Fundamental of Power Electronics
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Lecture - 67
Inductor example

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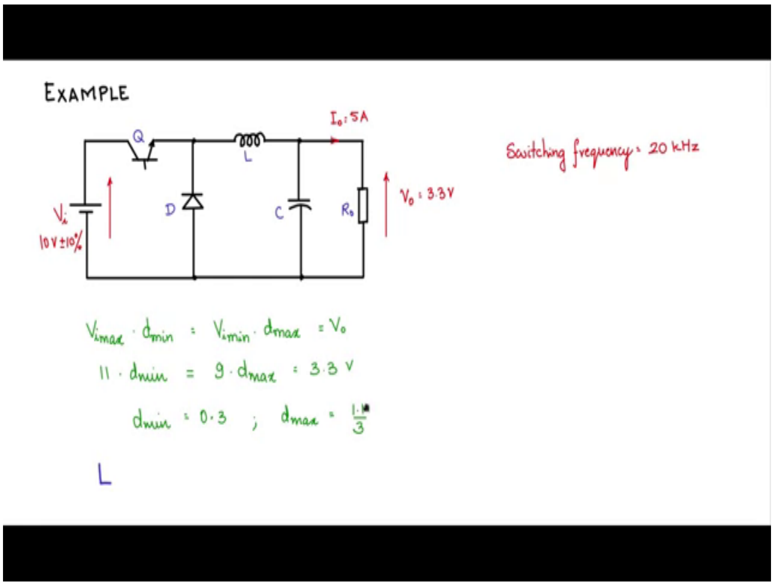

Let us now take an example and see how to design an Inductor. Consider a buck converter, we have discussed and studied the buck converter at some length, we know how it operates. This is V naught, let say V naught we want is 3.3 volts and I naught is 5 amp load requirement. The switching frequency is 20 kilo Hertz; 20000 Hertz, V i input voltage 10 volts plus or minus 10 percent varies from 10 volts minus 10 percent to 10 volt plus 10 percent. This is Q D L C and R naught and our job is to design L inductor.

So, let us try to find the duty cycle V i max into d min is equal to V i min in to d max should be equal to V naught, buck converter relationship. Now, V i max 10 volts plus 10 percent 10 percent of 10 volt is 1 volt. So, 11 volts into d min or 9 volts into d max is equal to 3.3 volts; d min from that relationship d min will turn out to be 0.3, d max is 1.1 by 3.

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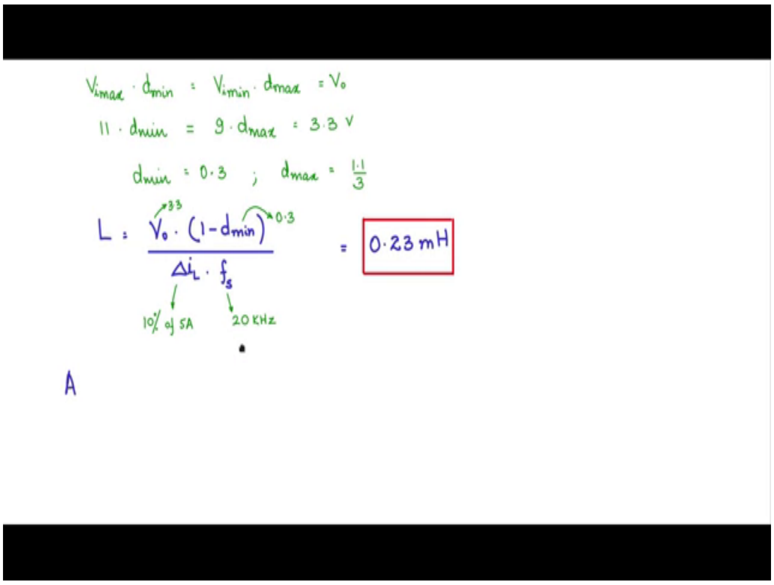

We will need the d min value, L is equal to V naught into 1 minus d min divided by delta i L into f s. While, we discussed the buck converter we had use this equation; we had developed this equation L is equal to V naught into 1 minus d by delta i L into f s. I am now including it has d min because, d min is worst case when d is minimum this value in the numerator within the brackets is maximum and I will get the larger value of L.

