Op-Amp Practical Applications: Design, Simulation and Implementation
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Lecture – 19
Op-amp with Positive Feedback: Inverting Schmitt Trigger

Welcome to this class.

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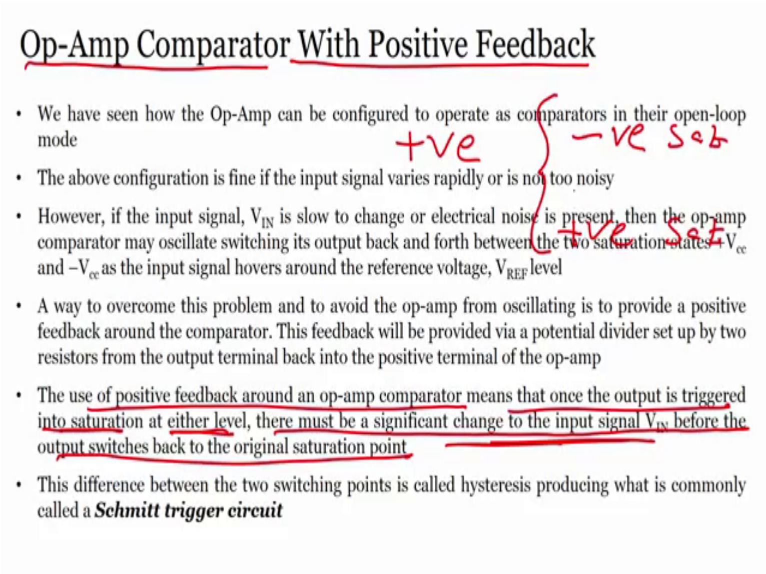

In this module we will see the other applications of the operation amplifier. So, this would this topic, I thought that it will be interesting for you to understand and that is about the multivibrator. So, how OPAMP can be used as a multivibrator? So, when we talk about operation amplifier one important thing that we have learned is it is characteristics as a comparator. So, how exactly OPAMP can be used as a comparator you know right it is very simple circuit.

So, when you want to design OPAMP as a comparator and from comparator to a multivibrator right how we can design it? So, this topic this module is for understanding how multivibrator can be designed. We will see how multivibrator we can design using the breadboard. And 3 of our favorite equipment starting from your dc power supply, we would have function generator and we will have oscilloscope. Of course, we will have breadboard or OPAMP and few components 2 resistors which is a passive component.

And we will apply sine wave and look at the signal, which will be a square wave ah. And you will see how the hysteresis happens and how this comparator acts as a multivibrator.

So, let us see how the multivibrators can be designed when we talk about operation amplifier and comparator with positive feedback.

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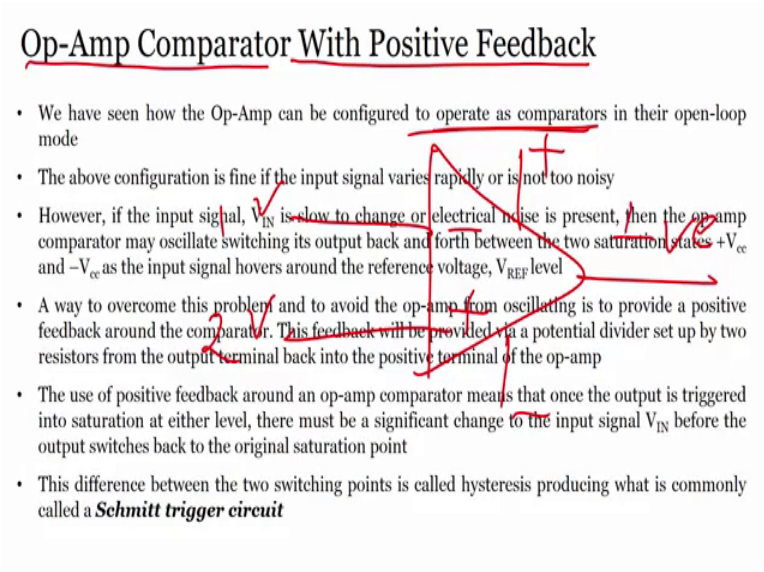

So, what will happen if an OPAMP comparator with positive feedback is designed? Alright, so, first we have seen how the OPAMP can be configured to operate as a comparators we have already seen that right in their open loop gain, open loop mode; that means, we just draw OPAMP we use here right, we have applied bias plus minus now you have already know, right. And we have seen that if the inverting terminal is, inverting terminal is let us say 2 volt non inverting terminal is one volt, then output will go to negative saturation right.

And if my inverting input is one volt, and non-inverting input is 2 volts; that means, my non inverting input is higher than inverting input my output will go to positive saturation. This is open loop right. Now if I apply positive feedback then what will happen right. So, what is that? The above configuration is fine; that means, this configuration is fine. However, is if the input signal varies rapidly or is not too noisy. Only this is fine when your input signal varies rapidly and is not too noisy you see. So, that is very important right, input signal is too noisy we cannot use OPAMP in open loop configuration.

So, if the input signal V in is slow to change or electrical noise is present, then the OPAMP comparator may oscillate switching it is output back and forth between 2 level saturation 2 saturation states, which states? Plus, V cc and minus V cc as the input signal hovers around the reference voltage V reference level, correct. So, that means, that if I have input is slow or noise is present, then the OPAMP will start oscillating and output will be between positive and negative saturation.

So, a way to overcome this problem a way to overcome this problem is to avoid OPAMP from oscillating right this is the answer, but how we can avoid the OPAMP from oscillating. Because we know that if the input signal is noisy it will start oscillating. So, how we can avoid the OPAMP to how we can avoid this problem that is to avoid the OPAMP from oscillating. So, the solution is we provide a positive feedback around the comparator we provide a positive feedback around the comparator.

So, what will happen this feedback will be provided via a potential divider we will see the circuit set up by 2 resistors from the output terminal back into the positive terminal back into the positive terminal of the OPAMP. This is how we will provide the feedback we will use potential divider circuit; which you already know with there are 2 resistors and we will apply the voltage across the potential divider circuit back to the positive terminal of the OPAMP. That is back to the non-inverting terminal of the operational amplifier.

Once we do that the use of positive feedback around the OPAMP comparator; means that, once the output is triggered into saturation at either level there must be a significant change to input signal V in before output switches back to it is original saturation point. What does it mean that, if I apply a positive feedback if I apply a positive feedback, if the output is triggered to negative over positive saturation, negative saturation or positive saturation right, I will have to overcome this negative and positive saturation values, then and then only I can switch back it is characteristics.

Otherwise what will happen? The once the output is triggered in saturation either level there must be significant change to the input signal before output switches back to original saturation point. By otherwise it will just be within the saturation region, we will see these things. We will see this thing in the experiment. So, you will know better what we are talking about right.

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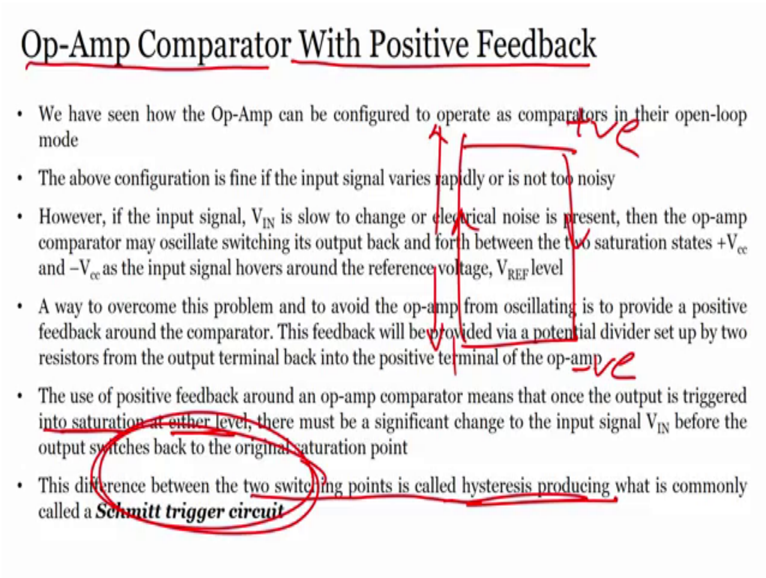

The difference between 2 switching points is called hysteresis; that means, it will switch between positive and negative, it will go here it will come back here right like this you will see the signal and let us say this is positive saturation, this is negative saturation. So, the OPAMP will oscillate between these 2 points, these 2 pints right and this is nothing but your hysteresis producing what is commonly called Schmitt trigger circuit.

So, the multivibrator is also called a Schmitt trigger circuit right. If somebody ask you what is different multivibrator in Schmitt trigger it is same thing it same thing, yes. How we can design the multivibrator you can always say that we can apply positive feedback to the comparator using the potential divider alright. So, it is easy you do not worry about it right.

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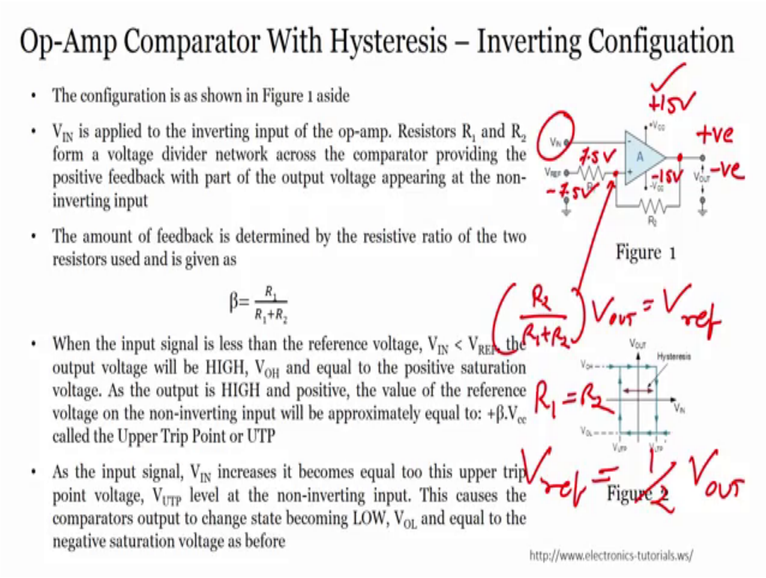

Let us see, let us see the functionality of the operational amplifier in it is inverting configuration. So, inverting configuration we will use the OPAMP and we will see how the hysteresis can be generated ok. So, the configuration we can see this configuration right. We have whatever see this V in is the input signal, V reference is the reference voltage whatever is a voltage here, the signal that is given is half is R 2 by R 1 plus R 2 R 1 plus R 2 that is half of V out if R 1 and R 2 are same it will be half of V out what.

What does it mean? The input here is fed using R 1 and R 2 right, output of V out and R 2 by R 1 that is been said R 2 by R 1 plus R 2 into V out is my V reference voltage is my V reference voltage. For R 1 equals to R 2 V reference voltage is nothing but half times V out is half times V out right. So, always you remember this will be half times your V out. Now if my V out is positive saturation suppose V out is positive saturation a positive is plus 15, negative is minus 15 right, then here it will be 7.5 volts right. If my V out is negative saturation, here it will be minus 7.5 volts.

So, my input signal should exceed this value then and then only I will see the change. My input signal should exceed this value; otherwise it will remain in this particular condition right. So, let us see what I have whatever I have told you here, whether it make sense from the test or not, let us see.

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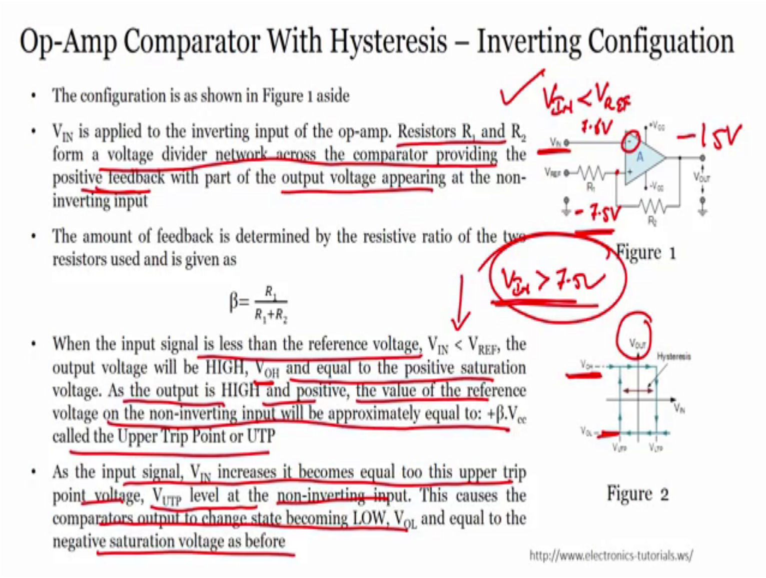

So, what you can see? V in is applied to the inverting input of the OPAMP resistors R 1 and R 2 form a voltage divider network across the comparator providing positive feedback right, it is providing a positive feedback. With a part of output voltage appearing at the input the amount of feedback is determined by the resistive ration is given by beta R 1 by R 1 plus R 2 you can say R 1 plus R 1 by R 2. Because we are taking voltage across this point we can both R 1 and R 2 are same, it does not matter because it will be half times your output voltage. If I want to give the input if I want to calculate the V reference voltage.

