Fundamentals of Power Electronics
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Lecture – 48
Buck converter – operation and waveforms

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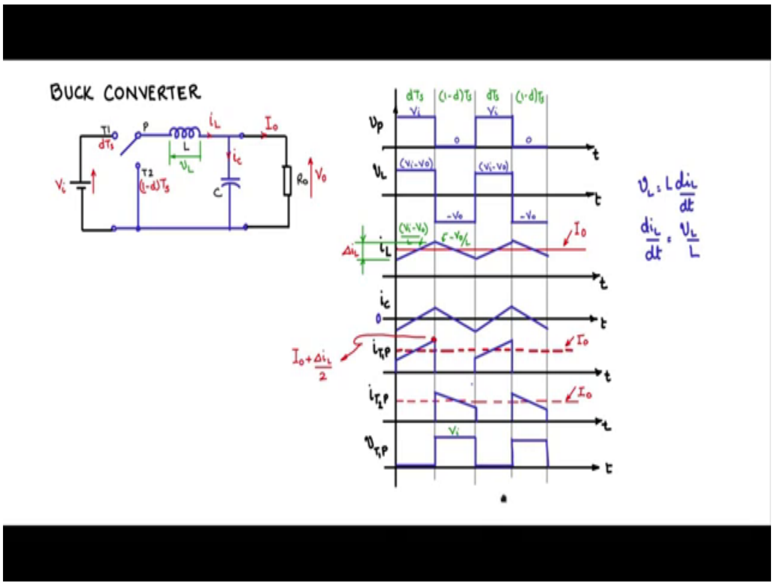

Let us now try to understand the Buck Converter. So, there is this unregulated voltage source V i here and this is the single pole double throw switch, an inductor followed by capacitance. Now this blue portions are the inner inside components of the buck converter, the black portion or external not under your control for design and this is the load. So, let us complete now this is the buck converter circuit we have seen and discussed.

Let us try to understand little bit more in detail this is the pole this is throw 1 this is throw 2 L C R naught V i unregulated this is dTs meaning that pole and throw 1 are connected for dTs period of time pole and throw 2 are connected for 1 minus dTs period of time, this is V naught this is I naught this is iL inductor current and this is the ic the capacitor current, let us also indicate the voltage v L across the inductor.

Now, let us try to understand the circuit visually graphically by looking at the waveforms. So, I am going to have the time on the x axis and the time is split into dTs 1 minus dTs dTs 1 minus dTs 2 switching periods. So, let us first draw a waveform v p with respect to time. So, during dTs p is connected to T1, so it is V i V in then during 1 minus dTs p is connected to T2 it is 0 then during dTs connected to V in and so the waveform had the pole P v P is given here so it is V i and V i.

Next let us try to draw the voltage v L this also we have seen, so during the time when during the time dTs when the pole p is connected to T1 V p is Vi and on the other side of the inductor it is V naught Vi minus V naught is appearing here and here when p is connected to T 2 v p is 0 and on other side you have V naught and you have minus V naught coming across the inductor. So, it repeats as a recycle in this fashion.

Next let us have a look at iL the current through the inductor, now current through the inductor has 2 components one component the I naught component and other component iC component see the I naught component is the DC current average current. So, it has to flow through R naught because capacitor current k naught have an average. So, entire DC current or the average current goes through R naught and the average 0 current flows through iC.

So, if you look at these 2 parts let us say this DC part is I naught and the AC part the part that flows through iC is given in this form let us say we draw this line how did I get this line. So, that is obtained from the Faradays law voltage across the inductor is given by L d iL by d t. So, this means that d iL by d t has a slope of v L by L, now if you see here the voltage v L during the dTs period is a fixed constant value Vi minus V naught so it is constant. So, Vi by L; L is a constant so Vi by L is a constant, so therefore the slope of d iL by d t has to be fixed therefore a straight line having a slope Vi minus V naught by v L.

