Electronics for Analog Signal Processing - II
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Lecture - 29
Converters

In the last class we had seen that the series pass regulator is not an efficient regulator. Efficiency was equal to V naught by V i approximately; and the...if V i varies widely, then let us say, V naught is 15 volts. V i varying from 20 to 30 volts particularly when it is in the maximum position. That is V i is 30 volts. Efficiency is less than 50 percent.

So, but in high power high current regulators, we would like to concentrate on efficiency. That also, size of the voltage regulator depends upon the power dissipation; and therefore, small size good efficiency regulators are particularly required in space applications and also in places where size matters a lot.

So, for that purpose, we will discuss a regulator which is based on switch mode, like Class D power amplifier that we had seen where efficiency is very nearly 100 percent. Theoretical efficiency is 100 percent. So similarly, we will therefore go for a switched mode power supply. The preliminary for this is an efficient D C to D C converter. D C to D C converters are commonly used in automotive electronics, etcetera for obtaining D C from a battery, very efficiently. So, let us understand the principle of D C to D C converter first; and later on we will see how it can be efficiently utilized in regulators also.

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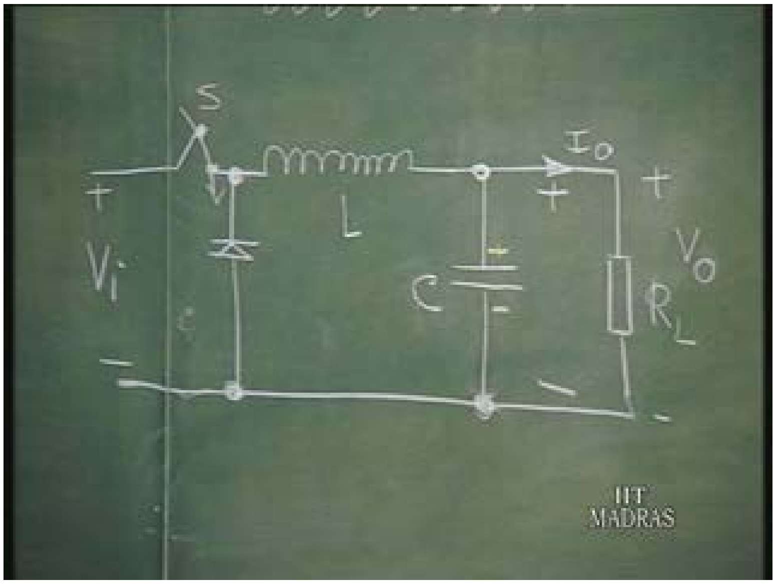

So, we have a D C voltage which is V i. We want to convert it into a D C voltage V naught, which is greater than V i, in an efficient manner. That means we will have to use either switches, inductors, capacitors and diodes and things like that. So, consider this circuit. This V i is connected to this circuit when the switch is closed; and the switch is periodically closing and opening; and there is a duty cycle associated with the switch. So, let us assume that this is the arrangement of duty cycle.

As far as the switch is concerned, it is on for a duration tau, off for the rest of the duration T minus tau, where the periodicity with which the switch is switched is T. So, duty cycle of this which we had earlier also defined is, tau by T.

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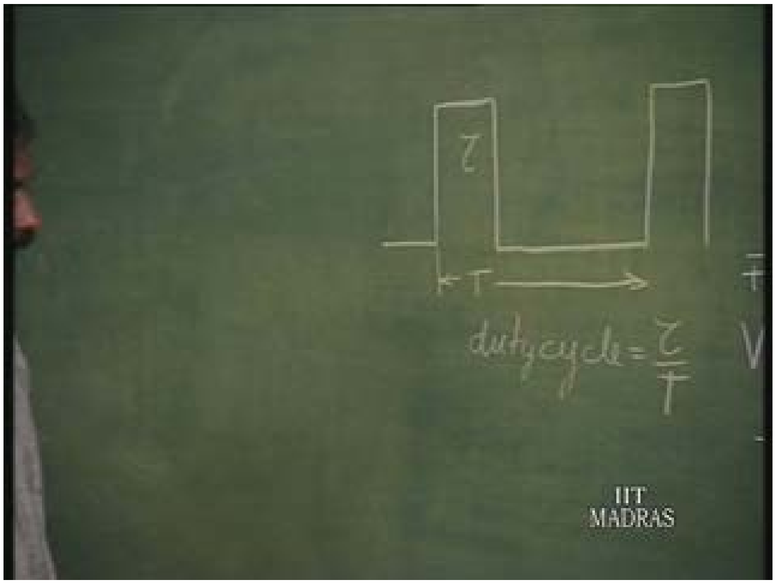

So, if such is the waveform which is appearing here because switch is closed for tau. Therefore, this is V i and when it is open, we want the...this voltage to be zero. That is done...instead of using another switch, we can as well use a diode which, because of the fact that the current in the inductor cannot change suddenly, as the switch is open, the current will continue to flow and that current will make the diode conduct and retain the potential equal to zero, ideally.

So, this earlier scheme where we had used complementary switches can be got rid of and we can use a single switch with the diode which is going to be switched by the current itself. When it is closed, the switch here is automatically open because this is reverse biased.

So, when the switch is closed, the diode D is not conducing. When the switch is open, diode is forced to conduct because of the current continuity in the inductor. So, let us suppose the inductor connectivity is i L. Now, this current is pumped into the load shunted by a capacitor so that the time variation in current is made to develop a very low voltage, because it is pumped into a capacitor.

As far as the average current is concerned, it flows through R L and develops a D C voltage V naught very efficiently. So, this combination of ideal L, ideal capacitor, ideal diode, ideal switch, should theoretically give you 100 percent efficiency. Most of the power is transferred to the load, D C power.

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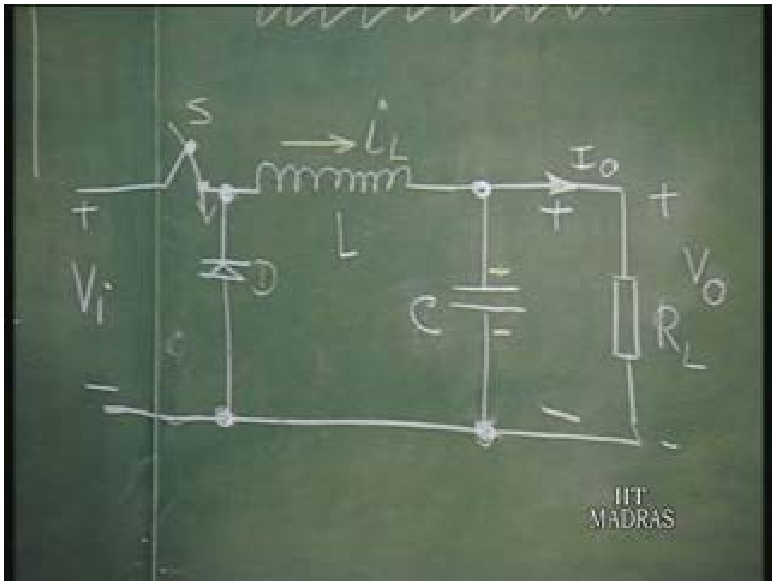

So, what it means is that if this is V i and this is tau over T, the average, which is really speaking, equal to V naught; that is the average of this waveform; is going to be T...tau V i by T. So, this is V naught. This kind of conversion is called down conversion. That is, output voltage in this arrangement is always less than the input voltage. Tau can utmost take on a value of T. So, output voltage is always less than input voltage.

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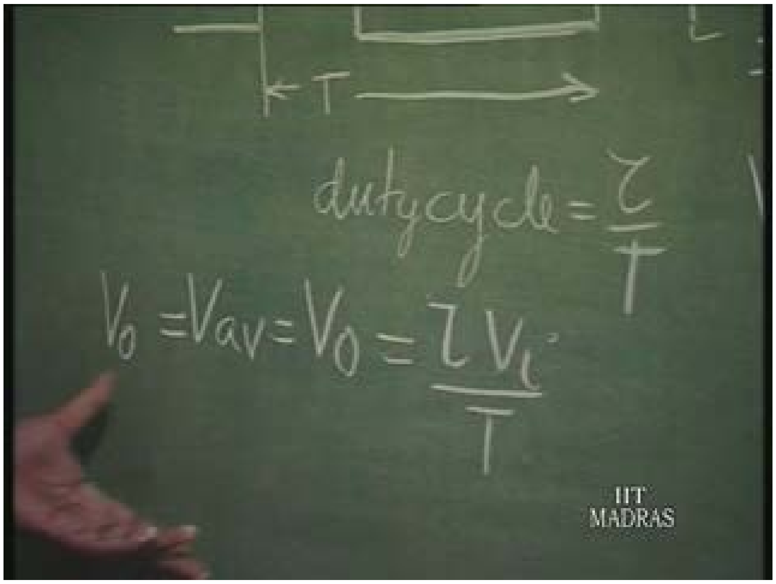

In a regulator, this converter can be used to get an output voltage which is always less than input voltage and maintain constant by adjusting tau over T. So, that is going to become a switched mode regulator. So, switched mode regulator is nothing but a converter with the duty cycle being controlled depending upon whether the output voltage is decreasing below reference value or increasing.

If the output voltage is decreasing, tau by T is increased. If the output voltage is increasing, tau by T is decreased, based on the command got by the comparator output, which receives output as well as reference, just like a conventional series pass regulator; but the efficiency is very good here.

So, let us try to understand the functioning of this in a better manner now. If this is the current, if this is the voltage waveform at this point, when V i is connected, the diode D is reverse biased; when V i is not connected, the current is sourcing the voltage here. Zero. Now, what about the current waveform? Let us therefore draw the current wave form of this particular inductor.

In the inductor, the current is going to be...when the switch is on, this voltage is V i; and this voltage, we are assuming is a D C, if we select L and C properly. So this, we will take it as a D C - V naught. So, the voltage across the inductor is V i minus V naught, a D C.

So, if the voltage across the inductor is a D C, the current in the inductor I is 1 over L integral V D T, 1 over L integral V DT. That means this is a constant. So, it is increasing linearly with respect to time. This is the inductive current i L. So, if we draw the current, it will be increasing linearly. That is, during the period tau.

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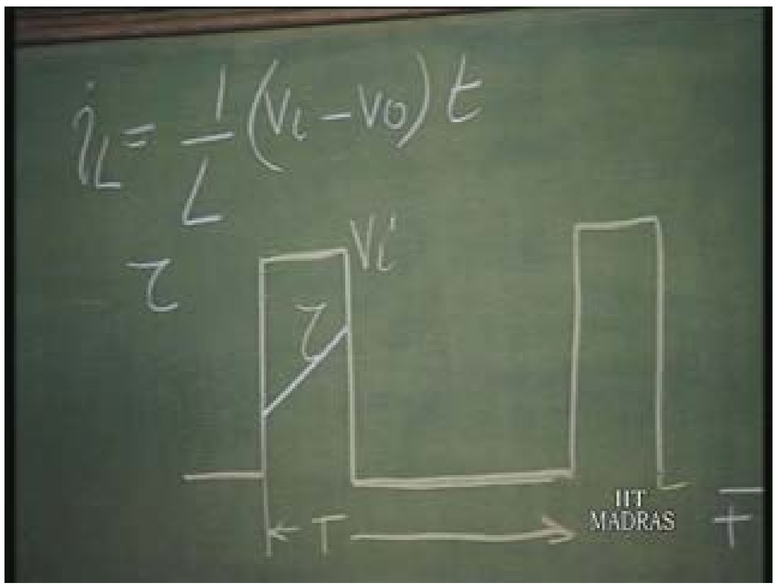

During this time, the switch is open; the current has already reached some value. So, this same current has to continue to flow and that current will force this diode to conduct. It will forward bias this diode and this voltage is going to maintain at zero, when the switch is open. So, this is zero and V naught is remaining same. That divided by L into T. That means current is going to decrease linearly with respect to time; that is determined by V naught by L, rate.

