Electrical Measurement and Electronic Instruments
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Lecture - 74
Instruments with op-amp based amplifiers – III

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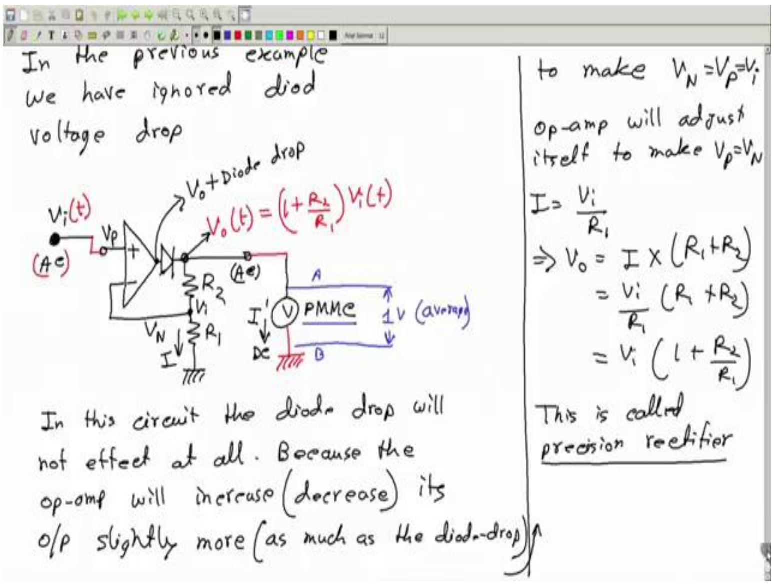

Hello and welcome. So, we are studying how to use op-amp based amplifiers to make different types of volt meters, electronic voltmeter circuits ok. And, all these were analog electronic volt meters not digital. So, the last example that we took it was of a precision rectifier. So, the beauty or specialty of this circuit is how we put this diode or rectifier in this circuit? Ok.

Instead of putting it here, if we had put it out here, then there will be some voltage drop across the diode, which will cause some inaccuracy or we have to take that into the calculation, but we if we put it here the op-amp itself takes care of these voltage drop. Whatever the voltage drop across the diode is the op-amp will increase it is output by the same amount more. So, that you know this diode voltage drop does not come into effect at all ok.

So, that is what was the beauty or speciality of precision rectifier was. And, in this way so, we have taken different examples for AC circuit DC circuits. So, this was AC half wave rectifier, previously while discussing DC circuits we have talked about you know voltage to current converter at and a lot of different things. So, let me just take another example today.

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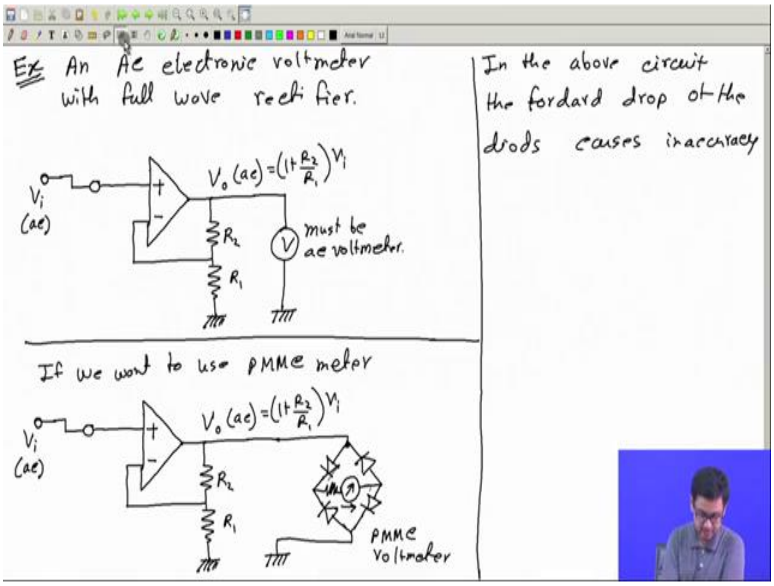

Another new circuit; so, the point I want to stress on highlight is that these circuits which we are drawing are not exhaustive sets or not all that one can do with this ok. So, if you think, if you invest some time you will come up with new circuits, a newer idea on your own and you will enjoy the subject, I guess.

