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**Lecture – 79**
**Pulse generator**

Hello. So, we are looking at this mono stable multi-vibrator or oscillator circuit.

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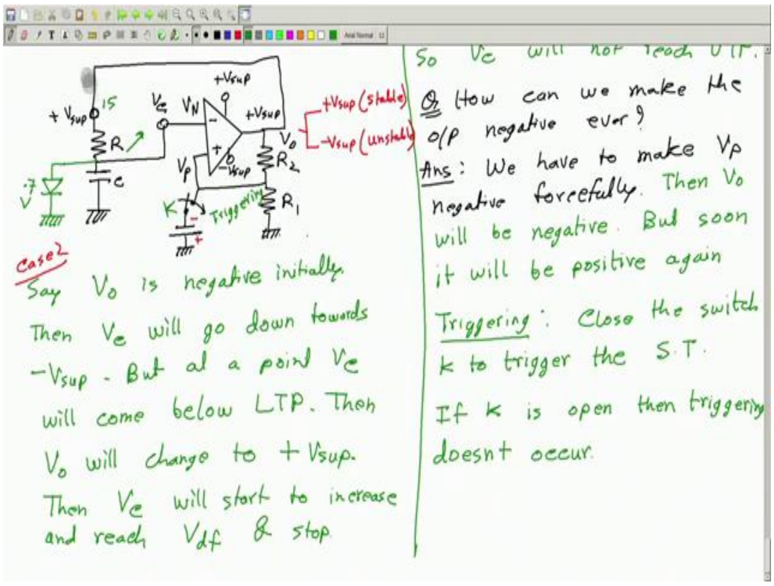


And, we so far we have seen that this circuit has two possible outputs or two possible states you can say, and the output Vo can be either positive or negative plus V supply or minus V supply. Among these two this is the stable output. So, if the output is positive at any point they need to remain positive and nothing will and the output will not change. But, minus output is not stable because if ever the output is negative then you see this negative output will try to make the capacitor voltage negative, ok. So, it will draw or pump out current from the capacitor, so the capacitor voltage will go down and down and at some moment this voltage will be lower than the lower trigger point of this Schmitt trigger and, when that happens the output will switch to positive. This is because this is a inverting type Schmitt trigger, ok.

So, once this is positive again, now the capacitor voltage will start to increase. But it will not be able to increase beyond 0.7 Volt or the forward voltage drop of this diode because after that even if this is positive the current will bypass through this diode and will not come to the capacitor and will not charge the capacitor beyond 0.7 Volt, ok. So, this is what we have seen.

And then an interesting question that we asked is that if positive output is the only stable output then can we ever make the output negative. And we said yes, we can do it forcefully how say if we connect a negative voltage directly at this point, ok, then V P will be negative it will go down. No matter whether this is positive or not because this is a direct connection, so this voltage will go to the negative value directly and therefore, this will this can become lower than V n, ok. And say if V N is 0.7 Volt at some moment and if you make this negative, sufficiently negative then this will be lower than V N, V P will be lower than V N. So, if this is lower output will be negative. So, in this way forcefully we can make the output negative, ok.

But then, so yeah we have we have to make V P negative forcefully, then V O will be negative, but soon it will come back to positive output, but soon it will be positive again. So, and ok; and there is another alternative instead of connecting the negative voltage directly here, ok, and this negative voltage connection this is called this we called triggering, ok. So, when you connect this switch the output of the circuit is triggered to become negative and after that in a short time it will become positive again, ok. This is called triggering.

And so, how to trigger? Call this switch K, close the switch K to trigger the Schmitt trigger and if K is open then triggering does not occur, ok. There is another possible modification of this triggering arrangement is this.

