Design and Simulation of DC-DC converters using open source tools
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Lecture – 12
Forward Converter Topology

In this video capsule, we shall discuss the isolated converters till now we have been discussing on the non isolated converters, like the buck boost and buck boost converters these were called the primary converters using these primary converters, other converters are derived called the derived converters and among the derived converters the isolated converters are also part, we shall introduce. In this session, this week's session an important component called the transformer a high frequency transformer that will play a very important role in the isolated converters the transformers do 2 main functions one is to provide isolation that is physical separation galvanic isolation between the output part of the circuit and the input part of the circuit another important feature is the terms ratio you have scope to design the terms ratio appropriately.

So, that you can have a wide operating range we shall definitely look at the design of the transformer both electrically and magnetically and see how to choose the code and also to design the windings and we shall look at how to solve some of the magnetic issue that will come like course saturation and things like that.

Even the inductor we will take the design values that we learnt in the last week and the build the inductor physical inductor. We need to choose the core for the inductor and we need to determine the windings and see how to introduce the air gap these physical issues and magnetic issues will be addressed in this course. So, this course this week we will focus more on these isolated converters with a bit more emphasis on the isolation components magnetic components like the transformer and the inductor. So, we will discuss the forward converter which is one of the buck derived converters, other buck derived converters are the push pull the half bridge and full bridge converters. The other family of converter that we will discuss is the buck boost family. One of the most popular buck boost derived converter is the fly back converter which is very, very popular and you will see it in most of the commercial power supplies.

So, we will definitely have to look at it and see, how we go about designing it is magnetic components and isolation components then, we will definitely have a look at simulation. We will take a few examples; circuit's put it through these capture using cesium and then, use a engine spice engine to simulate it and look at the results and see we can get more insights into the circuits.

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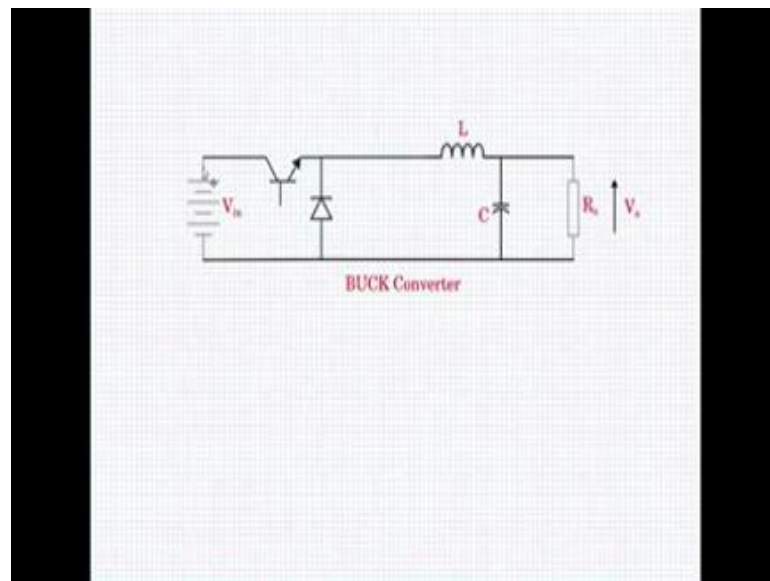
This is the buck converter circuit which you are by now, very familiar with we will be starting from this non isolated buck converter and developing the forward converter, which is an isolated converter and derive from this buck converter all buck derived converters will have the output co-portion which, is like this the diode inductor capacitor load combination this portion will be the prominent feature of the output, side of one buck derived converters there will be change in the input portions.

Let us start first with rearranging some of the components and see where we can put the transformer. Now this is the buck converter, we have put the switch on the positive arm of the supplier we can as well put this switch on the negative or the return path of the current without affecting the operation of this whole buck converter circuit. Let us do that for example, let me move this down and let me move this up let me reverse this in such a way that it is compatible for the return path the current flows in this direction and

