Electrical Measurement And Electronic Instruments
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Lecture – 83
Linear ohmmeter

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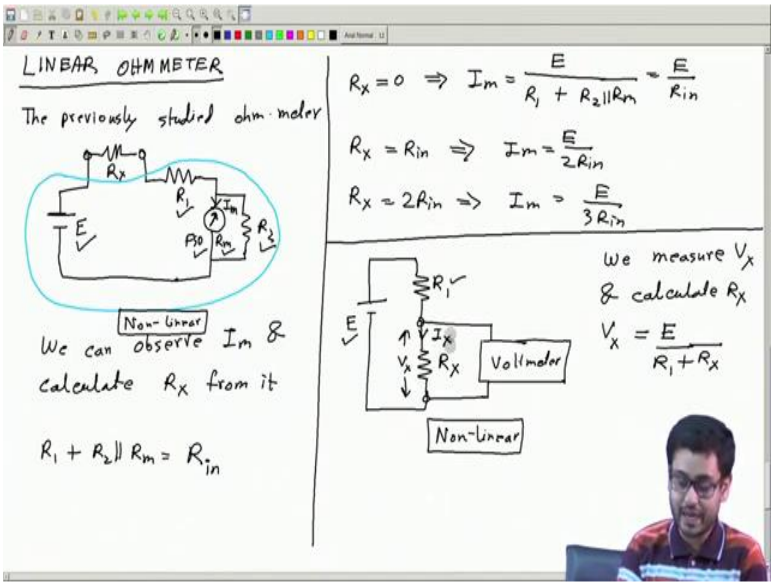

Hello and welcome. We are studying transistor level implementations of some instrumentations circuits; like, previously we have seen transistor level implementation of a voltmeter circuit, practical ammeter follower circuit. Let us talk about few more transistor level circuits which could be interesting ok. So, the one that we are talking about now is a Linear Ohmmeter. Before coming to that let me just briefly talk about a normal; that means, non-linear ohmmeter.

So, the previously we studied ohmmeter which we have studied it looks like this; it has a battery then in series with that we have a meter and some resistance we can have a bypass resistance also shunt R 2 and here we can connect the external resistance R X ok. So, this is the external resistance and this is the meter circuit. Now, you know that if I know the value of this E if it is known, if R 1 is known, if R 2 is known, if the R m meter resistance is known, full scale deflection current that is known, if everything is known then we can see the current Im then we can observe I m and calculate R X from it; so, a quick recapitulation of this.

Rx = 0 Im = $\frac{E}{R1+R2||Rm} = \frac{E}{Rin}$

Rx= Rin Im = $\frac{E}{2\ Rin}$

Rx = 2 Rin Im = $\frac{E}{3\ Rin}$

So, the relationship between R X and I is not linear. So, here it is increasing linearly 0, 1R in, 2R in, but the current you see this is if you call this is 1 unit, then this is half unit, this is one-third unit so, it is not linear.

One can think of similar other there are a lot of similar voltmeter circuits ok. So, one possible circuit is this where you take the unknown resistance R X and then in series with that you can have a R 1; you can have a voltage source call it E and what you measure is this voltage let this be a voltmeter, electronic or normal voltmeter. So, this is another possible ohmmeter circuit and here we measure this voltage V X we measure V X and then calculate R X because E will be known R will be R 1 will be known. So, what can I write?

Vx = $\frac{E}{Rx+R1}$

So, you see this is the reading, this is the output and this is the unknown quantity, this two are not linear, this is again not linear. So, this circuit is non-linear. So, there could be many different this is also non-linear. Now, we will see a circuit for linear ohmmeter and the let me first tell you the idea before coming to the actual circuit. The idea is that we will use a constant current source ok. So, what we will ok.

So, previous in the previous page here you see we are measuring the voltage across R X and the current that flows through Rx is generated by a constant voltage source this is a voltage source, but if we can generate this current call it Ix, if I can generate this current from a constant current source, so that Ix is constant then something nice will happen.

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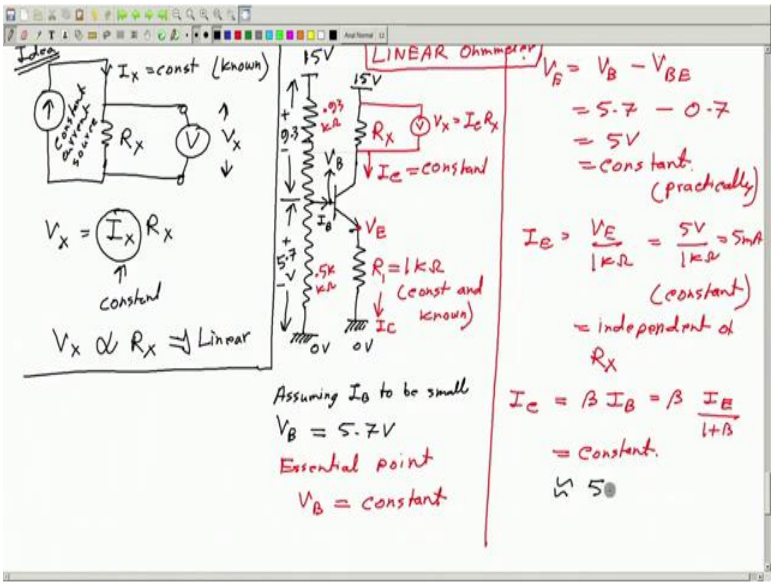

