Electronics for Analog Signal Processing - I

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Lecture - 5
Voltage Multiplier

In the last class, we saw how we could convert an AC, something like 100 sin omega t into a DC using a diode and capacitor combination; and we said, we could also use the same concept in order to clamp any AC voltage to a specific DC value, zero or otherwise. Now, the same idea was then put to use in designing what is called a voltage multiplier.

Today, we will take an example. Design a voltage multiplier; that is, a voltage, let us say AC voltage of 100 sin omega t, from which you derive a DC of 100, and then multiply it by some amount n, 100 times n, n being an integer.

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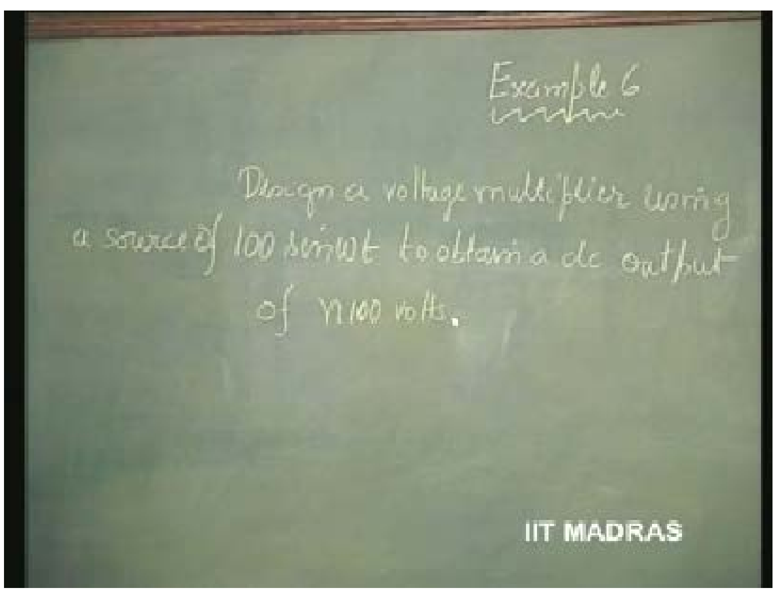

So, how this can be done and how this can be utilized in obtaining what I told you last time as an ionizer in order to obtain a high DC voltage which can be used to produce negative ions.

Let us see how this can be done. We have this 100 sin omega t available as an AC source, 100 sin omega t is available as an AC source, from which, we would like to obtain a DC of 100 volts; then, add on these 100 volts to 100 sin omega t to obtain again a DC of 200 volts, in order to obtain a doubler.

So, let us do that. I put a capacitor in series with a diode. This diode, I will put just for the sake of sort of synthesizing it in a very nice manner, instead of putting it this way; it is in the same loop. So, what will happen is, this particular thing is going to get charged now to the peak value of this AC, which is 100 volts.

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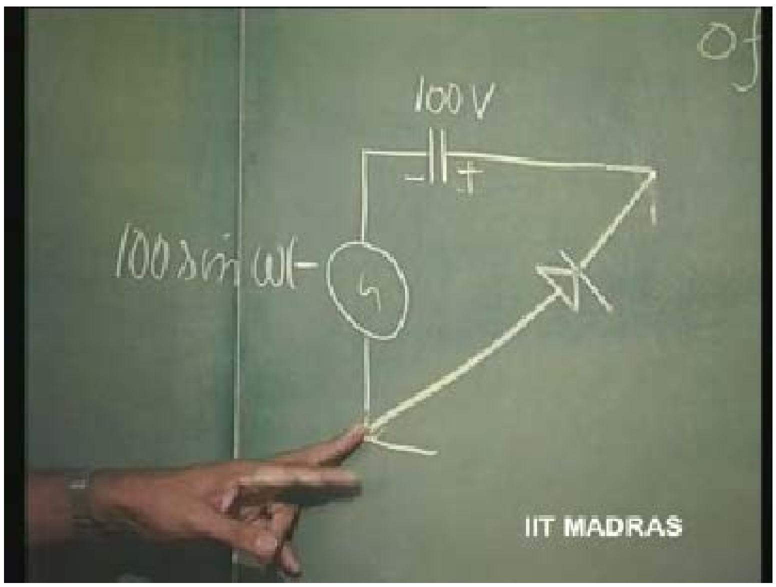

So, you have obtained here a DC of 100 volts just by connecting a diode to a capacitor like this. So, between this point and this point now, as we discussed in the last class, we have a 100 volts in series with an AC of 100 sin omega t; which means, this voltage between these two points is clamped to a value which is always going above zero. So, it will be prevented from going below zero by this diode conductor. So, this voltage is always going above zero by an extent of 200 volts, because of this additional DC here.

So, this is going above zero volts to 200 volts peak here. So, this can be again used as a peak detector now, by putting a capacitor and a diode in this direction, so that, this circuit now, which gets an input which is varying above zero going up to 200 volts, can get this as the input and charge this capacitor to the highest peak, positive peak here, which corresponds to 200 volts. So, the capacitor gets charged to 200 volts.

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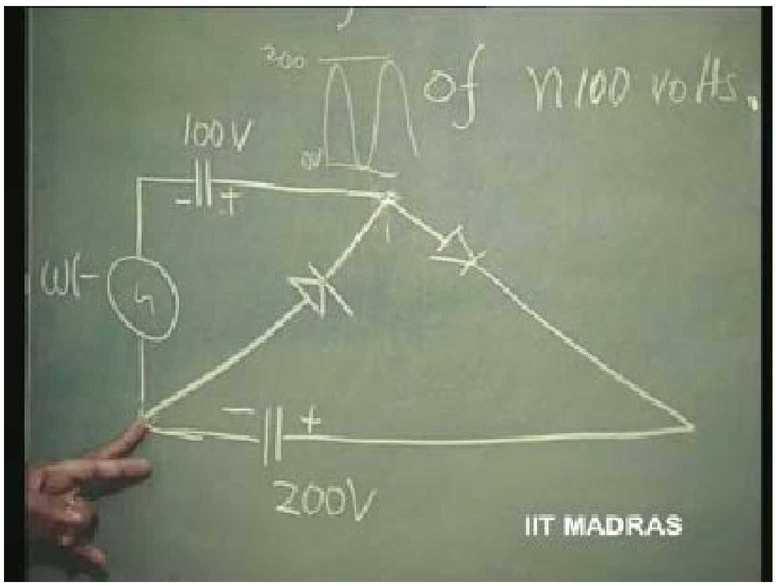

Now, between this and this again, we have these 100 volts, the capacitor is charged. Please trace this path - 100 volts, then, this 100 sin omega t is there, then, you have 200 volts. So again, we have 100 plus 100 sin omega t coming into picture, but in the other direction, 100 volts is in this direction, plus 100 sin omega t, this being positive and this being negative.

So, we can again put a capacitor and a diode in this direction to charge this capacitor in this direction. You see here, 100 volts positive, 200 volts positive minus 100 volts negative; so essentially, from here to here, we have 100 volts positive in this direction, and 100 sin omega t. Therefore, this effective voltage is going to be more positive than this and it will charge the capacitor to again the peak value of that; that corresponds to 200 volts.

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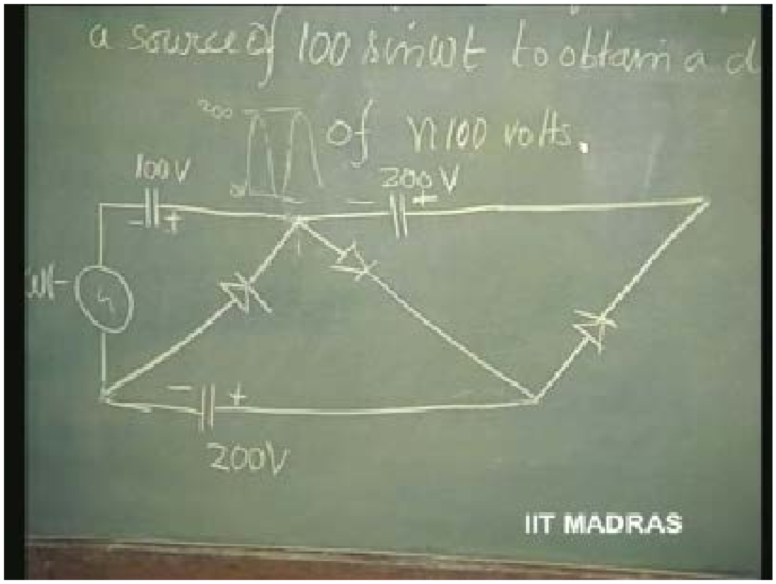

So, this process can go on and therefore, if you keep on doing this, and this is very easy to draw further, you can multiply it by any number of times. We will put always, you can see the pattern developing, diodes always going in the same direction, and the capacitors on either side of this kind of arrangement, to get charged to respective voltages.

So, this pattern can be repeated, and now you can see, if I take this as the ground, you have 200 volts here; from the same thing you would have, 200 plus 200, 400 volts positive here.

If I were to connect a similar circuit and then put the capacitor there, again, 200 volts will be added to that. So, n times 200 is what is got from this terminal to this; whereas, you can see here, if this is not grounded, if this is the common point, then, the same circuit will give you 100 from here to here and 300 from here to here. Again, this will be minus and this will be 200, 500 from here to here.

So, all the odd voltages, 100 - odd multiples - 100, 300, 500 can be got with this as common point; and even ones, 200, 400, 600, 800, so on and so forth can be got with this as the common point.

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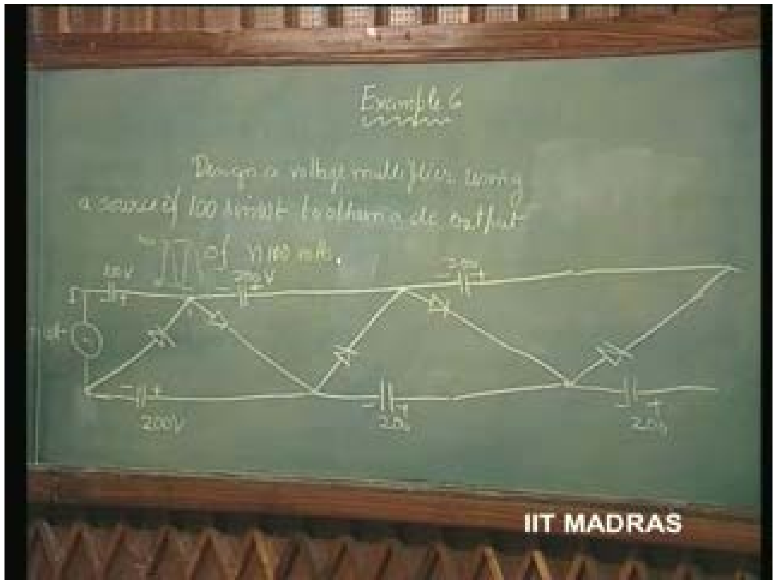

So, this is a very versatile high voltage generator, simple stuff, wherein you can directly connect this to the power supply; this circuit can be directly, without any transformer, it will generate DC voltage of any high magnitude for you without any problem.

The thing to remember here is that all these capacitors have to be good quality capacitors so that they can sustain these 200 volts without any leakage whatsoever. These diodes will have to sustain also the reverse bias voltage, which is going to occur across this, when they are not conducting, which is going to be about 200 volts again.

So, all these diodes should be sort of capable of not breaking down at those voltages and the leakage should be pretty small for these capacitors. Then, we can sustain this voltage as a large high voltage from this common point or this common point, depending upon the kind of n you are going to select.

So this, you can test in your laboratory very easily by using simple diodes and capacitors. This is one example that we have learnt how to solve by learning about what is called voltage multiplier circuit.

Another example that we will take today is regarding the clamping circuit. Let us say, I want a voltage which is a square wave or rectangular wave, let us say. I will make it general to be clamped to minus, let us say, 5 volts.

