Introduction to Electronic Circuits.
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Lecture-9.
Rectifiers and Power Supplies.

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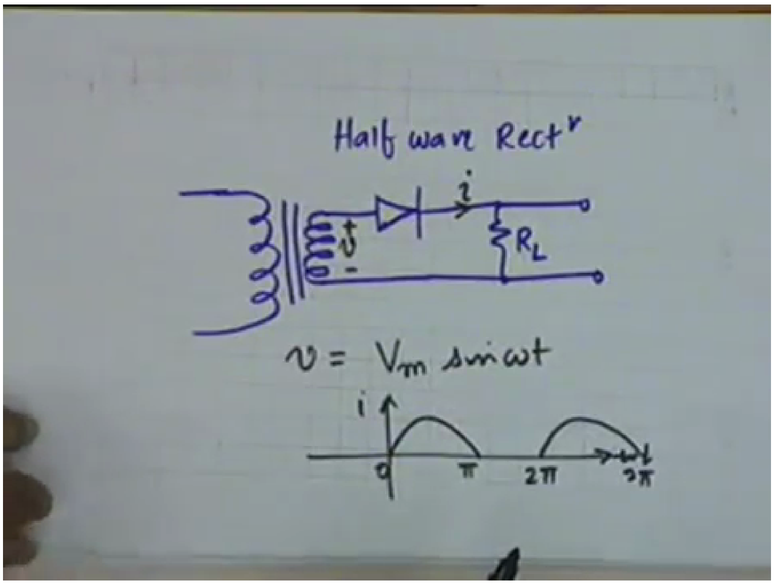

Professor: 9th lecture on the topic of today's lecture is rectifiers and power supplies. We are going to study some practical circuits in which diodes are utilised. And in our analysis of the circuits we shall assume that the diodes are ideal, that means diodes behave as switches, when they are on, the voltage drop across them is 0 and the current is limited only by the external circuit, there is no other limitation, this is what we are going to assume. A simplest rectifier circuit is the so-called half wave rectifier which uses only one diode. And the circuit is like this, the ac is applied between the 2 input points and then it is connected to a load rl.

The output voltage is taken from here and there is an ac source here, now the ac source you could connect to the dc main, i am sorry, the ac mains, the ac mains will give you 230 volts and therefore the voltage that you get across rl shall be fixed, it will be rectified 230 volts and its average value. In practice however we require varying voltages. For example for operating an op-amp we require +12 and -12, for operating a typical digital logic circuit perhaps require 5 volts. For some other application we might require 18 volts, for operating a high-voltage transmitter tube we may require a kilo volts of dc and therefore the dc level, the dc voltage that is developed is controlled by a device known as a transformer.

The transformer at the input circuit, this is the main supply, 230 volts 50 hertz, the purpose of the transformer is to step up or step down the ac voltage in such a manner that the appropriate dc voltage is developed across rl. So we shall call this simply v, the voltage across the transformer secondary and notice the voltage v is a sinusoidal voltage vm sin omega t. The translation of the transformer shall determine what v shall be. Obviously v can be positive as well as negative. And if we do this polarity, then when v is positive, v has this polarity, the diode conducts, when v has the opposite polarity, that is for the negative of cycle, the diode does not conduct.

And therefore the current in the circuit, the current in the circuit let us say i shall be half sinusoid, the i shall only reflect the positive half of v. In other words if you draw a sketch of i versus t, omega t, then what you shall get is only half sinusoids, 0 to pie, then pie to 2 pie it shall be 0 and then 2 pie to 3 pie it shall again we a half cycle and so on and so forth. All right, this will be the current waveform and the voltage across the load is simply current multiplied by resistance and therefore the voltage waveform shall also have the same magnitude, the same type of waveform, not magnitude, okay, the same type of waveform, current multiplied by rl.

Now in analysing the circuit, in analysing the circuit we assume that the transformer is ideal. In other words the transformer has no internal resistance, no losses, so that effectively if we look at, if we look at the transformer back, it behaves like an ideal voltage source, this is one assumption.

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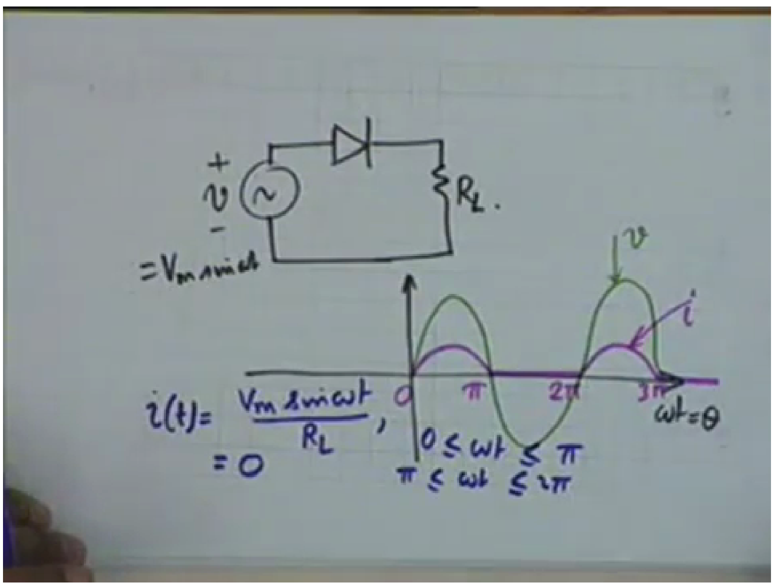

And the 2nd assumption is that the diode is ideal, that is it behaves like an ideal switch. Therefore the equivalent circuit of this, all the rectifier is that we apply v which is equal to vm sin omega t, replaced the transformer by an ideal voltage source, in practice it is not so, that our server as losses and therefore that shall be some drops, there shall be an internal resistance small r here which we are ignoring and then we have the load rl. The waveform as i have told you is like this, this is omega t equal to theta let us say. And we plot current as well as voltage, if the voltage waveform is like this, sinusoid, this is v, then the current waveform, the current flows only during positive half and therefore the current waveforms are like this, these are the current waveform.

