**Design of Power Electronic Converters**
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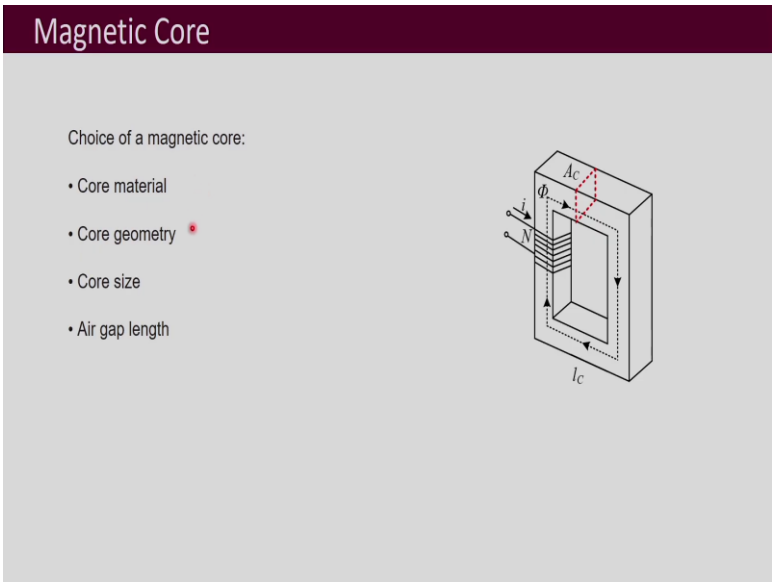
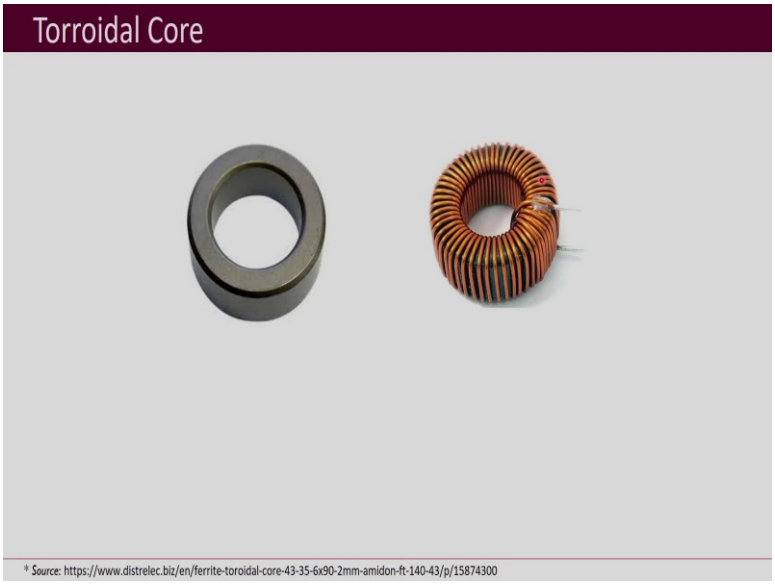
**Module: Magnetics Design**
**Lecture: 48**
**Magnetic Core**

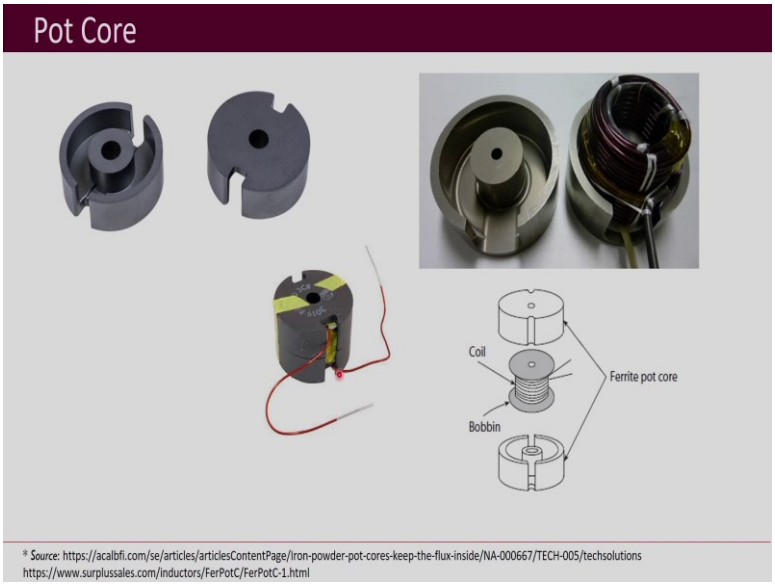
Welcome to the course on Design of Power Electronic Converters. So, today we will be discussing the magnetic cores.