So, this is going to be decreasing during T minus tau. It should obviously...if this is the steady state waveform, it should reach the same value. Again it will start increasing, so on... So, the current is going to be of this width.

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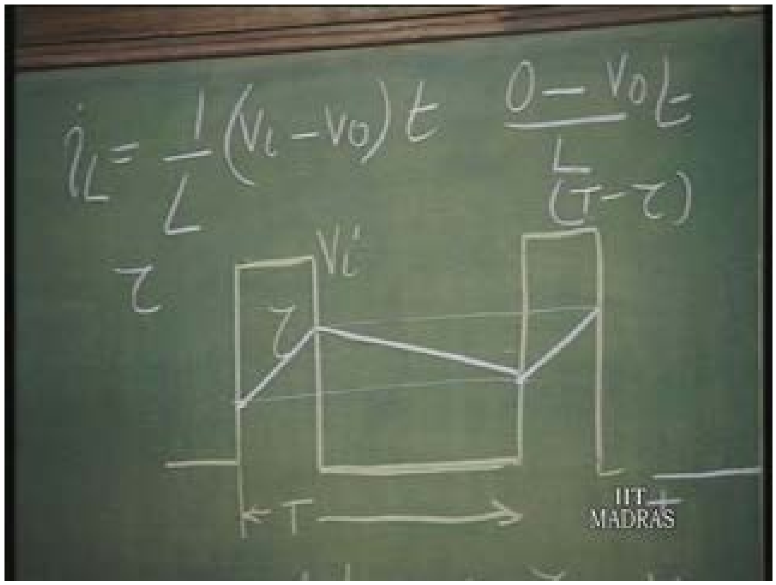

This is only an approximate waveform because strictly speaking, V naught is not constant, but we are assuming that this is an efficient filter circuit. So, V naught is going to be very nearly constant.

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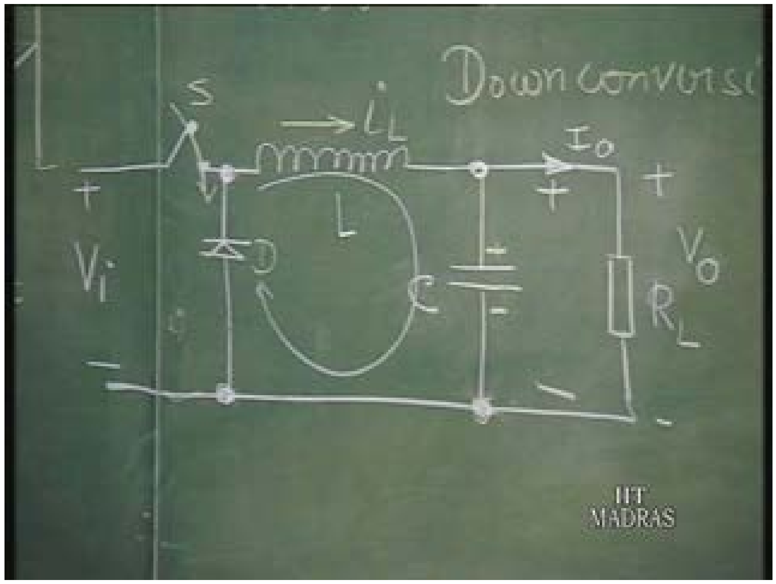

Then, this inductive current i L has an average now. Therefore, what is the average? That will be something like this, let us say. So, if this is i max, this is i minimum. I average is same as I naught because the average D C current cannot flow through the capacitor. This has to flow through the load, I naught.

So, I naught is simply i max, i L max. i L max and i L. So i L minimum by 2; that is the average. That means actually this area is same as this area around this line. This is positive area, this is negative area. These areas will be the same. That is what is meant by average.

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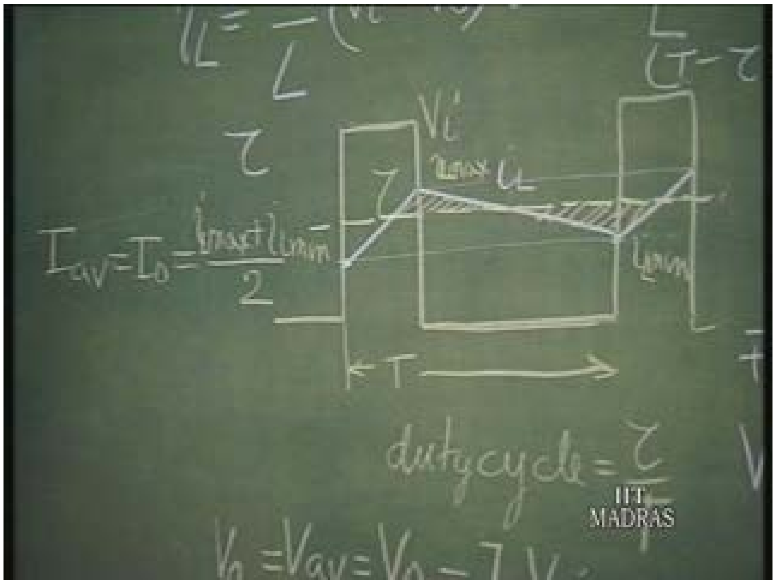

So I naught is, let us say known. We want certain average current to be delivered by the converter. So, I naught is known. So, i L max plus i L minimum by 2 is known. i L max plus i L minimum is nothing but twice I naught.

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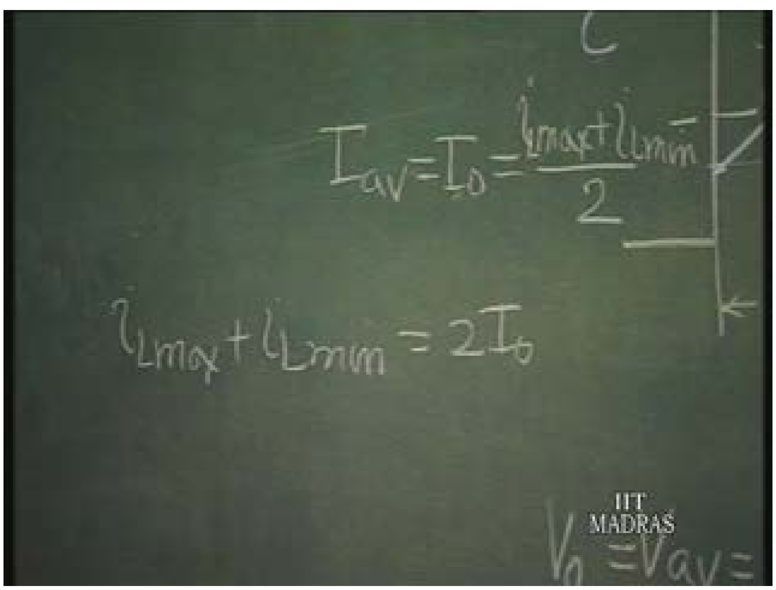

So, in a given circuit, if I naught is known, we will know what is the maximum current in the inductor plus minimum current. Maximum plus minimum. i L max minus i L minimum - that is this change in current. This, we will call as Delta i L. This should be equal to...practically, we want ripple to be small compared to the average. This should be some percentage. This should be normally less than 5 percent of the average; so less than. This is a typical thing, design. So, when I want the ripple in the current to be small, I want this to be less than 5 percent of the average. So, I naught by 20. So, 5 percent of the average.

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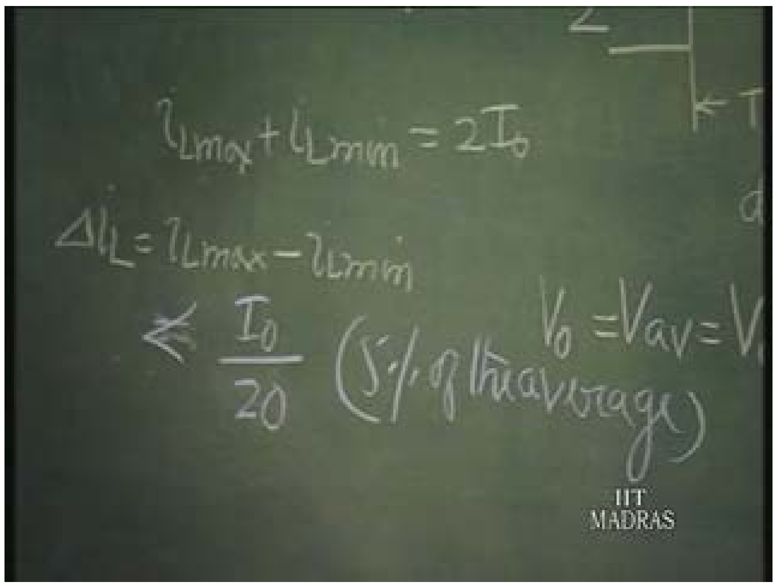

So from this, knowing I naught, I can find out i L max and i L minimum. So, the maximum current that is going to flow through the inductor is known. This is an important information and also the ripple in the inductor is known. Now, I would like to find out what the ripple in the output is. Assume that the average current flows through the resistance develop the voltage V naught. That we know already. We are designing it for a specific load and output voltage and current.

So, this is known. V naught is known as a constant. Over that, there is a ripple. What is that ripple? That ripple is only because this capacitor is not large enough to make the ripple extremely small, let us say. So, there will be some change in voltage across the capacitor. Change in voltage across the capacitor is considered as the ripple. So, what is voltage across the capacitor? 1 over C integral I capacitor d t is the voltage across the capacitor.

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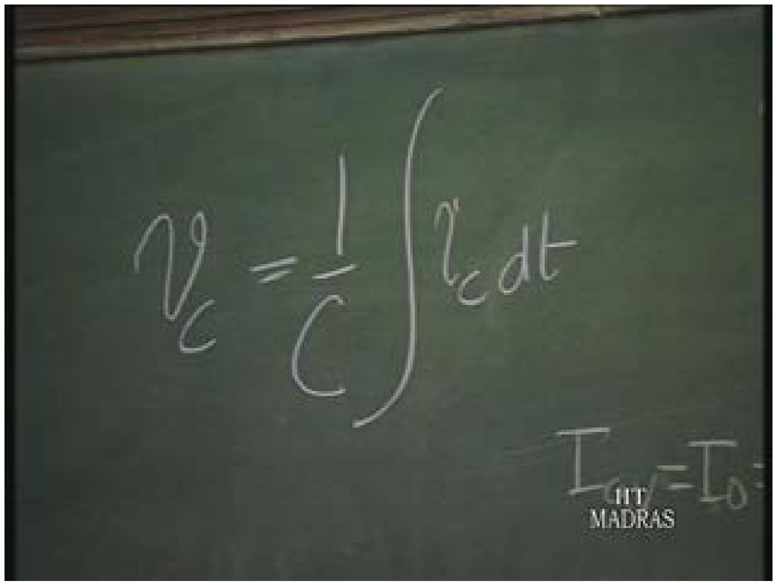

That means integral of the current waveform, changing current waveform...changing current waveform is what is marked in the...as a triangular waveform here. This average is removed. Then this is the changing current waveform riding over this. This current alone flows into the capacitor, we will assume.

Whatever is flowing through the resistance is negligible compared to what is flowing in the capacitor. So, we have selected such a large value of capacitor. Then, what is the integral i d t? Integral i d t is nothing but area under the curve. So, integral i d t is nothing but the area of this, this triangle.

So, if you draw the capacitor waveform, it will be...this voltage will be around V naught and it will be increasing up to this point and it will be decreasing. In fact, it will be increasing like this and decreasing up to this point. So, this is the voltage across the capacitor, slightly magnified; and average of this is V naught.