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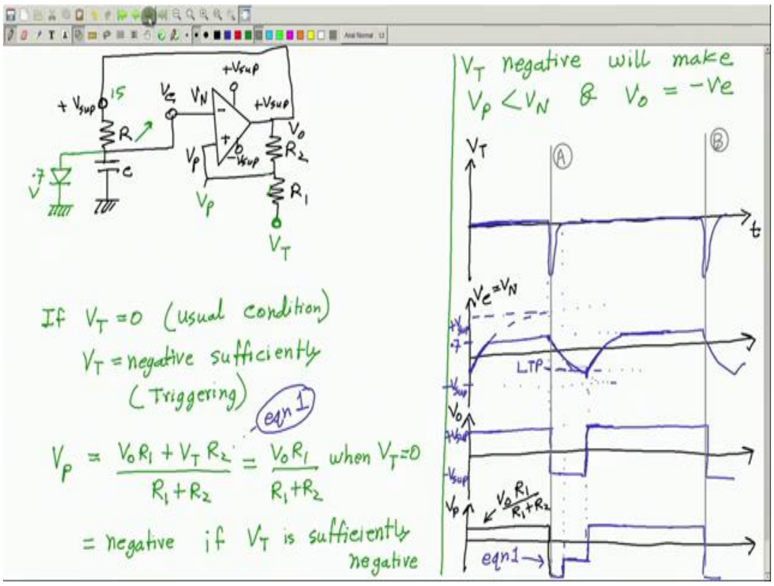


See, instead of having this what we do, we will apply a voltage here, say call this V T, ok. And V T can be positive, negative, 0, anything. So, now if V T = 0 then I mean this is like grounded, this is the normal circuit that we had here, ok. So, V T = 0 so, this is the normal I mean usual state, usual condition. And if I make V T < 0 , V T equal to negative, ok, sufficiently negative then this is like triggering this Schmitt trigger, so this is the triggering. Why? Because you see that this voltage V P, V P can be written as and this is basically some sort of average of V O and V T, ok. So, we can write

$$Vp = \frac{Vo\ R1 + VT\ R2}{R1 + R2}$$

$$Vp = \frac{Vo\ R1 + VT\ R2}{R1 + R2} = \frac{Vo\ R1}{R1 + R2}$$

So, this is the normal condition, normal feedback with this grounded. And this is equal to; this can be equal to some negative value if V T is negative, sufficiently negative, ok.

So, if this is negative then even if this is positive, if this is large enough compared to this then the total combination can be negative and when the V P is negative, you know then this is lower than V N. So, then this can be lower than V N. So, V T negative will make V P < V N and therefore, VO equal to negative output will be negative. So, this is called triggering. This way we can bring the output to negative value. And then it will not stay there for a long time it will go back to positive value, ok.

So, let us draw some timing diagram. So, this is time and say I draw V T, ok and what else is important? Let us draw V C there that is important, V C what else output definitely V O, ok. So, let us see how it works.

Say at some moment this voltage V T is 0, it is kept 0, ok. If this is 0 and say initially also V O is a positive, ok. Say, if V O is positive means equal to plus V supply, V O is positive then what is going to happen to V C? Say we start with some initial value of V C once again, the initial values are just assumptions, you can start from any value you choose, say I choose V C starts from this, ok.

So, if it is starting from this value then this is positive here so that means, this is positive plus V supply, V C starting from a negative value. So, it will try to go to plus V supply. So, it will try to go to this range plus V supply. So, it will try to go they are exponentially like this, but it will not reach there because once this voltage is greater than 0.7 Volt this diode will be on and the entire current will flow through the diode. So, this will not reach beyond 0.7 Volt. So, this is 0.7 Volt, ok, although this is not in proper scale 0.7 should be much closer to 0 than V supply, but ok, for this for now it is ok.

So, it will just reach up to this 0.7 and then it will not increase any further. So, then it will stay at that value, ok, it will stay at that value forever. This entire current goes through this, so capacitor is no longer charging. So, V C stays at this value and this V C same as V N. This is V C which is same as V N. So, this stays at this value forever, ok.

Now, see at this moment after a while I make V T negative for a brief period, like this, sufficiently negative, ok. So, till then you know this V C will remain at this position, output will also remain at that value up to this moment, ok. And at this moment what will happen? This V P will change, ok, this V P will. Let me also draw V P, V P. So, you see in this part, this V P will be also flat because here V P is same as this output multiplied by this potential divider fraction. So, this is $\frac{VO\ R1}{R1+R2}$ because V T = 0. So, V T is 0 means only V O will decide this voltage.