You see what I will do I will take a constant current source. So, this Ix will be constant unknown of course, known this is my Rx let me draw it slightly down Rx and then I measure this voltage with a voltmeter. So, call this V x. What can I write about V x?

Vx = Ix Rx

So, we need a constant current source, but you know constant current source are not nothing available in nature and in practically available they are realized using electronic circuits.

So, let us realize a constant current source. So, this was a constant current source ok; so, this was the idea behind the linear ohmmeter. Now, let us see how we can realize a constant current source, we will use R transistor ok. Let me draw the circuit here. So, what I will do. So, I will take this circuit. So, this is my transistor and what I will do is this I will say apply let this be my ground 0 volt, 0 volt; this is nothing, but a potential divider this is nothing, but a potential divider and I will take it in a way such that say this voltage is 5.7 volt from here to here and here I can take say 9.3 volt.

So, then this 5.7 plus 9.3 will actually be 15 volts. So, I actually calculated 15 first and then 15 minus 9.7 is 9.3 volt plus side, minus side, plus side, minus side ok. So, this gives me 5.7 here, this current you call I B, this point you call V B voltage ok. So, assuming I B to be small which is practical I can write that V B = 5.7 volt constant because a small amount of current will be drawn through this into.

So, even if I B is changing slightly I B can change because I mean as you discuss with IB can change, but even if it changes this current is small. So, a small thing whether it changes or not does not matter much. So, I will have this voltage here unchanged because if the current bypass is small. So, and I can generate this potential divider be maybe by taking this resistance as 5.7 kilo ohm, here maybe 9.3 kilo ohm maybe.

Then the current that is flowing through this is about 1 milliampere and I am assuming this current should be much less than rather 1 milliampere. If not let me take this resistances bit smaller I take 0.57 kilo ohm, here I take 0.93 kilo ohm, then this will be 10 milliampere and maybe this current is small much smaller than 10 milliampere if not I can take this resistance as small. So, the point here essential is this voltage is a constant voltage ok. So, the point essential point is VB is constant using this potential divider I have make that sure.

VE= VB – VBE = 5.7 – 0.7 = 5 V

Why because we know this V BE is practically constant it can be 0.6971, but not much changing from 0.7. So, this voltage is practically constant practically constant, this voltage is also practically constant so, this is practically constant or changing very less ignore that.

So, now if this voltage is constant and I will take a fixed resistance a constant resistance take R1 = 1 kilo ohm constant and known then what I can write about this current I E?

IE = $\frac{VE}{1Kohm}$ = 5V/ 1kohm = 5 mA

I have not taken care or talked and talked about this at all. So, this is constant and independent of this resistance call it R X. You can now guess I am calling it R X means this is going to be the unknown resistance that I want to measure ok. Now, what will be this current? So, how much will be this current call it I C ok. Now, I C is this current

IC = $\beta\ IB = \beta\ \frac{IE}{\beta+1}$

so, this is constant. So, I C is a constant. So, we have generated a constant current source and this does not depend on R x. Now, whatever value of our X you put within a range of course, within some range this current I C will remain constant and therefore, if you measure this voltage with a voltmeter this current is constant. So, voltmeter reading V X will be I C times R X proportional to R x.

So, this is a linear voltmeter and let me just recap how we got this current constant. We have applied a constant voltage at the base. We know the base emitter drop is constant. So, emitter voltage is constant and this resistance is constant so, this current is constant and practically this current and this current they are same actual practical quite close. I mean this plus this is this. So, sorry this plus this is this current I B + I C = I E and if I B is small I can think that these two currents are same. So, if this current is constant then this is also practically constant. So, I have got a constant current source. So, this is a this is a linear ohmmeter.

Let me just ask a small interesting question. The question is what is the maximum range of R X that we can insert in the circuit so that the behavior remains linear? I have not oh sorry, I forgot one thing I forgot to mention that this is also 15 volt. So, you know; that means, V X is this I C which is a constant multiplied by R X that much voltage drops across this and the remaining voltage will drop across the base collector junction.

