Electrical Measurement and Electronic Instruments

Prof. Avishek Chatterjee
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture – 71
Why we need electronic Instruments

Welcome, let us first briefly review what we have studied so far. In this part of the course, which is on Electronic Instruments?

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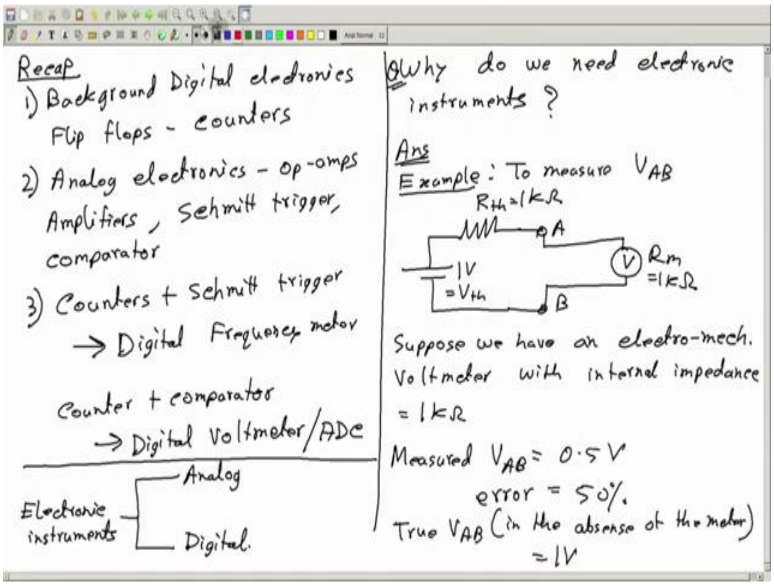

So, recap so, we have start studied some background digital electronics. So, here we have studied flip flops, then from flip flops we have designed counters, this is the most important things thing we need from this. Then we have studied from analog electronics op-amps. And, what have we studied there we have studied amplifiers, inverting non inverting difference amplifiers and Schmitt trigger ok, you can also say comparator that is trivial?

Now, after that we have come started to combine the elements from digital electronics and analog electronics to make nice measuring instruments. So, for example, we have taken counters, you know counters from here and plus Schmitt trigger, this gave us what frequency meter, digital frequency meter. Then, when we took say counter plus comparator this gave us what digital voltmeter, which is also same as ADC you know.

So, we have got some flavor of the electronic instruments, electronic instrument distance, because we have studied these instruments. But, probably I did never tell you before why do we need digital instruments at all, because with classical electromechanical instruments, we could measure almost anything voltage current resistance power energy everything. So, why do we need digital I mean not digital electronic instruments?

So, the question why this is a very important question I should tell you. Why do we need electronic instruments, active electronic instruments?. Just an word of fashion the students often make has a miss concept, that electronic instruments mean digital instruments. No electronic instruments can also be analog instruments with pointers, where pointers oscillates ok.

So, electronic instruments can be either analog or digital, it is never that electronic instruments mean only digital instruments no not at all ok. So, this is a common mistake that students have, many people have, that electronic instruments mean digital instruments no not at all, never ever do this mistake ok. So, the question is why do we need electronic instruments?. So, the answer we will see with some examples, where classical instruments failed I mean do not provide all the required, I mean required things ok.

Let us take an example. Suppose, we want to measure a voltage in a circuit, which circuit is equivalent to this it can be a complicated circuit, but maybe using Thevenin's law, we can reduce that circuit to this. So, this is voltage so, call it 1 volt and this is V t h Thevenin voltage and R t h is equal to 1 kilo ohm. The task is to measure the voltage between terminal A and B to measure V AB. How do we measure?

Now, we will take a voltmeter and we will connect it between this. Suppose, we have electromechanical voltmeter maybe PEM Simmons based or something electromechanical voltmeter with properties like, internal with internal impedance is equal to 1 kilo ohm. So, this also has R m meter resistance equal to 1 kilo ohm.