Now, here in this region V T is negative. So, V T negative means it will make V P also negative for this brief period. If this is negative this will also become negative because of this expression, this is negative, so this is negative. Now, if this is negative then you see V N was here, so here V N is positive, V P is negative, this will cause the output to go to negative V supply, right. So, the output will go to negative V supply. And let me just erase this a bit, ok.

Now, when the output is negative, then what happens? So, now, you see so, in this region see let me call this equation 1. So, here equation 1 is valid, ok. So, now you see V O is negative and V T is also negative here. So, these two negative things will make or keep the V P to negative definitely because V O is now negative and V T is also negative. So, these two together will make V P negative. So, it will stay there. Now, after a small while V T is becoming 0, ok. So, after this moment, if I come here V T is 0, after this point V T is 0. So, here this term will be 0, but now you see V O is already negative; V O is already negative because V O has gone negative.

Now, therefore, V P will still remain at the negative value, not as much as before because now V T is no longer negative only V O is negative, but anyway the combination will still remain negative, ok. So, this is how it will be. It will be less negative once this V O has reached 0 and it will remain like this if. So, you see V P is lower; V N is V N is at this point. So, V N is higher. So, output may remain negative. But there is another thing which has started to happen by now. What is that? That is the fact that this negative voltage is now making the capacitor negative, ok. So, this voltage will therefore, come down, will try to come down towards minus V supply. So, it will try to come down to this value exponentially like this, ok.

But at some point, it will reach the lower trigger point if this is the lower trigger point, ok, if this line is the lower trigger point of this Schmitt trigger, and you see this, it is coming below lower trigger point therefore, here output is my output, this is my output will become positive again. And once this output becomes positive, V P, this voltage will again go back to this value $\frac{VO\ R1}{R1+R2}$ where this is positive V supply. So, it will come back here to this height and it will remain there forever. This will also remain there. And now, what happens to the capacitor voltage?

This is positive, just you do the analysis on your own that is better. Do not please, please do not listen to me because if you just blindly listen you will not follow it really. So, do the analysis yourself, if you find any difficulty then check with my analysis, ok. So, we were here that output is positive V O is here negative and sorry not V O, V C; V C is negative output positive. So, this positive value will now bring the capacitor up to a higher voltage.

So, it will now come up, but how much up to 0.7 Volt only, because after that this diode will get short circuited or open, so entire current will flow through the diode and not through the capacitor. So, this will remain there forever like this. So, this will remain there forever output will remain positive, this will also remain there forever, until and unless I give another trigger at some point, ok.

So, this is the timing diagram. If I give say another trigger here then the entire thing will repeat again, ok. So, you can just copy this thing like this, similarly here it will go negative and then like it will repeat from this point this also will repeat, ok. So, if I mark this as point A, here this point B. So, point B onwards everything you can just copy from point B onwards, great, ok. Now, if you have understood this let us ask some interesting questions.

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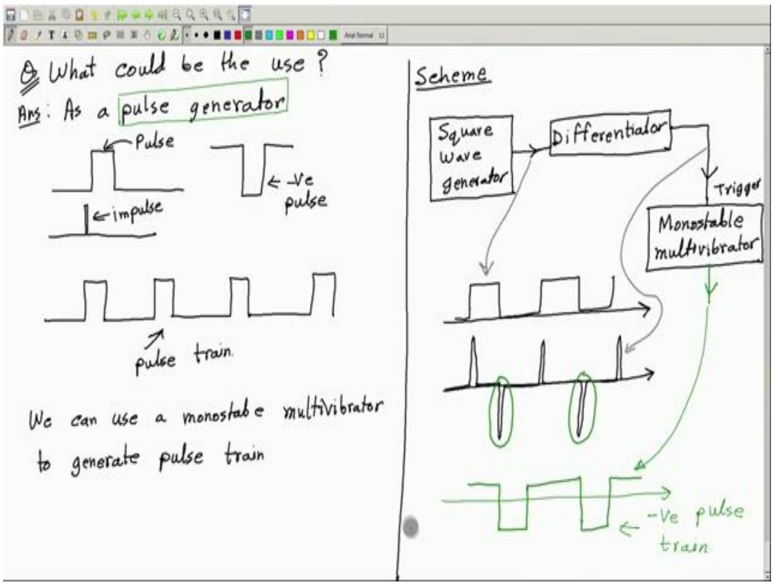


So, number 1, question number 1 ok. I think the most important question you might be thinking of is that what this is useful for. So, what is the use? What could be the use? Use or application, ok.

