Power Electronics with Wide Bandgap Devices
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Lecture-21
Electromagnetic Interference (EMI - Part 02)

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Hello, welcome to the course on power electronics with wide band gap devices. Today, I will continue the discussion on EMI. In the last lecture, I have already discussed about different types of EMIs. So, basically, so as I have discussed in the last class.

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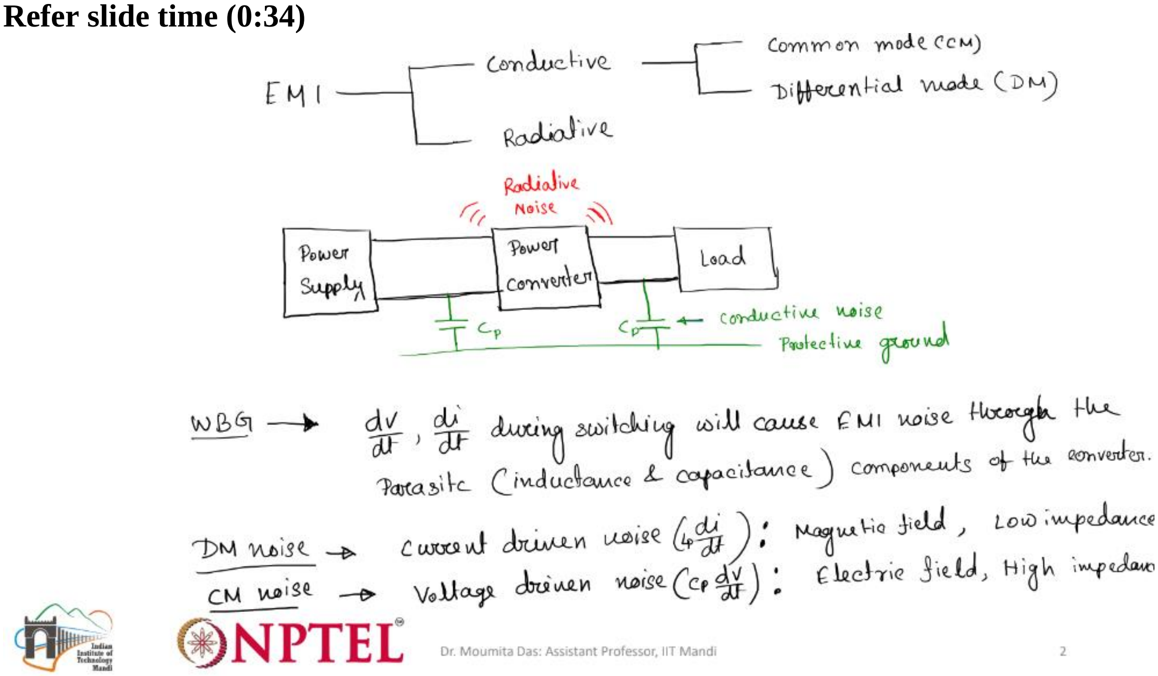

so the EMI, so EMI we have seen we can actually classify in two types, right. So, conduction mode EMI or conducting type EMI and then radiative EMI. Now in this also there are two different types of EMIs in conductive type.

One is common mode or CM which I have represented in the last lecture. and differential mode. In radiative also there are different categories that we have already discussed so that intra inter different types of radiative EMI can be present but today i will be focusing on conductive type of EMI and then how it is coming so if you see in power converter so basically any power converter there will be power supply first right so it can be any type of supply dc ac any type of power supply can be present So, power supply it is connected to the power converter. Again the power converter can be anything AC to DC, DC to DC or DC to AC or AC to AC can also be present right.

So, we can just say power converter over the equipment under test. either power converter or equipment under test. So, we have to check whether this power converter is getting affected by the EMI noise either conductive or radiative. So, if it is so then we have to provide the solution. before measuring this EMI, we have to first understand what are the EMIs that can be present in the power converter.

So, that is what I am going to discuss today. So, then this power converter will be connected to some load, right. So, this is the basic structure of any power electronics system. So, again load can be AC, DC, anything and power supply can be AC, DC, power converter can be any type of conversion. So, if you see here, so this is in this particular system, ideally this system should operate properly.

But in normal operation what happens? So, there will be EMI present due to radiative in this power converter right radiative kind of EMI so this is the radiative noise okay now again there can be some parasitic component to be present in the path. What are those parasitic component? One component is the parasitic capacitance. So this capacitance will be connected to the protective ground. So I can just make this protective ground common for all the parasitic capacitance. So this is protective ground This one, so this one is basically you can say this is the circuit ground.

Then circuit ground and the protective ground they are different. So, between circuit ground and the protective ground there will be parasitic capacitance which will cause this EMI to be present in the converter. So, now this parasitic capacitance will cause presence of, this is the reason for common mood noise or I can just say conductive noise So, the reason why these noises radiative or the conductive any EMI noise is become very significant in high frequency is due to dv/dt and di/dt. So, you know like when we are actually considering wide band gap devices. So, basically for wide band gap devices.

any device whenever we are considering silicon carbide or gallium nitride, the one of the important thing is that this converter should be able to operate at high frequency. Now, if it is operating at high frequency, then what will happen? The rate of change of voltage and the rate of change of current will also be higher, means this dv/dt and di/dt during switching will also become higher you know t will be very small for very high frequency operation that will cause this components to be very high and this will cause higher value of EMI noise to be present during switching will cause EMI noise through the parasitic inductance and the parasitic capacitance. Now, this green capacitances which I have shown here in this block diagram, these are parasitic capacitances, right. So, now these capacitances are not present in the circuit, but it will be there in any converter with respect to the protective ground. If the frequency is higher, then this component becomes quite significant through the parasitic this will be inductance and capacitance okay component Now, if this dv/dt and di/dt are present, so basically what happens? If dv/dt is present, CdV/dt will cause current to flow in the system.

that is parasitic like dv/dt with respect to the parasitic capacitance that will cause this noise to be present. So, basically if I try to quantify this dm noise and the cm noise. So, dm is with respect to differential mode and cm is with respect to the common mode. So, then dm noise It is basically current driven noise.