And the value of omega t are 0, pie, 2 pie, 3 pie and so on. And you notice that during the positive half cycles, that is i of t is equal to vm sin omega t divided by rl, this holds for omega t between 0 and pie, that is 0 is less than equal to omega t is less than equal to pie, whereas the current is 0 for pie is less than equal to omega t less than equal to 2 pie. One cycle is good enough to find out the average and other values, this is the current waveform. Okay, if this is the current waveform, then obviously it is dc value or the average value can be found out very simply.

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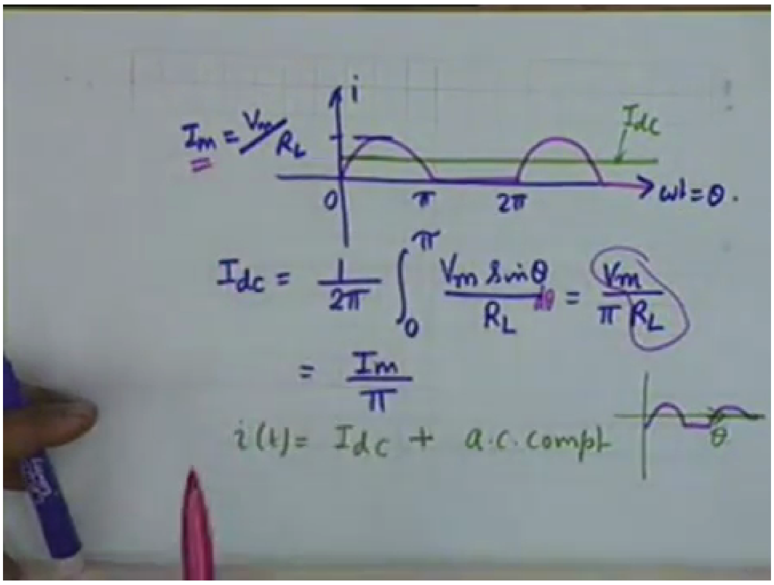

Let me draw the waveform again. This is 0, pie, 2 pie, however consideration can be limited to one, this is i and this is omega t equal to theta. Notice we are not working in terms of t, we are multiplying, we are making its omega t is the new variable because this helps us in doing the algebra and integration and so on. I dc, the average value of this current is obviously 1 over 2 pie, the average is to be over one period, 1 over 2 pie integral the current exists only over this interval, 0 to pie and therefore we integrate between 0 and pie and then vm sin of theta divided by rl, this is the average value of the current.

And if you integrate this, it is very easy to show that this is simply vm divided by pie rl. Pardon me?

Student: (())(9:26).

Professor: There has to be d theta of course, otherwise we cannot integrate. The value is vm divided by pie rl and you can see that vm by rl, vm by rl, this quantity is simply the peak value of the current. This is vm divided by rl and if you call this i sub m, then the current is simply i sub m divided by pie, all right, this is the average value. And the average value maybe, it is somewhere here, maybe this is idc, all right. Now you notice that the total waveform, total waveform can be considered as, that is i of t can be considered as idc lesson alternating component, plus an ac component.

Why ac because if you take out idc, obviously the waveform can go positive as well as negative. In other words if i plot this ac component, ac component versus theta, it will have simply this waveform and so on. It can go positive as well as negative and it is as if, as if it is a ripple superimposed upon idc. And it is called indeed the ripple component. This is a rather bad case of rectification. The value of the ripple, the value of the ripple is the difference between the maximum value of the current to the minimum value of the current. And so the value of the ripple here itself is im, all right, the value of the ripple is im. And we will see how to reduce the ripple later.

Student: (())(11:33) explain it again it is equal to idc plus ac component.

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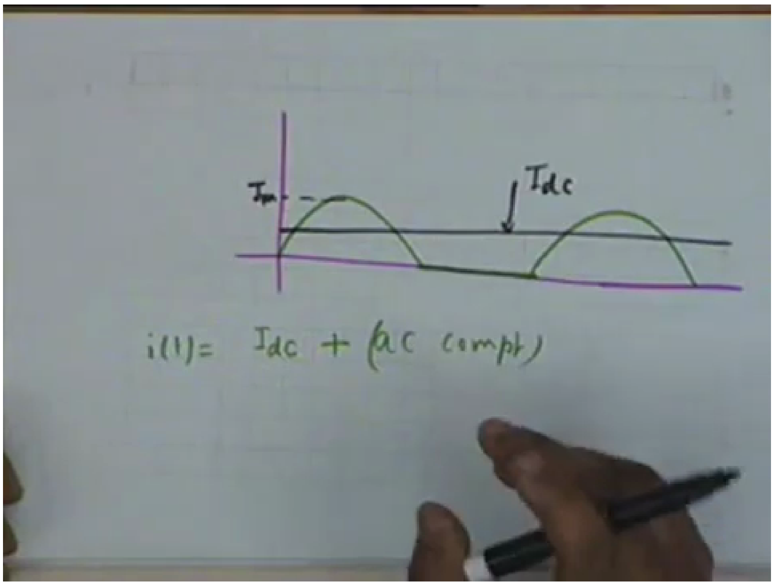

Professor: Okay, i will do that. My waveform of the current is like this, the green, the green curve. This as i said can be written as an average component idc plus a component which can go positive as well as negative. If i take out the average value from here, obviously, if the average value is, the level is somewhere else, support this is my idc level. If i take this out then obviously the current can be, current will be positive here, the ac component, i am not taking this, ac component ac component represents the green curve - the black curve. And therefore it can go positive as well as negative.