So, it can have many uses I will just talk about only one, this can be used as a pulse generator. What is a pulse first of all; what is a pulse? A pulse is a voltage like this, ok. So, this is say initially 0 and for a brief while it goes to positive, so this is called a pulse, ok. Similarly, this can also be a pulse, this is a negative pulse. So, this type of voltage pattern is called a pulse and if this pulse is very narrow, and the area under this is finite one in that case we call it an impulse. Impulse is a special type of pulse you can say where the duration is very small, but the area is nonzero; although the duration is small that is an impulse. We are not talking about impulse, now we are talking in general about pulse, ok.

And so, we can also have a pulse train, which means repeated sequence of pulses, this is a pulse train. And this type of signals is often very useful in many experiments in laboratory to generate the sequence or this train of pulses, ok. So, just like we need a function generator which can generate a square wave we or triangular wave, we also sometimes need a pulse generator pulse train for some experiments, ok.

So, this is also like a rectangular wave ok, this is also like a rectangular wave with duty cycle not equal to 50 percent, ok. So, to generate this type of pulse train we can use a monostable oscillator circuit which we have seen like this. So, we can use a monostable oscillator or multivibrator, it is also called multi can use a monostable multivibrator to generate pulse train. How? So, this scheme is as follows, ok.

So, let me draw the block diagram. So, what we will do? We will take a square wave generator; function generator and we already have studied this thing. So, you know how to generate a square wave.

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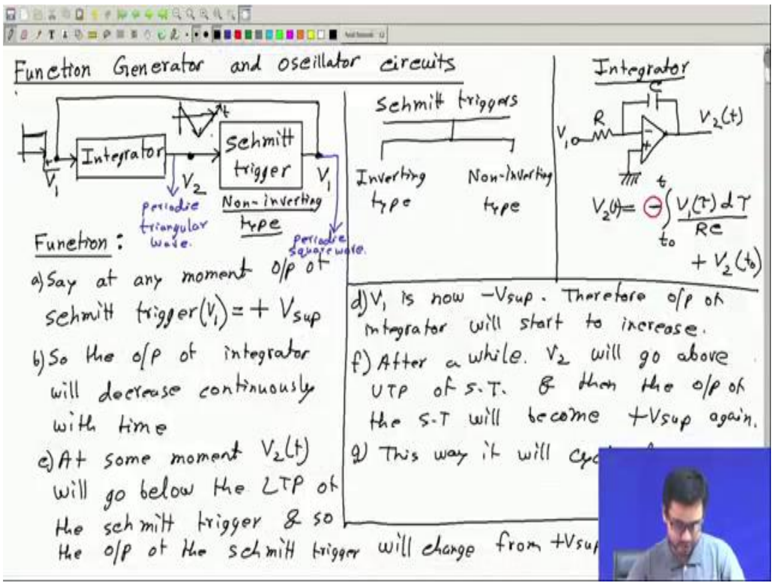

So, if I go back you see this chapter, we started with a function generator where we could generate a square wave here. So, take a square wave generator, from this you can take a differentiator. We have studied integrator, but not differentiator; I will talk about it soon. And from this you connect this to a monostable multivibrator or oscillator. This will together generate a pulse train. How? So, signal here at this point how does it look like? It is a square wave, ok.

Now, what is the function of a differentiator? You can guess as the name suggests it will just differentiate this function, ok; it will differentiate this function. So, the output here will look like this. Let me draw them on same axis. Say this is the square wave, this is here, then if I differentiate this what I get is this, 0 because here its 0. So, flat horizontal line derivative is 0, here you will get a pulse positive pulse because this voltage is increasing and then here again it will become 0 because here it is flat. Then there is a decreasing slope very high, so it will get a negative pulse or maybe impulse you can call it and then again 0 and then like this, ok.