I want this to be clamped to minus five volts and it should be only going to more negative values than minus 5 volts. This voltage is variable, let us say, this is variable. This particular value is variable.

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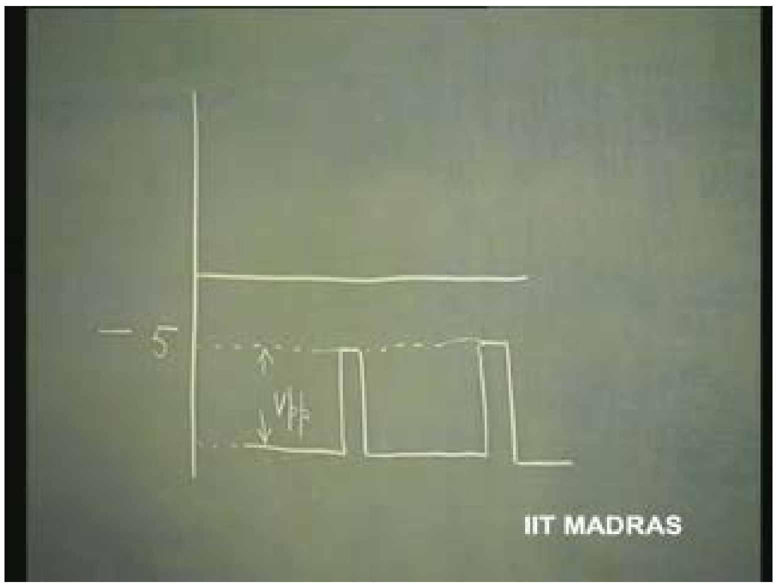

In this case, let us take this as v peak to peak. This v peak to peak is variable. I want to clamp this to minus 5 volts. What do I do? How do I develop a circuit for that?

As I told you, this AC voltage that we are requiring to be clamped can come in any format likes.

So this AC voltage is, let us say, changing in this following fashion. This is v peak to peak. That value can be anything. The only thing that is required is it is AC; there is no DC in it.

Let us say, this area and this area, these are equal. So actually, I should have drawn it more carefully. If you want this area to be equal, it has to go very high here.

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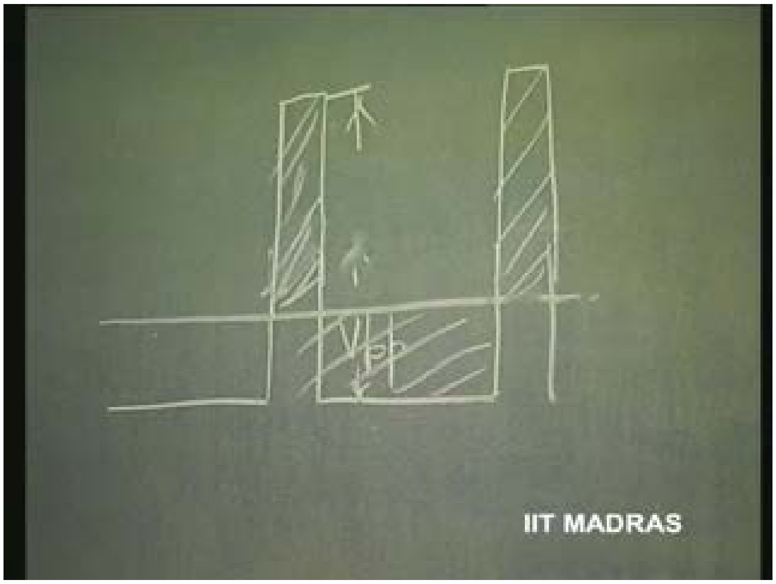

So, let us say this area - positive area and negative area - are equal so that, this is an AC; zero DC. So v peak to peak is extending all the way from here to here; this has to be clamped down to this.

So, I apply this voltage to mod circuit in order to get this out. So now, once again, you will see that, I should never allow this to be more negative than, that is, I should never allow it to become more positive than minus 5 volts.

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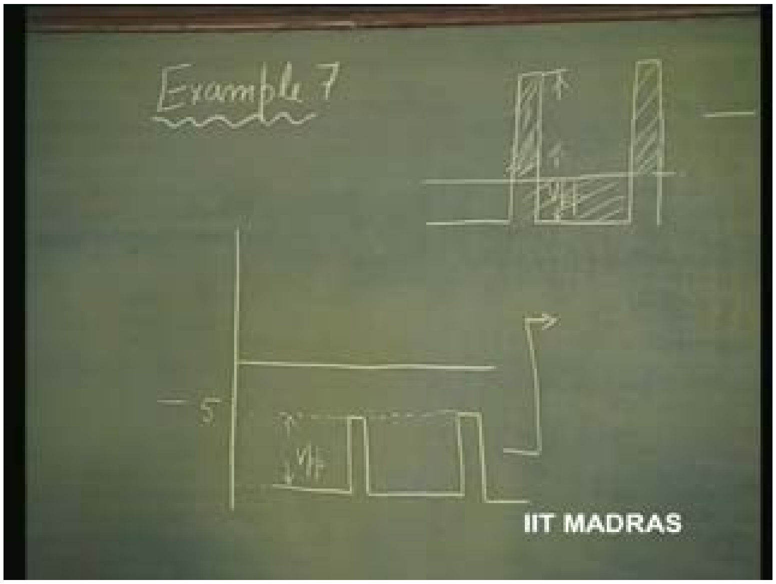

So, I should make it conduct as soon as minus 5 volts is reached. This is the logic - I should never allow it to become more positive than minus 5 volts.

So, I have this minus 5 volts clamping voltage and I put a diode so that the diode conducts, when this becomes more positive than minus 5 volts. Then, I can put a capacitor, and then this AC.

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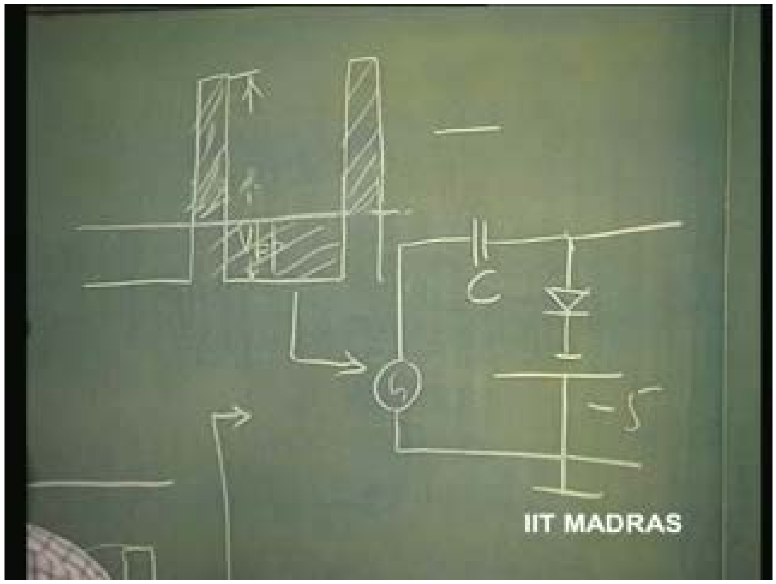

So, this is the AC that is applied which has no DC in it. If I apply this AC to this, the capacitor will automatically get charged in such a manner that this voltage output is always going to be more negative than minus 5 volts.

Now, continuing with our series of examples and problems, I am now going to give you a problem here which I hope you will work out, in order to illustrate the ability of these diodes to do proper wave shaping.

Now, I have a 100 sin omega t AC here, which can be, let us say, ground as a periodic waveform in the following fashion. So, this is the way v i is going to vary - going up to 100 here and minus 100 here.

I want this to be converted into a square wave. This is a typical problem even in your signal generators, what are called as RC signal generators, which are available in the laboratories.

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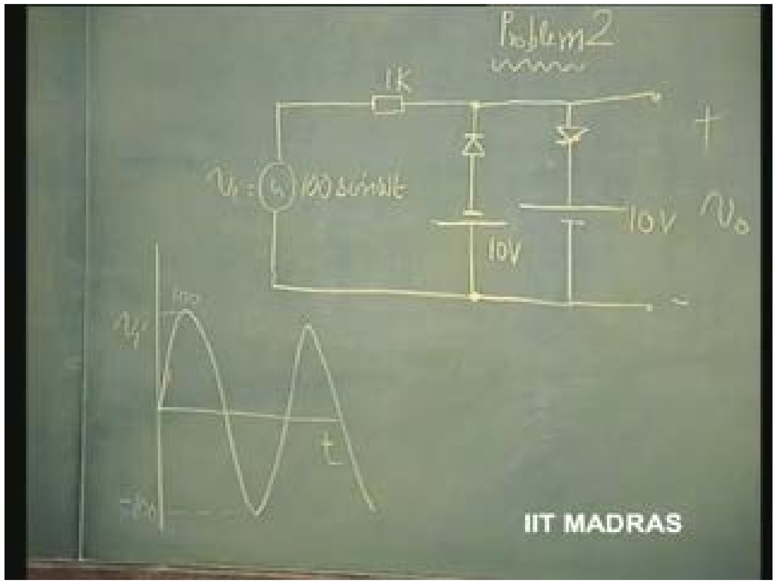

They are able to generate, let us say, a sinusoidal signal by some circuit, which we will be discussing later, how to generate sinusoidal signals.

After they generate the sinusoidal signal, they would like to convert it into a square wave because, they might need some square wave as test signal in a large number of applications. In such a situation, the circuit to convert this sin wave into a square wave is a simple circuit which is comprising of these two diode combinations, with minus 10 volts here and plus 10 volts there.

So, what happens to the output? These are called limiter circuits or clipper circuits. This diode does not allow this output to go above 10 volts because, you have 10 volts here; with respect to this point, this voltage cannot go above 10 volts. So, it will chop off anything that comes above 10 volts. So, you will see that the voltage will go up to 10 volts in this direction and get chopped off at this point.

Let us say, this is the 10 volts point. So, in this direction, you have almost something that is looking like a square wave, except for these regions where the voltage is less than 10; and in this direction, when it is going negative, this diode will never allow it to become more negative than this minus 10 volts; so it will chop off this portion of the waveform and you will get an output like this.

I have already solved partially the problem. I would like you to really find out the points at which these chopping off portions start, in terms of time. If this is T by t, this is T by 2 time period, in terms of the time period, please find out, at what point this chopping off portion will start.

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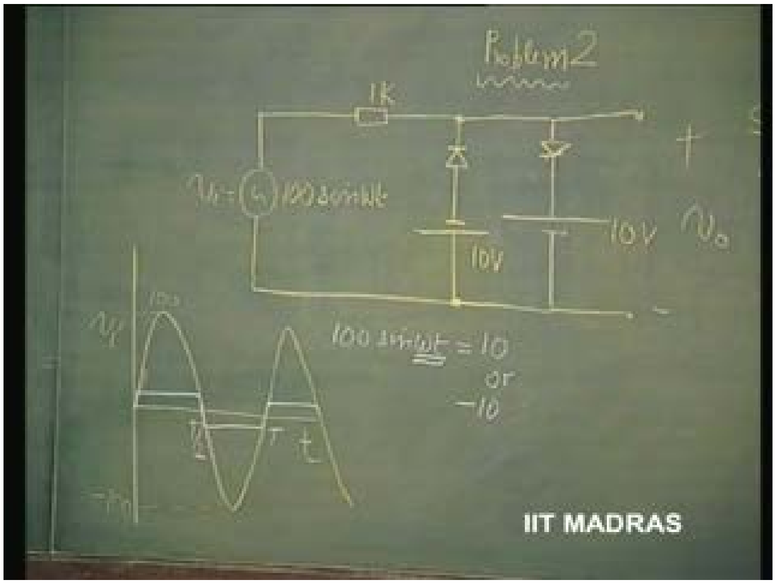

For that, what you have to do is, you have to equate this 100 sin omega t to a value which is equal to 10 volts plus or minus, and find out this time. So, please do work out this problem and find out these time intervals at which these are going to be limited to 10 volts.