So, let us take circuit an ac voltmeter, ac electronic voltmeter with full wave rectifier ok. So, what can we do? Let us take some simple idea and then we will refine it ok. So, we have a voltage unknown voltage to measure call it V i and then we assume this is small. So, we will amplify it to amplify it, we can take inverting or non-inverting amplifier, let us take a non-inverting amplifier ok. So, I am taking an amplifier non-inverting.

So, I give a negative feedback. So, a fraction of the output goes to the minus terminal, this is the input of the amplifier. So, I can connect the input voltage to the amplifier input, this is the output of the amplifier V o, this is grounded ok. So, this is the output voltage and if this is ac definitely then this is also ac and if this is R 2 this is R 1, then you know that this is given by Vi $(1 + \frac{R2}{R1})$, but this is ac and now we can measure it using a ac voltmeter.

So, this has to be a ac voltmeter simplest solution. So, this must be ac voltmeter like electro dynamic ok. And, we cannot use PMMC here, but if we want to use a PMMC instrument, because we know PMMC instruments are often higher more sensitive, than this electro dynamic and this scale is also linear. So, if I want to now use if we want to use PMMC meter, then what we can do is this ok.

So, we if it is a PMC meter then we cannot connect directly like this, because this is ac voltage. So, what we can do we can take our rectifier and we would like to take a full wave rectifier ok. So, what we can do is this. So, if let us first draw a full wave rectifier, the bridge I will draw a fast ok. So, this will be the input of the bridge. So, I would say like to have the current like this, in this direction. So, I will put the rectifier the diode in this way, then here I shall put my meter ok.

And, here I shall have the other diode. So, you see and the positive half the current will go like this. And, in the negative half when this side is at higher potential then the current will go like this. So, this is my meter and this is a PMMC meter, PMMC voltmeter ok. Fine we can use this circuit, because now you see the voltage here is a c, but the current that flows and it is d c, it is full wave rectified in 1 cycle it goes like this and in another cycle it also goes like this.

So, through the meter current always flow from left right ok. And, we can control the range of the meter with a suitable series resistance. If, you want to change the range of the meter, you can add it here. In theory you could add this resistance also here in this circuit, because it will finally, come into series with the meter.

But, now you observe the small problem in this circuit once again is that, the voltage drop across diodes should be taken care into the calculation ok. Otherwise, there will be some drop here, if we ignore that the ended reading actually that we will get across the meter will be less than what is here? So, we will have some error.

So, in this circuit in the above means this one above circuit the full diode the forward voltage drop forward drop of the diodes causes inaccuracy, if we do not take care into the calculation. So, now, what we can do? Ok. So, we will modify it, we will modify this circuit and try to make a circuit so, that this diode drop does not affect. So, let us try to make a modification.

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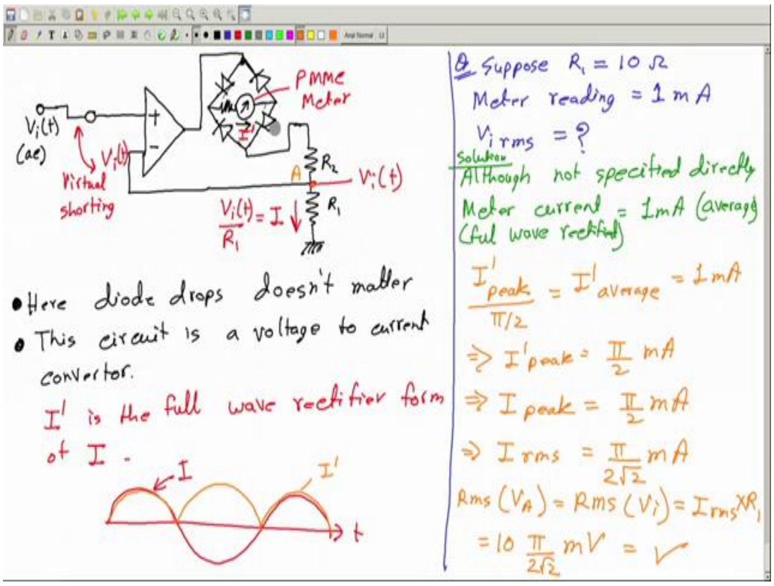

