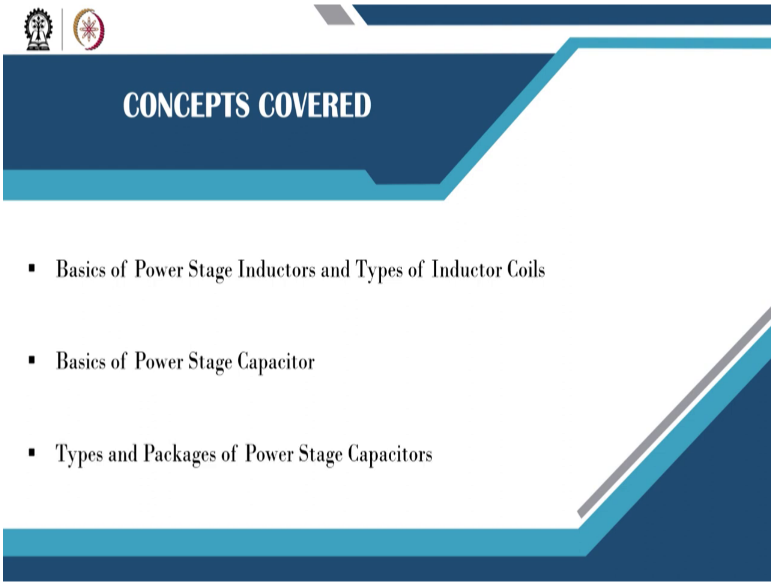
Digital Control in Switched Mode Power Converters and FPGA-based Prototyping

Prof. Santanu Kapat
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Module - 06
Digital Control Implementation and FPGA-based Prototyping
Lecture - 55
Reference Power Stage Design and Schematic for Buck and Boost Converters - I

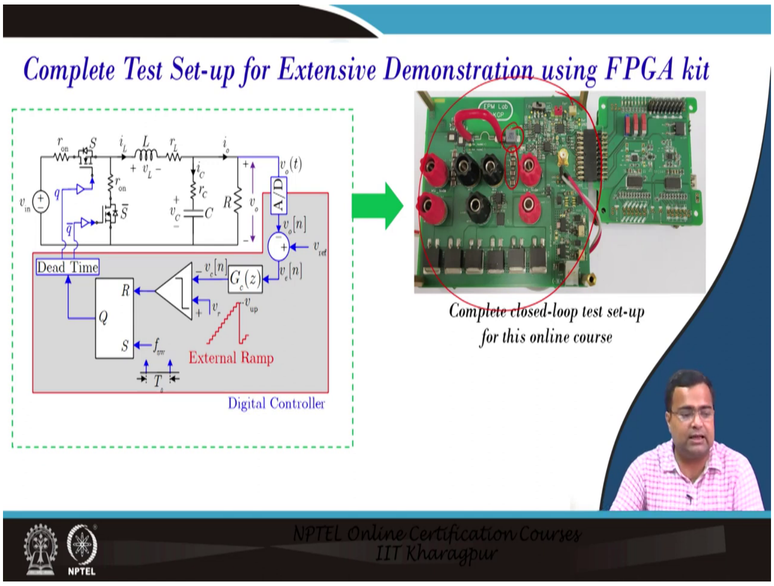
Welcome. In this lecture, we are going to discuss Reference Power Stage Design and Schematic for Buck and Boost Converter, and part of this lecture we will also continue in the next lecture.

(Refer Slide Time: 00:35)



