Power Management Integrated Circuits

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Lecture – 84
Boundary Conditions for Mode Transition in a Tri-Mode Buck-Boost Converter

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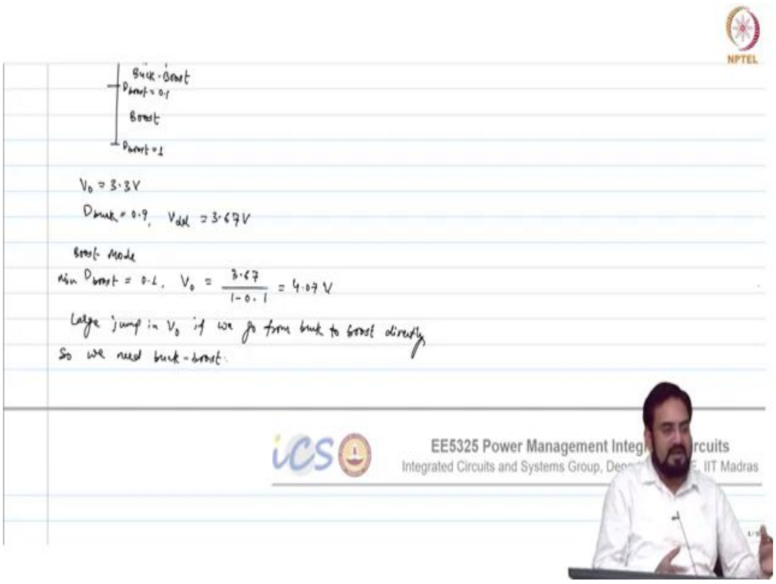

So, there will be a large jump in V out if we go from buck to boost directly. So, we need buck-boost. So, this is the main reason to have a buck-boost mode in between because the buck-boost region is basically more like a dead zone for buck and boost. So, you cannot regulate the output in between that region because of the limited or max or min duty cycle because your duty cycles are saturated; one is saturated on the higher side and the other is on the lower side. So, buck and boost cannot do anything, so you have to operate in buck-boost. Now, let's say I go to buck boost.

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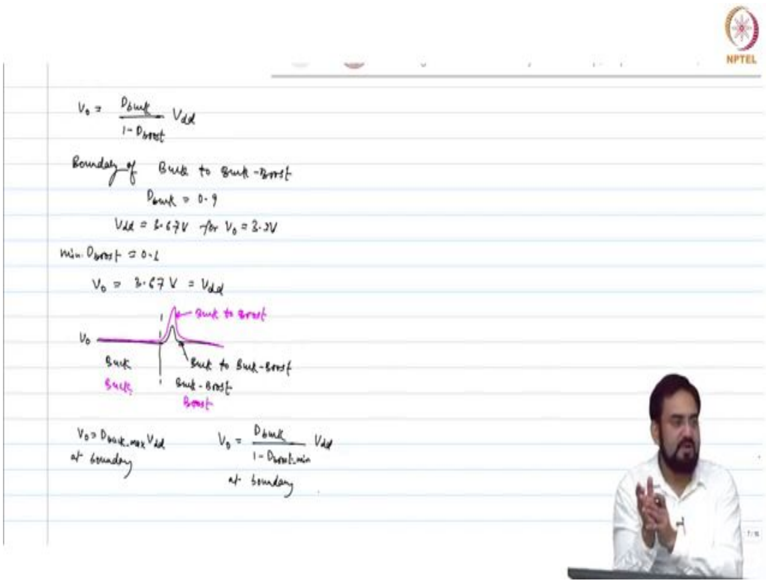

So, V out is I know is D buck over 1 minus D boost into V dd. What is the boundary condition? Boundary of buck to buck-boost is D buck equal to 0.9 ok. And we already calculated, what was the V dd? 3.67 volt for V out equal to 3.3 volt. So, when you enter buck boost mode what will be the D boost? 0.1, correct. So, what is V out here?

So, still your output is changed, how much now you have? From 4 volt 3.67. So, the change was 700 millivolt, here it is roughly half of that ok. So, still you have a jump, but it is not as large as the previous one. So, how do we fix this? So, your output will basically then jump and so this is the one case your other case is this buck to boost. And this guy is buck to buck-boost, this is V out ok.

So, in that case you will see that the overshoot will be more. And let us say my spec is 5 percent roughly. This is, I mean 5 percent of 3.3 volt is how much? 160 millivolt roughly. So, in both the cases you are basically not meeting the regulation spec. And if you are using let us say 3.3 volt devices where the supply is fixed, then 4 volt like you devices may damage also. So, this is undesired behavior and we need to fix this. How can I fix this?

You reduce the D buck ok. So, what will be the condition for that? I mean how do I know how much D buck is required here? At the boundary, so left hand side, so let us say you are at the boundary. So, this is buck; this is buck-boost and for this guy buck-boost. So, V out is nothing, but D buck max Vdd in the buck mode.

