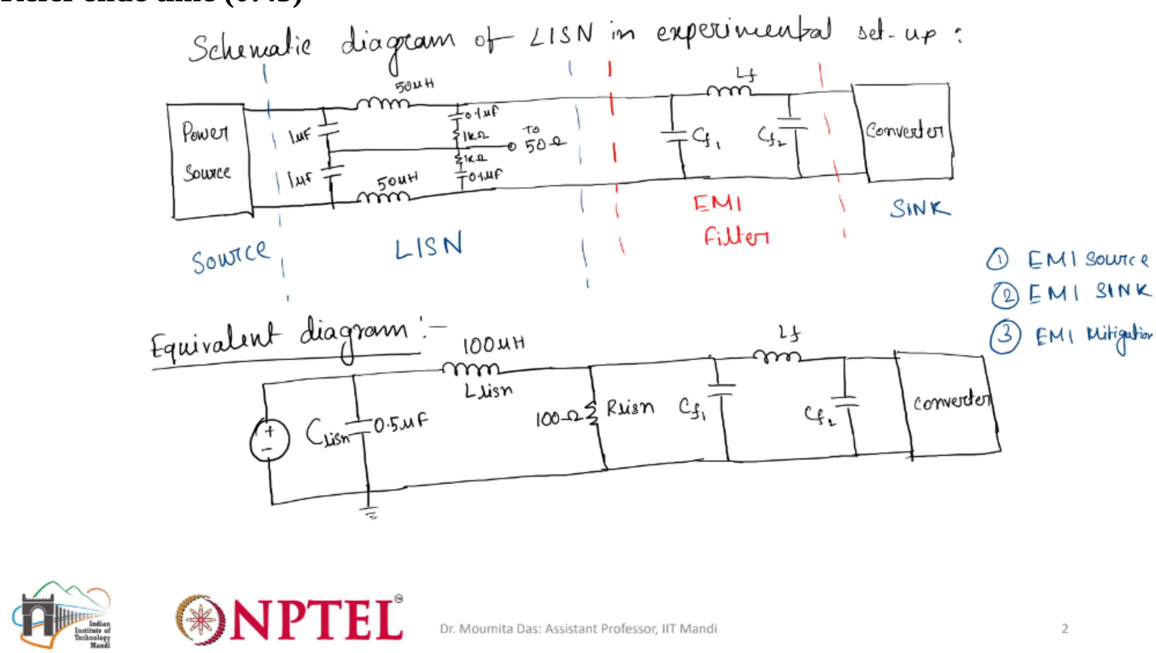
Power Electronics with Wide Bandgap Devices
Dr. Moumita das
School of Computing and Electrical Engineering
Indian Institute of Technology, Mandi

Lecture-22
Electromagnetic Interference (EMI - Part 03)

Electromagnetic Interference (EMI - Part 03)

Hello, welcome to the course on power electronics with wide band gap devices. Today I will continue the discussion on EMIs. So, in the last class I have already discussed about different types of EMIs and how to measure those EMIs. So, basically by using LISN we can measure EMIs. Then we have to separate out two different conductive EMIs. common mode and differential mode in order to design filter with respect to each EMI noise right.

Refer slide time (0:45)



So, now whenever we place LISN in any converter how the converter schematic looks like. So, schematic diagram of LISN in experimental setup. So basically whenever we have any setup that will have any kind of power sources. as I have discussed earlier this power sources can be either DC, AC anything so it can be battery also or renewable energy source it can be anything actually.

So this power source need to be connected to LISN. Now, we can use dual LISN in order to find out both the noises or we can use single LISN. So, here I am considering dual LISN which is having two different inductors which are of same value. So, here that is 50 micro Henry. then it is having two capacitors, right.

Now this capacitor is connected to a common point which is connected to another capacitor and resistor with respect to both the sides. Now the value of this capacitance R, this is 1 microfarad, this is 1 microfarad, this is 0.1 microfarad, this is 1 kilo ohm, This is 1 kilo ohm, this is 0.1 micro farad and this point is connected to 50 ohm resistance where the noises can be measured. Now this LISN output will be connected to converter directly.

If we need to connect any filter in order to reduce the noises, then that filter part will be coming next. So, let us say we have CLC type of filter, right. So, this is then will be connected to the converter itself. So now in this schematic diagram if you see, so if we divide different part, so this is with respect to EMI filter, this is with respect to the LISN, this is the source this is the sink. So, these are the different components.

So, basically if we need to consider any system, so there are actually in the equivalent circuit if we try to write down, so different system. So, basically there will be EMI source. Then EMI sink which is converter Then there will be EMI mitigation part. So, these three component will be there in any system. So, source is obviously any source, sink is the converter and the mitigation part there comes LISN plus EMI filter because LISN measures and then we connect the filter accordingly.