it returns back in this direction. So, the transistor is now compatible and made correct to the operation of the flow of the current.
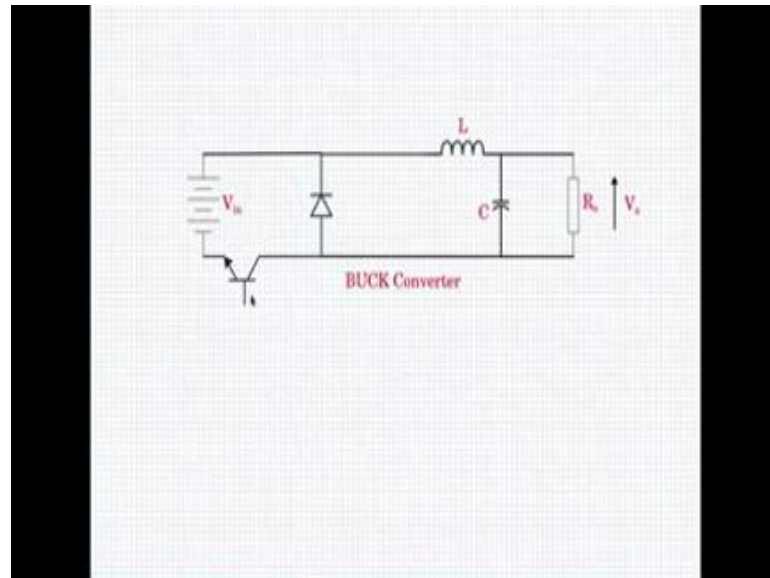
Now, this is still the same old buck converter the operation is exactly the same and you will see that when this transistor is on the V potential comes across the diode turns off the diode and the V potential charges the inductor and the voltage across the inductor is V in here minus v naught here. So, it is v minus v naught do in d t s period and during the time, when this is off there is no return current here current flow here the inductor is prevailing through the output capacitor and the load and this is conducting and this is 0. So, it is zero minus v naught, minus v naught is the rate at which the current fall.

So, the regular operation of the buck converter remains the same the input output relationship also remains the same mainly, what we have done is we have shifted from the positive rate. We have shifted the switch from the positive rate to the negative rate in doing this, we have made the gate drive or the base drive referred with respect to the ground point here or the negative point of the supply which is much easier to achieve next. What we will do we will further re position this d j t or a transistor in the following way.
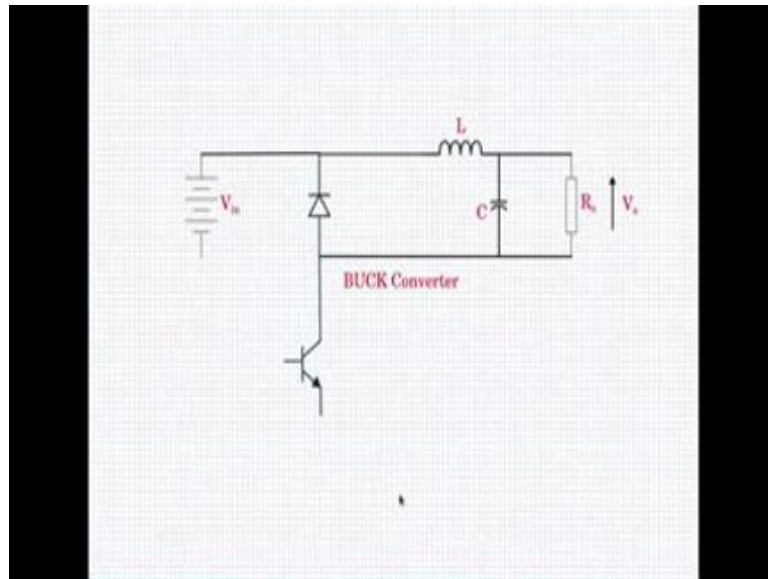
Let me click on this d j t switch and let me rotate it in such a way that it is facing in this fraction further, let me also position it such that it is in this kind of a topology. Now I will put in some labels, let us say this is a label indicator just like we do in spice and I will put say that this is V in that is; where the positive of the supply is attached and this is the ground. Now I need not have this I will remove this portions.
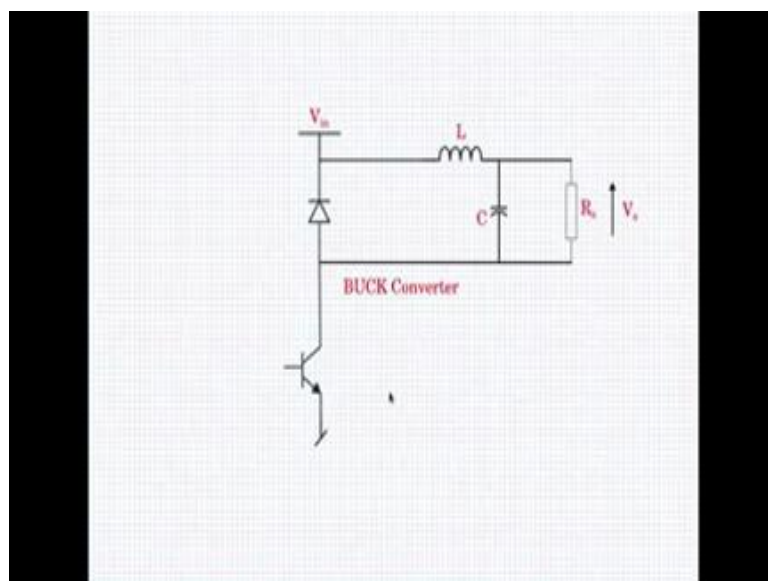
So, this is still the buck converter the same old buck converter and the operation still continues to remain same this d j t switch. When it is on there is a voltage V in which appears across the diode reverse passes the diode current flows through the inductor charging up the inductor and flows back in this fraction and when this switch is off the inductor free wheels through the output circuit operation remains the same input output relationship also remains the same. Now we need to introduce a transformer this is an appropriate place where, we can introduce the transformer and we will push the diode inside and start placing the transformer there.

