Architectural Design of Digital Integrated Circuits
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Lecture - 62
Low Power Digital Design Tips

Hello everyone. So, welcome to the course on Architectural Design of Digital IC Design. So, we have already seen that architectural optimization for speed power area. Now, we will see that for low power design today we will see for low power design, how to make our system for low power application; how we can do what are the methodology or what are the techniques are already there.

So, before to start with that we have to know why we have we actually need for low power design low power digital design. The primary reason for this is that now we are actually we are in the era of; that means, this machine learning or artificial intelligence where we need more processing powers, but at the same time we need the device should be mobile. So, that it the systems or the device should be battery driven.

So, battery driven system means it will have one actually that power capacity or the performance it is limited by the capacity of the battery. So, that is why; so, whenever we are running or you we are using the system, at that time if I use lesser energy or if we use low power. So, at that time I can use that particular electronic system design or that particular electronic device for a more time.

So, that is why we need to more actually concentrate on this low power digital design and before to start with this low power design, we have to know how many power factors are there which effects the digital circuits or which consumes the power whenever the circuit is basically running on the hardware.

So, today we will see those things what are the power requirement or what are the power actually consumption is basically taking place in case of our this digital VLSI system design which is the CMOS based system design. And, then we will see how we can make that energy consumption or that power consumption for the low power application.

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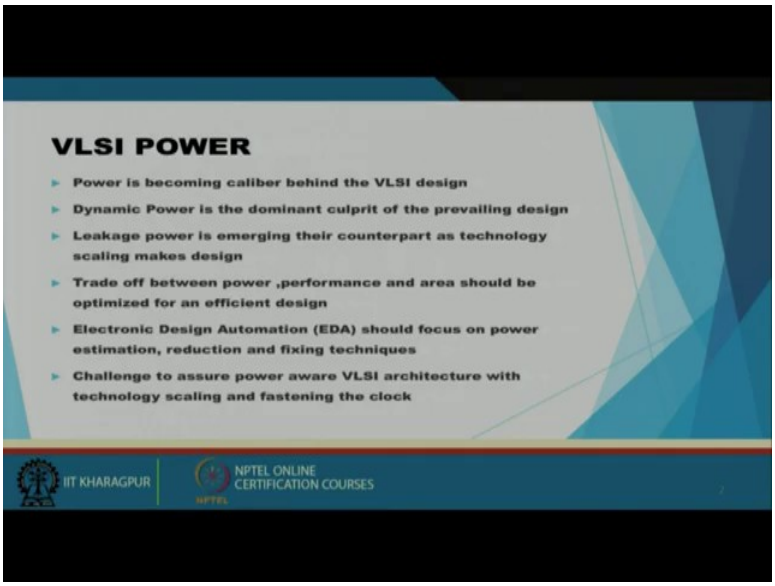

So, this VLSI power. So, power is becoming the caliber behind all the VLSI design system design. Now, dynamic power is the dominant culprit of the prevailing design. So, there must be actually various power, what I already said is that, then this the other power factor is this leakage power; what is leakage power that we will see later.

So, leakage power is emerging their counterpart as technology scaling makes the design. So, now a days day by day we are miniaturizing thus; that means, that we are reducing the technology to miniaturize the system. When that means, that means within a small area we want to integrate more and more number of transistors on to that particular area. So, what that is why we are day by day what we are we are changing the technology; that means, if we use 90 nanometre technology and now if we use that 7 nanometre technology or 3 nanometre technology.

So, at that time; that means, the factor the same area will be actually if we use 3 nanometre technology at that time and if we use 90 nanometre technology to implement the same design. So, at that time I will get the area reduction that will be of 30 percent. So, 90 divided by 3 means 30 percent area reduction I can do by using this same design implemented using 3 nanometre technology.

But at the same time it is not that we will gain the area, but at the same time whenever we are day by day whenever we are basically reducing this technology node this leakage power is becoming more and more dominant. So, leakage power is means that comes

because of this the device property itself ok. So, we will see in details later, then there is a trade off between the power performance and area should be optimized for an efficient design.

So, as I said that whenever we will actually consider for low power application; let us say I just want to have the low power design. So, at that time whenever I will focus on that power; that means, as my major constraint. So, at that time it may happen that I may lose the performance in terms of area or in terms of speed by which there I will compromise and I will get the gain in terms of power saving.