This output with respect to this is what is sketched here. If you assume that this is at a lower potential than this, then this sketch here is going to test positive, going to ten volts, and this is going to negative ten volts, like that, with reference.

So, it is always marked as plus and minus in this manner; that is the convention. Even here, you can mark this as plus minus, indicating thus, this is 100 sin omega t with this as plus and this as minus.

Now, we will discuss the other application that we had already indicated; that is, how to convert an AC into a DC. So, we said, by putting a diode and a transformer, let us say, this AC which is, let us say, in this case, 220 rms, fifty hertz, let us say, power line frequency. 220 volts rms, fifty hertz, is applied here and that is converted to something, let us say, depending upon the turns ratio, n is to 1.

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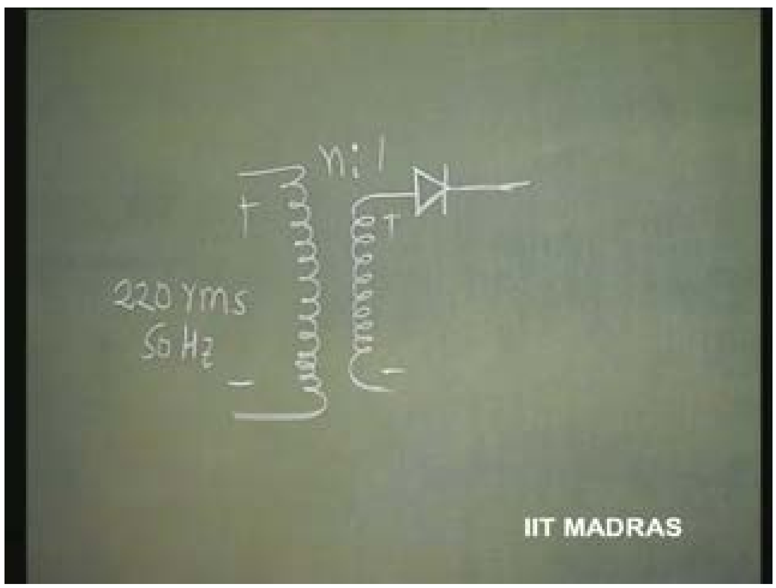

220 volts rms means, let us see what it is; 220 volts rms is 220 into root 2 sin 2 pi into 50 t - this is the actual waveform represented as a time waveform. 220 root 2 - that is the rms, multiplied by root 2, will give you the peak of the waveform; sin 2 pi into 50 hertz into t. So, this is what is called as omega in our expression. This is the omega 2 pi f; so, this is for you to design our converters later. You should know that it is 220 root 2 peak that is important.

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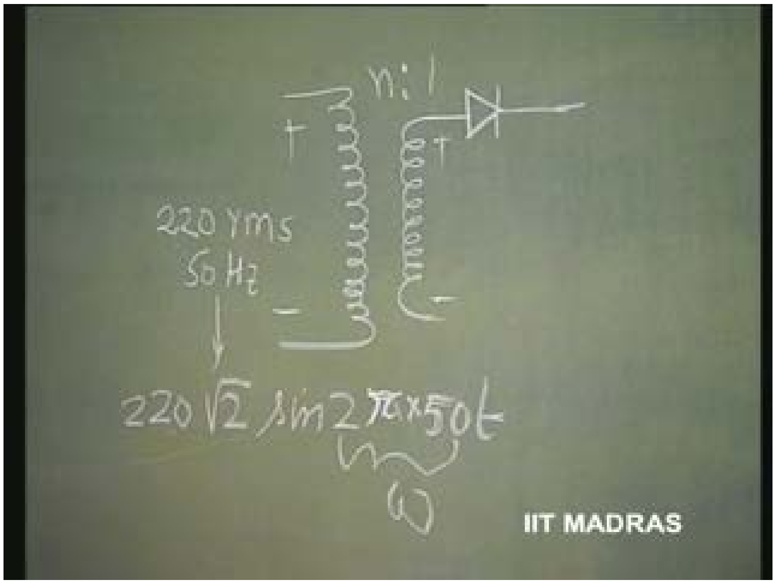

This circuit, once it is put here, we had discussed this; this capacitor gets simply charged to the peak value of the voltage. What is it? 220 root 2; 220 root 2 divided by n, because it is a n is to 1 transformer. This voltage here appearing will be 220 volts rms divided by n. That is, the rms value, which is 220 root 2 divided by n, that is the peak value, and this will get charged to the peak value of this. So, 220 root 2 divided by n is the peak value of the secondary voltage and therefore it gets charged to this.

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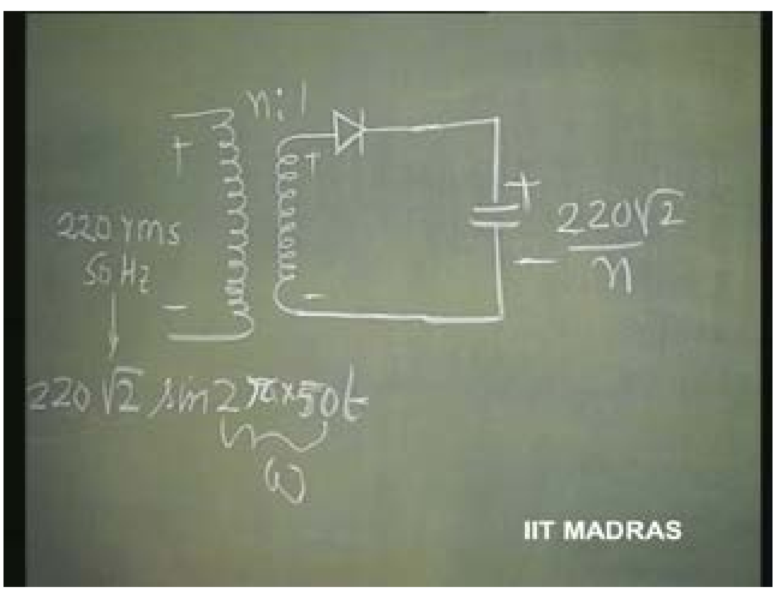

So now, depending upon the DC you want, you can select the value of n. Suppose you want a battery to be replaced; 12 volts battery to be replaced. You would like to know what is the transformer trans ratio that you have to put here, in order to get 12 volts as the DC here. So, what should you do?

220 root 2 is the peak of the rms value here in the primary; 220 root 2 divided by n is the peak of the rms in the secondary; and that has to be equated to whatever DC value you want to generate. So, this is going to give you the value of n you should choose. So, this is an important design equation as far as the rectifier, this circuit is called half wave rectifier, which we have discussed earlier.

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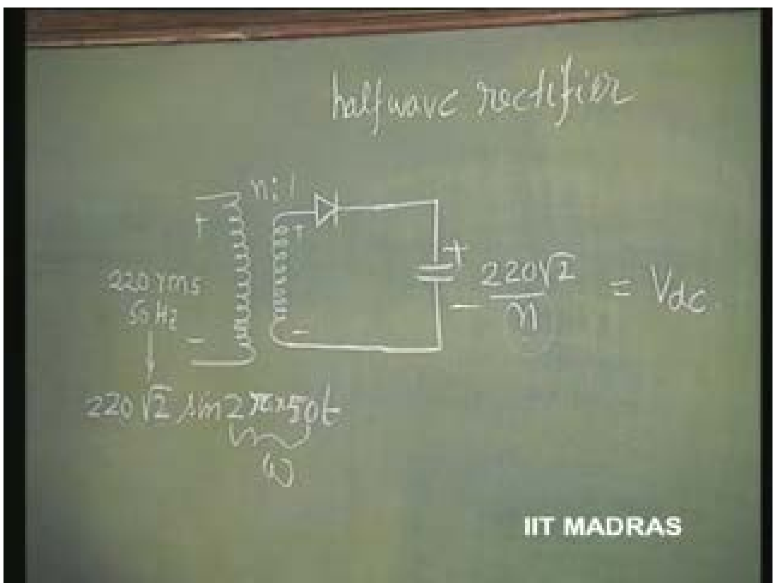

Half wave, because, if we put a resistance across this, which is likely to take place, because we cannot retain this voltage forever like this. In an ideal capacitor it is true; in a non ideal capacitor, there will be some leakage resistance across the capacitor.

In a practical situation, we would like to draw the current from the battery, in which case, if we have to draw, the capacitor has to deliver the current and the capacitor will discharge. Therefore, load for the capacitor is always going to be represented RL. So, the current that is going to flow through this is going to be the voltage across the capacitor divided by, vc divided by RL.

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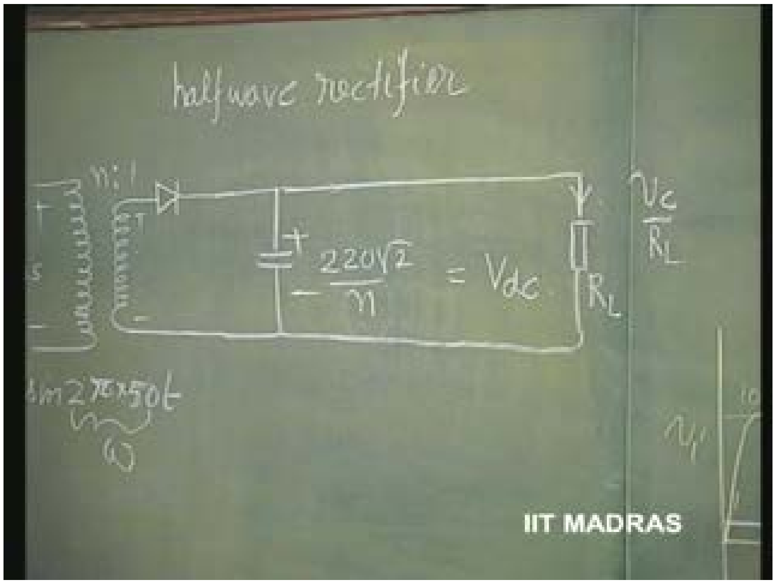

So, that much current it is demanding at every instant of time. When it is demanding that current, capacitor is discharging. All of you know that the capacitor discharges in an exponential fashion. This has been taught to you in your networks course. So, if v is the peak voltage across the capacitor, the discharge is going to be exponential; it is related in this manner.

So, this is the voltage across the capacitor at any instant of time, vp being the peak voltage to which capacitor was initially charged and t equal to zero is the time at which the discharge process starts.

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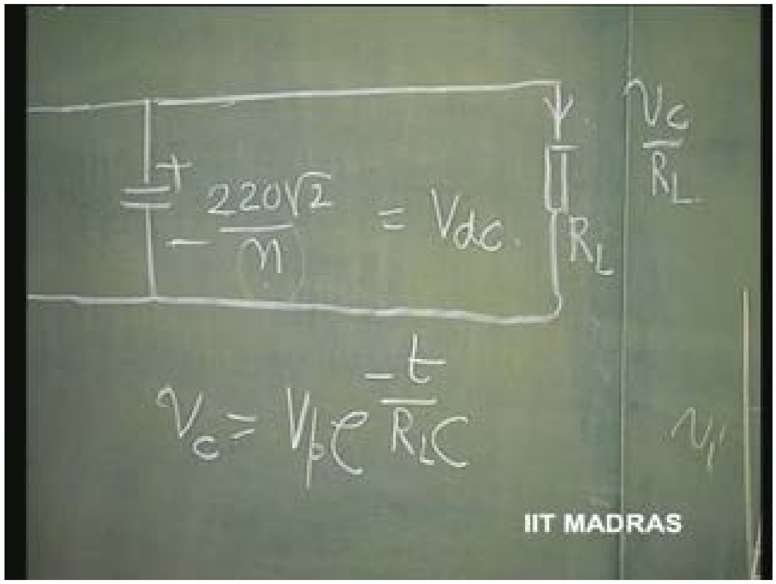

Then onwards, the capacitor will discharge. It will keep on discharging until you start charging. The moment the voltage of the capacitor falls below the voltage of the input, the discharge of the capacitor starts.

