Power Management Integrated Circuits
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Lecture – 83
Tri-Mode Buck-Boost Converter (Buck, Buck-Boost and Boost)

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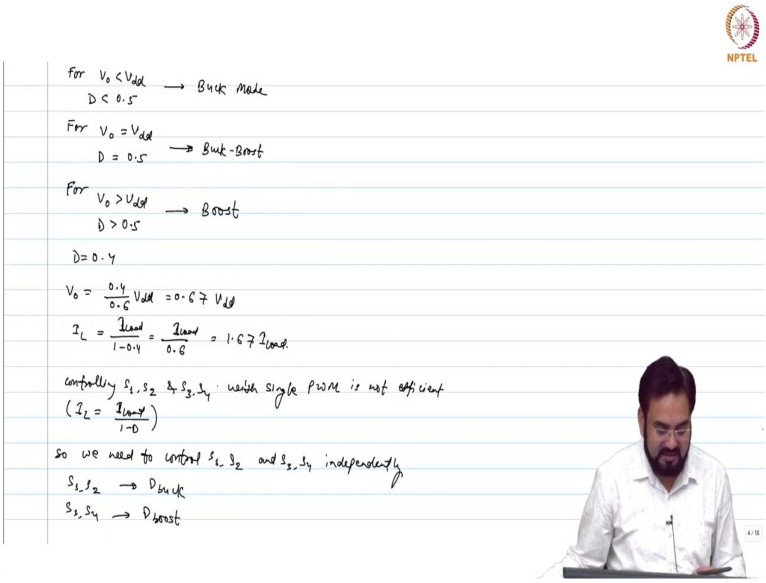

So, controlling S1, S2 and S3, S4 with a single PWM is not efficient. Why not sufficient? Because I L is equal to I load over 1 minus T. So the current will always be higher than load no matter whether you operate in buck or boost. So, we need to control S1, S2 independently, I will call it D buck; S3, S4, D boost.

Now, what will be the expression? V out equal to D buck over 1 minus D boost into V dd. Now, if I want V out equal to V dd, what will be the D buck and D boost? You can have infinite combinations, correct.

0.5, we can make both; then again you will end up having the same thing which you had earlier. Now if I make D buck equal to 0.9 and D boost equal to 0.1 then V out equal to V dd. What is the inductor current I L? How much? 1 over 1 minus 0.1, pretty close to 1.1; I load only a 10 percent increase. In the other case, it was a 2x increase. So, how do we control this?

So, there are three modes and this is called tri-mode buck-boost. Instead of operating all the four switches simultaneously, we operate them based on in which region we are ok.

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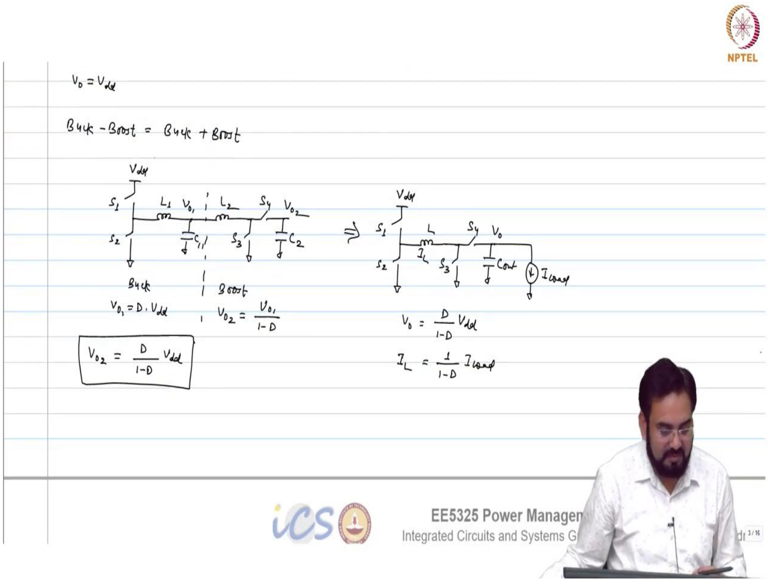

So, we divide them in three regions: buck mode, buck-boost mode and boost mode. Tell me what will be the states of the switches in buck mode? You have the circuit here, let me copy it. What will be the state of the switches?

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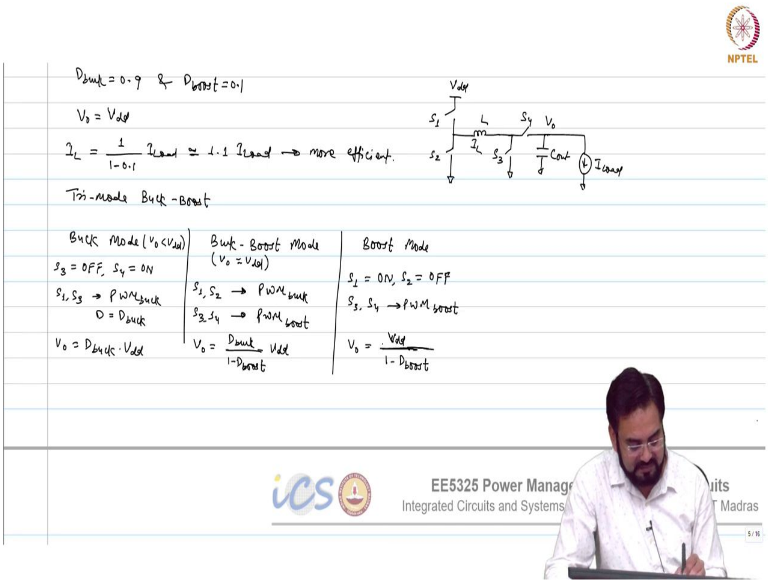

All 4 switches will be operating in buck-boost mode. So, in this case your V out is D buck times V dd. So, S1 S2 will be PWM buck. S3 S4 will be PWM boost. V out will be D buck over 1 minus D boost V dd. What about this case?

