Introduction to Electronic Circuits.
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Lecture-10.
Wave Shaping Circuits.

Professor: 10th lecture, here we are going to discuss wave shaping circuits. By definition wave shaping circuits are those which shape the waveform of a given wave. In that sense rectifiers are with shapers because they, in the half wave rectifier they reject the negative half of the wave, they only retain the positive half and the waveform of the output is quite different from the waveform of the input. So rectifiers are wave shapers, full with rectifier flips the negative half into the positive half, so that is also a wave shaper. And before taking other specific circuits, i wanted to do a couple of interesting examples on rectifiers, which are also as i said wave shapers.

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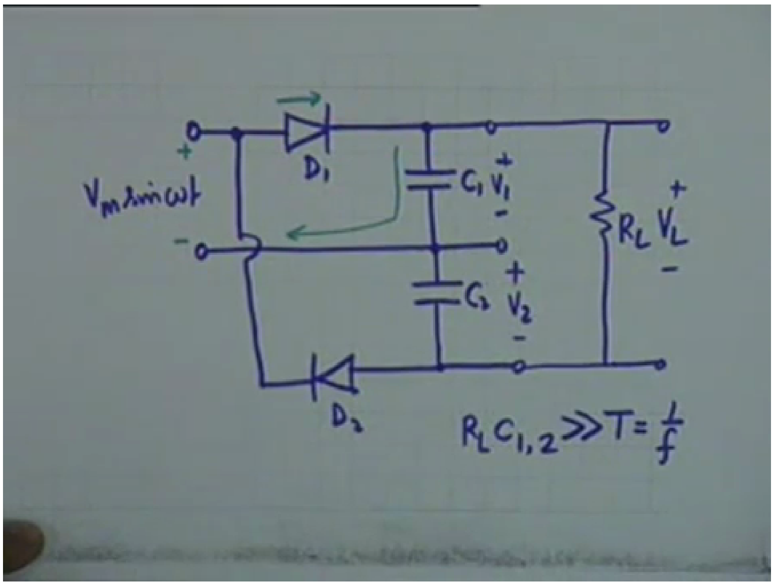

And one of the examples is this. We have circuit like this, try to draw with me, there are 2 diodes and capacitors c1 d1 and then the voltage across this is v1, then we have another capacitors c2 here and there is a diode d2 which connects like this, all right. The input between these 2 is vm sin of omega t and the voltage between these 2 points is taken as v2, v2 and the node that is the resistance across which you require a dc. Basically this is a rectifier circuit, a full wave rectifier, the load is here, rl. You are required to find out v1, v2 and vl under the condition that rl c1 or c 2 is much greater than the time period of the given sinusoid which is equal to 1 over f, is the question clear?

Alright, now let us see how this circuit works. When we have the positive half of the sine wave between these 2 points, that is this polarity is positive, this is negative, then obviously it is this diode which conducts d1, current flows like this and then comes back, comes back through the capacitor to the other point of the sinusoidal source, so the current flows like this. Can it also flows through the resistance rl? No because if it has to then, pardon me?

Student: It can come back (())(4:38).

Professor: It can come back to c2 via d2 to the supply. Pardon me?

Student: It can pass through rl and then come through c2.

Professor: It will pass through rl and come back through c2…

Student: (())(5:01). But in that case diode will also…

Professor: No, the diode is connected here, here the current has to come back to the same point where it leaves. It has to go to the other end of the voltage supply, all right, so the only path…, the other part is this rl, then via c2 and via this point, okay.

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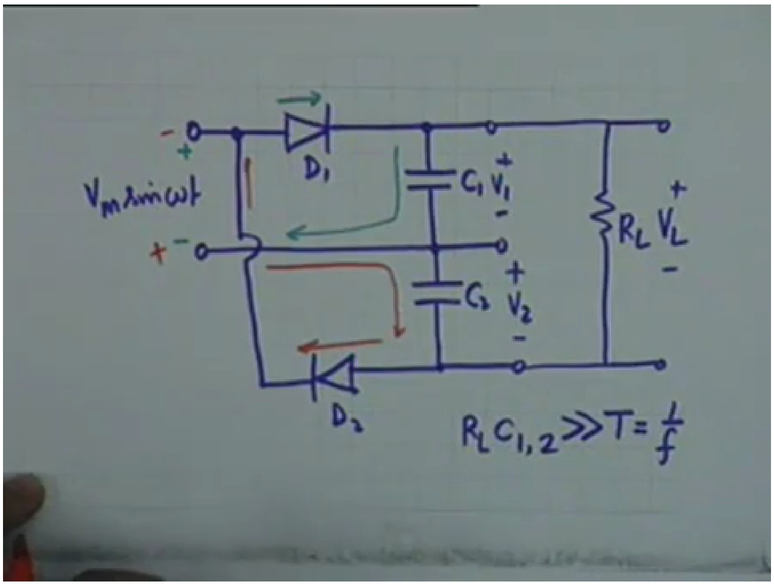

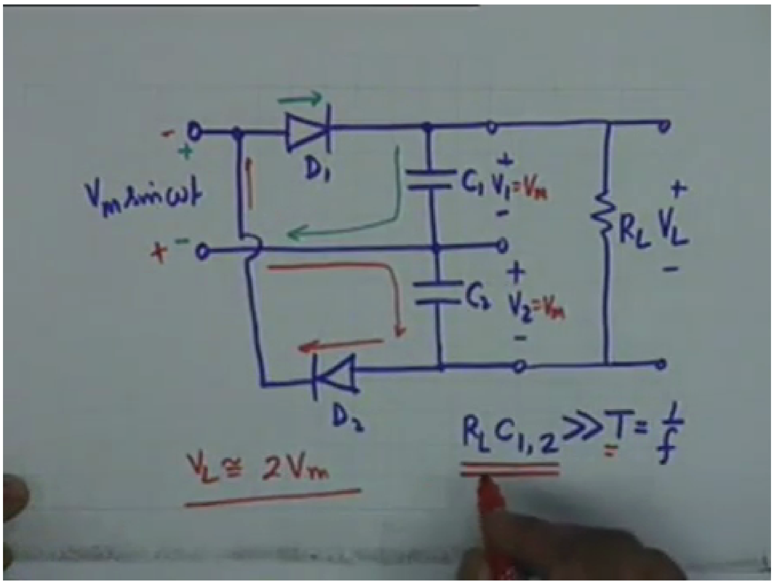

Let us consider the situation when it becomes negative, let say this is negative and this is positive. Then obviously the current passes through like this, through the capacitor c2, through that i would need to add to this point, here also a bath of the current might flow through rl, then through c1, but it has to come back to the same point, why should you come back to the same point? So this the green and the red, these are the 2 directions of the current. What actually happens is the following. That c1 charges to the peak of this voltage vm and c2 charges to again to the peak of the voltage but with the polarity this positive and this negative.