And the value of ripple, the ripple is defined as maximum value - minimum value. A very the maximum value is im and the minimum value is 0 and therefore the ripple is equal to im, right. The ripple current is equal to im. What we want is that the dc value, we want only the ac value, we do not want the ripple, so we want to get rid of the ripple. And we will see out to get rid of the people later. At 1st let us see if we can improve upon the situation. As i said this is a case is very bad example of rectification and also it is wasteful because the negative half of the voltage is not utilised at all. The current is dumped or that during the negative half of the cycle.

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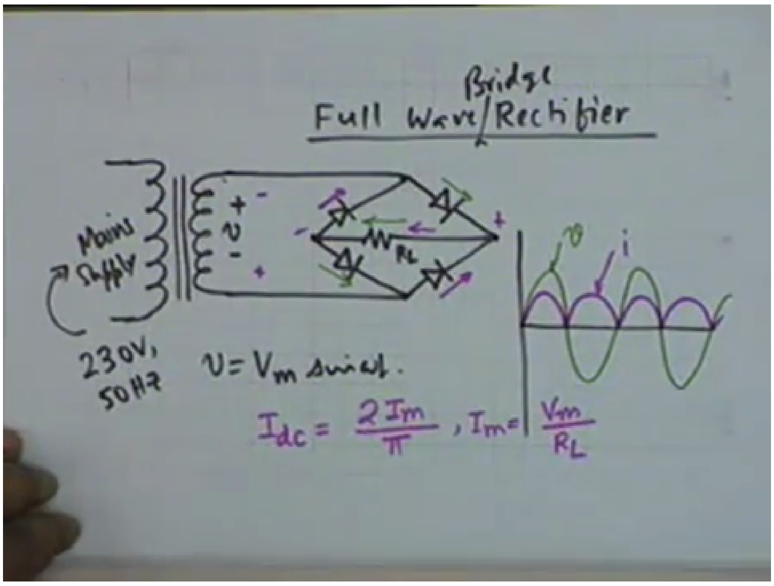

So can we do something to utilise a negative half also? And that brings us to a circuit known as a full wave rectifier. Full wave rectifier can be of different constructions, in one that uses 4 diode in a bridge configuration is called a full wave bridge rectifier. And it is constructed like this, you have a wheatstone bridge kind of arrangement and the input let us say is applied between this point and this point, the input ac is applied between these 2 points v, small v equal to vm sin omega t. And it is sure that during both halves of small v, current flows in the load, in the same direction and this is achieved like this.

You have a diode here, you have a diode here, that the load is connected between the other diagonal of the bridge, this is a load rl and another diode is connected like this. So when v has this polarity, the current flows like this, current flows like this, then through rl and them through this, right. On the other hand when the polarity goes reverse, that is the lower end becomes positive with respect to the upper end, the current flows like this, there is another diode connected here, connected here and a diode connected here, right.

So what happens, when this becomes positive and this becomes negative, current flows like this through this diode, then through this load is the same direction as in the previous case, then through this diode and finally through the source, is this point clear?

Student: We could have used only 2 diodes instead of 4 diodes.

Professor: Yes, we will come to this little later, we could have used 2 diodes only, we will come to that circuit a little later. But this is a very polar circuit, bridge rectifier, particularly for instrumentation applications. Well how does one supply the ac? Depending on what voltage, what dc voltage you want you should use a transformer to step up or step down and therefore what we have is, we have a transformer here, these parallel lines stand for the core of the transformer. Usually these are iron cored transformers and this is symbolically represented by these vertical line.

So there is a transformer here, i have shown that it is stepdown, this is the mains supply, mains supply, that is 230 volts, 230 volts and 50 hertz, all right. This is transformed into v which is vm sin omega t and in both halves, the current flows in the same direction through rl. And therefore if my voltage waveform is like this is like this then the current waveform, current shall be determined by. If the diodes are ideal than the current shall be determine only by rl, all right. So vm sin omega t by rl and it will flow like this. Then in the negative half also the current flows in the same direction and therefore it is as if the negative half is flipped into the positive half and the current flows like this.

And therefore both halves of the sinusoid are utilised and this is why it is called a full wave rectifier. Both halves of the sine wave are utilised and it is called a full wave rectifier. Because the diodes are in a bridge combination, it is called a full wave bridge rectifier. And obviously now, we will let me label them, this is v and this is i, obviously now as far as i is concerned, the dc value, the average value shall be twice the value for the half wave rectifier. And without any calculation i can say that idc shall be equal to twice im peak value divided by pie, where im is vm divided by rl, right, is this point clear?