Before this lecture, whenever I have done any derivation or gave you any explanation related to magnetic cores, I have shown you this diagram which is like a square magnetic core and which can be bound to make the inductor or transformer. But, this is just for your explanation purpose. The magnetic cores are available in different geometries and in different sizes. So, when you choose a magnetic core, the important thing that has to be selected are core materials, which we have discussed previously. Then next is the core geometry, core size and air gap length if it is needed.



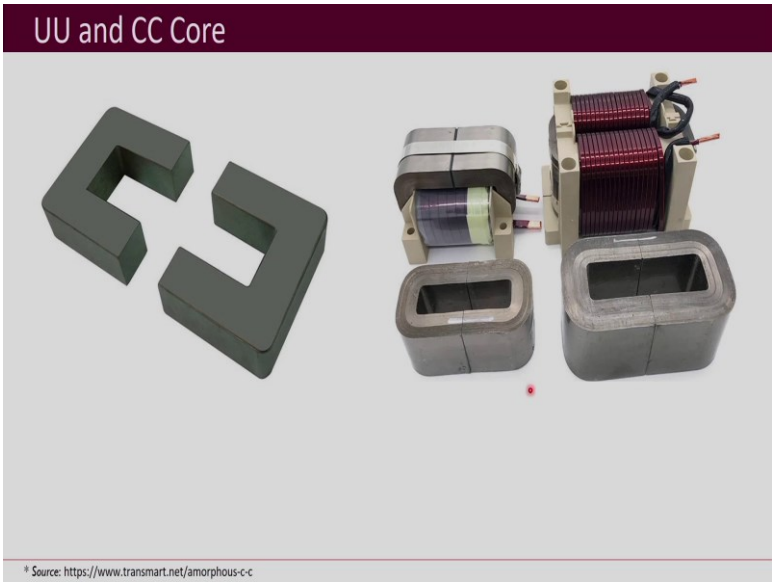

So, let us first look into the different types of the core geometries which are available. Now, I will show you pictures of only few of them. There are many different geometries of magnetic cores. So, one of the widely used core geometry is the toroidal core. So, this is the shape of the core. You can see that here it is just circular and then conductors are wound on it like this all throughout and then that makes you inductor. This is the toroidal core and it is very much used for making chokes especially for EMI purpose.




Then next is the pot core. It looks like the shape of a pot. So, that's why this name is given. This has got two parts in it. You can see here that this is one part of the pot core and top of it this other part is there and here this is shown how the conductors are wound on it. So, this is called as a bobbin which is used. This is a plastic casing.

So, this plastic casing goes inside the magnetic core and then on top of it these are the coils which are wound. So, this is like a bobbin. It is a casing which helps in winding of the conductors. So, here inside it the bobbin is there and on top of it these conductors are wound and this upper part will sit on top of this and from that these conductors will be accessible to

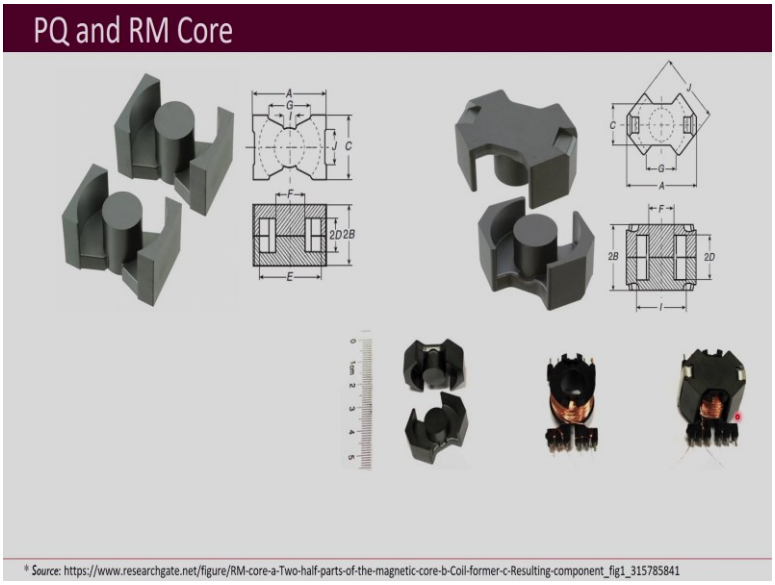
connect to the rest of the nearest of power electronic circuit. So, this is again another picture of it which is shown here. You can see that then these two are joined using some tape.