That means, that means v1, if rl was not there, forget about rl, if rl is not there, then no question of discharge of the capacitors come. So c1 voltage is held at vm, and c2 voltage is held at vm. So v1 equal to vm, v2 equal to vm and the voltage across the load would be twice vm. And therefore this is a voltage doubler, not only it holds the voltage at the peak value but it doubles the voltage because we have 2 paths v1 and v2, 2 capacitors. So it is a a voltage doubler peak detector circuit. Pardon?

Student: (())(7:05).

Professor: Suppose rl is not the, then this diode charges are capacitors c1 to the peak value vm, as soon as the voltage falls below vm, c1 holds the charge, diode fails to conduct. So c1 is charged to plus vm, similarly in the negative half, that is when this terminal becomes positive with respect to the upper terminal, current flows like this and c2 charges to vm, all right. Now when the diode, when one of the diodes is not conductive, the corresponding capacitor may find a path through rl for discharge if rl is there. If rl is inserted, then either capacitor, when it is not charging we try to discharge through rl, through r1 and through c2.

But this discharging tendency shall be restricted because of this relation. If the time constant is large, then the decay would be very small during one time period and therefore this voltage vl is approximately equal to twice vm, this is a practical voltage doubler circuit.

Student: Excuse me sir.

Professor: Yes?

Student: When c1 is charging in the 1st half of the cycle, why cannot the current go through rl side when rl present in the circuit.

Professor: Where does it come back then, it has to come back here.

Student: (())(8:47) potential difference across c1.

Professor: There is, this is vm.

Student: Then why cannot current come through rl?

Professor: The current can come through rl as i said it can come like this, it can come like this but the tendency is restricted because the time constant is large compared to the time period. That is in one time period the decay of the voltage either v1 and v2 due to discharge through rl will be negligible. If rl is not there then the voltage shall be exactly equal to twice vm. With rl, this twice vm passes a current through rl and therefore both c1 and c2 have a tendency to discharge. But this discharge during one time period shall be very small because of this relation and whatever charge is lost during one half cycle, one cycle shall be regained again during the next cycle, all right.

And therefore this voltage is approximately a constant equal to twice vm. This relation should be valid, suppose it was a short circuit, suppose rl was 0, so that rlc is negligible. Suppose rl is very small so that rlc is negligible, then obviously both c1 and c2 when c2 is not charging it will discharge through rl, all right. And if it is short-circuit the voltage will be 0. So you see vl depends on the value of rl, precisely the product c rl because it is this product c1 rl and c2 rl which is going to determine the decay during the period that either capacitor is not charged.

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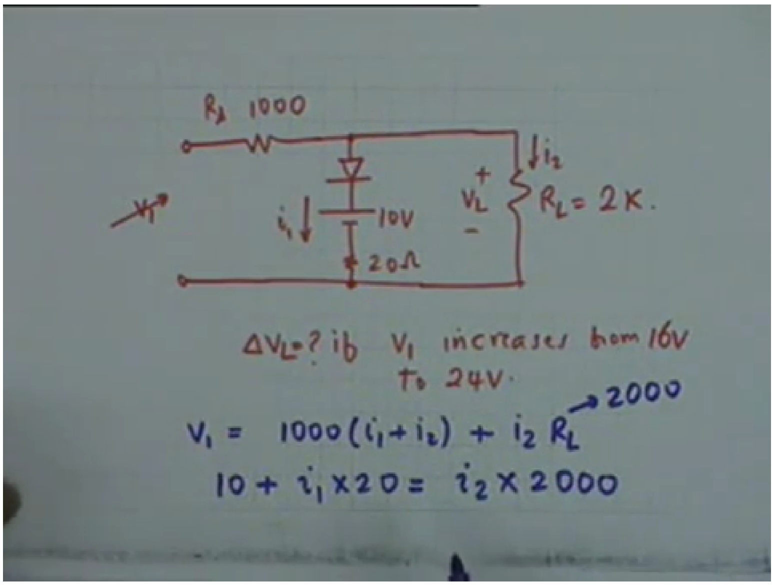

The 2[nd] problem which is also very interesting is the following. Suppose we have a dc v1 which fluctuates, a dc v1 which fluctuates. Maybe it is a rectified power supply but a power supply itself fluctuates, instead of 230 volts it sometimes becomes 240, sometimes falls to 210 and so on. So v1 fluctuates, our purpose is to reduce the fluctuation of the dc. That is in between v1, after v1 we shall put a circuit, the output of which shall be less fluctuating than v1. Such a circuit is known as a voltage regulator circuit. As you must have learnt, you must have seen in the domestic applications, the refrigerator does have a regulator, the tv, it is advisable to run from it from a regulator.

What basically it does is whatever the fluctuations in the power supply is, it could be an ac regulator or dc regulator. When 230 volts fluctuates and if i rectify this 230 volts and supplied to an electronic circuit, for example a public address system, we want the dc supply should not fluctuates. So fluctuating dc is required to be made as constant as possible. And one of the possible circuits is, this is what the problem is about. There is 1k resistor here called rs, rs could actually be internal impedance of the dc supply. And to reduce the fluctuation what we do is, we use a diode here, a battery of 10 volts and a resistance of 20 ohms, all right.

And then we have the load, let us say rl which is equal to 2 k, this is what is given. You are required to find out the variation in vl, that is delta vl if v1 increases from 16 volt 2, 16 volt to 24 volt which means a 50 percent rise, okay. A 50 percent increase in v1, what is the corresponding delta vl? You will see that the corresponding delta vl would be much less than 8 volts. And therefore in that sense the circuit acts as a voltage regulator. Let us see how to analyse this circuit. You see that this v1 is positive, then this diode always conduct, so let this current be i1 and let this current be i2, all right.

And then obviously we can write 2 kvl equations, one is that v1 is equal to 1000 i1 plus i2, all right, the drop across this, plus let us say, plus i2 times rl, well, rl is 2000. This is one of the equations around this loop and if you write around this loop, then we shall get 10+ i1 into 20, okay, should be equal to, this voltage drop, i am assuming diode to be ideal, so 10 volts plus -, then i1 times 20 should be equal to i2 times 2000, all right, from which you can eliminate i1. What you want is i2, you want to find out vl, you want to find out i2, i shall skip the algebra, if you do the algebra, that is eliminate i1 from this equation, then you can get i2 in terms of v1, right, you can get i2 in terms of v1 and therefore vl, vl is simply i2 times 2000 in terms of v1.

