Design of Power Electronic Converters
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Lecture 68
Grounds

Welcome to the course on Design of Power Electronic Converters. So, we were in the module of Hardware Design. And till now, we have looked into the different sections of power converters, then we also got familiar with the various components that are used in power converters. Then we also discussed printed circuit boards and several issues associated with PCBs. Now, in this lecture, we are going to look into grounds. Now, let us understand grounds using the example schematic that we have chosen.

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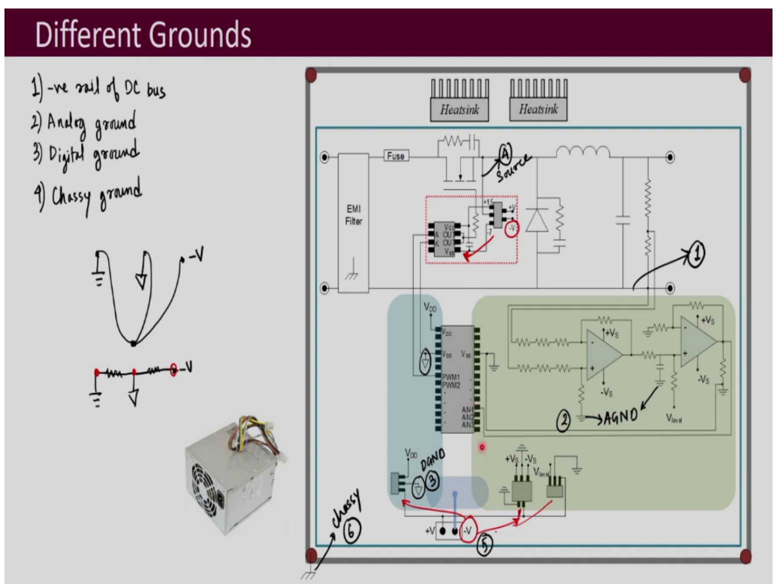

So, here in this simple schematic let us identify the different grounds. Now, I will use the word references instead of grounds because, usually when students hear grounds they have an imagination of Earth, means the one that is connected to Earth on earthing that is done that is what students relate it with the ground.

Ground here does not really mean Earth's ground that is one type of ground, ground is just the reference, reference here means one point with respect to which you are going to measure another point. So, the first one is here, just the power electronic circuit the buck converter. So, it has got this reference. So, this is the first reference the negative rail of the DC bus. So, the first one is the negative rail of DC bus.

Well of course, the bus is actually getting formed here, but the whole converter this buck converter circuit has the reference as this one. And then, here we have this analog circuit. Now, this analog circuit all the opamps all the signals are with respect to this ground. So, this the symbol that is used here represents the analog ground. So, these are your analog ground denoted as AGND. So, let us say this is the second reference or the second ground.

So, that is your analog ground. And then, over here there is digital circuit and your digital grounds. So, let us call them as DGND digital grounds. So, the third type of ground is the digital ground. Now, here only one microcontroller is shown. So, there are only two connections you will see here. But in a practical power converter, there will be many logic gates, maybe they are miniature digital ICs maybe there, so several components may be connected to the Digital Ground, means the reference for the digital circuit is your DGND.

Then further another reference what we see here for the driver circuit is this source, so this is the fourth one which is the source of the MOSFET. Because here the MOSFET the whole function of this driver is with respect to this source, so that is the reference for this driver circuit. So, that is what also you can call it as one ground here but this is not usually taken as ground because this part is normally floating.

So, that is why this is not considered as a separate ground type. Then further what we see here is that this is your isolated DC to DC converter which is used to supply this driver IC. So, the input of it is this the reference is V minus, which is the same V minus which is coming here and that V minus also is connected to all the rest of the power supply ICs which are present here to supply these low power side or the control side components.