So, anyway point is when the input signal is less than the reference voltage; that is, V in is less than reference voltage the output voltage will be high you see here. Output voltage would be high when V in is less than V reference. The output voltage will be high that is V OH and equal to positive saturation value. It will be here when V in is less than V reference voltage, why? Because the positive is higher than the negative; that means, it will go to the positive saturation comparator, correct.

So, as a output is high and positive the value of the reference voltage on non-inverting input will be equal to plus beta or upper trip point value; that means, that if I have positive saturation; that means, here is 15 plus 15 volts positive right. So, my reference voltage would be plus 7.5 volts that is what it means, alright. And this is nothing but my upper trip point, upper trip point, I have to exceed this value here then only I can change the single, then only I can change; that means, my V in should exceed 7.5 volts to see the change in the output, to see the change in the output alright.

So, as the input signal V in increases, it becomes equal to upper trip point value V UTP at the non-inverting input this causes the comparator output to change state becoming low V ol equal to negative saturation value as before; that means, that when I will reach this condition. Initially is this condition right V in is less than reference. Then in that case I have positive saturation, means my reference voltage is plus 7.5 volt. Now I keep on increasing V in voltage such that it increases is as greater than 7.5 volts when it gets greater than 7.5 volts, then what will happen? That the negative here it will be let us say 7.6 volts alright.

In that case you see 7.6 is greater than 7.5 yes. So, what will happen? What will happen my inverting voltage at inverting terminal is higher, than the voltage at non inverting terminal which is 7.5; hence, my output will go back to the to the negative saturation value and the output will be minus 15, right. Minus 15 volts will create the reference voltage of minus 7.5 volts. Now until and unless my V in is less than minus 7.5 volts it will not change the signal.

It will the output will remain at the low right. So now, it is at low level, again if I want to go to high level, it should exceed this value which is minus 7.5. Easy? Easy? Extremely easy, right? Same comparator same comparator, but here you are triggering from in high to low, low to high right it is also called a Schmitt trigger.

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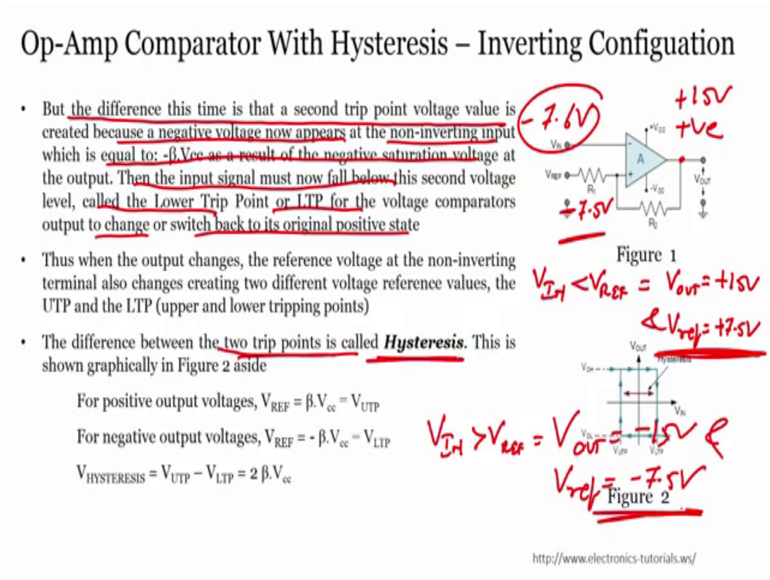

So let us see further the, but this time the difference is second trip point value voltage created, because of negative voltage appears in non-inverting input. The same thing what we are talking about right, the then the input signal must be now for below this second voltage called low trip point or LTP for the comparators output change or switch back to it is original positive state. Same thing what we have discussed is again a here right the. So, we have to we have to understand is when V in is less than V reference my output voltage is plus 15 volts and V reference voltage would be plus 7.5 volts, ok.

When my V in is greater than V reference my output voltage will be minus 15 volts, and my V reference would be minus 7.5 volts, ok. Now I have V reference 7.5, I have V reference minus 7.5; that means, if my V in is 6.5 or let us say 7 7 volts whereas, V reference voltage is 7.5 volts, my output will stay in positive saturation, that is positive 15 volts, alright. When this exceeds when this exceeds 7.5 volts; that means, it goes to let us say 7.6 volts, my output will go to negative saturation minus 15 volts and this will become minus 7.5 volts.

Now, to again change the output from negative to positive saturation, this voltage should be less than this voltage; that means, should be minus 7.6 volts. If minus 7.6 volts happens, then again this will be positive saturation, alright. This how it works switch on off and we define upper trip limit lower trip of limit alright. The difference between 2 trip points is called hysteresis.

So, what is hysteresis? Now we can design that the difference between the upper trip point and then the lower trip point in this particular case is called hysteresis is called hysteresis. Here, you see this one; this is your hysteresis very easy, extremely easy, super easy. Now everything for you becomes super easy because you already know how to use operation amplifier as various for various applications right. So, when I talk about comparator immediately your brain works that yes comparator very easy. My inverting higher than non-inverting output result, my negative saturation in non-inverting higher than inverting output is positive saturation.

R 1 R 2 is there, voltage divider R 2 by R 1 plus R 2 R 1 divided by R 1 plus R 2, right if R 1 is equals to R 2 is half times V out, so easy what is hysteresis, now you know; what is upper trip point, what is lower trip point you know, right.

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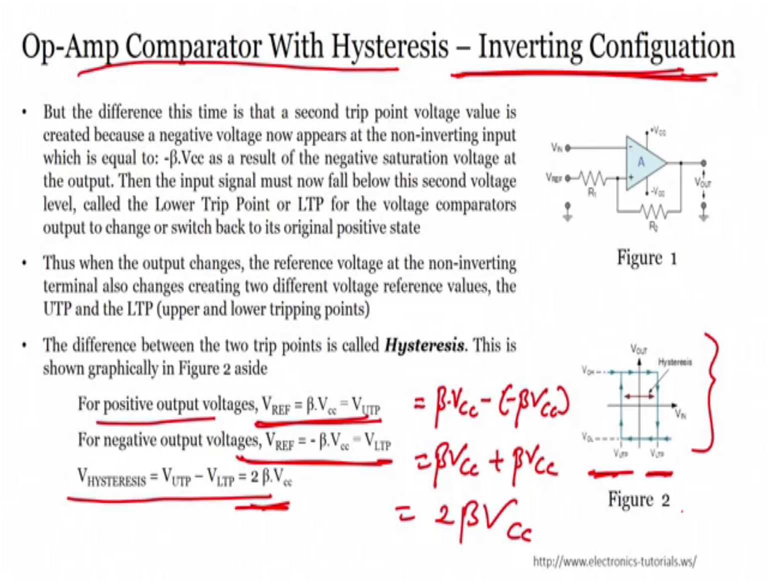

So, for positive output voltages V reference is beta into V cc. For negative output voltage is V reference equals to minus beta into V cc. So, hysteresis is nothing but V out V UTP minus V LTP. So, V UTP V UTP is beta into V cc minus minus of beta into V cc; is nothing but beta into V cc plus beta into V cc equals to 2 times beta into V cc. This is what you got here. This is what you got here. Easy? Extremely easy, right? This is how you create OPAMP comparator with hysteresis using the inverting configuration. Now to design the circuit using multisim, again you will ask our friend sitaram, who will show us how to perform the experiment using multisim.

So, in this module, we are going to discuss about Schmitt trigger, how to implement as Schmitt using operational amplifier by making use of TI board.

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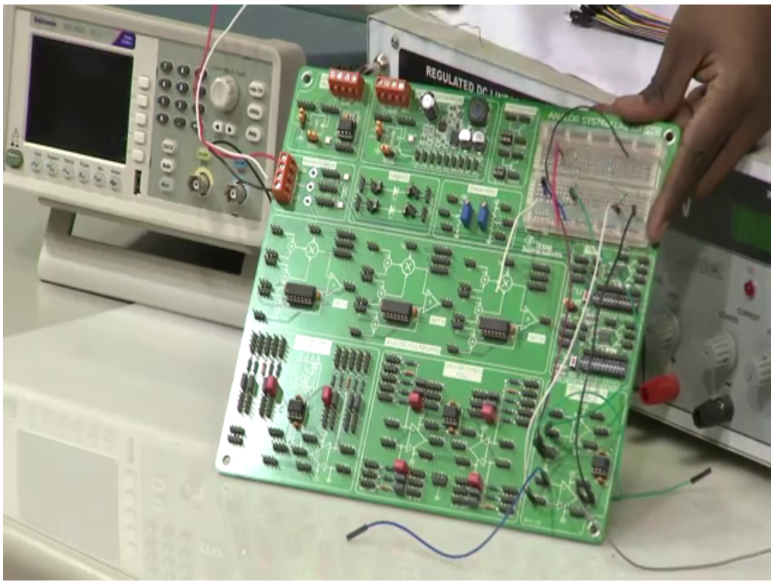

So, here we have TI board. Basically, this board contains all the OPAMPs required for that I will keep it here so that you can easily see the board. So, if you observe the TI board. It contains different subsystems starting from ldo regulator dc dc convertor transistors, if you want to place some transistor and dc if you want to make use of a transistor in your circuit you can connect it here. And it also has an input main power. So, once we powered, once we give input to this main power, it will be automatically powered all the operational amplifiers and all the circuits that we have used or all the subsystems that that are there in the boards.

. So, it has other subsystems to like in case if you want to place some diodes in your circuit you can make use of the subsystem of diodes here, trimmers as well as analog multipliers. So, along with these subsystems it also has an inverting type as well as non-inverting type or as well as a basic OPAMP types subsystems too. So, right now in this module we are going to use OPAMP type 3 basic one. So, in the subsystem they are using TL082.

So, as the name itself we can see that TL082, it is an TI based operational amplifier, it contains 2 OPAMPs inside; that means, it is a dual channel OPAMP. And when you observe here, one set of OPAMP you can see on the top side here, one set of OPAMP we can see on the top side. And another set of OPAMP we can see on the bottom. So, depend upon our experiment, we either use either the top one or the bottom one.

When you closely observe this board, in case, if you want to connect some external resistors or any other external component, this board can also provided an option of option with a smaller breadboard, it is also similar to our normal as usual regular bread boards, but it is a smaller in size so that any external, which is not available in the board like here resistors; which are not available in that or here other kind of transistors are anything can be connected and wired through this using any kind of jumpers. So, right now by using this board and by using this particular subsystem module, we are going to see how analogue using an OPAMP how inverting Schmitt trigger can be implemented.

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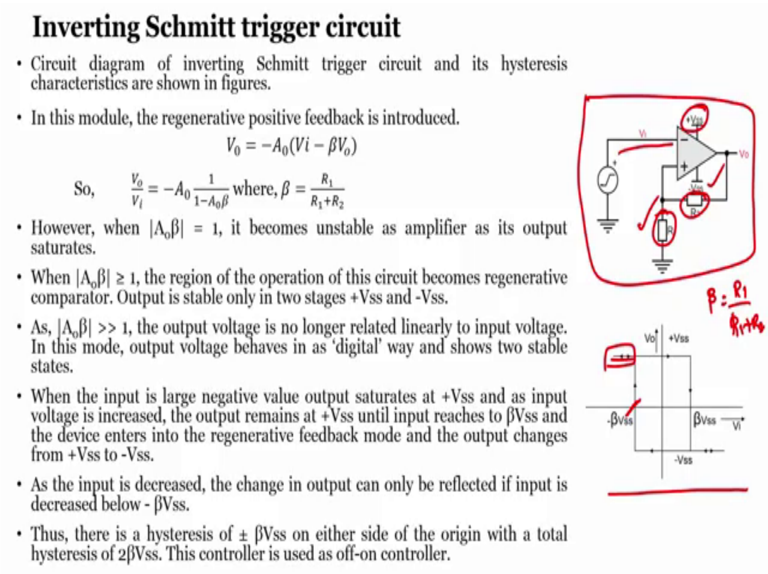

So, when we look into the slide. So, as we have seen in the class so, this is an inverting type of Schmitt trigger. I hope by this time you would have understand why it is called inverting type of Schmitt trigger. The reason is input is directly connected to your negative terminal of your OPAMP.

And as we have seen the difference between a Schmitt trigger and their normal negative feedback operational amplifier; that means, when you are using OPAMP as an amplifier, the major difference is that in case of an operational amplifier using a sn amplifier the feedback will be connected to the negative. So, that is called a negative feedback, but where as in case of Schmitt trigger, you can see the feedback is positive. So, as we know that the OPAMP, open loop gain itself is very, very higher; when you connecting a positive feedback the overall gain of the system will be even more higher as we have already seen in the class.

So, that is a reason the OPAMP will always be in a stage of saturation; will always be oscillate in saturation state, but when it oscillates. When it goes to plus V cc when it goes to minus V cc, that entirely depends upon the resistors R 1 and R 2 that we choose and depends upon the V ss and minus V ss that we choose. So, in this we will see as brief understanding on inverting type of Schmitt trigger circuit and simulation of by this inverting type of Schmitt trigger circuit, and once the simulation is done the results will be compared with the OPAMP circuit built using a TI board. So, as we know that the OPAMP V naught output voltage can be written as minus a naught into va minus beta into V naught; where the beta is nothing but your R 1 divided by R 1 plus R 2.