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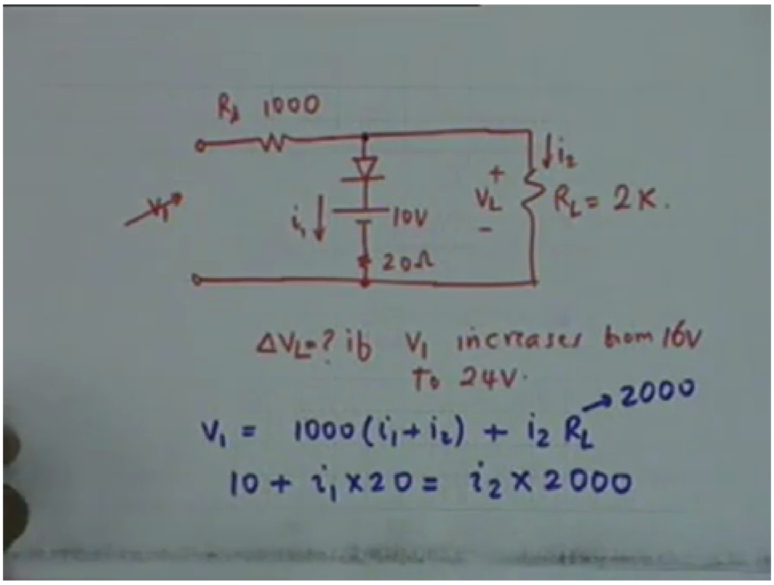

The relationship as i worked it out is vl equal to twice v1 +1000 divided by 103, which means that delta vl is equal to twice delta v1 divided by 103, all right. If i increment this by delta v1, then obviously delta vl should be equal to this. And therefore if delta v1, that is v1 increases from 16 to 24, then it is 2 times 8 divided by 103 and delta vl is 16 divided by 103 which is less than 0.16 volts. You see how things change, okay. So this circuit basically acts as a regulator. And there is an 8 volts location, 50 percent fluctuation. Now what is the percentage fluctuation? What is vl when v1 is equal to 16 volts?

You can calculate that out, we have the relation, vl is approximately equal to 10 volts. So 0.16 in 10 multiplied by 100, so much percentage approximately 1.6 percent. So 50 percent fluctuation in the input causes only 1.6 percent fluctuation in the output, which in effect then is a circuit for a voltage regulator. We shall, we shall consider other more sophisticated kinds of voltage regulators later in the course but i could not check the temptation of bring into your notice a circuit which is a useful circuit and which uses a diode. Yes, you had a question?

Student: Sir filter is essentially a type of voltage regulator, a filter circuit?

Professor: A filter circuit is not necessarily a regulator, a filter circuit basically improves the ripple content, that is a filter circuit makes a fluctuating quantity into a more or less constant quantity but if the supply changes, if the supply, suppose from 230 drops to 200, then the corresponding dc will also change. Given the constant, the supply is constant, the filter circuit improves the dc content, that is it rejects the ac, it makes the voltage more constant but it does not regulate. Yes?

Student: How do we get the confirm (())(18:11).

Professor: This is a specific circuit, we shall know, we shall describe the design of voltage regulator circuits later. This is a specific circuit, i just want to illustrate this with the help of an example. Yes?

Student: What is the use of the diode in the previous circuit? If there was no diode, you would still have the same result.

Professor: Yes, that is a good question. What is the use of the diode in this circuit? Yes?

Student: (())(18:49) if the fluctuation is such that the polarity changes, then the…

Professor: Then the diode will become effective, will become effective. There is another use for the diode. You see the 10 volts here, this is the use of the diode, the 10 volts here, it is not effective in sending a current through 100 ohms or 2k, is not that right? The 10 volts supply, till this voltage rises above 10 and this is the purpose of the diode. If the diode was not there, this equation would not have been valid. We have to take, we have to apply superposition, the effect of 10 would also you will have to apply. It is that this branch allows current only in this direction, that is actually current goes through the battery, the battery does not supply any current here, this is the purpose of the manner.

If the diode was not there, this voltage regulation actually would not have been there. You understand the purpose? This circuit is a unilateral circuit, it passes current only from top to bottom, not from bottom to top, as it would have been if the diode was not there. If the diode was not there, the battery would (())(20:10) 1000 as to 2000. Okay, any other question? Now let us consider some more wave shaping circuit.

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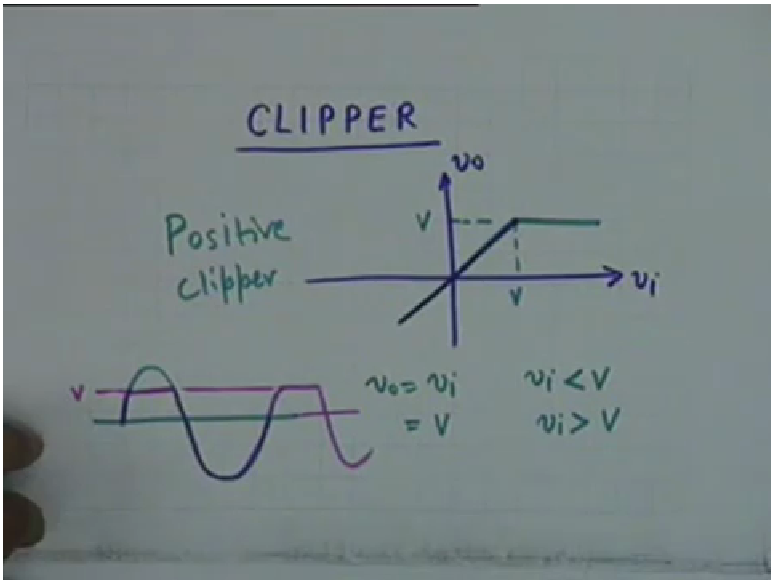

The 1st circuit that we consider is a clipper or a clipping circuit, a clipper circuit. The popular meaning of clipping is that have something long, you cut it off, you chop it off or you keep it off by means of the of the scissors, that is what a clipper circuit does. A clipper circuit is a circuit in which the output v0 versus vi is a straight line, is a straight line of let us say unity slope, it need not necessarily be unity but let us simplify this thing, of unity slope till the voltage, till the input voltage reaches let us say a positive value of capital v, beyond capital v the output is a constant, all right. In other words…

Student: Sir v0 is…

Professor: V0 is the output and vi is the input.

Student: (())(21:34).

Professor: Pardon me?

Student: (())(21:42).