Then this is another popular core geometry which is U core. So, this is the shape of U and two of these are joined together to make a complete magnetic core and in between of them actually you can place some material and you can create that air gap. So, this is those pictures which are shown of the inductors and the transformers made out of these cores. Now, this is another core which is called as the CC core. Now, you may be thinking that they all look same, but there is slight difference that you can see the edges over here. The corners are round in this case whereas the corners over here are not so much round. So, a round corner for C core or CC core and when it is not so, then you have got the U core. Here you can see that these are then joined together now, they may be joined using some strips or some tape. So, that is the joining of them.

Then here you can see that these are the conductors, which are wound and those are these conductors which are coming out. So, these conductors are wound on this one side of this magnetic core. Whereas, for this one you can see here that the conductors are wound on both the limbs and here the conductors are coming out. So, you can make transformers out of it or if there is only one then you can also make inductors out of it and sometimes here this is done on both the sides.

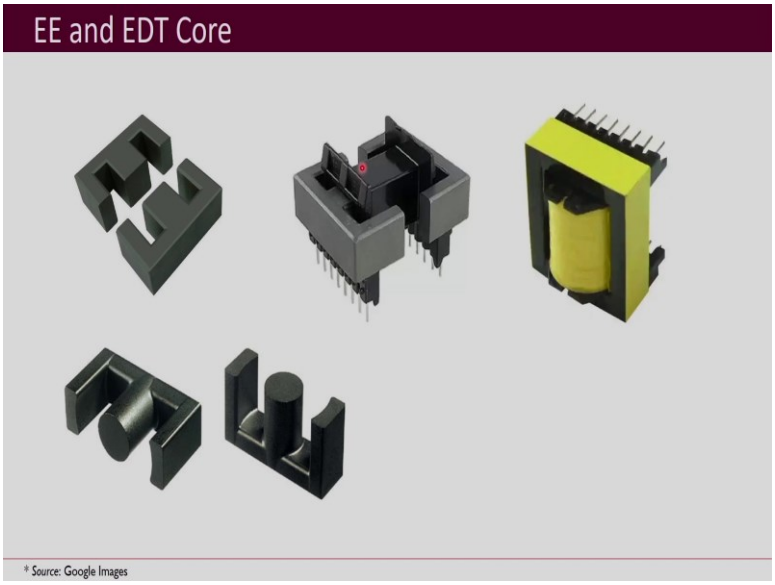
Sometimes if it's a transformer, then you have one coil, primary, which is first wound and then on top of it this is the secondary which is wound. So, those arrangements are also possible. Further to fix them there may be some arrangements which is shown here and it may be there to fix it or mount to the required place in the converter.




Then next to that this is PQ and RM core. So, this is the PQ core and this is the RM core. Now, here you again may be thinking that they are the same. But, they notice the difference. This is straight over here on the edge whereas over here this edge is not straight, it is bent. This kind of dimensional picture is also provided by the manufacturers of these cores and these are very important because you have to note down these dimensions and see whether the size of that core is going to be suitable for it or not. Choosing the size of the core is a very important thing in the magnetics design. You can see that this is the dimensional picture of the PQ core and this is the dimensional picture of the RM core and they are different and here it is shown how you make the magnetics out of it.