So, this is the complete system structure. So, now if we try to draw the equivalent diagram of this particular schematic diagram which I have shown. So, the equivalent diagram of this can actually represent let us consider the power source it is a voltage source right which is dc voltage so now this dc voltage will be connected to the capacitor which will be the equivalent capacitor of these two different one micro farad we can actually Then write it is 0 point because this is connected in series. So 0.5 microfarad.

So this is from LISN. Now there will be equivalent inductance. So they are also part of this LISN. So this will be 100 microH. Two inductances it will be actually coming in series.

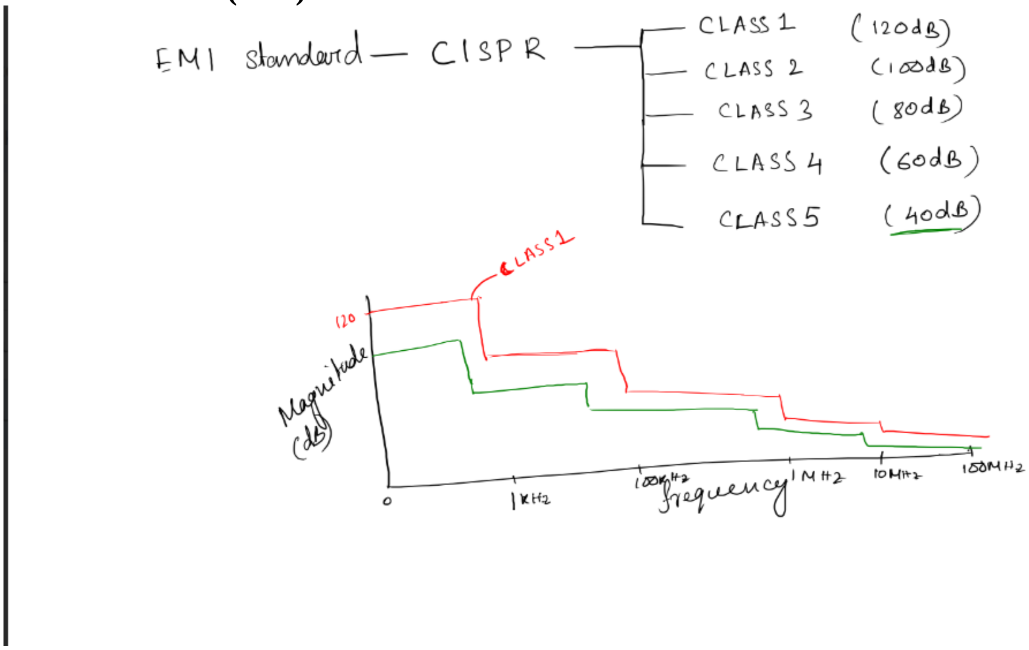
in the current path, in the power signal path. So, that is why it will be 100 micro H. So, now there will be another component with respect to LISN that is R LISN. That is 100 ohm. They all are connected to the protected ground, right.

or the circuit ground here you can see. So, basically it is connected to the negative point of the power supplies. So, that we can actually represent as ground. It is not the protective ground, it is the circuit ground. So, now this is then connected to the filter part.

So, let us say this is Cf1, Cf2, Lf. So here comes the filter part remains same because you know like it is part of the filter which is already like having component with respect to the filter structure. This is the converter connected to the converter. So, in this in the previous diagram you can see this is a dual LISN. So, different components are shown separately.

In the equivalent diagram I have shown here the equivalent component. So, this now can be utilized in order to understand the operation of the system.

Refer slide time (9:30)



So, now when we have this different like LISN and everything, when we measure the signal the noise then we need to also find out the limit so how to find out what is the limit so there is EMI standard it is actually given with respect to measurement of EMI so this is by this particular CISPR. So, this will give EMI standard. Now, it is having different classes under this CISPR.