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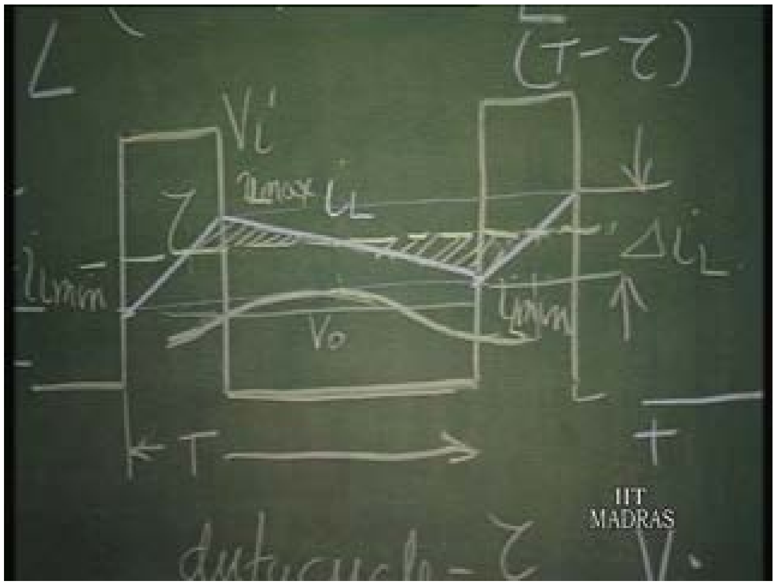

So, the voltage across the capacitor is increasing up to this point, from, from this point onwards, and decreasing up to this point.

So, the peak to peak ripple is 1 over C into the area of this. So, the area of this is nothing but the base. What is the base? Base is T by 2. So this T by 2 into the height which is Delta i L by 2. Delta i L is this. Delta i L by 2 into the height. Delta i L by 2 - half of it; base into height, half of it. So, the area is half of base Delta i L by 2 into the...that is height, into T by 2. So, this is equal to Delta i L by 8 C into T.

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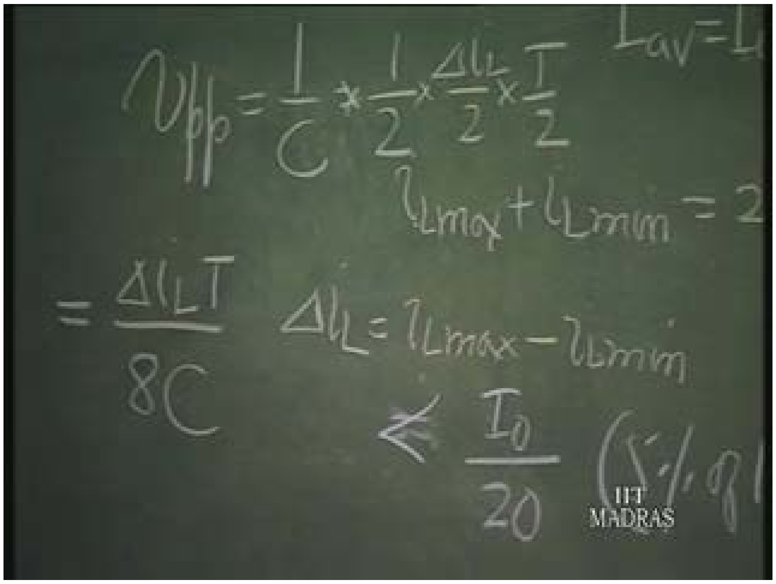

Delta i L is already known here. i L max minus i L minimum. So, i L max minus i L minimum; that we have already fixed. So, it is directly proportional to that. If you make that small, this peak to peak ripple also is going to be small; into T divided by 8 C. So, T is equal to, of course, 1 over F of the clock frequency at which it is switched; peak to peak ripple.

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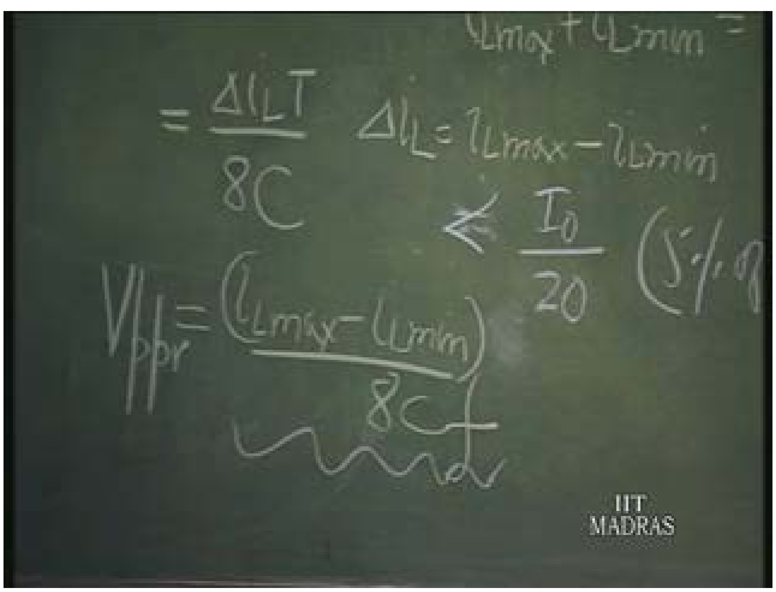

So, if you are told that this should be the peak to peak ripple, this should be such a percentage of V naught, then you can fix up the value of C from this equation. Knowing the switching frequency, knowing the peak to peak ripple, knowing i L max minus i L minimum which is a percentage of I naught, we can fix up the ripple; and also, we can fix up the inductor based on this equation here.

So, this is going to be...Delta i L is also equal to tau over...tau over...In fact, L into V i minus V naught; that is Delta i L. This is the change. During tau, V i minus V naught into L by tau over L is equal to Delta L, which is also equal to V naught by L into T minus tau.

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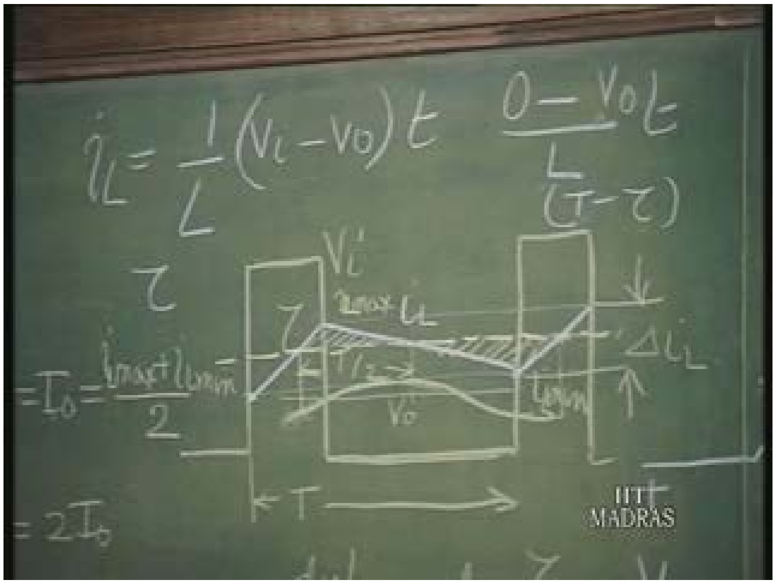

So, using this, we can find out the value of L and complete the design. So, this is how we can design an efficient converter for a specific voltage. One way is...if you have, let us say battery of 15 volts and you want a battery for 5 volts, voltage source for 5 volts, 15, 5... This is a typical situation of a circuit containing analog element which requires plus minus 15, you want to obtain a supply for digital which is 5 volts. So, an efficient way of converting is this.

Now, we will consider another D C to D C converter which is called up converter. Earlier, we had discussed what is called down converter where output voltage is always less than the input voltage. Now consider this converter where the arrangement of the inductor, diode and switch has changed somewhat. The diode was earlier put here. Inductor was there and the switch was here.

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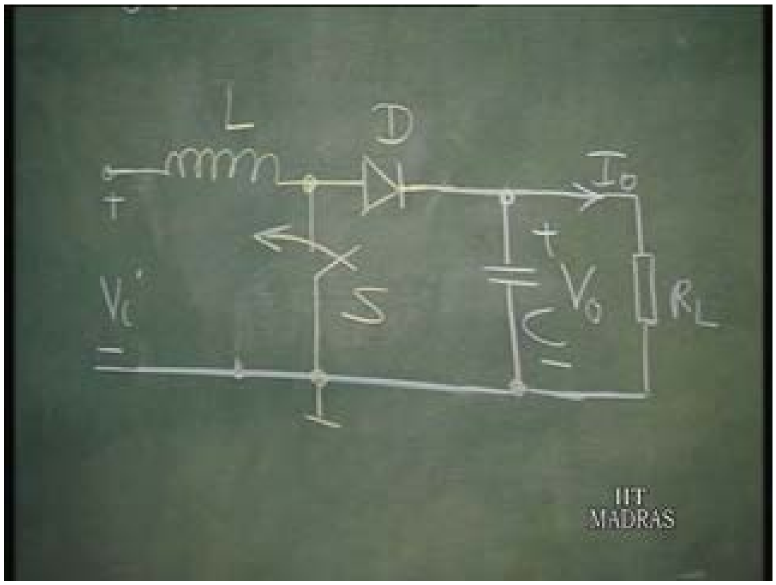

So, in this arrangement, when the switch S is closed, this voltage V i will directly come across L. So, the current in the inductor i L is going to increase linearly with respect to time with V i by L into T inductor. Voltage across the inductor is...this is closed; so this is zero. This is V i.

So, V i is being applied across the inductor. So, V i by L into T is the way in which current in the inductor will increase. Now, let us say at this point, S open. So, the moment S is open, the conduct in the...the current in the inductor should continue to flow. So, the diode facilitates a path for the current in the inductor to flow; and voltage across the inductor now...diode is conducting because current i L has to continue to flow.

So, switch S is open; voltage across the inductor is V i minus V naught by L into T is the way in which it should decrease. Current through the inductor now should decrease. That means this should be negative. That simply means V naught has to be greater than V i. So, if this is to decrease to the same extent as this is increasing, this has to be such that... We have an equation here. This is the duty cycle. Let us say, this is tau, this is T.

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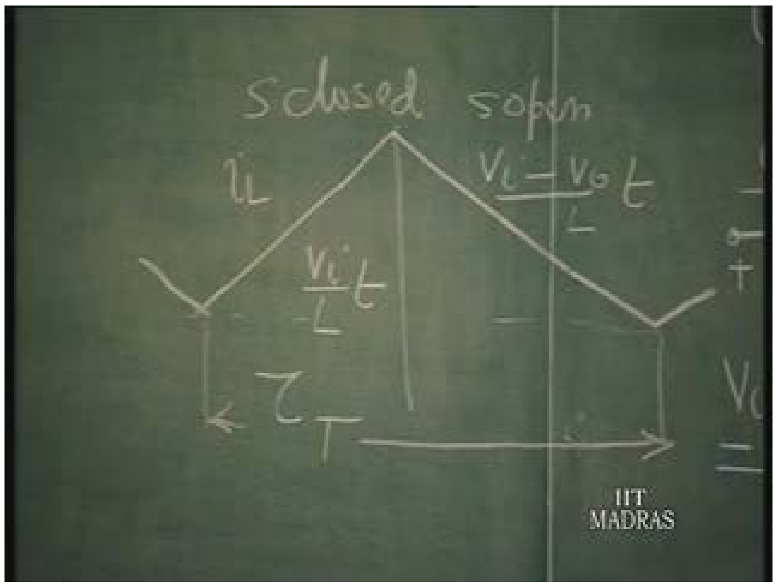

So, we have V i by L into tau. This change in current should be the same as V naught minus V i. Why... Why am I writing V naught minus V i? Because I know that V naught is greater than V i. That magnitude into T minus tau, this change in current.