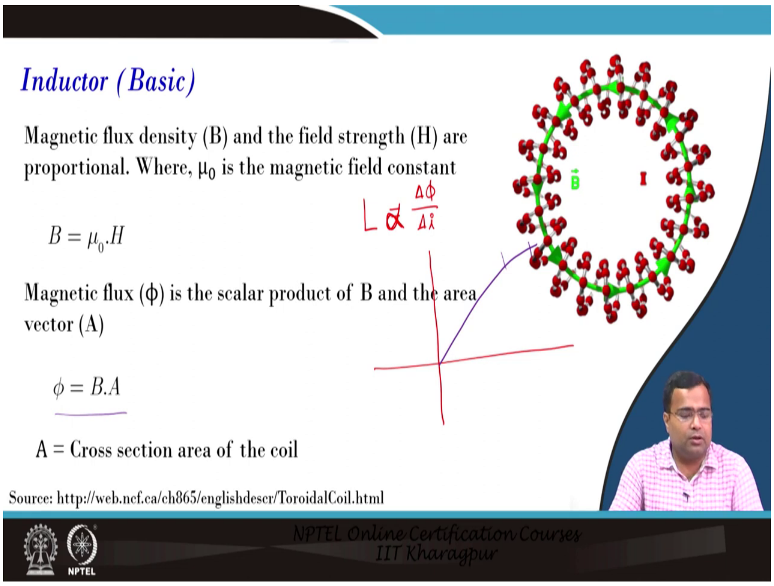
So, we will first talk about the basics of power stage inductors and their type of coil, the basics of power stage capacitor, and the types and packages of power stage capacitors.

(Refer Slide Time: 00:46)



So, we will start with our complete test setup because we will be talking about what are the component and schematic that we have used in our power stage. So, this is a typical buck converter and we are talking about this power stage circuit and where we will be talking about the inductor. So, this is the inductor and we have considered power stage capacitors. So, those capacitors are also their input side and output side the output side capacitor.

(Refer Slide Time: 01:19)

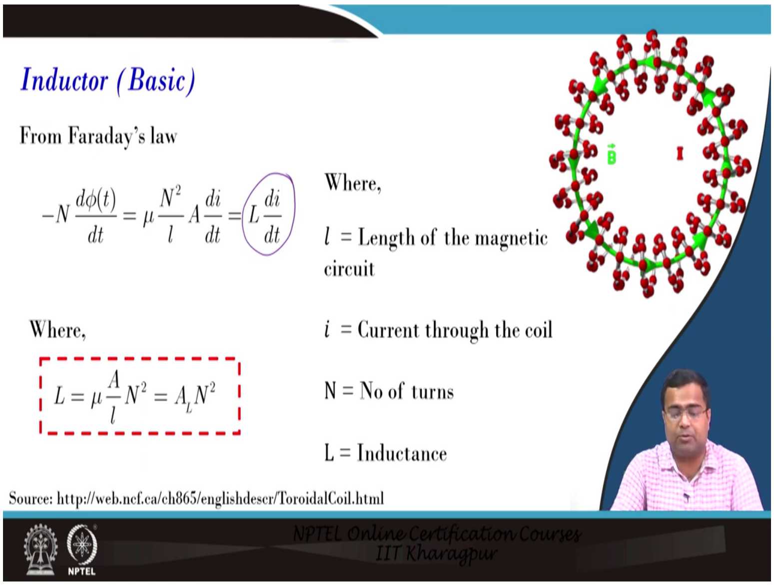


So, now in this lecture, we will first take the inductor. So, if you talk about the inductor, we know about the inductor B H characteristics, and we are trying to because we can define the inductance what is the value definition of inductance? It is nothing but the flux change by the current change. So, that is the proportionality factor; that means, inductance is proportional to the flux change by the current change.

So, as long as we are in the linear region of the B H curve then inductance will be constant, but if you enter into a non-linear region; that means if you go into this B H curve suppose you know if we talk about this kind of region. So, where your flux change will be less, but the current change will be more. So, the inductance value will reduce.

So, here we are not considering the hysteresis loop for the time being, but if we consider hysteresis there are other effects also. So, I am just first talking about the linear region where we want to operate our DC-DC converter ok. So, next to the magnetic flux all this expression of the scaling factor makes sense in the linear region in the phi equal to B into A because, in the linear region, we can draw the equivalent magnetic circuit, but when you go into the non-linear region then we have to consider the other factors also.