Right. This is current driven noise. Why it is current driven noise? Because you know when we are saying DM noise so basically what will happen due to change of current means di/dt. So, current driven noise it is coming due to the di/dt. So, L di/dt will cause this noise to be present right. So, basically this is why it is called current driven noise and this is due to this is actually due to actually the presence of magnetic field means this L.

L is basically not the actual inductor. So, I can just represent this as Lp. So, in terms of like parasitic inductance. So, this is due to the magnetic field. Again this magnetic field is not actual inductor or the transformer which we are considering in the converter.

This is parasitic magnetics, parasitic inductance which is present in the circuit. Now due to low impedance path. Okay, so basically if there is a magnetic field and if also there is a chance of low impedance, low impedance will cause higher value of di/dt and then higher value of di/dt with respect to the magnetic field, it will cause higher value of DM noise to be present. Okay, now similarly if I try to quantify this CM noise. So, this CM noise it is known as voltage driven noise.

So, voltage driven noise when I am saying so that is with respect to the dv/dt. So, this parasitic capacitance so I can also represent this capacitances as Cp. in order to make it clear that these are parasitic capacitances. So, this Cp with respect to this dv/dt will cause this CM noise to be present, right. Now, this is Due to the fact that there is electric field So when I am saying electric field so what happens so you can understand if there is a ground so basically circuit ground and The protective ground or the actual ground if they are different then what will happen is there will be electric field between these two grounds.

And this will cause parasitic capacitance to be present. And this electric field will cause the basically CM noise to be present. So, an electric field and also high impedance. So, you can understand with respect to capacitance. So, this is coming as high impedance and inductance it is coming as low impedance.

The current will be higher and here the voltage change will be higher. Rate of change of voltage will be higher. So, these are the reasons for this CM and DM noises. Now, if I have to Identify these noises in circuit. So then let's see how this is going to be.

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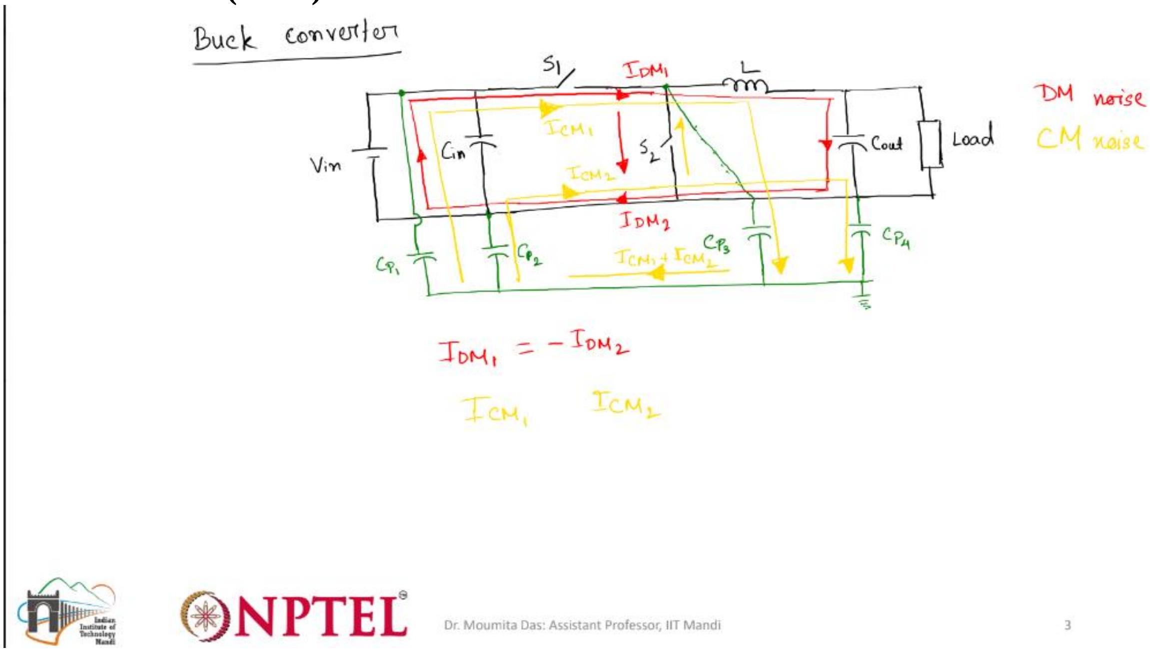

So let's consider example of a buck converter. So buck converter is the simple power electronics converter. So, in this, so let me just draw the circuit diagram of the buck converter, then I can show that how this CM noise and DM noise will be in that particular converter. So, with respect to buck converter, so you can see here, so this is the input voltage of the buck converter, the input capacitance of the buck converter. This is connected you know like if there is any like distance between Vin and Cin of the converter.

So this capacitance is present to make sure that there will be constant supply from the input. Now this is connected to let's say switch S1 and then in place of diode I am just drawing another switch. S2. Then there will be the inductor L and the output capacitor Co of the buck converter. And this is connected to the output load.

Let us say the load is this. So, any kind of load it can be. So, just representing it with like this. This is Cout. Right. Now, ideally this converter should not have any other component.