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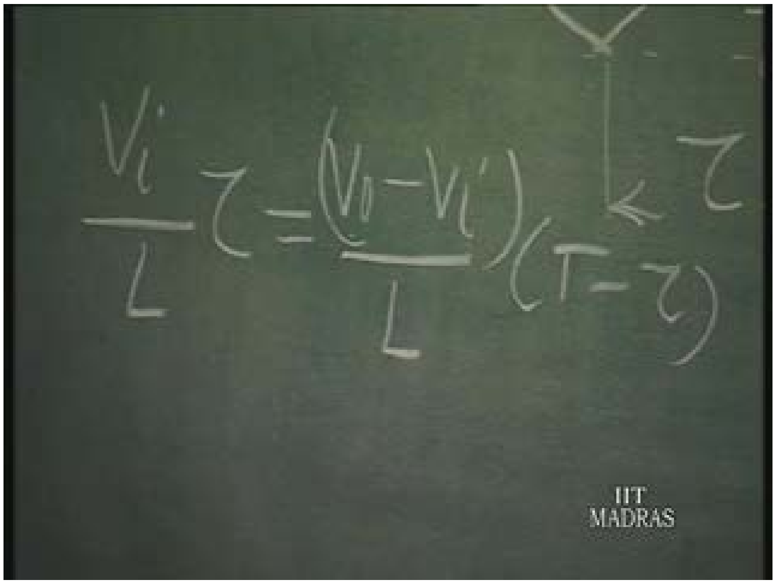

So, we can now...this is actually Delta i L, change in current, which is nothing but i max, i L max minus i L minimum - similar to what we got last time.

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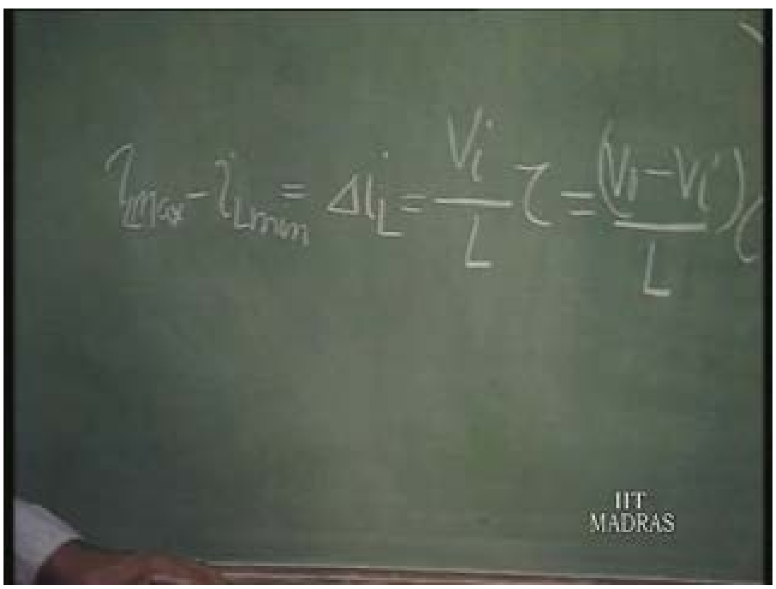

So, if you cancel this, we can get V i into tau equals V naught minus V i into T minus tau. So, from this equation, we can get... divided tau. So, this is V i by V naught minus V i is equal to T by tau minus 1.

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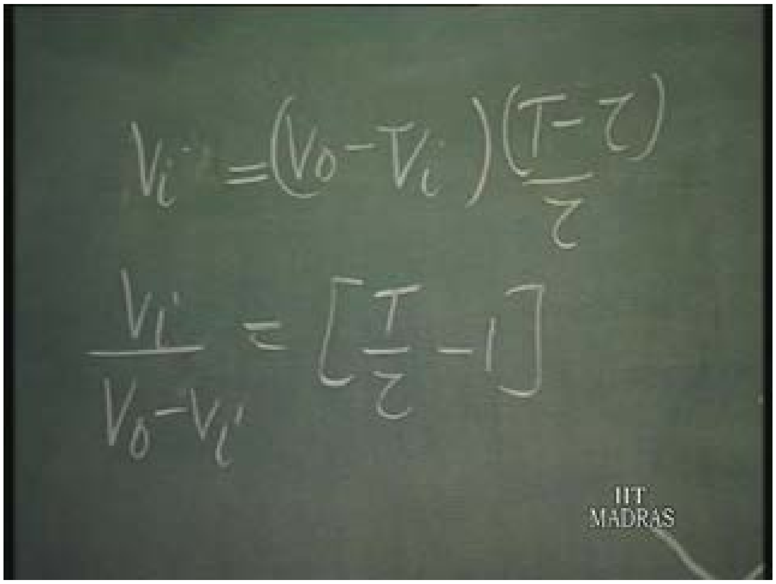

So, from this we can arrive at actually V naught over V i because V naught minus V i by V i therefore is equal to 1 by T by tau minus 1. So, this is V naught over V i minus 1.

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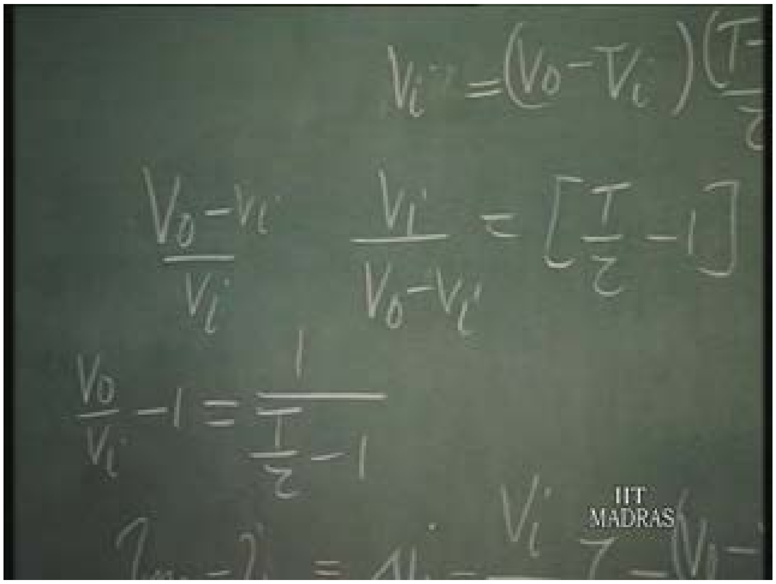

So, V naught over V i is 1 plus 1 minus T by tau minus 1. So, this will give you nothing but...T by tau goes up; that gets cancelled with that minus 1. So, T by tau minus 1.

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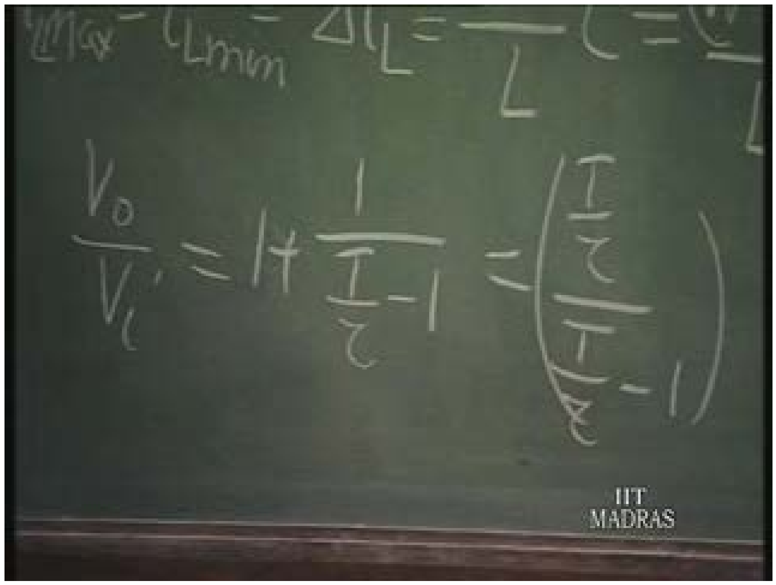

So, T by...T is greater than tau. So, this is a factor greater than 1. So, T by tau minus 1, T by tau. So, this is the thing, actually. This is actually T divided by T minus tau.

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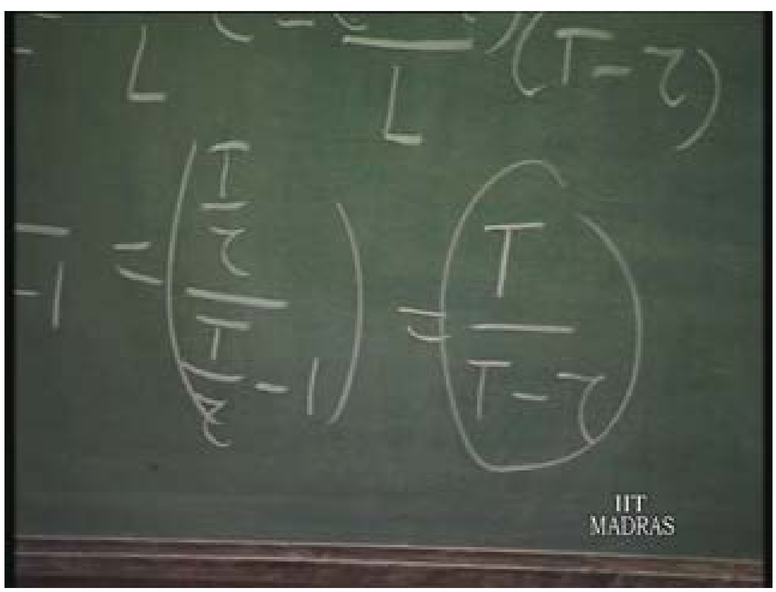

So, this is always higher than T minus tau. So, V naught is always higher than V i. So, this is called up converter. So, basic principle remains the same except that position of all these elements have got changed.

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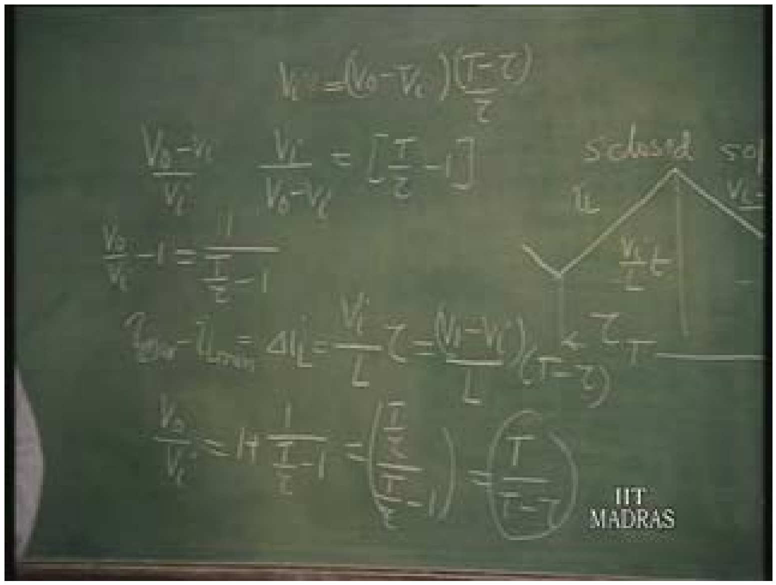

So, if you want a converter which is going to boost up the voltage, this is the arrangement. So, let us say, we have only car battery available and we want a large amount of D C supply, may be for the tube light or something like that. So, this inside the car...So, you can actually develop the voltage needed using this kind of converter.

