Electrical Measurement And Electronic Instruments

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Lecture - 60
Schmitt Trigger

Hello, in the last class we have seen how to convert a sine wave or a triangular wave into a square wave which can be applied at the input of a clock, at the input of a counter so that we can measure the frequency.

In particular we have seen what is the problem if the input signal is noisy and how we get rid of that using a Schmitt trigger. In the previous class, we have studied the functional behavior of a Schmitt trigger how it acts or what it does. We have not seen this circuitry or the realization how was Schmitt trigger is made. So, let us talk about that in this class ok.

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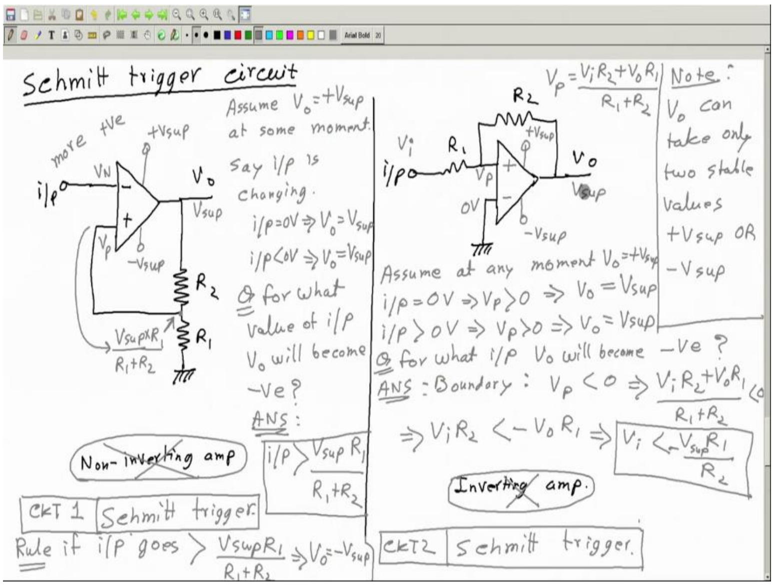

So, the topic is Schmitt Trigger circuit; you may already call that in an additional video we actually have seen this while studying op-amps and I just have mentioned that Schmitt trigger is nothing, but wrongly connected amplifiers inverting or non-inverting amplifiers ok. So, we found it like that let us first draw inverting and non-inverting amplifier.

So, let me draw the op-amp plus minus; you can give the input here, you can give feedback to the negative side; negative input like this is V o this is call this R 2 R 1, this is grounded which means this is what? This is non-inverting amplifier non-inverting amplifier right. Now, let me also draw side by side the inverting amplifier. So, this is the feedback resistance, this is the call it R 1, R 2 let me give the input here like the input here and this output this is what? This is inverting amplifier these are correct circuits.

Now, I will draw wrongly connected oppositely connected amplifiers what; what I will do? I will simply make this minus and this plus ok. So, let me make it minus and make this plus. So, now this is no longer a non-inverting amplifier ok. We have done detailed analysis by this is no longer an invert non-inverting amplifier, output will no longer be proportional to input.

Now, in this circuit output can take only two stable values which are either this V supply plus V supply or the minus V supply; these are the only two stable values of the output output will not take any other value between this plus and minus V supply ok. So, this is not an amplifier but this is Schmitt trigger ok. Similarly, here also if you make this opposite make this minus make this plus this will no longer be an inverting amplifier, this will become also a Schmitt trigger.

Here also output can take only two possible values; two possible stable values V supply and minus V supply ok. So, note for both this both this type of Schmitt triggers; they both will act as a Schmitt trigger, there is a small difference which we will study soon ok. For both of them V o can take only two values, two stable values plus V supply or minus V supply ok.

So, I request you please go back up in one of those videos where we did at detailed graphical analysis; I mean with drawing the static characteristic of an op-amp resolve how the output what should be the output voltage you may go back to those videos that will be helpful I guess ok.

But let me also tell you very quickly let me give you some intuition here. Consider this circuit if; if I give say some of, let us do the analysis this way. Let us take it for granted that output can take only these two values positive V supply or minus V let us take it for granted at this moment; I will just define it ok. So, assume V o = + V supply at some moment at some moment.