So, V minus is another reference over here. So, let us say that that is the fifth reference that is present in this circuit. Further, what we see is that, there is another reference which is this chassis. Now, when we discussed EMI filters, we saw that there will be two types of filtering one is your differential mode filtering and common mode filter. The common mode filter will be connected to the chassis, chassis ground.

So, that is the chassis ground which will be there inside the EMI filter. Now, what is this chassis ground? So, this chassis ground is basically the one point which is connected to the enclosure. So, this is the enclosure the box the metallic box of the power converter, which is represented over here by this gray outline. And these ones these brown circles that you see represent the screw.

So, these heat sinks, this board, and various other components that may be present inside the converter that are usually screwed due to that metallic box which is your enclosure. And then finally at one point all the connections I mean the ground the chassis ground is put, so that is where your this chassis ground is going to be connected, now that is connected to your this metallic enclosure. So, now this then can be for safety purpose may be connected to the earth or may not be connected also, sometimes it does not sometimes it is connected.

So, that is the chassis ground which is connected to the enclosure of the power converter. So, that is the fourth type of ground is your chassis ground here. So, what we see here is that there are many different references and some of them we are calling it grounds, so those are the references also which I have not noted down here, they also if you wish you can call it as ground because they are also some sort of reference.

So, now, what we also observe is that that the different grounds are connected as well, like when we see this analog circuit what we observe is that all these analog grounds are there they are connected together, they are supposed to be connected together, these power supply ICs they need not to be isolated. That means the input of that and the output of those power supply which is usually these regulated ICs are used, where they are non-isolated.

So, the reference is same. So, that means your V minus and your analog ground AGND they are supposed to be connected. Similarly, your this DGND and V- this referencs is also supposed to be connected. So, that means your DGND AGND they are connected to the V- point and this V- is further connected to this one which is your isolated power supply IC for the driver.

So, like that many points many different types of grounds may be connected, some may be connected some may not be connected to each other. Let us suppose we have to connect different types of ground then how do we connect those different types of grounds. So, usually we have to connect the grounds by star connection. So, if we have this let us say your AGND ground and then we have this DGND ground and this point your -V, if we have to connect it, so then we should be connecting this only at one point using a star connection.

So, this is the right way whereas if you connect like this in this manner, so then that is not a good idea, because then this has got some impedance over here and this also has got some impedance. So, when you are laying out what will happen is that this point potential and this point potential, this point potential are actually going to become different.

Of course, you may see that here also the impedances may be different of these three traces that you are using to form the star connection, but you can try to make it as equal as possible. Now, if there is only one, ground point is only one connection point then it is fine, you can have this kind of star connection, but usually, if this kind of an analog circuit, where there are many points, which are supposed to be connected to the analog ground, I had told you before also we use planes or polygons.

So, they can be one plane or a polygon for analog ground, there can be one polygon for your digital ground, and then these two have to be connected in this manner. And this V- point then can be brought out like this. So, this is kind of a star connection which is getting formed between them.

So, this is what is recommended for your mixed signal circuits PCB layout, the mixed signal means when you have both analog and digital types of circuits present together inside the same PCB. Now, you must ensure while you are doing this layout and making the connections that you do not create a second path between any two different types of grounds.

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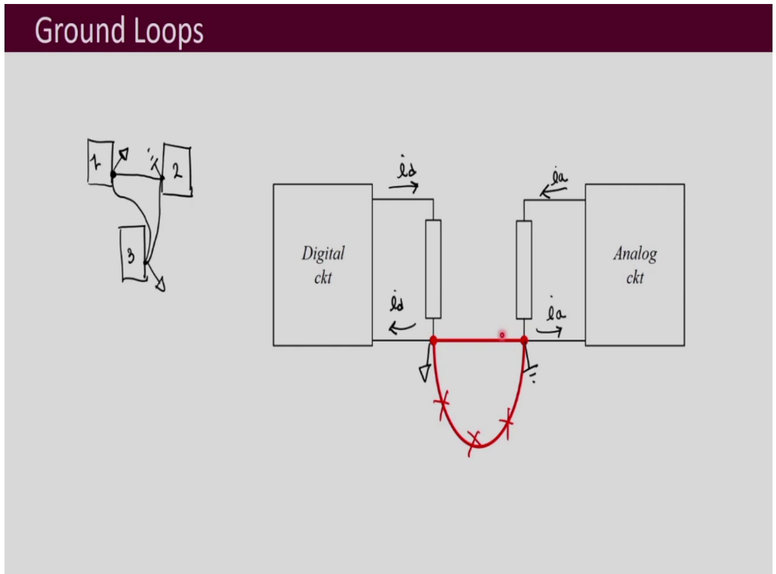