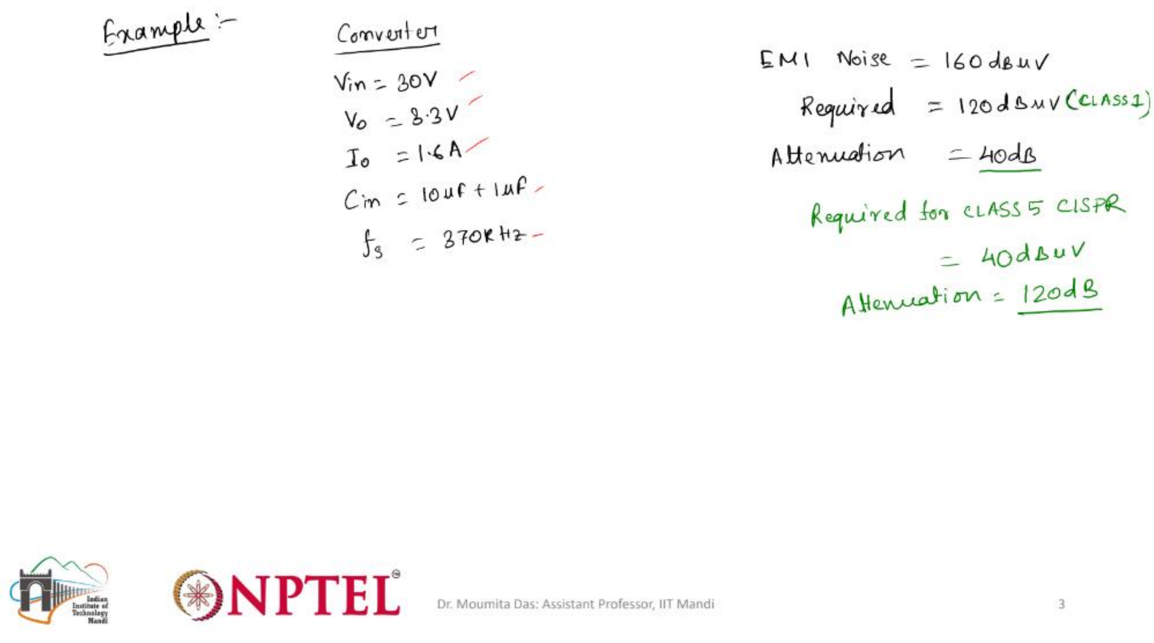
So, basically this is P, this is P, it is having let us say class 1, class two, class three, class four, class five. So whenever we are choosing any limit let's say so basically what happens if it is class 1, 2, 3, 4, 5 so class 1 means the limit is much higher let's say the magnitude of that particular limit so generally it is in the level of 120 dB so for class 2 it is around 100 dB and class 3 it is around 80 dB maximum magnitude basically when the frequency rises the magnitude also decreases so I'll just show you the structure of this DB and then let's say this is 40 dB so you can now understand so basically if it is with respect to any standard so then the magnitude versus frequency curve is So, it goes let us say 100 Megahertz, 10 Megahertz starting from 0. So, different points are there in log scale. So, 0, 10 kilohertz, 100 kilohertz, then 1 Megahertz like that these different scales are there. So, whenever we are measuring this with respect to class 1, so that means like 120 dB means like at 0 it is having maximum magnitude of 120 dB.

So, 0 it is having 120. As the frequency rises from 0 to let us say it is 1 kilohertz, 1 kilohertz then 100 kilohertz then 1 megahertz. Just giving you an example, this may not be the actual values. So, 1 kilohertz then 100 then 1 Megahertz. So, then this limit will be such that it will actually follow this kind of envelope.

As the frequency rises, this envelope looks like this. So, let us say this is with respect to any particular class, class 1. Now, as the class, it reaches to, it is in class 2, then probably it will start little below than class 1 like this. like this it will go on. So, you can see here this EMI noise has to be within this particular envelope.

If at 0 this envelope like if with the noise is beyond this particular value, then we have to design a filter. Means let us say this we have just take just giving you an example of the input and output, we have a converter.

Refer slide time (14:30)



So, while designing the filter, I will discuss in details how to design filter with respect to required attenuation. This is just to give you an example. So, if we have a converter, any converter, specification is given such that Vin equals to 30 volts.

