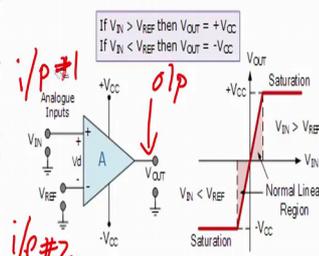


Figure 1.a

Ref: <http://www.electronics-tutorials.ws/>

Now, yesterday I told you right our day before that when we are looking at the modules that what exactly a to d converters are there and what are they d to a converters. So, we have seen that when you apply analog a voltage and you want to get the digital output you are use a to d, a to d converter.

There are several types of a to d converter several types from d to a converters that we will have a we already had a glimpse of those and the detail of those would be covered in a next course which is a higher level than what we are teach what we are learning in this particular course.

So, we will see some advanced version of a to d, d to a and some applications or in terms of projects of operation amplifier at several applications also not op amp, but also certain analog circuits analog electronic modules and we will take few examples whether it is an ECG or whether we had to control a motor or we want to control the LED.

So, we will have several examples in the next course not this course. So, that you understand that in this course you have learned about op-amp, you learn about the indicator circuit, you have learn about the their applications, but what are the advanced versions how now you can actually implement those circuits and form or formulate a project alright.

So, that will be the part of another course, but let us focus on this one which is the op-amp based comparator and once you know that that the comparator is nothing, but the devices are compared to input voltages and provides the output right based on high or low signal based on the input signal; that means, if the input signal is higher than the reference voltage will give you a high, when the input signal is less than reference voltage it will give you low correct.

Now, it has two analog input terminals and 1 binary digital output converter. So, this is the output terminal these are input terminals input 1, this is input 2 right. So, these are two analog input signals or terminals to which we apply analog signal alright and here we get either plus or minus; that means, that it works as a binary.

What is binary? Binary has two; one is when it is high this one when it is low it is 0 binary right only 2 digits 2 digit 1 and 0. So, most of the digital circuits that works on the binary signals and few of the circuit works between 1 and 0 is 1 and 0; the intermediate state between 1 and 0 and that is what we call fuzzy logic we call it is a fuzzy f u z z y right.

So, understand what is fuzzy logic why we are using it whether it is important or not, but right why I am telling you this thing because you should not just assume that there are or when you talk about digital is 1 and 0; there can be many intermediate state between 1 and 0 as well all right, but for here when we talk about digital we are only talking about 2 states that is 1 and 0 we are not considering the fuzzy logic we are not considering that.

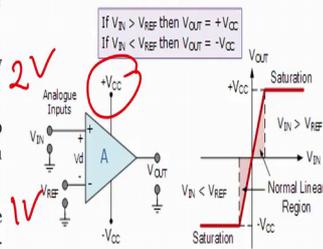
So, let us not consider fuzzy logic here what we consider is just digital output that is 1 which is high 0, which is low or plus V CC and minus V CC alright. So, we have seen 3 things right we have seen three things first is that the op-amp let us see once again men as many times you repeat it is better because you our brain remembers many times when you give the same kind of information right..

If you have taken a course on artificial intelligence you will see number of iterations that you have to give a number of time you have to train your a n n to make it close to what we actually want to get the output. So number of times you train your brain number of times you say the same thing your brain try tries to remember it so that is why we are kind of repeating the same things so that we all remember what exactly comparators are?

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Op-Amp Based Comparators

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2V

1V

2-1=1V

Let us see one by one again a comparator is nothing but 2 inputs voltages providing a digital output either high or low based on input signal first point. Second point it is a 1 bit analog to digital converter third point it has two analog input terminals and 1e digital output terminal these three things we have seen right.

Let us see the forth thing, forth thing is a comparator is operated in an open loop configuration thus act as a specialized high gain differential amplifier. Open loop extremely high gain we all know right closed loop we can change the gain open loop is we cannot change again right it is extremely high.

Now, it will also exit if amplifier because it will take the difference between the 2 input voltages and it gives output, but it is not really amplifying it because there is no feedback here we cannot have any amplification factor right, but at the same time avoids amplifier because it will directly give you plus V_{CC} .

So, minus 1 minus 0.1 volt for example, let us say 2 volt is here, 1 volt is here; 2 minus 1 is 1 volt right at the input, but output directly we see high or low which is not 1, which is not 1 it will be minus V_{CC} plus V_{CC} . So, it is it is extremely high that is why we say kind of differential amplifier even there is no feedback or there is no feedback resistor and there is a because it is open loop op-amp it is the where it has very high gain alright.

Now, what we see next that they are commonly used in devices that measure digitize analog signal such as a to d converters and controlling applications that is the application of the op-amp op-amp based comparator.

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Figure 1.a
Ref: <http://www.electronics-tutorials.us/>

So, once we understood that this is a open loop gain open loop high gain then we see that whatever the difference right our output will be either plus or it will be minus it is digital 1 or 0 similar kind of things. Now, when you do this; that means, that it is trying to convert the analog input into digital output into digital output; that means, it can be used it can be used in a to d converters, it can be used in a to d converters alright.

Finally, a typical op-amp as comparator is shown in figure 1 you see figure 1 a, this one which is your figure now what exactly this figure is let us see.

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Figure 1.a
Ref: <http://www.electronics-tutorials.us/>

You can see here if V_{IN} is greater this you consider this first case when V_{IN} is greater than V_{REF} then V_{OUT} is plus V_{CC} when this voltage is higher than this voltage then your V_{OUT} gets V_{CC} alright. Second case when V_{IN} is less than V_{REF} V_{OUT} goes to minus V_{CC} right.