Now, during this time the voltage applied across the inductor is negative and the slope will be minus V naught by L and because it is minus V naught by L so negative slope. So, minus V naught by L positive slope negative slope so on it keeps going. Next let us have a look at iC the capacitor current see I naught is the fixed DC value remove the I naught component from iL what remains is the AC part, so the ripple part so you will see the iC are the a capacitor current contains the 0 average portion or just only the ripple portion of the current of the inductor current.

So, it will have the same ripple envelope wave shape average is 0, next let us look at current through T 1 P when pole is connected to T 1 there will a current flow when the pole is not connected to T 1 current flow is 0. So, let us say T 1 P in this direction, so you have let me draw this I naught level because it is the inductor current that has to flow either through throw T 1 or through throw T 2. So, the level the inductor current has to be level as to the P the same, so this portion of the inductor current this portion of the inductor current which I am indicating will flow through T 1 P.

So, let us indicate that and this portion of the inductor current will not flow through T 1 P because during that time 1 minus dTs time T 1 is cannot connected. So, T 2 P if you see is mutually exclusive T 1P you will see that the current flows during the other portion 1 minus d portion. So, this portion of the inductor current flows through T 2 P that is here so the inductor freewheels in this fashion.

So, when the T 1P is connected inductor is charging up like this it is going up inductor is charging up and then when it moves in this fashion and when pole is connected to T 2 inductor is discharging it is falling. So, it is freewheeling through this so the current flow is in the direction T 2 to P current flows in the direction T 2 to P. So, if you take the inductor current peak to peak ripple we will call that as delta iL. So, if you take the peak value of the current flowing in T 1 P it is I naught level I naught plus delta iL by 2 this from here to here it is delta iL. So, from level I naught to peak it is delta iL by 2.

So, this can be used for designing the switches rating the switches, then let us look at voltage across T 1 P these are all useful waveforms to rate the switches. So, during the time when dTs T 1 P is connected 0 voltage when it is not connected P is connected to T 2. So, p is at 0 potential T 1 is at Vi potential it has to support Vi during the off condition.

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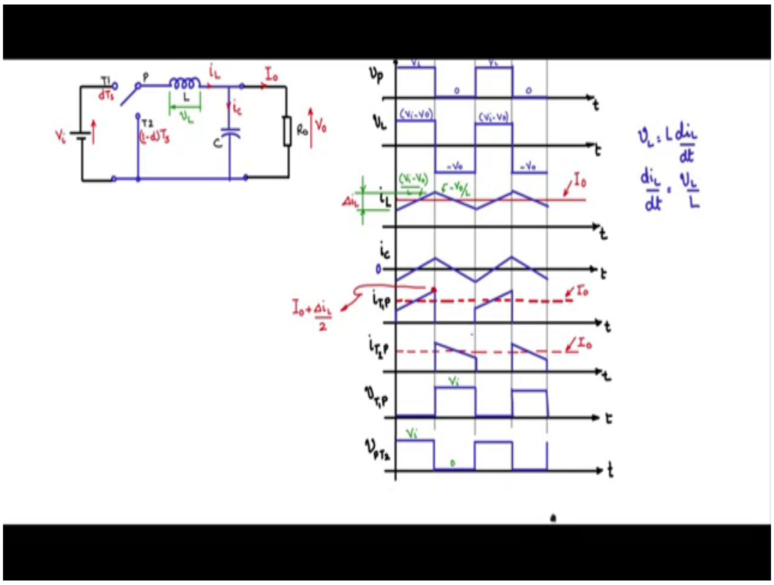

So, this is the voltage across T 1 p voltage across T 2 P, so voltage across T 2 P so actually P voltage P is more positive compared to T 2. So, during the time and; during the time and T 1 is connected to P is at a positive potential compared to T 2 because T 2 is always at ground. Therefore, P being more positive I am putting it as v PT 2 voltage is from P to T 2. So, it is suppose to withstand Vi here 0 Vi and 0 in this fashion, so these are the important waveforms that you should obtain even on a lossy low scope when you use the buck converter circuit.