So, the value of the beta depends upon the resistors R 1 R 2 that reaches. So, this is this is a responsible or the values of R 1 and R 2 are responsible to decide what thresholds to be used for va circuit. So, as we have already discussed as we have already seen in our professors lecture that, the relation between the thresholds are depends upon beta value. So, what is beta? So, beta is related with the resistance that we have choose. It is nothing but R 1 divided by R 1 plus R 2.

So, beta into minus V ss is our lower threshold value, and beta into plus V ss is our the higher threshold value. So, how the output is related to the input. So, when we look into the characteristics curve are relation between input and output, we can understand that as my input is keep on increase[ing]- keep on decreasing to minus beta V ss.

So, one (Refer Time: 22:09) minus beta V ss the value will become plus V ss. Since it is inverting, when the input voltage is lower than the lower threshold value, then the output will become higher that we can see here. Similarly, when the input is greater than beta V ss, then the input becomes then the output becomes lower. So, lower in this in this case is nothing but minus V ss. So, it will always shift from plus V ss to minus V ss or from minus V ss to plus V ss.

But that depends upon 2 thresholds, that thresholds entirely depends upon the beta value and V cc plus V cc and minus V c that is nothing but the power supplies that we are giving it an OPAMP to operate it.

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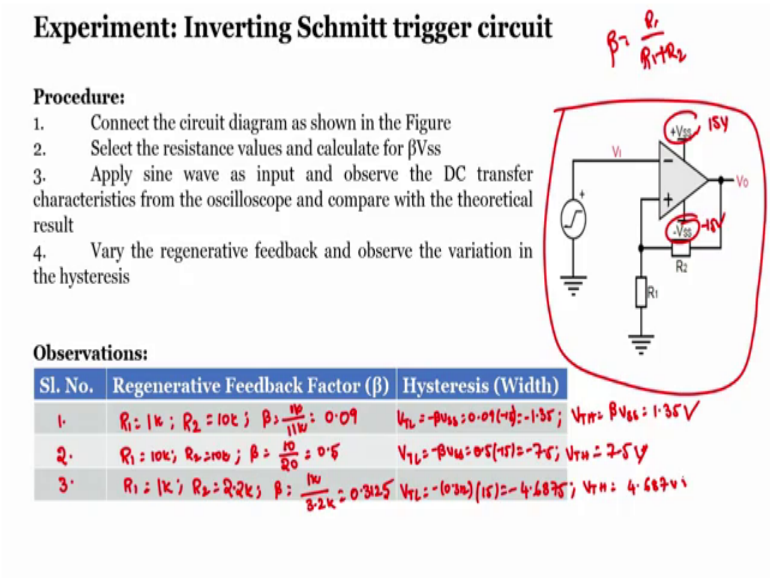

So, when we look into the circuit, when we look into the circuit and the procedure the procedure that we follow for in order to do the experiment on a Schmitt trigger. So, consider we will be connecting the circuit in the same fashion. So, before connecting it will also see the simulation by connecting the same thing. So, in order to do the simulation, let us consider few different resistance value, and we will see the theoretical value of the beta by with the values of resistance that we have considered as well as the hysteresis width.

And where exactly what is nothing but a lower threshold value in this case and what is the higher threshold value. So, for that let us consider different resistance value. Now first one, I will consider R 1 as 1 kilo R 2 as 10 kilo. So, as we know that beta, the relation between R 1 R 2 is beta is equal to R 1 by R 1 plus R 2. So, it is nothing but it is nothing but one divided by 11 k. 1 k divided by 11 k, now what is the value of one divided by 11 k? So, we will see the value.

So, one 1 k divided by 11 k so, k k cancelled. So, the beta is nothing but 0.09, that is our beta value now. So, the lower threshold, the lower threshold V TL I am considering, it is nothing but minus beta into V ss which is nothing but 0.09 into minus 15.

So, 0.09 into minus 15 when we calculate it. So, again we will go to calci 0.09 into 15 1.35. So, why 15? Because I am going to use plus V cc and minus V cc as 15 volts and minus 15 volts. So, R 1 initially I will be considering 1 k and R 2 as n k and similarly this is minus this is lower threshold what about the higher threshold. So, it is nothing but beta into V ss which is nothing but one point, plus 1.35 this is minus 1.35 this is plus 1.35. So, I will re write this once again. So, these are the threshold, we will see in simulation. So, next we will consider other 2 values too.

Let us check R 1 as 10 k R 2 as 10 k. So, what will be the value beta? It is nothing but 10 by 20 so, which is 0.5. So, V TL lower threshold value will be minus beta into V ss which is 0.5 into minus 15, 7.5 and V th is plus 7.5 volts is not it? These are all higher and lower threshold values. Then we will also see for other resistance value is to R 1 as 1 k and R 2 as 2.2 k, R 2 as 2.2 k. So, then beta will be 1 k divided by 1 plus 2 point to 3.2 k. So, when we calculate one divided by 3.2, it is nothing but 0.3125, 0.3125, these are beta value.

Then what about V TL? It is nothing but minus 0.3125 in to 15. So, it is nothing but 15 into 0.3125 right, 4.6875 approximately, 4.7 or 4.6875. And higher threshold value is 4 point plus 4.6875 volts right. So, what you mean by hysteresis width? When we look into the previous one, this is nothing but our hysteresis width. The difference between the lower pressure and our higher threshold. So, when we see that in this case 1.35 plus 1.35, 7.5 and 7.5, 4.68775 and plus 4.6875, those will be hysteresis width.

Now we will verify the same thing with our simulation, then will we will verify with our TI board too. So, let me go back to the simulation.

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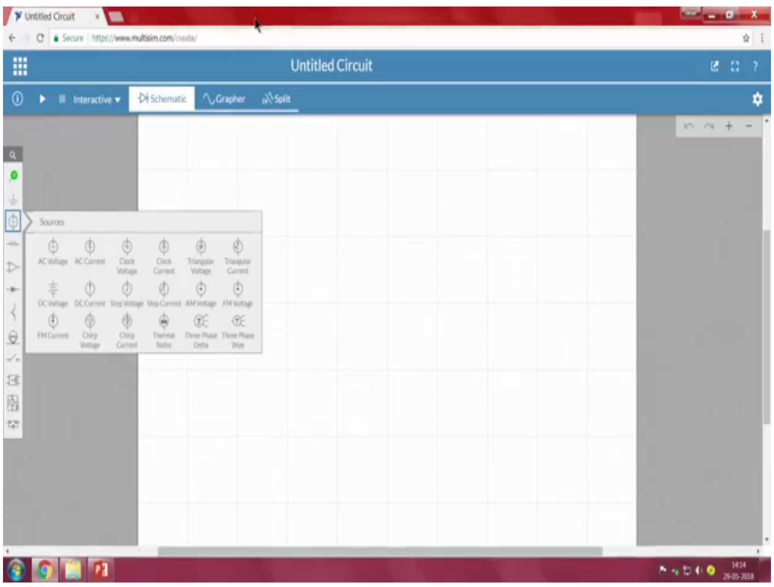

We will look into the multisim, as we have already seen about the multisim in the previous sessions too. So, once again I just repeat, this is an multisim online circuit simulation builder software. So, here if you observe on the left side, we have a different modules that we can place on this circuit board. So, starting with analysis and annotation. So, where if you want to measure voltage or if you want to measure current, both voltage and current and if you want to connect any ground references points and at different types of sources ok. Different types of voltage sources here we can see.

And resistors in case if you want to replace resistors, capacitors inductors potentiometers fuses everything, and operational amplifiers 3 OPAMP base 5 OPAMP base like and then normal 97132 OPAMPs basic OPAMPs diodes transistors and indicators everything. So, whichever we require we can place it on the circuit board, we can connect the circuit whatever we have seen before connecting it on a breadboard, and we can visualize the response of the circuit using the grapher. Now we will connect the same circuit that, we have used that we are going to verify the working of the circuit in our multisim.

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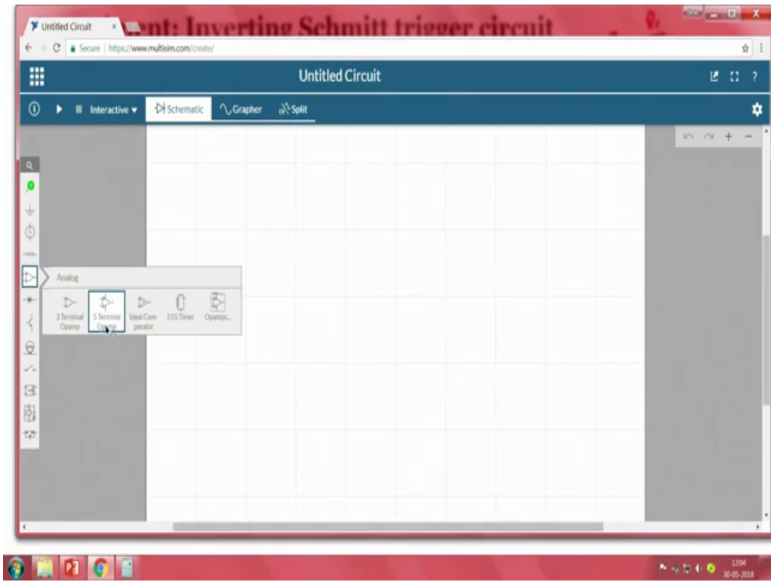

So, first one is I have to take an OPAMP, I am going to take 5 terminal OPAMP, I am placing 5 terminal OPAMP here, right.

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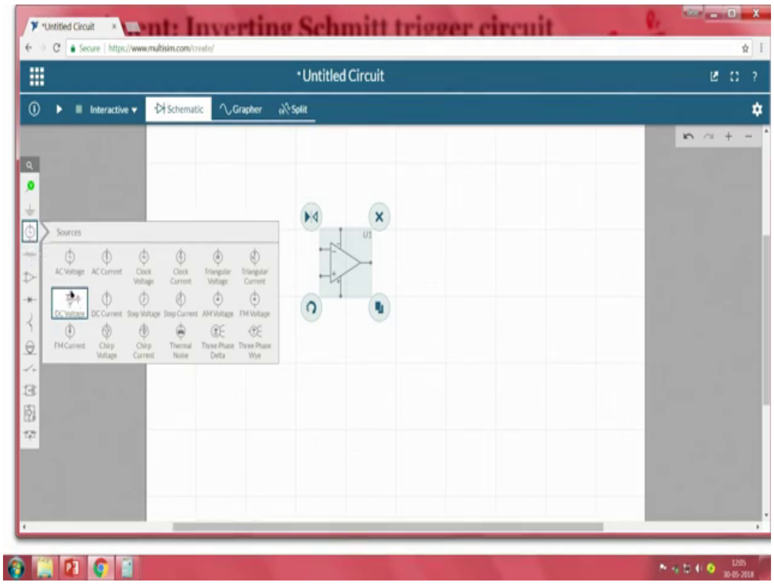

So, since it is an inverting type of OPAMP. So, what I will do is, it to just match with our circuit connections I am swapping it. Now if I see this is the negative and this is the positive terminal. So, since I have to power it, I will take a dc voltage source, I will place it here.

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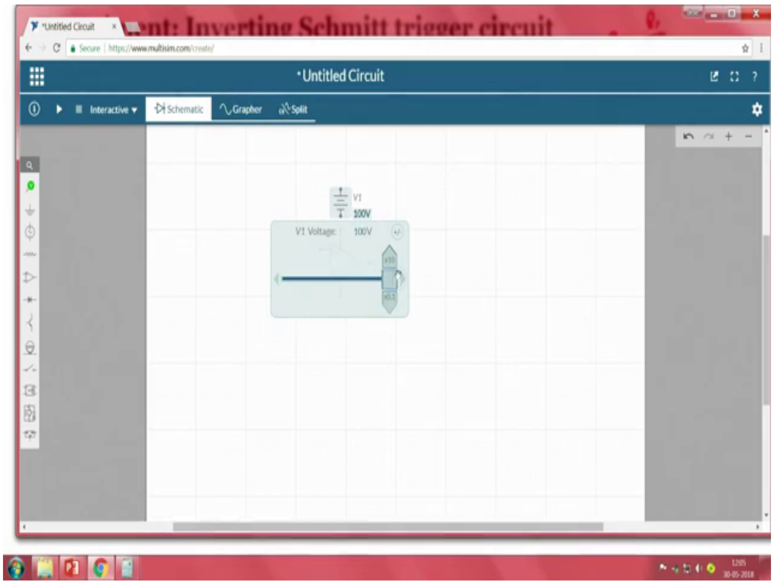

Now, this value should be 15 volts, right? 15.

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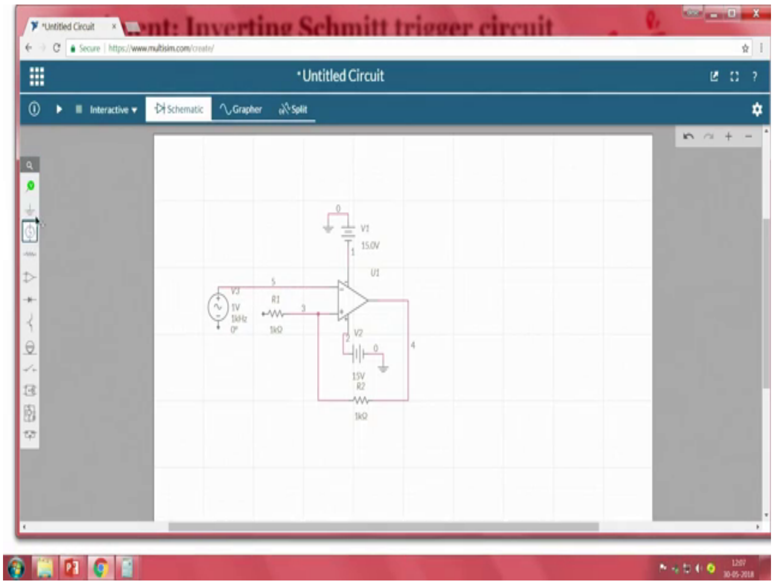

So, since the negative terminal is connecting it to the negative terminal, observe here, the negative is connecting it to the negative. So, even that it shows a 15, it is nothing but a minus 15 volts is connected here right, and I have to connect a ground.