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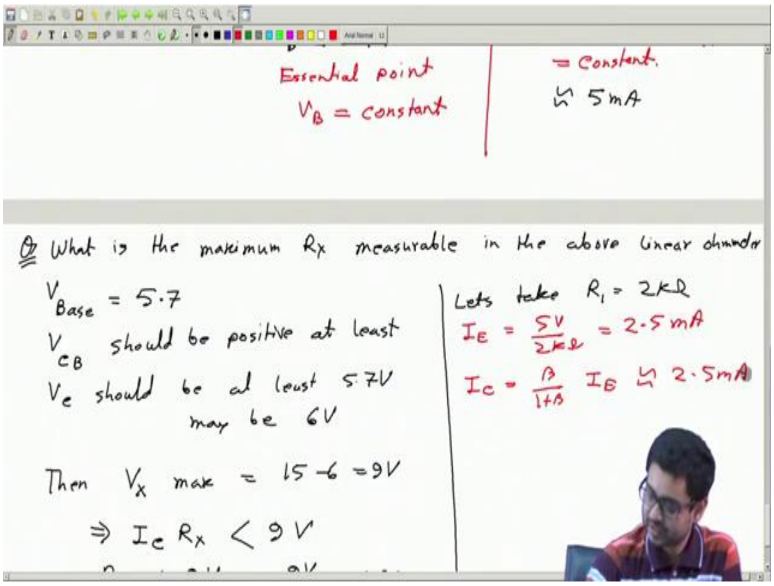

So, let us ask what is the maximum R X measurable approximately what is the maximum R X measurable in the above linear ohmmeter? So, the answer is very simple. So, we know V E this point is at 5 volt this is at 5 volt oh, this is that this is at 5.7 volt. So, let us start from V B base voltage V base = 5.7V and V collected to base has to be greater than some threshold which you can get from the transistor characteristic, but it is definitely it should be positive should be positive at least.

And, not just positive maybe it should be more than half volt or something one some threshold which you can get from transistor characteristic, but it should be positive at least otherwise the transistor will not act in the active region sorry, yeah. So, we need at least at least more than 0 volt drop positive voltage drop so that so that we get I C = β I B otherwise these relationships will not be true. So, that means, V C should be at least 5.7 volt maybe because I do not have the transistor characteristic maybe 6 volt is maybe 6 volt is practical.

Now so, which is greater than maybe 6 volt let us because I am doing an approximate estimation not precise calculation. If so, then the maximum voltage drop that I can allow across R X then V X max = 15 - 6 = 9 volt right and this implies I C R X is at max 9 volt should not be more than that and from this I can calculate R X equal to R X should be less than 9 volt by I C whatever is the value of I C.

So, let us take it from here I E is 5 milliampere. Let us take beta very large then $\beta/1+\beta$ = 1. So, then this is 5 milliampere, then this you can write 9 volt by 5 milliampere. So, this is 9 by 5 or 18 by 10, 1.8 kilo ohm. So, this is the maximum resistance that you can put here and you will get linear behavior if you put more resistance then the behavior will not remain same.

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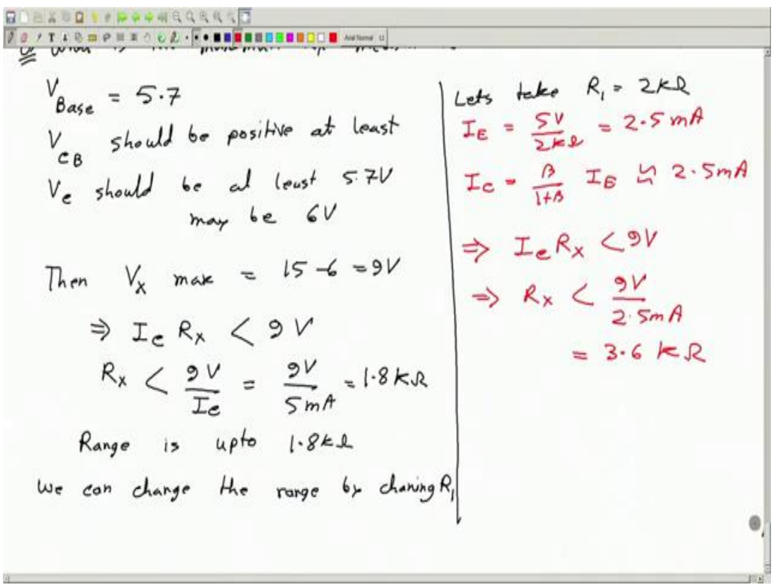

But, what you can do? So, this is the maximum range. So, range is up to 1.8 kiloohm, you can change the range. We can change the range by changing this resistance R 1 changing R 1. How?

IE = 5V/2kohm= 2.5mA

IC = $\frac{\beta}{1+\beta}$ IE $\approx 2.5mA$

IC $Rx < 9$ V

$Rx < 9/2.5$mA = 3.6kohm

We shall take one more circuit with transistors in the next class.

Thank you.