Power Management Integrated Circuits
Dr. Qadeer Ahmad Khan
Department of Electrical Engineering
Indian Institute of Technology, Madras

Lecture – 74
Non–Linear Control of DC-DC Converts, Phase-Shift between iL and vc

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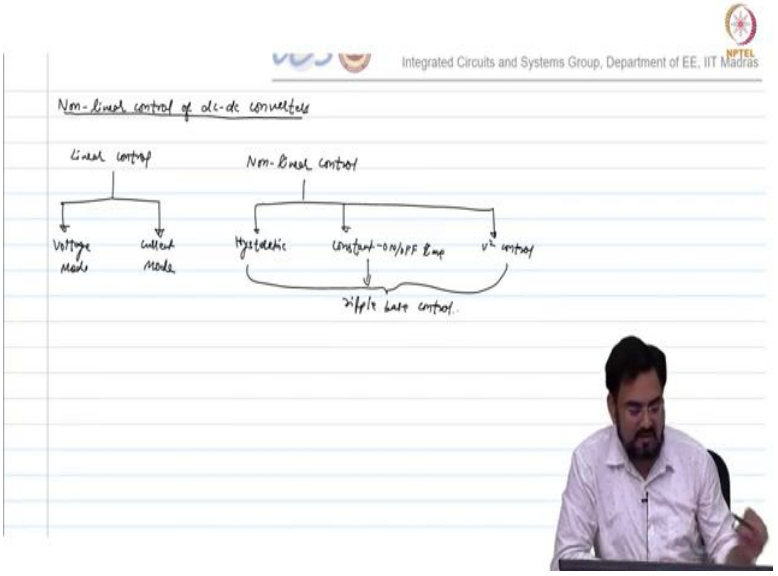

So, so far we talked about linear control and linear control we know. We looked at voltage mode and current mode. In Non-Linear you have hysteretic constant ON or OFF time. So, I mean they are usually interrelated and there are some other methods also some people call it like v square control is another, but we will not talk about that is another hysteretic control. But everything is here actually ripple based, it is all ripple based I mean all three are ripple based control.

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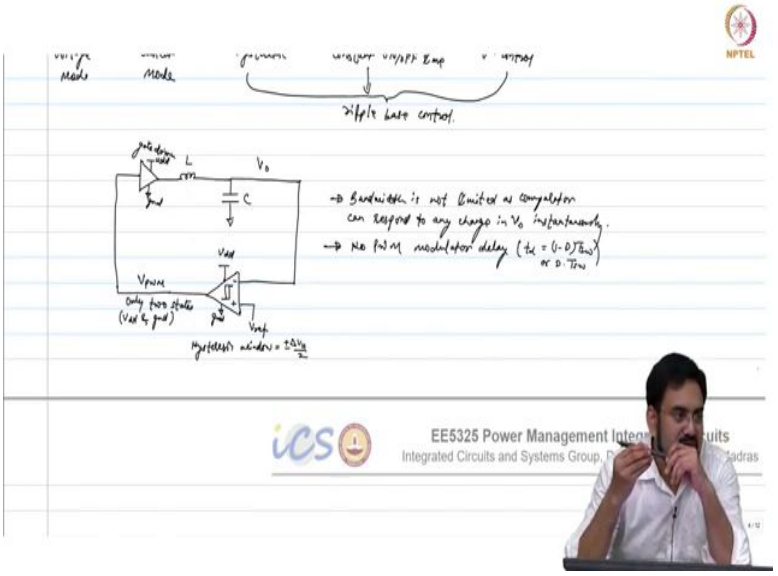

So, now let us say I have L and C, this is my output. In the feedback if I have a comparator and let's say this is a hysteretic comparator with plus minus delta V H by 2 ok, which means, peak to peak is V H. This is V ref plus minus and this is your V out and I have this is your gate driver.

When I say gate driver, you can assume it has a nonoverlap clock and buffers everything in it. So, I do not draw the same thing again. And if I call this V p wm. So, what would happen here?

This is nonlinear; it can have only two states, ok. What are those two states? In linear control that was a continuous voltage control, but here that is not possible because this comparator gain is very high. So, the moment it sees even a small difference between V ref and V out it will just trip to V dd or ground.

So, if this is V dd and this is ground, let me write and the hysteretic window is plus minus delta VH by 2, V dd and ground. So, which means you are directly getting the clock here instead of taking the V control and comparing with the ramp. So, what is the benefit of this? Can anybody tell? Forget about quiescent power. Tell me more from the dynamic point of view. Low transient, transient response, speed everything, how?

Student: Like faster, instantaneous.

Instantaneous, it is non synchronous. So, the first thing is it is non synchronous ok. So, you do not have a PWM clock delay that is the one thing and we already saw that I mean where you actually apply the load it may make a big difference in your transient response because of the sampling delay. So, and then once you compensate, you are limiting the bandwidth to one tenth of your switching frequency. So, there are two things which are limiting your transient response; one is your bandwidth, other is your delay in the PWM modulator.

So, the PWM modulator is gone here. So, that delay is completely removed. Now, the comparator can react instantaneously so there is no bandwidth limitation as such. So, bandwidth is not limited as the comparator can respond to any change in V out instantaneously. So, this is one thing no PWM modulator delay and if you remember, what was that? td equal to 1 minus D into T sw or D into T sw, two cases; trailing edge and leading edge ok. So, why do we not use this? Why do we care about compensation? All that makes the circuit so complicated. Just use a comparator in the feedback and you are done.

Student: It is operating variable frequency.