As compared to the half wave rectifier, because both halves are utilised and they are identical in area and therefore the area under the curve is simply twice to the previous area. And therefore the dc value or the average value becomes twice the previous value, twice im by pie. One of the disadvantages of this circuit is that it uses 4 diodes. And that during each half, during each half of the waveform the load is in series with 2 diodes, 1, 2, similarly 1 and 2. And therefore if the diodes are nonideal, then twice the drop across one diode shall occur during each half of current flow. And therefore the internal resistance of the dc supply between these 2 points, this is the polarity will be higher than in the half wave rectifier.

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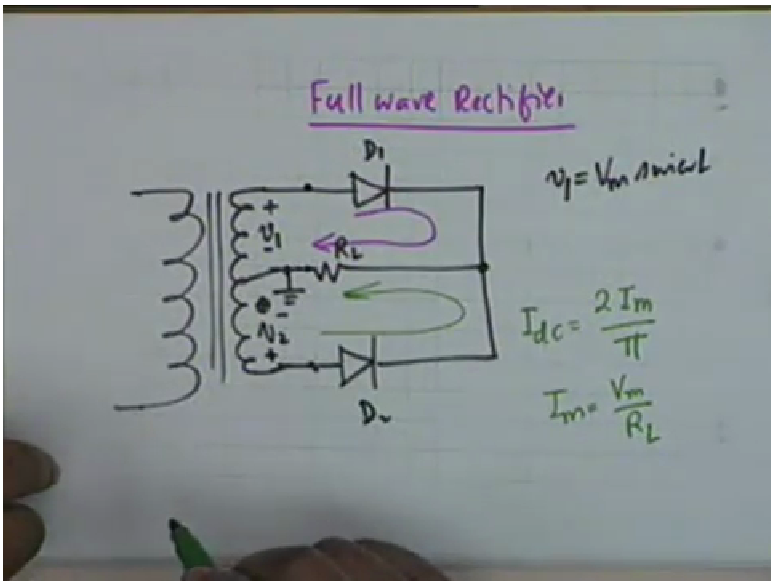

That occurs only when the diodes are nonideal and all practical diodes are nonideal. And therefore this is a disadvantage. But the advantage of this circuit as compared to the one that we are going to discuss now using only 2 diodes is that the transformer becomes inexpensive. Why, because in the alternative circuit for a full wave rectifier, full wave rectifier using only 2 diodes instead of 4 in a bridge requires a transformer which is to be centre tapped. That is i require a transformer like this, okay, 1st let me draw the rectifier circuit, then i shall draw the transformer.

We have, the load is here and this is one of the diodes, we call this d1 and the other diode is here, all right. The circuit is like this, you have transformer here and the load is connected to the centrepoint of the transformer which usually is connected to ground but it is not necessary that it is, usually this point is connected to ground. And the primary of the transformer is the usual circuit, 230 volts, 50 hertz, it is either stepped up or stepped down by means of this transformers, centre tapped transformer, so the 2 halves are identical in other words if i call this voltage as v1 and the voltage as v 2, it should have the opposite polarity, then v1 and v2, except for polarity, they are identical, right.

So let us say v1 equal to vm sin omega t, then v2 is simply the opposite of vm, phase difference of 180 degrees. We have taken this polarity to indicate that when the transformer, when the transformer is such that the secondary voltage from here to here has higher potential here compared to the lower point, then it is this diode d1 which conducts. That is when the transformer, when the excitation is such that this point is positive with respect to the lower point, then v1 is positive and v2 is negative, is that clear? You are measuring the voltage between this point and this point, this is what is transformed. For example if this is a 1 is to 2 transformer, then 230 volts here will lead to 460 volts here with this polarity positive and this negative.

Now the total voltage from here to here is the, is v1 plus v1 - v2 because i have taken the opposite polarity. You need not bother about the polarity now but the only thing you have to consider is when this point is positive with respect to this point, then this is positive with respect to this point, centre tapped. And a centre tapped is positive with respect to the lowest point and therefore it is only d1 which can conduct a d2 cannot conduct. When d1 conducts the current flows like this through rl it goes back to the transformer centre tapped. On the other hand when the transformer changes its polarity, secondary voltage changes its polarity, v2 becomes positive, that is this point becomes positive with respect to ground, so d1 cannot conduct, it is d2 which conducts.

In both cases the current flows through rl in the same direction and therefore the 2 diodes here achieve the same purpose as 4 diodes in the bridge rectifier circuit, except for the fact that it requires a costly transformer. The cost of a diode is much less than the cost of a transformer. And the total cost of this circuit is much higher than the cost of the bridge rectifier circuit stub and therefore a bridge rectifier circuit is very popular in non-critical applications, non-critical where the diode nonidealness is not of great concern, does not affect your performance very badly, right. So the bridge rectifier is favoured.

Whereas this will be favoured in critical applications, critical applications where you will be prepared to spend the money required for a centre tapped transformer. You notice that idc, if the diodes are ideal, idc is the same as in the previous case, namely twice im divided by pie where im is equal to vm divided by rl. What is this vm? It is the peak value of either half, either v1 or v2, is that clear? Whereas in the previous case vm was the total voltage, vm was the peak value of the total voltage developed across this. So does it mean that this develops a lower voltage as compared to the 2 diodes rectifier? Yes?