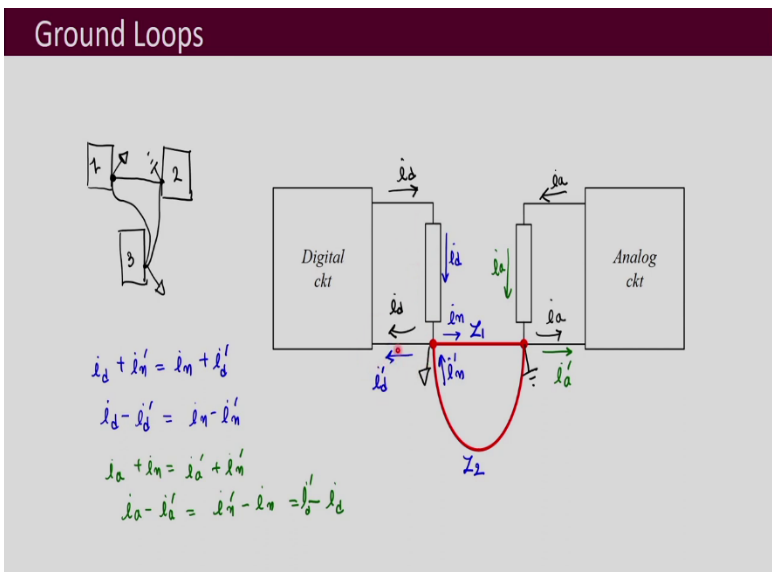

So, what I mean by that is let us say there is one IC, let us say this is a digital one. And then, there is another one which is, this is IC number 1, this is IC 2 and this is IC 3. And this is analog, one of them is analog and others are digital. So, if you create a connection like this, and then we created connection to this point, so and then further we created another path for it via like this. So, let us say this is your DGND, this is your analog ground and this is again your digital ground.

So, now, this kind of formation is called as the ground loop that means there is not just a single path between two types of grounds, but there are multiple paths, there is a second path between two types of grounds, now this is undesirable it should be avoided. Now, what is the reason that ground loops should be avoided, let us look into it. So, let us say there is a digital circuit and there is some kind of load that is impedance which is represented here and there is another part of in the same PCBs analog circuit and that is another also impedance which is denoted here.

Now, initially, suppose that this is not present. So, this is cross, this is not present. There is only single path between these two types of grounds. So, this is your digital ground and this is your analog ground. Now, let us see the current that was flowing here was i_d i digital, and the same current is supposed to return that is your i digital.

And here the current that was flowing was i analog in the circuit and the return current was your, needs to be same that is your i_a i analog. Now, if there is this part is not there, there is only a single point connection between them only single path is present between them, you know that no current can flow through this. So, whatever was flowing here i_d the same will be returning in i_a, whatever was flowing here with the same will be returning.

So, the digital circuit and the analog circuit are not going to interfere with each other. Now, let us say there is another connection path. There is not single path between your two types of grounds, so another path somehow getting formed by some means. So, let us remove it and now you have to note down that this has got an impedance, this path has got an impedance of Z_1 and this path has got an impedance of Z_2. So, now, when the currents will be flowing, this i_d current will come here and it has got what we see here there are three paths here.