So, that would be the worst case. So, let us plug-in these values as 10 percent of 5 amps which is 0.5 amps. Here first is 20 kilo Hertz, this is 3.3 volts 0.3 and you will land up with L 0.23 milli Henry. So, this is the value of L, that is the first step in the design of inductor, find the value of L which we have done from the understanding of how the buck converter operates.

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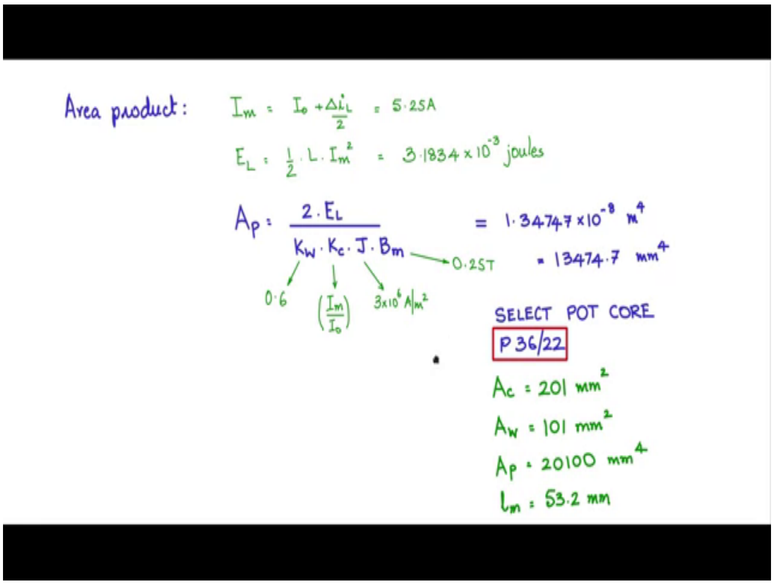

Next let us try to find the area product. So, for finding the area product we need these values, what is I m because in the energy equation we have L is equal half L I m square. What is I m? I m is you know that the current in the inductor the average value is I naught and there is superimposed on that delta i ripple peak to peak. So, the peak value will be I m plus delta i L by 2. This we know, we have studied 5 plus 0.25, 5.25 amps.

Then the energy in the inductor at peak current will be half L I m square which will turn out to be 3.1834 into 10 to the power of minus 3 joules. And, now the area product can be calculated 2 E L divided by K w K c J b m. We know all the values here, I am going to take K w as 0.6 and experienced winder will wind this, K c is the crust factor which is I m by I naught, I naught is the rms value.

You can find that out J is 3 into 10 to the power of 6 amp per meter square, B m is 0.25 Tesla for ferrites we are using ferrites. And, this will work out to be 1.34747 into 10 to the power of minus 8 meter to the power of 4. Or, it works out to be 1 multiplied by 10 to the power of 12, you will get 13474.7 mm to the power of 4. Now, look into the core table and try to select a core which will give a value greater than this.