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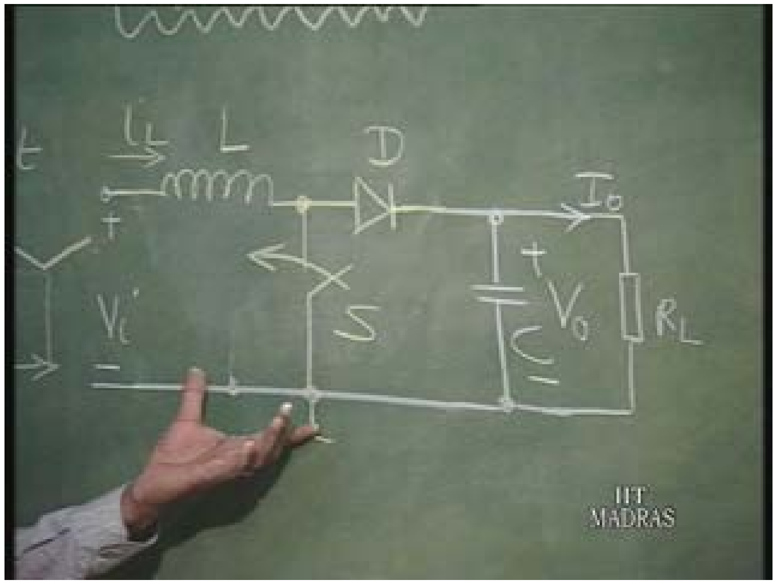

We have seen down conversion, then up conversion. We would like to now have an arrangement where it can be inverted. What I mean is with reference to a common point, reference...we have let us say, plus 5; only plus 5. We would like to get minus 5. This will be the situation when we are dealing with, let us say a logic circuit supply which is only, let us say plus 5. But, we would like to generate both plus 5 and minus 5 for making our analog circuits work; dual supply.

So, this inversion can be done also very efficiently by using this kind of circuit, same thing. The L switch and the diode have been now rearranged in such a manner that this can give inversion. That is, if it is plus something, you can get minus as the output voltage with reference to the same common point.

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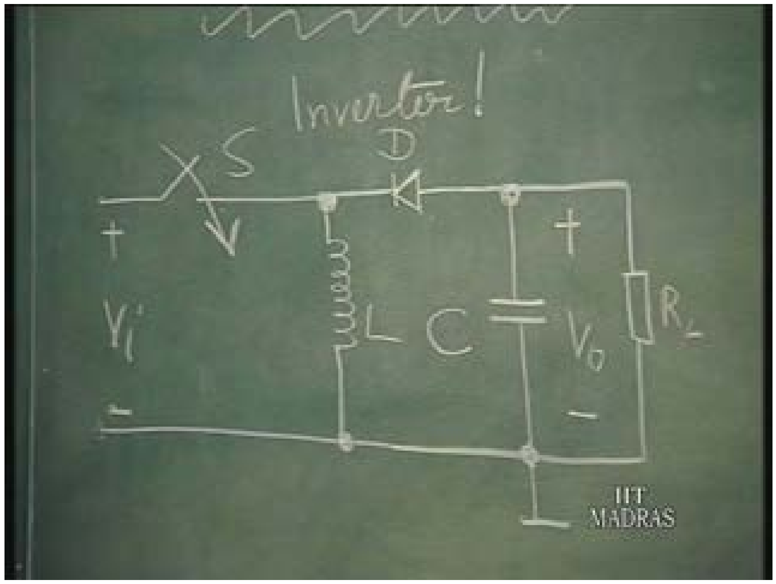

So, this in fact is the most popular circuit for switched board regulators primarily because here there is no restriction on the fact that output voltage has to be always less then input voltage or output voltage can only be more than the input voltage, or anything. Output voltage can be anything in relation to input voltage. That means it can do both boosting and at...what is that? – reducing.

So, this kind of flexibility is very necessary in the case of switched mode regulator circuits and therefore this is the most popular configuration for switched mode power regulators.

Let us discuss this. When S is closed, when S is closed, this V i is coming directly across the inductor. So, inductive current i L now is going to be...V i is across inductor; therefore, V i by L into T...so, when switch S is open, this inductive current should force the diode to conduct because it will...it is flowing in this direction. It will continue to flow in this direction. Then it will charge the capacitor plus and minus this way. This inductive current is charging the capacitor, plus minus.

So, V naught is, really speaking, negative as regards polarity, even though what is marked here is plus minus, actual voltage is negative. And therefore, this is the voltage across the inductor. So, that is V naught by L into t. When the switch S is open, the voltage across the inductor is V naught. When the switch S is closed, the voltage across the inductor is V i. And when it is V i, this particular diode is going to be reverse biased having a negative voltage with respect to this coming across it. So, the diode is reverse biased, automatically off.

So, when it is closed, when the diode is closed, when the switch is open because the inductive current flows here, automatically, charging of the capacitor occurs. It restores whatever it has lost during this phase of this being open. So, this is the way the current is going to change Delta i L. Again, average current, etcetera are the...can be evaluated.

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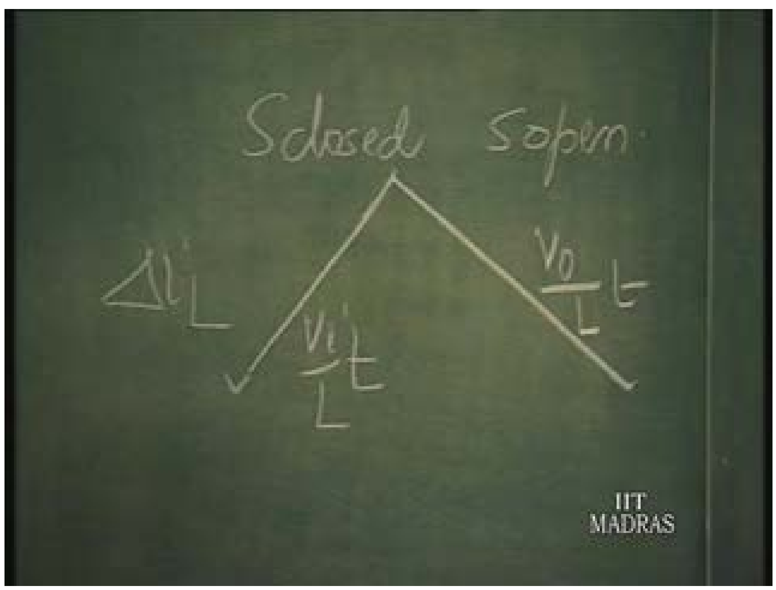

Only thing is V naught is here negative; and therefore, we can write it as...we will put it, magnitude of V naught minus, so that you are not confused. So, V i by L into tau...This is tau, let us say, during which it is closed. This is the time period T. So, V i by L into tau is the same as V naught by L into T minus tau. So, this is equal to Delta i L.

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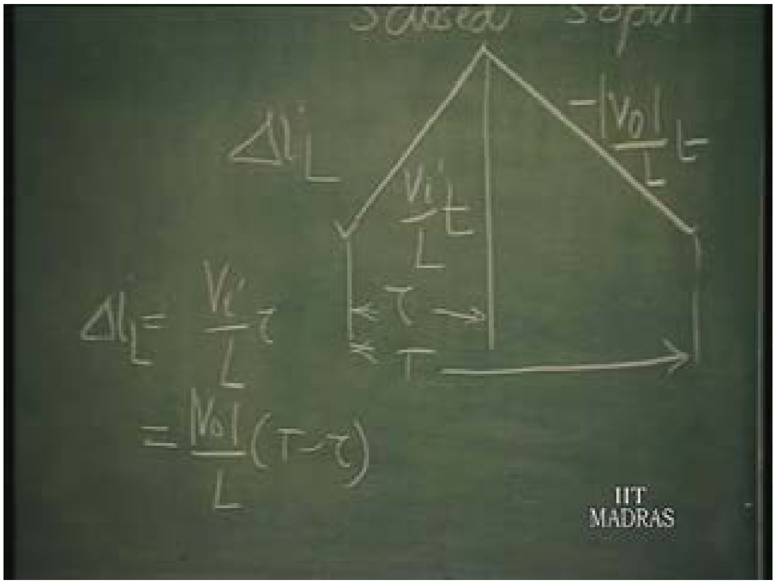

So, from this we get V naught by V i is equal to T minus...sorry. V i into tau. So, tau by T minus tau. So, tau and T minus tau can be greater than 1 or less than 1; and therefore, V naught can be greater than V i or less than V i or equal to V i because when tau is equal to T by 2, it is equal to V i.

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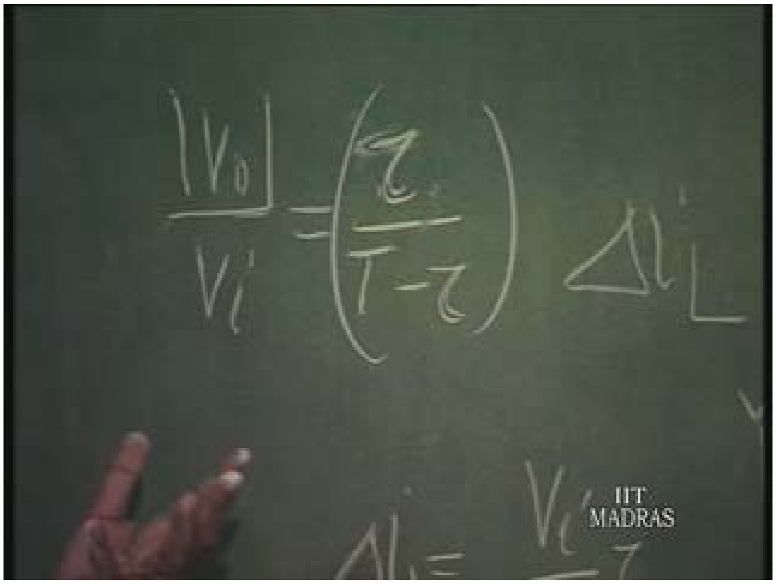

So, this is a very convenient way of adjusting the output voltage to whatever value you want. It can be greater than that or less than that; and it is going to be regulated depending upon the ratio tau by T. So, this is a very popular circuit, as I pointed out, because of this reason.

One factor common to all the three converters is this. We have assumed that inductor is ideal, capacitor is ideal, switch is ideal, diode is ideal. This is not going to be the case. Let us discuss one by one.

First and foremost, switch S - this could be a morse switch or bipolar switch. So, if it is bipolar switch, when it is closed, VCEsat is coming across it and current through it is going to be determined by the inductor. Maximum current in the inductor will flow through it; and therefore minimum current also in the circuit is going to flow through it.

So, it is going to fluctuate from maximum to minimum; and the...what matters is the maximum current. So, when it is closed, maximum current flows through it. So, there is going to be a power dissipated when it is closed. This is what we have to bother about. There is certain amount of power dissipated when it is closed; and when it is open, there will be a voltage across it. And this voltage, for example here, V i plus V naught magnitude, is what is going to come across this. And therefore, it should be dissipating certain amount of power because now leakage current will flow through it. So, leakage current times this voltage is the power dissipating. So, power gets dissipated both when it is closed and as well as when it is open.

Similarly, with this diode, this diode drop is more than the switch drop when it is closed. Diode drop is V Gamma which is normally greater than VCEsat, when it is closed. So, that is the disadvantage of using diodes as switches, but it is a very simple switch. Therefore, this V diode...when V Gamma into the...again average current flowing through the diode, will give you the power dissipated in the diode, when it is closed. When it is open, again, we have V i plus magnitude of V naught across it; and the leakage current will flow through it. So, that is the power dissipated in the diode.