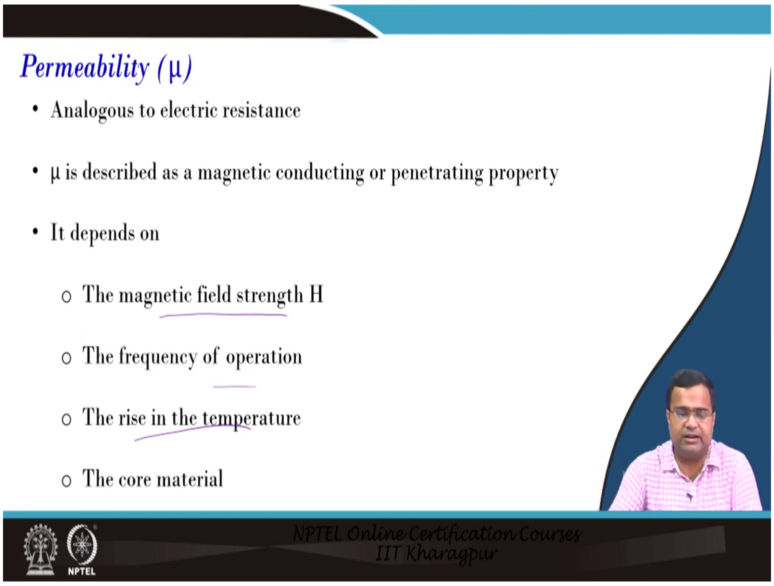
(Refer Slide Time: 02:45)



So, then if you go by Faraday's law you know how this l di it; that means, the voltage across inductance is developed and it comes from the change in flux and these are the basic formula the how to decide the inductor. So; that means, you have to take the cross-sectional area number of turns of the winding because you want to wrap that wire partiparticularlyucting wire on top of a core; that means, whether it is an air core inductor or ferrite core inductor. So, there are different types of inductors.

So, where l is the length of the magnetic circuit, i is the current through the coil N number of turns, and L is the inductance.

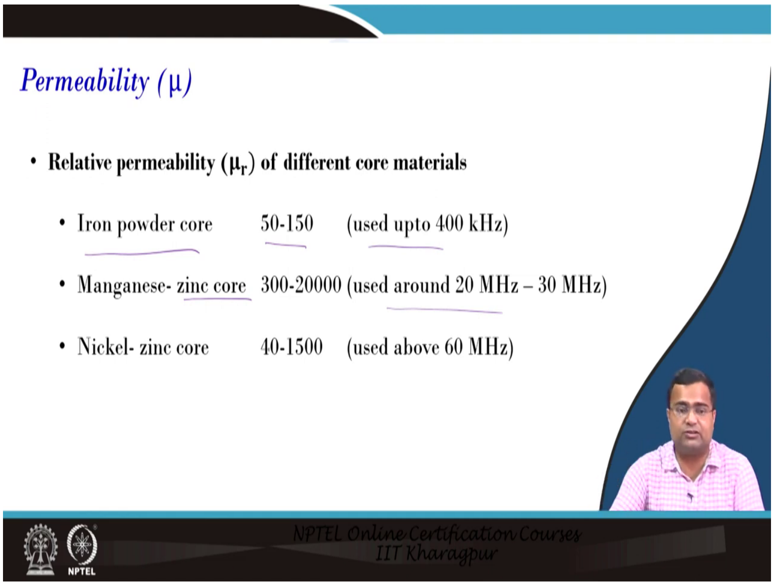
(Refer Slide Time: 03:28)



The permeability of the inductance these are the all basic magnetic circuit we know that permeability is analogous to electric resistance and this permeability describes as magnetic conducting; that means if the permeability is high then what will happen? Whether you will pass more number of lines some force for a given area cross-sectional area or not that we can know all.

So, it depends on the magnetic field strength frequency of operation because if you are operating at a higher frequency then the core losses may increase; that means, some of the magnetic like hysteresis loss you know eddy current loss are frequency dependent. So, that loss can go up. If the rise of the temperature increases then the core material very much matters in terms of permeability.