So, what will be the measured voltage measured V AB will be how much when we connect this voltmeter, what will be the reading of this voltmeter? The reading will be not equal to 1 volt, it will be half volt, because as soon as you connect it, it will draw some current ok. Some current will flow and therefore, this voltage will get divided into this and this, this is equal to 1 kilo ohm, this is equal to 1 kilo ohm. So, therefore, the voltage across this you know will be half kilo ohm. So, this will be 0.5 kilo ohm.

So, error is how much? Error is 50 percent, the true voltage was you know true or true V AB, which is in the absence of in the I mean absence of the meter was 1 volt sorry this is not ohm this is volt ok. Sorry. So, true value was 1 volt and measured value is half. So, we have a error and why do we have this error? This error comes from the fact that the internal resistance of this circuit is comparable and equal in this case to the internal resistance of the voltmeter.

We ideally want the voltmeter resistance to be infinite or much larger than the resistance of the circuit. So, this is not true in this case therefore, we have an error.

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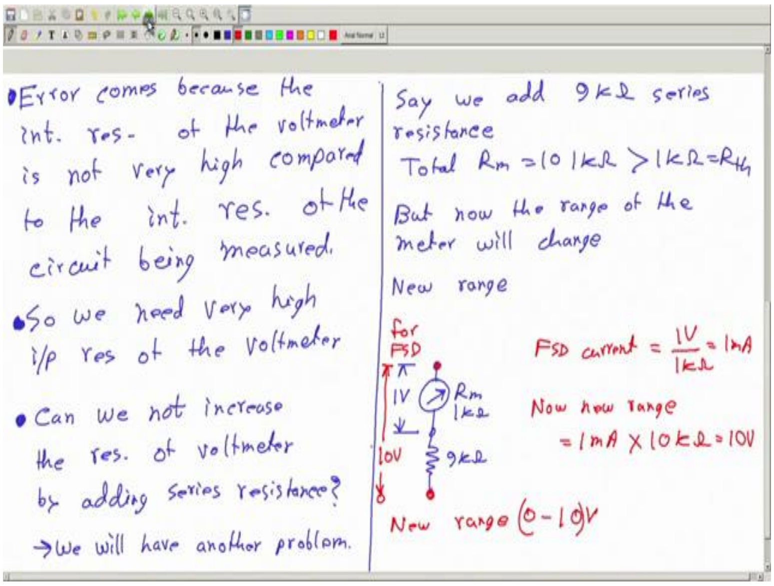

So, let me put a note error comes, because the internal resistance of the voltmeter is not very high compared to the internal resistance of the circuit being measured ok. So, this is the reason behind the error. So, therefore, we need so, this is of course, so, we need very high internal resistance, or you can call input resistance of the voltmeter. So, we need very high input resistance of the voltmeter. So, this is a important fact that we have learned here.

Now, the second thing is ok. How can we increase the internal resistance? We can you know, we can increase the internal resistance of a voltmeter by adding a resistance in series right. So, let us ask can we not increase the resistance of voltmeter by adding series resistance. This is a simple trick we can use you know. But, then we will have another problem the problem is that, we will have another problem ok.

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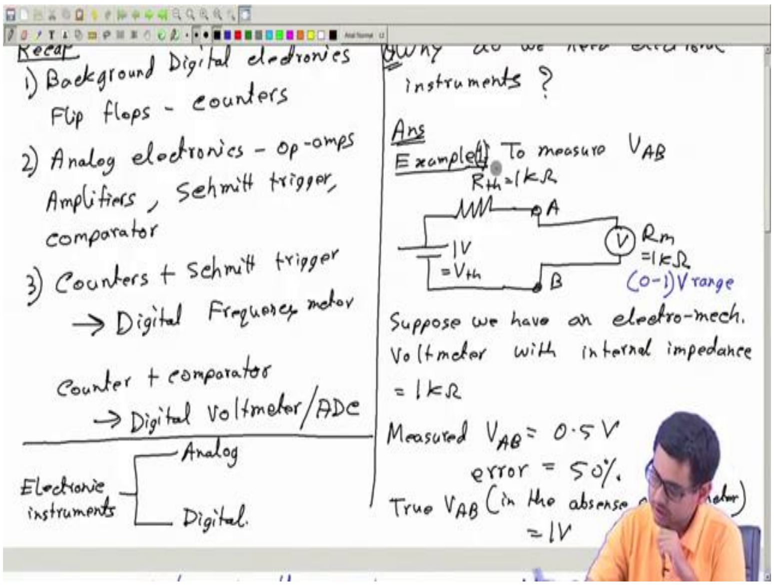

