Power Management Integrated Circuits
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Lecture – 76
Hysteretic Converter – Simulation Demo

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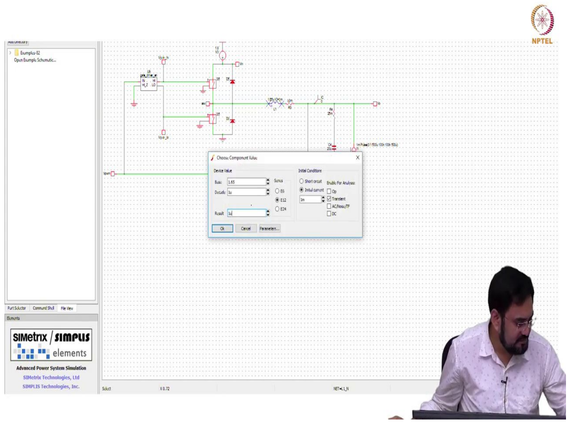

Let us put the values 1 micro 10 micro 20 milli and 5 ok. So, hysteresis is 5 10 milli. Let us put 5 milli, I need to check whether its hysteresis is peak to peak or half so, that we can look at the output. So, this is your output. So, looks like it is going peak to peak 5 milli. So, this should be 10 in that case.

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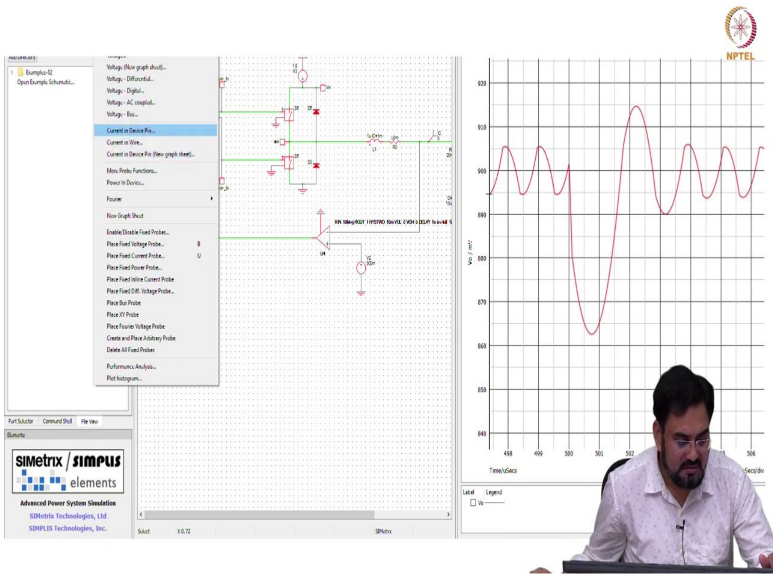

By the way, I think we did our calculation at 0.5. So, output should be 0.9. So, let us see if the peaks are aligned or not. So, probe current; so, peaks are not aligned.

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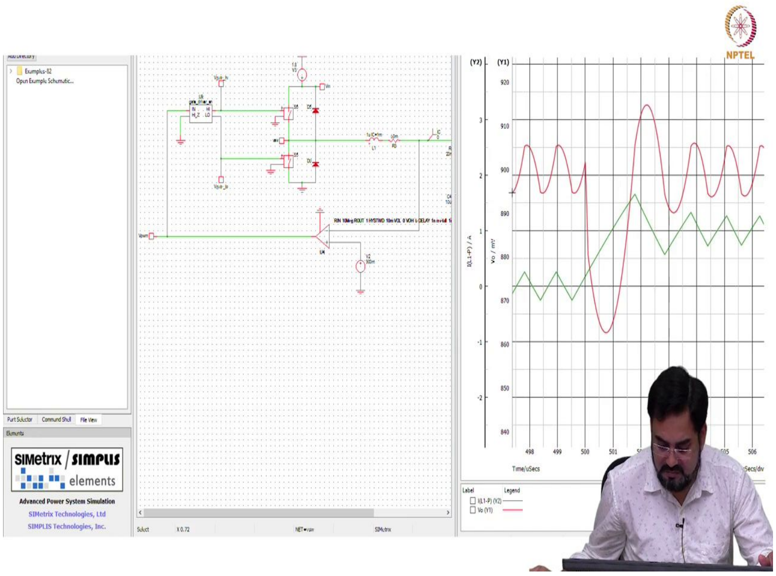

You can see here; you will still see some roll off here non-linearity.