If this vm and this vm are rectifier identical, then obviously the 2 diode rectifier develops a higher voltage and this is why we pay the price. Effectively it is the peak value of the voltage developed across half of the transformer and more the number of turns the more you pay because they use more copper, copper wire and you use more core, more iron and you have to pay for the metal. So this is an expensive proposition but in critical applications this is what shall be preferred. For example in the laboratory power supply that you see, i defined the power supply lasted. What is a power supply? It is a rectifier in combination with a filter, filter gets rid of the ripple component, ac components, all right.

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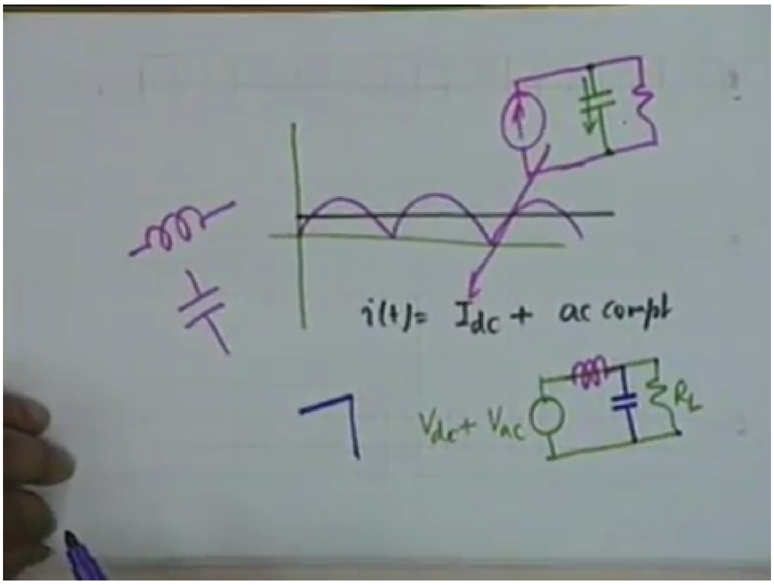

In the full wave rectifier, if this is the waveform of the current and the average is let us say somewhere here, then you see ift is equal to idc plus an ac component. And the ac component has the same waveform as this violet curve, except that this black lines represent the 0 level, alright, the black represents the 0 level. The question now arises how do we improve the situation, how do we get rid of the ripple. This is also a bad case of a ripple and therefore what we do is we apply a filter. There are various kinds of filters that can be used and as i told you earlier, filters will use either an inductor or a capacitor or both.

The idea is that if you have a current, if you have a current, let us say consider a current generator, this supplies a load and this current consists of dc, dc as well as ac, if somehow we do not allow the ac component to pass through the resistance, then obviously we shall do our job. That is if we provide, the basic idea is this, basic concept, if we provide across the load a 2 terminal component which allows only ac to pass but not dc, obviously that component has to be a capacitor.

So as far as a capacitor is concerned, if you component passes through the, through the capacitor, it is the dc which passes through the resistance and therefore as far as ac is concerned, the capacitor provides an easy path, so most of the ac flows through the capacitor, nothing goes to the dc, to the load, all right. This is what basically filtering is. Or the alternative way of looking at this is that we have a vdc plus v ac, a voltage source and then what i do is, it is connected to the load rl, well i do not allow the ac component to go to rl, to drop across rl.

What i do is i use some inductor here, inductor as you know drops the ac component. As far as dc is concerned, the inductor is a short, is not that right. The inductor, the voltage across inductor is l di by dt, so as far as dc component is concerned, d dt of idc is equal to 0. And therefore an inductor does not drop dc. So the dc shall be dropped across rl and it is receiving shall be dropped in the inductor. And better structure would be, we used an inductor as well as a capacitor, all right. Accordingly this is called a capacitor filter, if we have a single inductor, it is called an inductor filter.

If you have a situation like this, an inductor and a capacitor, it is called a l filter, it looks like the letter l looked from the lower side, okay, it is called an l filter. Or you could have, you could have an inductor, then a capacitor and again an inductor, then a capacitor and again an inductor, then the load. This obviously looks like a, an english letter t and therefore this is called a t filter. You could have, a variation of this is, you have a capacitor here 1^{st} to start with, then you have an inductor, then you have a capacitor and then the load, this obviously looks like the greek letter pie and therefore it is called the pie filter. There are various kinds of filters possible, capacitor filter, inductor filter, l filter, t filter and pie filter. And all of them use inductors and resistors, the basic idea is, inductors and capacitors.

The basic idea is, will you notice that in all these circuits, whenever we use a capacitor, the capacitor is in shunt, capacitor provides a shunt path, it shunts out the current, whereas an inductor is in the series part, so it drops the ac voltage. If we voltage is not allowed to go to the load by means of the inductor which is therefore to be put in series, whereas capacitor provides an easy path for the alternating component of current and therefore it is provided in shunt. So that before the current can have an opportunity to reach the load, it is shunted out. All right, is that clear?