Inductor, whenever it is in operation, because that is both when it is closed and open, inductive current continuously flows. So, this inductive current is going to pass through the resistance of the coil of the inductor and dissipates certain amount of power.

There is going to be both series resistance as well as shunt resistance associated with the capacitor which will also cause certain amount of power loss. So, all these power losses added together will cause certain amount of deduction in efficiency from 100 percent. So, if you assume that the power output is going to be based on R L which is V naught square divided by R L, output power...

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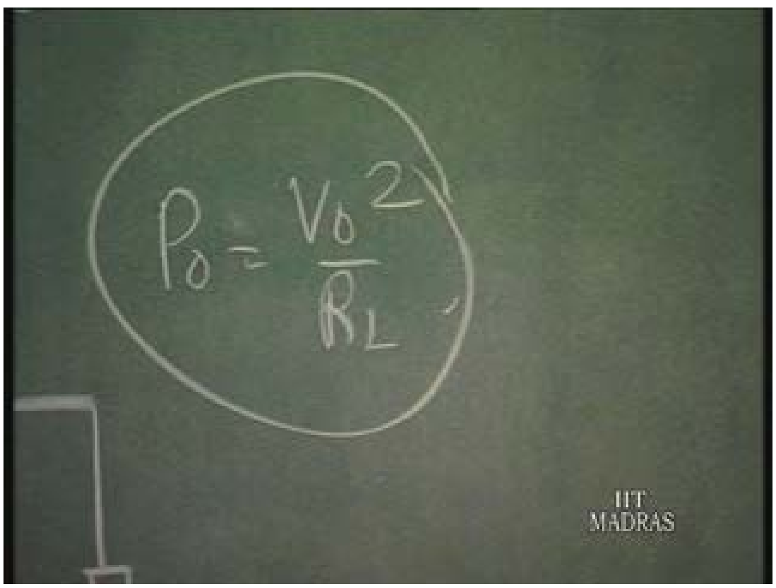

So, this may be, let us say 1 watt or 10 watts or something like that. You might have to subtract about 10 to 20 percent more power at the input to account for all the power loss in these devices. So, that...to that extent, this particular circuit is going to be sort of causing certain amount of loss.

We can therefore find out from this, input average current, because V i into, let us say I i; whatever it is, current that is going to be taken. During the time it is going to be connected to V i, this is the input power I i. V i into I i average that is going to be taken when the switch is closed.

So, given the output power assuming that the efficiency is 100 percent, you can find out I i average. So, you can find out the average current that is passing through the switch. So, this I i average will be definitely different from the I naught average because V naught and V i are different; but power is the same. Power input is same as power output, if the efficiency is 100 percent. Otherwise, power output plus the losses will be equal to the power input from which you can find out I i average.

So essentially, technique is, power output plus power dissipated due to losses in the switches as well as inductors, will be the power input.

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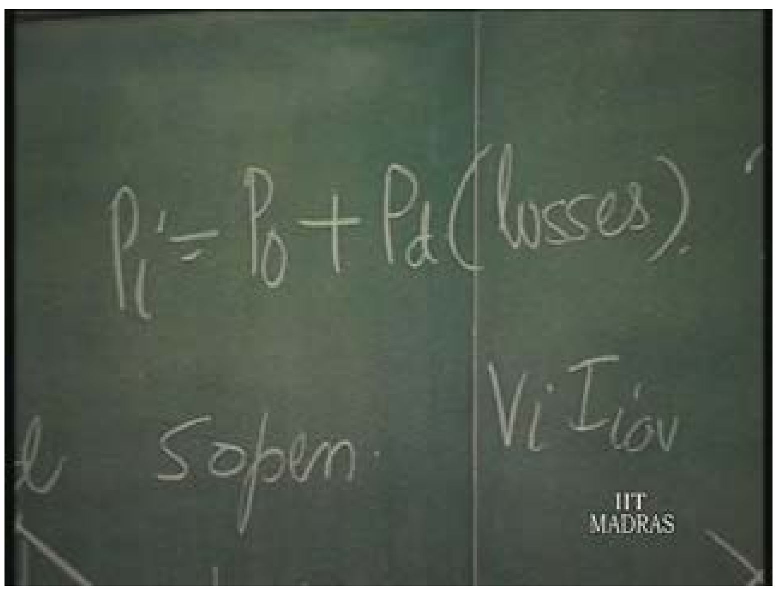

Input voltage is known. So, I i average current that is to be delivered when the switch is closed can be also found out.

We had discussed all about converters. Now, let us consider these converter which just now we have finished discussing. This is the converter which we are going to use for in regulator.

This is called switched mode power supply; or popularly it is called S M P S design.

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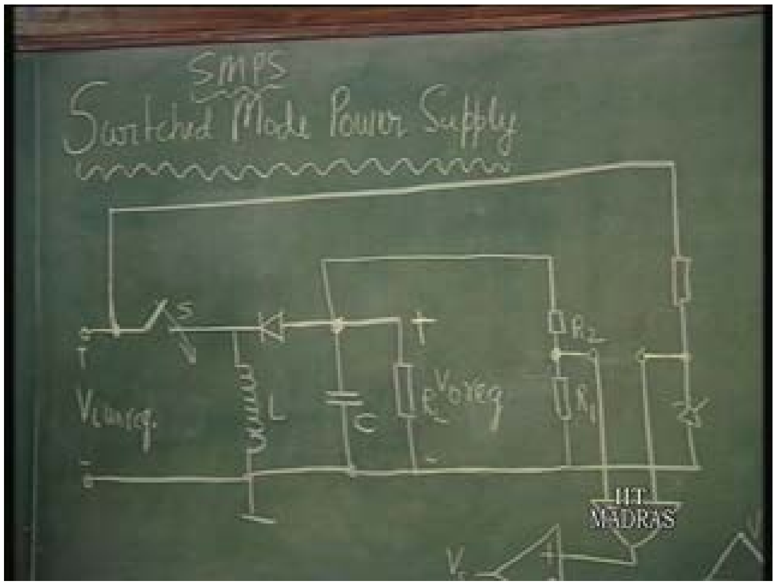

It is a very commonly used unit in almost all your television receivers and appliances. So, let us now consider how this can be designed. We have found out that we have an unregulated voltage, V i unregulated. We want to maintain across the load, a regulated output voltage. We have now got a relationship between this and this in the following manner; that, this can be converted to a voltage based on the ratio...

Now, V naught magnitude divided by V i is going to be equal to tau by T minus tau. Is it correct? Tau by T minus tau. So, I can now control this tau divided by T minus tau in such a manner that this remains, V naught remains constant. That means magnitude of V naught should remain constant; that equal to V i into tau...

Obviously, it changes this V i because V i changes. Then, I will make tau by T such that V i into this factor remains constant. This should remain constant. What is it that facilitates that?

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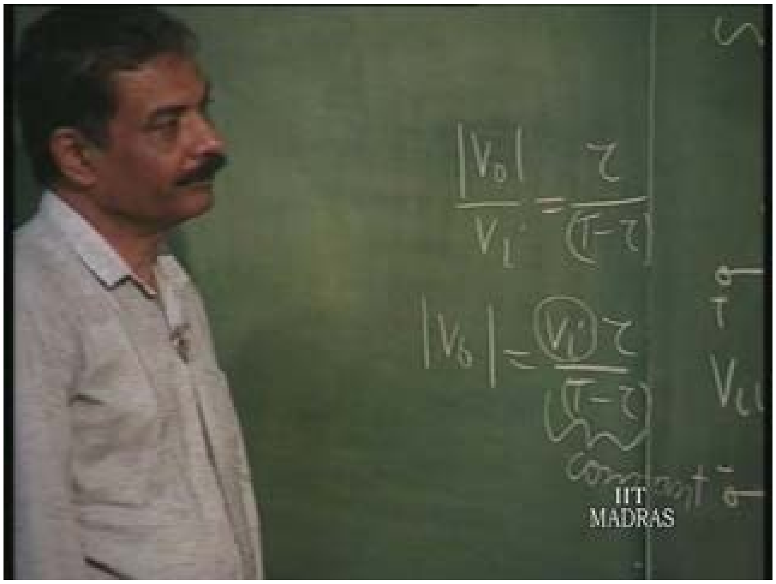

So, we are sensing V naught. If this is V naught, we have that network R 1 and R 2 which we had earlier used. So, that means this is R 1 by R 1 plus R 2 into V naught. Compare it with a reference V z. This reference is got from the same supply, let us say; positive supply V z.

So this reference is compared with V naught into R 1 by R 1 plus R two using a comparator, voltage comparator; and output of this is going to some D C. It will tell us whether this is, this is higher than this or lower than this; and based on this information, we will convert that D C voltage into pulse width. Based on the usual method that we have earlier also adopted in Class D power amplifiers, a signal generator which gives the clock frequency at which it is switched; 1 over T is the clock frequency.

So, this can be generated by using the function generator circuit that we had already discussed earlier, a stable multi vibrator. The stable multi vibrator can be designed to work at a clock frequency f c; and the triangular wave form that is generated can be given. And we know the relationship between this D T cycle here and V p and this voltage, V reference. So, this particular thing therefore is going to be...we will say, V control of the switch. This is V c. This is how we have been calling it. So, this is the control for the switch here.

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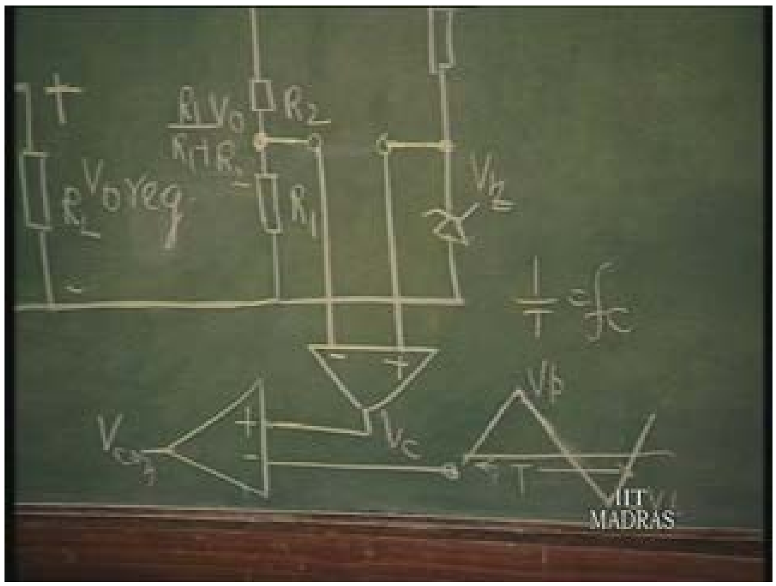

So, for what time it is going to be controlled, etcetera, is going to be decided by this switch here. So, this output of the output level here will be such that it is closed or open depending upon the duty cycle period here.

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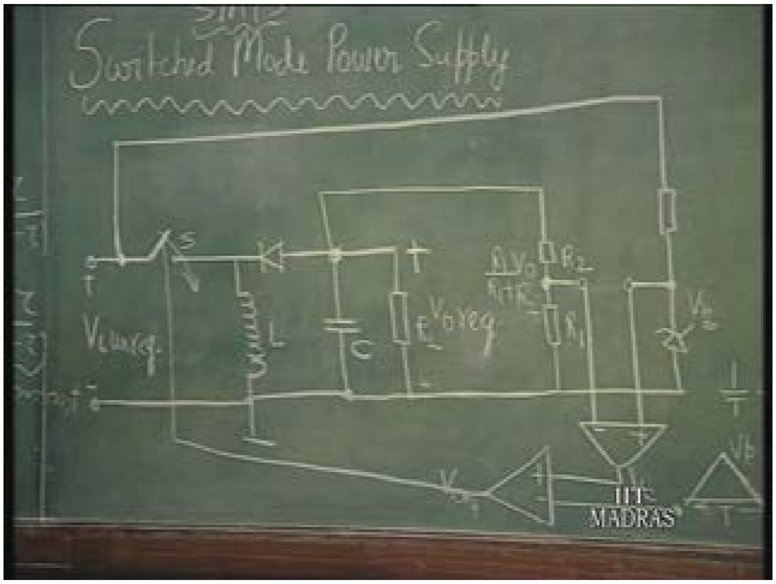

So, this is the complete schematic for a switched mode power supply. What additional things that is needed is a signal generator at the clock frequency; the typical clock frequency that is used for all these purposes is, nowadays, we can go up to megahertz. Earlier it was up to a 100 Kilohertz. Now, you can go even up to 1 megahertz.