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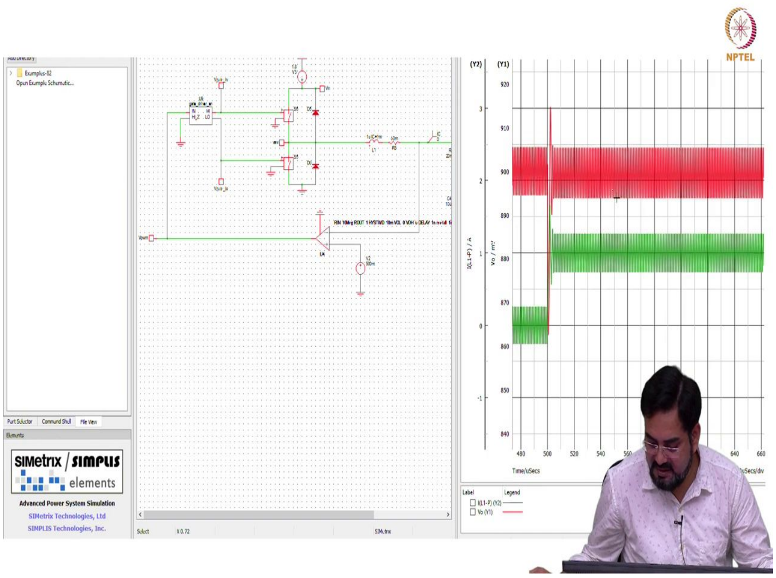

One thing you can see here when your output is changing. So, your comparator is forcing duty cycle, one all the way until your output is or the inductor current goes to load current and then it settles back. So, that is the advantage actually. So, your output will be limited why you; if you remember, we to slope of the inductor actually. You do not have any bandwidth limitation here that is why you get a transient response good. So, now in order to meet; let us check the frequency.

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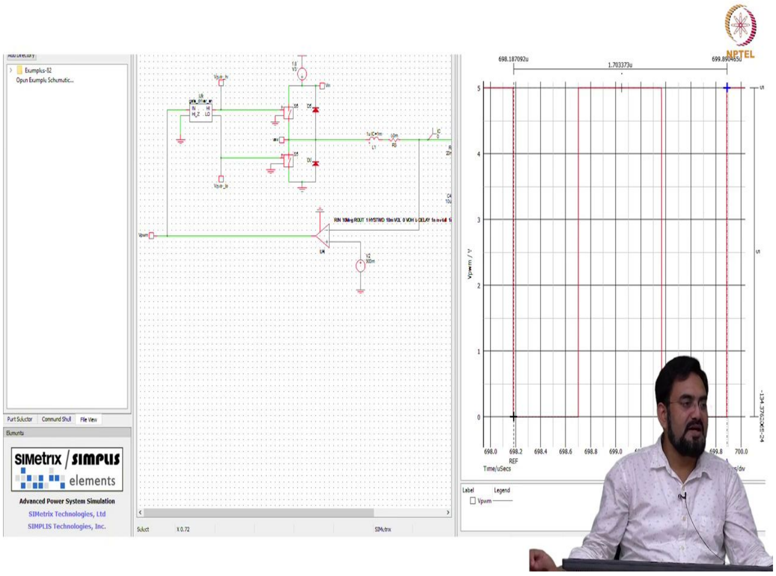

So, it is coming 1.7 micro, but we designed for 1 micro; because output is now not bounded. So, that is why your frequency is increasing because now you have a phase shift. So, that will introduce delay.