If this voltage keeps on going lower and lower than the capacitor voltage, this diode is all the time reverse biased, and the capacitor will be keeping on discharging. If this voltage, at any moment, increases above the voltage of the capacitor, then, the diode conducts and it starts charging the capacitor back to the input voltage.

So, in the case of a waveform like this, we will see that a sin wave which is the input, this peak being, this peak divided by n is this peak, so, this in this case is 220 root 2 by n. It will charge at t equal to zero, let us say, it was not charged, it will charge up to this point. It will charge up to this point. Then, it will try to discharge because this voltage has gone below the capacitor voltage; it will try to discharge.

But the voltage here might not have gone down at all. It has remained almost the same. So, immediately, the diode will conduct. The capacitor will get charged to the input voltage.

Again, it will try to discharge. This process will go on until the rate of discharge is going to be slower than the rate at which input voltage is decreasing.

If this rate is faster than this discharge rate, this discharge will go on like this; very slowly, until this point is reached. So, the actual waveform of this arrangement where the resistance is loading the capacitor , is not going to be remaining at the peak at all times. It will keep on discharging and will follow the input again up to this point and again start discharging like this. So the waveform is going to be like this.

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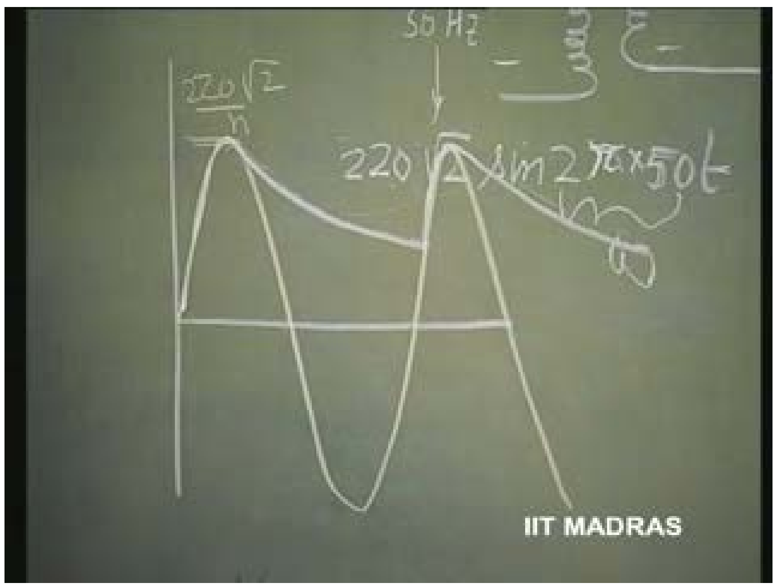

So, how do I prevent this discharge being so large as this? The only way is, before this time occurs, the amount of voltage that is coming down should be extremely small. That is possible by selecting RL into C, time constant, has to be made very much greater than the time T period. This time, T, is the time within which it is going to discharge, most probably.

So, this RL into C - if it is made very large; very large compared to T, this capacitor has to be so chosen that it is much greater than T by RL.

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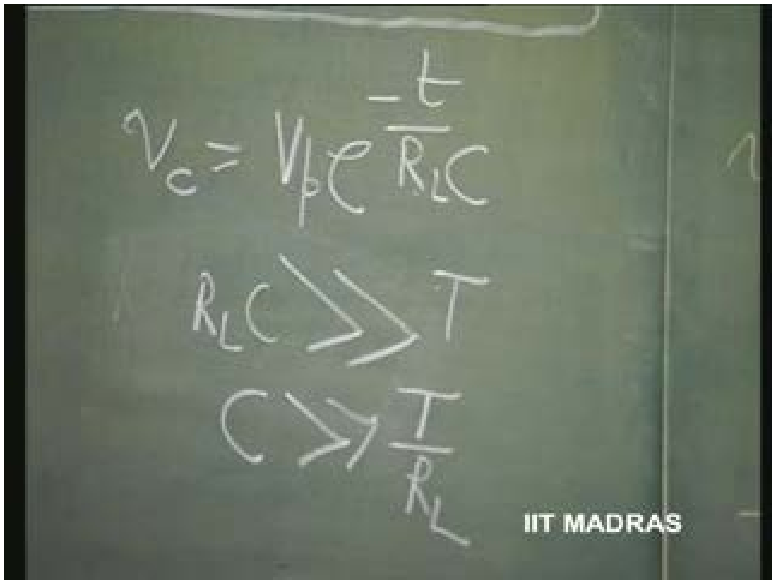

What is the value of T? That value of T, we know, is corresponding to 20 milliseconds. T is equal to 20 milliseconds because, f is equal to 50 hertz. So 1 over f is equal to T. So, we get this as 1 by 50 seconds or 20 milliseconds. So, we know the value of T in the case of 50 hertz waveform.

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So, we can find out for a given load. This we know. How do we know? Let us say, we have to design a 12 volts supply which is capable of delivering maximum current of 1 milliampere. Then, the load is equivalent to 12 volts divided by 1 milliampere, which is equal to 12 kilo ohms. If we want, on the other hand, a load of 1 ampere current to be delivered, then, 12 volts divided by 1 ampere corresponds to 12 ohms. So, you can put down the value of load resistance knowing how much maximum current you would like to draw from your battery for a given voltage. So, that voltage divided by a current will give you the effective load.

Your radio receiver under full volume giving maximum power to your loud speaker is going to deliver, let us say, need, some amount of current like 100 milliamperes; and the voltage needed is 12 volts. Then, 12 volts divided by 100 milliamperes, which corresponds to 12 volts divided by point 1 ampere, which means, 120 ohms, is the load resistance that the radio is going to be represented.

So, you can put down that load resistance there and find out how much discharge is going to occur within a time of 20 milliseconds. So, let us now see how much discharge is going to occur. If the discharge itself is going to be such that it is going to be extremely small, that means, let us see how it looks like.

So, let us now see a situation where I have done my design very nicely, taking care to see that T, when it is 20 milliseconds, RL when it is 120 ohms or so, C is made much greater than whatever I get there. Let us do that for that. RL is equal to 120 ohms, T is 20 milliseconds; so, C is to be made much greater than 20 milliseconds divided by 120 ohms, which is going to be 1 by 6 into 10 to power minus 3 Farads. This is Farads.

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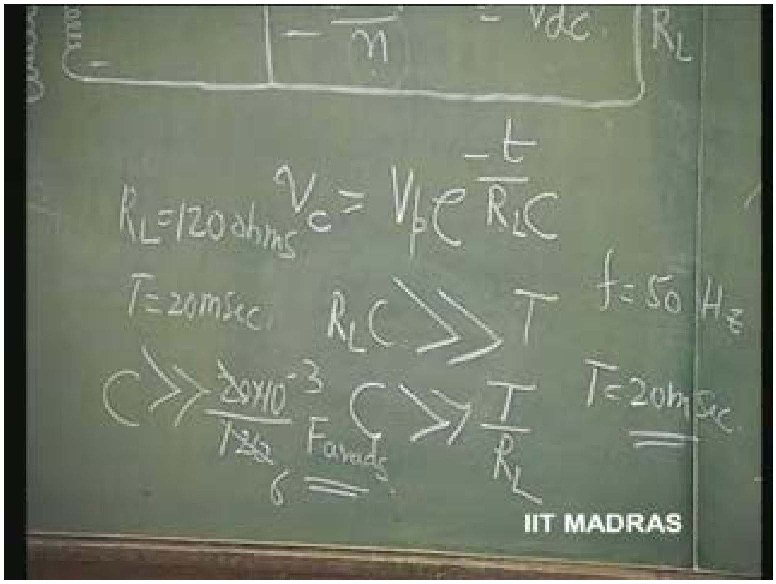

How much is it? This is nothing but 1000 divided by 6 microfarads; C must be made much greater than this. So, such capacitors are available as, let us say, is something like much greater than 1000 by 6, means, you can make it. This is going to be about 200. If you think that this 1200, this will be 200 microfarads; much greater than 200 microfarads, means, 2000 microfarads.

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That is a good practical design; make it 10 times whatever this gives; around 200 microfarads electrolytic capacitor, if you use here, you can satisfy this equation. What does it mean? The amount of discharge is extremely small. That means, this is not going to be coming down this much at all; it will be as good as remaining almost equal to v p.

So, this is the way discharge is going to take place; almost equal to v p. Amount of discharge is extremely small and is going to remain like that.

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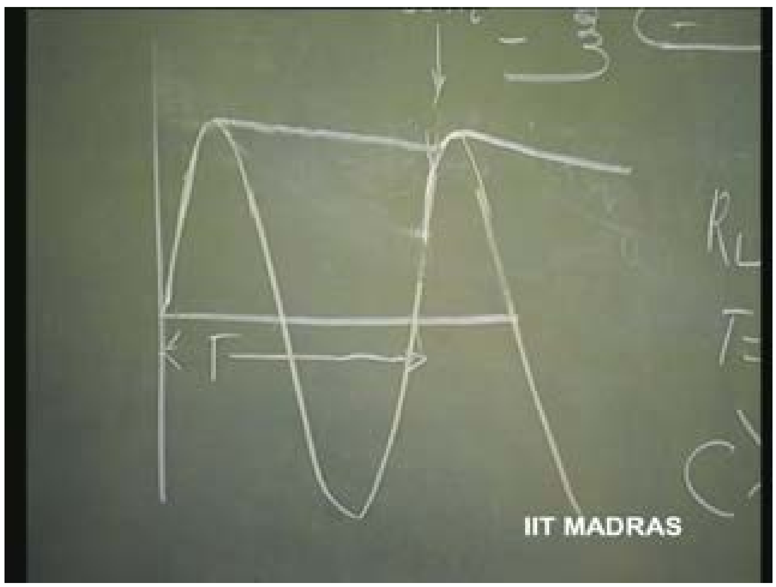

What does it mean? Again, let us say, in terms of mathematics, v c is v p into e to power minus t by RL C. You know that, e to power minus x can be expanded; and when we expand it, it will be, v p into 1 minus, e to power minus x can expand, as 1 minus, the first term that will come is x, if this is x, 1 minus x; and then, it will be x square by factorial 2, x 3 by factorial 3, and so on.

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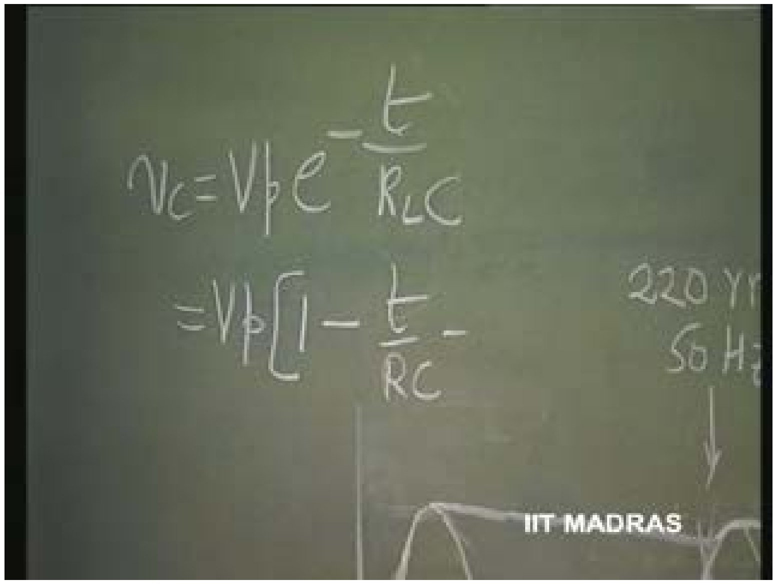

We are not interested in the higher order terms, because, we are going to make sure that the time interval involved is such that t by RC is much less than 1; t by RC is, t by RC is going to be much less than 1. 1 is going to be much greater than t by RC, under the worst situations.