The only problem is these are all power switches; may be amperes of currents have to be switched at frequencies of the order of 1 megahertz. Technology is improving such that we have morse switches which are becoming available. We can operate it as higher frequency as 1 megahertz handling currents of the order of amperes.

So, why do you go for such high frequencies? Primarily, we will see that the inductor size and the capacitor size for filtering out and averaging become smaller and smaller; and therefore, this entire S M P S becomes a very small size comparable to the sizes involved in microelectronic, other structures.

So, this is the reason we go for S M P S working at high frequencies delivering large amount of power to whatever system you want. And this whole thing can be put...all these switching circuits can be put in an integrating form except that this have to be discrete circuitry. So, such regulators which will be basically hybrid circuits are available commercially for a variety of applications.

This Example 24 will clarify certain aspects of design of converters.

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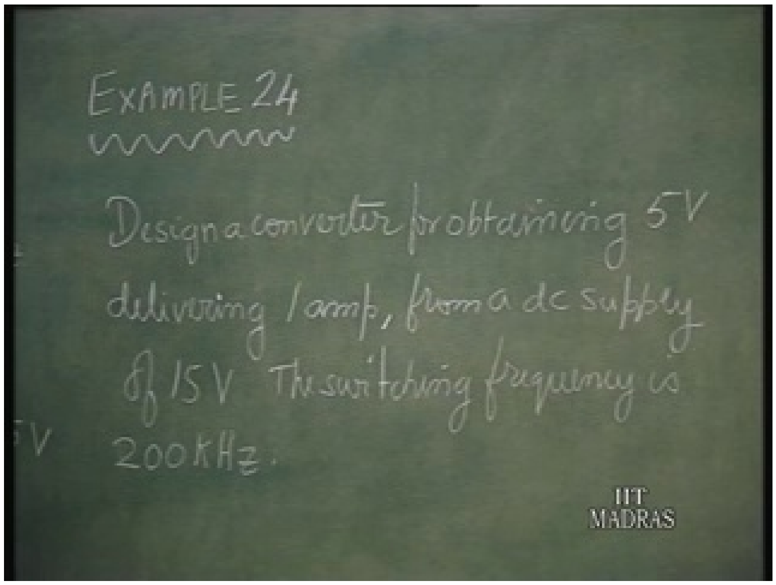

Design a converter for obtaining 5 volts delivering 1 ampere from a D C supply of 15 volts. The switching frequency is 200 Kilohertz. So, let us now see the basic schematic.

15 volts is the input voltage given. 5 volts is what is required to be obtained with the D C current of 1 ampere.

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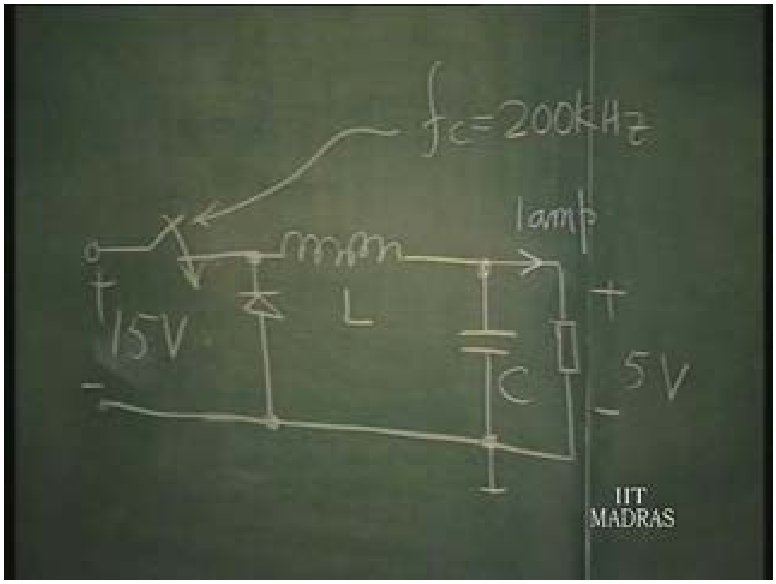

So, we have to design our converter, which means, we have to give the specification for L, C and the diode D and the switch S.

So, let us assume something about ripples. Obviously, since nothing is given in the design...but we have to accept some reasonably, some small value of ripple across the output. So, we will assume that the ripple, peak to peak ripple across the capacitor, this should be, let us say, let us say, 10 percent of V naught. This is not very low because if you make it very low, capacitor might have to be too large.

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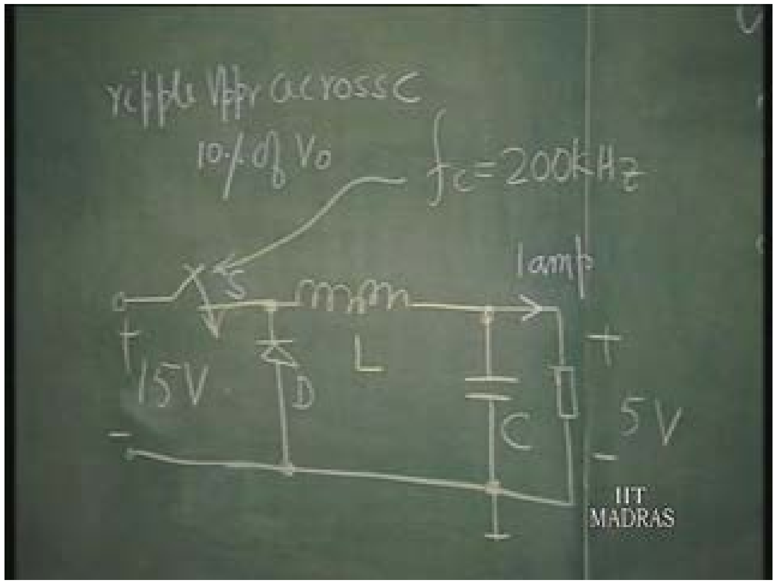

So, 10 percent of V naught is a reasonably acceptable value, let us say. That means peak to peak ripple is going to be 1 by 10 of 5 volts. Peak to peak ripple therefore is going to be one-tenth of 5 volts. So, this is going to be point 5 volts. That will be acceptable across the capacitor.

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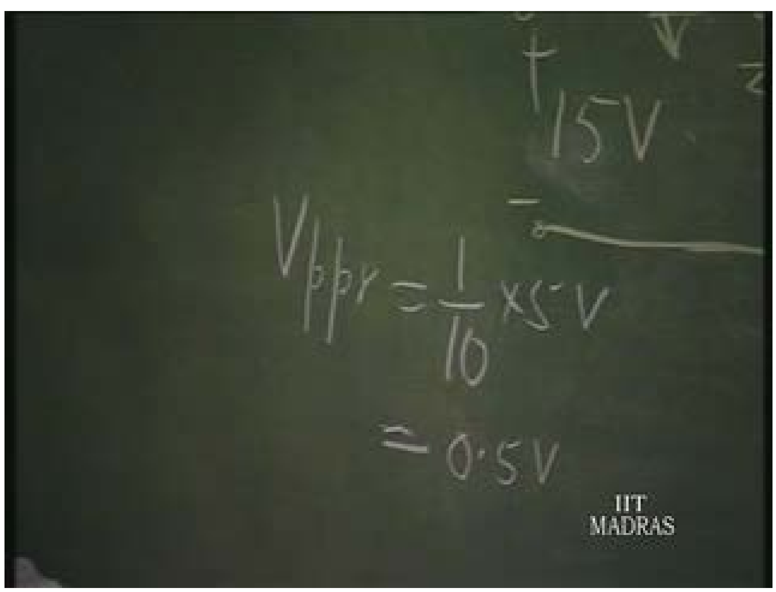

Now, we have already estimated the peak to peak ripple in our earlier exercise which is nothing but 8 f c. That into Delta i L. So, let us now...this, we have now fixed as point 5 volts. Delta i L I told you, we will take it as 20 percent of I average. So, 20 percent of I naught which means one-fifth of I naught which is given as 1 ampere. So, one-fifth ampere is the Delta i L, which is acceptable.

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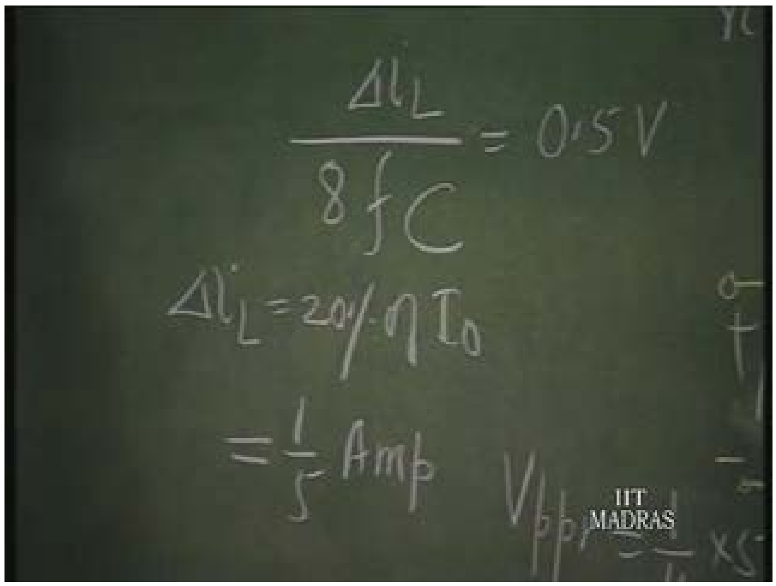

So, that means one-fifth into 1 over 8; f is given as 200 Kilohertz, into C is equal to point 5. So, C is equal to 1 by point 5 into...this is 5 into 10. 5 into 8 – 40, into 200, 10 to the power minus 3. So, this is 20. So, 10 to the power minus 6 – one-fourth of a microfarad.

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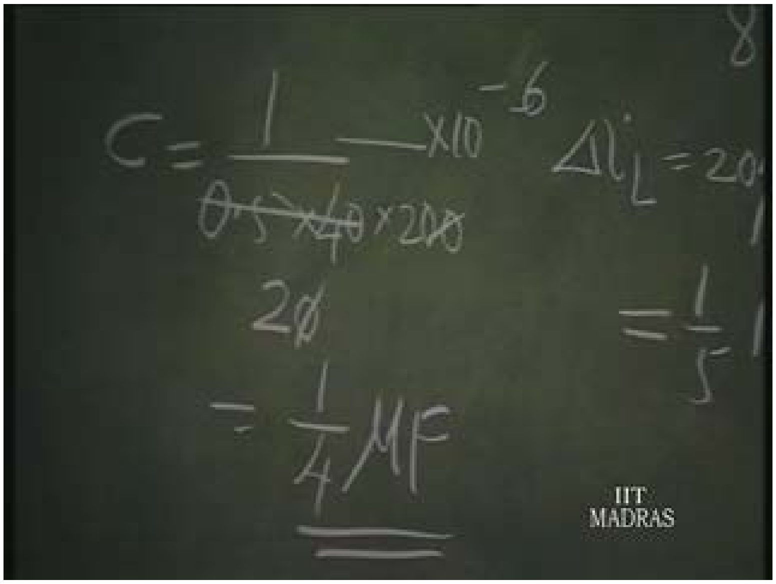

So, if you use a capacitor here which is point 25 microfarad, this should be good high frequency capacitor because this switching frequency is 200 Kilohertz. Please remember that. So, you have to use a good high frequency capacitor here. Point good quality capacitor with very low series resistance, etcetera. Capacitor is already determined.