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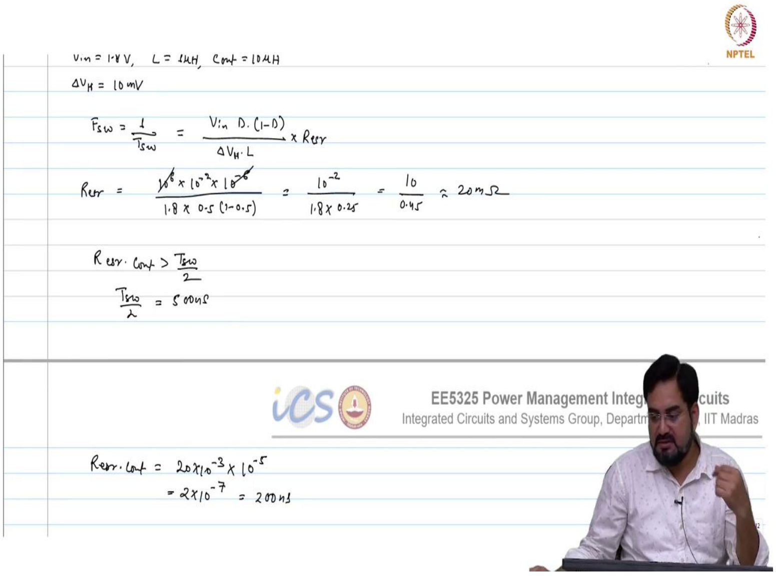

So, now to meet that condition, how much Resr I require or let us say increase the cap because I want to limit the ripple to 10 milli volts. So, how much you require? 2.5 times more. So, let us make it 25 micro farad. So, one thing you can see now, you do not have any ringing here. I mean it goes, it dips and settles back very quickly; In in there, you are seeing some ringing because of that phase like.

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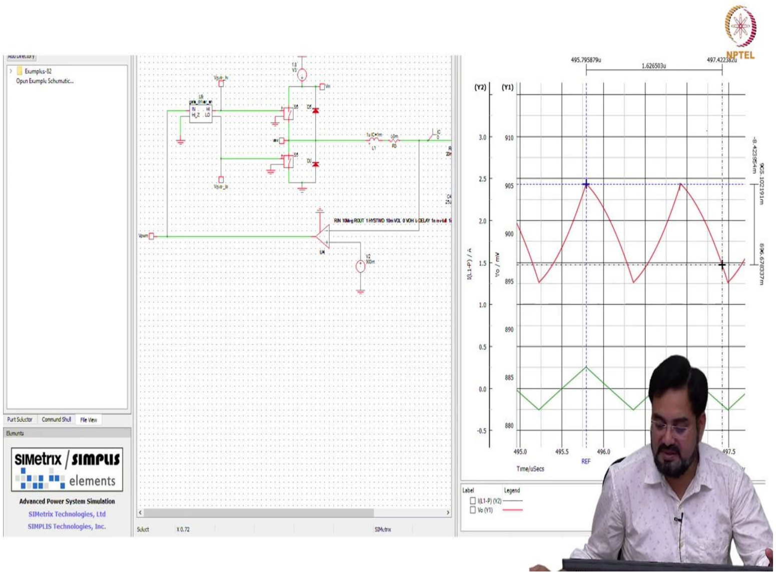

Now you do not see any curve there which was at the peak around the peak. So, your output is well bounded within your hysteresis window. So, we kept plus minus 5 millivolt, we can see 9905 and 895 rho current in your. Now you can see here. So, the peaks are see the valley is coming at valley and peak is coming at peak, let us look at frequency. So, it may not be exactly 1 micro because we did not I mean we assume that the ripple due to capacitor is 0, but it is not actually 0. So, if you take that effect also, then you can re calculate your switching frequency. But let us see it should be pretty close, let us see how much of here? It is 1.16.