The idea is essentially to put this part, I mean somewhere here ok. So, what I will do, let me take this rectifier bridge with the meter and see let me first keep it away, then I will make some space ok. And, then I this is connected, then I will put this actually here. So, I open this part I bring it here and I wish I could rotate this, but I cannot rotate it. So, I connect it like this ok.

So, you see the current will flow like this in the positive half through the meter from left to right and will go like this. In the negative half current will go from here, again left to right through the meter and like this and will enter this ok. So, this is a full wave rectifier circuit because current through the meter is always from left to right both in the positive cycle and in the negative cycle. So, here the diode drops does not matter. So, this is very important to note ok.

And, you also observe that this is actually a voltage to current converter. So, this circuit is a voltage to current converter, why? So, you observe this is at voltage V i input due to virtual shorting principle this potential will also be V i, this is time varying call it t, this is also t. So, at any and every moment ideally this point will be at the same potential as this ok. This is due to virtual shorting. And, so, here I can write this is this point is at V i t right.

If, this is at V i t then this current I I can be written as this is same as V i / R 1 right. So, this is this current and the same current must flow through this, which means it will eventually flow through this meter and definitely this is a PMMC meter ok. So, this current

I is the same current which flows through the meter I.. The only difference is that here this is purely a c, but this is half wave rectified ok. So, let me call it I I prime ok, I prime is the half wave rectified first and our form of I ok. I is ac I is so, if this is I, then I prime is definitely this is I prime ok.

Now, can we take a numerical example on this ok? Let us take a numerical example for practice question. Suppose, let us take R 1 = R 2 or ok, let us take R 1 = 10 ohm. And, meter reading is equal to 1 milliampere, then V i r m s is equal to how much? So, this is the question ok. So, we have the circuit and circuit parameters are given ok. R 1 value is given R 2 value is not given, but we shall see R 2 is not required and so, the reading of the meter is given how much is the input voltage ok.

So, I mean that is how we should use our voltmeter right. We observe the reading of the meter and from that we have to specify the input voltage or we have to estimate the input voltage. So, we know 1 milliampere current is flowing through this. Even, it is not specified explicitly this 1 milliampere is average current ok, because this is a PMMC meter and PMMC meter so, only the average value ok.

So, although solution although not specified directly or explicitly meter current is 1 milliampere average ok, meter current which is full wave oh sorry I made a mistake this is full wave, meter current which is full wave rectified is 1 milliampere on an average ok. So, this current, this current the average of I prime is 1 milliampere ok. So, what can you say about the peak.

$\frac{I'peak}{\pi/2}$ =I'avg = 1 ms

I'peak =$\pi/2$ mA

Ipeak = $\pi/2$ mA

Irms= $\pi/2\sqrt{2}$ mA

Rms(VA) = rms(Vi)= Irms x R1

this is how you can do it? So, this is a full wave rectified voltage to current converter. And, this way we can measure the unknown voltage by observing did heating of this meter.

So, I guess, I have talked enough about voltage measurement. I will now talk about current measurement with op-amp based amplifier circuits ok.