So, those type of trade offs are already there because this power area and speed all are basically mostly there have a relation like if I increase the speed or if I; that means, all the time or in all aspects I cannot gain. Sometimes it may happen that I can gain or this is my major constraint, but at the same time I have to compromise somewhere else. So, that is why there will be actually for an efficient design if we have found out the optimal position or optimal; that means, amount of power consumption the area consumption as well as the corresponding speed.

Then the design should be called as an efficient system design. Then the electronic design automation should focus on power estimation reduction and fixing techniques. So, like this whatever that architectural optimization or that in terms of speed or power, all these are now this; that means, the latest EDA tool they can do most of them just by running the algorithm in the algorithmic form; that means, you do not have to bother about that.

I need this architectural optimization and then, but it is that the EDA designer, EDA tool designer whatever that manually I can do they have tried to do that automatically; that means, the logical optimization. If we if I know that this is the logic to do the logically optimization. So, in the algorithmic form in the EDA tool they have already provided whenever you will do the synthesis.

So, synthesis means your logic part will be converted into the corresponding gate level. So, at that time they run that architectural optimization, gate level optimization, logic level optimization. So, every optimization they process and they come up with the optimized expression which will be converted or which will be represented through gates. So, that much the EDA tool has developed so far that they can do it automatically.

But the thing is that the in in timing also they can do they can apply using this static timing analysis whatever we have seen that manually whatever I can calculate, but is if there are let us say if there are millions of paths manually to check each and every; that means, hand handcrafted calculation of each of these paths that is not at all possible.

So, at that time, but if the tool does the static timing analysis then it actually computes each of these it takes each of these paths and it computes it the timing analysis for each of these paths and then it shows you as a report. So, from there if it violates any of your constant timing constant, at that time it will immediately report that this particular path is violating this this this ok.

So, that is why this this area optimization as well as the timing optimization both has been automatically done using the EDA tool, but more actually more of these techniques should be incorporated in the EDA tool. So, that manually also I can in the architectural; that means, optimization changes or some logic level changes or some device level changes I can do the that to achieve the low power.

But if we just put some automated kind of things to basically reduce the power consumption on the circuit, that only can do using this EDA tool, but recent days actually EDA tool, they automatically you can provide some of the low power technique or you can use some of the low power technique to. So, that your design automatically it will be becoming low power applicable to low power applications or low power VLSI design.

So, then the challenge to assure power aware VLSI architecture with technology scaling and fastening the clock ok. So; that means, this all these are basically related to this power consumption in VLSI. Now, then why actually if you can ask me one question is that then everything is automated then why we have to know all these; that why we have to know or why we have to be bothered about that what is the power consumption what technology or what; that means, tips I or what techniques I can use to reduce the power or what techniques I will use for optimizing the gate levels or these logic levels.

The answer for this question is that this EDA tool has already developed mean some of the engineers or some of the designers has already know this factor know this; that means, this he or she has the knowledge. He has developed this kind so that in the next time you can run it automatically; that means, if you provide these constraints. So, that tool will automatically try to optimize your circuit based on the corresponding logic.

So, first if you if you are a designer. So, then you have to know what is happening otherwise if you do not know what is happening then at that time or how we have to do at that time whatever the tool will give you the solution you have to rely on that. So, it is not that automated things are all the time it is correct it will give you the optimized circuit it is the best solution it will provide to you, but manually you can check that I am getting if you think that you are getting the proper; that means, you are getting the optimized circuit.

So, at that time you are satisfied then go ahead with that otherwise if you have the knowledge you can verify that I still more there is a more options to do the optimization at the logic level or at the architecture level or at the; that means, this gate level. So, at that time you can do that manually and you can just make your design much more efficient than the automated one ok. So, that is why we have to know what are the tricks what are the techniques we use for optimization in terms of area power as well as the speed.