Suppose let us go back to this example say this meter had a range of 0 to 1 volt, 0 to 1 volt range ok. Now, say we say we add 9 kilo ohm series resistance. So, definitely the total internal resistance, then total Rm will be equal to 10 kilo ohm much greater than 1 kilo ohm, which is the Thevenin resistance of the circuit. So, then this will give less a error as expected.

But, now the range of the meter will change. What will be the new range? So, you see in the original meter this was 1 kilo ohm and we used to get full scale deflection, if 1 volt is applied across these 2 points right, but now we have a serious resistance added 9 kilo ohm ok. So, 1 volt, so, for FSD for Full Scale Deflection, we need 1 volt here across this.

Now, how much voltage do we need, between these two terminals, for full scale deflection? Again, we will need the same amount of current to flow ok. So, previously for full scale deflection the current that was flowing. So, FSD current it was 1 volt / 1 kilo ohm, this is 1 milliampere. So, this will remain same so, we need same 1 milliampere current to flow ok.

And, now so, now, new range will be 1 milliampere ok. So, that should flow and that will we have to multiply with 10 kilo ohm ok. So, that will be the total voltage you have to apply across this. So, this will be 1 milli ampere multiplied by 10 kilo ohm, which is 10 volt. So; that means, we have to apply 10 volt across this then only we will get 1 volt sorry a full scale deflection here.

But, now if we want to measure 1 volt ok, with this meter whose full scale deflection is now changed to 10 volt, if we apply 1 volt then the deflection will be only 10 percent right. So, new range is how much? 10 volt, 0 to 10 volt, 0 to 10 volt.

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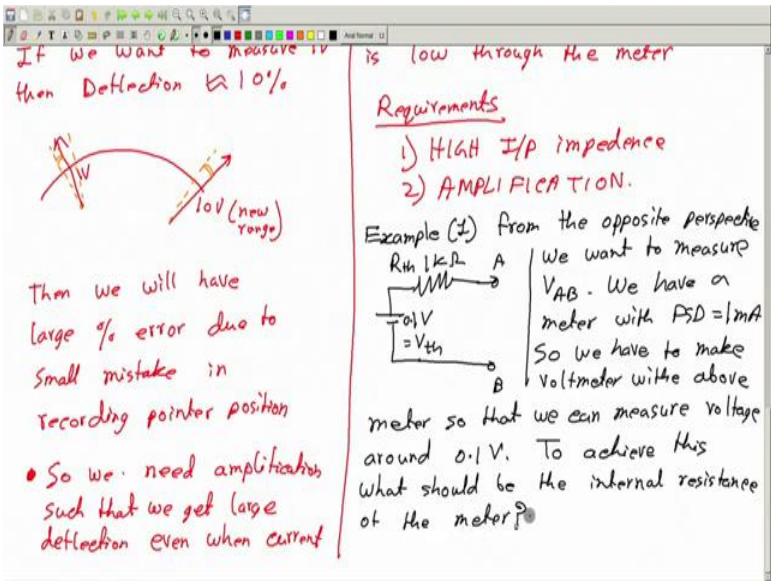

So, if we apply now, if we apply 1 volt or if we want to measure 1 volt, then deflection will be around 10 percent ok. So, the pointer will be only here this is 10 volt we are applying 1 volt ok. So, this is actually the new range and what is wrong?. If the deflection is small, if the deflection is small, then we may make error in recording the position of the pointer, we may make sense like error due to parallax error or something. So, we may think the act pointer is not here, but say actually it is a maybe slightly here or slightly here ok.

