Design and Simulation of DC-DC converters using open source tools
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Lecture – 18
Flyback Converter Topology

The converters that we are going to discuss are the Flyback Converter and this is one of the most popular converters that you will find in the commercial products. It is a buck boost derived converter and.

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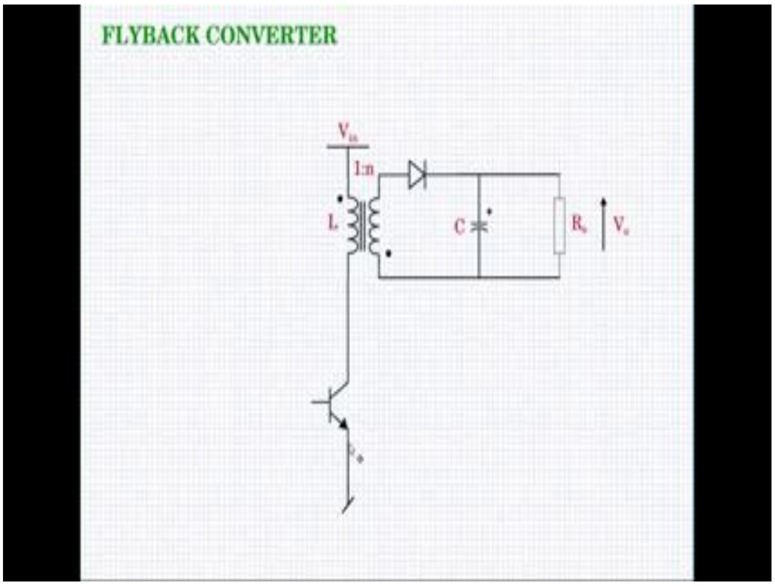

We start by looking at the Buck Boost Circuit. The Buck Boost Circuit as you see here must be familiar to you. We have studied this and we have also simulated this. So, like we did in the forward converter, we would like to push this switch or semi-conductor switch to the return rail and just connect the top rail that is a positive rail by a conductor. So, let us first do that. We will move the switch to the negative rail like this. Now this is still a buck boost converter and we will like in the forward converter, we will like to remove this battery and replace it by a label. So, let us remove that let me position a label here and we will call that one as v in label and we need to rotate this device.

So, let me now rotate this device position it in this fashion and then how do you did pointing to the left, that you can put the gate circuit on this side. Now you are free to remove this conductor and let us place a ground here which will complete the repositioning of the buck converters circuit, we have not done anything except reposition of the circuit. Now we have to include isolation and isolation will be included at this point. Operation of the buck converter is still exactly the same when the switch is on the inductor gets charged in this fashion, when the switch is off the inductor free wheels through the output in this fashion. What we could do is we could still have the inductor like this and make a coupling to the inverter. Let us have a kind of a you push the naming here and let us couple that inductor such that we can have interpose an isolation here and let the freewheeling action of the inductor happen through the secondary.

So, let me clear up this plotter here. After having cleared up the plotter this is how it looks and with the galvanically isolated in that term you have to recall that this is not a transformer this is an inductor, I will explain to you in a moment. But before that we have to give the diode polarities and let me place this dot here and I shall place one more dot here.

Now if you look at the operation when the b j t is on the inductor is getting charged and the dot is positive and the dot is positive the diode will be reverse bias because this is positive with respective to like this. This is positive with respect to this the diode is fully reverse bias. Now, when the switch is off the energy stored in the inductor as to free wheel; there is a reverse for the polarity the non-dot end becomes positive dot end becomes negative. Non-dot end becomes positive dot end becomes negative and this will keep rising till a forward biases the diode and prevails in this fashion.

So, this would give the action of transferring the inductance energy into the output. So, the energy that was charged within the inductor during the on state is delivered to the output during the off state. So, this is not acting like a direct transformer where in the case of transformer whenever there is a current flowing in the primary there will be a current flowing in the secondary and power flow with be instant by instant. So, this has to be designed as an inductor as it acts like one.