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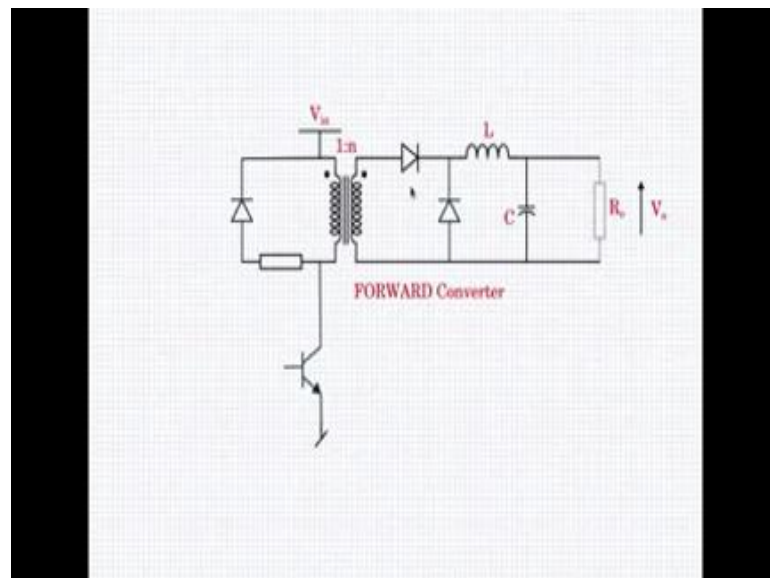
Now, what we shall do we shall move this diode inside a bit like this we will make some space to introduce the transformer here. So, let me position it in this fraction here, you will have the transformer coming in that place there the transformer. Now is in the situation where, it can operate properly when the switch is on and the switch is on there is a voltage appears appearing for the primary that primary voltage gets transformed to the secondary and the diode is reversed by this diode is out of the picture the inductor gets charged and so on.

And when the switch is off the inductor is prevailing like this and the secondary of the transformer is a short circuited and there is no chance for the core flux to reset and, if the

core flux does not reset in the next cycle you will see that the moment this is on the current will be in such a way that it will try to saturate the core we will more on this later. But to complete the circuit we need to insert a diode here such that, when the inductor is prevailing there is no short circuiting of the secondary of the transformer this diode will prevent short circuit current in the secondary, like this way it decouples the buck portion of the circuited. So, let me now clear up the clutter and we will put the circuit neatly in the following manner.

So, now I have cleared up the clutter and then connected to the circuit properly and you see that this is the isolated buck converter and this is called the forward converter. So, no longer should we call this as buck converter it should be called the forward converter, forward because the power is that the power is sent forward into the output section during the time, when the switch is on as against the fly back converter when the power is sent into the output, when the switch is off. So, it is a just a nomenclature and the convention this is called a forward converter in the literature world over. So, we will stick to that name.

After having placed the transformer here, let us now assign the dot polarities to the binary and the secondary. So, let us that is the dot end for the primary and likewise this is the dot end for the secondary assigning dot polarities is very very important you have to do that for every transformer for ever coupled component that, you would have what it basically indicates is that the relative polarities of various windings.

Now in this case when, the transistor is on this non dot end is connected to the ground the dot end is connected to the Vn. So, the dot end is positive with respect to the non dot end likewise the secondary side the dot end would be positive with respect to the non dot end and when, the transformer when the transistor is off there will be a reversible polarity where the non dot end is positive with respect to dot end, also on the secondary side. So, it is very, very important that you test the top polarity assignments for every transformer that you would use it in a certain way.

Now, we have to give a code reset flux reset path for the transformer when the d j t is off the inductor here is prevailing this diode is off the transformer secondary is open

circuited the transformer primary is also open circuited you have to now give a path for the core flux to reset. So, let us provide a resistance diode combination here such that the core flux can get reset to in this pump. So, let me use a register first in this fraction and then a diode which will get connected like this here and then of course, complete the connection the by making divide connection in this fraction now this circuit is a fully functional for a converter circuit. So, when the transistor is on when the switch is on here this is at ground potential this is a v potential this diode is reversed by as it is out of picture this whole arm is out of the picture. So, this voltage is transferred here and charges of the inductor in the normal beam. So, it will be a buck converter.