Professor: V0 in the output voltage, v0 is equal to vi where vi is less than v, where v i is less than capital v. Okay, this is what we are worried about, okay, vi is less than v. If this is equal to v, when vi is greater than v, all right. This is the definition of a positive clipper, positive clipper. That is when vi goes more positive than capital v, then it simply chops off. For example, if you have a sine wave like this, if you have a sine wave like this as the input and this is the level let us say capital v, then the output of the circuit shall be simply, it will be chopped off, the peak will be clipped off and then negative half it will go like this, then again it will come like this might will be chopped off and so on. Is that clear?

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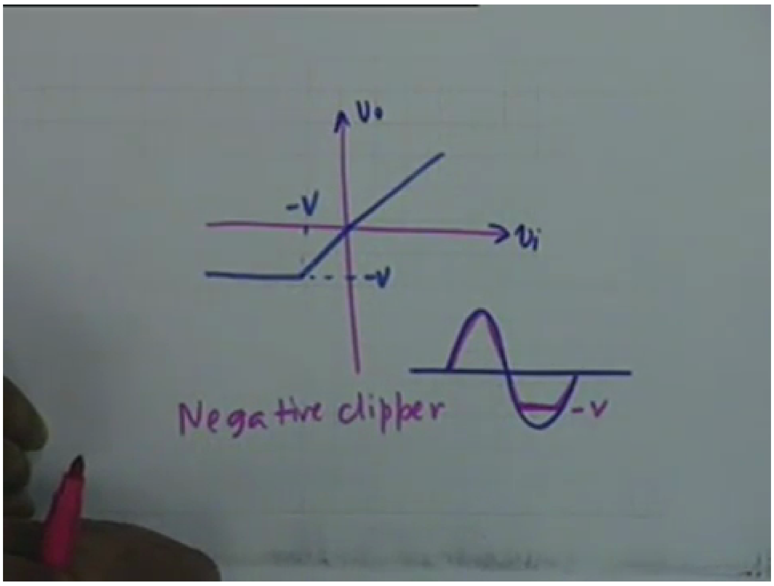

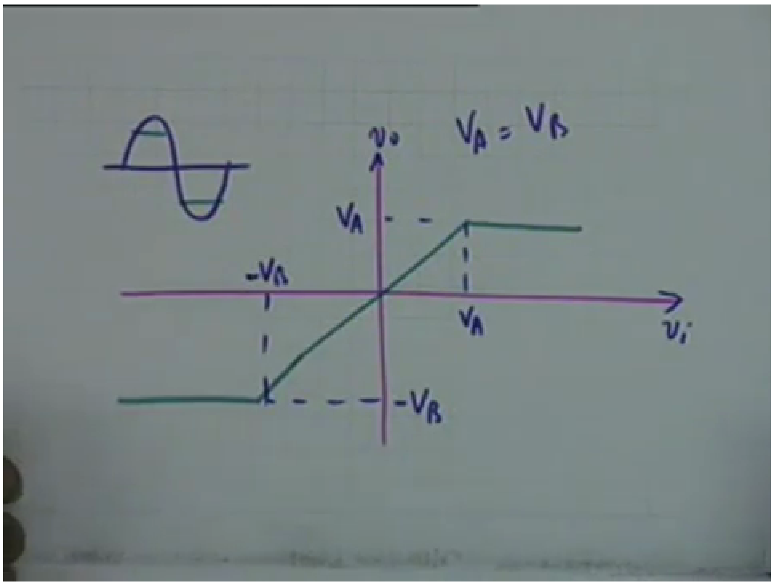

This is called as a positive clipper, the top of the waveform is clipped at capital v, it cannot go beyond capital v. On the other hand you could have negative clipper also, a negative clipper by definition is the one in which the output during the positive values is not effective but the output cannot go beyond let us say - v. This is a negative clipper, this is vi and this is v0. So that if you have a sine wave like this, as we have a sine wave like this and this level is let say - v, then the output of the circuit shall be this. Positive half is not affected, in the negative half it cannot go beyond - v, then it comes back. So this is a negative clipper.

If you want to shape the wave such that part of the positive portion is clipped off and part of the negative portion is also clipped off, then obviously the characteristic shall be like this. Maybe it clips off at this level and perhaps it clips off at this level where this could be va let say and this could be - vb. So when, this is v0 and this vi, when v, v i is between va and - vb, when the input voltage lies within this range, the output is exactly equal to the input. When the input exceeds va, the output saturates at va or clips off at va.

When the input price to go below - vb, the output saturates at - vb. So this is a positive as well as negative clipper. So it is a clipper for both halves, positive as well as negative half. If va is equal to vb, then it is called a symmetric clipper. That is if va is equal to vb, then the chopping of shall be symmetrically done, all right. On the other hand if va is not equal to vb, it is called an asymmetric clipper. A clipper circuit has many many applications as we shall see later. And the circuit implementation of a clipper circuit will do for the most general circuits, for the most general clipping that is in a symmetric on both sides, then you can specialise it to any particular positive clipping or negative clippings.

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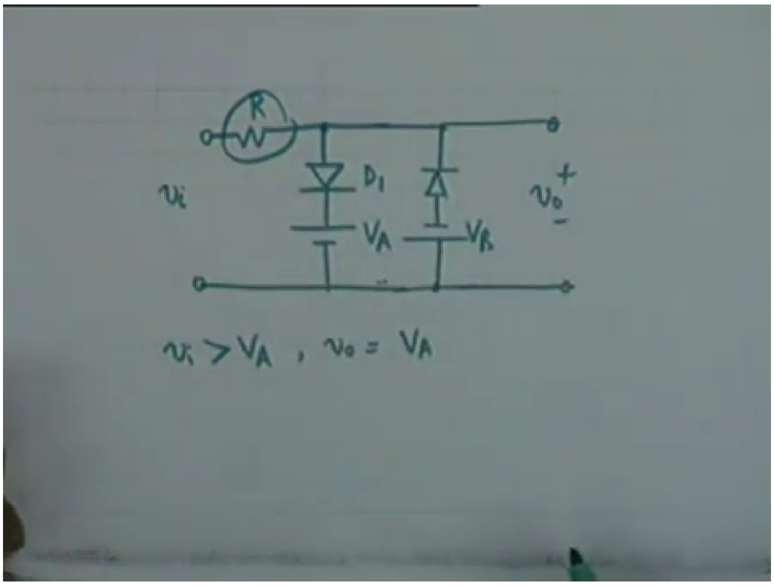

And the circuit is simply like this, that you have an input vi that is to be clipped, in the positive as well as negative half, so what you do is include a resistance r, then you have a diode and a battery va, a diode d1 and a battery va, this ensures that the voltage across this cannot exceed plus va, is not that right? Whenever the diode conducts, it acts as a short-circuit and therefore the output saturates off, levels off at va. On the other hand if you want to level off at - vb, all that love to do is to reverse the polarity of the diode and the polarity of the batteries, v sub b.