And, then this will be the error say this is 0.1 volt ok. So, the relative error is therefore, becomes 0.1 out of 1 in this case 10 percent. But, if the pointer was here, if the pointer is giving me full scale deflection; then if I make same error, same error so, this gap is same as this gap ok. If this is same as this gap, but then the relative error percentage error will be small right. If I make same error in noting the position of the pointer when the pointer is almost towards the right the percentage error will be less, but if the pointer is close to 0 if I make same error same small error percentage error will be large ok.

So, then we will have large percentage error due to small mistake, say in recording pointer position. So, what have we learned we have learnt that, we should have high input resistance for a voltmeter and for that if we just increase the input resistance by adding series resistance, then the problem is I mean very increasingly resistance, but that will cause less current to flow through the meter.

So, the deflection of the meter will be less and if we make small error in recording the pointer position the percentage error will be a huge. So, it is again chicken and egg problem. We need high input impedance, but if we increase input impedance, then less current flows and we may make slight error in recording the pointer position which will lead to large percentage error.

So, therefore, we need what is called amplification. So, that even when small amount of current is flowing the pointer will deflect a lot ok. So, the point is so, we need amplification, such that we get large deflection even when current is low through the meter. So, these are the two important things. Very important thing these are the two important requirements; number 1 high input impedance and amplification, which we cannot obtain with amplification, which we cannot obtain with classical electromechanical instruments, new amplification is possible there ok.

So, these are complementary I mean not contradicting requirements, which we cannot achieve with classical instruments therefore, we will need electronic instruments. So, we have seen 1 example let us call this example 1 ok. Now, we can talk about the same example 1 from a different perspective from the opposite perspective ok. So, now we will say that, suppose we have a circuit where the voltage Thevenin equivalent voltage between A B is 1 volt and it is internal resistance is 1 kilo ohm. So, this is a small voltage 1 volt 1 kilo ohm ok. So, in fact, we can make it even smaller ok. Let us make it 0.1 volt.

So, basically; that means, now we are trying to measure a small voltage ok. And, we will see, what is the problem with electromechanical instruments, when we are trying to measure small voltages?. Now, once again so, we want to measure we want to measure V A B, which is supposed to be 0.1 volt and we will use the same instrument as before. So, in our previous instrument so, we had a instrument whose full scale deflection current was 1 milliampere. So, we will use the same instrument ok. So, but we will tell it in a different way same story from a different angle different perspective.

So, now we say that we have meter with FSD current equal to 1 milliampere. So; that means, it requires 1 milli ampere current to see full scale deflection maximum deflection.

And, we want to make a voltmeter out of this meter ok, which can measure this voltage which is around 0.1 volt. So, we have to make a voltmeter with above meter or above spec. So, that we can measure voltage around 0.1 volt so, if we want to achieve this ok, what should be the internal impedance of the meter? To achieve this what should be the internal impedance or resistance of the meter. So, this is the question ok.

Same situation almost same situation as before now we are asking the question from the opposite perspective ok. So, this time we are saying that we will have ammeter whose full scale deflection current is this much. Now, tell me what the resistance of the meter should be so, that we can measure this 1 volt.

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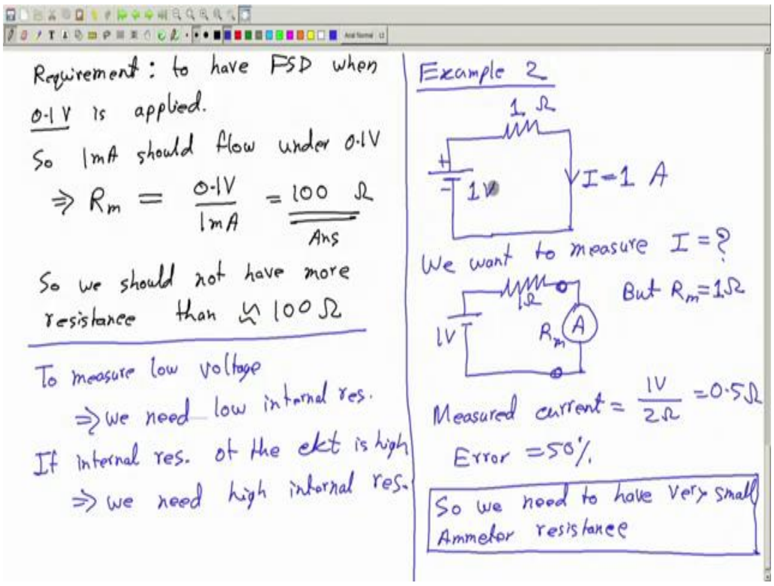