When the switch is off at that point there is a reversal of polarity here the inductor is prevailing and the primary side here will prevail in this fraction and thereby reset the core flux. So, this part is very, very important without this part this core this transformer isolated forward converter will not work. So, this prevailing path is very, very crucial path this is right now a loss in prevailing part later on I will also discuss touch upon loss less prevailing path for now, we have to now look at the input output relationship and then the reforms before looking at the input output relationship. Let me place here the transformation ratio one is to n now this indicated that for every one winding or n windings here or just to indicate that n two by n one is n. If n is greater than 1 then it is step up transformer, if it is less than 1 it is step down transformer.

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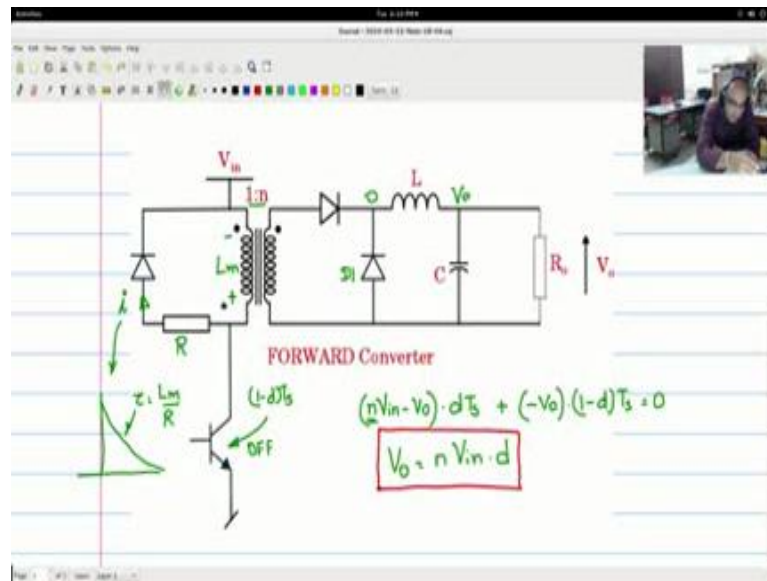
Now, this forward converter I have added this one is to n terms ratio. What is basically means is for every 1 term here? There are n terms in the secondary, n can be greater than 1 for stepping up, n can be less than 1 for stepping down. Now, let us say that doing the d t s period. So, during the d t s period this transistor is on. So, what is the voltage here?

The voltage here is V in and the voltage that appears across on this side is n times V in because; of the terms ratio 1 is to n. Now n times v in comes here at the core of the buck converter and here you are having V naught. So, you see that during d t s time you have n V in minus V naught as your inductor voltage into d t s plus during the 1 minus d t s time this is v transistor is off. So, during the 1 minus d t s time we have the transistor going off. So, that is that is this during the one minus d t s time this is off, now this would become plus there is a reversible polarity, there is a free through this diode. Let us say I call this diode D1 and this is at zero volt d one is ideal. So, you have minus V naught appearing across the inductor into 1 minus d t s. Now that should be equal to zero this will be re lead you to the input output relationship very similar to the buck converter except that you have a n term appearing here.

So, if you read items solve for V naught you get V naught which is equal to n times v in into D. So, this would be the input output relationship for the forward converter that what

we have drawn shown here, and when this inductor when the inductor here is prevailing in this fashion this diode is off secondary is open the primary is also prevailing in this fraction. In the primary this is positive with respect to the dot end. So, there will be a prevailing action happening here now this one of the moment it is prevailing let us say diode is ideal there is a l n in the primary the inductance and this resistance R. So, in a l by R ratio, there will be a current which will be decay in.

So, it will be decay in with a l by r time constant exponentially. So, exponentially the flux will decay. So, here if say this is some resistance R then l n is your inductance the current I here will have a wave shape which starts falling like that with the time constant of dou equals l m by R. So, you will have a falling time constant like this. So, by the time it reaches 0 here, the core flux would have almost come to 0 flux 8. So, this is a very important portion the diode r combination is a very important portion of forward converter to bring about core resulting.

Of course there is one major problem with this R it is dissipative. So, it will bring down the efficiency right now, we will go with this r type of core result glossy core result, later on I will explain a method where you can have a loss less core result to.

Next, let us look at the wave forms of the forward converter which will give us more insight and then which will lead us to the design of the various components.