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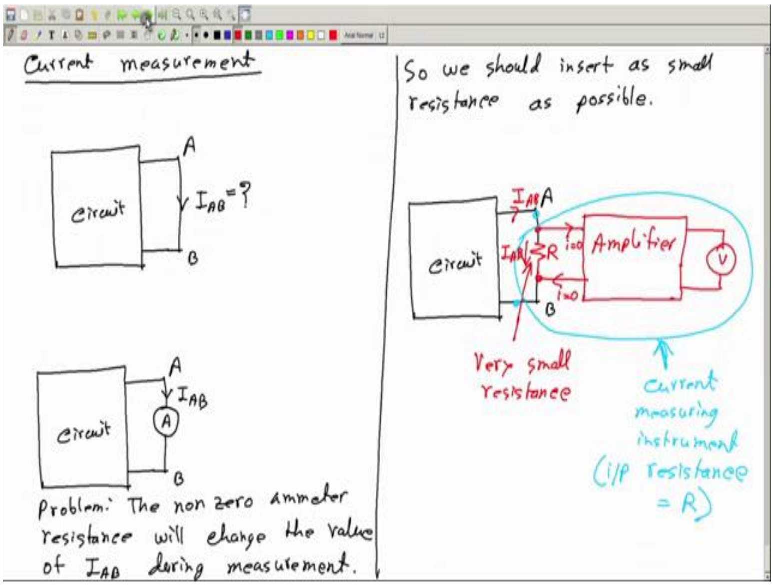

So, now let us talk about current measurement. Suppose, I have a network or a circuit a complicated circuit and one of it is branch is A B. And, through which the current I AB is flowing ok. And, I want to know how much is I AB; I want to measure this current. Now, the useful way we measure it is by inserting an ammeter in the circuit. So, let me insert an ammeter.

Now, this ammeter can tell me the value of I AB, but there is a problem. The problem is that, the ammeter has some internal resistance and the moment you insert these internal resistances in this circuit, in this branch where no resistance was there. So, the resistance is increased. So, the fidelity current can change, the current can decrease right ok. And, the more the internal resistance of the ammeter is the current will decrease more.

So, therefore, the value that we will actually measure will not be same as the current, which was there in the absence of the meter. So, the problem is the non-zero meter resistance ammeter resistance will change the value of I AB during measurement. So, if I want to measure it I insert the ammeter, but then the current changes. So, how can we get rid of this problem the only solution is the resistance of this meter should be as small as possible.

So, we should insert as small resistance as possible, but you know, if it is a PMMC meter or any electromechanical meter, it is made up of a coil and the coil has some resistance. If, you want to decrease the resistance then you either have to make very big thick coil, I am at thick you have to take thick conductor and the meter will be big in size, huge in size costly not which is not feasible.

And, else if you reduce the number of turns of the meter, then also the resistance will be small, but then the sensitivity of the meter will be very low. So, what we shall do is this. We shall insert a small resistance so, a very small resistance as small as possible and then we shall measure the voltage across this resistance by amplifying it. So, we shall take an amplifier and here we shall have a voltmeter.

So, you see this is a very small resistance, very small resistance as small as feasible considering other factors of the order of maybe 1 ohm 2 ohm several ohms, but if we you know if we take a small resistance, then the voltage drop across it will also be small. Particularly if the current that you are measuring is small, then this voltage drop will also be small. And, therefore, to measure it successfully accurately we must amplify it so, but this is the scheme right.

So, this is the scheme and you see the this is my so, this is the measuring instrument, current measuring instrument, which is made up of all these things together. Instead of just one ammeter we have all these things together, but the input impedance ok, if I just call this resistance as R, the input impedance of this meter or instrument ok, which is made up of all these things together. So, input resistance is how much can you guess this is nothing, but R why? Because, input resistance is nothing, but the ratio of the voltage between these two points ok.

So, these are the input terminals, which is same as these two. So, this voltage divided by this current should be the input impedance. And, you can assume that an ideal amplifier should have these currents here equal to 0 or negligible ok.

An ideal ampere should not take any current or much current so, this current is negligible. So, this current if you call it I AB, it flows almost through this resistance R so, this is also I AB, it flows through this resistance R. It does not go to the amplifier, that is the beauty of an amplifier, that is one of the necessary property of an amplifier, that it should not take any current, it should not draw any current or draw minimum possible current.