So, if you see here this particular line this particular line is when V_{IN} is greater than V_{CC} so from here it goes to saturation here it goes to my negative saturation region this one see we in less than reference this V_{IN} greater than reference and this is what is a normal region normal linear region; This is the region this is not like if you draw like this they shade here. Let us let us see clearly this region.

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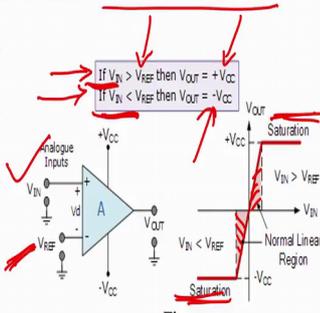


Figure 1.a
Ref: <http://www.electronics-tutorials.us/>

This we call normally linear region alright this region is saturation, this is also saturation alright. So, it is very easy to understand comparator now every one of us knows that when you apply a voltage input signal which is greater than V reference or output will be plus V CC. When our voltage is less than V reference output would be minus V CC alright easy.

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Op-Amp Based Comparators – Example 1

- Consider the Op-Amp as comparator configuration shown below in Figure 1.b. The Bias voltages, $+V_{cc}$ and $-V_{cc}$ are +15 V and -15 V. The input to the non-inverting terminal is 5 V and the inverting terminal is grounded. Find out the value of output voltage

Solution

$V_{REF} = 0$ V (since inverting terminal is grounded as per info given)

$V_{IN} = 5$ V

Since $V_{IN} > V_{REF}$, $V_{OUT} = +V_{cc} = +15$ V

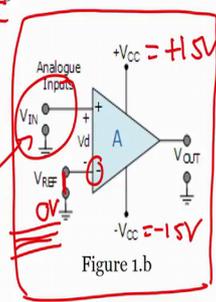


Figure 1.b

$$\begin{aligned} \textcircled{1} & \rightarrow V_{IN} > V_{REF} = +V_{CC} \\ \textcircled{2} & \rightarrow V_{IN} < V_{REF} = -V_{CC} \end{aligned}$$

Now, let us go to the next slide and let us see the example of the op-amp based comparator. So, suppose you are given a circuit which is here. The circuit is given to you

alright and you are asked that consider the op-amp as comparator configuration as shown here you can see the bias voltage is bias voltages plus V_{CC} and minus V_{CC} are plus 15 and minus 15 plus V_{CC} is how much plus 15 minus V_{CC} how much minus 15 right.

The input to the non inverting terminal is 5 volts this input this input is how much this input is 5 volts, and the inverting terminal is grounded you see inverting terminal inverting terminal is grounded. Find out volt value of the output voltage find out the value of the output voltage; that means, that if the inverting terminal this inverting terminal is grounded; that means, $V_{reference}$ is connected to ground; that means, here is 0 0 volts right.

So, now what we have one input signal is 5, another input signal is 0, what is comparator is we have seen two things right V_{IN} greater than V_{REF} second was V_{IN} less than V_{REF} in this case 5 volts minus 0 volt. So, V_{IN} is greater than V_{REF} or V_{IN} is less than V_{REF} which is the current condition you see $V_{reference}$ is 0, V_{IN} is 5.

So, which is the condition this first condition or second condition think easy. So, the answer is first right because 5 volts is greater than 0 volt. So, the answer is this condition and when you have this condition we already know then it is equals to plus V_{CC} right this we know.

When this is first condition the answer is equals to plus V_{CC} , but if it is second condition which is V_{IN} is less than V_{REF} ; then our answer would be minus V_{CC} . For this particular example our answer is our answer is plus 15 volts plus 15 volts because you satisfy the condition which is V_{IN} is greater than $V_{reference}$ and when we have this condition we know that V_{out} is nothing, but plus V_{CC} which is plus 15 volts.

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Op-Amp Based Comparators – Example 1 ✓

- Consider the Op-Amp as comparator configuration shown below in Figure 1.b. The Bias voltages, $+V_{cc}$ and $-V_{cc}$ are $+15\text{ V}$ and -15 V . The input to the non-inverting terminal is 5 V and the inverting terminal is grounded. Find out the value of output voltage

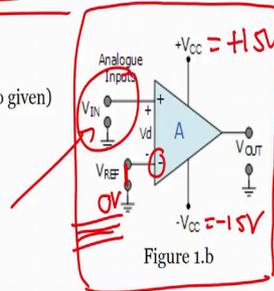
Solution

$V_{REF} = 0\text{ V}$ (since inverting terminal is grounded as per info given)

$V_{IN} = 5\text{ V}$

Since $V_{IN} > V_{REF}$, $V_{OUT} = +V_{cc} = +15\text{ V}$

$$V_{OUT} = +V_{cc}$$



So, it is super easy this is the easiest kind of circuit for you to understand when you talk about op-amp which is comparator extremely simple and extremely useful alright. So, this is our comparator let us see the next slide.

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Op-Amp Based Comparators – Example 2 ✓

- Consider the Op-Amp as comparator configuration shown below in Figure 1.c. The Bias voltages, $+V_{cc}$ and $-V_{cc}$ are $+15\text{ V}$ and 0 V . The input to the non-inverting terminal is 5 V and the inverting terminal is 10 V . Find out the value of output voltage

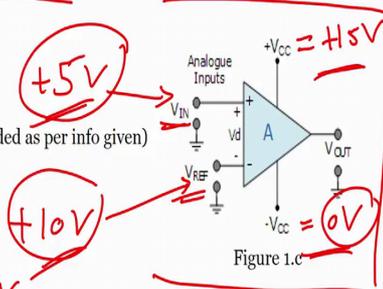
Solution

$V_{REF} = 10\text{ V}$ (since inverting terminal is grounded as per info given)

$V_{IN} = 5\text{ V}$

Since $V_{IN} < V_{REF}$, $V_{OUT} = -V_{cc} = 0\text{ V}$

$$\begin{aligned} V_{IN} > V_{REF} &= +V_{cc} \\ \Rightarrow V_{IN} < V_{REF} &= -V_{cc} \end{aligned}$$



And we have one more example let us see one more example in this case another circuit again when you see another circuit is same here plus V_{CC} how much you are applying plus V_{CC} and minus V_{CC} are plus 15 and 0 volt ok. So, here V_{CC} is given plus 15 volts right minus V_{CC} is given 0 volts correct.