This ensures, this path ensures that the output voltage cannot go below - vb. When this diode conducts, the voltage across these 2 points shall be - vb. And therefore you can now specialise this to a positive clipper, negative clipper, symmetric clipper or asymmetric clipper. For example if this branch is not there, then it is simply a positive clipper. If this branch is not there, then it is simply a negative clipper, if both are there and va is not equal to vb, then it is asymmetric clipper, if both are there and va is equal to vb, then it is a symmetric clipper. Let us take an example. Suppose, suppose we consider the positive clipping, all right.

That is vi, suppose vi exceeds va, then you know v0 remains at va, i am gurdwara, i am going to explain a little bit about the function of r, why is r there, okay. If vi exceeds va, then v0 is equal to va. So what happens to the reference vi - v0? Obviously that has to be dropped somewhere and that is how this resistance is essential, right. And the value of this resistance is determined by how much current you require, right. If you need a large current, if you need a large current, obviously this resistance has to be small because this determine the current, all right. Okay.

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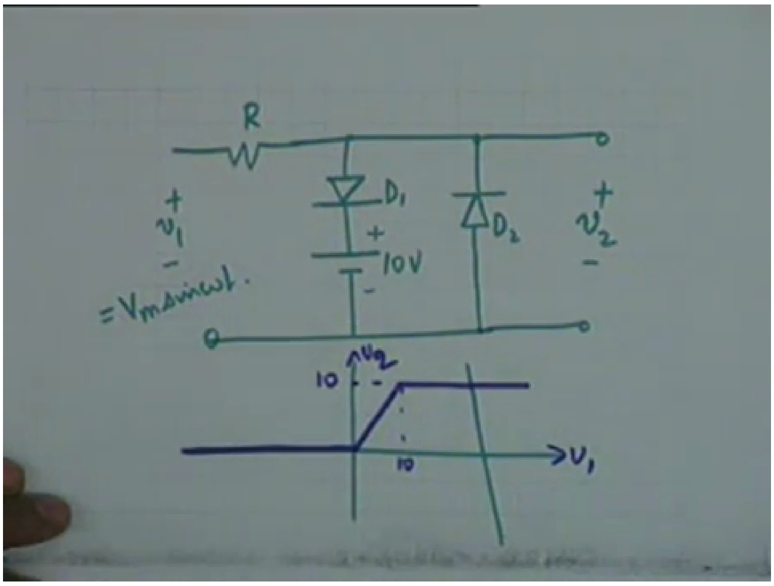

Let us take an example, this example is a resistance r, a diode is a + 10 volt, d1 10 volt plus - and in the other branch the battery is absent, no battery, this is d2 and we wish to find out v2 when v1 is a sinusoid, v1 is a sinusoid vm sin omega t, all right. You see the characteristic of this circuit is vb equal to 0 and therefore the characteristic is simply, simply this, forget about this line. It is like this, where this voltage is 10, this is 10 and in the negative half it is simply the negative axis. So this is v0, this is v0 and this is v1, is that okay?

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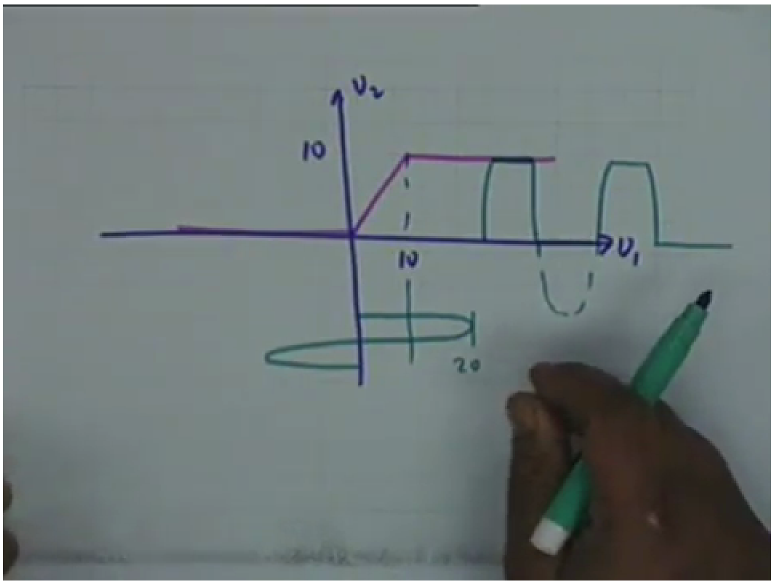

Now suppose i supply, let me draw it again. My characteristic is like this, this is 10 and this is 10, suppose i apply a sinusoid at the input. I must mark my v1 and v 2, suppose v1 is a sinusoid going like this whose peak value is greater than 10, then what shall i have at the output? What am i plotting here, i am plotting v1 versus omega t, okay. This axis is omega t, then at the output what i shall observe is it will go like this, level off at 10, come back and then, and then remains 0. Then again it will go up, level off, come back and go to 0, is that clear? The negative halves are chopped off totally, the positive halves are chopped off at 10.

If this voltage, if this peak value was at 20, then at the middle quantitative chopped off, all right, this is the waveform. Now you can calculate its average value, effective value and so on and so forth. This is about clipper circuits, the next we consider clamping circuits.

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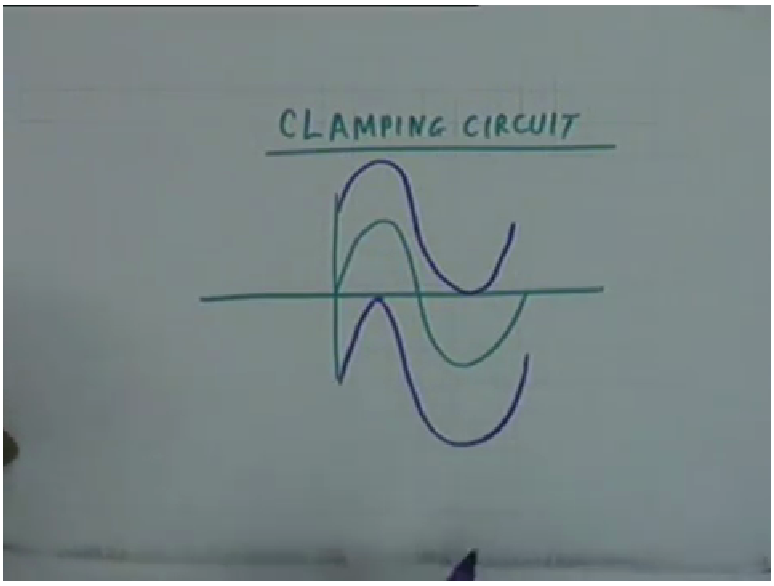

Clamping circuit, okay. A clamping circuit is a dc, is alternatively can be alternatively looked upon as a dc shifting circuit or average level shifting circuit. For example you have an, you have a sinusoid like this, suppose i want to shift this sinusoid up so that the minimum value is 0. Then obviously my sinusoid would be like this, okay. These i want to shift it up, i could also shift it down, such that the peak value is 0, okay, maximum could be 0. Do you understand what i am doing, so what i am doing is and simply adding a dc, adding a dc either positive or negative so that the waveform is either shifted up or down.