Right. But in practical scenario what will happen? There will be different parasitic capacitance. Sorry, I will just use different color for the parasitic component. So this parasitic capacitance to be present. Let's say this is Cp1, Cp2. These all are parasitic capacitances, but the values with respect to different point of the circuit, it will be different.

So, that is why I am just representing it in terms of 1, 2 like this and then again there will be like parasitic capacitances from here to let us say ground and again there will be point. Okay. So now these all are connected to the protective or protective ground Cp3 Cp4. Now if you see here so then basically the common mode and the differential mode current we can actually figure out so let's consider this differential mode noise i am just representing in red color right. So, it will be in the similar direction as the power signal.

So, generally what happens the power signal it goes from the input through the switches to either like switch S2 or maybe through L to the output capacitor right. So, this is the direction of the current and the return path will be through the circuit ground and this will be the direction of the current. So, it will be sometime it will be through this inductor and the capacitor and sometime it can be like this also. So, this is how generally this differential mode current path will be. It will be along with the power line, power signal line.

Now when I try to represent the common mode noise. So common mode noise will be in the similar direction. Differential mode noise it will be in opposite direction. You can see here. So this like positive of the differential mode and the negative return part they are in the opposite direction.

If you check the arrows they are in the opposite direction. But in case of common mode noise they will be in the similar direction. So, let me just use different color. So, this yellow it is visible. So, if I try to represent in this yellow color.

So, then the current will be. So, it will come from this. You know like this is due to this electric field. So, this is basically voltage driven noise. So, then it will come from this parasitic capacitance.

Let's take it. So this is the parasitic capacitance noise so it will come from this from this particular path and It will flow along with this. Okay. One will come from this. Another, since there is a parasitic capacitance, it is connected here in this path.

So, it will go in this direction. Hopefully, this is visible to you. This will go in this direction. Right. Again there is another capacitor Cp3 and Cp4 are there. So, basically it will have return path through that.

So, basically any of this like Cp3 or Cp4 it will be like provide the. So, this is actually this will provide return path. So, we will just. So it will provide return path for this. This is the return path and then the upper capacitor which is connected this Cp3 it will provide return path through this.

So you can now check. So basically arrows you can just see how these arrows are connected. Right. So this will provide return path for different current. So you can check here so the positive and negative current of this differential sorry this is common mode so just representing the common mode in yellow color and then differential mode in the red color. So differential this is common mode noise common mode noise path.

And then this is differential mode noise path. So, if I try to represent the this like this two different current of the differential mode. So, basically Idm1. So, IDM1 here like when it is going forward and then I dm2. So they are basically opposite. Means IDM1 and IDM2 are having different sign, different arrow.

And similarly if I try to represent this ICM1 and ICM2. they are in the similar direction. So, that is the difference between differential mode and the common mode noise. So, you can check here the return path of this differential mode and common mode noises are also shown here.

So, this will return through this path. So, you can check. So, this is this one like whatever is going in the forward we can say this is like CM1 and then whatever coming in the return this is like you can check like this will be of similar magnitudes ICM1 plus ICM2. So, it will be having ICM1 plus ICM2. So, basically IDM1 will be IDM2. IDM1 will be equal to IDM2 but sign will be different whereas the return current so basically ICM1 plus ICM2 will provide the return path current and the similarly ICM1 and ICM2 it will be through the two different power lines, this positive and the negative lines, right.

So, they will be of different they can be of different magnitude or may be similar. So, may be also basically this ICM1 and ICM2 relation if I want to establish. So, then it may be may not be similar. So, basically ICM1 and ICM2 They may be equal or may not be equal. So, this relationship is depending upon the parasitic capacitance values.

So, now this is with respect to the buck converter. Similarly, this path can be represented for any other converter means like this EMI noise path, conductive kind of EMI noise. So, this is like common mode and the differential, these two different types of EMI noise.

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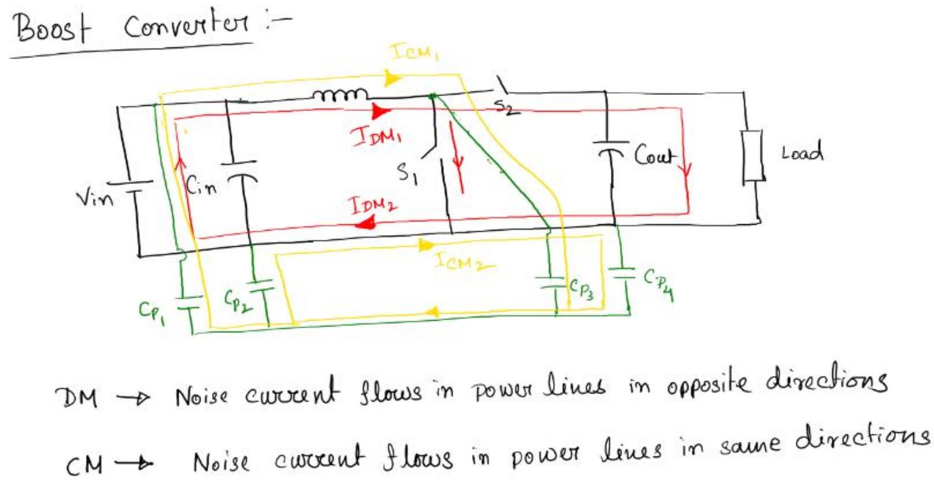

In the converter, we can analyze by actually finding out the parasitic component values and how this di/dt and dv/dt of the converter switches is going to be from there we can analyze what will be the values of the CM and the DM noise just to give the example of another converter so i am also considering another boost converter so that it will become clear to you it is the similar to the buck converter exactly similar. So, I will just draw the circuit diagram. So, then the all type of generally the converter either will be boost or the buck.