Now, the requirement is that to have full scale deflection, full scale FSD full scale deflection when 0.1 volt is applied, because this is the requirement right. If we get less deflection than this then as we just have told before, there is a chance of having more percentage error. If the deflection is small, you know if the deflection is just say one division in the meter and we make say half division error in reading, then there is a huge relative error. But, if the deflection is very high say the deflection is 10 division and if we make again half division error, then the error is only half out of 10 which is smaller.

So, therefore, we always like to have as large deflection as possible ok. So, therefore, we want to have large deflection full scale deflection only with this much voltage ok. So; that means, with this voltage full scale deflection current that is 1 milliampere must flow ok.

So, 1 milliampere should flow under this 0.1volt voltage ok, which implies meter resistance should be this voltage by 1 milli ampere. So, this is 0.1 kilo ohms 100 kilo ohm right. This is what we will need this is the answer ok. So, this was the question, what should be the value of the internal resistance?

Suppose, the internal resistance is more than this, what will happen less current will flow? So, the deflection will be less and error in measurement will be percentage error relative error will be more. So, we should not have more than this resistance, if we want full scale deflection; full scale deflection. But, less resistance is fine then more current will flow, but the pointer may go outside the range ok, that is a situation you forget ok.

So; that means, we should not have so, we should not have more resistance than approximately this was not kilo ohm, this was a 100 ohm sorry mistake ok. So, we should not have more than 100 ohm right. But, now you know that the circuit the internal resistance of the circuit is much higher than the voltmeter resistance.

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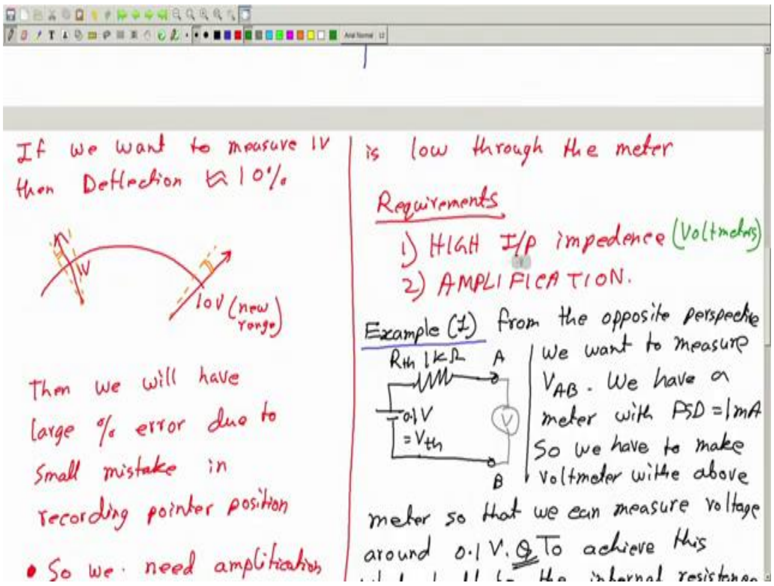

So, what will happen, when current starts to flow in this circuit when we connect a voltmeter. So, this resistance is only 100 ohm this is 1 kilo ohm. So, when current flows most of the voltage will drop here. So, therefore, the voltage across the meter will be only about 10 percent of this. So, 90 percent of almost 90 percent of volt voltage will drop here. So, we will have a huge error we will get a reading which is around so, this is like 1/11 or

1/10 approximately. So, we will have a reading which is only 10 percent of the true value. So, huge error we cannot afford that ok.