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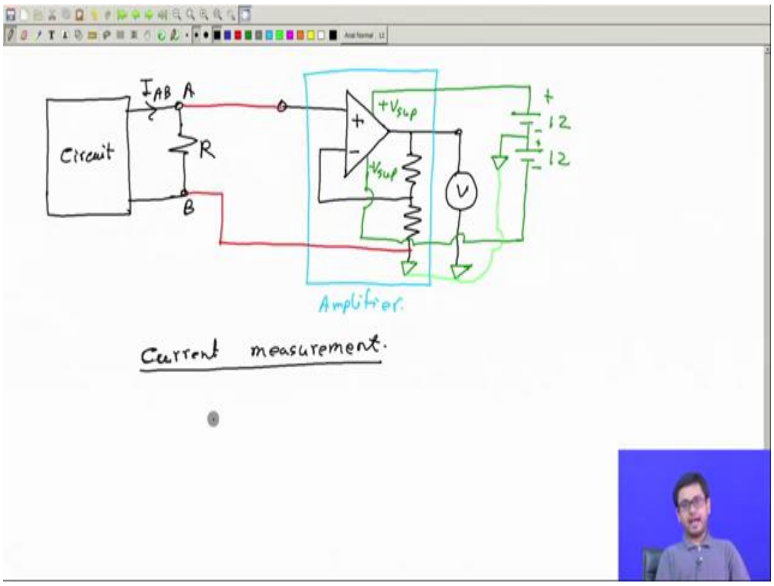

So, now, let us draw maybe a circuit so, we shall draw op-amp based circuit. So, this is the circuit that we want to measure or probe. So, this current, which flows through this branch A B call it I AB, we want to measure the value of I AB. And, here we have a small resistance inserted call it R.

Now, this is one part of the circuit, another part will have the amplifier. So, let me draw an amplifier, whichever amplifier you like ok. I shall take a non-inverting amplifier; I like that. So, this is a non-inverting amplifier. And, I suppose we want to measure the output voltage. So, we put a voltmeter here right. So, this is a non-inverting amplifier. So, this is the voltmeter. So, this is the input of the amplifier, amplifier this is of course, the voltmeter this is this circuit, this is a small resistance.

Now, there is a big question, how do I connect it? Because, you see I want to measure the voltage between these two terminals A and B and my ammeter as I have drawn has only 1 input. So, do you can you guess how should I measure the this voltage. Basically, this amplifier measures the voltage applied at this point with respect to the ground. So, what I have to do? I can connect one of the terminals to the ground and, the other terminal here ok. So, as you mean there is no other connection between this circuit and this circuit, otherwise you know we may short circuit some something ok. So, assuming so, assuming that there is no other connection, between this part of the circuit and this circuit other than only these two red lines ok.

So, this is the way to measure it and if you want bit more detail I shall put it say how to connect, the power supply of this amplifier. So, say I have a plus minus 12 volt power supply ok, then this is this is the reference point ground later, I shall draw it this way to indicate that this is just a reference point. And, this is possibly not connected to connected physically to earth ok. We do not have to connect this to physical physically to earth ok. And, so, this power supply goes here this is V supply plus V supply and minus V supply ok.

So, essentially this is the reference point, which is it actually means this point this point and this point are actually connected. If, I put same symbol in 3 parts of a of a circuit; that means, these are actually connected. So, you can think that not think it is really that these are actually connected and this point is connected to this ok. So, this is current measuring circuit great. Now so, we said oh I think we have enough examples, if you need more examples if you ask for more examples, please go through the text books suggested.

If, you need any help ask us in the forum we shall we will be happy to make more videos on this and share with you if you want if you need. And, so, we shall stop this topic here in our next class we shall take up a new topic, which is instrumentation amplifier. What is instrumentation amplifier? That is again an amplifier made up of op-amp, but not one on one op-amp that is made up of several op-amps 3 op-amps maybe. And, we shall see how that offers simultaneously more gain than one op-amp can offer and also very high input impedance ok.

And, then once you learn that a circuit that instrumentation amplifier circuit in principle all the circuits that we have studied in this chapter, you may modify these circuits in this chapter and replace this single op-amp based amplifiers with the instrumentation amplifier in principle ok. You may have to do some tricks for that, I request you think how to do that.

Thank you.