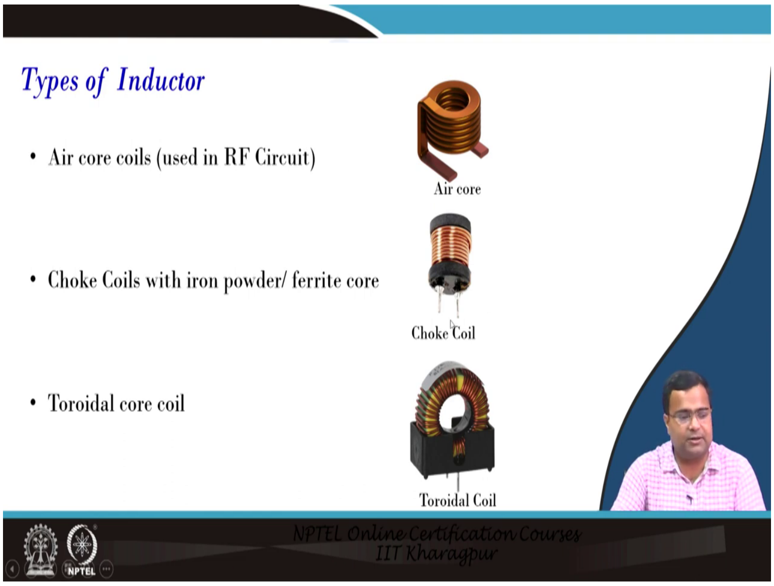
(Refer Slide Time: 04:20)



So, relative permeability; means, the core can be iron powder core and that is typically used for low frequency up to 400 kilohertz even for our traditional ah; that means, ferrite core we use iron powder core where we will go up to you know the inductance value can be in the relative permeability in the order of 50 to 150 and we can effectively operate 100 kilohertz or few 100 kilohertz.

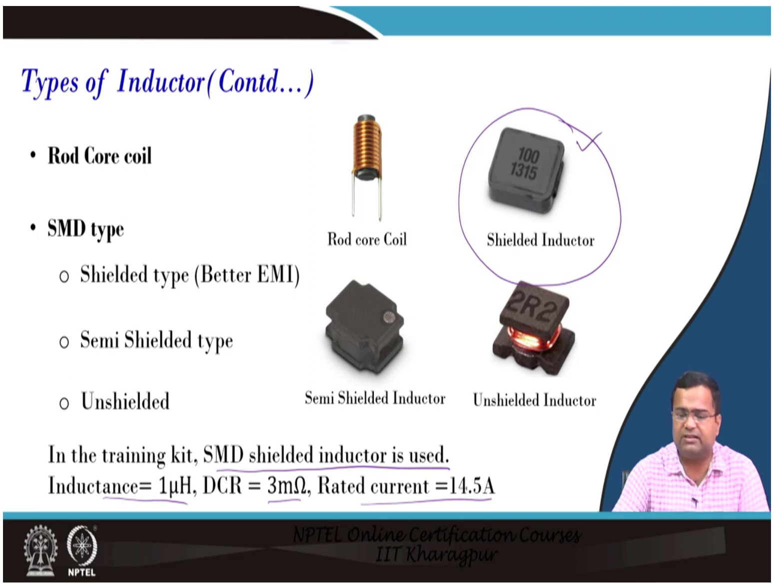
If you use a zinc core then you know we can go for high frequency the nickel-zinc we can go for an even much higher switching frequency. So; that means, we have to be very careful about the core material to operate the converter at a higher switching frequency.

(Refer Slide Time: 05:10)



Now the type of inductor can be an air core coil ok and these are used in RF circuits, then it can be a choke coil with iron powder or ferrite core and this can be this is a choke coil or it can be the toroidal core coil. So, we often use you know these first two cores for a power inductor.

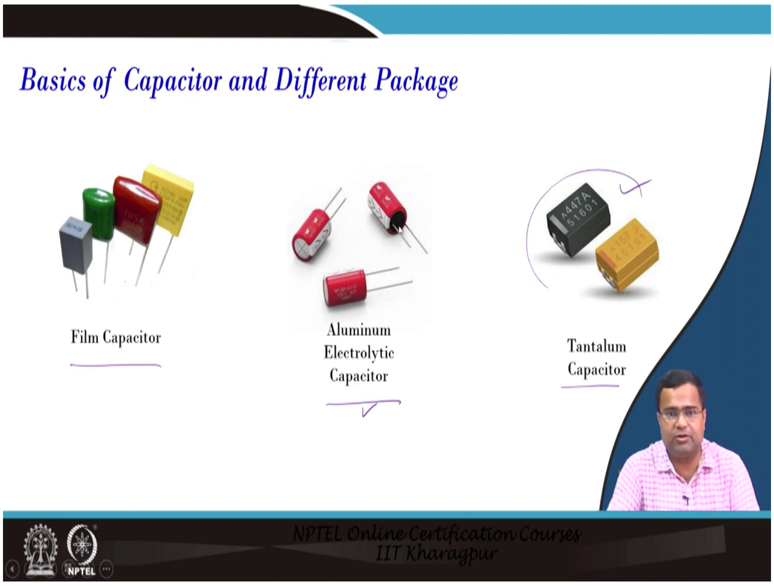
(Refer Slide Time: 05:36)



Then rod core coil SMD type shielded type. So, if you go for SMD type surface mount type then it can be shielded for better EMI and this is what we are using in our course shielded type.