So, this quantity is going to be extremely small. So, I can ignore all the higher order terms and assume that this is approximately equal to this. That means, this is a linear decrease, if the decrease is very small. So, in a sensible design, this can always be taken, if this assumption is valid, for a good filter, capacitive filter, you have capacitor voltage falling linearly with time as an approximation to this.

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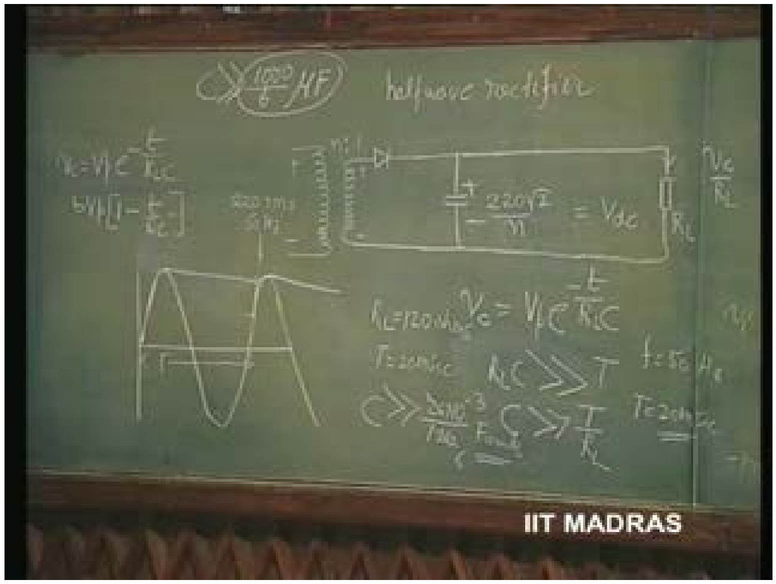

So, maximum time interval taken here is approximately equal to T; that is the overall discharge that is occurring from this point onwards to this; and this is very nearly equal to v p itself.

So, v p to v p into 1 minus T by RC is very nearly equal to v p for practical purposes. That means, the DC voltage is v p itself; that is, 220 root 2 by n is the peak voltage that remains as such if this design is adapted. Then, if you want to now find out how much discharge has occurred, that can be approximated as v p into 1 minus T by RC or strictly speaking, the variation in voltage is v p into T by RC; v p to v p into 1 minus T by RC.

So, this is what is called peak to peak ripple. This is the ripple that is riding over this capacitor. There is a small variation in voltage which is going to occur at fifty hertz. That is all that is there in the DC supply. So, by putting a huge capacitor here for the load RL, I have been able to retain the DC almost at v p itself; there is a ripple of v p into T by RC. I can approximate this waveform as a sort of triangular waveform, because, I said if this is discharge that is occurring linearly and again increasing, again decreasing, this ripple voltage is what is occurring there.

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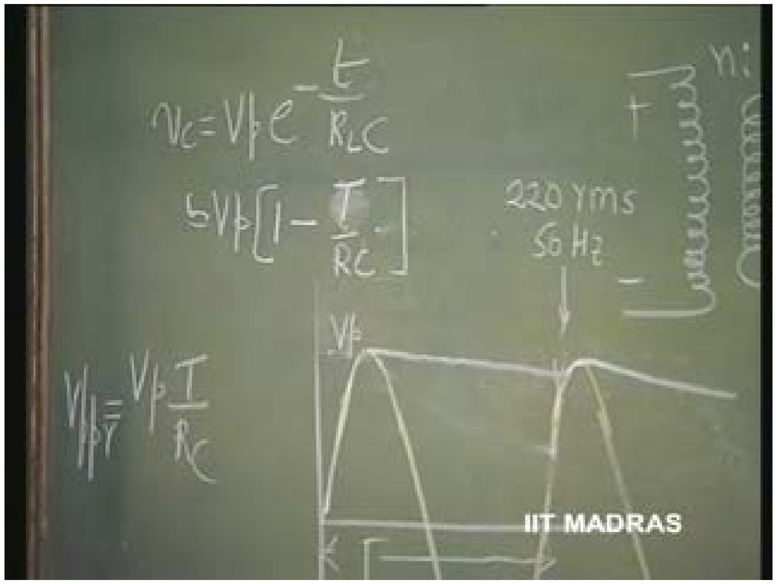

I would like to give a problem at this stage - problem 3. What is it? The problem 3 is going to be: find out the rms value of the ripple voltage, when it is a triangular waveform, given that the peak to peak value is v p into T by RC. Problem 3 is a triangular waveform, has peak to peak value equal to v p into T by RC; determine its rms value.

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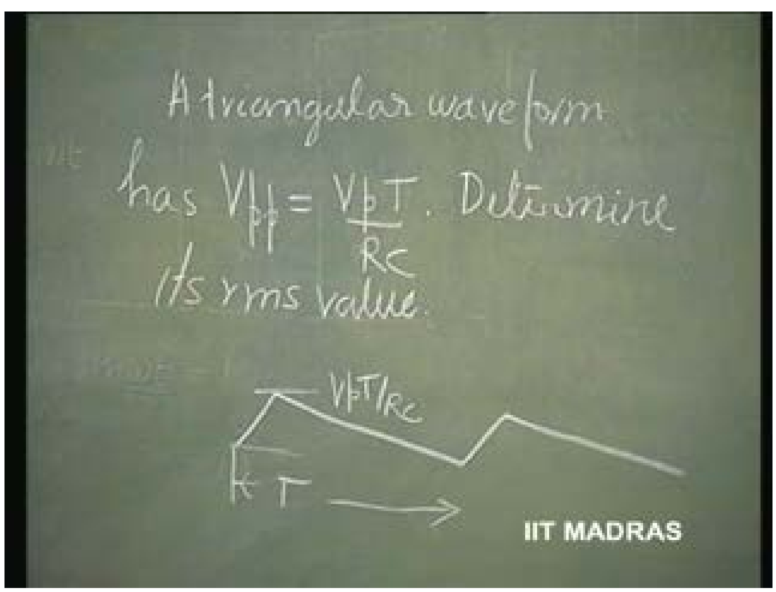

How do you do it? Simple. You have to find out root mean square; that means, this triangular waveform has to be squared and after that you have to take the average over the time interval T. Find out the time, this rms value of the triangular waveform. This can be of any shape, right? In our case, it is of this shape. This time interval is T and this is v p T by RC. So, if you determine this, then we know that ripple factor. What is it? Define. Earlier, I have defined this. Ripple factor is defined as rms value of the ripple divided by the average, which is going to be, you will get a factor K into V p T by RC.

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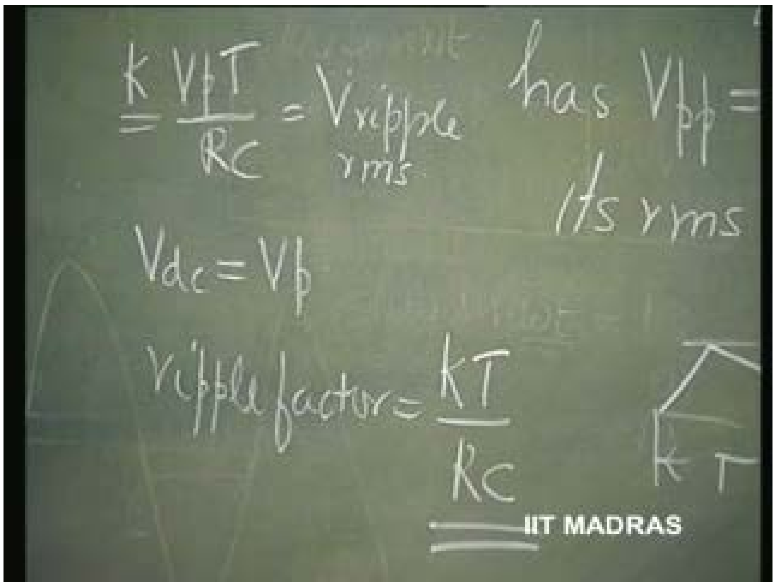

This K is what you get as some value. When you find out the rms, I want you to find out the value of K. This is the rms value of the ripple. This divided by DC which is v peak is called the ripple factor; v ripple rms divided by v c, which is nothing but KT divided by RC.

We have discussed this in the last class. We have found out this value for a half wave rectifier and a full wave rectifier - this value. That has also been given as a homework problem for you. Please find out how much ripple factor a half wave rectifier has. What is a half wave rectifier? Just this waveform, just this waveform. Full wave rectifier is this waveform here. Here, we are not interested in those two; they are all of theoretical interest. We would like to make a pakka DC supply voltage for our application.

So, we have made use of the peak detector and put a load across that and seen how this peak detector now changes its behavior. That is a better way of designing a DC supply than trying to understand it in terms of half wave rectifiers and then putting a capacitor. It is not done that way.

What is done is, I would like to convert it into a DC; then, I would like to put a capacitor; then, it does the peak detection. Then, I would like to investigate what happens when a load is connected across it and how the discharge can be minimized; that will give us the equation for what to select as capacitor value, in order to minimize the discharge.

Then, I can approximate and say that, under these circumstances, this ripple reduction occurs and the ripple reduction is going to be to this extent. It is only going to change from v p to v p into 1 minus T by RC, T by RC being extremely small compared to 1. This ripple is going to be extremely small and this ripple value, peak to peak value, is going to be v p into T by RC.

That can be converted into rms value by solving this problem, which you must do; which you have done already in your networks, converting any periodic waveform with certain values of peak etcetera into the rms value.

We will come out with the answer in the next class, if you have not been able to work out this. Again it can be shown, how it can be worked out, further steps can be given, in the next class.

Then, the DC value being equal to v p approximately, the ripple factor is nothing but the rms value of the ripple divided by the DC value which comes close as KT by RC. So, this tells us that T by RC being extremely small, ripple is very small in this case. This is basically a very good battery replacement using a power supply, the complete design of which you already have here.

So, for any given problem, you should be able to know these things. First of all, what should be the turns ratio that I should select; based on what value of DC, I should have. Therefore, n is fixed. Then, I should know what is the maximum current I am going to draw with this power supply. That will tell us that V dc divided by that current, maximum current, will be the worst case resistance which is going to cause maximum ripple.

So, that is what is you have chosen. So, if that ripple is itself kept very small, then, other situations where less current is drawn, the ripple is going to be still smaller. So, we do this design for what is called the worst case situation; where, RL is the lowest; where the current drawn is the highest.

In situations like television, radio receiver, etcetera, you have to consider what is the maximum ever current that is likely to be drawn by this power supply, and use that as the load in estimating what should be the value of capacitor that we have to connect. After doing this, then, we already know that our approximation is very good. Therefore, T by RC is extremely small; therefore, we can say that instead of e to power minus T by RL C, we can approximate it into 1 minus T by RC, then, the peak to peak value ripple is this value.