So, let us consider the op-amp is comparator as shown below considered. Now the bias voltage is I plus 15 and 0 done input to the inverting terminal is plus 5 volts this input is plus 5 volts, all right. Let me write ϕ correctly 5 volts alright and the inverting terminal is 10 volts, this one is 10 volts find out value of output voltage there is a question find out the value of output voltage when you are given these conditions plus 15 0 plus 5 plus 10.

In this case let us again see what was the condition V_{IN} greater than V_{REF} plus V_{CC} V_{IN} less than V_{REF} minus V_{CC} right, this is a condition.

So, here what you see you see this is V_{IN} right V_{IN} this is V_{REF} ; V_{REF} V_{IN} is greater than V_{REF} or V is less than V_{REF} then we can understand that the second condition is proper which is V_{IN} is less than V_{REF} right 5 volts is less than 10 volts that is why we have to consider the second condition and our answer should be minus V_{CC} .

So, here what we are we are given minus V_{CC} is 0 volt minus V_{CC} is 0 volt that is why when you considered this particular example right in which your V_{IN} is less than V_{REF} and output will reach to 0 volts. So, your answer is V_{IN} is less than V_{REF} V is minus V_{CC} which is equals to 0 right.

So, you guys understood now what first is we see comparator right we saw the function plus V V_{IN} is greater than V_{REF} is positive saturation, V_{IN} is less than V_{REF} negative saturation right. We have seen example one example was plus 15 minus 15 and we have seen that V_{IN} is greater than V_{REF} then answer was plus 15.

Second example plus 15 min 0 volts plus V_{CC} minus V_{CC} in this case the given input voltage is 4 plus 5 volts and plus 10 volts here we see that V_{IN} is less than V_{REF} and that is why the output voltage would be minus V_{CC} which is equals to 0 volts. Until now we have seen this much of things right. So, it is extremely clear to all of us what exactly the comparator is good.

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The Op-Amp Comparator- Experiment

Aim: To study the working of Op-Amp based Comparator

Part 1

- Connect the circuit as shown in the Figure 2 aside
- Apply V_{IN} through a potentiometer/variable power supply as shown
- Observe the output at V_{out} and note down the value in table
- Also observe how the LED is glowing as the potentiometer value is changed

SL. No.	V_{IN}	V_{REF}	V_{out}
1			$R_1 = R_2$
2			

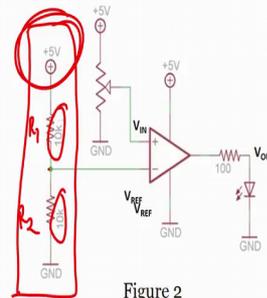


Figure 2

$$\left(\frac{R_2}{R_1 + R_2} \right) V_{IN}$$

Now, if I really want to study the comparator understand it is understand its characteristics or its application I had to perform the experiment right theory is ok, but we have to perform experiment and if you want to perform the experiment how can we perform this experiment alright.

So, you can see the circuit the circuit here is drawn which is figure 2 what easily the circuit is circuit is if you see this one alright just concentrate on this part which is I am drawing in a red kind of rectangle you can see here there is one register R 1, second register R 2, value is 10 K value is 10 K right; and we are taking the voltage across a resistor R 2 across resistor R 2.

So, what is this? The circuit yesterday we have seen or last models we have seen. What does the circuit is circuit is nothing, but you are, but your voltage divider right voltage divider or potential divider right. So, here your formula would be R 2 divided by R 1 plus R 2 into V IN here what is V IN V IN is plus 5 volts V IN is plus 5 volts.

So, your R 2 divided by R 1 plus R 2 if all the values are same R 1 equals to R 2 when you have case when R 1 equals to R 2 right for this case your this formula.

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2			

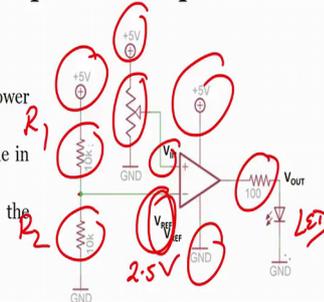


Figure 2

$$\left(\frac{R_2}{R_1 + R_2} \right) V_{IN} \Rightarrow \frac{1}{2} \times 5V = 2.5V$$

Let us write here easy way of understanding alright. So, we have this R 1 we have this R 2 to write R 1 R 2 in this case when R 1 equals to R 2 our formula our formula was formula was R 2 upon R 1 plus R 2 into V IN right this will become in this case R 1 equals to R 2 half V IN half V IN right.

What is our V IN V IN is 5 volts so if I replace V IN by 5 volts what will be my answer my answer would be 2.5 volts answer would be 2.5 volts; that means, that V reference here I am applying how much voltage 2.5 volts alright.

Now, we have a potentiometer we have a pot yes the last modules we have seen what is a potentiometer and how we can change the resistance right. Now, if I apply plus 5 volts across this pot right and if I have if I generate a voltage here then I can change the voltage depending on the change of the register here I am applying plus V CC I am applying ground and I have the output which is your LED which is my LED.

Here is the current limiting resistor to the LED now what I have to see if my V IN. So, lot of circles let us remove it if my V IN right this is 2.5 volts 2.5 volts.