So, this; so at this point what can I write? V supply positive. So, what will be the put value of the voltage at this point? Their supply potential divider rule here because no current goes in this branch, this current is 0 you know. So, this is 0 volt; so,

$$\frac{Vsupply\ R1}{R1 + R2}$$

So, this is the voltage at this point; now I give some input here which I can change ok; say also say input is changing. Now, if the input is say 0 volt if I; if I make the input equal to 0 volt, what will be the output? Say if this is 0 volt, this is this is positive, this is also positive right this is positive. So, this is also positive if R1 = R2; then this is nothing, but half of this; so that is also positive. So, this is always positive if this is positive this is positive, so this is also positive.

So, this point is at the same value like this and it is positive. Now, if this is 0 this is positive, so V P is at a higher value than V N. So, output will be positive V supplied. So, it will remain that positive supply if I make this equal to 0. If I make it lower than 0; if I make it lower than 0 ok. Let me also write what I just said right now input equal to 0 volt implies V o equal to V supply.

Now, if I take input equal to less than 0; so this is negative, this is positive. So, V P is at higher value and if V P is at higher value what is the output? Output is positive ok. So, then let me write input equal input less than 0 will also imply output equal to V supply. If I make the input say slightly positive slightly positive; slightly positive input, then what will be the output? This is positive but this is slightly positive and so if this is more positive the output will be still positive because as long as this is at higher potential, the output will be positive right.

So, if out input is slightly positive; output will remain at V supply will not change, but now say I make the input more and more positive ok. So, I make it more positive; then it depends whether this input is greater than the current value of V P or not ok. If the input is less than V P; then output will remain positive, but if I make input higher and higher more and more positive; then at some value this V N will be greater than V P and then the output will become immediately negative.

Now, let me ask at what value of the input; this output will become negative ok? So, question; for what value of input V o will become negative? This is the question, what is the answer? The answer is simple; the input has to be greater than the value of V P which is this ok. So, answer is the input must be greater than this value;

$$\frac{Vsupply\ R1}{R1 + R2}$$

; if the input is, so this is the rule if the input is greater than this value; this is a positive number because V supply is right now this is output is positive; so a positive value is coming here.

Now, if I make the input more positive than this; that means, V N more positive than V P; then output will switch immediately from a positive value to negative value right. So, this is the boundary or transition value, this is the value of the input if you make the input beyond these more positive than this; output will become negative ok. So, here I can write the rule if input goes beyond greater than

$$\frac{\mathrm{Vsupply\ R1}}{\mathrm{R1 + R2}}$$

; this will make V o negative; V o equal to negative darkness negative V supply ok. So, I can let me write minus V supply.

Fine, now then what will happen? Then so; so now so the moment when input has gone below this value; above this value sorry above this value, output is now negative. So, let me now write that now ok; now output is negative at this. So, let us see what will happen after this. So, now output is negative and input that has gone above this value ok. Now, so if; so this is minus V supply if this is minus V supply, then this will also be -

$$\frac{Vsupply\ R1}{R1 + R2}$$

potential divider rule and then the same value comes here.

So, this is now negative; so now this is negative ok. So, at this moment this is negative and input is positive. Now say if I am decreasing the input ok. So, now, I am decreasing lowering the input what will happen to the output? Output will change the moment input which the same as V N goes below V P ok. So, now, output will change ok.

I could write it here if input goes below ok; now if input goes below this value this is minus $-\frac{Vsupply\ R1}{R1+R2}$

; if input is decreasing and now it becomes lower than this value, then output will become output will change. If this is lower than this then output will become positive again because this is lower, this is higher then output will be positive; positive again ok.

So, the moment input goes lower than this; output will become positive V supply ok. So, that is the rule. So, let me it is let me write that starting from the starting from the fact that now V o is negative V supply ok. So, I could ask the same question for what value of input V o will become positive now; it is now already negative. So, for what value of input it will become positive? And the answer is input has to go below this value ok. So, this is the boundary value of the input or transition value of the input, when both these are V N and V P are equal and then if you decrease input further; then output will be positive ok.