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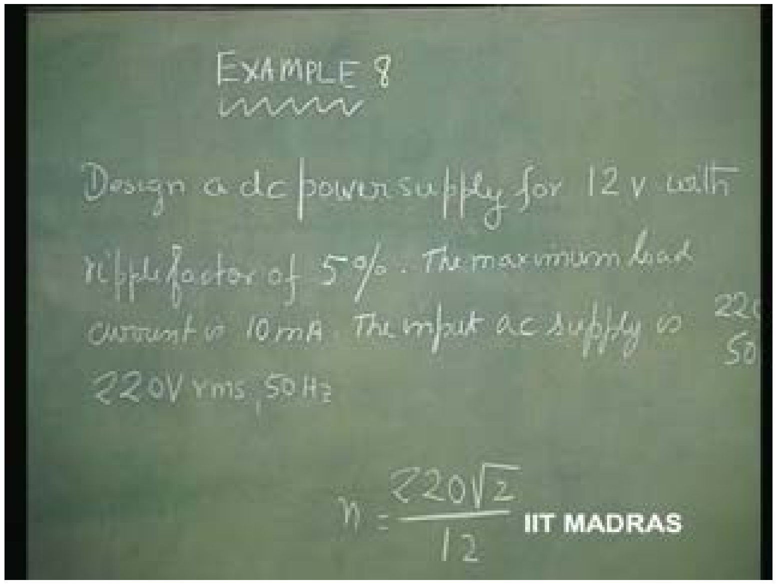

Now, we will try to work out an example - Example 8, wherein, I will tell you how to design a power supply. Now, this is very important that when you are confronted with a design problem, how you have to give specification of all the devices, electronic devices, that you are likely to use for the design. Therefore, this example will illustrate how a design problem has to be tackled.

Design a dc power supply for 12 volts with ripple factor; we have defined this ripple factor earlier, of 5 percent; the maximum load current is 10 milliampere. This also, I have discussed; that, we design for the worst case situation where the power supply is going to deliver the maximum current; that is given as 10 milliamperes or equivalently, I can say, that the load RL is 12 volts d c divided by 10, that is, milliamperes, which is 1 point 2 kilo ohms.

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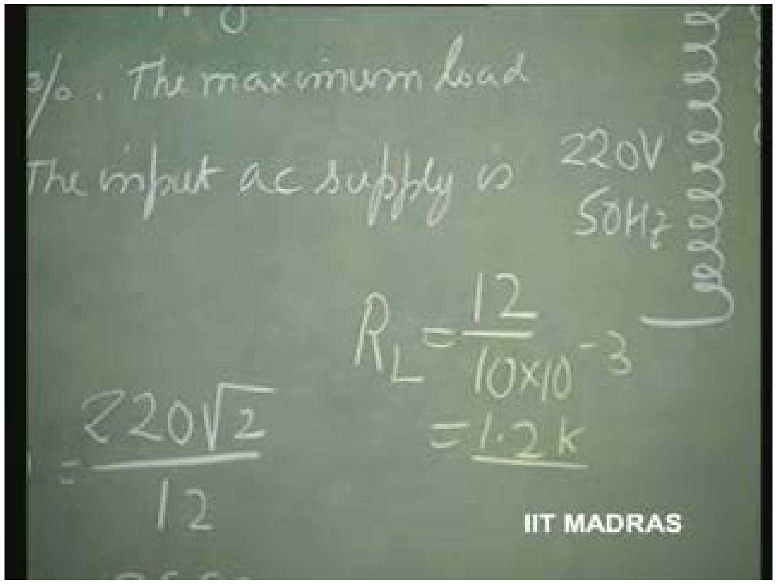

That is the maximum loading you will have with a minimum load resistance, across the 12 volts. The input AC supply is 220 volts rms with 50 hertz; and that is applied to a transformer primary; and the secondary should be so adjusted that we should get a DC output voltage of 12 volts. This is what is specified.

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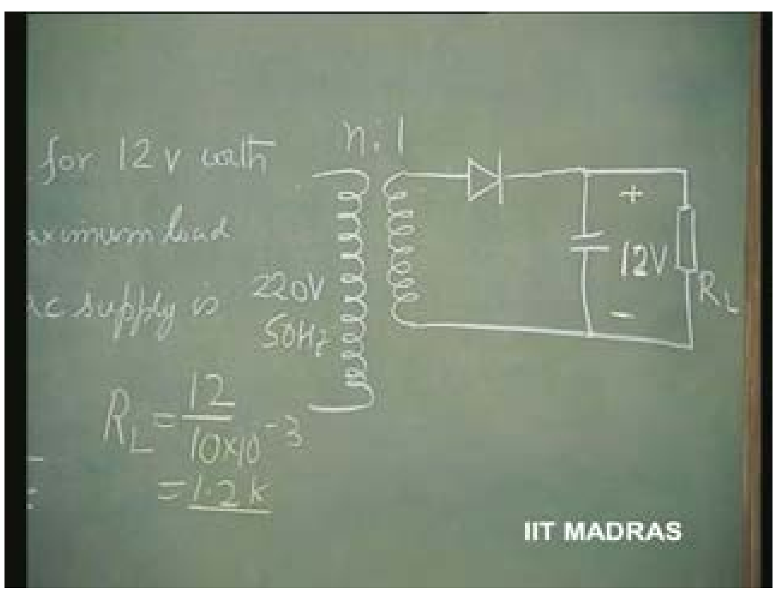

Now, let us try to first evaluate the most important thing in the design; that is, turns ratio. 220 volts into root 2 is the peak value of the primary AC voltage, 220 being the rms value. 220 into root 2 is the peak value and therefore, the secondary peak value is 220 root 2 by n. That should be equal to 12 volts DC; that is what we have learnt.

Therefore n, turns ratio, is equal to 220 volts root 2 divided by 12, which is nothing but 12 25 point 92 as the trans ratio we have to select. That is the first part of the design is over, wherein, we have specified the transformer trans ratio.

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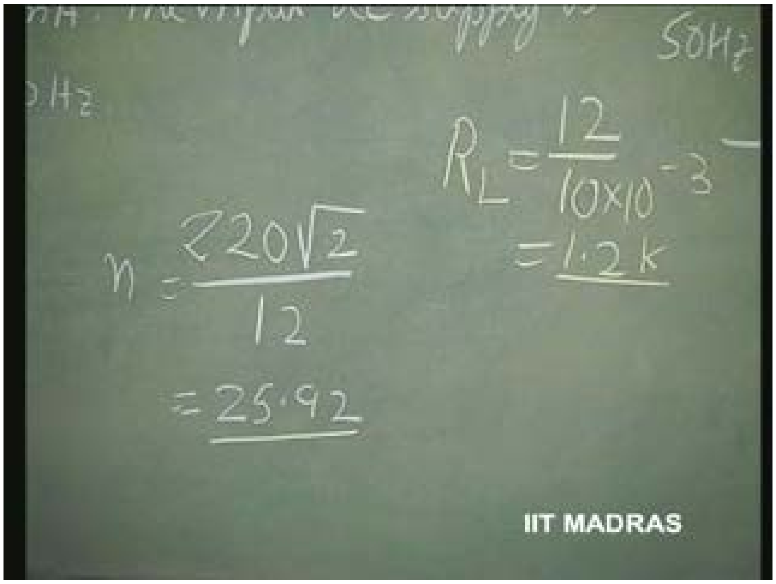

Next, we had to choose the capacitor in such a manner that the ripple factor is 5 percent. What is ripple factor? Ripple factor by definition, which we have defined as rms value of the ripple by DC. That is given as 5 percent; 5 by 100, which is rms value of the ripple. I have told you to work this out as a homework problem.

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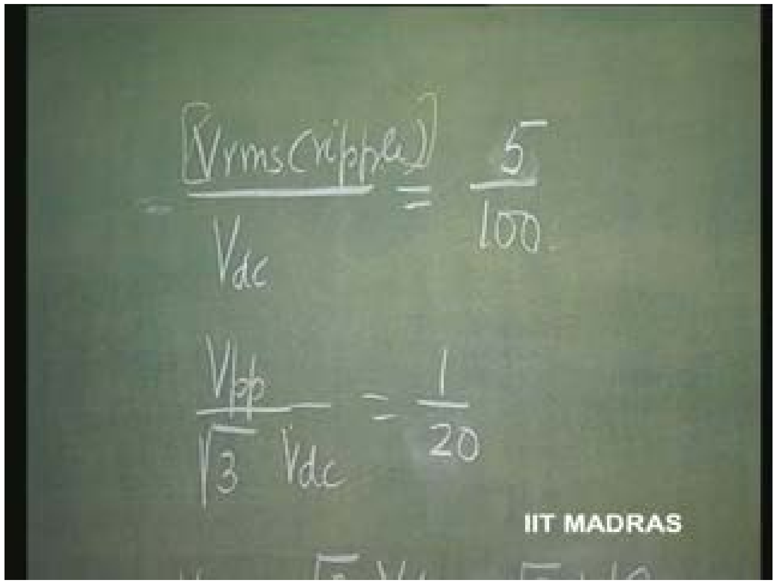

So, given that, the peak to peak value of the ripple is v peak to peak, you are asked to find out the rms value of the waveform assuming that it is a triangular waveform.

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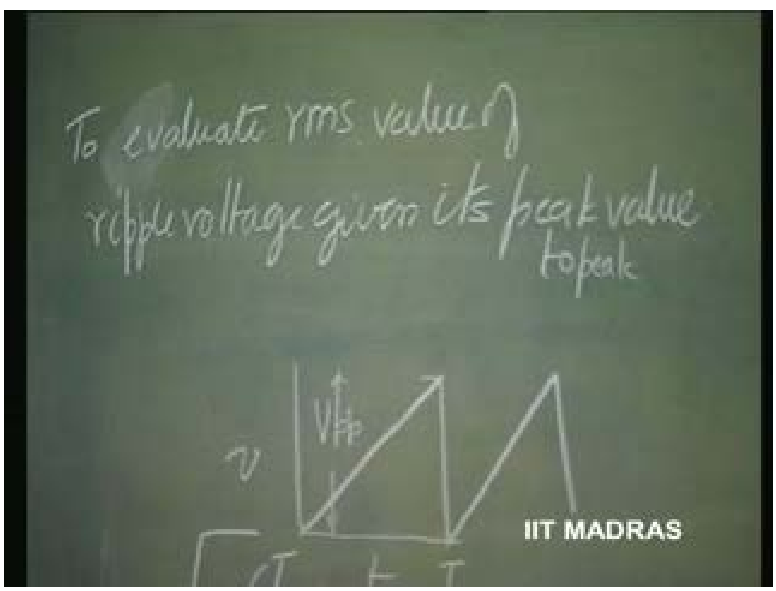

To evaluate rms value of ripple voltage, given its peak value or peak to peak value. Peak to peak value is known, then, rms value by definition is square root of average 1 over t zero to t. The waveform here is vpp by t into t; that is the waveform here, assuming that this is zero.

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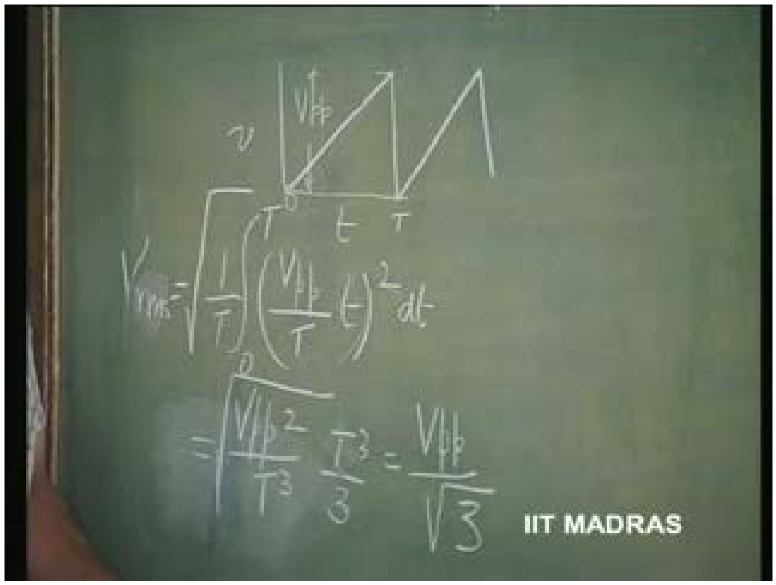

vpp by t is the slope into t. That square, so square mean square root dt. So, this is the integral integral you have to solve. So, we get this integrating vpp square comes out, t cube comes out, and integral of t square is t cube by 3. So, substituting the limits, it is t cube by 3; so this gets cancelled with this. This vpp by root 3 - this is the answer for rms value of any triangular waveform whose peak to peak value is given as v peak to peak. So, this is the answer.