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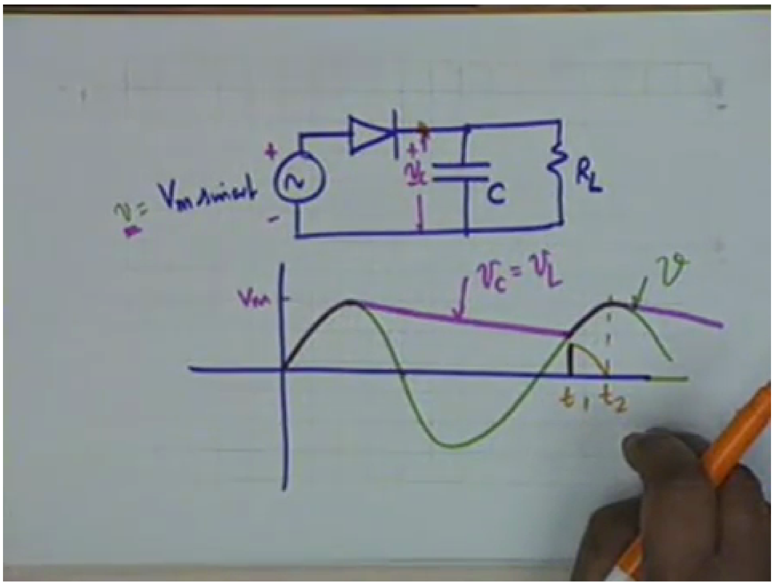

We consider at this point in the course only from simplest filter, namely let us consider a half wave rectifier and a capacitor filter. Capacitor c, then this is rl and let say we replace the transformer by means of an ideal voltage source which is vm sin omega t. Then you know that without the capacitor, without the capacitor, the waveform of the current, let us look at the voltage, waveform of the, waveform of v 1st. Waveform of v is like this, okay, now let us see how does the current flows. To start with, let me use a different colour, to start with you see, when small v is positive and negative like this, when its polarity is like this, what happens, the diode passes current, this current charges the capacitor, all right.

This current the current passing through the diode, it charges the capacitor, all right. There is a current through rl also, we will come to that but it charges the capacitor. And therefore the capacitor voltage, if you call this voltage as v sub c, v sub c, it is the same as the voltage across the load because the 2 components and in parallel, v sub c is same as vl. What happens to v sub c, it arises, it accumulates charge and how long can it accumulate charge? When it goes on accumulating charge till it reaches the peak value.

At this point this voltage itself decreases and the capacitor cannot change its voltage instantaneously and therefore the capacitor holds at the maximum value let say vm, the capacitor holds that the maximum value vm, this voltage diminishes below vm and therefore the diode ceases to conduct, is that clear?

Student: No.

Professor: No, all right. When v, small v is driving like this, this is a waveform for v, when small v rises, the diode conducts, diode drops nothing, the diode is ideal and therefore the total voltage vm sin omega t appears across vc. And what happens when this voltage rises, the capacitor also charges. Capacitor charges what voltage, it charges up to v equal to vm, now what happens? Small v now decreases below vm, the capacitor cannot change its charge. And therefore it remains that vm, however this voltage decreases below vm, so the diode becomes reverse biased.

The diode conducts only when the anode is positive with respect to the cathode, the cathode has become positive with respect to anode, therefore the diode ceases to conduct. What happens to the capacitor then? Capacitor becomes disconnected from the supply and that it finds a path through rl. So it supplies a current to rl, all right, and the capacitor voltage gradually decreases, it decreases in an exponential manner. And therefore the capacitor voltage starts decreasing like this till, well during the whole of this period, during the whole of this interval, the diode remains inactive, the diode is not occurring, it becomes, it remains open.

As soon as the capacitor voltage reaches this point, now it finds that indeed the anode of the diode, the voltage across, the voltage at the anode of the diode is now increasing and therefore the capacitor which had lost some charge now begin acquiring charge again, all right, up to the maximum, right. Then once again the diode ceases to conduct and therefore the capacitor once again starts diminishing like this. This is the waveform of v sub c, the voltage across the capacitor which is the same as the voltage across the load vl.

And you notice that when the capacitor was not there, the voltage waveform would simply consist of the positive half of this, then the positive half of this and then the positive half of the next cycle and so on. Now what is happening is this large gap, this negative half which was left completely neutralise, the capacitor now because of its property of storing charge, it fills out some of the voids. What he would have liked is if it would have remained constant like this, then obviously we would have got an absolutely constant value of dc.

Unfortunately that does not happen because there is a load and as soon as the diode starts being open or non-conducting, as soon as the diode becomes non-conducting, then the capacitor to this charge through rl. The charge decays exponentially till the diode gets an opportunity to conduct again. And this repeats and therefore if you observe, if you connect an oscilloscope across the load, what you shall observe is this. And exponentially decaying waveform then a little rise, then again and exponentially decaying wave, little rise, again exponential and so on, this is what we shall repeat. Is not it obvious that the area under the voltage curve, under the capacitor voltage or the load voltage curve has now increased and therefore the dc value has increased, is that okay?

This is one way of rectifying the situation in half wave rectifier. Not only that, if the dc value is increased, what is the other phenomenon that accompanies this? The ripple voltage, that is the maximum fluctuation between maximum and minimum has decreased and therefore this is what the filter does. One way of looking at the filter and the capacitor is, very simplistic way that the alternating component of the current is provided an easy path. Another way, another more illuminating way is to look at the charging and discharging of the capacitor.

Now let us go a little deeper into this phenomenon and see what happens to the diode current, okay. Obviously the diode does not conduct during this decaying path, it starts conducting here, all right. And as you know the diode current is limited only by, when the diode conducts, the diode current is limited only by the external load. And therefore what happens is the diode starts conducting here, let me use the different colour. The diode starts conducting here, similarly the diode current rises and when does the diode stop conducting? At this point and what happens is that the diode current flows like this, it flows in a pulse during a part of the half wave.