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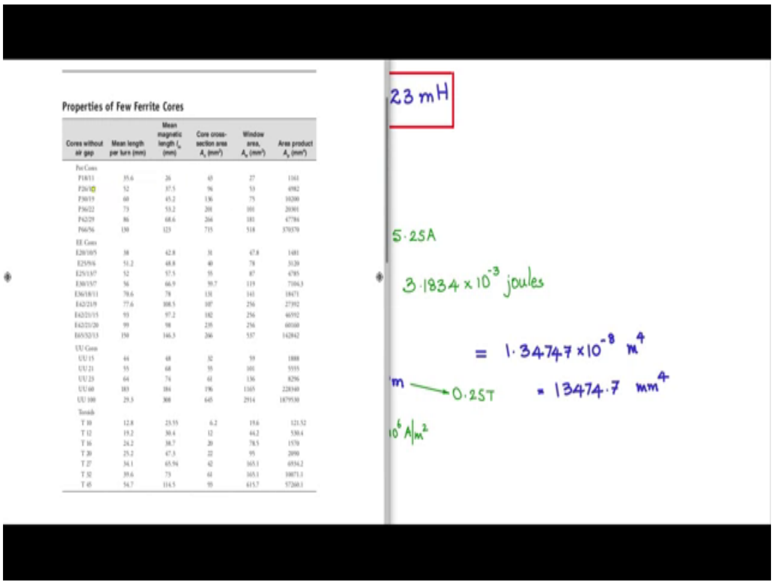

Now, let us look at the core table. Now, here is the core table I am now looking at the area product column, this is the area product column. Then look at this 1347, 13474 you are having 10200 P 30 power 19 greater than that 20301. Now, this is greater than the one that we have calculated. So, it may is good to choose P 36 bar 22 pot core of course, you can choose any other core shapes, but let us say for now for example, we choose this pot core. So, select pot core P 36 bar 22. So, this is the core that we have selected.

Now, what are the values for this core, the selected core? We have the core cross section area of 201 mm square. We have the window area of 101 mm square and we have the mean magnetic length of 53.2. So, let us write that down here; core cross section area of 201 mm square, window area 101 mm square, total area product which is the multiplication of this 20100 mm to the power of 4 and l m that is the mean magnetic length 53.2 mm. So, these are the parameters for the selected core which is the pot core P 36 bar 22.

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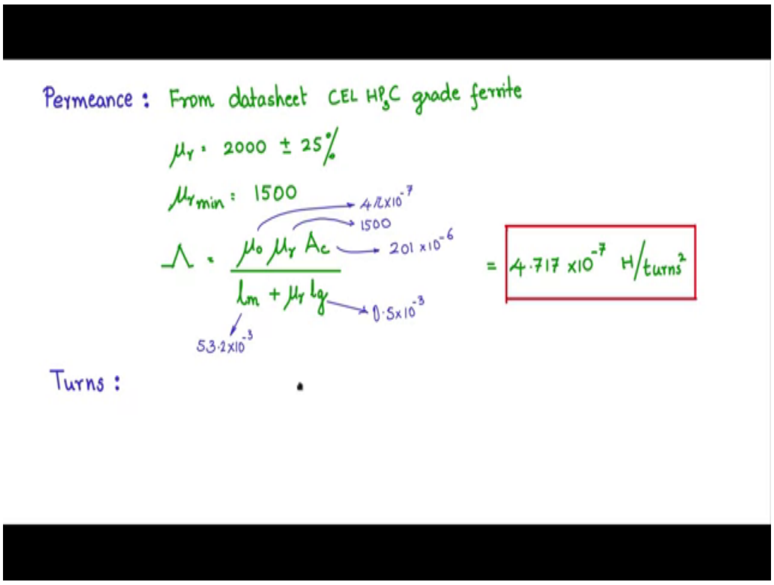

Next let us calculate the permeance. See from the datasheet of CEL HP 3 C grade ferrite, I have obtained the value of relative permeability as 2000 plus or minus 25 percent, where the worst case permeability minimum value is 2000 minus 25 percent 1500. So, I will use this minimum permeability for the calculations in evaluating permeance.

So, in the permeance; if you look at the permeance equation mu naught mu r A c by l m plus mu r l g, this is what we had developed. We know A c, we know mu r, we know mu naught, we know l m mu r l g; l g the air gap. You pick up a piece of paper or mylar sheet, measure the thickness of that and then you can plug that in here. For now, I am going to take a paper of thickness 0.5 mm.