Coming back now, rms value of ripple divided by dc is equal to 5 percent. Therefore, v peak to peak divided by root 3, that is the rms value, converted into peak to peak by root 3 divided by dc is equal to 1 by 20.

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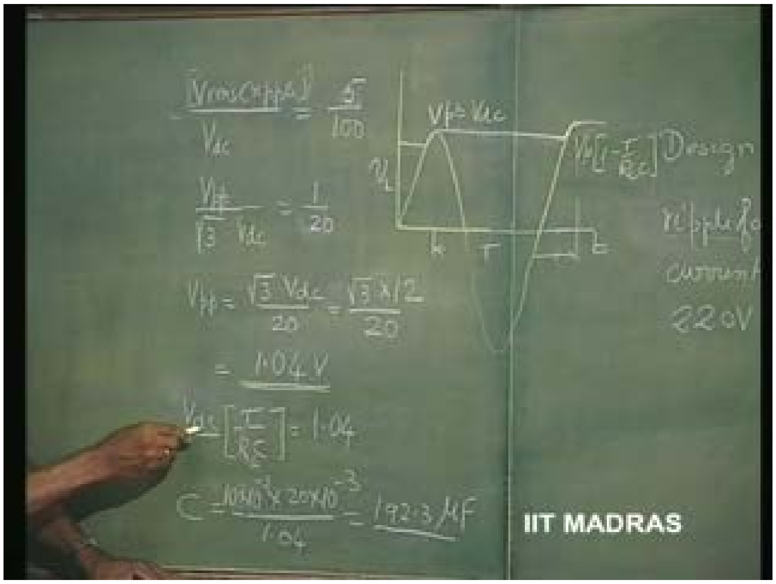

So, v peak to peak is 1 point 04 volts. That is the answer we get for the 10 percent, 5 percent ripple. So, v dc, this ripple we have seen. This vp is equal, very nearly equal, to v dc; and, this is vp into 1 minus T by RL C. This is what we had assumed in the class.

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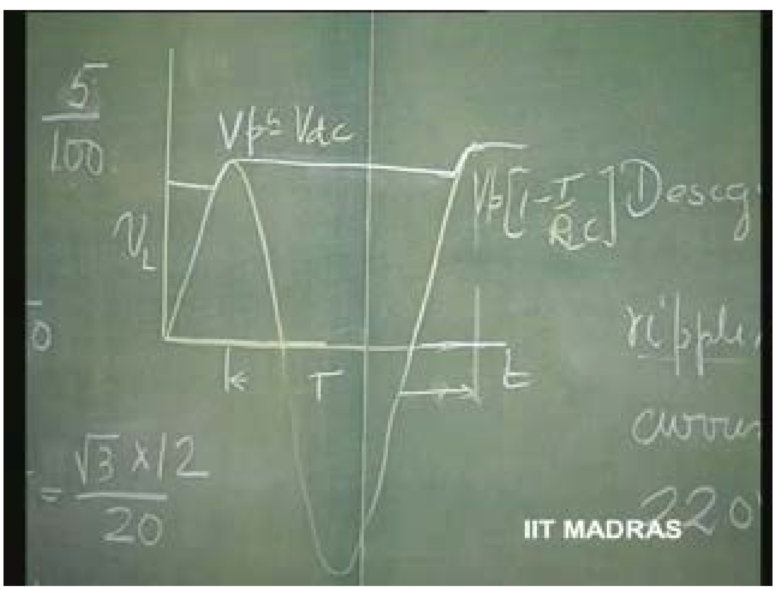

So, the peak to peak ripple is v dc into T by RL C. That is already worked out as 1 point 04 volts.

So, from this, we can obtain the value of C, if we know v dc by RL. v dc by RL, is given as 10 milliamperes, maximum current drawn by the load; so, 10 milliamperes ten milli amperes, into T 20 milliseconds divided by 1 point zero 4, is nothing but the value of C which is 192 point 3 microfarad.

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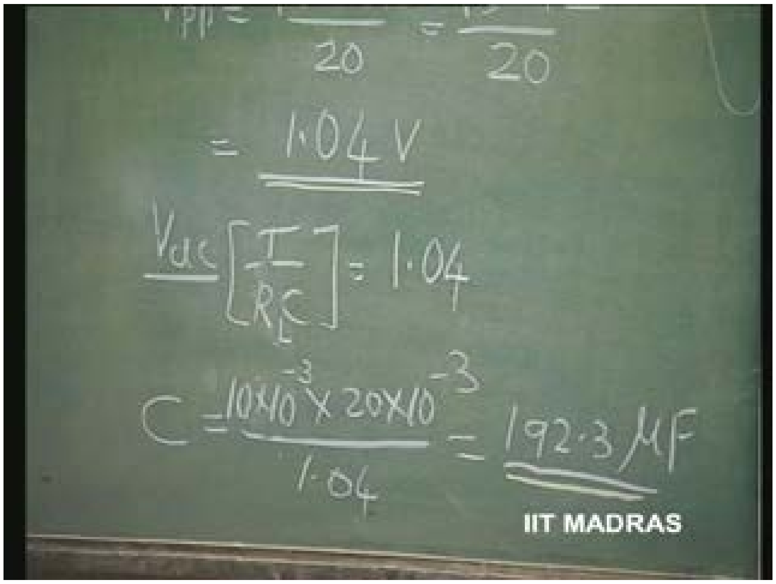

So, the value of C is to be made greater than 192 point 3 microfarad, in order to contain the ripple at 5 percent; so that part of the design is also over.

Now, we have this getting charged to very nearly 12 volts. This, fluctuating with peak to peak value of 12 volts this way and 12 volts that way. Therefore, during the time when the diode is not conducting, that is, during this time - entire time - the diode is not conducting, the voltage, input voltage, can go to its negative peak of 12 volts. So, at that time, the reverse bias voltage across the diode is minus plus 12 volts; that is, 24 volts.

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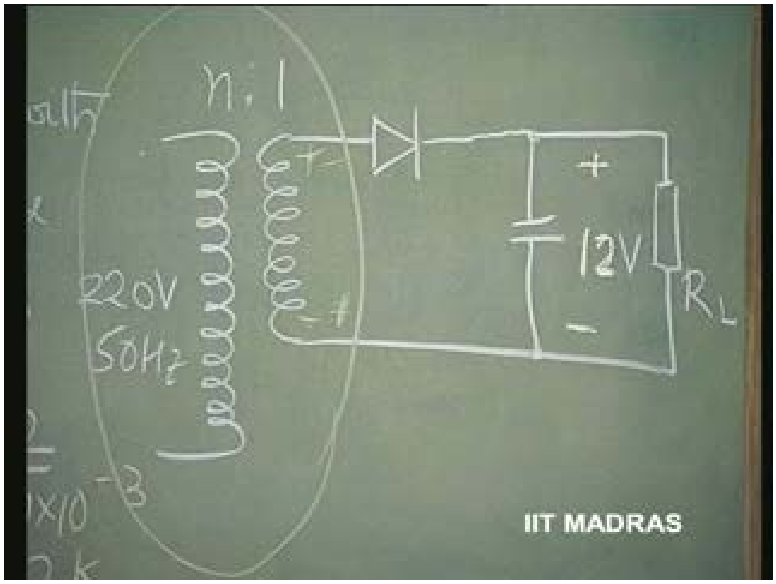

So, the diode specification, the peak inverse voltage rating, peak inverse voltage rating, PIV rating for the diode, this is peak inverse voltage rating for the diode, should be greater than our 24 volts. This is one rating for it; and the capacitor voltage rating should be greater than 12 volts, the DC voltage across it.

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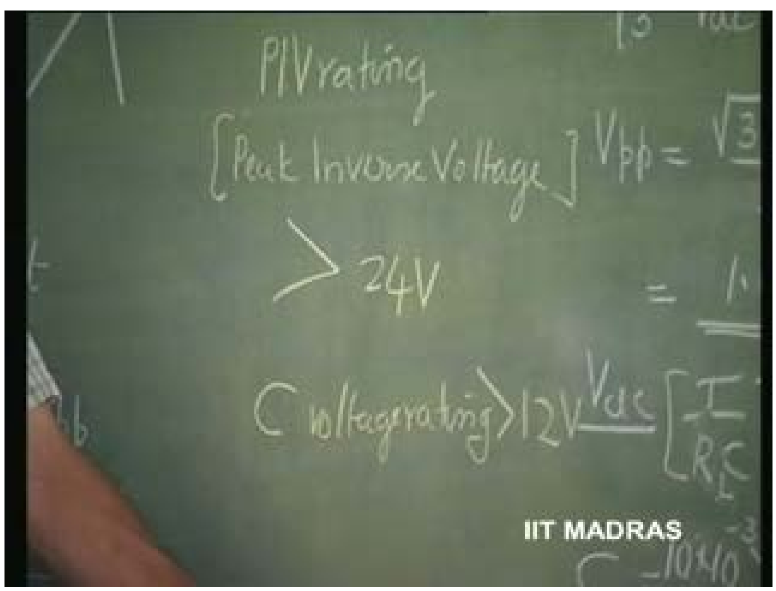

So, these are the two ratings that we have to bear in mind while designing this power supply. There is some other rating for the diode that becomes very important in its specification. Depending upon the load current that we take, obviously, the current through the diode, whenever the diode conducts, the current for the load as well as charging the capacitance is given through the diode.

So, the current through the diode is nothing but vL by RL plus C dvL by dt, that is charging the capacitance. vL is essentially remaining constant at vp; so, that is, v dc divided by RL. So, this is essentially remaining unaltered in our design. We have done such a good design that the peak voltage is going to be retained as v dc. Only thing is for that trouble, we have chosen the capacitor to be very large; and therefore, c d vl by dt is the charging of the capacitor done during a very small interval of time when it is connected through the diode to the input.

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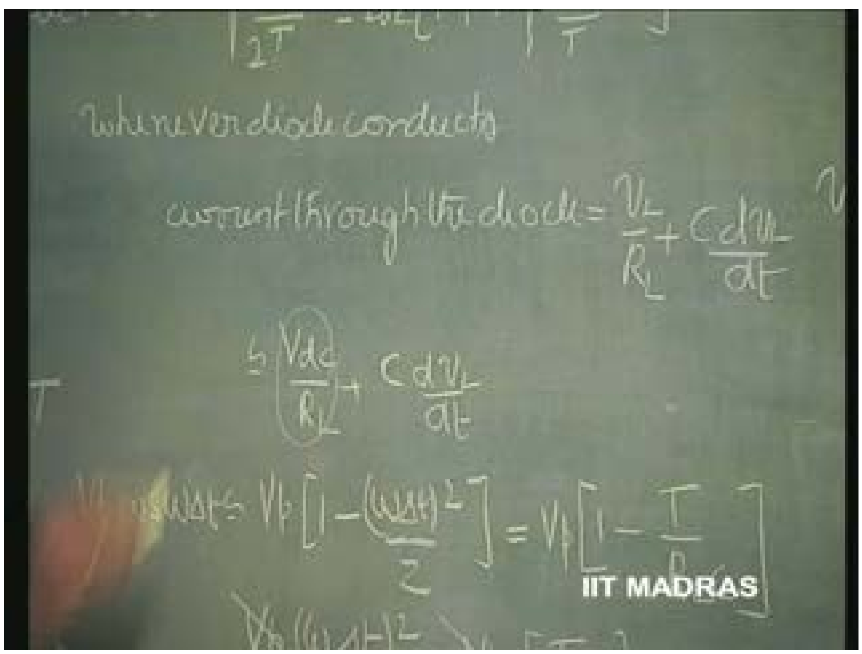

This is the time, the capacitor takes for charging; and this is the time during which it is discharging. So, the amount of discharge, that charge should be equal to what it has acquired here. That time interval is delta t, let us say, suppose, it is very small.