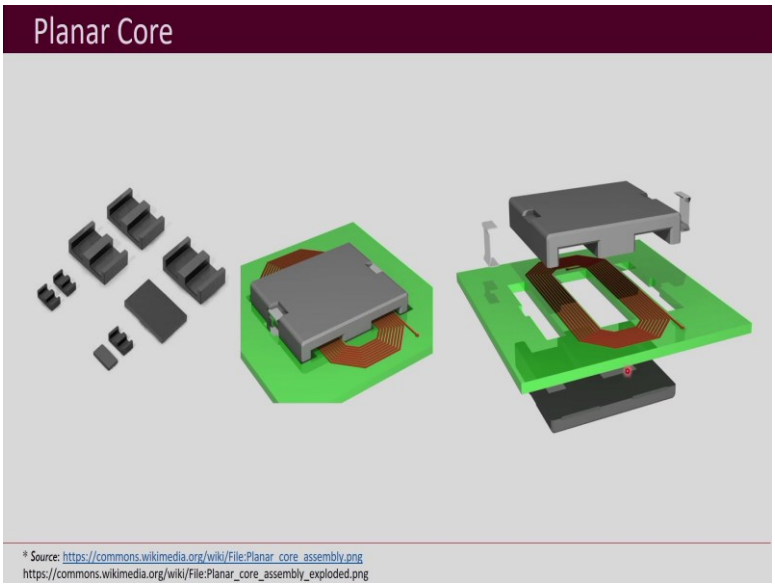
So, these are the two cores and then further this is the bobbin. So, this is a circular bobbin which is going to go inside between these two cylinders and then a wire will be wound on it and here you can see that there is some projection coming out of it. For this actually you connect the wire here and then these pins can be soldered to the PCB.

So, some of these inductors may be PCB mounted that means you can straight away soldered those magnetics into the PCB and then you place this bobbin over here with conductor and finally you put the other part of the core on top of it and then you can join them together using some strips or some tapes.



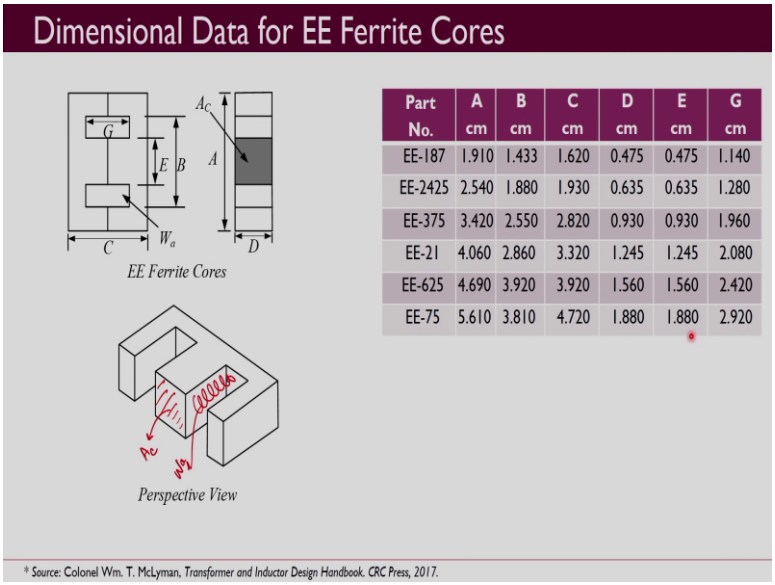

Then next a very popular type of core is EE core. So, it is a shape of an E. So, two Es are joined together and in between air gap can be given and this is the nature of the bobbin. You can see that this is the plastic casing. This black plastic casing and this itself will have the pins which you can use to mount on the PCB or anywhere else on the converter wherever it is required and then you wound the conductors over the bobbin and then you can also put insulation tapes over it and it can be many times joined by putting tapes all around the joining of the two cores. These pins of the bobbin can be outside and you can use it to mount into the places or soldered it to the PCB as required. So, this one shape is EE and another shape is EDT.

So, this is similar. Only thing is that there in between it is circular as compared to here, which is rectangular. So, here this is circular and it is a cylindrical inside. So, that is EDT core otherwise, the arrangements are similar but the bobbin is also again going to be cylindrical then instead of this kind of rectangular bobbin.




Till now I have shown you that you have the core and you put the bobbin. You put the wire over it now. There is another type of core which is called as the planar core. So, these are the pictures of the planar core. So, here these conductors are put on the PCB.