So, plug in the values; let us say mu naught is 4 pi into 10 to the power of minus 7, mu r is 1500 as given here, A c is 201 10 to the power of minus 6 meter square, l m is 53.2 in to 10 to the power minus 3 meters, mu r is 1500 again and l g is 0.5 mm so, 0.5 into 10 to the power minus 3 meters. So, this will work out to 4.717 10 to the power of minus 7 Henry per turn square. So, this is the value of the permeance.

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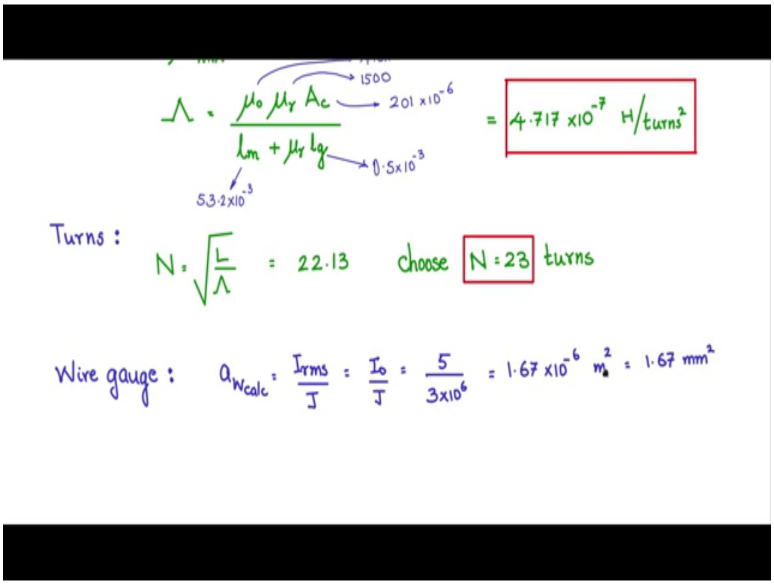

So, once we have obtained the permeance, next it is easy for us to obtain the turns; number of turns that are needed to be bound on the inductor core. This is given by the relation N is equal to root of L by permeance square root of that. So, this is 23.13, choose round it off to the upper next upper integer 23 turns and this is N. Next we have to find the wire gauge, the area of cross section of the wire be calculated I rms by J which is I naught by J. This case which is 5 amps by 3 into 10 to the power 6 which comes turns out 1.67 10 to the power of minus 6 meters square or 1.67 mm square.

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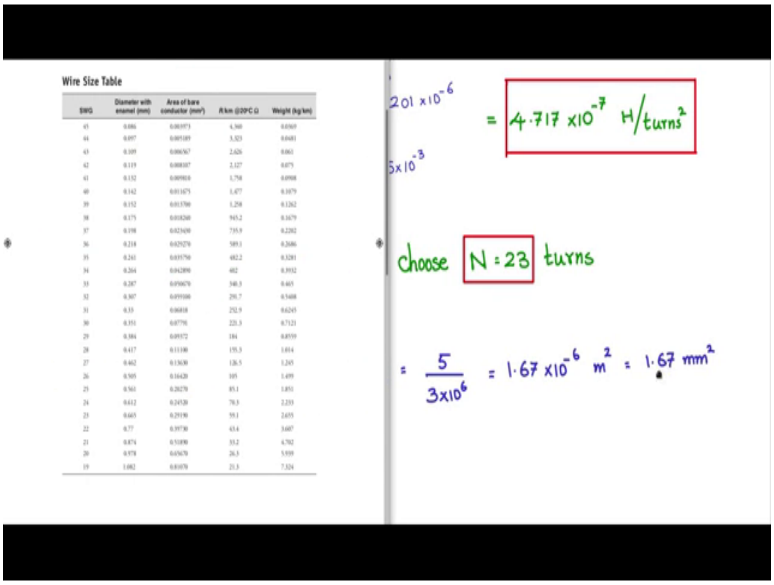

Now, look into the wire table. So, look into the wire table; we need to look at a wire bare conductor area having greater than 1.67 mm square.