Any other? Let us say I am not, I do not worry about the frequency.

Student: Resolution.

Resolution, why resolution? If output is always limited between plus delta and minus delta so, average will remain at V ref.

So, what is the profile of inductor current? This, this ok. And if this is my average current, if this is a I load. So, what will the profile of output voltage? Parabolic and where will be the peak of that? Where will be the peak? So, value will be here.

See negative charge, you have positive charge here. So, during this time the capacitor is? C out is discharging and during this time C out is charging, correct. So, the moment it hits the valley it has to charge. So, which means your valley has to occur here and peak has to occur here, correct. So, your shape will be, let me draw this color ok. And if you integrate you will

get the same thing actually. Now, how much is this, the peak to peak in time difference? T sw by 4, which is 90 degrees.

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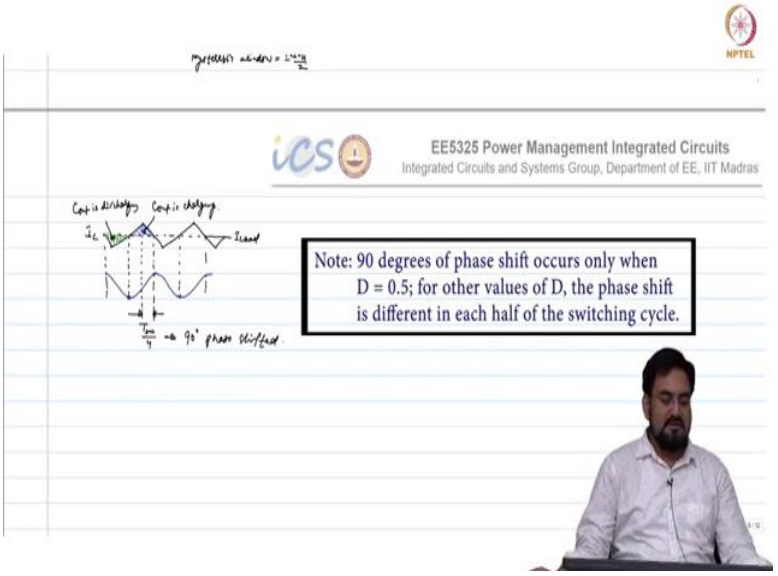

And it is quite obvious you have a capacitor. So, the current when it is dumped into the capacitor what would happen is you are integrating it. So, it will create a minus 90 degree phase shift. So, 90 degrees of phase shift. So, now, what will this comparator do? You are asking the comparator that if V out goes above V ref plus V H by 2 whatever the delta is output will go to 0. And if it goes less than V ref minus VH by 2, delta V H by 2 it will go to high. So, now, my output is going here let us say. Let us say this is V H V ref by V H by 2 correct and when I say my comparator says you go to change the state of the output, what would happen?

It will try to change right away, correct. Which means or you can say that comparator will take the decision after your duty cycle changes, correct. Because, if you look at the duty cycle point here when you set or reset let me draw the PWM, then it will be more clear.

So, during this time, let me take some better color. So, this was 0, it goes 1 here, draw little bit lower. So, look at the current so, inductor current is rising from here. So, your PWM will be high. And it will remain high until this point, correct. Then it will go to 0, then low, high, this is V of PWM. So, now, let us say this is your crossing point hysteretic window you

tripped here, but your output is still rising which means; you are not able to bound the output between plus minus delta V H by 2. So it will always cross.

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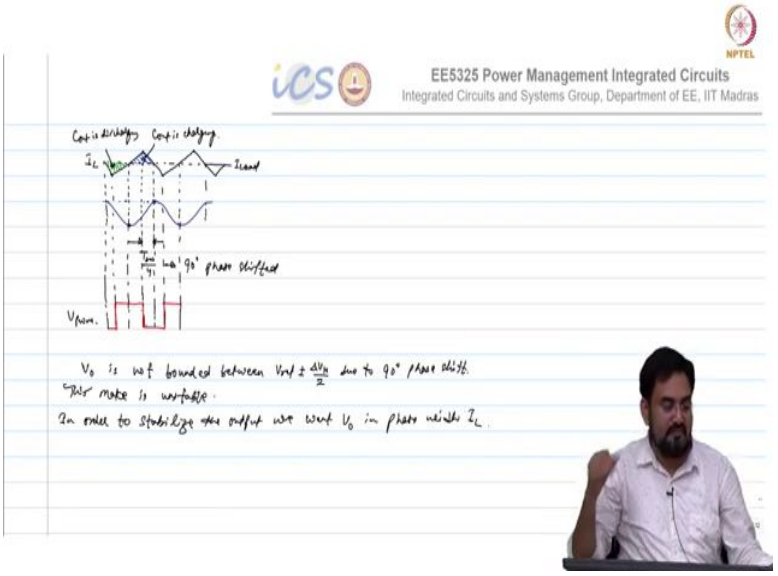

The reason is I mean you can see your inductor will keep charging the output. When you reset the duty cycle, just look at these two triangles. If I reset here or sorry, reset here at this point; then unless your charge or the current goes below I load output will keep on charging ok.

So, which means there is an extra charge which is dumped into the cap and that is coming only because of this 90 degree phase shift. So, what do I want actually? I want this output to be in phase with current. So, V out is not bounded between V ref plus minus delta V H by 2 due to this makes it unstable. When output is not bonded, then it can go anywhere. So, output can even build up and become large, so it is uncontrolled. So, in order to stabilize the output we want V out in phase with I L.