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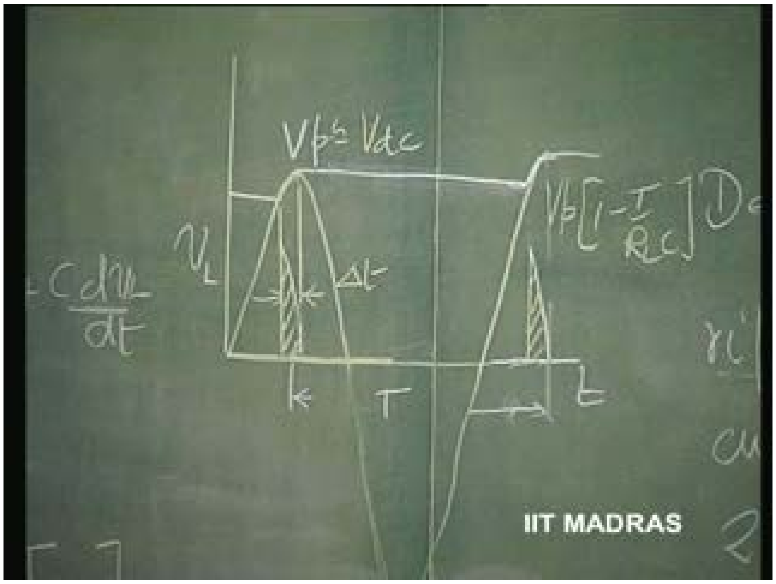

We would like to know how the current varies. Current is maximum at the time of starting of the charge and goes on to zero as far the capacitor is concerned; and therefore, the average current at that point, at that instant of time, is only the DC current that is flowing through the load. So, the DC current plus the capacitive average current is the average current through the diode whenever it is getting connected.

This happens every t seconds, this happens. Therefore it is a periodic rating; that is in the sense, it is a repetitive rating, average current rating, for the diode which is to be specified.

How do we get the value of this? This is already known to us. This is given as 10 milliampere for the problem. How do we find out this value? This is done by, again, approximation, valid approximation.

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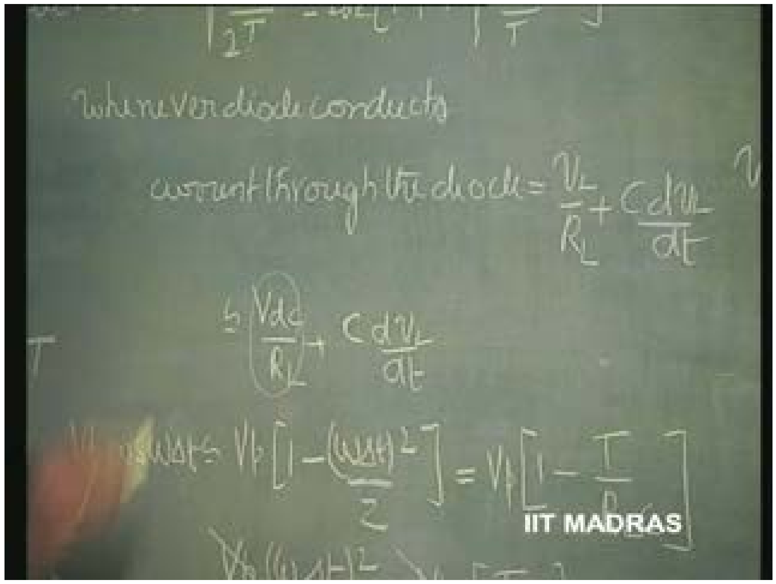

This interval of time is very small; that is how we have done our design. During this interval of time, we would like to know, what the voltage at this point is, where it is joining the input.

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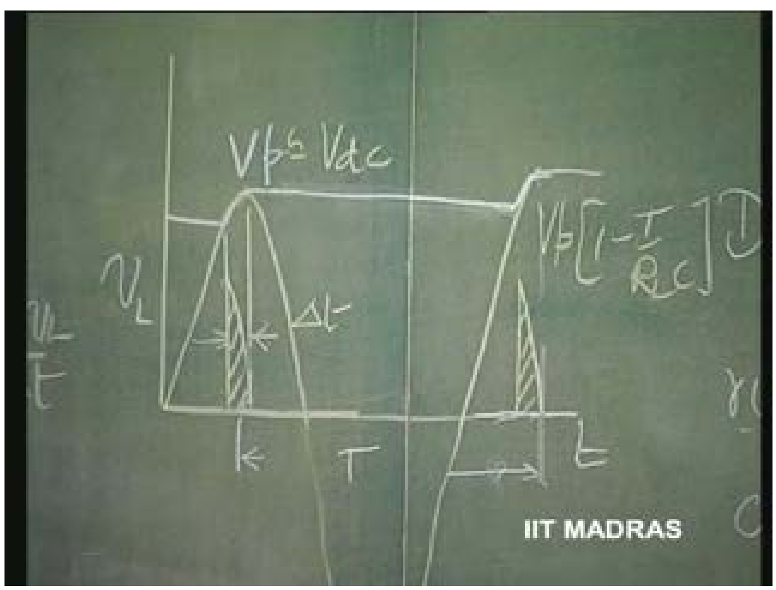

So, at that point of time, the voltage is, vp into 1 minus T by RL C. That is known to us. It is same as vp cos omega delta t, because this, if you take this as zero, this is nothing but a cosine waveform. So, this part of the waveform is defined by a cosine function - vp cos omega delta t. If omega delta t is very small, then it can be approximated as vp into 1 minus omega delta t square by 2. 1 minus x square by 2, cos x is, so on. So this, when it is very small, we can forget the higher order term terms and only take this; and equating now, this side to this side, we will get delta t as this.

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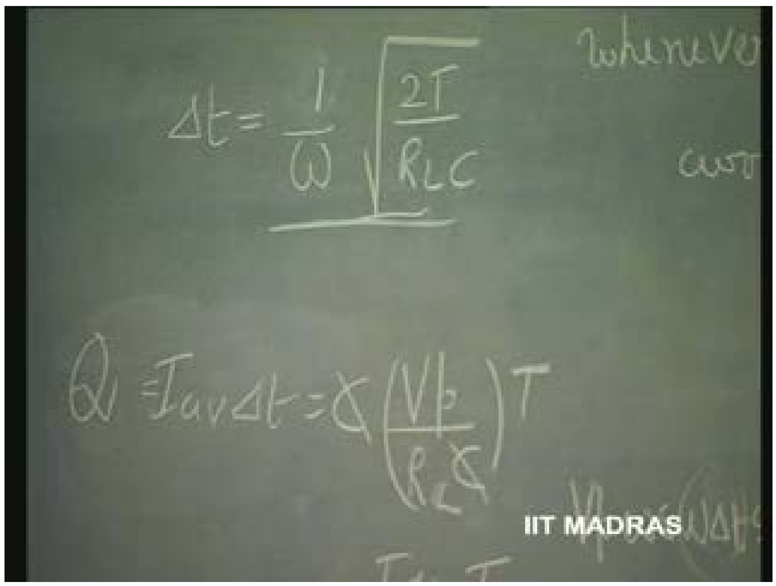

And if delta t is this, then I average into delta t is the charge acquired by the capacitor during the time of charging; and the discharge is, C into peak to peak value of the voltage that is lost; so, C into vp by RL C into T. That is, the charge that is lost; is equated to charge that is gained. So, C C gets cancelled; vp by RL is I dc; that into T is nothing but I average into delta t.

So, this is an important equation. I average into delta t is I dc into T. So, I average is therefore is equal to I dc divided by delta t. Substituting this value, we get I dc into omega T. omega T is 2 pi the root of RL C by 2 pi. This is an important equation which tells us here that the total average current in the diode is I dc plus I dc into 2 pi root of RL C by 2 T.

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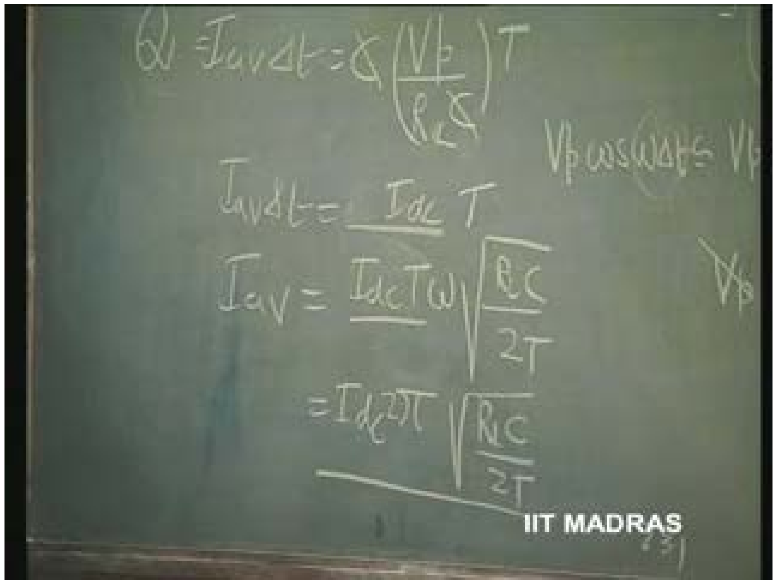

So this is, I dc into 1 plus pi; take the 2 inside 4; so, 2 RL C by T. This is the factor by which the average current is going to be sort of increased. So this factor, if you evaluate for this problem, it will be roughly, very nearly, about 23 point 1. Please try to evaluate taking all the values of RL which is 1 point 2 K; C is 192 point 3 microfarad; and T is 20 milliseconds.

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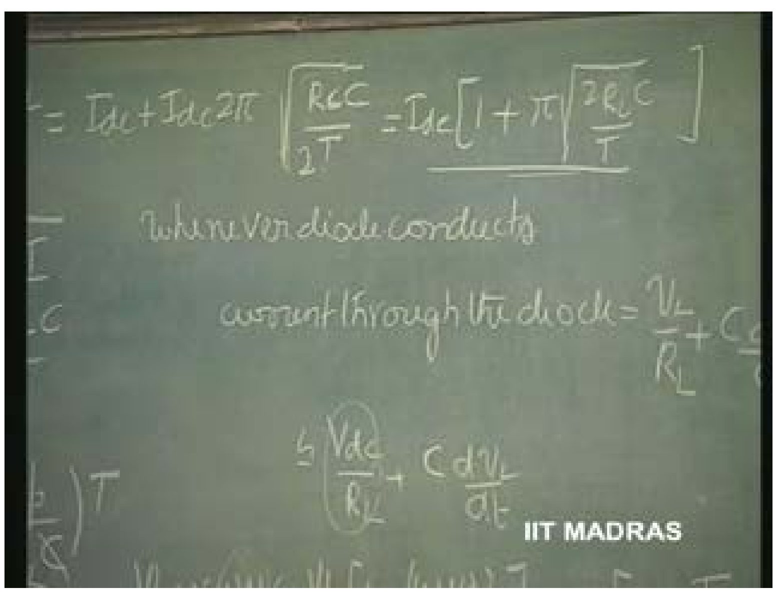

So, it comes out to be very nearly, sort of, much greater than this I dc. I would like you to evaluate this; and this is the one which normally fixes up the value of average current, peak repetitive average current.

So, please work this out; this factor 2 RL C divided by T; it is roughly about 23 point 1. So, that is about pi into that value; so, this is 3 into about 4, about 10 to 12 times more than the I dc value.

So, please evaluate this. This is an important rating. The peak value also is evaluated easily because, if this is linearly reducing, if this is the peak value, the average value is half the peak value. So, if we treat this as the average, then, the peak value is going to be twice this. So, that way, we can evaluate both the peak repetitive rating and the average repetitive rating of the sort of diode.