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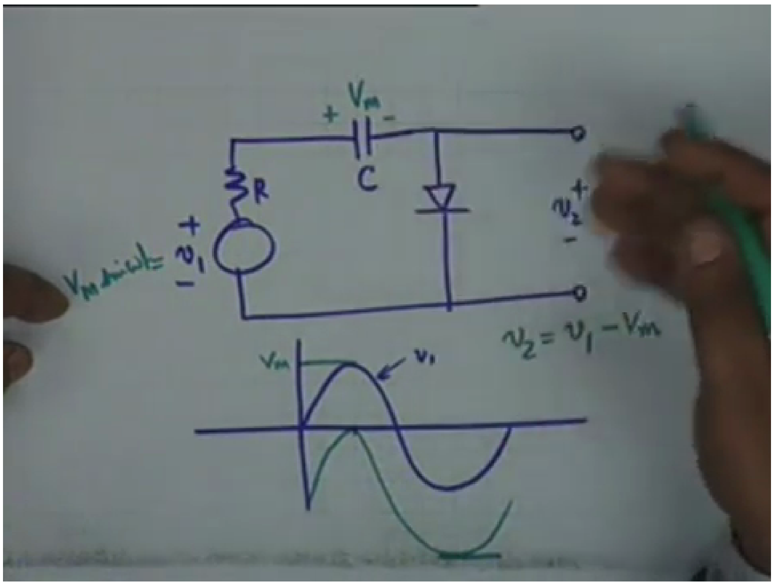

The circuit which performs this job is called the clamping circuit. Let us take a few examples and a clamping circuit also is an application of this simple diode. Suppose we take an example like this, i have v1, in resistance r, then i have a capacitor c, all right, i have capacitor c and a diode across this. Now what do you think, if this is v2, this is a sinusoid, okay, sinusoid or any other waveform, i do not really care, let us say it is sinusoid like this, all right. Then what do you think, what do you think would be the maximum positive value of v2? When the diode conducts, when the diode conducts the voltage across this is 0 and therefore what will happen is this voltage, this waveform of v1 shall go down, such that the maximum positive value is 0.

Now why does it go, suppose v1 equal to vm sin omega t, let us look at the action of the circuit. What happens is during the positive half, during the positive half c charges, all right, c charges to what voltage?

Student: Vm.

Professor: Vm, with this polarity, plus -. Agreed? When v goes, v1 goes negative, then the circuit does not conduct and therefore c remains at vm, c remains that the peak value, all right. It is very important that you understand this simple circuit. And you see by kcl, by kvl that v2 is nothing but v1 - vm, is not that right? V2 is equal to v1 - vm, right. So when, during the positive half, well if this is v1 and you subtract vm from it. This is vm, what happens, this, the waveform goes orderly down, so that the maximum value is vm, maximum value is 0, is that clear?

Student: Could you repeat this once again, explaining?

Professor: By kvl v2…

Student: (())(36:12).

Professor: Pardon?

Student: The earlier part sir for the capacitor.

Professor: Okay the capacitor, during the positive cycle the capacitor charges, it charges to the peak value. And this voltage goes down, the diode does not conduct anymore, so the capacitor does not get a path to discharge and therefore it remains at vm irrespective of what goes on in the external world. And by kvl v2 is this voltage v1, no current in the circuit - vm and therefore what happens is v1, this waveform comes bodily down by vm, in other words its maximum value now becomes 0 and the minimum value becomes -2 vm, that is all. There is no distortion in the waveform, waveform does not get clipped, there is no distortion, all that happens is it goes bodily down. Now if this diode was reversed, then obviously what we would do is the minimum would be lifted to 0, the minimum would be lifted to 0, the maximum would go to twice vm, right. Now suppose you say, yah?

Student: In both the positive and the negative cycles, the diode would not conduct or would it conduct in the positive cycle?

Professor: Well it would, in the 1st cycle. In the very 1st cycle the diode would conduct, then it will remain at vm, right, it will not budge, let us put it that way. It will only budge if you connect a load here, then the capacitor gets its path to discharge, all right.

Student: Can it be replaced by constant voltage source which is equal to vm?

Professor: Can it be replaced by a constant voltage source which is equal to vm?

Student: Then we will not be able to design the (())(38:07).

Professor: Which one, which one is a constant voltage source, v2?

Student: In place of c?

Professor: In place of c cannot be replaced by a battery, battery equal to vm…?

Student: This is a series connection of (())(38:24).

Professor: But why would you like to replace a capacitor by a battery?

Student: Is not it equivalent i am asking.

Professor: Oh, is not it, yes, it is equivalent, yes, because this is constant, yes. That is quite correct, but as a practical engineer you will not do that because battery is much more costly affair than a capacitor, also it has to be maintained, a battery requires maintenance, all right. What you can do by a passive element, you will not use an active element for that purpose. Now the question is does it have to be clamped at 0? Does it maximum, can i clamp the maximum at let us +5 volts or can i clamp the minimum at -5 volts? All that i have to do is to add a battery, now you have to add a battery to the diode, all right.