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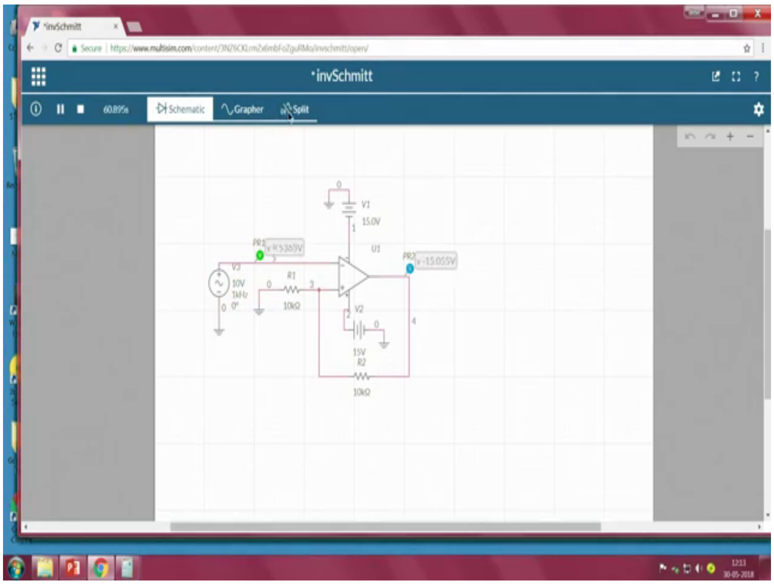

So, I am taking a ground, and connecting it here no negative supply is done. So, what about positive supply? Yes, we also have to give plus 15. So, plus 15 should be connected here, I am connecting plus 15 here.

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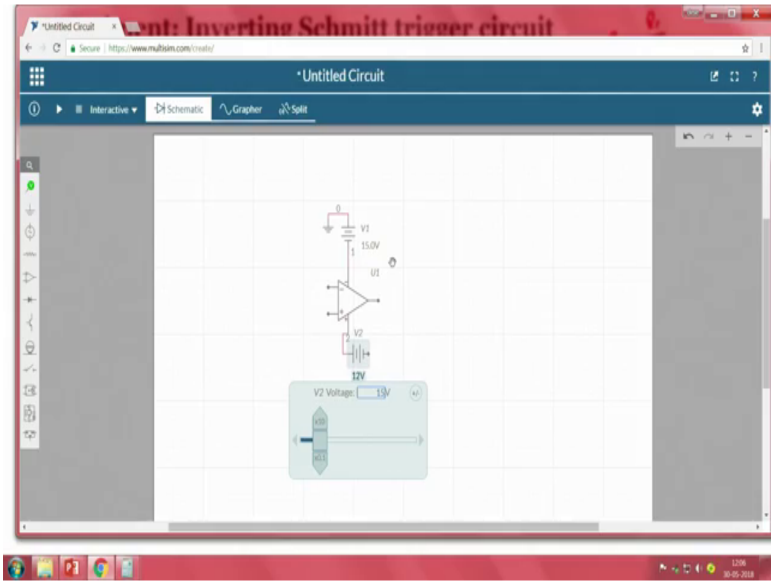

Since the default is 12 I am changing it to 15, because we are change we are using 15 volts power supply in this case, and the other terminal is ground.

So, the plus V cc and minus V cc connections for our OPAMP is done.

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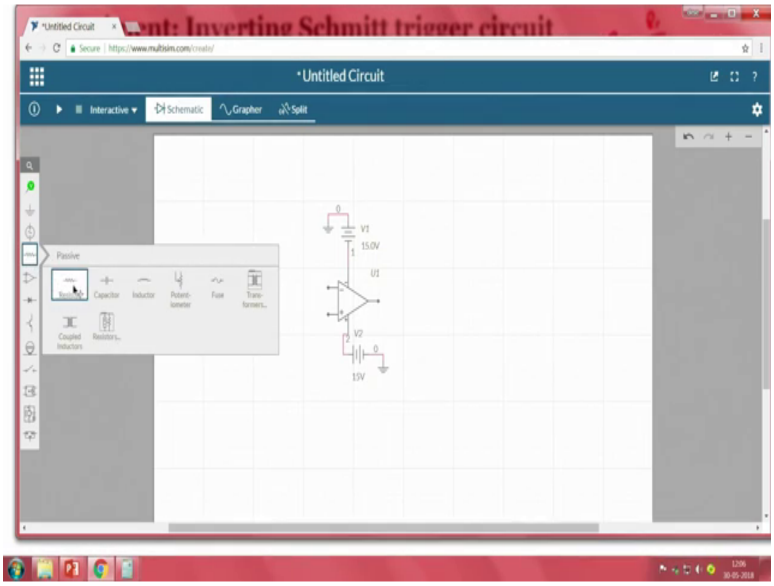

Now, next thing is we have to take a resistors, connect it. So, we know that since it is an inverting Schmitt trigger right, it should always be a positive feedback. So, I am connecting one resistor to the positive terminal. One more resistor should be first feedback. From here to here, and where is input to be connected? Since it is an inverting

Schmitt trigger input should always connected to the negative terminal right. So, I am connecting input to the negative terminal.

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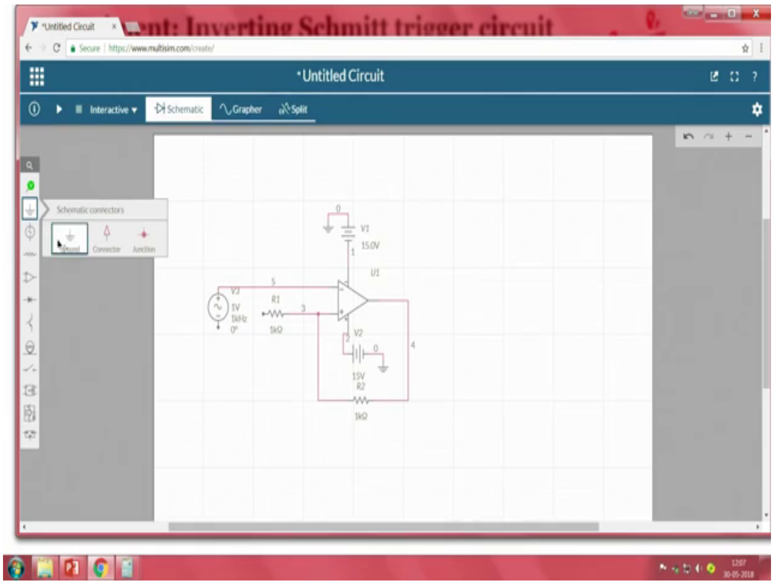

And other terminal of the source should be grounded right and what about this terminal? Other terminal of the resistor, it should be grounded right.

So, ground taking ground and I am connecting. So, does it look similar to our circuit that we have seen in our in our slide see positive voltage to be connected to the negative terminal, and R 1 should be connected to the positive right. So, we can see here right. So, R 1, but resistance values so, one should be R 1 should be 1 k R 2 should be 10 k.

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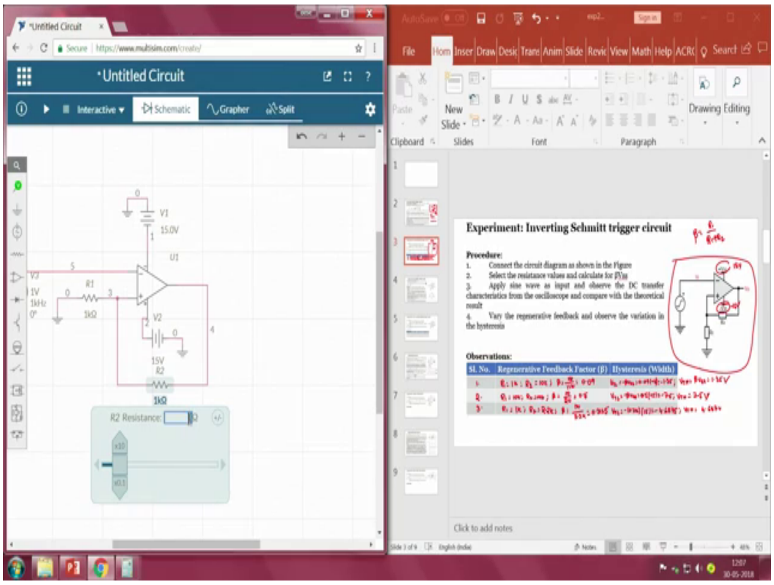

So, this I will change it to 10 k. Clear? Now we have to compare input and output. So, in order to see the input signal as well as an output signal, we have to connect oscilloscope to that.

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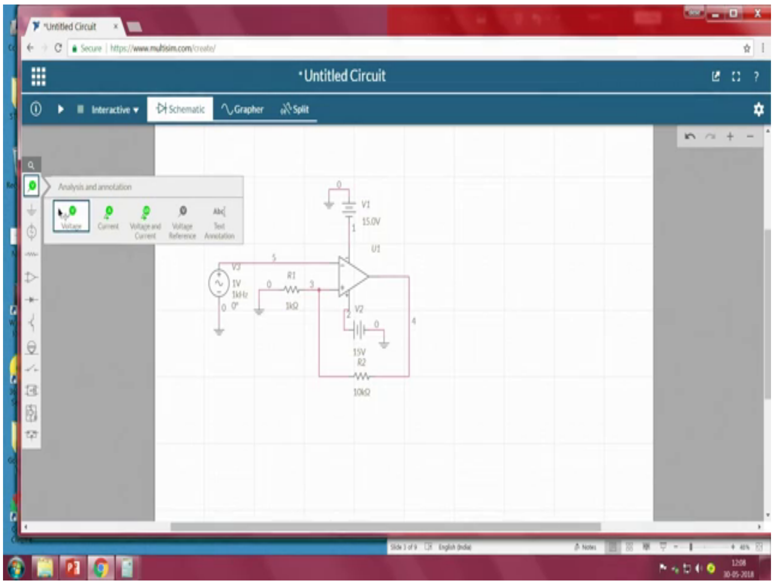

So, I will take voltage probes for the analysis purpose. And I will be connecting 1 to 10 input. So, the green indicates the input signal that is been connected to this.

And I will take one more probe; I will connect it at the output side. So, the blue indicates the output signal. Now, what is the value input voltage value that we have to apply to the system in order to see the change in the output. So, since the thresholds that we set the resistance that we that we have set is 1 k and 10 k, for that resistances the threshold value is nothing but 0.0 and the threshold voltage is minus 1.35. So, in order to see that that change the input voltage should be higher than the threshold values, is not is not it?

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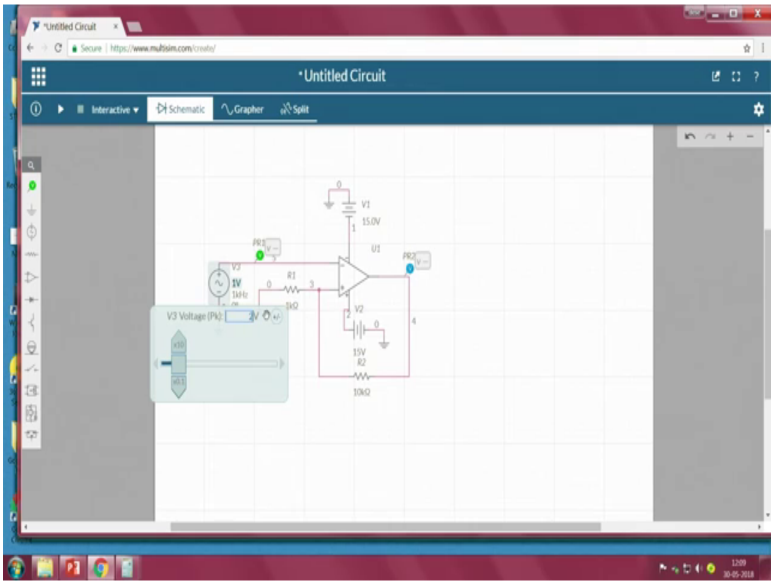

So, for that reason what I do is that, I will take peak value as 2 volts. So, peak to peak is 4 volts so that we can see the change.