If the capacitor was not there, the diode current was flowing throughout the positive half cycle, the diode correct was flowing like this. Now the diode current flows only for a small interval of time, let us call this as t2 and this as t1. It is during t2 and t1, it is during t2 - t1 that diode current flows. In any every subsequent positive half cycle, this is what happens, the diode currents flows impulses. You can see, you can see this also on the oscilloscope. If you take the current waveform, how do you take that, how do you observe the current waveform? How do you observe a current waveform in an oscilloscope?

We allow the current to drop a resistance. So we use a small resistance here, maybe 10 ohms, this shall of course affect the performance of the circuit badly, it will deteriorate the performance of the circuit but you can at least see. If you use if you use a small resistance here and connect the oscilloscope terminals across this, then you can see the diode waveform and you can see that it flows in pulses like this. This would be the shape that one can observe on this oscilloscope. Alright, that the diode current flows for a short interval, now can you tell me if t2 - t1 becomes shorter and shorter…

Student: (())(42:36).

Student: That is right, the power laws in the diode decrease this. Not only that, the something else that happens to the dc voltage that is developed. If t2 - t1 was 0, then the vdc would have been constant. And therefore the shorter the interval of diode conduction the better would be the rectification or the less will be the ripple voltage.

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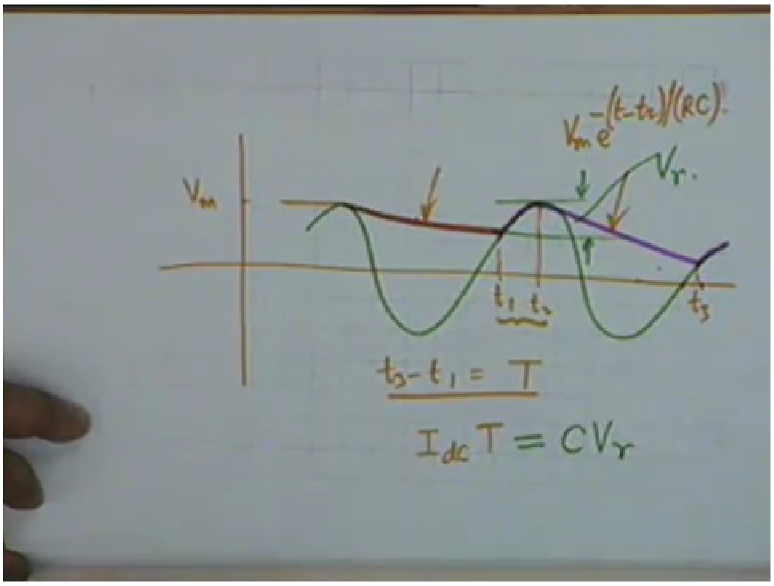

Professor: Now if i draw this waveform again, let us say i start from, forget about the initial part. Initially for the 1st cycle, for the 1st of cycle the capacitor charges, then except for this part the phenomenon is repetitive, so forget about that. What i have is from here let say this voltage is vm, from here there is an exponential decay, let me use a different colour, there is a next potential decay, then a try this, the capacitor charges, then there is an exponential decay like this and so on. Alright, what i said was that this, this was t1 and this was t2.

If t2 - t1, now before that, can you tell me what what will be the equation to this decay? Exponential, so it will be vm's, it starts decaying from vm e to the power - t - t2 divided by rc, okay. This is the equation to this curve, right. So it exponentially decays, now if t1 - t2 is small, if t1 - t2 is small then what is the difference between, what is the difference between t3 and t1? T3 - t1 should be equal to one complete period, it in that right? So t3 - t1 should be equal to capital t, the time period of the wave.

This happens exactly at the same point, exactly at the same point in the next cycle and so on and so forth.

Student: Excuse me sir. Sir why do you get in the decay of the voltage that is due to the capacitor, voltage across the capacitor, what do you get t1 - t2?

Professor: It is t - t2, at t equal to t2 the value is vm and then it decays. Similarly you can write for this path, you have to have (())(45:36). But do you understand this front, that the difference between t3 and t1 is exactly equal to 1 time period, all right, is that clear?

Student: Sir can you explain it again?

Professor: Can you explain that again. You see between t3, that is the point at which it starts charging again and the point it had started charging earlier, the difference in exactly one time period, all right. From here to here it is one time period, we have advanced by t 1 here, this is also advanced t1 and therefore it is exactly one time period. It is important understand that it is one time period. Then in this time period how much charge has been transferred to the load? Obviously idc times capital t, during one time period the total charge transferred from the capacitor to the load and this is replenished during t1 to t2, is in that right?

This charge, the charge that the capacitor loses to the load, it is a beautiful physical equality, conservation of charge, the charge that the capacitor loses, it is that amount of charge, only that amount of charge that the capacitor against doing the time that the diode conducts, all right. So if this difference, if this difference is vr, then what is vr, vr is obviously the difference between the maximum value and the minimum value of the voltage across the load. And therefore vr is the, by definition recruit voltage, all right. This is the recruit voltage.

And if a capacitor charges through a voltage vr, much charge does it acquires? C times vr and therefore these 2 should be equal. Is this clear? The capacitor loses charge during this period, all right and the charge lost is equal to idc multiplied by capital t. I have made an assumption here which you did not object to.

Student: That the capacitor discharges 0 time.

Professor: No, that is not…

Student: (())(48:14).

Professor: No, even not that. Capacitor charges only between t3 and t2, capacitor discharges only between t3 and t2, whereas i multiply idc by t, t3 - t2 is not capital t, t3 - t1 is capital t.

Student: (())(48:38).