So, then it will be clear for all kinds of converter. So, again it will be having input capacitor similar to the buck converter right. Here inductor is present at the input in the So, there, here the same type of switch S1 and then there is a switch S2 which is connected to output capacitor C out, C out, right. Now, this is connected to the load. okay so this is also having similar type of situation so basically it will be having DM and the CM noise so now if I have to provide so if I have to provide the parasitic capacitance path it will be also similar so I am using same color just to make sure that I mean you can just connect these two diagram. So, it will be also having this like with respect this particular switch there will be a parasitic capacitance like this and similarly one another parasitic So this is Cp1, Cp2, Cp3, Cp4.

Right. Now similar font color if I use. So basically line color. Then DM noise path will be through this with respect to the power signal. So, one DM1 will be in this direction and

DM2 will be in this direction. So, it will complete the path like this. So, it will be having this path and this path and here it will be having this path.

right so this is with respect to DM noise and similarly the CM noise it is connected like this so it will go like this and through this capacitance it will be having return path similarly in this one it will be it will go like this so just it will go like this. So, basically through this capacitance it will be having return path. So, just connect this return path. So, here the direction of ICM1 and ICM2 it will be in the similar direction.

So, you can check here IDM1, IDM2. and then similarly you can check here ICM1 ICM2. So, these two currents are of same direction. So, IDM1 and IDM2 you can check and ICM1 and ICM2. This will be the path for common mode and the differential mode noises. So, here noise current flows in power lines in opposite directions.

that you can already see. IDM 1 and 2, they are in the opposite direction. And CM, we can say noise current flows in power lines in same directions that you can see with respect to ICM1 and ICM2. ICM 1 and 2. So, these are the noises which you needed to know with respect to the conductive EMI.

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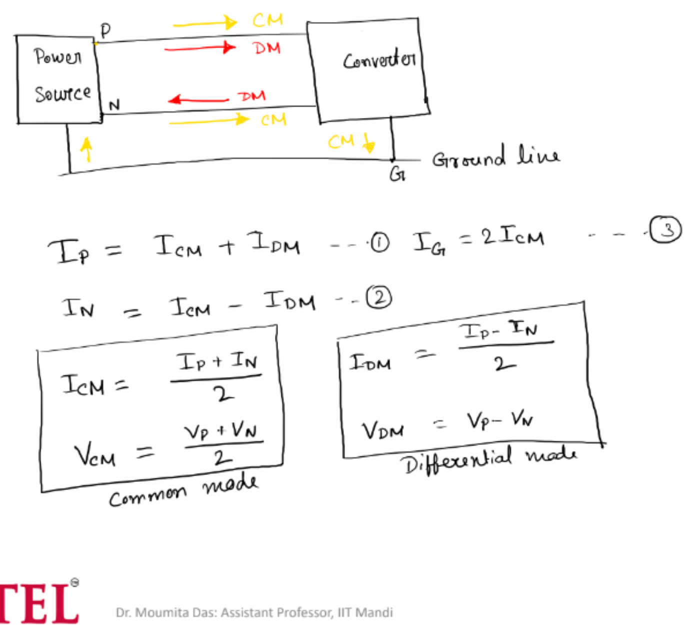

So, now if I try to analyze these noises, so then how I can analyze? So, I can just draw the block diagram again.

and then this is the converter with load i'm drawing now or the equipment under test i'll just write converter so then it will be easier for you to connect Right. So now this power source is connected to the converter. Now you have already seen the path for the differential mode and the so differential mode path will be like this. And with respect to the ground line, so then the common mode path will be like this.

So, I will just define this is not a problem. Right. So, if I try to, so if I consider this current from this power source, so basically there are two points. So, positive and the negative if I consider this is the positive point and this is the negative point. And current from the positive point if I consider IP and current from the negative point if I consider IM. So, the net current in each line I will be getting as IP is basically summation of common mode and the differential mode current because they are in the same direction.

So, basically ICM plus IDM. Now, IN is basically difference between ICM minus IDM. So power line I am just now representing positive and the negative line. So whatever is providing forward path that I am considering as positive line and that current with respect to that particular line I am considering IP. And the return path I am considering as negative line which I am representing in terms of IN. This can be anything like with respect to AC source also it can be there just considering these two lines as P and N that it doesn't have to be only DC source right.

So now this positive negative currents we are getting. Now if I have to now if you see this current so this ground current if I try to find out this ground current basically so the ground line I am considering as like current with respect to ground line G. So this line I am representing as G. So the current in the ground line will be 2 ICM. that you can understand so basically positive line and negative line both direction common mode current is flowing in the same direction so the twice of this each line current will be going to the ground or the summation of positive and the negative line current will be going to the ground. So, in this case we are considering in positive and the negative line same currents are flowing.

So, that is why I am representing the with same current ICM and this twice ICM will be going to the ground line. Now, this if I try to like these equations, these three equations, so if I say 1 and 2 and 3, if I solve this 1 and 2, then what I will get? ICM equal to IP plus IN divided by 2, right. And then similarly, IDM I will be getting as IP minus IN divided by 2, right. So, then similarly this is with respect to the current I am getting. Now, if I want to find out the voltage, common mode voltage, ultimately then what I will get? VCM also I will be getting similarly as Vp plus Vn divided by 2, right.

Similarly, the Vdm will be Vp minus Vn. So now you can see from this particular thing so common mode current and voltage we are sorry this is differential mode and this is common mode. This is with respect to common mode and this is differential mode. So, this voltage and current we can get from any converter. So, whether it is buck converter, boost converter. So, this relationship we can find out because we will be having the information of IP and IN, VP and VN.