Now I am going to kind of flip this secondary portion of the circuit such that the plus appears up, that as we are used to we would like to have the positive on top of the negative at the bottom. So, what I will do I will flip this portion of the circuit like this. So, you see that this is just a direct flip and position in this fashion. So, after having flip the circuit I would like to do one more major change which is the diode being shifted to the upper rail here and the bottom rail is a plane conductor. You see that there is no change in the operation.

Now, let us say for example, when the inductance is a conducting when the switch is on the dot end is positive. The dot end is positive here and the diode is reverse biased because this is positive dot end, here is positive with respect to this diode is reverse biased and off. When the switch is off there is a reverse of the polarity non-dot end is positive. Non-dot end is positive and this will try to force in a freewheeling current through the diode in this fashion.

So, there is no harm in putting the diode in this direction on the positive way. So, what we shall do? Let me remove that and flip it and position it in this direction and make the connection here on the bottom rail. So, after having the clear upon the clatter this is the final circuit this is the Flyback Converter Circuit. The I have still indicated l here saying that, this is an inductor and they should be designed as an inductor and after designing the primary inductor you just put at turns ratio and I depending upon the turns ratio and what is the number of turns that you want to accommodate into the into area of the code.

Now, here you can now put one is to n to indicate that there is a turns ratio coming into the picture. So, this is the, this is how the Flyback Converter is set up and will operate. The operation of the Flyback Converter and the wave forms will be exactly like that of the Buck Boost Converter except that we have put this extra turns here. All the wave forms at various points will be similar to what has been discussed in the Buck Boost Converter. If you put 1 is to 1 than 1 to 1 the same wave forms can be used for every component.

The only difference is n here. So, if suppose for example, we have this n a generic variable, now if you are having v naught and when this is freewheeling rolling the time when this is off this is freewheeling like this because the non-direct end is positive. At the time v naught is connected directly across the second rail and across the primary you will have v naught by n appearing here. So, v naught by n with non-dot end positive plus v in will be the voltage that you will see across the transistor. So, the transistor should be capable of withstanding beam plus v naught by n. So, that would be the rating for this device.

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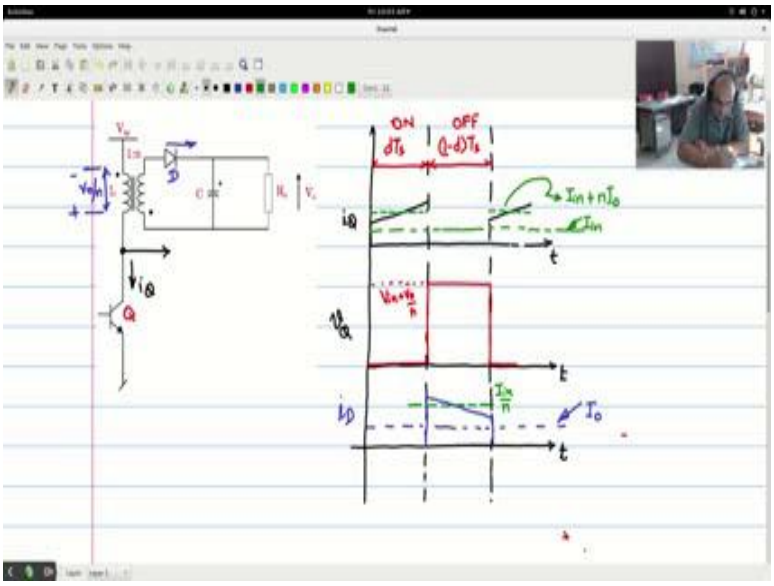

Otherwise all other ratings will be according to the buck boost wave forms. This is the Flyback Converter topology. Let us have some wave forms to ensure clarity. So, let us say that I have two time periods one is the d t s period when the transistor is on and other is one minus d t s period d t s period, when the transistor is off. So, I should say this is on time of the transistor and this is the off time of the transistor Q. So, with respect to these time frames, let me now first try to put the current i Q.

