Power Management Integrated Circuits

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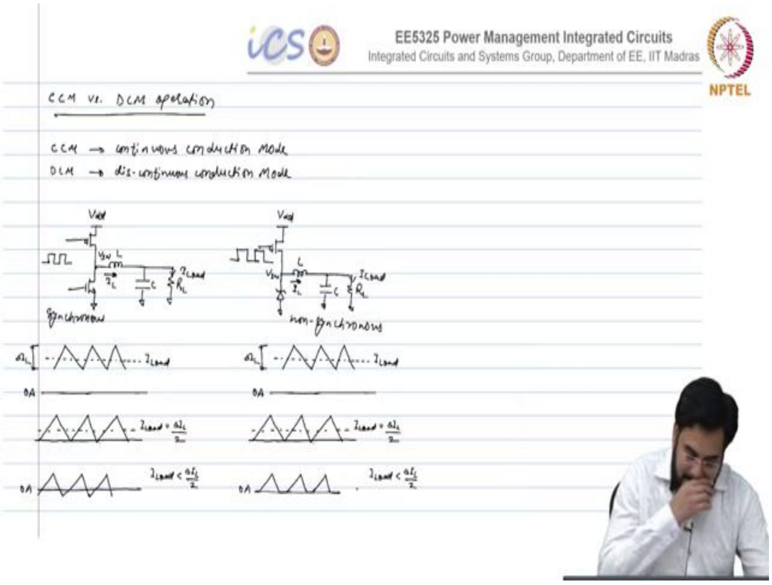
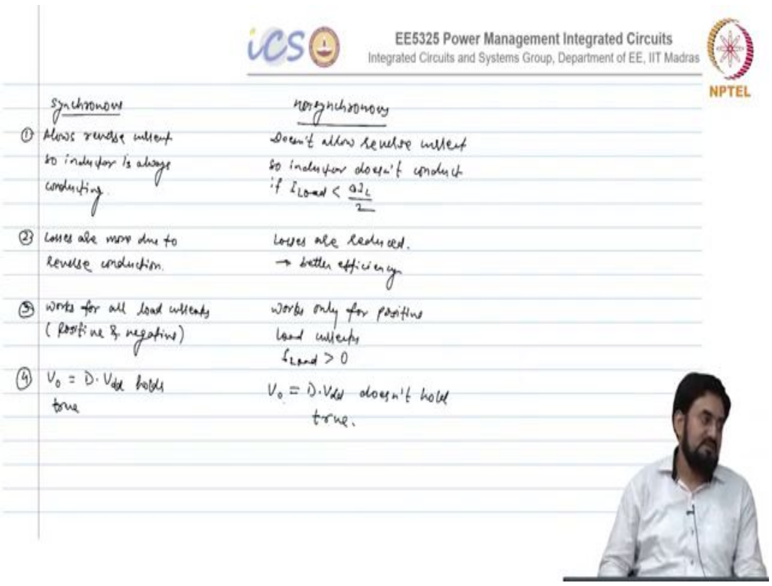
Lecture – 42
CCM Vs DCM Operation in DC-DC Converters



CCM stands for continuous conduction mode and DCM stands for discontinuous conduction mode. Figures of the synchronous and non-synchronous converter are shown in the above image.

As you can see in the above image, if we keep reducing the I_{LOAD} then its valley will hit 0 amperes at I_{LOAD} equal to $\Delta I_L/2$. On further decreasing the I_{LOAD}, the inductor current will go negative. In the synchronous converter, the current can flow in both directions from NMOS whereas, in a non-synchronous converter, the diode will allow current in one direction.

Current in NMOS in the synchronous converter can flow bidirectional. If we operate a synchronous converter in CCM, it does not matter what the load current is. It will work for both negative, positive, and zero load current. But in the case of the non-synchronous converter, the current will not go negative and becomes zero because the diode will not allow the reverse current. The average current will be I_{LOAD} in both cases. For non-synchronous converter $\Delta I_L/2 > I_{LOAD}$.



Synchronous converter allows reverse current, so the inductor is always conducting, no matter whether it is a reverse current or forward current, current will keep flowing. The non-synchronous converter does not allow reverse current. So, the inductor does not conduct, when I_{LOAD} is less than $\Delta I_L/2$. Non-synchronous will have better efficiency because we are not dumping any current in the ground and all the current drawn from supply goes to the load. The synchronous converter will have more losses due to the reverse conduction.

The synchronous converter works for all load currents whereas the non-synchronous converter works only for the positive load currents. But in most cases, our requirement is a positive load. So, non-synchronous is not a problem, but the problem is the diode drop. If somehow we can make this diode with a 0 forward voltage then we would prefer this non-synchronous behavior rather than synchronous behavior.

So, we implement some logic, and when the current crosses 0 or goes below 0 we turn off the bottom switch. The moment we turn off the bottom switch it will behave like a diode because it will not allow the reverse current. And which means we are able to implement an ideal diode with bottom switch and some extra logic.

We know that when reverse current flows then the voltage at the V_{SW} node will go positive. So, all we have to do is to find the 0 crossing point i.e. when the voltage at the V_{SW} node goes from negative to positive we turn off the NMOS and it will behave like an ideal diode.

In DCM, V_{out} will not be equal to D times Vdd. For the same duty cycle, the average current will be more in DCM compared to CCM. If we force the same duty cycle then the inductor is supplying more current than the load in DCM then the output voltage will start increasing. We have to reduce the duty cycle to reduce the output voltage so that means, D into Vdd is not valid at all in DCM.