Power Management Integrated Circuits
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Lecture – 41

Choosing the Inductor and Capacitor for a Buck Converter

Inductor current ripple :

$$\Delta I_L = \frac{V_{dd}(1-D)D\,T_{SW}}{L}$$

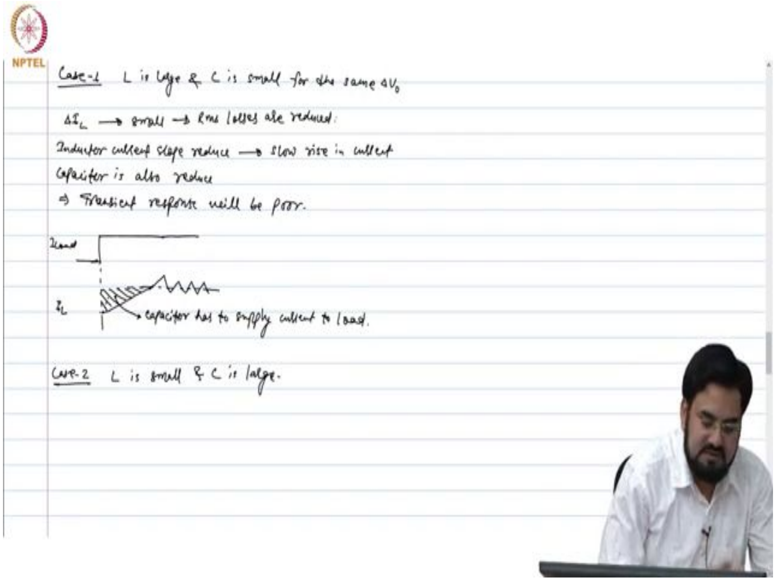
Output Voltage ripple :

$$\Delta V_o = \frac{V_{dd}(1-D)D}{8LC\,F_{SW}^2}$$

Ripple voltage will not change for the same LC product, switching frequency, Vdd, and duty cycle. We can choose different L and C as long as their product is constant. For the same ripple voltage, we can choose either a large inductor and a small capacitor or a large capacitor and a small inductor.

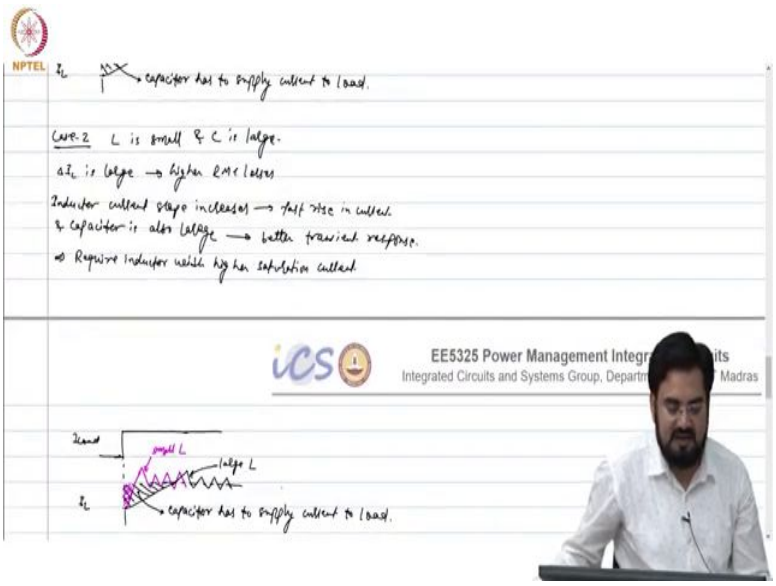
Case 1: Large Inductor and Small Capacitor

RMS losses are reduced because ripple current is small in this case. The slope of the inductor current will be small in this case due to large inductor value. During load transient, the inductor current will take more time to reach the new load current value because of the smaller slope. The capacitor has to supply more charge during transient and this will degrade the transient response. A smaller capacitor will have more undershoot or overshoot in voltage and will further degrade the transient response. As you can see in the below figure shaded region area is the charge supplied by the capacitor to load during the transient response. If the slope of the inductor current increases then this area will decrease.



Case 2: Large Capacitor and Small Inductor

Case 2 is exactly the opposite of the previous case. RMS losses will be higher because of the higher peak to peak inductor ripple current. Inductor current slope will increase because of smaller inductor value. As you can see in the below figure, the area of shaded is smaller for small L which is the charge supplied by the capacitor. Transient response will improve in this case. A large capacitor will further improve the transient response by reducing the undershoot and overshoot of output voltage.



Most of the time we try to reduce the inductor, but make sure peak inductor current does not cross the saturation current of the inductor. On reaching saturation, the inductor may get damaged and its value will also decrease. If we are more concerned about the ripple current and we are using an inductor that has a very low I_{SAT} then we have to go with case 1. But if we have an inductor that has a very high I_{SAT} then we try to minimize L and increase C because that will improve transient response.

If we look at the inductor trend, the smaller the value of the inductor is the fewer windings are. So, resistance will reduce and the area of the core is also small. Magnetic losses will be less and the saturation current will be higher for a small inductor. So, If we pick the same series of inductors i.e. they are manufactured using the same material, same core, etc., as we reduce the value of the inductor, I_{SAT} will start increasing and R_{dcr} will also start reducing.

When we know V_{in}, V_{out}, and F_{SW}, we can calculate the value of peak current for the value of the inductor we choose. If V_{out} is not fixed then we can calculate the peak current for the worst case of 50% duty cycle and see if the inductor we are selecting can afford that much peak current. We keep some margin between the peak current and I_{SAT} because we do not want to just hit the I_{SAT} value.

Saturation of the inductor is defined when its value falls 30 percent below the typical value. If you are using 1µH and the current at which it goes 0.7µH, that defines the saturation current. This condition is for soft saturation, but there is something called hard saturation where the inductor value will fall very quickly. It depends on the type of inductor you are using, the magnetic core inductor will mostly have hard saturation and iron core or air core inductor may have soft saturation.