So, you see these are complementary right to measured so, let me write this point to highlight the different color. To measure low voltage, we need low internal low internal resistance. According to this second example this example as you have seen to avoid large relative error, but you see if the internal resistance of the circuit resist, this means the Thevenin resistance of the circuit, which circuit the circuit where we are measuring the voltage is high, if this is high then we need high internal resistance as we have seen in the previous example previous to previous ok.

So, these are complementary. So, therefore, we cannot successfully measure with low error voltage where the voltage itself is small and the Thevenin resistance of the circuit is high ok. So, we cannot measure those things with classical electromechanical instruments.

Let us take another example. So, more examples we take I think the idea will be more and more clear to you, but if you have already understood this you may just keep this part. So, this time example 2, we will take an ammeter or a current measuring scenario ok. So, suppose that we have a circuit like this. Say this is 1 volt, this is 1 kilo ohm and this is a closed circuit ok. So, this current will be how much this will be this is 1 volt ok, this current will be 1 milliampere.

So, if this is around 1 volt this is around 1 kilo ohm. So, this current will be 1 milliampere, but we want to measure it using a ammeter we want to measure this current I how much is I? So, what we will do? So, we will insert an ammeter in this circuit to measure this current ok. Let me just change the numbers a bit let me take this 1 ohm ok, I am just changing the example a different situation. So, this is 1 ohm, this is 1 volt so, this is 1 ampere. And we want to measure this current. So, if we insert an ammeter.

But, the ammeter resistance internal resistance of ammeter call it R m, R m is also say 1 ohm, we know for an ammeter the internal resistance is smaller. So, we are taking a small number 1 ohm; 1 ohm is small small number ok, but in this case in this circuit this resistance itself is also small right. So, therefore, what will happen measured current will be equal to how much? So, when we insert this ammeter the measured current will be 1 volt divided by this plus this. So, 1 volt/1 ohm+1 ohm 2 ohm. So, this will be half ohm, you see a error is 50 percent. This was the true current; this is the measured current ok.

And why do we have this error? We have this error, because this resistance the internal resistance of the circuit of this part, itself is small and comparable to the ammeter resistance. Therefore, we have a problem right. So, you know so, we need to have very small ammeter resistance, but also there is a requirement is another requirement ok. To understand that let me please allow me to change all these numbers once again ok, to make it more interesting. Let me make it 1 millivolt, let me make it 1 are not so, much that we make it 100 millivolts ok.

Let us continue with the previous number only we can so, this is 1 volt that we will just continue with this number. So, this is 1 volt so, the original current was 1 ampere right. So, we are trying to measure a current which is around 1 ampere. So, this also put another requirement that, the meter that we will insert should give full scale deflection at 1 ampere.

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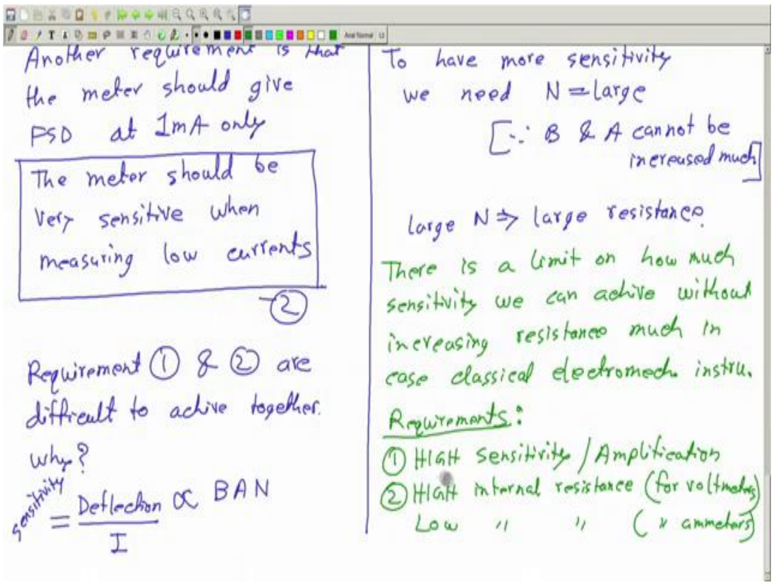