Now, let us say that over here, the current that flows is i_n and here another current which is i_n' which is flowing. And so, what we will be returning here will be i_d'. So, what we can write is that by KCL that i_d plus i_n' will be equal to i_n plus i_d'. Now, why is this I have written as i_n and i_n', because no doubt that the impedances are going to be different, because there are two different paths through which the connections are getting formed in the PCB.

So, now, what will happen what we can write is that your i_d-i_d' will be equal to your i_n-i_n'. Now, let us look into this circuit. So, the current that was flowing here your i_a. Now, here there are two currents i_n coming in and i_n' leaving at this node. And so, the current that then returns let us call it as i_a'. So, what we can write further is that your i_a + i_n is going to be equal to i_a'+i_n'.

So, now, what we see is that i_a-i_a' this is equal to i_n'-i_n which is this difference you can see that is equal to i_d'-i_d. So, from this what we understand is that this difference between your analog currents what comes in here and what returns is related to the differences of currents in what comes in and what returns in the digital circuit. So, the noise of the digital circuit has now entered into the analog circuit.

So, now, the digital circuit will then start interinterfering the performance of the analog circuit. And so, this is undesirable, so that is why we should not have multiple paths between two different types of grounds, there should not be only single path should be there ground loops need to be avoided inside a PCB. So, we have to be very careful in doing the layout of grounds.

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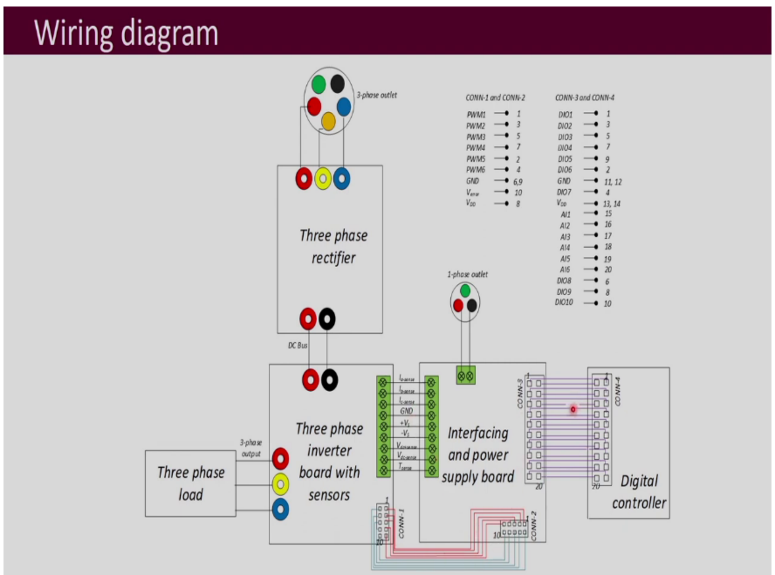

Now, this was all about the PCB grounds. Now, when you have a power converter, you may not necessarily be having only one PCB, you may be having multiple PCBs and when you want to test it or use it then different types of equipment or appliances may be connected to the power converter. So, how they are connected? Those connections can be also drawn in a schematic and that is called as the wiring diagram.

Wiring diagram is simply just the presentation of the different connections that are there between different types of equipment or appliances that may be there in a setup. So, here one example is shown here. In this you can see here that it is a three phase outlet with three phases coming in then there is a three phase rectifier, which is going to rectify and create the DC and then that DC is connected to a three phase inverter. Now, this three phase inverter is connected to three phase load. So, these are the three connectors that you can see.

Now, this three phase inverter will have the drivers and also it has the sensors inside it. So, all those sense signals will be going to to this board which is called as the interfacing and power supply board. And you can see here that there is two connections CONN 1 and CONN 2 which are connected to each other. And what we see here is that these are mainly carrying the PWM gate pulses and some other digital signals associated and the power supplies associated with them.