So, not way of like it was coming 1.6 earlier ah; now if you keep increasing the capacitor, then you will get closer to 1 mega Hertz. But if we change the Resr, let us I change the make this Resr 40 milli. What should be the frequency?

Student: Frequency is proportional to Resr.

So, it will get double, almost double. So, let us see if that happens. So, now, we can see output looks much cleaner now, it is almost linear because the non-linearity is gone; the basically the component which is coming from the capacitor is not there at all.

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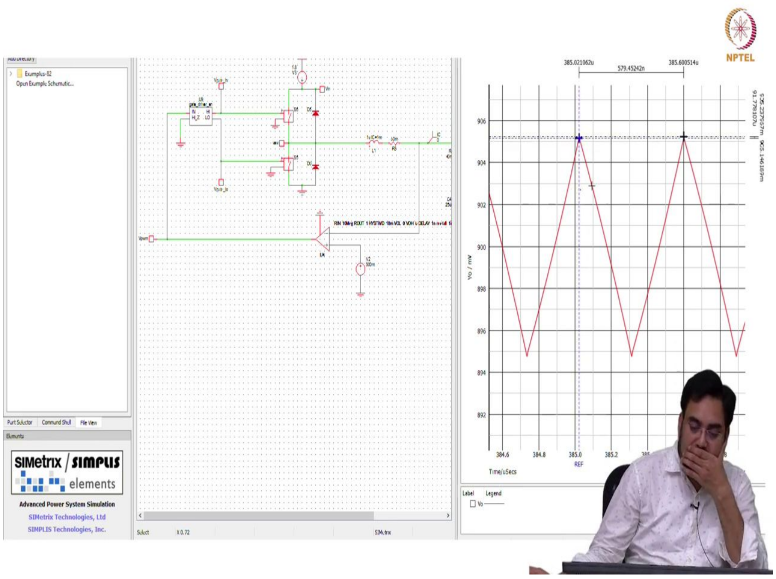

So, it should be 500 nano. Where is the other curser? Why it is coming 600 nano 600 nano is how much? 1.16. Wait, let us measure here. I think duty cycle is change there because we have applied the load ah. So, we need to measure here. It is coming 579. How much is this? 579.

Student: 579? 1.14.

No, not 1.14; 1.75. Any way I will check and see; maybe a delay in the comparator is causing that. So, it is less than what? Because so, there are several things, which we did not take into account, the delays which are coming due to this power fet and then your comparator everything. So, it will further reduce your frequency.

So, this was the 20 milli is the bare minimum for 10 micro 20 milli, we calculated. No sorry, 20 milli for 25 micro; 20 milli was for that switching frequency, but we were not meeting that R c product greater than T sw by 2. So, we had to make it 25 micron.

So, now you can see I mean you already saw so, but the problem we I cannot arbitrary keep increasing the Resr, it will hamper my. I mean even let us say I can get back the switching frequency by reducing this hysteresis window, but the problem is when you have apply a transient instantaneous, I R drop will happen here.

So, let us say I am applying 1 amp so, if I make it 50 milli amp; so, 50 milli volt drop right away will be seen by this and then on top of that from the capacitor discharge you will see. So, your transient may degrade. So, that is why we cannot just keep increasing that so. So, I am applying 1 amp you can see, but still this if you look at a transient response, this looks much better compared to your any other control like voltage mode because we are not limited by bandwidth.

So, in terms of transient, this is very good the only problem is variable frequency. What is the other problem? So, variable frequency is 1.

What about the noise? So, if you look at this comparator is limiting the output between plus minus delta V H by 2 and a V F, we define peak to peak ripple 10 millivolt; then we have only room of 5 milli volt on the higher side and 5 milli volt on the lower side; now let us say your my output is load is switching; when the load is switching, it will create a noise in the output random noise.