Another requirement on the meter is that, the meter should give full scale deflection at 1 ampere only right. And so, this is the original current that we want to measure this could have been even smaller ok. I mean, if I just simply make say this is 1 milli volt right, then this is 1 if this is 1 ohm, then this current is 1 milli ampere ok, then the requirement for us is to measure this 1 milli ampere current and in this case sorry this was not 1 ohm this was so, this will be this is 1 millivolt this will be half milliampere error will remain same as it is ok.

So, but now the requirement is we have to measure 1 milliampere. So, with 1 milliampere, which I should get full deflection so; that means, the meter should be very sensitive, when measuring; when measuring low currents. So, these are the two requirements right. So, you are measuring a low current so, it should be sensitive to low current and the internal resistance should also be small and these two are contradictory.

Do you know why? Because, so let me first write this is 1, this is 2, requirement 1 and 2 are contradictory are difficult to achieve together why? Say, we need a high sensitivity. So, just consider a PEM Scimitar and for a PEM scimitar how much is the deflection? So, for PEM scimitar you we know that the deflection is proportional to you know it is proportional to the flux density B area of the coil number of turns in the coil what else B A and the current.

Now, we know this current is small, but we want large deflection ok. So, this is sensitivity, this is the sensitivity it is proportional to this and we want high deflection at small current; that means, high sensitivity, how can we have high sensitivity? Can we increase increased B a lot practically, if we are using a permanent magnet you can never possibly get something like 100 tesla flux density no it is not available ok.

So, this there is a limit on being practical, permanent magnets natural magnets cannot have indefinitely large flux density. Area of the coil, can you make ammeter which is I mean normal meters that you have seen in lab are of this size. Now, if we want to make the sensitivity 10 times can you make ammeter which is 10 times larger no I mean that is impractical, N possibly you can change N number of turns, you have to increase number of turns.

And, if you want to increase number of turns what will happen? You will also increase the resistance of the coil, because the coil is getting longer and longer I mean the length of the wear is getting longer as you increase the number of turn. And, you cannot make it simultaneously thick, then the meter will be heavy big costly all those things. So, there is a limit on the electro mechanical instruments. So, that you cannot achieve simultaneously high sensitivity with low resistance of the meter, there is a limit how much you can achieve, but what if we need more than that then electronic instruments are useful.

So, let me just summarize. So, what I have just said to have let me just write to have more sensitivity, we need N to be large since B and A cannot be increased much. And this implies so, N large N implies large resistance. So, there is a limit; there is a limit on how much sensitivity we can achieve with the without increasing resistance much in case of classical electromechanical instruments like PMMC etcetera ok.

So, this is the reason why we need electronic instruments, by the way 1 small 0.1 small mistake that often we have seen people to make. So, we have said the 2 requirements ok, 2 requirements for electronic instruments is that high input impedance and amplification. Now, this high input impedance is true for volt meters. So, when talking about volt meters? Do not say ever by mistake that we need high input impedance or internal impedance for an ammeter, for an ammeter we need low internal resistance ok, it is opposite.

So, let me rather write. So, requirements that we have to fulfill with electronic instruments, number 1 high sensitivity or amplification. So, if I am trying to measure a small voltage I have to somehow fast make it larger, bigger then measure or if I am trying to measure a small current, somehow I have to amplify it is effect the effect of small current I have to amplify.

So, this is the requirement amplification. And secondly, high resistance, high internal resistance or input resistance, for voltmeter and low internal resistance for ammeters. If I make an ammeter with electronic circuits, that should have low resistance, if I make a voltmeter with electronic circuits that should have high internal resistance. So, these are the two requirements you must bear in mind before we proceed further.

Thank you.