So, for this Schmitt trigger ok; so let me write the rule.

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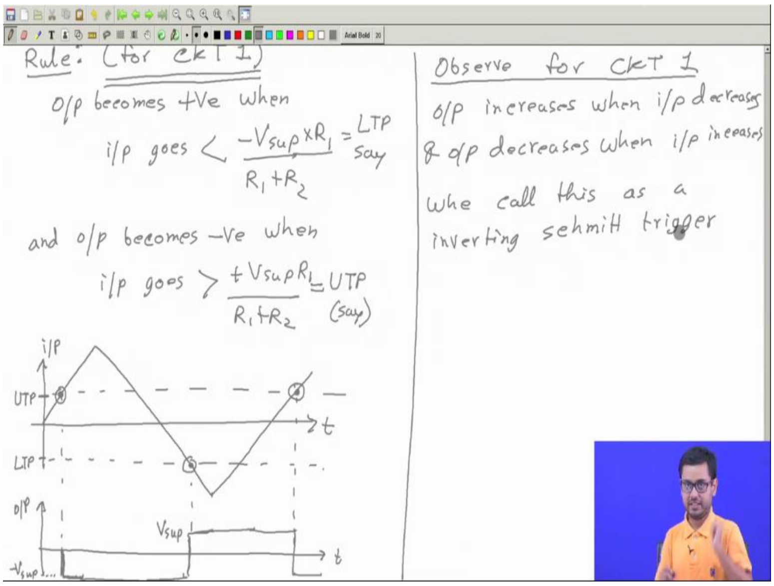

Output becomes positive if or when input goes below and output becomes negative when input goes above ok. So, let me draw some diagram time versus say input say the input is changing like this; maybe a triangular wave, you can also use sine wave and say this height represents the value of this V supply ok.

So, let me call this value as the upper trigger point let me just give it a name a particle point; say I let me call this value the negative we supply oh this multiplied by R 1; R 1 (Refer Time: 20:16) let me call this as LTP say ok.

So, let me denote this height say this height is same as this UTP and I am saying this height is LTP right and then how will the output be output? So, you see at this moment, output is sorry input is crossing the upper trigger point is going above this; so output will become negative. So, at this moment output will become negative I do not know what it was before that but at this moment it will surely become negative and it will remain negative until and unless here input goes below this lower trigger point ok; so here and then it will become positive.

So, up to this point it will remain negative; negative means minus V supply and here it will become plus V supply and it will remain; so until and unless I reach this point when it will become again negative ok. So, this is how this circuit works and let me call this, let me call this as circuit 1; circuit 1 and let me call this as the other one I will call it at circuit 2.

So, what I have done here this is for circuit 1 ok; just observe. So, this is for circuit 1 observe for circuit 1 again. The output decreases when input increases; similarly, here output increases when input decreases. Output increases when input decreases and output decreases; goes down, goes low when input increases opposite behavior input increases, output decreases right.

So, we call this as a inverting Schmitt trigger; twice inverting? Because when input increases, output decreases this is called an inverting Schmitt trigger which is nothing, but wrongly or oppositely connected non-inverting amplifier ok. So, we did the analysis for this; now let us do the analysis for this circuit how will this behave ok.

Let me start writing from here; once again I will my approach will be very similar ok. So, my approach will be I will take it granted at this moment that output can take only two stable values positive V supply and negative V supply I will justify that later. For now let us assume output can be either positive V supply or negative V supply. So, let us assume at any moment V o output = + V supply positive ok.

So, this is positive and this is this is at 0 volt. So, this is input call it V i and this you can call V P. Now, output is positive; say if input is 0 if say input is equal to 0; 0 volt, then this is 0, this is positive what will be V P? At a some sort of average of this two voltages; V i and V o you know this is nothing, but let me also write the value of V P here

$$Vp = \frac{Vi\ R2+V0\ R1}{R1+R2}$$

a weighted average of V i and V o this is V P. Now if input is 0 volt, then V P will be positive this is positive. So, assuming this is positive V supply; so this is positive, this is 0; so this is this will be positive of course, ok.