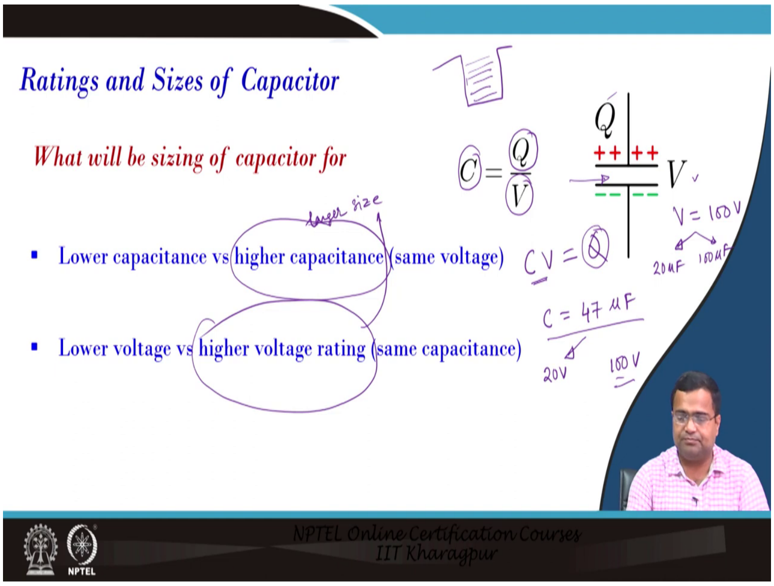
Then semi shielded or it can be unshielded in this training kit we are using a shielded core; which means, the inductance value of 1 micro henry, DCR around 3 milliohm, and we rated the current as 14.5 so; which means, around 14 ampere current. So, this is the core that we have selected.

(Refer Slide Time: 06:14)



Now, if you go to the capacitor we know the capacitor can be a film capacitor or it can be an aluminum electrolyte capacitor, which is a very common capacitor or it can be a tantalum capacitor. So, these are a bit expensive, but all these are SMD this is SMD type this is through the hole you know and this aluminum capacitor here is you know through the hole, but it can be SMD also.

(Refer Slide Time: 06:44)



Now, we want to understand some basics of capacitors. So, I want to pose some questions, any capacitor you take the capacitor has two plates conducting plates and in between, there will be dielectric ok. So, there are different types of dielectric material, but for any capacitor where you choose, you have to choose two things one we decide the value of the what is the voltage rating of the capacitor and what is the capacitance value we are going to take.

So, this gives us this formula the capacitance value is nothing but your charge storage divided by the voltage; that means, C into V equal to Q. So, the question is if we want to select let us say we want to select 47 micro farad capacitor, then I want to ask you once you want to select 47 micro farad capacitor, the next question will immediately come what is the voltage rating of the capacitor? That means, what will happen to the same capacitor if we go for let us say 20 volt rating if we go for a 100-volt rating will it be the same in size then there is no need for a voltage rating.