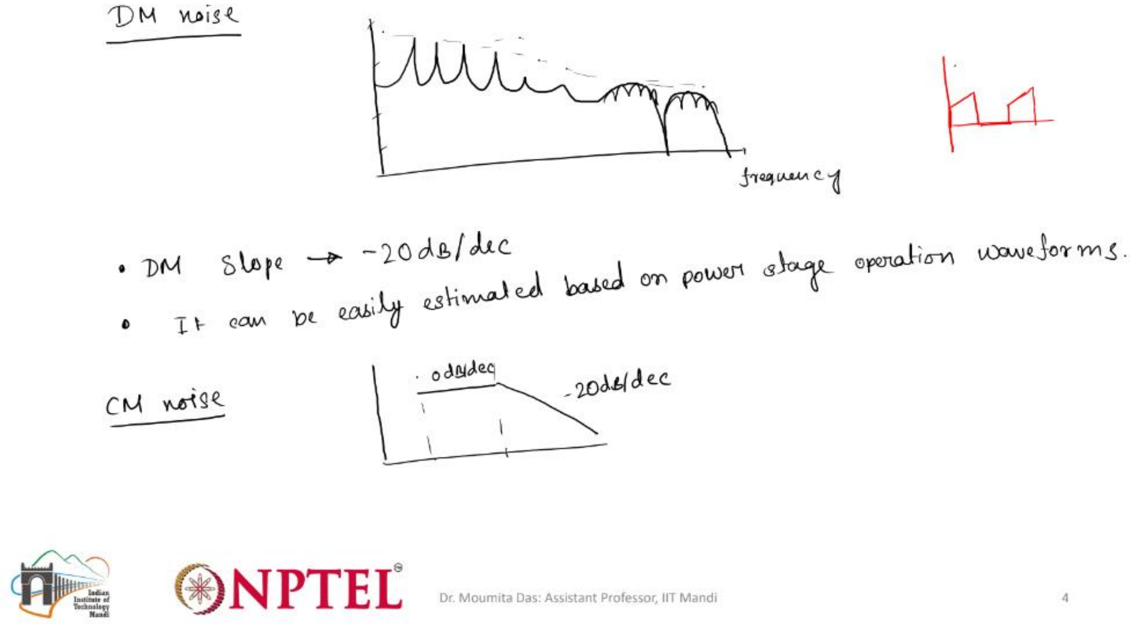
Vout equals to 3.3 volts. Then Iout equals to 1.6 ampere. Cin equals to 10 microfarad, this is the electrolytic capacitor and then 1 microfarad is the ceramic capacitor, the high frequency and the low frequency, two different capacitances. So, then fs is the switching frequency which is of 370 kilohertz. this can be anything so basically input output is important here what is given and Io so this this generally we get from any system for any system this specification is given so frequency it is depending upon the application or like based on our design we can select like what will be the system frequency and then input capacitance also we can select as per the requirement Now, if we have this converter now after connecting the LISN.

So, if we measure this EMI noise it is of 160 dB micro volt. So, this is the unit of EMI noise dB micro volt. Now, if we select class 1 CISPR limitation So, then the required noise with respect to that how much I have shown? This is like just example I am giving you 120. So, then required noise with respect to class 1 120 dB micro volt. Now, the attenuation how much is required? So, then we have to design filter with respect to this particular attenuation.

Now, this is with respect to the class 1. Now, if we select class 5, so you can see this class 5 it is given 40 dB. So then if it is class 5 then the required equals to it has to be 40 dB. right. Then attenuation how much we will be needing sorry we will be needing that will be around 120 dB.

So, then we have to design filter for that. So, this is the reason this limit selection is very important obviously as you can understand from this like if the if we can provide limit as per class 5 so that is having very less noise as compared to class 1 so obviously system performance will be much better in terms of noise again like then we have to design filter with respect to 120 decibel if if we select class 1 then the filter requirement will be 40 decibel so then i mean like obviously there has to be a optimization point so that the system size should not get affected by the emi filter size if we try to design emi filter for like 120 db obviously the filter size will be higher than that of the 40 dB. So, we have to see how much noise we can allow or what limit we can actually select for particular system which can be suitable for the application for particular application accordingly we can actually design the filter ok. This is with respect to the standard and how to select like the different standard and how to choose the attenuation with respect to that ok. Obviously we have to design filter that is like the thing what we have to consider.

Refer slide time (19:15)



So then how this different noises looks like. So if we try to see DM noise. So basically if like the actual noise anyway like I will show you later but if I try to draw the dm noise so then the magnitude will be let's say there will be like different magnitude with respect to the frequency. So different magnitude will be there. So magnitude will be having slope of so this kind of thing and it is obviously it will be having a slope something like this and it will be having some high frequency component like this.

So this slope the entire slope you can see here so this slope will be having minus 20 decibel per decade. decade so basically the slope of this DM noise okay so this slope will be there slope DM now it is easy to measure because let you know why because we can actually measure it from the power signal itself it can be easily estimated based on power stage operation waveforms. Okay. Now, CM noise, so DM noise will have much more like high frequency component. But the CM noise, it will be generally, it is like, it will be constant 0 dB per decade and also the slope will be constant minus 20 dB.

So, it is having constant flat kind of slope and the DM noise it is having the high frequency kind of slope as you can also see basically you know like the DM noise it is basically which I have already shown earlier. So, it is with respect to the inductor current profile. So, it will be having trapezoidal kind of current high frequency current which will be kind of structure of the DM noise. So, it will be having high frequency component whereas the CM noise it is mostly flat kind of noise. So, because you know like the component which goes into the parasitic capacitance.