So, this implies V P greater than 0 positive and if this is greater than 0; the static characteristic of op-amp says this is greater than V N. So, output will be positive output will remain positive output will remain at positive value. Now, say I make input greater than 0, so this is positive, this is positive V P will of course, be positive and therefore, output will remain positive.

Now, say I make input less than 0; then what will happen? If it is slightly negative, but this is sufficiently positive ok; so, here you can see this is slightly negative this is sufficiently positive; so their combination can be still positive. So, this can still be positive, so output will remain positive.

So that means, slight negative input will not change the output. So, I have to make input sufficiently negative; negative enough so that this point V P goes below V N; 0 volt then only output will change. So, let me ask the same question, the question is for what input V o will change; will change or will become, so in the right now it is positive will become negative? Let me make some space ok. So, this is the question for what input output will become negative; answer what is the answer?

I have to make it sufficiently negative so that V P is slightly lower than 0 volt and then we will then the output will change ok. So, what is the boundary condition? The boundary condition is that the value of V P should be so that; sorry value of V i should be so that V P is equal to 0 for that is the boundary condition ok. So, the boundary condition; so the boundary condition is the condition when V P = 0 exactly equal to 0.

this is the boundary condition. So, if you make V and what is the value of V o; at this moment V supply ok; so I can write this as V supply.

So, this is the boundary condition if you make V i lower than this then output will go from positive to negative ok. Similarly, now once this is already negative then what will happen ok? Now let us see.

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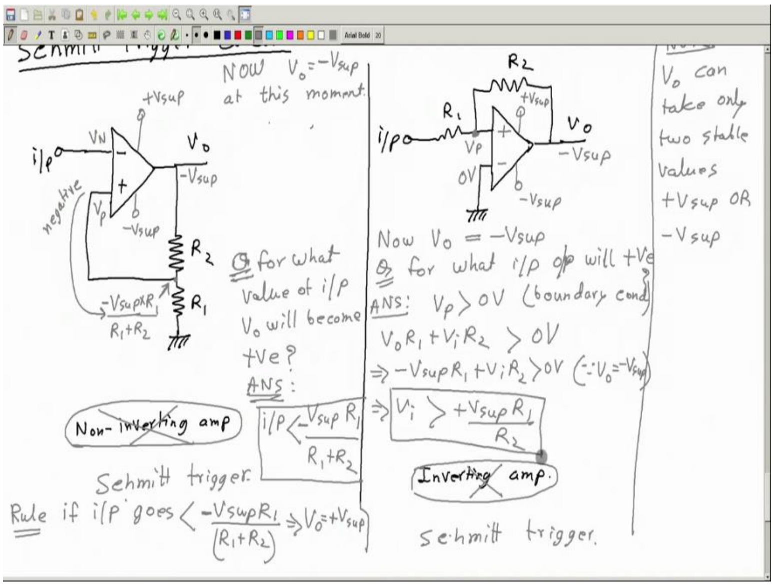

So, now this is now output is already negative. Now, V o is already negative ok; so this is minus V supply. Now, I will ask again the same question for what input output will become positive; will become positive? So, that is the question ok. So, for what input output will become positive? So, it will become positive when this V P goes above 0 volt; this is 0 volt. So, V P has to go above 0 volt so; that means, so the answer V P has to be greater than 0 volt. Now how what is V P? V P is nothing but V o; so we have it here ok.

So, let us put that value $\frac{Vi\ R2+V0\ R1}{R1+R2}$; this has to be greater than 0. So, which means this has to greater; be greater than 0 and at this moment V o = - V supply. So, from this I can write V minus V supplied R1 by; this is greater than 0 this; this is the condition ok. So, this is the boundary condition boundary condition and since V o is equal to minus V supply.

So, from this I can write that V i has to be greater than I bring this on that side. So, it becomes plus V supply R 1 and divided by R 2. So, this is the condition ok; so let me write the rule for this; this circuit the second circuit; circuit 2 ok.