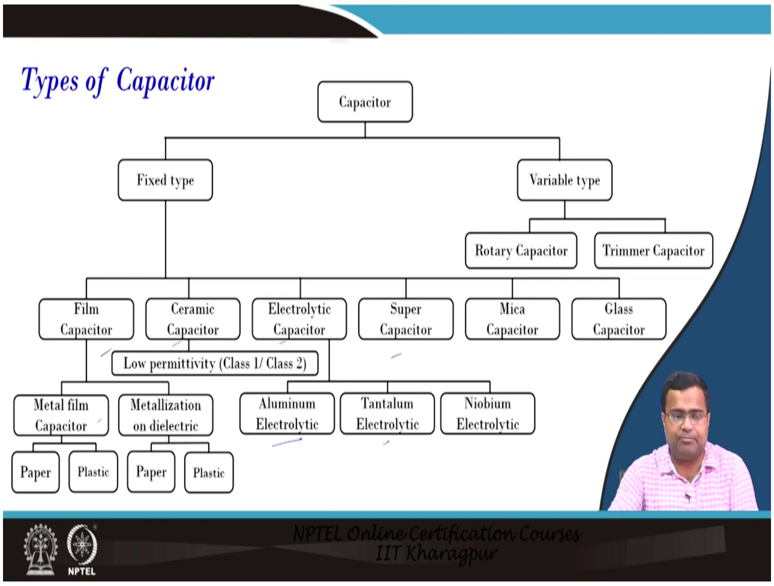
So, for the same capacitor value if the voltage rating increases what will happen? So, these are the question of lower capacitance versus higher capacitance that will come; that means if the voltage increases then as per this formula the Q will increase. So, it is like a bucket of water ok so; that means, this charge will; that means, what is the storage capacitor of the capacitor?

So, for the same capacitance value if you go for a higher voltage rating; that means, it has to store more charge as a result the size of the capacity will increase, but if you go for a lower voltage then the storage charge requirement will be small and the size of the capacitor will be smaller; that means, for the same capacitance value higher voltage capacitor sizes will be larger than the smaller voltage capacitor.

Now, for the same voltage rating; that means, I say my voltage rating is 100 volt, the next question what will happen for a smaller cap and the largest cap? One is the 20 micro farad versus 100 micro farad. So, naturally again it will come to C into V charge will increase. So, a larger capacitor value will have a larger size for the same voltage rating because the Q will increase. So, you can answer this question with the lower capacitance versus higher capacitance at the same voltage. So, this will be a larger size the second case will be the larger size.

Similarly, for the same capacitance higher voltage, it will also give rise to a larger size. So, you have to be very careful about the selection of the capacitor typically for the conservative choice if the peak voltage is 20 volts we typically take a 50 volt capacitor or so, so you have to give some safe margin.

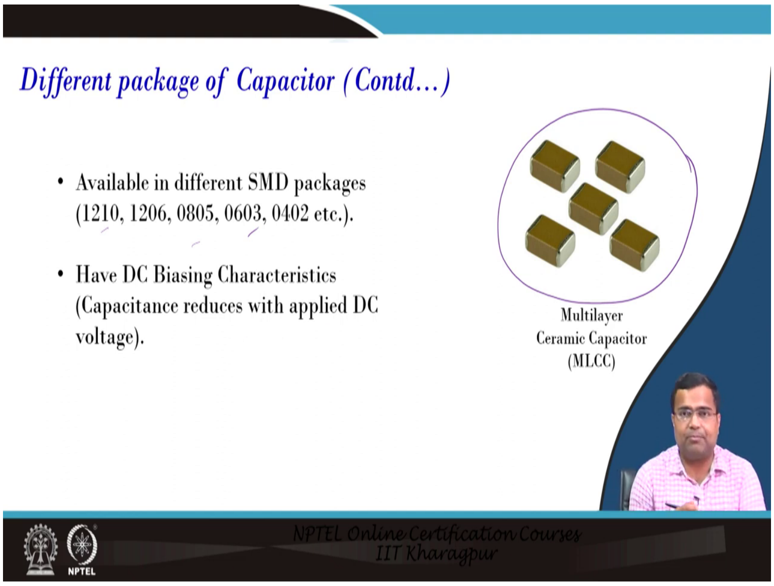
(Refer Slide Time: 09:50)



Type of capacitor the capacitor can be fixed type variable type can be rotary cap trimming capacitor the fixed type can be a film capacitor, ceramic capacitor, electrolyte capacitor, super capacitor, then there are other capacitors also. So, we generally use ceramic capacitor is low permittivity these capacitors are often used in parallel with the larger electrolyte capacitor and used is to reduce the ESR effect ok and These capacitors are supposed to absorb high-frequency components.