Now i Q will look something like this. Whenever the transistor is on the buck part of the inductor current which flows through the transistor only will be seen here. And this flat top value equivalent flat top value in the case of the Flyback Converter is like as we discussed in the buck boost converter will be a value equal to i in a bridge average of this value plus i naught average what is whatever is flowing through the secondary when the transistor is off i naught average into n in the turns ratio n i naught.

So, average of this would be i in average. So, average of this will be i in. The flat top value would be i in present i naught. Now if you look at another important wave form and that is the wave form V Q across the transistor and at this point. So, let us say we look at this point and during the time when the transistor is suppose to be on, it is just the conduction state this is also conduction whatever the conduction drop. Now the moment the trans the switch is off the diode will be freewheeling is now that a inductor energy is going to free wheel and dump into the diode, into the capacitor. Capacitor voltage is v naught when the director is conducting v naught appears across the secondary with the non-dot end as positive. So, non-dot end are positive will be appearing across this l on the primary side. So, you would probably see plus minus v naught by n appearing across primary winding. So, therefore, V Q would see a voltage which is I should say v in plus v naught by n.

So, this is what will appear across this and so on. The secondary current would current through the diode would of course, be flowing only during this portion I will probably indicate that rule. I will extend the graph y axis lines and show that the secondary side or the diode current will flow only during this time. So, this will be the current that flows through d that is here d and average of this has to be i naught just like as we discussed in the buck boost converter case.

The capacitor will draw zero average current and this flat top value equivalent flat top value would be i in by n reflected on to the secondary side plus i naught. So, this is how the diode current well it look like. This is how the ratings from these wave forms you can derive the ratings and select the components of the Flyback Converter, and also including schematic of the Flyback Converter in gschem. So, that you can simulate that and carry it out. You see this is the schematic you have switch here Flyback Converter.

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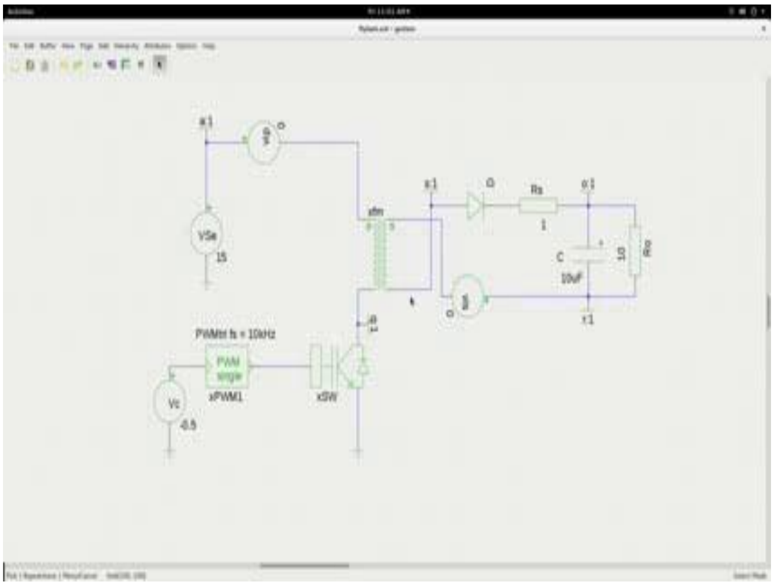

From the non-dot end I am connecting it to the anode of the diode and put a resistance series because you will get numerical instability issues, convergence problems you do not put this and it charges up this capacitance this is the load. You cannot simulate this for very extended period of time because you can get convergence issues because Flyback generally has to be operated in close loop because if the load is not sufficient the capacitance will not have a discharge path if your duty cycle is large.