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The Op-Amp Comparator- Experiment ✓

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- Observe the output at V_{out} and note down the value in table
- Also observe how the LED is glowing as the potentiometer value is changed

Sl. No.	V_{IN}	V_{REF}	V_{out}
1			
2			

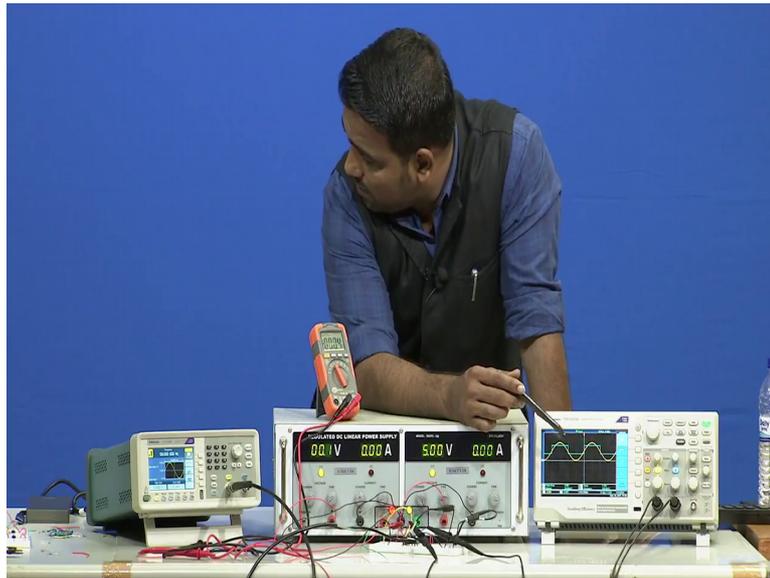
Figure 2

If V_{IN} is greater than V_{REF} (2.5 volts) my output LED will glow alright and if my V_{IN} is less than 2.5 volts then my LED will not glow correct. So, what is written here let us see let me just clear the screen alright 2.5 volts connect the circuit as shown in figure 2 will connect it apply V_{IN} through a potentiometer or variable power supply through here will apply V_{IN} observe V_{OUT} and note down the value in table.

So, we will apply V_{IN} we have a reference voltage will measure the V_{OUT} alright and also observe how the LED is glowing is the potentiometer value is changed. So, we will see if we use LED it will glow if you are not using it then we can only measure the V_{OUT} and this will see that V_{OUT} would be plus 5 volts.

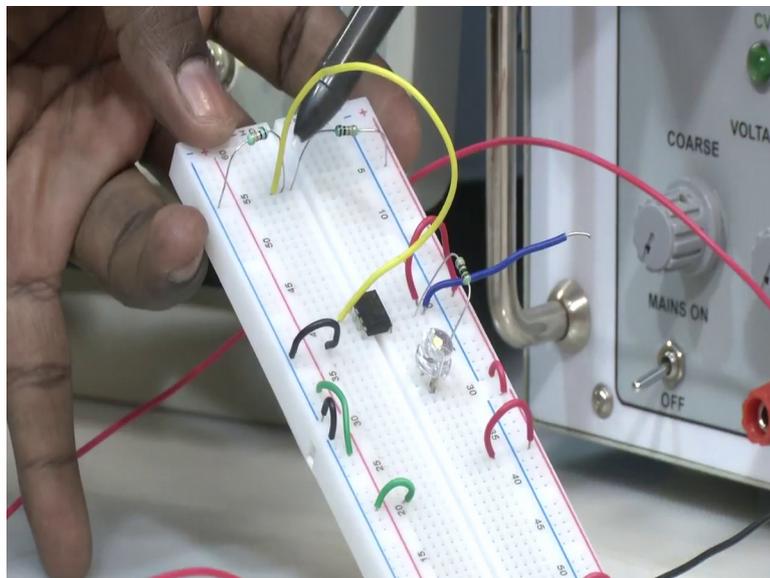
So, what we are assuming right if V_{IN} is greater than 2.5 volts our V_{OUT} could be close to plus 5 volts if V_{IN} is less than 2.5 volts our V_{OUT} would be 0 volt, this is what we are assuming alright. Now, let us do actual experiment and see whether we get this values or not alright. So, let us again welcome Sitharam who will help us to perform this particular experiment of a comparator.

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And we will see how this comparator can be we can use op-amp as a comparator and how this comparator circuit works alright.

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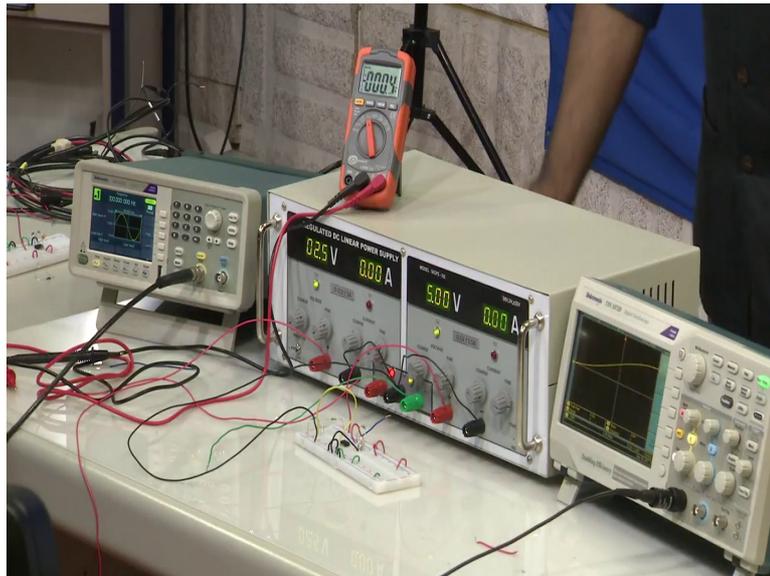
So, you will see here on the breadboard you see here on the breadboard what you can see you can see a LED you can see a LED right and then what you see op-amp and then you have the current limiting resistor to the LED and you are applying V reference through the potentiometer or through the potential divider the 2 resistors we are applying voltage

1 which is V reference to the one terminal which is inverting terminal of the operational amplifier right.