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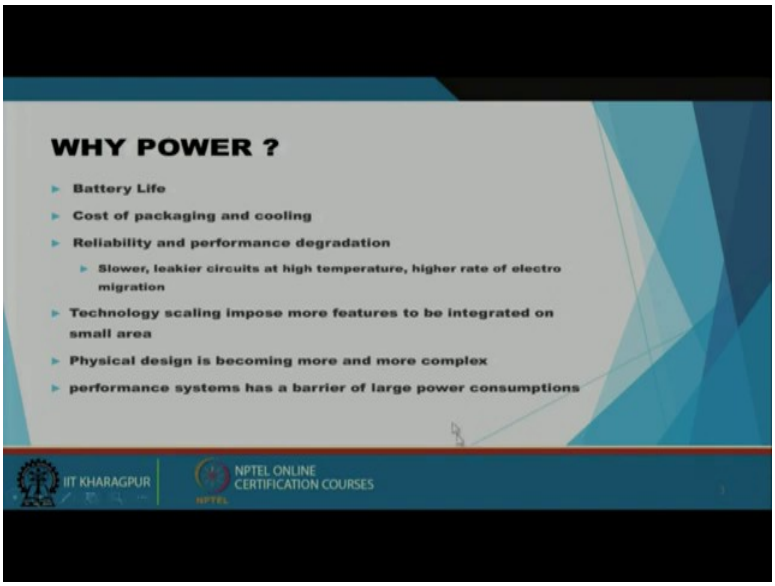

So, then why actually this power consumption is very much important or why we should know about this or we should we should be bothered about this power consumption in VLSI system design, the primary thing what I said is the battery life. So, more of that system now actually the all the systems basically we need is the miniature system. So, miniature systems they have a limited power budget; that means, sometimes for these for

like actually if we have constant power source at that time we can just; that means, we can we cannot think of the power consumption it should be low power or something else.

But the thing is that, but still actually if we are having that constant power. So, still we have to be bothered about power consumption why because nowadays if you see; that means, that if you have installed that air cooler air conditioner or if you have installed that fridge or if you have installed that washing machine. So, every of these system basically comes with the electronic system inside of it.

So, if the power consumption for those electronic systems is more at that time the electricity bill will be higher. So, that is why you might be seeing that every of this particular heavy electronics product they comes with some; that means, energy rating. So, energy rating means what actually that is the information about the power consumption. So, more the; that means, if the 5 star energy rating the device cost is higher three star energy rating, device cost is much lower. So, lower the energy rating lower the price.

So, why because at that time whenever you will use low power device. So, at that time it needs some extra protection or extra care while you are designing those electronic system. So, which makes the price higher. So, that is why it is not that whether that is constantly power driven or it is battery driven that does not matter, but every electronic system. We should focus on the energy consumption or the power consumption should be lower then the cost of packaging and cooling.

Because actually if we what is the meaning of this line is that suppose whenever suppose if you are using mobile phone and you are playing some games if your processors this graphics processor or your that mobile processors. If it is taking too much of energy too much of energy if it is consumed. So, at that time the corresponding the circuit will be also heat up more.

So, whenever this circuit will be heating up more to avoid the burning case of this those particular IC you need the packaging and the cooling of those ICs. So, at that time if your energy consumption is more your heating will be more. So, heating more means you need some advanced technique for cooling and advanced technique for packaging which will increase the cost again. But if you reduce the energy consumption inside of the circuit so, at that time heating will be less.

So, with hm; that means, at that time it is not that costly packaging costly cooling system you have to use. So, then the other point is that reliability and performance degradation. Slower lackier circuit at high temperature higher rate of electro migration means what again you if you just see that ok. Sometimes you might be notice that if you if you are suppose you are working on your laptop. So, if the laptop processors is basically overheated it does not get to bypass the air from your back of the laptop.

So, at that time you will be filling that your laptop is basic basically becoming very much slower it becomes laggy so; that means, as the temperature is increasing inside of the chip or inside of the printed circuit board which is placed on your laptop. So, which is basically making the performance degradation.

So, that is why at that time whenever this performance degradation is happening. So, at that time the point of reliability also comes; that means, it may happen that the whole circuit is basically burned because of this overheating. So, that is why and sometimes you might be seeing actually there is some burning; that means, fire also it can ignite whenever there is an overheating case.

So, that is why you might be seeing that in every server room they have a very sophisticated cooling system. So, that as the data are processing all that for huge time huge amount of datas are processing at the server; that means, 24 cross 7.

So, that is why it creates a lot of heat. So, that is why we need a very sophisticated cooling system at the server rooms. So, these are the things. So, that is why power consumption is one of the major; that means, aspects which we have to consider while we are considering VLSI system design. Then this technology scaling impose more features to be integrated on small area physical design is becoming more and more complex performance system has a barrier or large power consumption ok.

So, all these particular points make us to be more careful or to be bothered about the power consumption in VLSI circuit system design.