So, you will have to manage duty cycle to see that the charges within a limit and the transform of the circuit saturated or what you could do is you could put transformer with the linear model and simulate it for extended periods of time or you could also use the other tip which I had mentioned earlier, you could use the linear model the transformer go to the stable state take this state values and then plug in the state value and then you put use for short duration simulations. Anyway this is the schematic that you can use try it out and then try to get insights of the various wave forms. Monitor the current which is flowing through the switch monitor also the current which is flowing through the secondary of the Flyback transformer and try to see they all are as per our theoretical deductions.

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Now, apart from this I am also including value to download and see some m files I have here a Flyback design and the forward designs. So, try the forward design which we have discussed extensively and then you can go and try this Flyback design I have put up generic Flyback Converter design which is multi-output. You can go through the design equation which is an m file and you can probably change the input specification from multi-output to single output and see the results that you get. Probably in a next week we will discuss on the multi-output part of the design and how multi-output transformers can be? How multi-output power supplies can be tackled?

There are few other m files here one is the wires dot m files this is actually containing as a (Refer Time: 18:27) there is a standard wire gauge table. So, I have kind of put them all together in one file. So, that you do not have to search for them. So, this will get executed automatically these are the wire gauges s w g 45 44. So, from the data (Refer Time: 18:43) I have picked them and then put here and then I have put in some course. Now ferrite metlas powdered iron and you can increase I have put only few of them I put some bar codes, I have put some e-codes, u-codes things like that which was available here in out department you can add to them you can take different data sheets and add many more types of codes, this is a template which you can use.

Likewise I have put the metlas and powdered iron code. So, when you run forward converter the time when the design equations come for choosing v a code from the area for a calculation this these are the data in this m files would be take it out because they are functions and then used for the design purposes. I will show you what example for the forward converter. I will open octal and switch over to this directory and what I will do is execute this forward design. So, let us say forward underscore design just written. So, it will ask which core material you want to choose and I will say ferrite and then let us say (Refer Time: 20:14) and if it comes back again it means that the first iteration it would not fit there is cross check equation you will remember we discussed that all the terms should fit into the window area should all the terms into the wire cross section area should be less than k w a w. So, if that cross check does not it will go and hit the next size of the core and then again to the calculation.

So, again you have a freedom to choose the code again I will choose that and the part core it will go for the next size and once it has formed the proper value in last (Refer Time: 20:49) put it into m file. So, let me (Refer Time: 20:52) put it into test and I will save the text dot m gets created also flashes on to the screen the various results. So, if you then click on this test or I will click with g edit. So, I it will be a forward converter specification. These are the specification, these are the designer variable forward converters transformer specs like the primary v a secondary v a it has chosen plot core 26 bar 16 number of terms with the primary. What is a gauge of wire number of terms in the demagnetising? What is the gauge of wire turns in the secondary gauge of the wire? So on; powers switch powers switch are ratings, diode ratings, freewheeling in diode rating, inductor design so on, so forth.

So, the entire converter power supply is designed. So, this is a nice tone to have this is done in octal it will work in mat lab too, current security mat lab also. So, I will remove this text dot file. You can execute it and try it out. I will close this likewise you can also try to do it for the Flyback design which I have given a sample design spec here. Let me open this forward converter design m file. What goes into it is basically the first part of the specification will be seeing the d c link even the comments here nominal d c link minimum d c link maximum d c link output or in arrays to indicate that there it can take multiple outputs.

So, they will turn (Refer Time: 22:41) output ripple, the output current and designer variable like f s that the switching frequency d and j are current density, k w for inductance, k w for transformer k w for inductance so on. Now the power calculation turns ratio to the ratio calculation power converter transform a design you first calculate the area product and then there is an alteration within it where it will check whether it will or the windings will fit it.

So, all this calculation which we had discussed formally put into a code form and then the inductor design again it will grow into a while loop here. We use the energy calculation, energy to calculate the area of product of the code. Here this is where energy (Refer Time: 23:29) m square and the capacitor the output diode it holds thing in it. Finally, the output you need to output you need to file (Refer Time: 23:37). So, this is m file written in octane it will work in MATLAB 2 try it out and enjoy that.