Next, we have to find out the i n; let us say, tau over T, because we know that ...Tau over T into V i is equal to V i Tau over T is the average, which is V naught. So, tau over T is equal to V naught; V naught is 5 volts. V i is 15 volts. 1 over 3.

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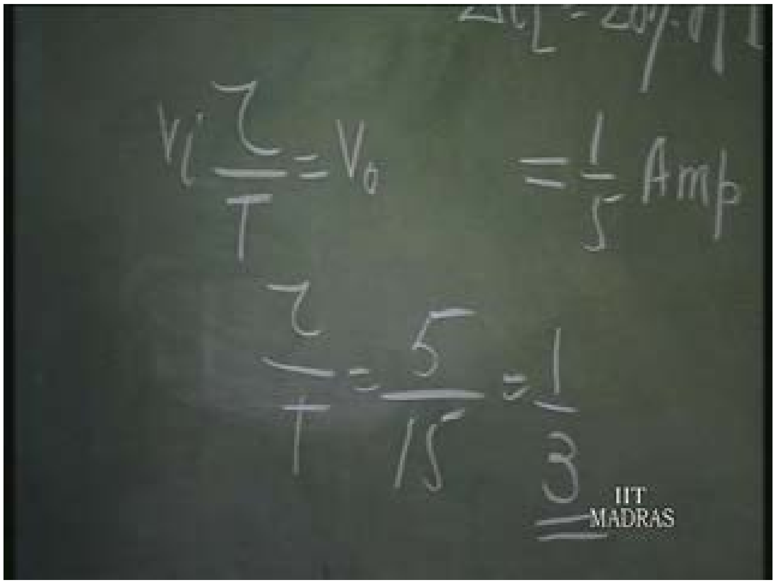

So, tau over T is equal to 1 over 3. Now, using this information, we can actually find out the inductor because inductor value is, strictly speaking, the voltage across the inductor is going to fall at this rate; V naught over L into T minus tau. V naught over L into T minus tau or V i minus V naught; this also is equal to V i minus V naught over L into tau.

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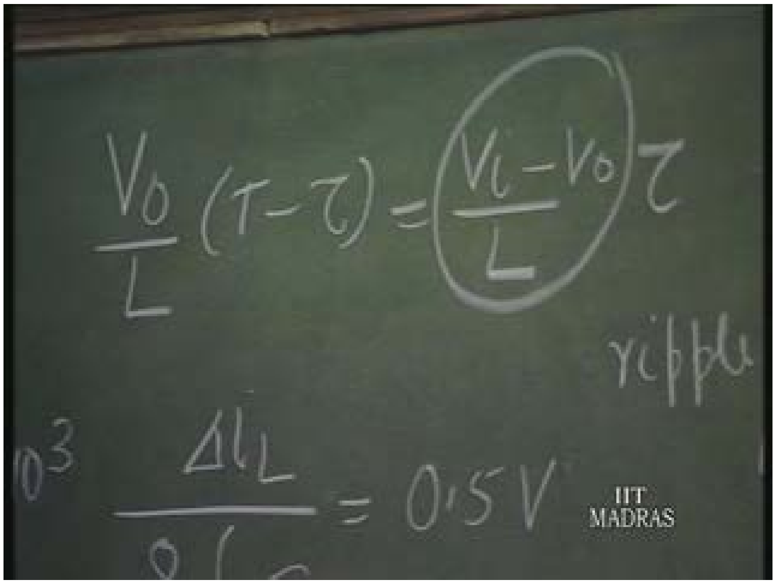

So, this is nothing but tau over T into T, which is 1 over f. So, we know this is Delta i l. This is equal to 1 over 5 amperes. 1 over 5 amperes; and that is also equal to V i minus V naught, which is 15 minus 5 by L into tau over T which is 1 over 3 into 1 over 200 Kilohertz.

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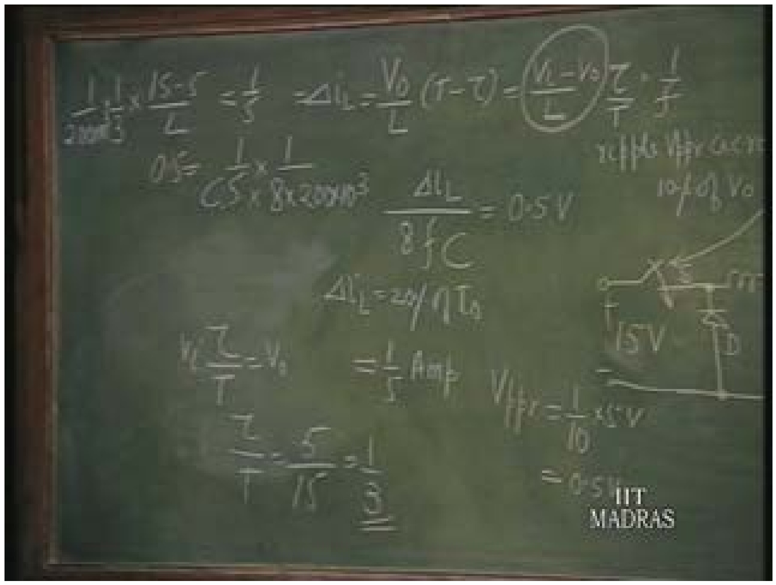

So from this, we will get the value of the inductor L as... This will go there and this will come up. 50 divided by 200 into 10 to the power 3 into 3.

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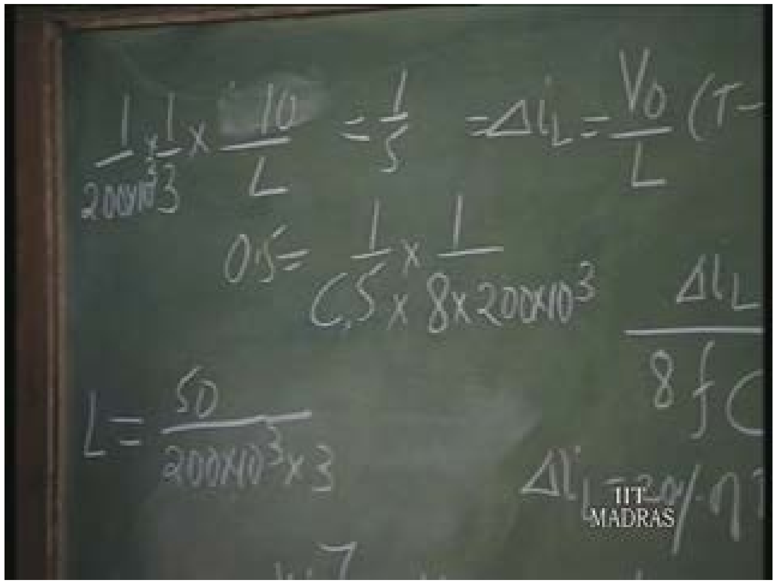

So, 1 by 12 millihenries or 1000 by 12 microhenries. So, you can see...this is the order of the inductor involved - 1 by 12 milli...

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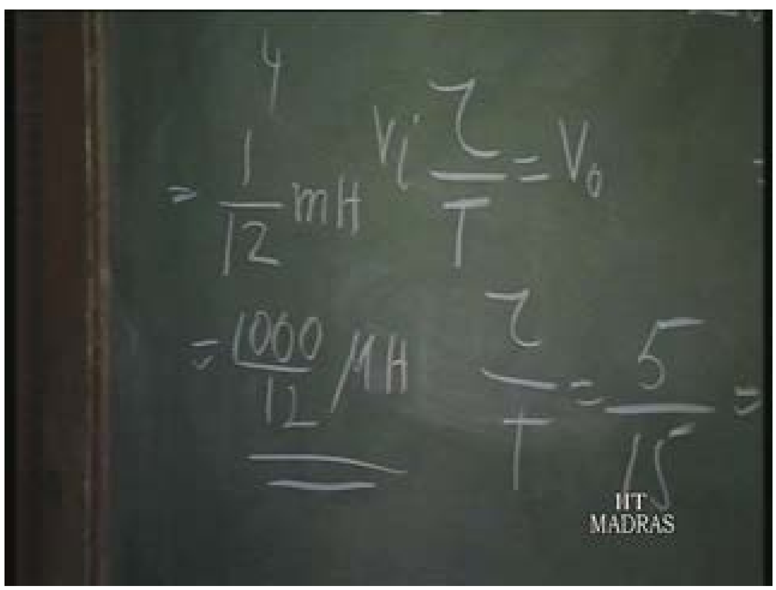

Already we have assumed the current as one-fifth ampere. So, maximum current in the inductor is point 1 plus I average. Point 2 is the peak to peak; point 1 plus I average.

That means the maximum current is 1 point 1 ampere. So, the inductor has to be designed to carry a maximum current of 1 point 1 ampere; and its value should be 1 by 12 millihenries. So, you have to take the proper wire for that; should be operated at 200 Kilo hertz .

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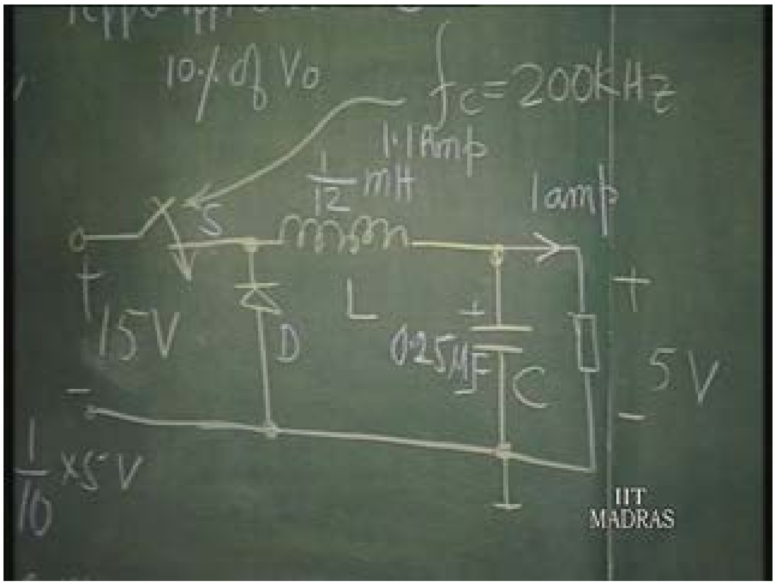

So, it is a high quality inductor. The switch here is going to carry the same kind of peak current - 1 point 1 ampere. This one...this also, when it is closed, is going to carry 1 point 1 ampere.

So, the current ratings are fixed. Voltage is...15 volts will come across the switch here and 15 minus 5, actually 15 will come across the diode also. So, 15 volts will come across the diode as well as this as the reverse voltage. The power ratings have to be determined based on the forward voltage drop of the diode.

If at 1 ampere, V Gamma is 1 volt, let us say; 1 volt into 1 point 1 ampere. That is about 1 ampere, you can say average. So, 1 volt into 1 ampere is 1 watt switching power. So, this is the power dissipated when it is on; average power is going to be still lower.

So, when it is on, power dissipated is 1 watt here. Similarly, VCEsat into 1 ampere is going to be the power that is likely to be dissipated in this; so, this is the story of design of this converter.