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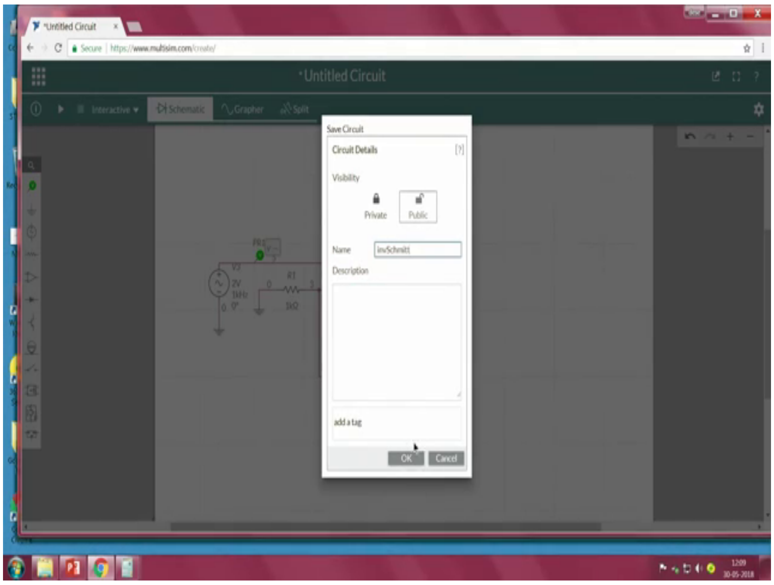

Now once the circuit is done, let me save the circuit, save and this is nothing but inverting Schmitt trigger, ok. Inverting Schmitt trigger ok, I am saving it.

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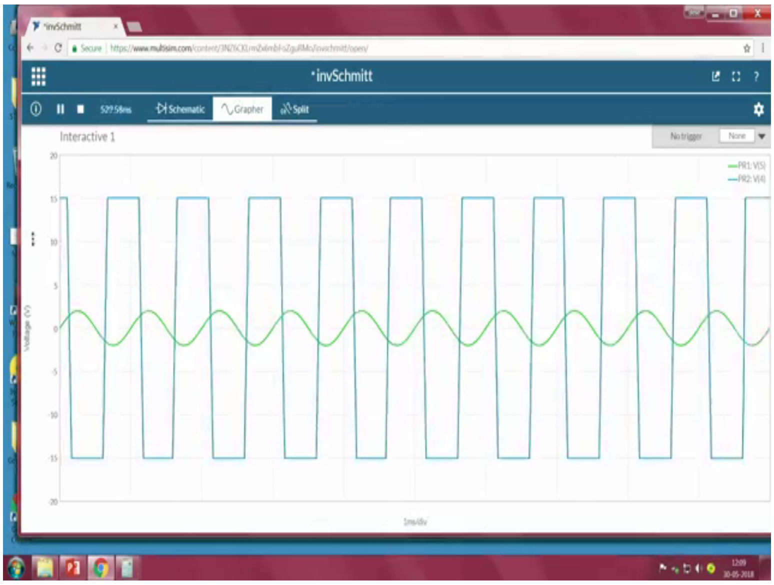

So, I will go to the grapher let me run the circuit, right. We got a signal, but if you observe the signal we have 2 things in the same here in inner grapher. One is the green color other one is a blue color. So, the green color indicates our input signal. Whereas, the blue color indicates our output signal is not it? Now how do we understand? Weather at what time, it is switching on at what time it is switching off; when we remember when we recall what we have discussed in the Schmitt trigger or what a professor what professor has discussed in the inverting Schmitt trigger time.

We know that when the input signal is greater than higher threshold value then output should be minus V cc. Similarly, when the input signal is lower than lower threshold value, the output will be plus V cc. Since in our case, plus V cc and minus V cc are plus 15 and minus 15 volts, you can you can see the change from plus 15 to minus 15, but whether it is switching happen at the lower threshold at the higher threshold; that we have to see. For that reason, what I will do that, I will create a cursors, I will cursors and for our easy to understand I will also increase the time division.

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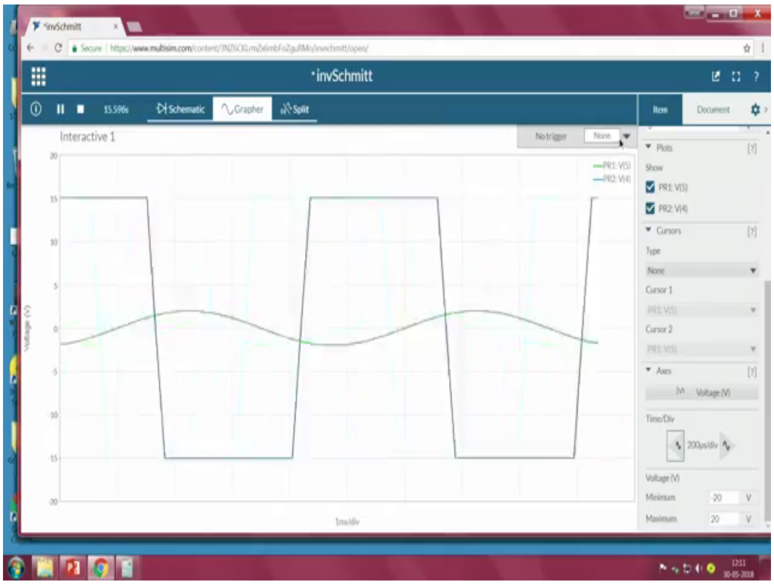

So, it is nothing but a zooming. I am increasing the time division.

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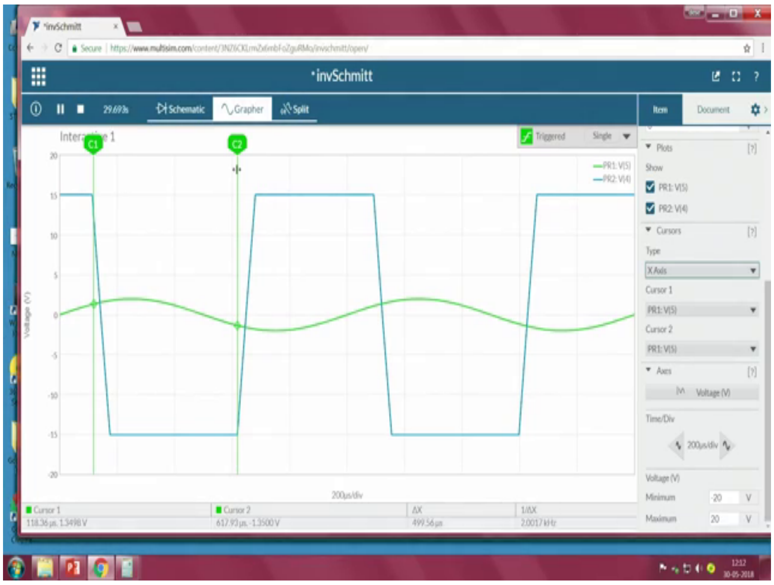

So, we can see and I will create a cursor, cursor x axis cursor. Now observe, now we will move the cursor, we can notice here cursor 1, what is at what input voltage it is at.

So, we when we look into the threshold value, threshold is nothing but 1.35 volts. So, if my input is greater than 1.35, then it should go to minus V cc, is not it? Now close slowly move towards 1.35 right. So, somewhere close yeah, 1.34, we can see that it is going to minus V cc, right? Now another thing is, when the input is greater than 1.35, then the output should be plus V cc just observe. So, I will be keep on moving or I will take another cursor, we can visualize it in cursor 2 here. So, slowly move, move, move and observe this minus 1.35, right. Then it is initiated to plus V cc, right, it is clear? Now you will also see, we will see for another set of resistance values what is that 10 k and 10 k.

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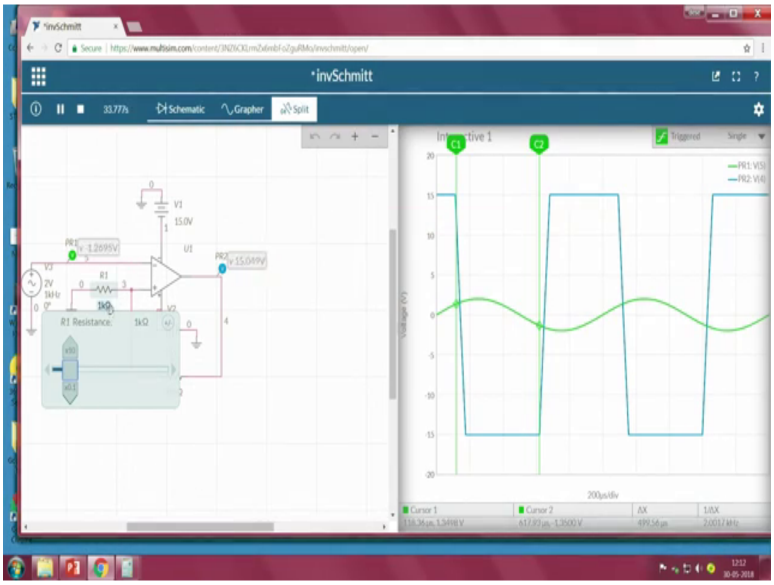

So, 10 k so, I will change the resistance value to be 10 k now, right.

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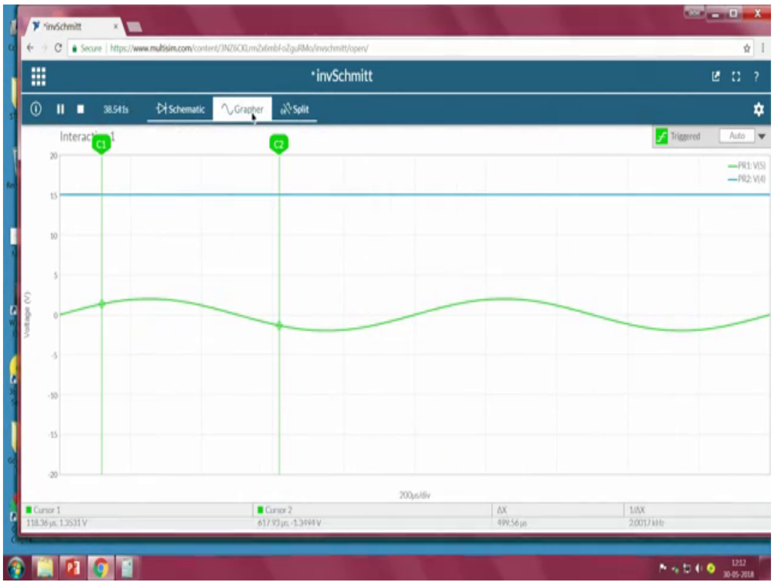

So, I will now, what is happening here? When we observe that, when you look into only the grapher, I can only see plus 15 I mean, I cannot see any change in the pulses, I cannot see any pulses, the reason is that the input voltage, when we look into the higher threshold and lower threshold values, right the higher threshold value 7, 7.5 lower threshold value is minus 7.5, but what about my input? Input is lower than the threshold value, that is the reason we can only see one output V cc.

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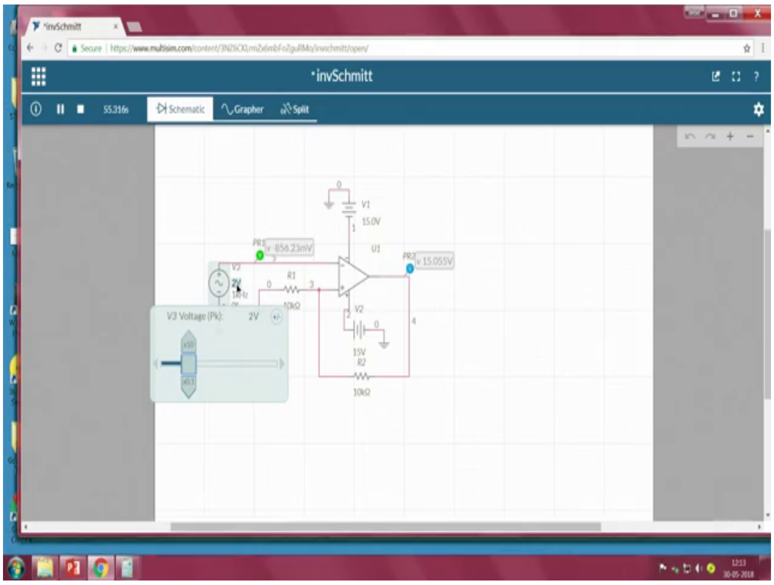

So, in order to see the effect of the system effect of circuit, the thing is we will change our input peak value to higher than our higher threshold value. So, what I do? I will go to somewhere around 10 volts. Peak value is 10 volts; that means, peak to peak is 20 volts, now when we see yes, we observed it.

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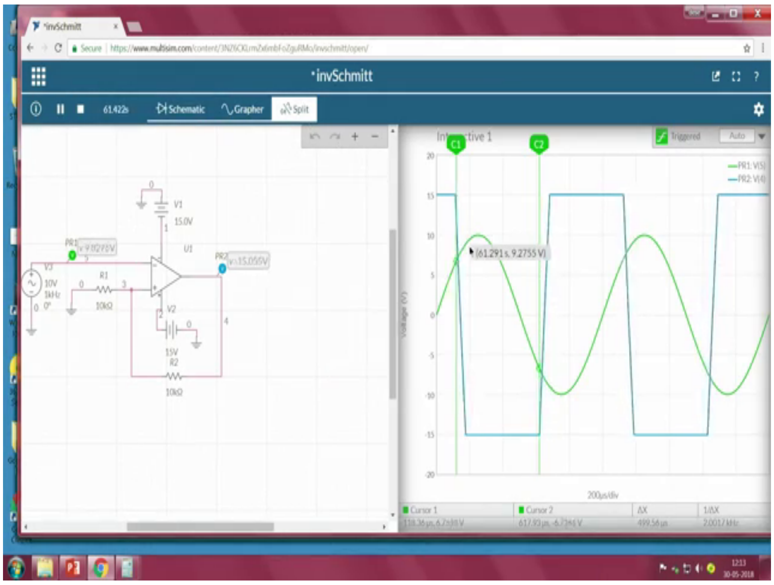

So, I will make it as single.