Professor: That is the correct option. What i am assuming is that the diode current flows for a very short time, then this t2 - t1 is very small. Therefore i should use an approximation sign here, this is approximately equal. Let me repeat, the charge lost by the capacitor during one period is idc multiplied by t and the charge gained by the capacitor, it can gain only when the diode current flows, therefore it gains during the time interval t2, t1 to t2 and that charge is c times vr, if vr is recruit voltage. And therefore the required value of c to obtain a required ripple level, obviously the ripple level is dependent on c.

Suppose rc product is very large, then obviously the decay would be very small. So t2 - t1 would be small, is that clear? If the rc product is very large, then the decay would be small, it will fall very slowly and therefore t2 - t1 will be still smaller and the ripple voltage will be smaller. So it is the value of capacitance c which controls the ripple voltage.

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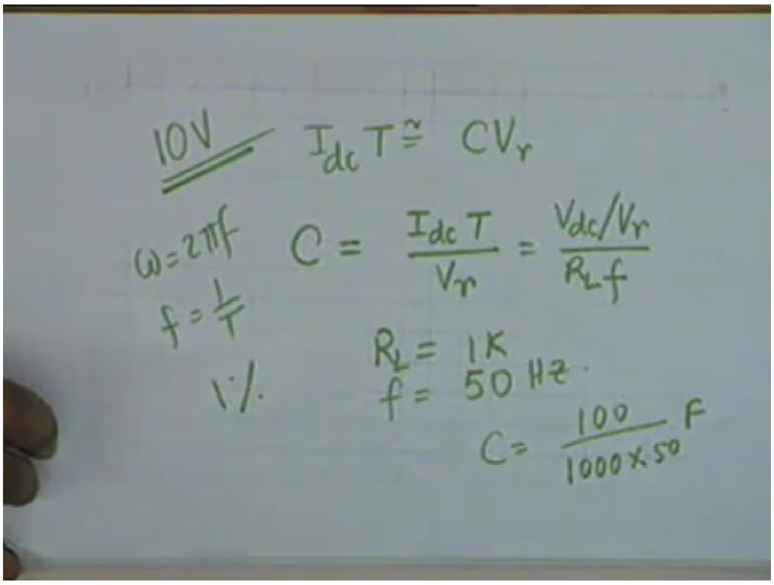

And to get a certain ripple voltage vr, the relationship is that idc t shall be equal to cvr, approximately. And therefore the required value of c is given by idc capital t divided by vr, all right. Now what is idc, it is v dc divided by rl. And what is capital t in terms of frequency? 1 by f, capital t is 1 by f, f is in hertz, omega, omega is 2 pie f and f is 1 over t, f is just frequency in cycles per second or in hertz. So it becomes rl f then v dc by vr. All right, is that clear? V dc by vr, now suppose i want, suppose my rl is 1k, what is my f? 50 hertz, 50 hertz.

And suppose i want a 1 percent will, what does 1 percent will mean? 1 percent, vr is 1 percent of v dc. Therefore what would be v dc divided by vr? 100. No. V dc by vr, vr is by v dc is 0.01 if it is 1 percent ripple, 1 percent ripple, all right. Therefore i can calculate my c, it would be hundred divided by 1k is 1000 multiplied by 50, so many farads. It would be a large capacitors, whatever the value is, it will be in the order of 100s of micro farads but this is the type of capacitance that has to be used. Now if vdc is specified, if v dc is specified then you can calculate the turns ratio required for the transformer.

Suppose that v dc specified is 10 volts, then v dc is approximately equal to what? Vdc, the dc voltage required across the capacitor the load is 10 volts, then v dc will be approximately equal to vm, the peak voltage across the secondary. And therefore the transformation ratio that you need is 230 is to 10, is that correct?

Student: But then v dc is equal to vm only?

Professor: Vdc is approximately equal to vm because they are same.

Student: Please explain.

Professor: Okay, you see, v dc ideally, if the capacitor was infinitely large, if rc product was very large, then the ripple voltage would have been very small and therefore the capacitor would have discharged very slowly. And therefore the voltage, dc voltage would have been approximately will do vm, the peak value. In any case, in this example we have specified that the initial voltage is only one percent and therefore the voltage across the load can deviate from vm by only 0.01. Can it increase by 0.01?

Student: No.

Professor: No, it is decrease because the capacitor the case and therefore v dc is approximately equal to vm. Now beware of the trap, what i am saying is this is so, then my turns ratio of the transformer, because i am feeding the transformer…

Student: (())(54:07) opposite, it will be 10 is to 230.

Professor: No, i have to step down and therefore the primary must have larger number of turns. But i still have made a mistake which will not be detected. 10 is the peak value of the secondary, 230 is rms, so we must multiply it by root 2, this would be the turns ratio. Is that clear? And the total rectifier design is complete, all that you need is the transformer, you have specified the turns ratio, go to the market and buy the, buy the costliest transformer, the costlier it is the better is the quality. You buy a cheap transformer and you make your life miserable and you buy a capacitor. The capacitor also there are various qualities of capacitors.

Hundreds of microfarads of capacitors, 500 microfarads is available only in electrolyte, it is an electrolytic capacitor and there are differences between bell capacitors and other company capacitors. There are good company, bad company than so on and you should buy the best that is available. And you can go to the lab and wire up the circuit, i guess you have an experiment to do with a half wave rectifier in the laboratory. And you can observe all these waveforms and the phenomena in the laboratory. On the next occasion, that is monday we shall take up some wave shaping circuits.