So, this is the voltage which we have here and this goes to the monostable multivibrator. Where? It goes to the trigger means it goes to this point, right. So, you see here we are applying this voltage which is normally 0, but periodically it becomes very high positive and very high I mean high negative.

Now, this negative pulse’s, these are the important things that we will consider will act like these pulses, ok. There are also these positive things, I mean like this here, and I request you that you please think yourself and be satisfied with the fact that this will not have effect in a much effect, ok. So, this will not be effective; only these negative pulses will cause this capacitor voltage to vary like this, this, output to vary like this, ok.

So, if you have these pulses then you see the output of this circuit varies like this. So, here we will have the output which will be like this. So, you know here it goes to negative, it stays at negative for some time, then it goes to positive stays ever until and unless next pulse comes, next negative pulse comes and so on. This is the voltage that will have at the output, ok.

So, this will be a pulse train negative pulse train, ok. So, this way we can make a pulse generator, great. And then yeah; now, if you ok, what if you want a positive pulse train instead of a negative pulse train, what can you do? The simplest answer is just feed it to a inverting amplifier, an inverting amplifier will change the sign of the voltage right that simple, ok.

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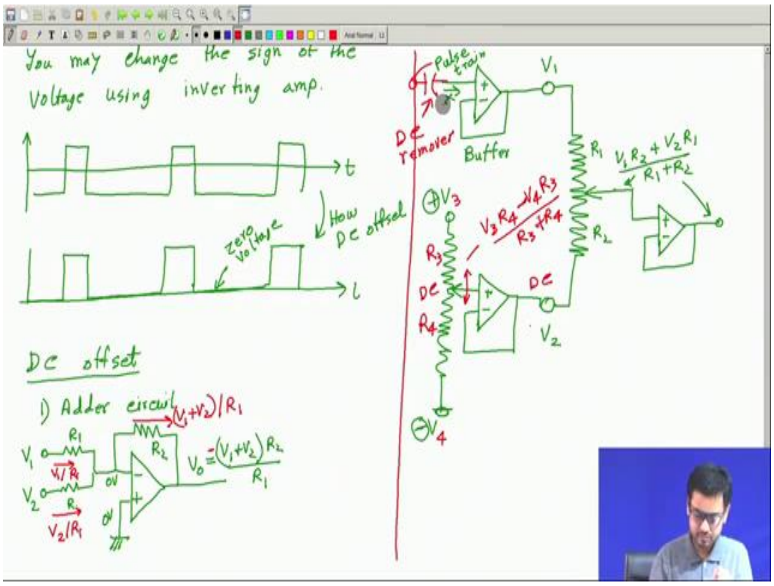

So, you may change the sign of the voltage using inverting amplifier, ok. Now, what is you may need? Suppose, ok. So, if you once you say change the sign of this voltage you will get this and this is the 0 level, ok. So, you see the pulse train is normally negative and it goes to positive sometimes, but what if you want the pulse train with the pattern like this where this is the 0 level. So, this is the 0-voltage level.

So, how can you come from this to this, ok; so, this could be an interesting question to talk about, ok. So, let us talk about this briefly. So, this is like a DC offset addition, right. So, this is DC offset addition. Now, how can we realize this? Do you know? They did there are many possible solutions. So, one possible solution which comes in mind first is just an adder circuit, ok. What is an adder circuit? It is just like this; basically, an inverting amplifier which has multiple inputs R 1, R 1, R 2. If this voltage is V 1, this voltage is V 2 then output VO = (V1 + V2) R2/ R1. Why? Please recall that we have studied this during when we were studying digital to analog converter, we have studied this circuit. And let me just tell you briefly why this is so.

So, this current if this is V 1, so this is ok. This is at 0 Volt. Due to virtual sorting this will also remain at 0 Volt. So, this current is how much? This is V1/R1. So, this current is V 1/R1. This current is V2/R1. So, therefore, this total current here will be (V1+V2)/R1, ok.