So, then we can find out what can be the noises, the value of the current and voltage of the noises in the particular converter. now how this noises generally looks like so basically if you see any converter so with respect to differential mode it is the same current which is flowing in the circuit see here in the boost converter if you check so the boost converter the switches whatever current it is flowing the same current will be flowing in the differential mode noise.

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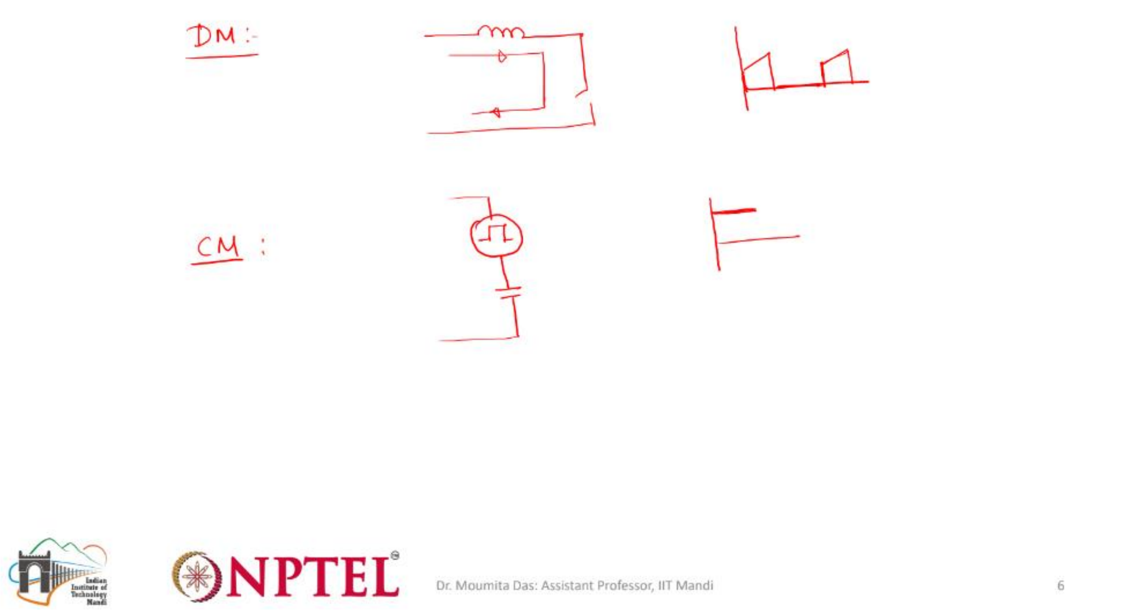

so The shape of the differential mode noise so it is basically if I try to draw the equivalent diagram so then power line so it is flowing through the switches for boost converter right. So this kind of noises are present.

So, then the noise will be similar. So, like switch on and off will be there. So, remember these noises are due to the switching operation. So, then when the switch is on the inductor current whatever it will be. Let's say I am considering the continuous kind of current operation. So, then this current will be there in this particular noise part right.

Switch on and off it is going to be like this. So noise shape it will be kind of like this similar to the inductor current. Only thing is that in the negative side it will be zero. So, this is the shape of the DM noises and if I consider the CM noises. So, CM noises is going to be bit different because if I try to consider the same equivalent circuit you remember this like there is a point which is connected from this to the ground. So, then with respect to that so the switching signal whatever is coming, so this coming with respect to, just a minute, the equivalent diagram will have, so this switch signal will be there and then there will be parasitic capacitance path.

So, it will be kind of flat topped kind of signal we will be getting. So, this flat topped kind of signal will be getting in this kind of CM noise and that we need to measure with respect to the particular converter, right. So, here we can get mostly trapezoidal kind of signal and here we can get mostly flat topped kind of signal with respect to its switching. Now, this noise is How to measure these noises or what are the steps we need to follow now? So, now you know about these different noises. Now, what to do with these noises?

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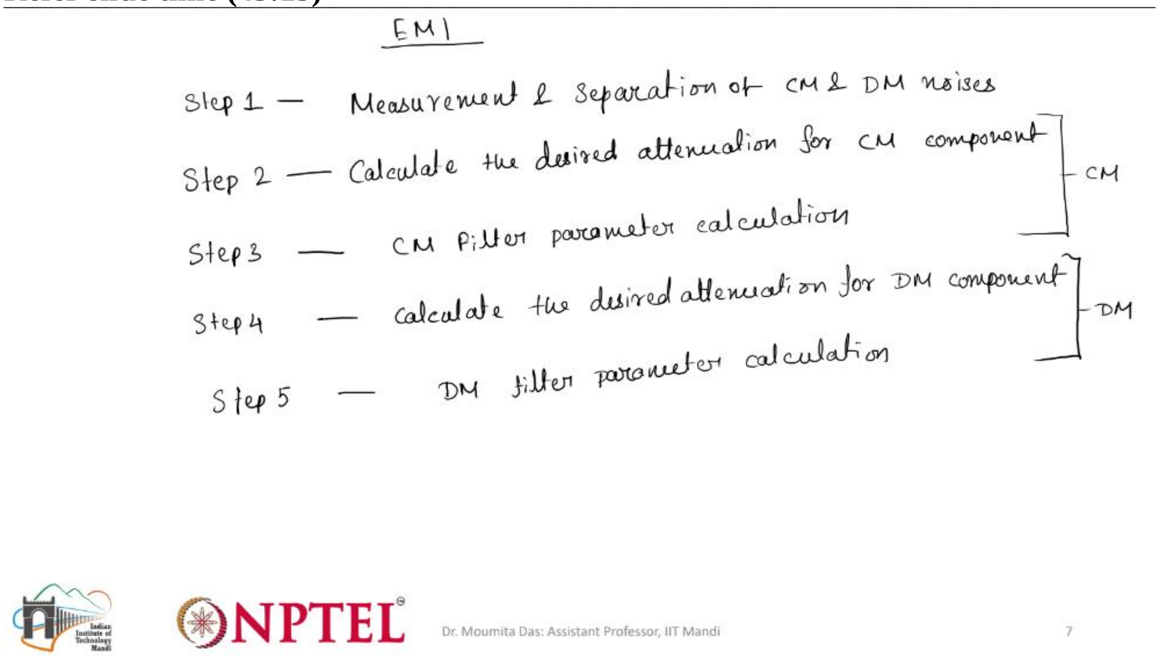