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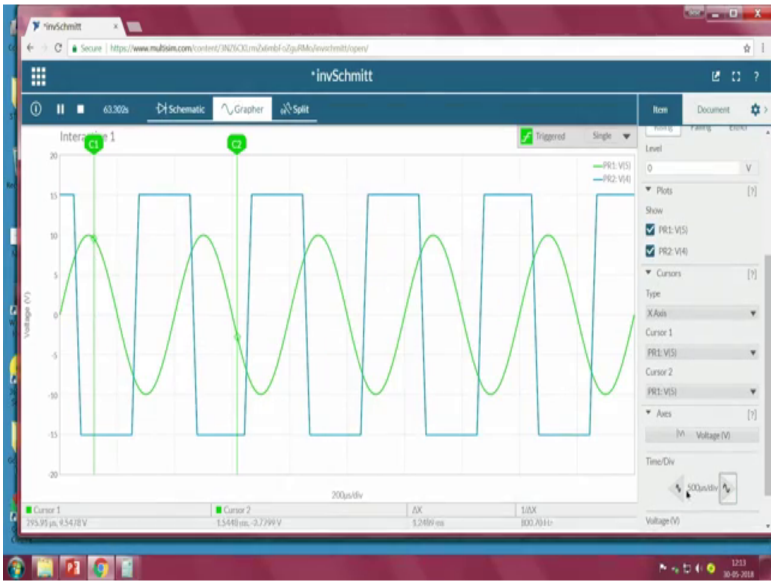

So, then go to the grapher I will go to the settings, I will increase little bit, ok. Now here we observe. So, what are the thresholds now? 1, 7.5 minus 7.5 and plus 7.5 so; that means, when the input signal is greater than higher threshold value in this case is 7.5, the output should be minus V cc, that means minus 15 volts. And in if the input is lower than 7.5 volts; that means, lower than minus 7.5, that is our lower threshold value, the output should be plus V cc.

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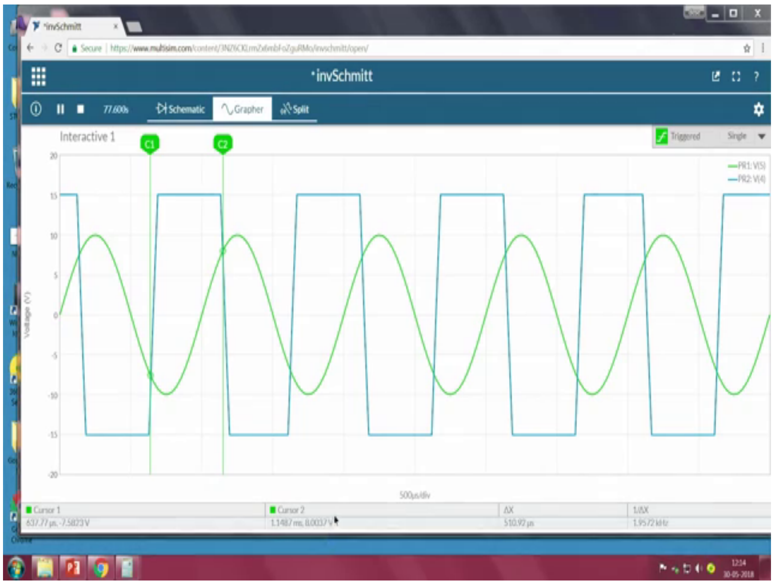

That means output should be plus 15, let us observe. So, I will move the cursor towards minus V cc, minus 7.5 sorry, lower threshold value, I can it is almost close to yeah minus 7.3, right 7.5 8 I can see the cursor one. So, it has it is going towards plus V cc right. So, which is similar to what we have discussed. then I will take this 1, I will move closely towards more than plus V cc, meaning, the higher threshold value 7 point plus 7.75 observer here, this is somewhere around 8 volts. So, I will move towards 7.5, 7.6 7.4, 7 approximately 7.5. We can say that whenever the input is higher than the 7.5, we can see it is moving towards our minus V cc; which means that, it is acting as whatever we have expected, now we look for other settings too.

So, other resistance value that we choose is one is 1 k other one is 2.2 k.

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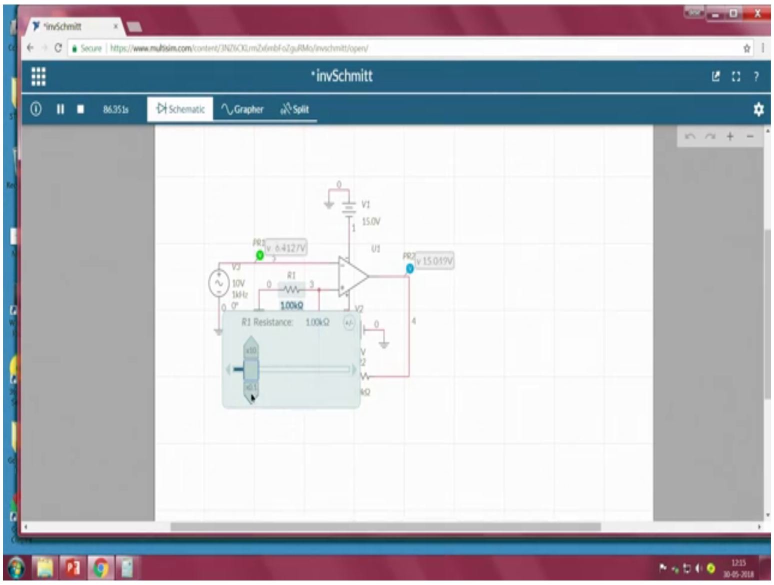

This is 1 k so, I will change it to 1 k and they should be 2.2 k, 2.2 k.

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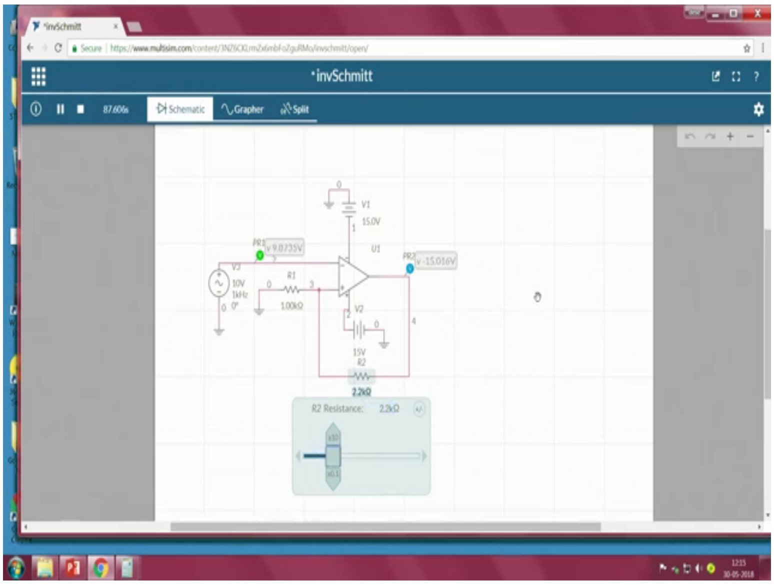

Now what are the thresholds? Higher threshold is 4.6875 lower threshold is minus 4.6875.

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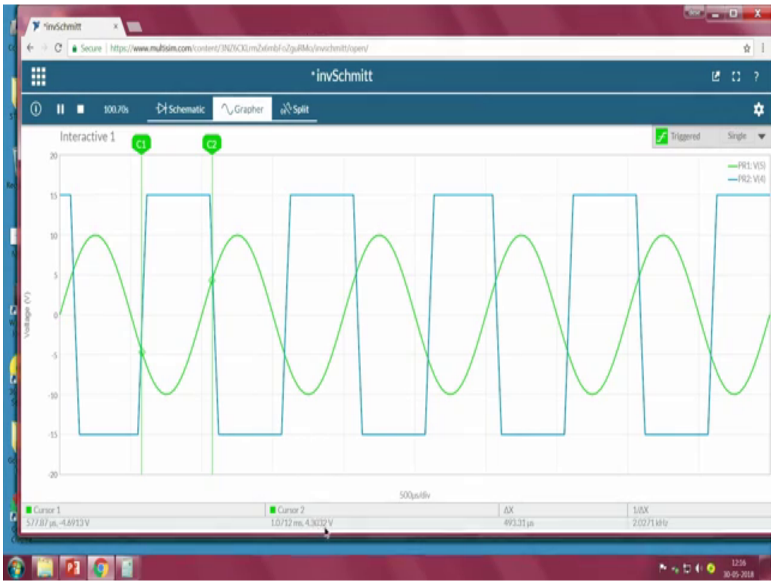

Meaning, when we look into the circuit, how should it work? The circuit should work like when the input voltage is greater than 4.6875, the output should be minus V cc meaning minus 15 volts, and when the input is lower than minus 4.6875, the output should be plus V cc meaning plus 15. Now what I will do? I will move my cursor towards 4867, minus 4.6875.

So, I am closely moving to somewhere related to 4.6875 yeah 4.69. So, approximately equal to that, I can see when the input is higher going to lower than this particular threshold value, the output is going towards plus 15 volts. Similarly, when I move towards first to higher thresholds, somewhere here you can observe cursor 2 4.3032. So, I will I have to little increase 48, 469, sorry, 4 point yeah, somewhere around 4.7 approximately. I can see that when the input is higher than the, that higher threshold value; so, the output is the output is minus V cc.

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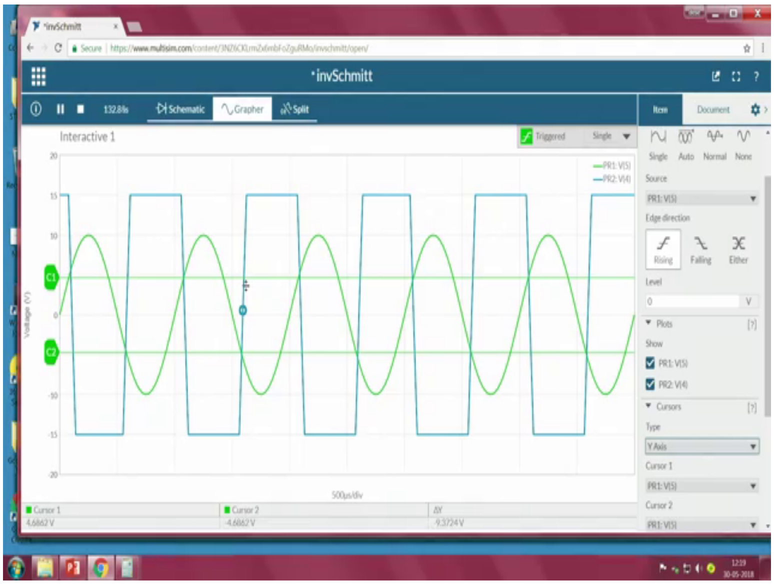

So, I will put using y axis cursors, right we can see the thresholds too 6 point, 6 4.6875 right.

So, 4.6875, yeah, 4.68 minus 4.68, yes. So, this is the C1 whichever if you notice here this C1 is nothing but our higher threshold value. So, we can clearly see that, when the input voltage this green color line is greater than the C1 value this higher threshold, this is going to the output is going to minus V cc. When the input is lower than C2 which is nothing but our lower threshold value minus 4.68 the output is going to plus V cc.

Now in realistic way, where we use such kind of a triggers? Imagine for example, like say imagine I have an water heater and I want to switch on at one particular temperature, but I should be switched off at another particular temperature. It should not be below the same temperature; when you observe the difference between a comparator and Schmitt trigger, we can see some black between the switching on and switching off, it is not at the same time.

Whereas in case of a comparator, if the input is higher than the particular threshold it will on if it is lower than that same threshold value it will off, but in this case it is not like that. When the input is greater than one particular threshold, it is which going to low and when the input is lower than the threshold, that that threshold it is not going to high. But in order to make it high, the input should be even higher than, even lower than the first threshold value, only then it goes to the high right. So, this is how our this is a difference between the inverting Schmitt trigger and a comparator. Right now we will see by connecting the same circuit using the TI board. And we will see whether the experimental results are matching with the simulation, as well as our theoretical calculations too.

Now, when we look into the board as we have already seen, the complete the board how it looks like everything in our last sessions. So, we are going to use only this particular part which is OPAMP basic type. So, this board contains TL082 as we have already know that, this is a dual OPAMP. So, within the single IC it has 2 OPAMPs. One OPAMP is at this point, other OPAMP connectors are at this point.

Now the powering the powering is done by using this connector here. The powering is done using this connector. So, since we are using plus V cc and minus V cc as plus 15 and minus 15 we are using the power supply, we are using this power supply channels which is the red one is plus 15, plus 15 the green one is minus 15, and this is the ground terminal, the black one we can see here, the black one is the ground.