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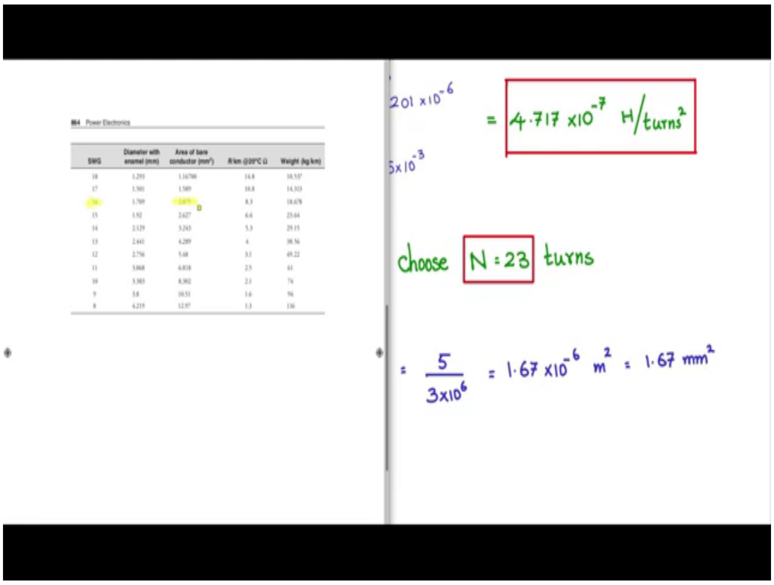

Let us go down this and you see that here SWG 16. Now, here in this row we will find SWG 16 which has bare conductor area of 2.075 mm square greater than this. So, pick that value.

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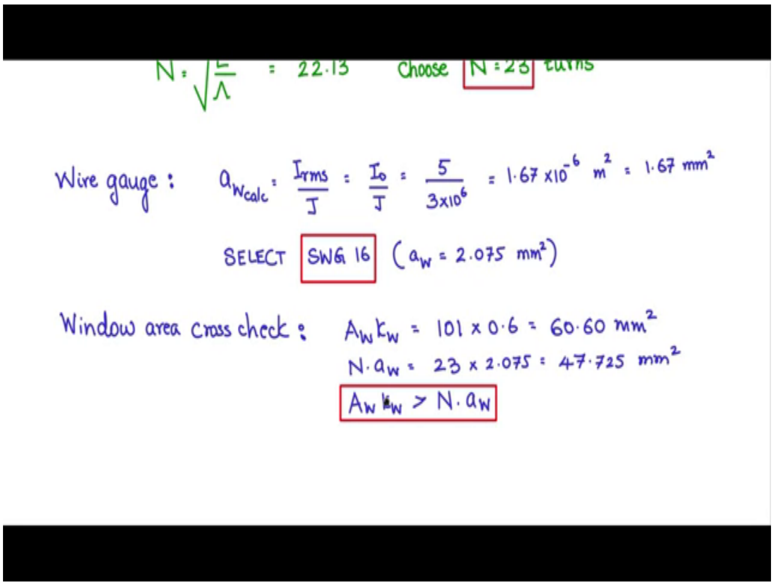

So, now let us write down select SWG 16 which has a wire cross section area of 2.075 mm square. SWG 16 is selected and this has to be bound on to the inductor core which we have chosen P 36 power 22. There is a last check that we need to do what is known as the window area check, to see if the windings will fit into the available window area.

A w K w is 101 mm square into 0.6 which 60.60 and N into a w that is wire cross section as we have read from the read out from the wire table is 23 into 2.075 which is 47.75. And, you see that A w K w is greater than N into a w and therefore, the inequalities satisfied. And, you know that this number of turns or this gauge will fit into the available window area. And therefore, the design is successfully completed.