So, and V out is D buck over 1 minus D boost min, let me write this way at boundary ok. And this is at boundary when I say boundary you are looking at a very thin line where you are looking at the left hand side and right hand side. So, on the left hand side you have a buck and right hand side you have a buck boost ok. So, if you are slightly lower than 0.9, then you operate in buck mode.

And when you require more than 0.9 cycle you enter buck boost mode. So, you are right at the boundary and we want to find when we enter buck-boost.

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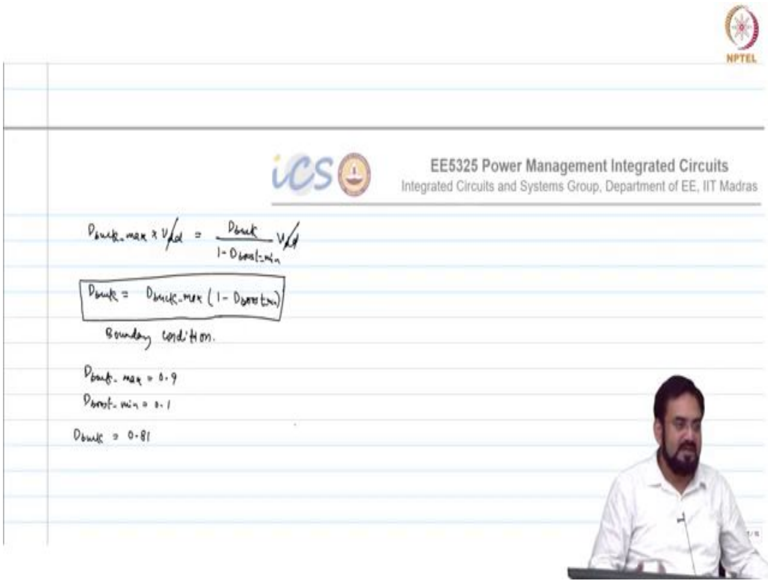

Buck-boost mode what will be the required D buck, which means both the output voltages are same, your Vdd are same. So, these two which means D buck max into Vdd should be equal to D buck over 1 minus D boost, this is gone. So, which means D buck is D buck max into 1 minus D boost. This is your boundary condition for buck to buck-boost. Same thing you can do for buck-boost to boost ok. So, the left hand side equation will change in that case basically the left hand side you will be operating in buck boost and right hand side you will be operating in boost.

So, in buck-boost your equation will remain same D buck over 1 minus D boost ok. In what condition you will enter the boost? So, now let us do the same thing again. So, we know that D buck max is 0.9 D boost min equal to 0.1. So, what is D buck? Ok. So, now if you operate in the buck -boost you make your D buck 0.81 and your D boost is 0.1 you can achieve the same voltage which is equal to 0.9 of D buck, ok. So, you would not see any overshoot in the output, it will remain at the same constant voltage. Now, after that what do you need to do? Now, you let us say further my Vdd is further reducing, I want to increase the duty cycle. So, which duty cycle will you have to increase, D boost or D buck?

You can achieve a higher voltage by increasing both whether you increase D buck or increase D boost, your output will be basically the same output for lower voltage, lower Vdd. So, which one makes more sense, to increase D buck or D boost?

If you increase D boost, you have a 10 percent margin there roughly, which means 10 percent more current you will be burning and you will lose your efficiency. So, it does not make any sense. So, you have to increase the D buck and let the D buck saturate then after that you increase D boost, that is more logical.

Why do I forcefully saturate D buck at 0.8 when I have D buck max available up to 0.9? That is how you control actually. So, you have to monitor the duty cycle and see where exactly we are and you switch your duty cycle control. We will see how we generate this duty cycle, you can do it in a digital way or analog. So, buck and boost is simple, you know how to do it. But in the buck-boost you require both the duty cycles.

You have only one control voltage and you have to generate both duty cycles. So, I know this is my boundary condition when the buck duty cycle is saturated to 0.9, if I jump directly to buck-boost I will see this kind of jump. So, now, in order to fix that at a boundary condition when I start my both a buck and boost, I have to reduce the buck duty cycle to 0.8, correct.

So, when you are operating at 0.8 buck you start increasing the boost duty cycle, what will increase here, what will happen to the inductor current when you increase the boost duty cycle?

It will start increasing. But I if I fix that D boost at 0.1, I still have a 10 percent margin. And start increasing the D buck and let it go until 0.9, my inductor current will not change, it is because you lose efficiency and we are doing everything for efficiency. So, why do I lose efficiency unnecessarily? If I can achieve 1 or 2 percent more then I will do that, it is a big deal 2 percent efficiency is a big deal actually.

If somebody can give you like 15-20 minutes more battery life in your phone it is a big deal. And you realize that when your battery is near 0 percentage actually. So, the converter is all about efficiency here, these switching converters. If you can achieve 1 percent more just do it actually.