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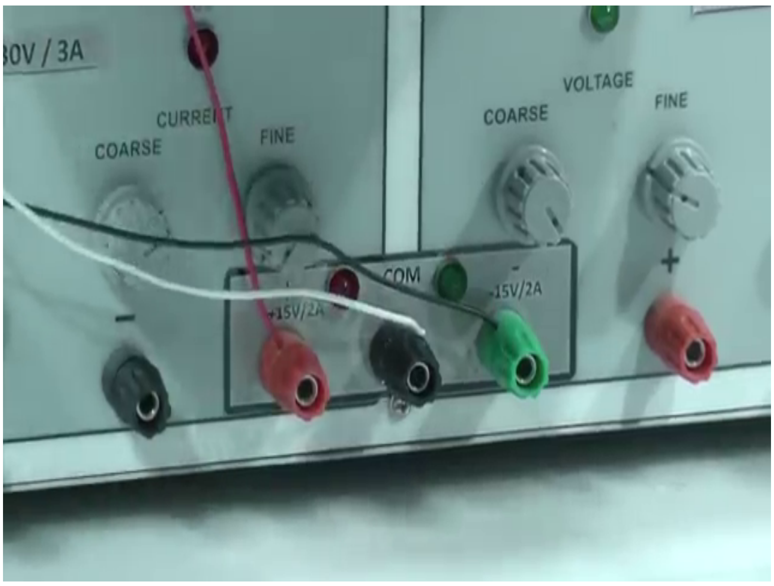

So, using this wires the red is connected to plus 15, the black is connected to minus 15 and the white is connected to ground. So, we are connecting in the same way. Here if you observe, the red is connected to the positive supply. So, since it is connected here all the OPAMPs are powered with the same V cc. And the black is connected to the negative value here; we can see here this is a negative right.

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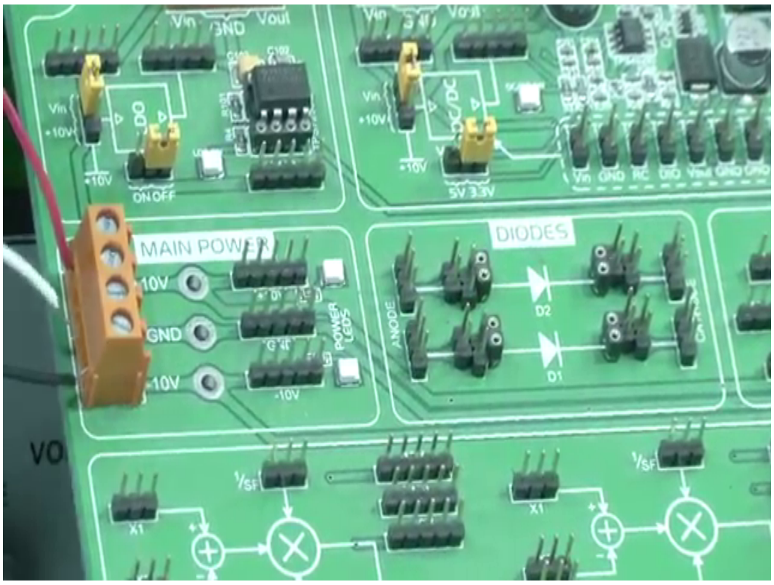

And the white one is connected to the ground, right. We can clearly see here; that means, the OPAMP right now it is working with plus 15 and minus 15 volts. Since the OPAMP can go can powered by even more slightly more than plus or minus 15 volts. So, are using plus 15 and minus 15, because even in a simulation and even in a theoretical calculations of higher threshold and lower threshold.

We have used plus 15 and minus 15.

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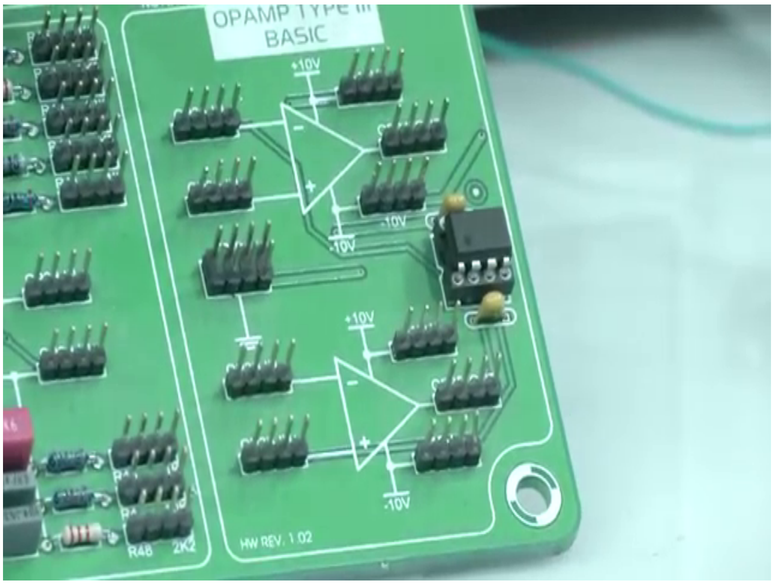

Now what we do is that, we will use this particular portion of the OPAMP, and this particular portion does not contain any resistors, but we require resistance, is not it? So, what we do is that?

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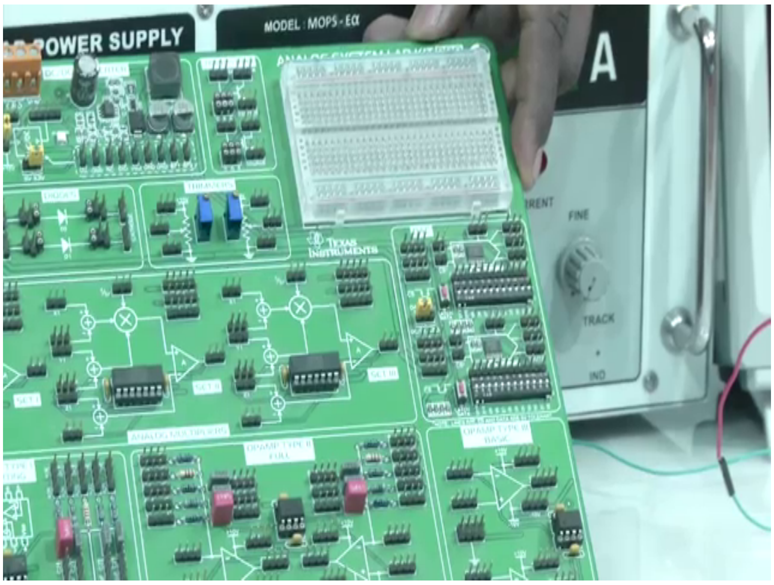

We use this breadboard to connect those resistance value. So, what are the resistance that we have used 1 k 10 k and 2.2 k. So, using this breadboard we will connect the resistance, and we will wire it using the jumpers. So, when you clear when we see this OPAMP, the negative terminal is a top one, the positive terminal is a bottom one, right? And the negative terminal has some bulk connectors.

So, using the jumpers, we can wire from this bulk connectors to our bread board. And when we see even the positive terminal, we have another bulk connectors even using this we can wire it. Then the bottom one is already grounded; whenever we require a ground we can take directly from here right.

And output we can see here, this is our output. And we do not have to connect any plus V cc and minus V cc; here since, we have powered it at that particular at the main power source. Now we will take resistors we will take a jumper wires and will connect it. So, first one we will use R 1 as 1 k R 2 as 10 k, right. So, we will use R 1 as 1 k and R 2 as 10 k. So, how do we connect it? The negative terminal has to be connected with connected with function generator. So, if you observe here, if you observe this is our function generator, these are function generator probes.

So, the resistance now we are using is 1 kilo and 10 kilo, and we are using a function generator we are using a function generator to provide the required signal. So, what signal that we use what are the thresholds. If you remember, it is lower threshold is minus 1.35 volts and a higher threshold is 1.35. Now we have to put our input signal higher than the positive and the negative threshold values. So, we will set we will set in this function generator. So, the peak value should be of the peak value should be more than 1.35.

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So, we will take 2 volts, in this simulation we have taken peak to peak of 4 volts or peak value as 2 volts. So, frequency of 100 watts we will. So, we will go to amplitude sorry, amplitude and the peak value peak to peak how much, we set 4. So, we will set the value as 4 peak to peak, right. So, input voltage is greater than our threshold values. So now, we will switch on. So, we will switch on the supply. So, this starts giving us the input value. Now this has to be connected to where we should connected to the negative terminal. This we should be connected to a negative terminal. Now when we look into the board so, which is a negative terminal in this point? This particular portion is the negative connector. So, we will be connecting to this point right.

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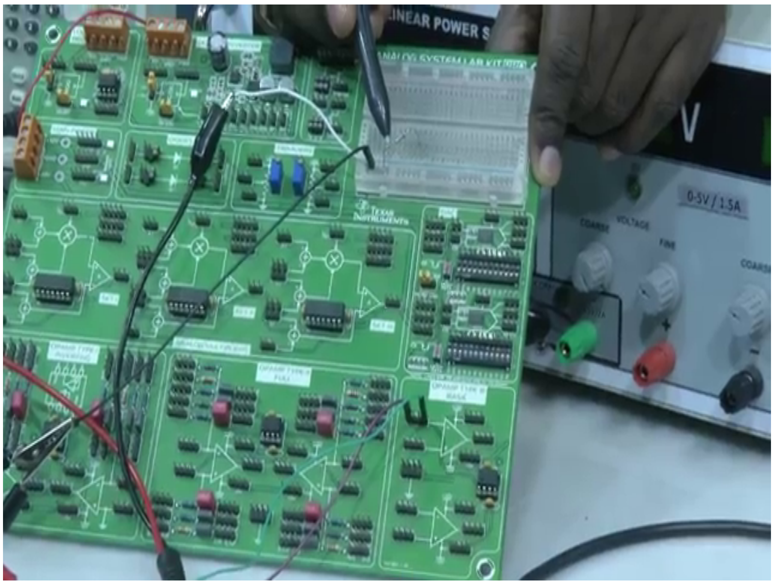

So, this input is connected to this. In order to visualize both input and output from the CRO, one connector from the CRO. So, in order to visualize our input signal, what we do is, one channel of the CRO is again connecting it to the channel of the CRO is connecting it to the input. So, here we can see this is connected one channel is connected to input here. Now the grounds of the both should be shorted. So, what we do is that so, we will use in a breadboard. So, the grounds everything we will connected to the negative terminal here so, negative is ground for us. So, all grounds we can common it. So, we are connecting to ground, then we have to connect R 1 and R 2 resistors. So, we will take 1 k resistor and 10 k resistance.

So now we are taking a 1 k resistor and that should be connected this is 1 k is nothing but our R 1. So, this should be connected between positive terminal and the ground. So, if you observe here, the one lead of the resistor is connected to the negative is connected to the negative here.

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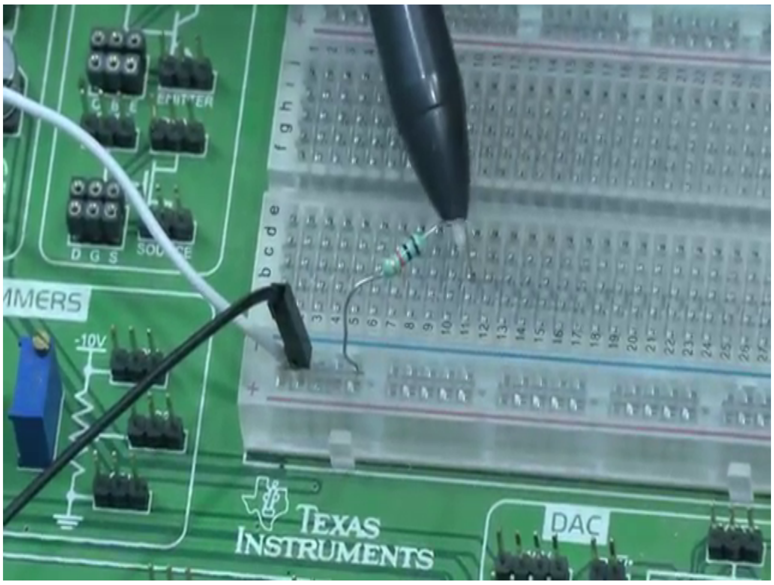

And other lead of a resistor we are going to connect it to the positive terminal of OPAMP. So, positive terminal of OPAMP is this particular point. So, to the positive terminal to the resistor other part is, other part is we have to connect a feedback residence. So, feedback resistance is 10 kilo. So, we will take 10 kilo. So, 10 kilo should be connected across positive terminal and output voltage. So, if you observe the one terminal of 10 kilo is connected to the junction point, right here we can see the junction point.

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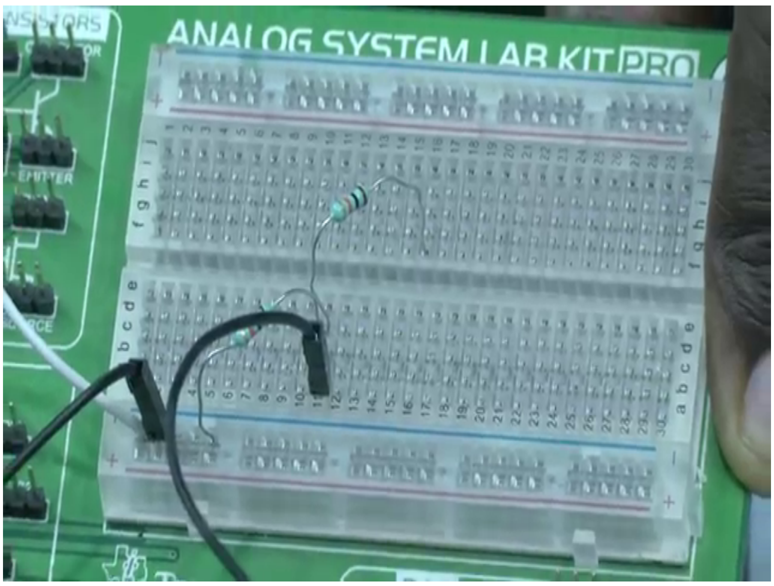

This junction point is nothing but this junction is connected to the positive terminal of OPAMP. The other terminal of op map you are going to connect it to the output voltage. So, we will use one more jumper. And so, this is our output, this is being connected to the other terminal of resistor, right clear. Now the ground, the ground should be connected. So, we will take one more jumper, the ground from here should will be shorted to this particular ground so that everything will be at same point. So, take ground and to ground, right circuit is clear.