So, understand again output is connected through limiting resistor to the LED input inverting terminal connected through potential divider right to the op-amp inverting input non inverting input will apply using the potentiometer or we by using the power supply.

So, let us here so instead of this potential maintainer converting the power supply you can directly apply through this DC power supply right if you apply 0, 1, 2, 3 you will see at a point when it is greater than 2.5 volts we will be able to see the glow in the LED and we will measure the voltage across the potential divider initially then we will increase the voltage and then we will see what is the output alright. So, let us perform the experiment.

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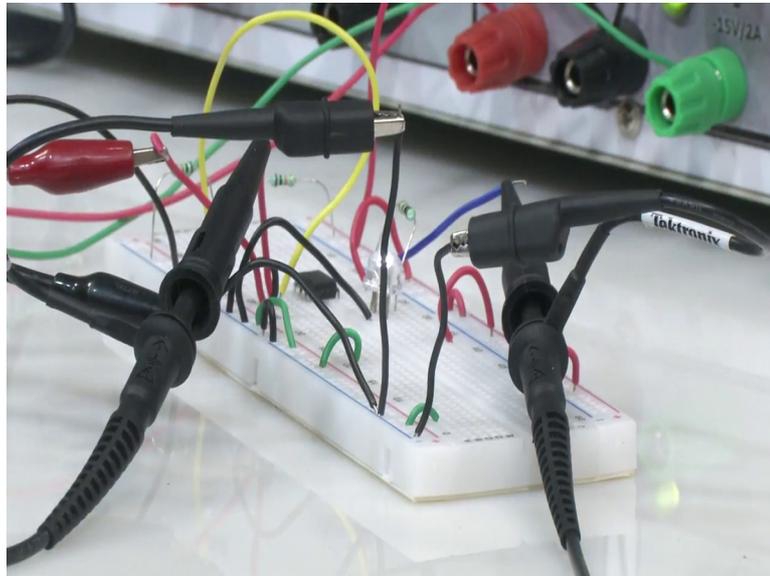


We will apply the op we will apply bias voltage across the operational amplifier. So, you all know what is bias voltage plus 15 minus 15 right. So, for this particular DC power supply we already know the centre terminal 3 terminals in the centre right red black and green through that we can apply plus 15 and minus 15 alright.

Now, you see so here yes in this case I am sorry in this case since our circuit required plus 5 volts and 0 volts so that is why we are applying plus 5 and 0 not plus 15 and minus 15 for this for this particular circuit of comparator. Now, we have connected plus 5

volts to plus V CC as you can see on the DC power supply and ground to the minus V CC alright. Now we will apply voltage to the non inverting terminal of the op-amp alright.

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Now, let us first see what is the what is the voltage across the potential divider. What is the voltage across the potential divider potential divider is this circuit alright it is this circuit.

So, what let us see now we can use the multimeter we can use the multimeter and we can see what is the voltage.

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So, if you see in the multimeters you can see the voltage is about 2.5 volts excellent; that means, that the resistance that resistors that he has selected this time they are extremely close or extremely accurate or having same value with minimum tolerance right that is why we see 2.5, 2.501 so that is good so 2.5 volts we are applying occurs the inverting terminal.

Now, let us apply different voltages through the power supply through the power supply to the non inverting terminal. So, can you please apply now you see he is increasing from 0 slowly 1.7, 1.9 and we see there is no glow in LED right there is no glow; that means, that you are inverting terminal is still high which is obvious because the inverting terminal is 2.5 volts non inverting terminal is 1 volt.

So, still V_{IN} is less than V_{REF} when V_{IN} will be greater than V_{REF} then only we can see the output plus 5 volts. So, plus 1.6, 1.2 2.1, 2.2, 3, 4, 2.5 see 2.6 and suddenly at a certain point you should be able to see the you should be able to see the LED working or if the LED is it is not connected properly is it connected.

Because the second terminal of LED we have not grounded that is why we cannot see otherwise you will be able to see now you can see here again can you reduce the voltage please so that students can understand reduce the voltage you can see the DC power supply he is reducing it reducing it to 2.4 bring it to 2.4 yes.

Now, you focus on this one which is your LED and you cannot see LED glowing right you cannot see LED glowing. Now make it 2.5 so at 2.5 we can now you see it is slightly greater than 2.5 as soon as it increases little bit greater than 2.5 you will immediately starts looking at the LED glowing; that means, that the output is high output is high very easy to understand right.

Now, if you keep on increasing it does not matter because it cannot go more than 5 volts so 3.4, 3.5, 3.6 that is it that is enough. So, you can just see that the LED is on right in this particular case whenever V_{IN} is greater than $V_{reference}$ and what happens when V_{IN} is less than $V_{reference}$.

So, let us slowly decrease the voltage and you focus here on the LED and you will see that at certain point if you compared to keep on decreasing, keep on decreasing, keep on decreasing, keep on decreasing, and it stops what points out 2.4; you see now 2.4 can you make it again 2.5 2.4 to 2.34 and 5 excellent this 2.5 now V_m is that through the $V_{reference}$ also right 2.5 so this is not exactly 2.5 this little bit 2.5 2 something right.