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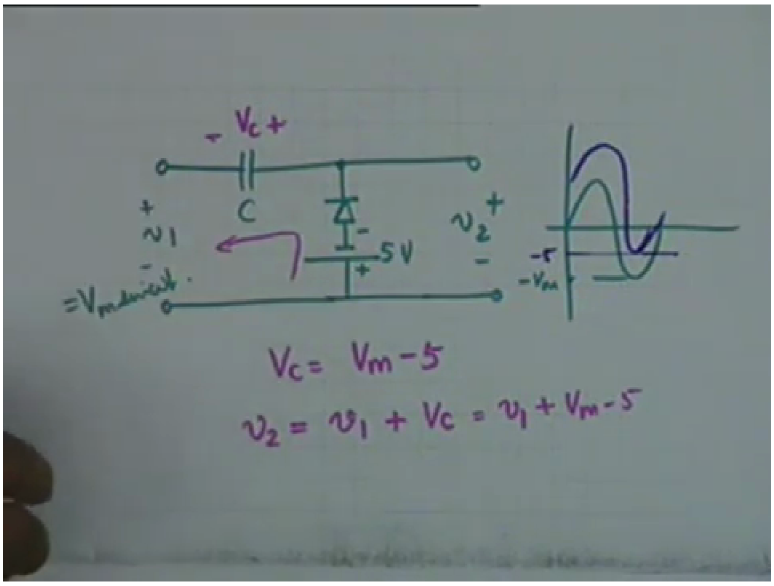

And look at this circuit, let us take a specific circuit. Let us say v1, now i am omitting that internal resistance and so on because it is only the voltage that we are concerned with. There is a capacitor and suppose i have circuit like this, maybe (())(39:33) experience the diode is in the other direction and we have a negative battery here, let us say 5 volts - plus. This is my v2, now what is the relation between v1 and v2 ? V1 is again vm sin omega t. Let us look at the working of this circuit. Obviously, obviously when v1 is positive, then in the positive half cycle the diode does not conduct.

And therefore there is no current through c1. When v1 is negative, then in the negative half cycle this diode conducts and the current flows like this. And therefore there is a voltage v sub c developed across c which is of this polarity - plus, is that okay, is that okay? Now what is the value of vc?

Student: Vm - (())(40:40).

Professor: Vm, vc would be v minimum, vm, okay, v -5. Because vc +5 should be equal to vm, is that okay. Now what is v2, v2 is equal to v1, v1 plus vc, why plus vc, - plus, - plus. Vm plus vc, that is equal to v1 plus vm -5. All right, is that clear? Now if you draw the waveforms now, this is the original waveform where this is - vm. Now where would this, how would this be, would this be raised or lowered?

Student: (())(41:35).

Professor: It would be raised by, from - vm it would be raised by, yes, 5 volts. It would be clamped at what? The negative be would be clamped at -5 volts. Do not you see the battery is across the output, so if - -5 is this level, then all that will happen is this voltage will go up and this will go up, i do not know, you can draw it, is that clear?

Student: Yes.

Professor: So your clamping can be at any level. Yes?

Student: Sir is it not possible to do this operation without having a battery but by controlling the value of capacitance?

Professor: No, if the battery was not there then clamping would be at 0.

Student: Sir is it necessary that during one half cycle the capacitor gets charged to vm?

Professor: Not the capacitor, the total voltage across this cannot exceed vm and therefore vc +5 volts should be equal to vm.

Student: (())(42:47).

Professor: Pardon me?

Student: Maybe less than that.

Professor: Why? It cannot be less than that because the capacitor will charge till the diode conducts. When the diode will conduct to a value such that the voltage across the capacitor plus the battery voltage is equal to the - negative maximum.

Student: But it may be possible that it takes several (())(43:09).

Professor: In practical case yes it is everything is ideal, then one cycle is good enough because the voltage will go up to -5, - vm and the whole thing will go up to - vm, the capacitor will charge and then the capacitor will refuse to budge, it will remain at - vc, whatever the voltage is. Is that okay? So this is an example of negative clamping at an is arbitrarily set levels, - 5 volt. Similarly you could get positive clamping at let us say +2. Is it possible to get clamping at both levels, both positive and negative clamping? Obviously not because it is simply it is a dc level shift, there is no distortion in the waveform.

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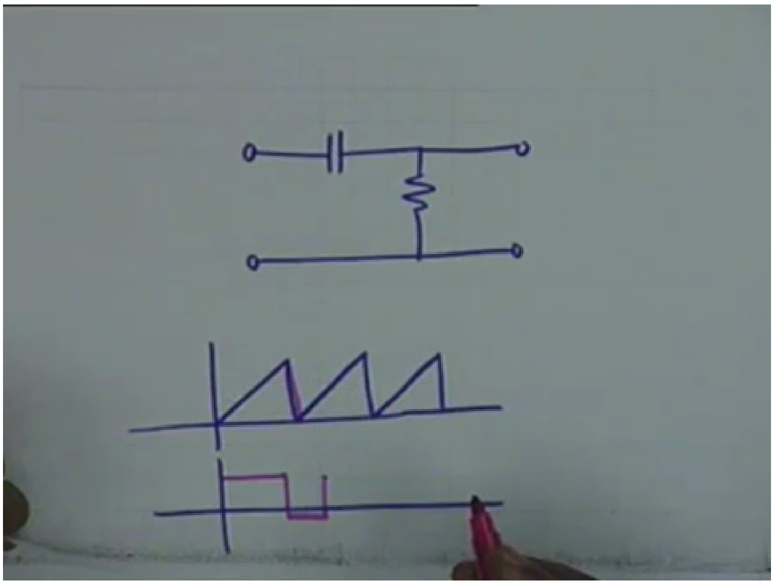

So if you raise it you raise it, you can raise and simultaneously lower it, then effectively will be lowered, all right. Okay. We next consider a circuit which we might have encountered early, a differential shaping circuit. Differential shaping circuit is also a wave shipping circuit. That is whatever the wave is given, it is differentiated and the wave shape is changed. If we differentiate a sine wave, what is the shape of a resulting wave?

Student: Cos wave.

Professor: Cosine. Does the waveform change? No, there is only a phase shift, that is not the case of the waveform is non-sinusoidal. For example if the waveform is like this, a sawtooth, have i introduced a sawtooth?

Student: Yes.

Professor: Yes. If the waveform is like this, then what would be its differentiated waveform? It would be a constant up to this, then 0, hold it…

Student: Infinite (())(45:24). Derivative is not there.

Professor: Derivative is not defined, you will get an impulse function. Have you heard of impulse function? No, we will come to it later. Let us say for the time being that it is not, it does not drop instantaneously, let us say it drops with a slight slope, all right. What happens is that from here it goes negative over a certain range, then again it goes positive and so on.

Student: It will not be negative. It would be negative.

Professor: Why not?

Student: It will be for a very short interval for which…(())(45:57).