So, this is the current and this current when you multiply with this resistance R 2, that will give the voltage drop across this, that will give the voltage drop across this and this is at 0 Volt, so what will be the potential here? It will be 0 Volt minus this voltage drop, ok. I will have a minus sign here. So, this is one answer.

Another and there could be many possible solutions, ok. So, let us see another possible circuit, which is, let us leave that. I think this ok, we can do it not that is not much different from this. So, we can do it no problem, it is not difficult. So, let this is this be one voltage and to this I want to add a DC voltage, ok. So, let there to be two voltages. And, what I shall do? Ok, let me draw it here. Let this be 1 voltage to which I want to add another DC voltage this can be plus or minus.

Now, what I do? I take potential divider I take the output from here. And so, what will be this voltage? Ok. So, this voltage will definitely be, call it V 1, V 2 and if this is R 1, this is R 2 then this voltage will be $\frac{V1\ R2+V2\ R1}{R1+R2}$, ok. So, this will be the voltage here if no current is drawn. To make sure that there is no current being drawn I will connect a buffer. So, this is just a buffer, we have studied negative feedback. So, this will be the voltage at this point and similarly also at this point because this is just a buffer. So, this way we can add two voltages.

Now, among these two voltages one of them is going to be this pulse train. So, what I can do is let me take another buffer minus plus and this be the here I will have the pulse train. So, this will simply copy this pulse, this voltage from here to here, this is just a buffer. What is a buffer? A buffer is something which copies one voltage from one point to another, but without drawing any current no current is drawn that is the beauty.

So, why is that advantageous? If no current is drawn then whatever circuit is here before this pulse train that is not loaded, that is not affected much, because no current is drawn. So, that circuit is not going to be affected. So, if required I can put a buffer. And here what I will do is this, let me take another buffer. Maybe I do not need so many buffers, and here I will take another potential divider. Here, I will give a positive voltage plus V something and here I will give minus V, ok.

So, therefore, you know you see if I change this jockey up or down, then the voltage that I have here at this point will become positive or negative. If I bring it up it becomes more and more positive, if I bring it down it becomes more and more negative. And this voltage you can again express as with this potential divider rule similarly, this multiplied by this resistance plus this multiplied by this divided by whole resistance, ok.

$\frac{V3R4+V4\,R3}{R3+R4}$ So, you can bring it up or down. If you bring up this voltage will be more positive because then R 3 is reducing and its effect R 4 effect will be more, V 4 is negative let me write this minus, ok, fine.

So, this way you can change this voltage. This is the DC voltage. So, this DC voltage comes here and this DC voltage gets added to this V 1 which is same as this pulse train, right. This is very similar to this circuit actually. I mean I just have this buffer and these two buffers which you can connect here, and instead of having this inverting amplifier I have this 1 is to 1 buffer that is this is very similar, ok. And here I also have the flexibility to change the amount of DC offset, ok. And sometimes we connect a capacitor here, before the pulse I mean before we feed the pulse train to this capacitor will eliminate or remove any DC component that this may have.

So, if we want to remove the DC component that it has, so that can be removed with this capacitor and then with this voltage or with this arrangement we can add the desired amount of DC. So any DC part that the original signal has will be gone and the new DC part which I can control how much I want to add will be added. So, this is like a DC remover, ok. So, you know that capacitor will not allow DC signal to flow or low frequency signals, it is allowed only at the high frequency signals. So, the proper value of the capacitor is to be chosen, that is another prop thing, ok. Now, ok.

The last thing that we may discuss is we can do a small ok; let us take a small example problem. So, in this circuit how much is the duration of the pulse? So, this is called the pulse width, ok. So, let us compute the value of this pulse width, ok.