So, if you want to measure this voltage you can see what is the input voltage 2 point you can see here on the multimeter it is 2.525 is 2.525 while your reference voltage can you 2.524 volts is your input voltage.

Now, you see the reference voltage across the potential divider the reference voltage across the potential divider is 2.499 or 2.501; that means, your V_{IN} is greater than 2.5 which is a reference voltage that is why you can see the LED glowing very easy, very easy extremely easy experiment anyone and everyone can do it once you know what is comparator right alright so that is good that we have understood what exactly is a comparator.

Now, all of us can perform this experiment of a comparator you can go tomorrow and start doing a comparator and you can see by you can glow the LED. So, understand this thing until unless you ground the circuit it will not finish it right you cannot keep on hanging it. So, same thing when we are using LED with a current limiting resistor you had to ground the LED right.

So, one is register output register LED ground alright and cathode is ground not a node is run cathode is ground. So, LED box enough forward bias you should know it if you do

not know it I have to take a separate lecture separate course for this to understand what is forward bias reverse bias how semiconductor devices can be operated, and if it is a photo diode how it will operate, if it is LED how it operates, it was a pin down how it operates.

But any case anyway I am assuming right now that you all know how to operate a LED and when you have an LED then it can work in a forward bias condition. When this forward bias; that means, you are a node is positive cathode is ground in this case we have done the same thing and we could see how an op-amp can be used as a comparator and the LED was taken as an example to show that output is high and output is low alright.

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The Op-Amp Comparator- Experiment

Aim: To study the working of Op-Amp based Comparator

Part 2

- Connect the circuit as shown in the Figure 3 aside. This is same circuit as in Part 1
- Now, disconnect the potentiometer/ variable power supply from V_{IN}
- Apply a 5V peak-to-peak sine wave at 100 Hz directly at V_{IN}
- Observe the output at V_{OUT} and note down its peak to peak output value. Comment on the shape of the output signal

Figure 3

SL. No.	V_{IN}	V_{REF}	V_{out}
1			
2			

So, let us move to the next module and before we start the next module what I feel is we have one more part of the comparator and here it is very interesting that is that if we draw the similar circuit which is here right. What we have a similar circuit which is here and we want to test in a different way.

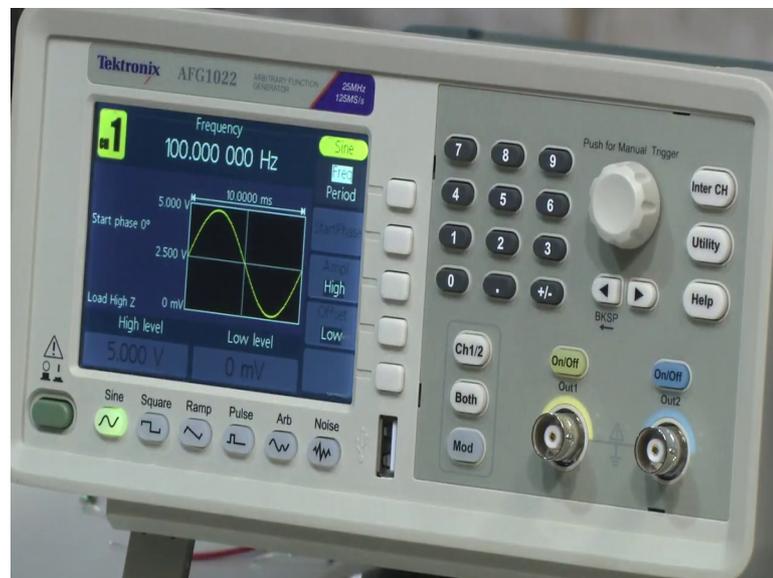
What do exactly we want to test let us see connect the circuit as shown in figure we will connect it what is we are connected same thing plus 5 volts through the DC power supply will apply to V_{IN} then we have potential divider 2.5 volts, 2 V reference that is the given now let us write clearly 2.5 volts alright. Now, disconnect the potentiometer variable supply from V_{IN} ; that means, that we have to disconnect this one from the variable supply apply 5 volts peak to peak sin wave at 100 hertz directly to V_{IN} .

Now, instead of applying here what will apply it V IN V apply 5 volts right peak to peak, peak to peak sin wave at 100 hertz frequency at 100 hertz frequency alright. So, observe the output V OUT and note down its peak to peak well output voltage comment on the shape of the output signal.

So, we can use the oscilloscope and we can see the shape of the output signal for first what we will do first the same circuit we can use it in just one thing we had to do different is that we had to disconnect this particular part right and connect this V IN to the plus 5 volts peak to peak sin wave which is at 100 hertz alright.

So, now, let us do this experiment let us see what kind of output voltage we observe and then we also see what is the shape because we have to comment on the shape right. So, for commenting on the shape you have to first see what is the shape of the output of signal so we will observe these 2 things let us see once again let us call Sitharam to help us alright. So, here we are applying we are applying 5 volts peak to peak 100 at 100 hertz.