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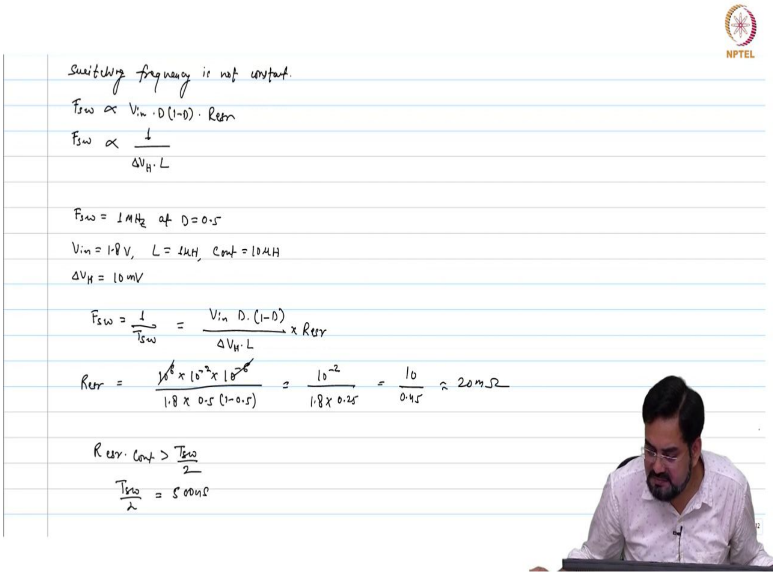

Student: Yes.

So, at any time, your comparator might trip actually; if it tries to cross that window. So, you might see random output coming at the comparator. So, it will not be looking like a clean PWM at one frequency, what your frequency may go all the way around and it will look very bad actually.

So, a spectrum will not be at one frequency, but it may spread and interfere with your system. So, noise is another problem and there are some techniques which how we get rid. So, that is why it is not very good. So, one way is like I should increase the hysteresis window. So, if I increase the hysteresis window, then which means I will get larger ripple output. So, there is a tradeoff between your ripple and your noise and also if I increase the ripple, then hysteresis window then my transient response also will go bad because now I have to wait 50 milli volt.

So, let us make it 10 times more ripple. So, which means you are looking at a 950 milli volt and lower side is 850 milli volt. So, unless my output goes below 850 milli volt, the comparator will not respond. So, you cannot achieve better than 50 millivolt undershoot here and then after that you have all the delays and everything. So, it may go very bad.

So, there is a tradeoff here and now we will see how we do so, which means we have to have some other way of decoupling the esr and hysteresis window; which means decoupling the output ripple and hysteresis of the comparator. So, we will take the feedback from somewhere else instead of taking from the output ok. So, next class we will talk about that.

So, this is only suitable for large esr you can say. For a small esr it so, let us make Resr 1 millivolt. It is very almost impossible to design this; it will always be unstable, but most of the time we look for a very high quality cap. So, then in that case, it will not work with that. So, now, we will see a technique where you can still design a hysteretic converter and make the R esr 0.

So, it will be completely independent of R esr and also the switching frequency will not depend on your L and R e s r or any power path actually this. So, it will be only a function of your; so, basically now it will be in your full control, the switching frequency. That is what in my thesis after that if you read that chapter all talks about that actually; fixed frequency hysteretic.

Now, if you have frequencies in control, then you can make it fixed frequency also ok. So, I know I cannot change R esr, the only thing I can change is the hysteretic window, but I hysteretic window will get reflected window ripple also and I cannot make it very low. I cannot make 1 millivolt ripple.

It will become much more sensitive to noise and also you cannot control with such a high resolution that hysteresis. So, we will see what are the different ways to control the frequency and you can exactly lock at two frequencies you want actually at. One I can always operate at 1 megahertz irrespective of where V in in and V out so, are.