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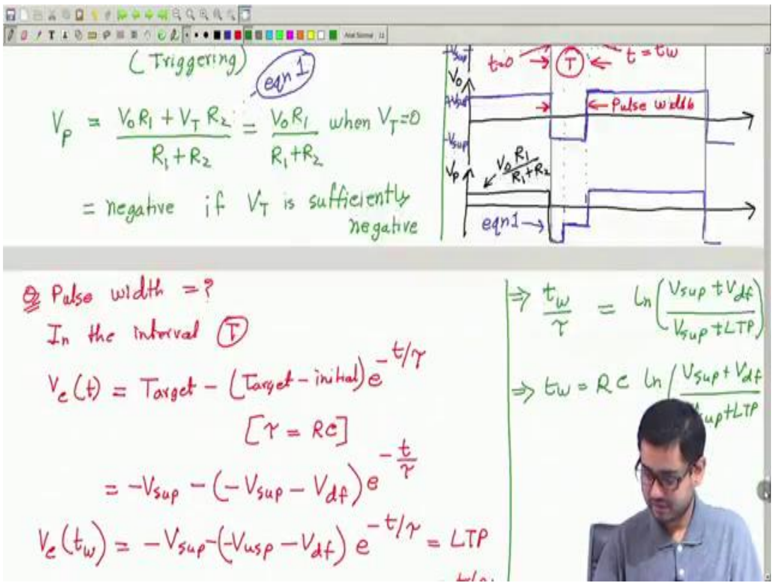


So, how can we compute this pulse width? So, you just observe that this time is the same time which is required by the capacitor voltage to go from 0.7 Volt to the lower trigger point, ok. So, this is the time required for I mean this is the pulse width. So, let us compute this time, time required for the capacitor voltage to go from minus from plus 0.7 to the lower trigger point, ok.

Now, what is the expression of V C, capacitor voltage here? Call this time interval, call this T, ok. So, in the interval T, we can write V C as a function of T starting from this as my T 0, ok, so this is T = 0.

$$Vc(t) = \text{target} - (\text{target} - \text{initial})\, e^{\frac{-t}{\tau}}$$

$$= -Vsup - (-Vsup - Vdf)\, e^{\frac{-t}{\tau}}$$

$$V(tw) = -Vsup - (-Vsup - Vdf)\, e^{\frac{-t}{\tau}} = LTP$$

$$\frac{Vsup + LTP}{Vsup + Vdf} = e^{\frac{-tw}{\tau}}$$

$$Tw = RC \ln\left(\frac{Vsup + Vdf}{Vsup + LTP}\right)$$

I am doing it quickly because we did it many a times and therefore, you have to bring V C lower than this voltage V P which is same as this. So, this is the lower trigger point, ok.

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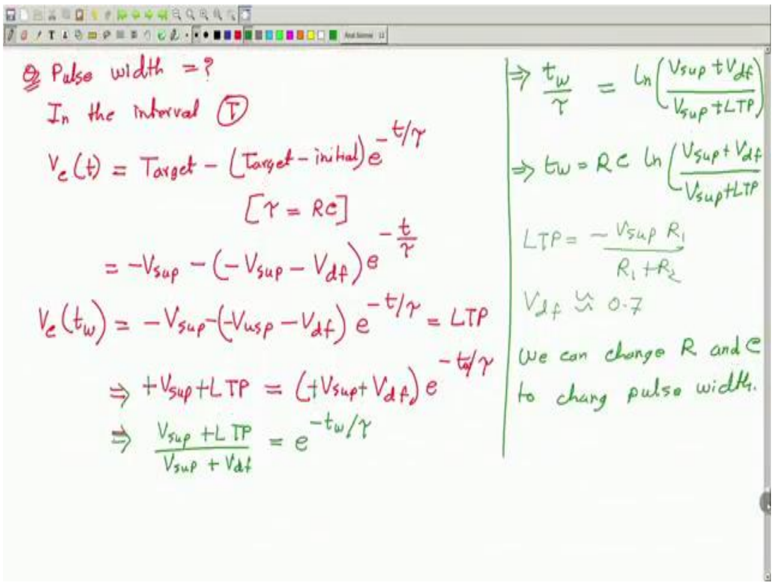


So, this is the lower trigger point, and so let us write it LTP = $\frac{-Vsup\ R1}{R1+R2}$. You can put this value here, you can put 0.7 here, V df is approximately 0.7 Volt. And now you can we can change R and or R C to change pulse width. If we want to control the pulse width make it small or large. We can change this capacitance, you can make it variable, you can make this variable and then that will give you variable pulse width generator, ok. I think this is all for this class. We will meet again in the next class.

Thank you.