And then further we see here there is another one the board which is digital controller and then there are two connectors which are connecting the digital controller and this interfacing and power supply board is CONN 4 and CONN 3 and it has got various digital IOs and analog input pin in it. And this here single phase outlet, this is giving the power supply to this board. So, we see all here so many connections are there.

Now, here as well you have to check how the grounds are connected or what are all the different references that are present in your entire experimental setup or the experimental connections that you are forming. For example, here you can see that this ground is connected between this board and this interfacing and power supply board. Further what we see here is the same ground which is between your connection 3 and connection 4 between these two, and there is ground connection also over here, which is going.

So, you have to see whether there is a possible ground loop that is getting formed because of this PCB via these other external connections of grounds that are present so that you have to be very careful about. So, if not inside the PCB, if externally through some connections and through some cables, if any ground loop is getting formed or not, that is what you can check through the wiring diagram. Apart from that, ground loops may also be getting formed through the electrical outlets which have got the earth points in them. So, how that can happen let us look into it.

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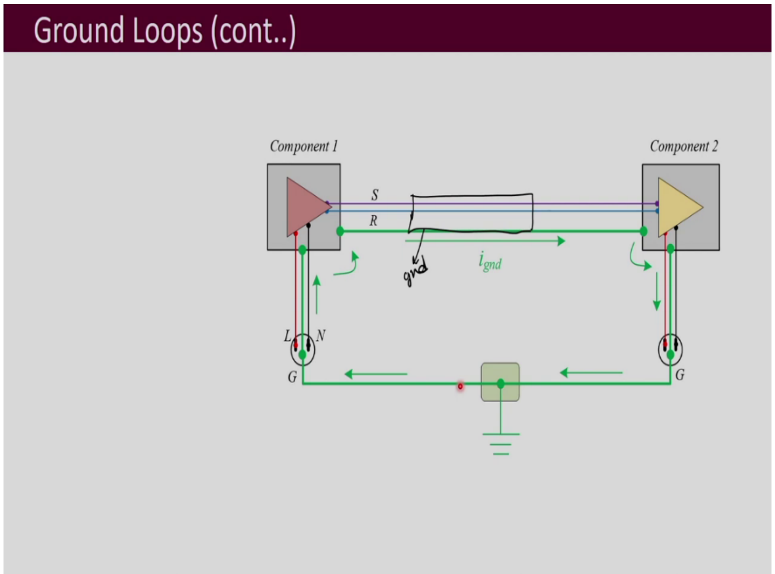

So, let us say this is one component. So, this component here does not mean your some IC or one device inside the PCB, this is a whole box, means there is let us say a PCB inside it which is represented by this triangle. And this gray box is what is the enclosure of that component or the equipment. And it is getting the supply from this electrical outlet. And this is the Earth or the ground which is connected here and this ground is there an electrical outlet is what is connected to the Earth.

And then there is another component here which is receiving some of the signals from this component one and this S and R which are sending those signals. And here also this is getting its supply from one electrical outlet and the enclosure of this, this gray box is what is the enclosure representation that is connected also to the ground. Now, if suppose this is a cable, which is let us say is a shielded cable, so with using a shielded cable, so that shielded cable is usually going to be connected to the ground.

So, what it means from there is that these two enclosures are also getting connected via this shielded cable. So, then, what we observe is that if we say that there is a ground loop that is getting formed via this ground wire the earth wire we can say that. So here, what we see is that this green wire, it comes here and through the inclusion because inclusion is metallic so it gives path for current to flow, it is a conducting material.

So, then these two are then connected and so the ground current can flow and then it can go to the second component. So, then what we see is that if there is any interference and that interference induces a voltage in this wire, so what will happen is that it will enter into component 1 it will travel to component 2, because of this connection, that is there a ground loop that has formed.

So, that is what is undesirable ground loop not necessarily is going to get formed via your PCBs or the connection of different PCBs, it can also get formed by the connection of your the way you are connecting to the electrical outlet and further whatever other cables that may be connecting to other components in the vicinity.