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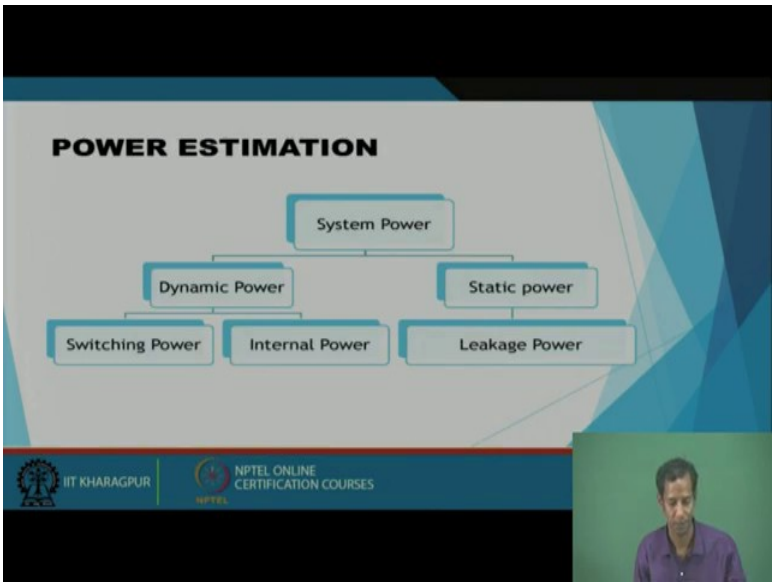

So, then how we can estimate; that means, what are the sources of power which are there inside of this VLSI digital circuit design. So, the system power we can calculate it basically dominates by two type of power; one power is this dynamic power another power is the static power.

So, in dynamic power you have two type of power; the one power is basically the switching power another one is the internal power in static power it you are having this leakage power. So, now, what is this switching power, the switching power is that whenever your design or your system is in the idle mode. So, at that time nothing is happening inside of the chip; that means, at that time the switching activities are not happening inside of your IC.

So, that it does not consume the corresponding it is not at that time the power consumption will be much more lower, but at that time this static power means what it is the internal power which is required to drive or the because of the internal property of the MOS this particular this internal power and the leakage power they are already there it is something like that if you take one example suppose you have charged your mobile phone ok.

So, now whenever you are talking or if you are using via; that means, internets and you are talking you are playing games. So, at that time the battery can run for let us say 20 hours or 24 hours, but if you do not touch if you do not use the phone, but still actually

fully charged and then you just place it somewhere after 7 days do you think that the 100 percent charge will be there. No why because of this internal this internal power and the leakage power is already running.

But, at that time what happen it can run for let us say 7 days or 15 days to drain that 100 percent battery life, but some energy or some power is already consumed internally though it is not running any applications or anything it is doing. So, because of that, that power source is known as this internal or leakage power and majorly whenever we are working the switching power will be the dominant one. And, this is the major power contribution to the to overall system power consumption ok.

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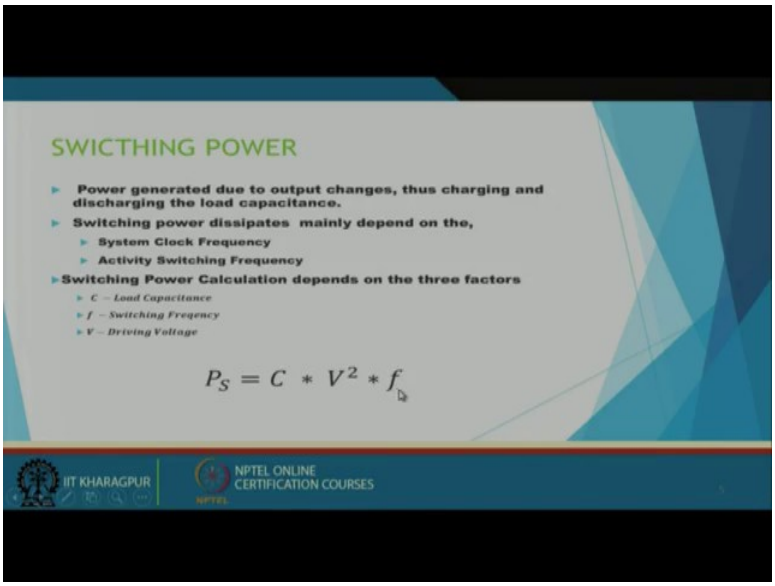

Then actually the switching power is that the power which is generated due to output changes and thus charging and discharging of the load capacitance. Switching power dissipates mainly depend on the system clock frequency and activity switching frequency. Switching power calculation depends on three factors the capacitive load the switching frequency and the driving voltage. The equation for the switching voltage is that C into V square into f.