So, it is very flat. It is almost flat and parallel to the surface of the PCB. So, this green one is PCB and then you make holes in the PCB of the proper size and shape, and this planar core can go inside it from both the sides. You can see from the top side and the bottom side of the PCB, this can go inside through these cuts which are made in the PCB and then these traces can be there on the PCB. So, when these are joined together on the board itself using the PCB itself, magnetics and inductor or transformer can be created. So, that is the planar core.




| Part No. | A cm | B cm | C cm | D cm | E cm | G cm |
|---|---|---|---|---|---|---|
| EE-187 | 1.910 | 1.433 | 1.620 | 0.475 | 0.475 | 1.140 |
| EE-2425 | 2.540 | 1.880 | 1.930 | 0.635 | 0.635 | 1.280 |
| EE-375 | 3.420 | 2.550 | 2.820 | 0.930 | 0.930 | 1.960 |
| EE-21 | 4.060 | 2.860 | 3.320 | 1.245 | 1.245 | 2.080 |
| EE-625 | 4.690 | 3.920 | 3.920 | 1.560 | 1.560 | 2.420 |
| EE-75 | 5.610 | 3.810 | 4.720 | 1.880 | 1.880 | 2.920 |

So, that was the different geometries in some pictures which I showed you for giving an idea of different types of cores. I told you can explore many other geometries for yourself. Now, what are the things that you should note down from the manufacturers data sheet? First is the data of dimensions.

Now, here I am giving example of EE ferrite cores. So, this is the dimensional picture. It has got these kind of two windows in it. This is the part which we will go to join together. So, then this is one diagram and this is another diagram which is actually showing you the cross sectional area A which is this area.

So, this is the cross sectional area, $A_c$ and then further other dimensions are also given. This part of the area is $W_a$, the window area. Now, here this will be half of it and then both of these are joined together. So, that $W_a$ is the total window area and the length of it is $G$ part.

Then further the total length is $C$ and the distance between these two is this length that is denoted by $E$ and this total length is denoted as the $B$ length and then further total of this is $A$, which is given here and then this part of it is $D$ that is also provided.

So, those dimensional datas are given here. The values of them now, are given for different part numbers because these EE cores will be available in different sizes. So, different sizes are given for different part numbers. So, in case of EE-187 for example, this $A$, $B$, $C$, $D$, $E$, $G$ are given. Similarly, for other core sizes also these datas are given. You should be noting down these from the manufacturers data sheet because these are further required for designing the magnetics.

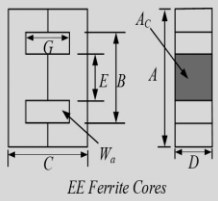
## Design Data for EE Ferrite Cores

| Part No. | $W_{tcu}$ gm | $W_{tfe}$ | MLT cm | MPL cm | $W_a/A_c$ | $A_c$ cm$^2$ | $W_a$ cm$^2$ | $A_p$ cm$^4$ | $K_g$ cm$^5$ | $A_t$ cm$^2$ | *AL mH/1K |
|---|---|---|---|---|---|---|---|---|---|---|---|
| EE-187 | 6.8 | 4.4 | 3.8 | 4.01 | 2.239 | 0.226 | 0.506 | 0.114 | 0.0027 | 14.4 | 501 |
| EE-2425 | 13.9 | 9.5 | 4.9 | 4.85 | 2.010 | 0.395 | 0.794 | 0.314 | 0.0101 | 23.5 | 768 |
| EE-375 | 36.4 | 33.0 | 6.6 | 6.94 | 1.769 | 0.870 | 1.539 | 1.339 | 0.0706 | 45.3 | 1160 |
| EE- 21 | 47.3 | 57.0 | 8.1 | 7.75 | 1.103 | 1.490 | 1.643 | 2.448 | 0.1801 | 60.9 | 1696 |
| EE-625 | 64.4 | 103.0 | 9.4 | 8.90 | 0.825 | 2.340 | 1.930 | 4.516 | 0.4497 | 81.8 | 2330 |
| EE-75 | 111.1 | 179.0 | 11.2 | 10.70 | 0.831 | 3.370 | 2.799 | 9.433 | 1.1353 | 118.0 | 3519 |

* This AL value has been normalized for a permeability of 1K. For a close approximation of AL for other values of permeability, multiply this AL value by the new permeability in kilo-perm. If the new permeability is 2500, then use 2.5.