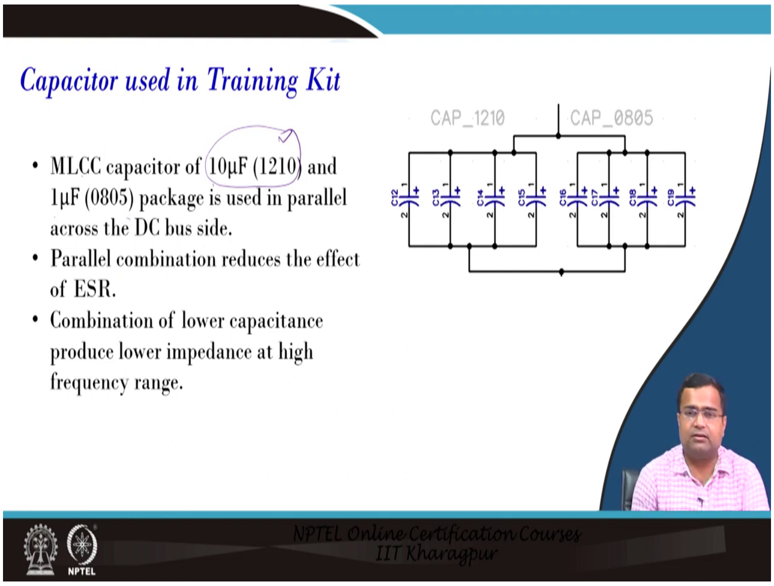
The film capacitor can be metallic film metallization and you know there are paper or plastic-type then electrolyte capacitors can be aluminum electrolytes, tantalum capacitors, and then niobium electrolyte capacitors. So, there are different types it depends on the cost, size, and package these things are important because when you are going for high-frequency high power density then what type of capacitor package should we use those are very important.

(Refer Slide Time: 10:56)



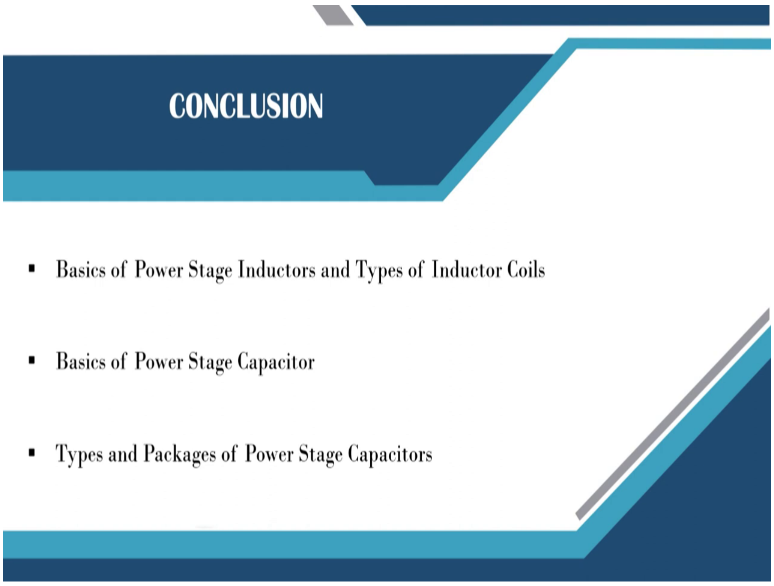
Different packets so, this is a multilayer ceramic capacitor and this capacitor are very much used in high-frequency DC-DC converter available SMD package it can be 1210, 1206, 0805 packages 0603, 0402 etcetera and we need to check the DC bias characteristics. So, capacitance reduces with applied DC voltage; that means, if you apply a large DC voltage the capacitor voltage can reduce. So, you have to take that into account.

(Refer Slide Time: 11:28)



So, in this teaching kit, we have to consider the input side and output side caps. So, we have considered multiple caps in parallel there is a common 10 we have taken 10 10 milli micro farad multilayer capacitors and 1 micro farad. So, these are 1210 packages; that means, they are higher storage capacity and 1 microfarad 0805 packages used in parallel. So, this parallel is used to reduce the ESR effect and to absorb the high-frequency noise.

(Refer Slide Time: 12:04)



So, in summary, we have discussed the basics of power stage inductors and capacitors we have discussed basic power stage capacitor and some aspects of power state packages in different packages. In the next lecture, we will continue with the driver circuit as well as the current sense circuit and some aspects of the schematic of the power stage for this reference kit; which means the training kit. That is it for today.

Thank you very much.