So; that means, it is again if you just take one example is that suppose while you are walking at that time how much energy you are consuming and while you are running at that time how much energy you are consuming both are not same; that means, whenever we you are walking at that time you consume lesser energy whenever you are running at

that time you are consuming more energy. The same things also actually same fundamentals work here whenever your system clock frequency is higher; that means, you are sampling the data you are working with your data at very higher rate.

So, at that time your power consumption will be more if your system clock frequency is slower. So, at that time the corresponding energy consumption will be lower then again depending on this capacitive load; that means, while you are delivering more power; that means, your load your capacitive load if it is more at that time you will consume more power; that means, at that time your driving power should be more so, that you can distribute the power constant output to the other circuit. So, that is why you need more power consumption at that time rather than if you are using the capacitive load lesser.

Then again the third part is that what voltage means you need the supply voltage which is nothing, but the VDD. So, if you increase the VDD. So, at that time your power consumption will be more just like a means actually if we use 1.8 volt at that time the power consumption will be affected by v square.

Whenever you will use for lower voltage let us say 0.85 volt or 0.5 volt. So, at that time you will be consumed lower power as because this particular switching power is proportionate to the voltage square. So, any of this capacitive load or this voltage or the frequency if you can reduce, at that time you will get the corresponding; that means, benefit in terms of power consumption.

So, here you see this power consumption and the frequency means what it has proportional. So, power consumption will be increased if the speed of operation of your circuit that is increased. So, it is a trade-off we need operating speed of our system that will be more, but at that time it also increased the power consumption switching power consumption of our circuit.

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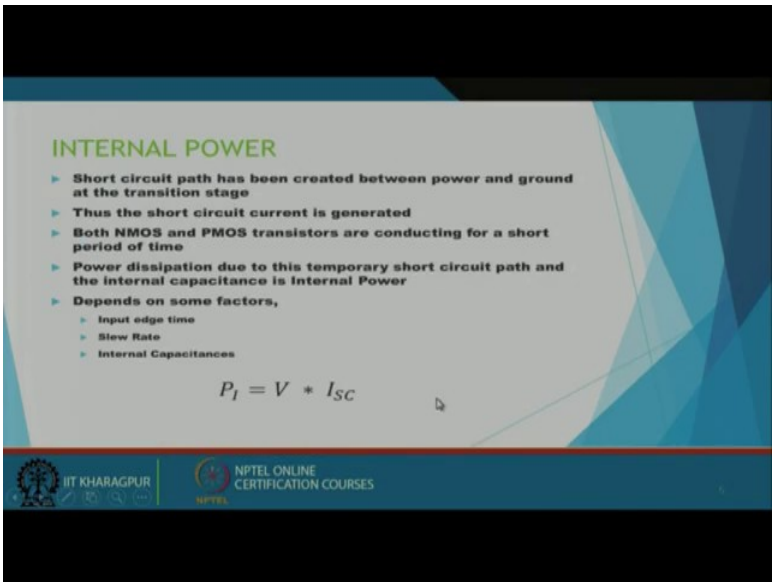

So, then the internal power internal power is the short circuit path which has been created between the power and the ground at the transmission stage. Thus, the short circuit current is generated and because of this short circuit current this both this NMOS and PMOS transistors are conducting for a short period of time; and which consumes the power dissipation due to this temporary short circuit path and the internal capacitance is the internal power.

So, depending on the factors the input edge time, slew rate and internal capacitance the internal power should be the voltage multiplied with the short circuit current. So, a short circuit current basically depends on what. So, what is short circuit currents short circuit current is the basically the connection between the your power supply and the ground where NMOS and PMOS are for a very short time they are being making that particular path; that means, from ground to source.

So, sorry that power supply VDD to ground. So, because of that you will have one short circuit current and because of that short circuit current you can consume some of the internal power with respect to this voltage into the current is nothing, but your power. So, depending on that we can get some of the internal power which is if the system is not at all running, but still there will be this power all the time.

So, thank you for today again we will see some of the other features of this power consumption first mainly we will see what are the power sources are there; that means,

what are the affecting factors for this power consumption in VLSI circuit then we will see the techniques how you can basically reduce the power consumption in digital VLSI systems all that.

Thank you for today.