So, what steps we need to follow in order to analyze these EMI noises? Basically, first we need to see what are the noises present.

So, the step 1, EMI. designed. So, basically if I say step 1, step 1 we have to find out what are the different noises. So, basically measurement and separation of CM and DM noises we have to measure we have to separate step 2 now you know about different noises you can separate out these noises but first we have to measure we have to know how to measure then if we measure then the step 2 what it will be once we have the information then we have to calculate the desired attenuation for CM component. We have separated CM and DM. Now we have to see whether the CM noise within the specified limit or not.

The limit I will be discussing like what are the limits that is provided for EMI. So we have to check these noises within the limit or not. If it is within the limit then it is fine. If it is not within the limit then what we have to do? Then we have to follow the step 3.

CM filter design. filter parameter. So, we have to design filter for CM noise. So, we will be designing filter for CM. Now, step 3 it is for CM part. Step 4 will be now we have to check for DM as well right. Calculate Similarly calculate the desired attenuation for DM component.

Similarly to the step 2 for DM. Right. Now step 5 similarly we have to see if it is within the limit or not. If it is not then we have to design DM filter. DM filter parameter calculation. Now this process we have to check like by connecting filter in the system we have to see the noises are attenuated to the desired level or not. If it is not then what we have to do we have to again follow the same procedure again measure and then we have to see that how much filter is required then we have to change the filter parameter value and then we have to check again this is and then end.

So, these are the five step. So, this is for the DM part and this is for the CM part. Okay fine, first we have to find out CM and DM noises that also you know from the circuit. But how to measure these noises? So this is like the first step probably we need to see. What are the measurement procedure for different noises? Because you know these noises as you have seen, so this will be in the very high frequency level. So in the megahertz and gigahertz in that particular level. So, then what we need to do in order to find out these noises for because you know normal oscilloscope it will not give you these noises right.

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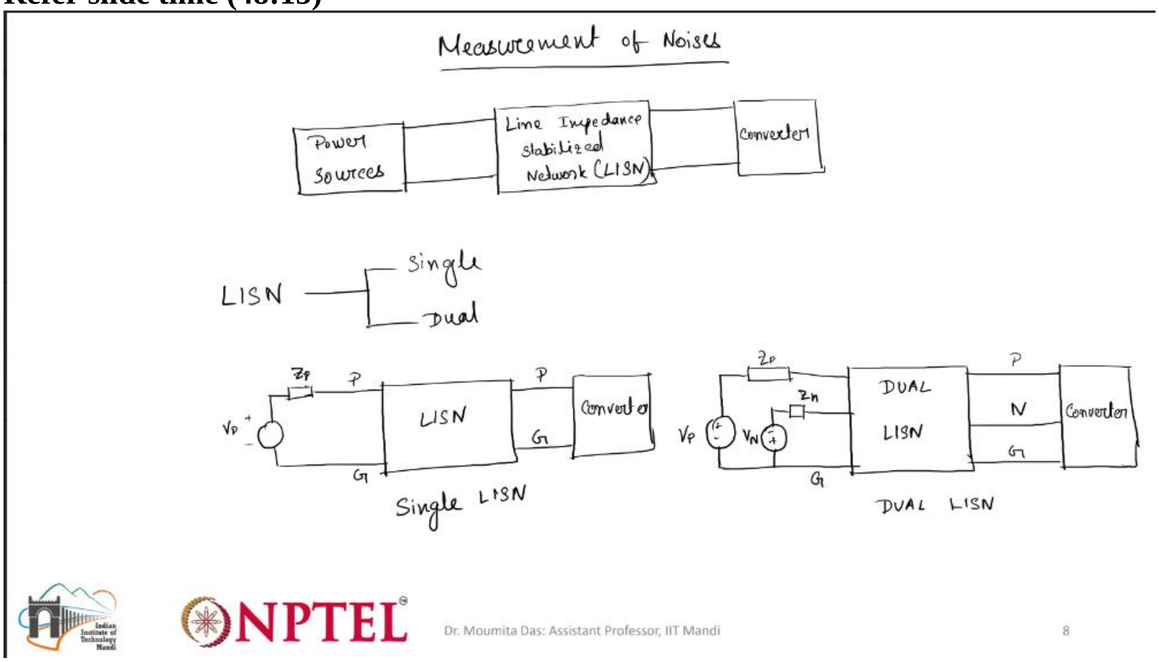

So, then and also like we need a setup to find out these different noises. So, that is why the first step will be the measurement. Right. When I say measurement of the noises. So, then how we have to do? So, basically this till now you have seen the power sources.