So, what we have done? The input is connected to the positive negative terminal, since it is an inverting Schmitt trigger; input is connected to the negative terminal as well as CRO first CRO probe is also connected to the negative terminal. And R 1 resistor is connected across positive terminal of OPAMP to the ground, right? The ground is also connected to the ground terminal that we have we can see here, yes. And R 2 resistor is connected across connected in the feedback; that means, across positive terminal of an OPAMP and the output voltage. In order to visualize an output, we will take another CRO probe; we will take another CRO probe. And we will be connecting it to output voltages. Other terminal of CRO probe will be connected to ground, right.

So, we will switch on CRO, function generator is already switched on. Let me switch on CRO.

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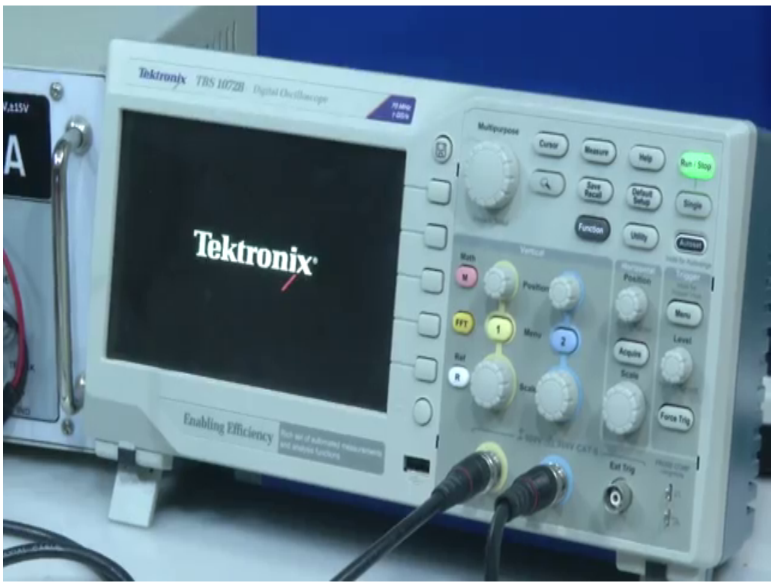

So, this yellow is input and the blue is output. We can see whatever the signal that is coming from our function generator will be in yellow in color; the output received from the OPAMP voltage will be blue in color.

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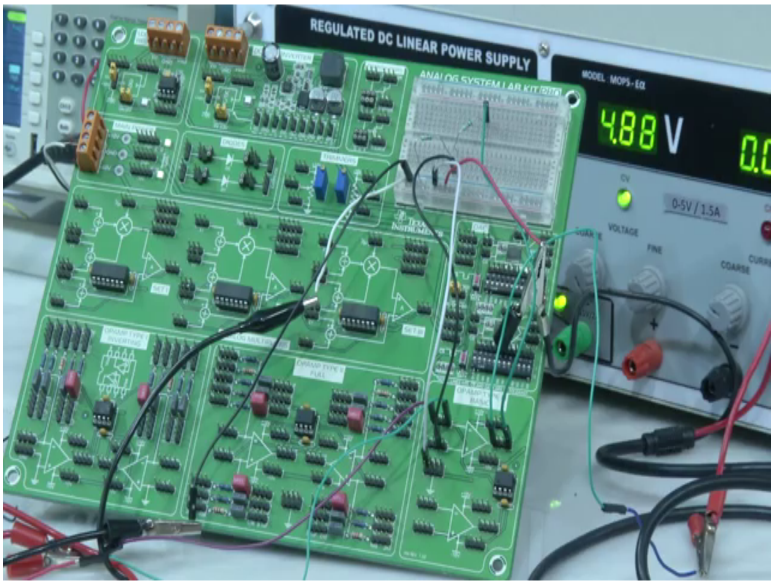

Now, so, if we see here we made all the connections now, and input is also connected to the negative terminal out, and CRO is also connected to the negative terminal, that is nothing but from the source. And output is also connected another terminal another channel of CRO is connected to the output of operational amplifier.

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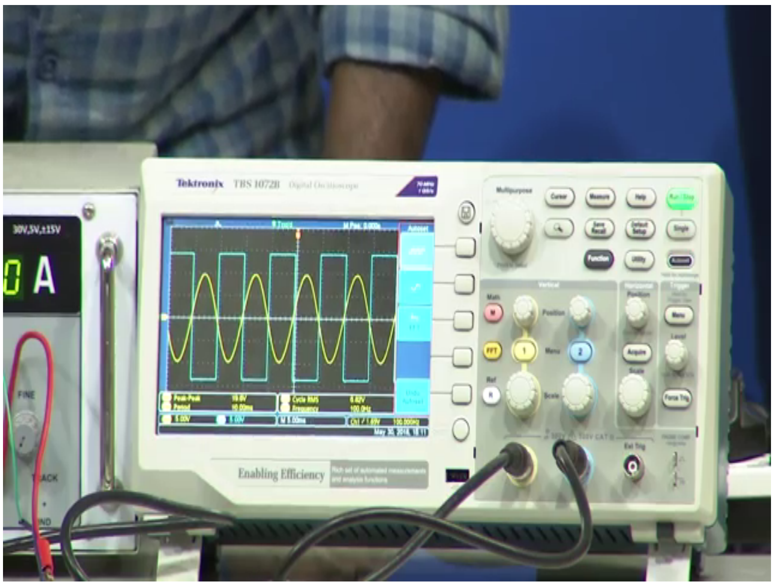

So, when we look into the CRO output, we can see here the yellow represents R input right, this is R input and the blue represents our output value. Now what are the threshold since the resistor that we have used is 1 k and 10 k, the thresholds are 1.35 is a higher threshold value, and the lower threshold is minus 1.35.

So, when input is greater than higher threshold, the output should be plus minus V cc. Since it is an inverting it will be always [FL] inverting. So, I will cursor here and, I will make channel one cursor, and the I will take amplitude, ok. I will take time and here the cursor one I will select the cursor one I am selected the cursor one here we can see, and when you see the cursor one reading, I will take any one of the peak, any one of the value.

I will move slowly towards one 1.35. So, right now it is at 7 volt, I will decrease, decrease, decrease; decrease to now it is at 2 volts. Now, right now 3.6, 112, 1.8, 1.4. So, when we see that or what we can do that we can create since it is very difficult to tune here, we can create you know voltage thresholds as we have seen in our simulation 2. So, I will go to the cursors, rather than taking an time I will make it is amplitude cursors. So, one I will set it to the voltage when you see the cursor 1, it should be plus 1.35, I will make it as 1.35.

So, approximately as 1.4 and cursor 2, I will go to the cursor 2, I will make it as minus 1.35 approximately 1.4 or 1.2. So, when we see that, I have already created a 2 cursors, right. And when we look into this particular portion, this is one threshold and the bottom one is the another threshold value. So, when are the input signal is greater than this particular, see here, this is first threshold. So, I will go to the channel one, the dark yellow one first yellow one is the first threshold the bottom yellow one is the other threshold.

Now when the input yellow line the sinusoidal wave is greater than this threshold, the output is going to minus V cc, right. Now when it is going to positive V cc it is going to plus V cc only when the input is lower than lower than the lower threshold value right. So, it is clear that it is following as per our as per our theoretical and as well as our simulation too. Now we look into the other resistance value. So, other resistance what we have taken? We have taken 10 k and 10 k.

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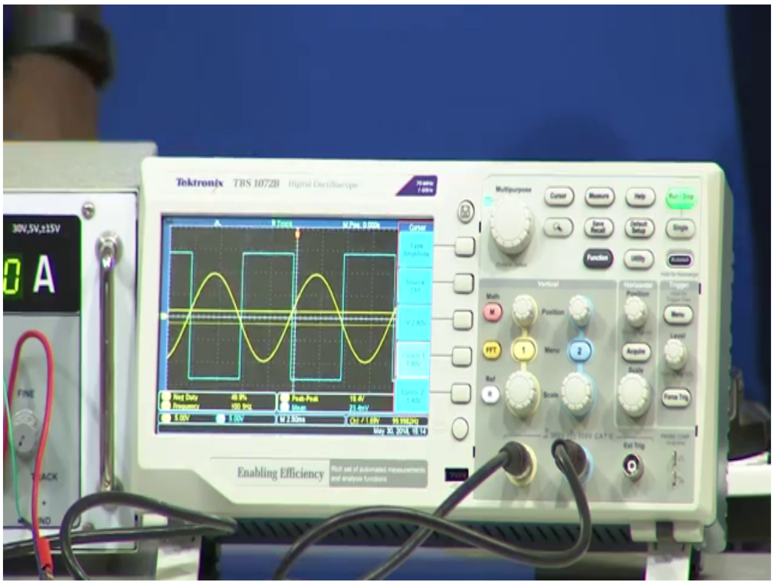

So, when we will look into the board. Now we are right now the circuit is connected with 1 k and 10 k, we will replace this 1 k resistor when we see this is 1 k resistor which is connected to ground and reference. We will replace 1 k resistor. So, before replacing it, we will be switching off the power supply. So, connecting across ground and negative terminal, right because the feedback resistor is already 10 kilo ohm resistance. Now we have connected 10 k both 10 k resistors, right as one as input one is input R 1 resistance and other one is a feedback resistance.

Now, let me switch on the circuit, I just switched on the circuit. Now what are the thresholds now? It is nothing but beta into V cc beta is R 1 by R 1 plus R 2. So, which is nothing but 1 by 2 7.5 into sorry, 0.5 into 15 volts it is 7.5. So, the higher threshold is 7.5 lower threshold is minus 7.5. So, the output will become the output will become higher only when the input signal is lower than the lower threshold value. Whereas that means, when the input signal is greater than 7.5 it become minus V cc when the input is lower than minus 7.5 it will become plus V cc. And that is what we have also seen in our simulation to.

Now, we will look into the CRO how is the signal is a, right. Now when we look into that so, we have to change our cursors because this is the cursors are placed based upon the previous values, previous resistance value. Now when I move the cursor towards when you look into the cursor one, right. Now the value is at somewhere around 2.2 I will move towards 7.5 positive 7.5, 6, 6.8, 7, 7.4, I am making it to 7.4. So, because it is very hard to make it 7.5 on this and again I will go to the cursor 2.

So, cursor 2 I will make it as minus 7.5, oh. It is going positive so, I will move it down move it down now right now it is at minus 8.6 slowly coming up minus 7.4. So, we can see cursor one is connected to 7.4 cursor 2 is connected to minus 7.4. So, this is cursor 1, the top yellow line we can see here this top yellow line is cursor 1, the bottom yellow line is cursor 2, right. So, here we can easily see that when the input signal input sinusoidal signal this line right, when input sinusoidal signal is greater than the first cursor the output is going to minus V cc. And the input, sensorial signal is lower than the lower threshold value, the output is becoming plus V cc, right which is also similar what we have seen.

Now, we will take 1 k and 2.2 k. So, the values of our thresholds are minus 4.6875 and plus 4.6875. So, when we look into the board, we will switch off the power supply once. So, the output is becoming 0, when we focus on the board, we can see replacing of 10 k with so, 10 k resistor is the feedback resistor. So, R 1 is 1 k resistor and R 2 is 2.2. So, both the resistors has to be changed. So now, we are connecting R 1 which is 2.2, sorry R 1 is 1 kilo. So, we are connecting 1 kilo across ground and positive input terminal.

And the feedback resistor is replaced with 2.2 k. So, the beta value will become 1 kilo divided by 3.2 k which is 0.3125, right. And higher threshold and lower thresholds are 4.687 and minus 4.687. So, how does it work? When the input voltage is greater than plus 4.6875, the output should be minus V cc. And again when the input is lower than minus 4.6875, then the output will become plus V cc. Now when we look into the CRO, the connections are done, when we look into the CRO, we can see here that now we have to replace our cursors points.

Now, what we do is, we will go to the cursor 1, we will make it as 4.68. So, right now it is at 6, 5, 5.2 so, 4.8. So, the cursor one this yellow line is at 4.6, 4.8 so, we need 4.68 so, 4.6. I moved then I will go to the cursor 2, I will change it to 4.6, right. So, here we can observe that, when the input signal is greater than this yellow line the first yellow line, right the output is becoming minus V cc. Whereas, when the input is lower than second cursor line, it is going to plus V cc.

Yeah, we can see here, when the input is greater than plus V cc, sorry, first cursor line which is 4.6, then the output is minus V c minus V cc. And when the input is lower than minus 4.6, this particular yellow line, the bottom yellow line, the output has become plus V cc right. So, when we verified both the theoretical practical as well as simulation got the same thing. I hope you understand the practical applications of the Schmitt trigger, as well as how to do the connections, and how to verify the working of the Schmitt trigger, inverting type of Schmitt trigger. In next module, we will discuss about non inverting type of Schmitt trigger.

Thank you.