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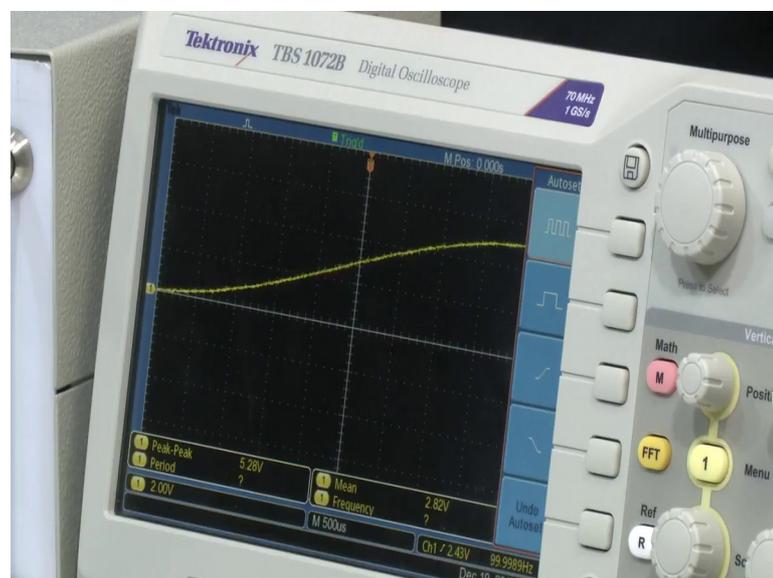


So, we are again using the function generator function generator or signal generator it generates signals at different frequency. So, what is doing he is now changing the frequency to 100 hertz and the voltage is already set at 5 volts right. You can see and he has pressed sin wave button for the sin wave; that means, that we can apply we can apply sin wave of 5 volts peak to peak, peak to peak you can see, 0 millivolts 2 5 volts right.

If you see on the screen you can see it is from 0 y axis from 0 to 5 millivolts that means, peak to peak signal is 5 volts from 0 to 5 volts frequency is 100 hertz and the sin it is a sin wave. First what you have to do you have to connect your probe. So, you are you connect your probe.

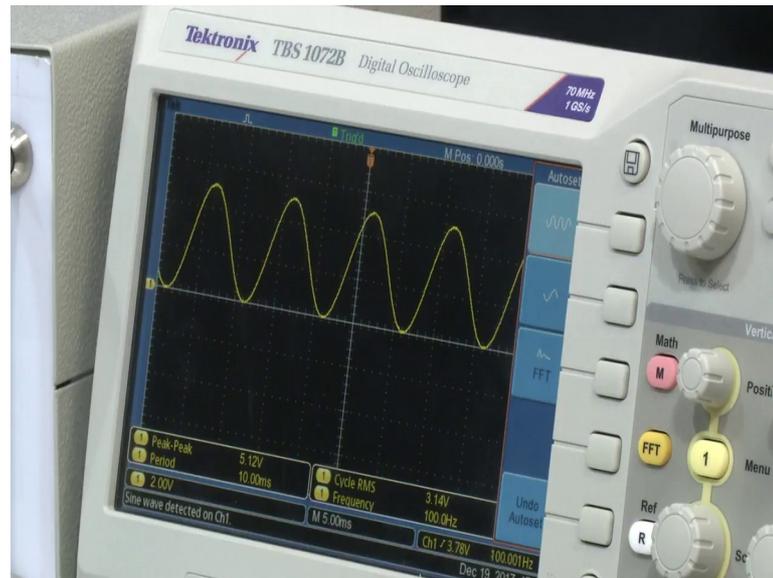
Now, you have to check the probe with the oscilloscope yesterday also we have seen this on the last model we have seen in this. Let us see once again we have to connect the oscilloscope; now we all check the probe, now we will connect the signal to see whether it is 5 volts and 100 hertz or not using the oscilloscope ok.

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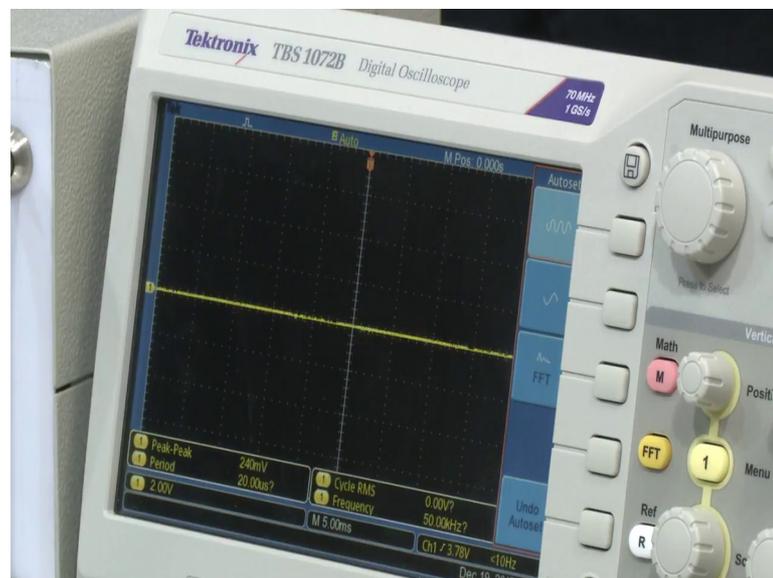
So, we are connecting the probe 2 probes together and we are looking at the signal in the oscilloscope.

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And what we see is the voltage is 5.12 volts; right frequency is 99.8 100 hertz ok. So, now we make sure we have we now know that the frequency from the function generator is 100 hertz.

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We have also confirmed that the voltage from the function generator is 5 volt; we have also confirmed that the wave or input signal is sin wave 3 things we are confirmed. Now, we are connecting this sin wave signal at the non inverting non inverting terminal of the operational amplifier you see. So, what happens when we apply 5 volts you can again see

the LED glowing, can you see the LED glowing yes. Why shall I help you out so if you see the LED is glowing because 5 volt is greater than your V reference; voltage 5 volts is greater than your V reference voltage.

Now, we have we have to see the output voltage right. So, before we see the output voltage let us first again see the screen. Can you please see the screen yes.