S1 is always on; S2 is always off. Now, it is looking like a conventional boost converter where S3 S4 is PWM boost and your V out is V dd over 1 minus D boost ok. So, how do we decide when to enter which mode? So, we always define maximum and minimum duty cycle.

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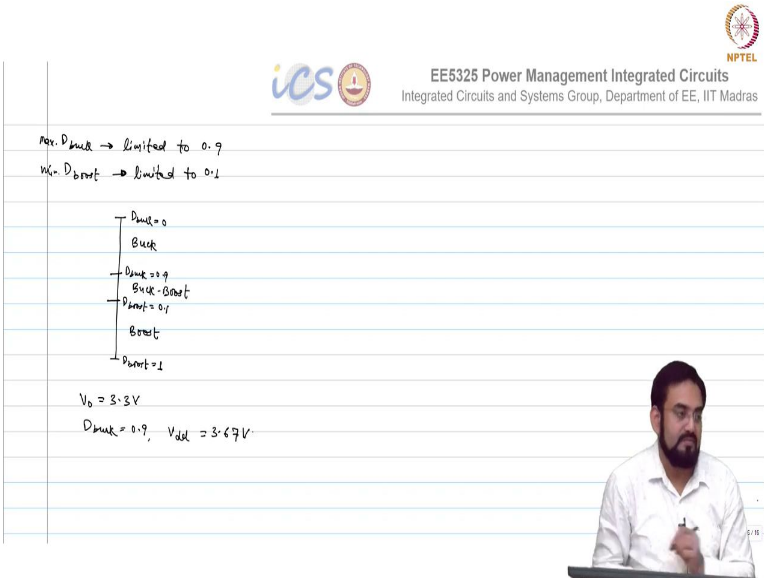

So, when you hit the boundary let us say my D buck is limited to 0.9 D buck max and minimum d boost is limited to 0.1 ok. So, you do not really need to look at the output because this duty cycle may vary for the same output depending upon the losses.

So, output will not tell you exactly the same thing. Let us say you have no load condition under load condition, the duty cycle will be different for the same output. So, in reality you have to look at the duty cycle when it is saturating. So, now, you have. So, this is let us say D buck equal to 0.9, D boost equal to 0.1 ok; D boost equal to 1 and D buck equal to 0. So, this is your buck region.

Now the duty cycle is saturated to 0.9 ok. When the duty cycle is saturated to 0.9, then you have no option, but to enter buck boost and here boost. So, why can't we enter directly from buck to boost? Can we do that?

What will happen to the output? What is the output in case of 0.9 D buck 0.9? Let us forget about the losses, just ideal condition. What is the output in case of D boost 0.1?

Roughly 20 percent increase in the output. So, let us say I am operating at so, let us let us take an example. Let us say V dd equal to 5 volt. So, and sorry, V out equal to let us say 1.2 volt and D is 0.9, D buck 0.9. So, what will be the V dd? 1.2 over 0.9. How much or let me take a better example? Because, the devices you are using are 1.8 volt. So, input hardly changes. So, most of the input when it is changing you will see with the battery voltage; lithium-ion battery.

So, let us take the example of a lithium-ion battery. So, let us say my this is 3.3 volt and no so, what is the V dd here or battery voltage? 3.3 by 0.9 which is 3.67 correct. Now I am going directly from here to 10 percent. So, your V dd is not changing. Let us say you are operating at V dd equal to 3.6 volt, my output is very well regulated at 3.3 volt. My duty cycle is saturated. Now I directly jump to boost ok.

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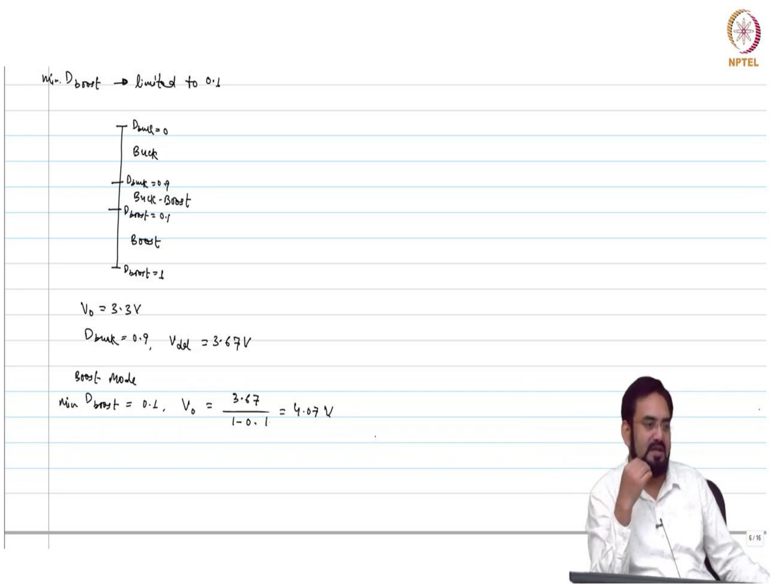

So, boost mode D boost. This is the minimum duty cycle; I cannot achieve less than this. So, I have to operate at 0.1 ok. So, what will be the V out? Because my V dd is not changing. 4 volt ok. So, your output will jump to 4 volt from 3.3 volt which is a difference of 700 millivolt. Let us say you have a feedback loop and everything ok. The feedback will try to recover ok, but how will the feedback recover? In this case, you have a boost mode; so, it will go to the buck mode again and it will go back and forth and ultimately you will get a large ripple in the output. So, it does not make sense to jump directly to boost mode, but to go to buck-boost first.