* Source: Colonel Wm. T. McLyman, *Transformer and Inductor Design Handbook. CRC Press, 2017.*

## Dimensional Data for EE Ferrite Cores




EE Ferrite Cores

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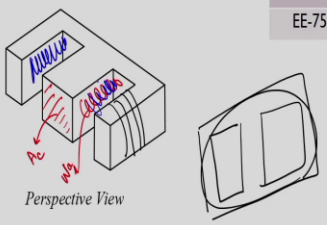



Perspective View

* Source: Colonel Wm. T. McLyman, *Transformer and Inductor Design Handbook. CRC Press, 2017.*

Other important data which you have to note down from manufacturers datasheet are design data, and these are also provided by the manufacturer. So, for those same EE cores, this design data is given. So, $W_{tcu}$ is given in *gm*, and this is the copper weight. So, you have to wind copper wires on it. So, what could be the copper weight? So, that is a copper weight which is given and then a weight of iron means basically weight on the ferrite. That is also provided by the manufacturer.

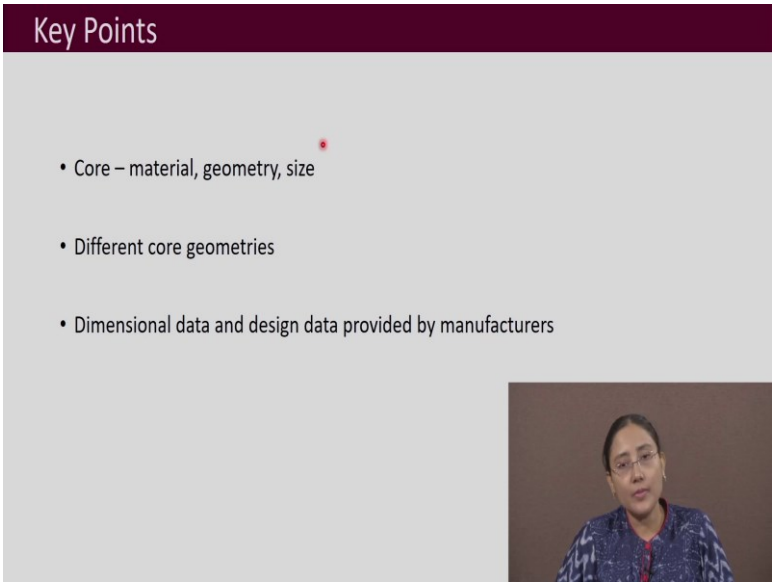
Then further *MLT* is the mean length turn. So, here you will be winding, there will be turns and these turns will have mean length. So, that is the mean length turn. Then *MPL* is the magnetic path length. I have shown this to you before also, when you have this kind of geometry.

So, then the total magnetic path length is MPL. Then next is window area. I just explained you what is window area? This is the window. So, this part is the window on which conductors are going to be wound here. So, we will be discussing this window area later on.

So, that is called as area product and this is the core geometry coefficient. We will be discussing this also later on and this is the surface area. So, what is the surface area? Surface

area means this has got the surface. So, what is the outer surface area of it? Area of that surface is $A_t$, and then this is *AL*, the unit is *mH/1K*. This is *1k*, and *1k* means *1000*.

So, that means, for *1000* how much is the H? I mean how much is the inductance you will be getting for *1000* turns? That also is a value which is sometimes provided by some of the manufacturers. So, that is given over here. Then further we left out cross-sectional area $A_c$. I have just shown this you and this ratio $W_a$ by $A_c$. This is also sometimes provided in the datasheet and you can look for that. I mean of course you can do it for yourself, but this ratio is also sometimes given.




So, what are the key points of this lecture? The key points are that for selection of the core important things are material, geometry and the size. There are different core geometries and for one particular core geometry also there are different sizes which are available. When you look into the datasheet, you should note down the dimensional data and the design data for the particular core that you have selected. Thank you.