It is connected to the converter. It is connected to the converter. Here in between power source and converter there will be one network. which will be connected to measure these different noises. What is this network? That is known as LISN or Line Impedance Stabilized Network.

or known as LISN. So, this network we have to place in between power sources and the converter. This network when we are placing, so then it will provide us values of common mode and the differential mode noises. Basically, noises we can get and then from there we can actually separate out or we can separate out in the experiment itself. First, we let us see that what this network is and how this network can provide us different noises, right. So, this LISN can also be like single or dual so if it is single so then generally it will be connected to any of the lines like either positive or the negative and ground and if it is dual then it will be connected to both the lines and ground right so basically the block diagram of LISN is such that so if it is single Then positive ground and the converter positive P and ground G. Similarly for the power source P and then this is connected to plus and negative and then it is connected to G.

So, this is the Zp, so impedance with respect to the positive point. So, this is single LISN. If it is dual LISN, so then it will be There will be positive, there will be negative, there will be ground. And then it will be connected to the converter.

Then this is Zp. This is, let's say this is Vp. Vp it is connected to ground. Similarly, there will be negative point minus plus Vn which will be connected again this particular point through Zn to be connected to ground right. So, this is how this dual LISN, so this is dual LISN block diagram looks like.

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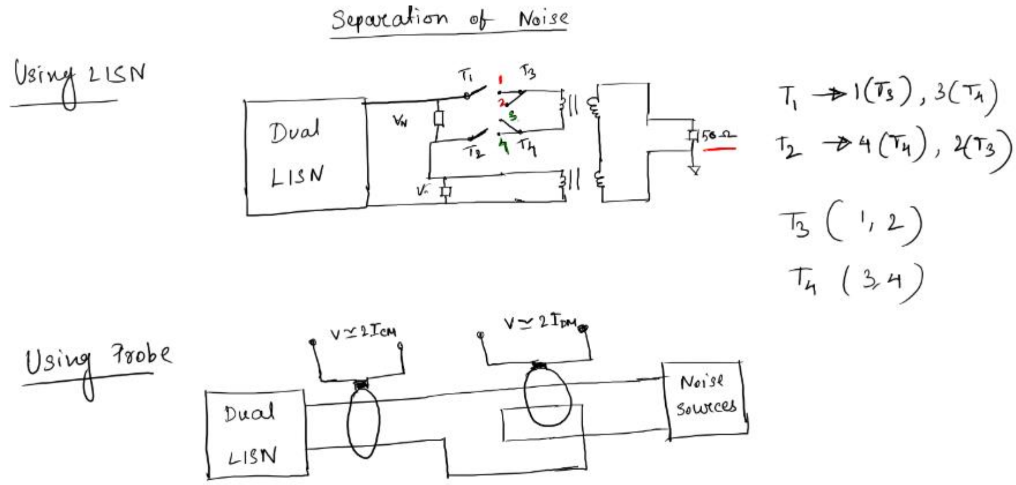

now This LISN again like if we have to use it for different noises means you know there are like two different points measurement and separation. So, we also need to separate this DM and CM noise because you know filter for this two noises are different one is current driven one is voltage driven.

Then the filter requirement one will be capacitive another will be inductive. So, that is why we need to separate out so that we can design the filter accordingly right. So, then for separation also there are actually different kind of method people can use. So, I will just tell you about like two methods using LISN. If we want to separate out So separation of noise So using LISN if we want to separate out so the diagram so basically configuration of the network should be like this.

So I have shown you the dual LISN how it is connected. So this is the dual LISN. We need dual LISN for separation, right. Then we will have complete information of CM and DM noises. So, then it will be connected to this particular point and then this is one impedance will be connected here between this two points.

So, this is Vn and this is Vp. So, again one impedance will be connected here. This will be connected to the, this will be connected again to one transformer.

This will be attenuated at 50 ohm resistance. Okay. Look out. Now, you can see here this, this is Vn. These points, so basically here two points are there. So, here the switch can be connected like this or this means this is 1, 2. Similarly, this will be connected like this, right or maybe it can be connected like this, 1 or 2 point. So, now this point, this point, so this point can be connected to 1 or 2, similarly this point can be connected to 1 and 2.

Maybe I can just write this as 3, 4, so then it, ok, fine, no problem. So, basically we can just write here T1 and T2. So, T1 can be connected to 1, 2, of T3 and then T2 can be connected to 1, 2 of T4. So, wherever, so like basically these two points will tell, so basically different points.

So, when T1 is connected to 1, just a minute. So, T1 can be connected to 0.1 or 0.3. Similarly, T2 can be connected to 0.4 and here it will be 0.2, 0.2. So, if you can't see it properly I will just highlight this is 1, this is 2 and with respect to this, this is 3 and this is 4.

3, 4 are with respect to T4 and with respect to T3, this T3 points are T3 has 2 points 1 and 2 and T4 has 2 points. 3 and 4. Sometime the T1 can be connected to 1 and sometime it can be connected to 3. So, means sometime it can be connected to T3, sometime it can be connected to T4. When it is connected to 1 that is connected to T3, when it is connected to 3 then it can be connected to T4. Now similarly T2 can be connected to four so in that time it is connected to T4 and then when it is connected to two so that time it will be connected to T3 so both can be connected to both point so in order to measure these two different noises so one is that so T1 can be connected to one and T2 connected can be connected to four the similar way like that the connection can be changed in order to find out the other noises.

So that way this CM and DM noises can be separately find out by changing this switching position through the LISN network. So that is the network if we want to use for separation. So this is how we can actually find out two different noises. If we don't want to use LISN network, so for that what we have to do, we have to provide this different network connection. If we don't want to do that, we can also finding out from the probe. So, by using probe, if we want to find out, then what we have to do? We have to use similarly dual LISN, there we don't need this different network connection.