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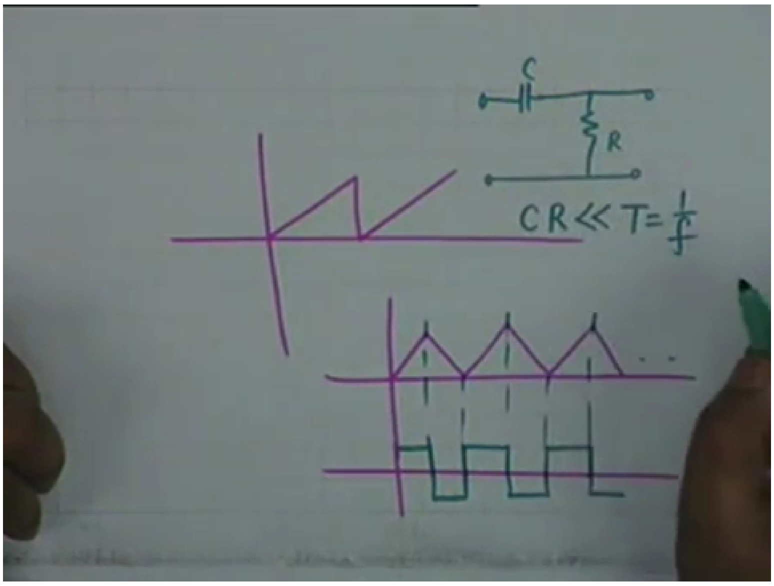

Professor: Yes, my figure unfortunately has got distorted. So let us, okay, let us make it triangular, let us make a triangle, okay. Then obviously its differentiated waveform shall be like this. Over this portion it will be positive then it would be negative, then positive, then negative and so on. So you see for a triangular wave we have produced a rectangular wave, from a triangular wave by differentiating we have produced a wave, this is indeed wave shaping. And this is performed by the simple circuit that is a capacitor in series with a resistor where the capacitor value and the resistor value are so chosen that cr product is much less than, cr, what is the unit?

Student: (())(47:15). Time constant.

Professor: Time, it is much less than the time period of the periodic wave which you want to differentiate, this is equal to 1 over f, all right. Under this condition what happens is the following.

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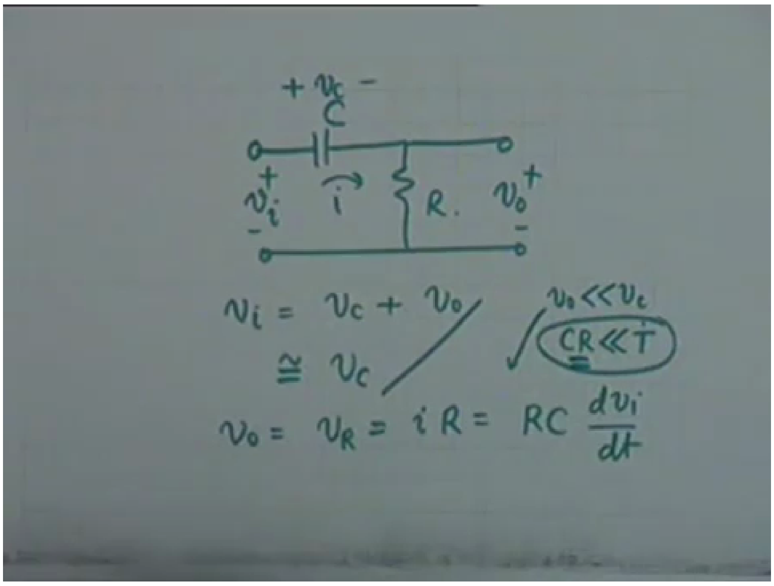

You write c and then r, let say this is vi and this is v0, let say this is v sub c, then this is vi is equal to v sub c plus v0 by kvl and this v0 is much less than vc which will be satisfied if the condition cr is much less than capital t, all right. Then this is approximately equal to v sub c, all right and therefore v0 which is equal to vr is given by i times r, i is the current in the circuit and i is nothing but c d vi by dt, all right. And therefore the output voltage is proportional to the differential coefficient of the input voltage. And this is why it is called a differentiating circuit. This is slightly hazy as to why this is needed, you should remember that the price that you pay for a good differentiator is to have an output voltage which is very small.

If you want to increase the output voltage by increasing r, then the quality of differentiation also falls down because of this approximation that vc is much greater than v 0. And this will be satisfied if cr is much less than t, in essence it means that this current, this current is approximately held, physically what it means is this current is approximately held as a, at a constant value. When will this so happen? It will happen that irrespective of, irrespective of positive or negative polarity of vi, c gets very little time to discharge through r and this is what this means, cr is much greater than t.

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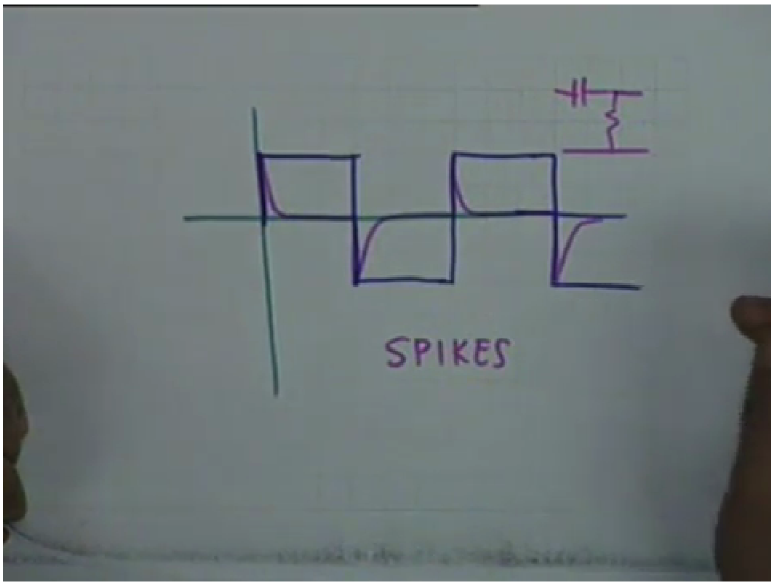

Okay, let us take an example, let us suppose that we have, we have a square wave like this, well, let us suppose it is a perfect square wave. What you expect is, what you expect is, in the practical circuit, if i have c and then r like this, in an ideal circuit d dt is infinity, d dt here is - infinity, all right. In a practical circuit what happens is the capacitor charges, all right, the capacitor charges almost instantaneously if r is very small, in other words the cr product is very small. The capacitor charges almost instantaneously like this, then, then the voltage becomes a constant, the capacitor, input becomes a constant, the capacitor tries to discharge.

It discharges to 0, when it comes here the capacitor charges in the other direction, other direction, almost instantaneously and then it discharges like this and so on. This is what we shall observe if you feed a rectangular periodic pulse at the input. These are pulses of large height and very small width and therefore they are called spikes. We shall get the spike like waveform, this you can vary easily observed in the laboratory by taking a capacitor and a small resistor from the laboratory assistant, simply wire it up like this, take a pulse generator which produces rectangular pulses, feed the input and see what happens at the at the output.

You observe the output in an oscilloscope, i believe this is one of the experiments in 110m. We shall consider next time tomorrow integrating circuit and their implementation by op-amps, differentiating as well as integrating circuits.