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The Op-Amp Comparator- Experiment

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Part 2

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SL. No.	V_{IN}	V_{REF}	V_{out}
1			
2			

Figure 3

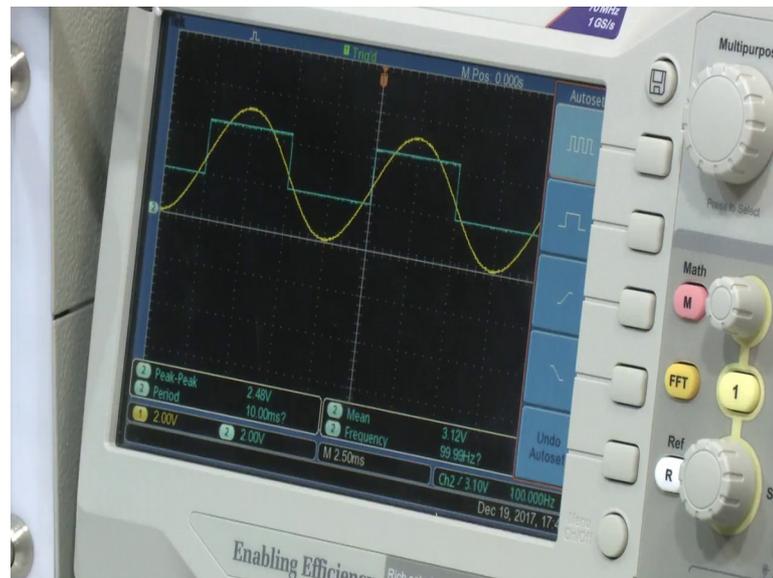
Here what we have done see what he is doing he is not connecting this, but he has connected here 5 volts peak to peak right peak to peak, peak to peak 100 hertz 100 hertz this signal he has connected to the non inverting terminal; this signal we have connected to the non inverting terminal.

Now when you when he is applying 5 volts at non inverting terminal he could see that LED is on because 5 volts is greater than 2.5 volts right; 2.5 volts by 2.5 volts V reference. So, input signal is greater than 2.5 volts means output will be plus 5 volt output will be plus 5 volt that is why LED is on right.

What we have to do here is that we have to observe the output voltage and note down its peak to peak output value peak to peak output value; that means, how can we observe the peak to peak output value we have to connect it to the oscilloscope. So, when I connect the output to the oscilloscope output to the oscilloscope and I will see what exactly the peak to peak voltage is there all right.

So, let us go back to the breadboard let us see coming back to the breadboard alright. So, now he has connected the LED still on means they apply voltage is 5 volts which is V_{IN} reference was the voltage is 2.5 volts, let us see the signal in the oscilloscope. Can you please see the signal in the oscilloscope can you show it alright.

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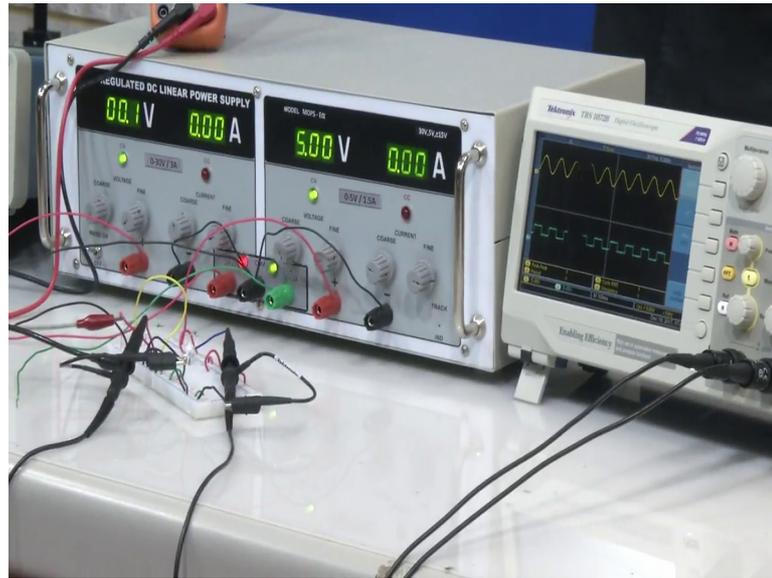
So, what we see what we see if you can zoom out yes. So, you can you show Sitharam where is our input signal input signal is this one which is our sin wave right it is how much we have applied 2 volts is it t volts input signal so 5.2 volts and 100 hertz right.

The input signal was 5.2 volts we all remember because that because it was 5.2 volts that is why it is the LED on otherwise LED will be off. But what is the output what is the output you can see output is of 5 volts right we have 5 volts is it 5 volts; approximately 5 volts yeah, but it is close to 5 volts it is close to 5 volts.

But look at the shape look at the shape it is not anymore sin wave it is not anymore sin wave what it is the square wave. It is the square wave; that means, that even we apply sin wave the output is what 0 and 1 in indirectly we can say output is nothing, but 0 and 1 that is a square wave right.

So, this is the beauty of the comparator that your input signal is sin wave your output can be square wave output can be square wave alright. So, the point is that when we use a comparator when we use a comparator and we apply a voltage V_{IN} greater than V

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So, in this particular exercise what we have seen that we can use op-amp as a comparator then we have seen that when we apply V_{IN} greater than $V_{reference}$ how can the comparator operate. And finally we finally we have seen that when we use 5 volt sin wave peak to peak right then the output voltage here the output voltage will result in a square wave right now applying a sin wave here, sin wave here, the output would be square alright.

So, I hope that you understand you understood the role of an operational amplifier as a comparator and you will go through this lecture once again so that you completely understand what I have discussed in this particular module and we will continue with the application of an operational amplifier as an integrator, and as a differentiator.

Now, in the following modules how exactly the op-amp can be used as an integrator and how we can use as a differentiator we have to see in the in the following module. So, for now we will stop this lecture at this point and I will see you in the next module with the application of an operational amplifier as an integrator and application of an operational amplifier as a differentiator.

Till then you take care bye.