Refer slide time (19:15)

Conducting EMI noise mitigation technique :—

1. Hardware design & layout
2. switching frequency control
3. di/dt & dv/dt reduction by controlling gate drive

Reduction at the source

4. Active / Passive filters (1^{st} order, 2^{nd} order, 3^{rd} order - - -)
5. Internal filter inbuilt with topologies

Reduction along the Path.

So, it will be having mostly the flat kind of like noise profile than that of the DM noise. now we have this noise we know how to measure this noise now what we have to do we have to mitigate this noises we have to provide solution so that the converter should not get affected we know the limit so now we have to find out what are the methods we can use in order to reduce this noise so conducting so we are here since we are talking about only DM and CM noises so we can say conducting EMI noise mitigation Right, so this EMI noise mitigation techniques, there are actually many methods. So till now I have only discussed about the filter part, but there can be different methods. So let's see what are those methods.

So first is that hardware design and layout. So the design of the hardware and the layout everything should be such that we can reduce the noise itself. So that comes from the converter design itself. Second is that switching frequency control. As I have told you as we go for higher frequency then the noises associated with it become significant because you know like the noises generally it is coming from the parasitic components due to the presence of the parasitic components. So, then this parasitic component at low frequency the magnitude of these components will not be very significant, but when the frequency increases these parasitic components become significant to the system.

So, then that can cause problem of this noises. So, that is why if the switching frequency we can control, so that this noise effect will be less. So, then we can actually minimize this noise problem. Third is that di/dt and dv/dt reduction by controlling gate drive.

So this is something comes from the driver part. So we can actually change the slope of di/dt and dv/dt how much it is going to be how fast the switch can turn on how fast the switch can turn off or how slow we can make it so that it will not affect the actual duty cycle so this comes from the gate driver part so we can actually there are actually many methods so we can easily control the gate resistance to change the slope so that can actually affect this di/dt and dv/dt obviously at higher frequency then we have to select the optimum value of di/dt and dv/dt so that it should not affect the actual duty cycle so generally it is expected to have very like this di/dt and dv/dt slope to be very fast so that the it will be close to the square wave again like if it is close to the square wave there will be a different problems So, one of the problems is this EMI noise. So, if we can reduce this or if we can control this so that EMI can be controlled or maybe EMI noise can be kept within the specified limit. So, then that can also be done from the gate drive circuit. Obviously, we have to see other part of the circuit, it is not getting affected by this.

That part we need to look after. So all these three technique which I have given here for the mitigation of the EMI noise. So that comes under reduction at the source. This is the EMI we are actually reducing from the source itself. We are not adding any filter or anything. by changing the system architecture by changing the operation frequency or operation this di/dt and dv/dt so we are actually reducing the EMI noise okay so this is these techniques can help to reduce this EMI noise to a certain point now fourth point is that by using active or passive filters this already i'm like talking it like if we need to reduce the noise then we have to use the filters Now it can be active filter or passive filter.

We will have detailed discussion of this filter design later. So passive filter obviously you can understand. So the passive components will be there and some active component will be there. So how it will be that we will see later. But now this filters like any of the filter passive or active if we can actually connect.

So then we can actually reduce. the noise. Then again these filters can be designed based on the requirement of the attenuation as I have discussed in the previous slide. So, if attenuation is more then the filter requirement will be more. If attenuation will be if it is less then the filter requirement will be less. So, that is how we can actually design the filter right.

So, now this filters are actually different types. So, filters actually it is different types of filter. we can use first order, second order, third order Based on the requirement of the attenuation that we have to select. Again this first order, second order, third order so on. So, these filters can be of different type. High pass, low pass, different type of filter, T type, pi type.

So, different filters can be there. So, that like filter itself is a big like area of discussion. So, I will not go that much in details of filter design. But I will discuss about the part which is required for EMI.

noise reduction. So, that part I will discuss in details. So, you can also go through the design of the filters part if you are interested. So, you may find different books for that. So, now 6 is that internal filter inbuilt with topologies. So this sometime what happen like if the converter topology itself is having some filters somehow sometime it can also help in the reduction of the EMI noise. So that obviously it is not part of the EMI filter but it is part of the converter.

So it helps in that process also. so this is so this is in this the reduction will be along the path okay so now this like first three points anyway like it is part of the source so dv/dt di /dt switching frequency control so this already partly i have discussed in the gate drive design so this part i will not be discussing in details i will be discussing in details about the active and passive filter part and how we can design this filter for EMI noise noise detection that discussion will be in the next class So, again the same references you can refer for this and thank you. That is all for today.