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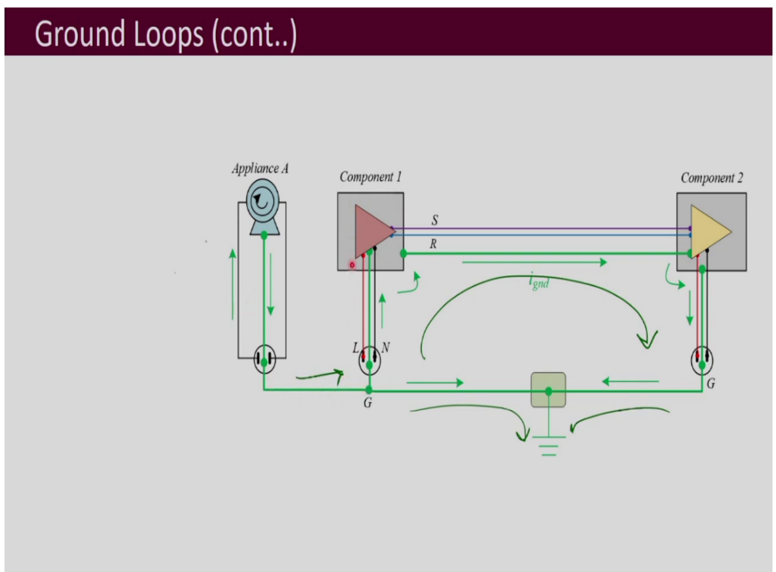

Further another example of ground loop problem is that let us say there is an appliance let us say a motor which is having some common mode currents in it. So, those common mode currents are going to find their path through this ground wire. Now, if again, these two are connected, this component 1 and component 2 are connected by this ground connection, then now, what will happen is that this cell which was first just was straight coming to the earth this current, this current which was just simply coming to the earth.

Now, it has got another path through it, it has got a second path because of this connection. And so, now, again, the impedances are going to be different for each one of them. So, some part of this current will then enter over here. And so, whatever was the common mode noise of this motor, that will start affecting component 1 and component 2 as well. So, that is why ground loops one has to be very, very careful for it may disrupt the functioning of your power converter. And so, from very beginning, you should pay attention to whether any kind of ground loop via any means is getting formed or not.

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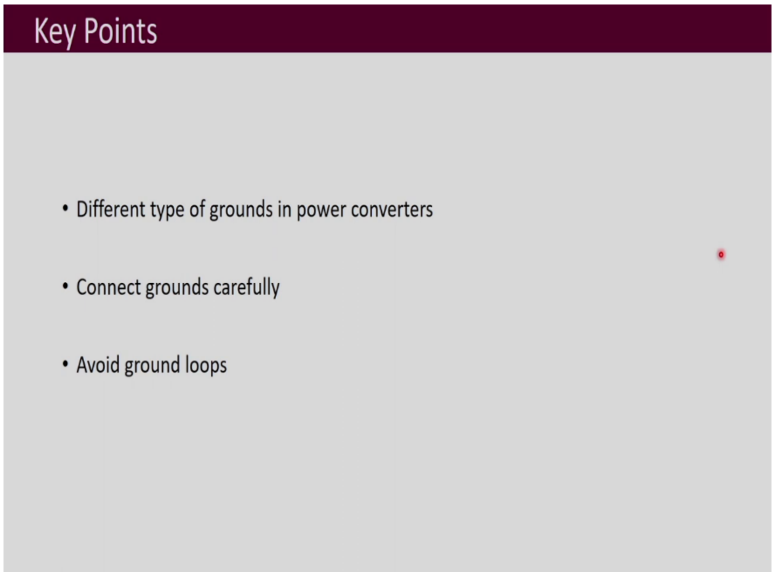

So, the key points of this lecture are that there are different types of grounds present in a power converter. And you need to connect grounds very carefully and take all measures so that ground loops are avoided. Thank you.