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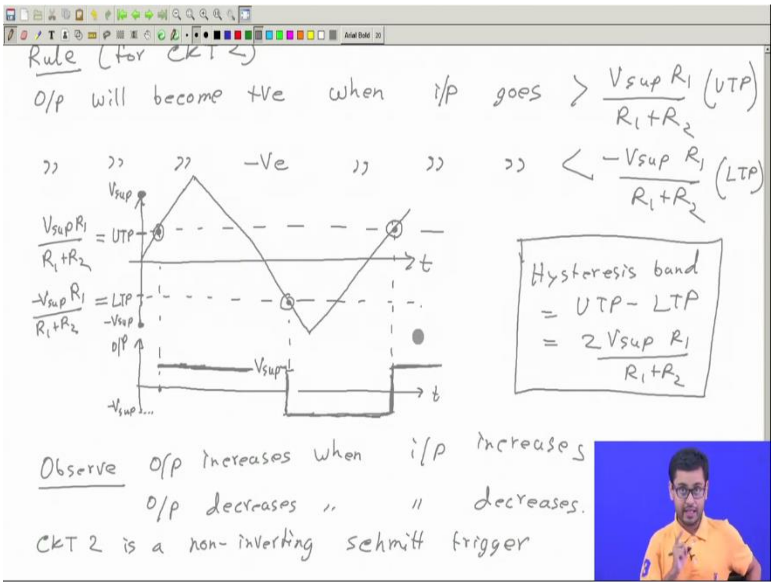

The rule for circuit 2; output will become positive when input goes above this V supply R 1 goes above V supply R 1/ (R1 + R2). Similarly, output will become negative when input goes let us see it is written here minus V supply R 1/R 2; below so; that means, this I can call the upper trigger point; this I will call the lower trigger point ok.

So, once again if I give; if I give this input, the question is how will the output look like ok? So, for this circuit you see output will become positive when input goes above the upper trigger point ok. So, this is the upper trigger point which is same as V supply R1/(R1+R2) ok; somewhere here I will have V supply, somewhere down there I will have the value minus V supply and this lower trigger point = - V supply R1/(R1+ R 2) ok.

Now if the input goes above this, output will become positive. So, here it will become positive I do not know what it was before this, but here it will become positive and it will remain positive until and unless input goes below this value which is here. So, here it will go negative like this and here it will become positive again like this ok. So, you observe output increases when input increases ok, you see here input is increasing, output is also increasing. Similarly, here you see input decreasing, output decreasing. So, there is a correlation between the input and output unlike the previous circuit where the thing was reversed.

So, here output also decreases; when input decreases ok. So, we call it; we call this circuit it is a no-inverting type Schmitt trigger. So, circuit 2 is a non-inverting Schmitt trigger c h m i t t trigger because input and output changes together; one increases, so the other also increases ok. But the previous one as I said before that was a inverting symmetric.

So, let me conclude this video; this class by saying that so what have we done so in this class? We have drawn initially two amplifier circuits, non-inverting and inverting, then we have swept the plus minus inputs here as well as here as well as and we say that this acts as a Schmitt trigger where the output can be only positive or negative positive V supply or negative V supply and we have asked a question that for what value of input the output will change from positive to negative or negative to positive; here as well as here.

So, for what input output will become positive to negative and negative to positive? To find that, you simply have to consider the rule of the op-amp which says output becomes positive if V P is higher than V N. So, find out the value of input which will may make V P higher than 0 volt or lower than 0 volt.

Similarly, here you know in this circuit V P is at this voltage which depends on V supply. So, find out the value of input which will make the input lower than V P or higher than V P so that the output becomes positive or negative ok. So, this is what we have seen and this transition values of input, we have called their upper trigger point or lower trigger point. Yes and oh last thing, as you know that the hysteresis band hysteresis band is what? Is the gap as you have defined before between these two values upper trigger point minus lower trigger point.

So, therefore, for this circuit this will become 2 Vsupply R1/ (R1+R2). Similarly, you can find hysteresis band for the other circuit and one important point last thing; in this circuit which was originally or non-inverting amplifier, we have modified it this becomes a inverting type Schmitt trigger which means output decreases, if input increases. On the other hand, in this circuit which was originally an inverting amplifier when we change the plus minus sign; this behaves like a non-inverting Schmitt trigger which means output also increases, if input increases.

Thank you.