We have to use dual LISN that is for sure. So, then one CM noise for CM noise what we can do? These two lines we can just check the probe we can connect this way because you know this current are flowing in the similar direction. So, then if we try to connect the probe this way then this probe connection will give us actually voltage equivalent to 2ICM . Now, this probe if we try to connect it bit different way So, if we have, if we twist it here like this and then if we measure the current here, so then here this will give us the voltage which is equivalent to 2IDM, right. Now, this is how this noise can be find out by measuring separately.

So, here we can find out basically voltages we can see in the probe. So, this voltage which will be equivalent to this current levels. So, again we can use this same in the equation in order to find out like different current and then we can design the filter and using LISN already you know how to find it. So, these are the different methods what we have to follow. So now you know about how we have to use LISN and we have to separate the noises and everything.

So how this LISN looks like? So till now I haven't told you about LISN network. So what this LISN network consists of? So, it must be having some network configuration, some resistance, capacitance all these things.

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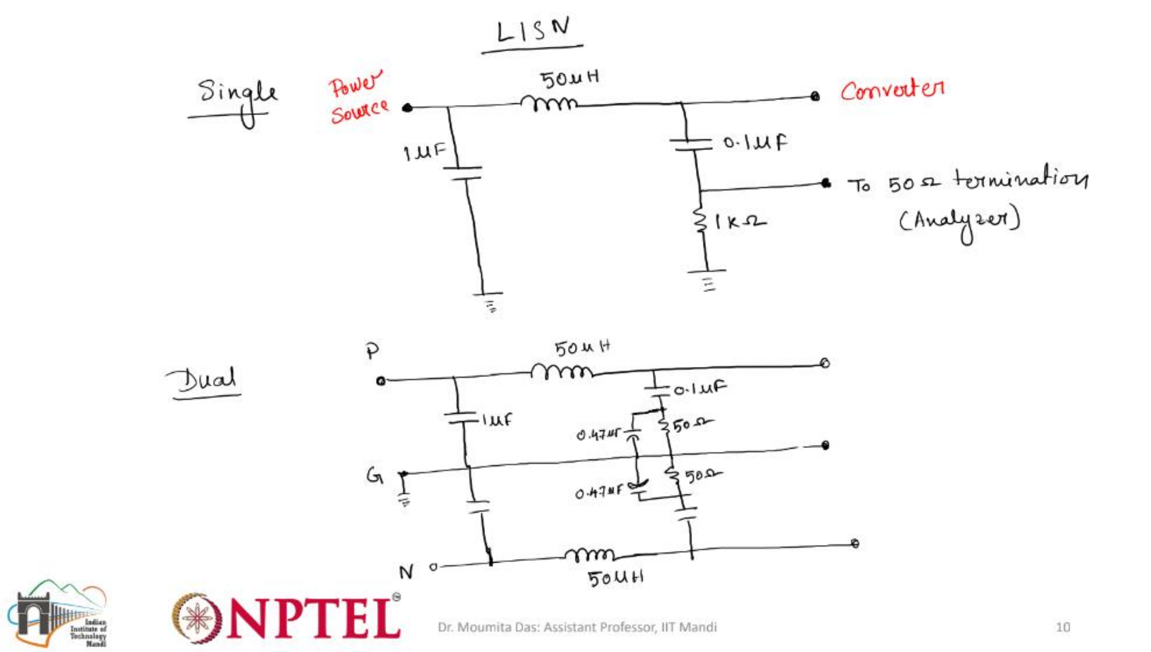

So, basically if I consider single LISN, so then it looks like, so it is having, so if I consider LISN of 50 micro Henry, so then it is having inductance which is of 50 micro Henry. But this is not the only parameter which it is having. It is also having capacitors which is of 1 micro farad.

Now it can be connected to very small value of resistance here or maybe it can be directly connected to ground. actual ground not the circuit ground so it can be connected to ground like this. Now here another capacitance will be there which is generally of 0.1 micro farad and this will be connected to very high value of resistances which will be of 1 kilo ohm.

So here if I have to connect a resistance in series with 1 micro farad it will be around 1, 2 ohm but with 0.

1 micro farad it will be 1 kilo ohm. Now this will be this point will be connected to the analyzer which is having 50 ohm attenuation. So to 50 ohm termination Which you have already seen in the previous here at the output here you can see where the 50 ohm termination is shown. So now this 50 ohm termination it will be connected which will go to the analyzer. and this will be connected to this point will be connected so basically it's this point these two different points will be connected this will be connected to source power source this will be connected to the converter or the equipment which is under test. So, in between this power source and the converter, this network will be present and this network will give us different noises.

Now, if I have to draw the circuit diagram for dual LISN, so it will be the similar, only thing is that like everything will be twice. So, basically there the positive and the negative points are connected separately. So, we will be having the similar inductance. So, this is with respect to positive line and then obviously this similar capacitance will be connected and that connection is to ground. So, this ground line will be coming in between.

you can see here so this basically ground line which will be coming in between now here this 0.1 microfarad capacitor will be there and again this like resistance with respect to this will be there and then here the same capacitance will be connected here this is 1 microfarad this is 50 And this will be connected to negative line. Sorry, here one inductance will also come. Same inductance like positive line it will be connected here.

Right. Again here the resistance and the this capacitance will be there and this will be 0.47 micro Okay, this is with respect to the dual LISN. So, this point generally goes to the 50 ohm termination.

So, here I am just showing it 50 ohm goes to this. Okay, so this is how the network looks like. So, single and dual LISN. So, this network we need to use for the measurement. So, yeah, more about this I will be discussing in the next class. So, different other noises, how it looks and what is the level of attenuation or what is the limit that is provided for EMI noise and how to design filter.

So, that I will be discussing in the next class. Thank you. So, just a minute, these are the references you need to refer for this lecture. Thank you.