Digital Control in Switched Mode Power Converters and FPGA-based Prototyping

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Module - 12
Hardware Case Studies of Advanced Digital Control Techniques and Course Summary
Lecture - 118
Industry-Driven Architecture for Digital Control System Solutions in SMPCs

Welcome. In this lecture, we are going to discuss some industry is driven (Refer Time: 00:31) digital control architecture and their system solution for high-power locations and we want to link our course concept with this kind of architecture.

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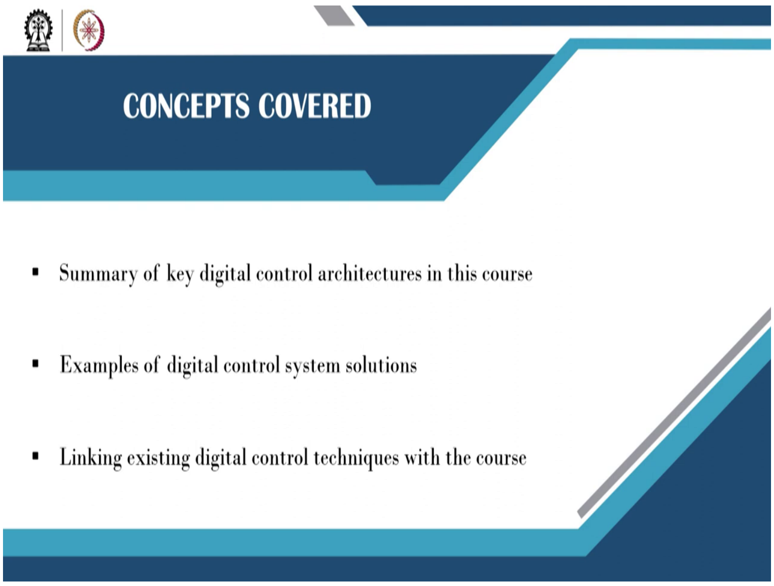

So, we will take will summary of digital control architecture in this course then an example of a digital control system solution and how can you link existing digital control techniques with this course ok.

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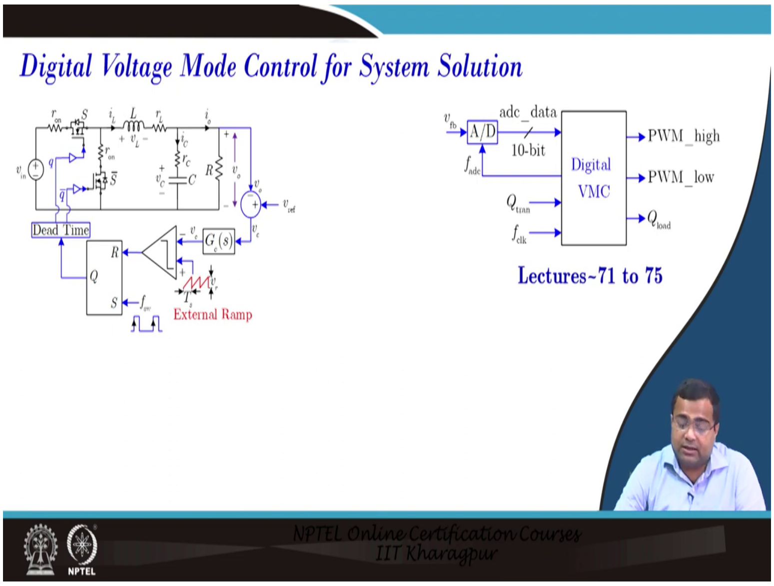

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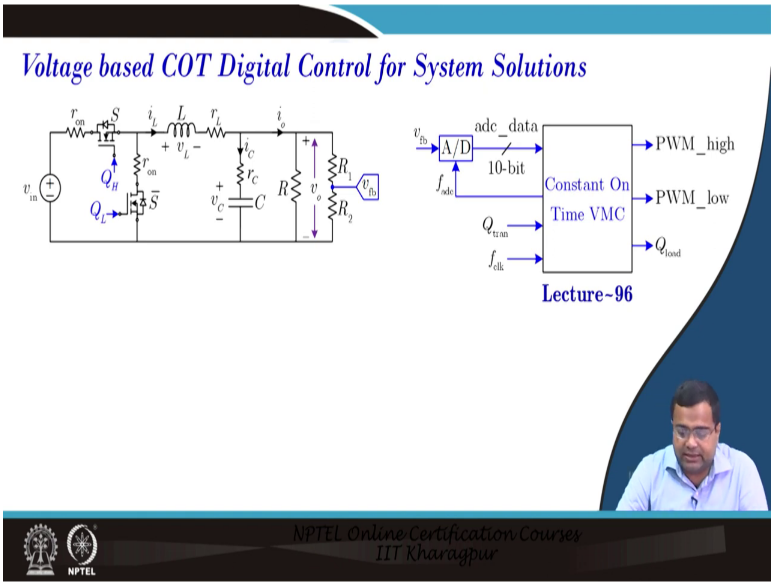

So, for the digital control system solution, we have discussed digital voltage mode control in lecture number 71 and 75. We have synthesized the Verilog HDL code, we have discussed digital-based voltage-based constant on-time digital control and we have discussed with Verilog HDL synthesis we did in lecture number 96.

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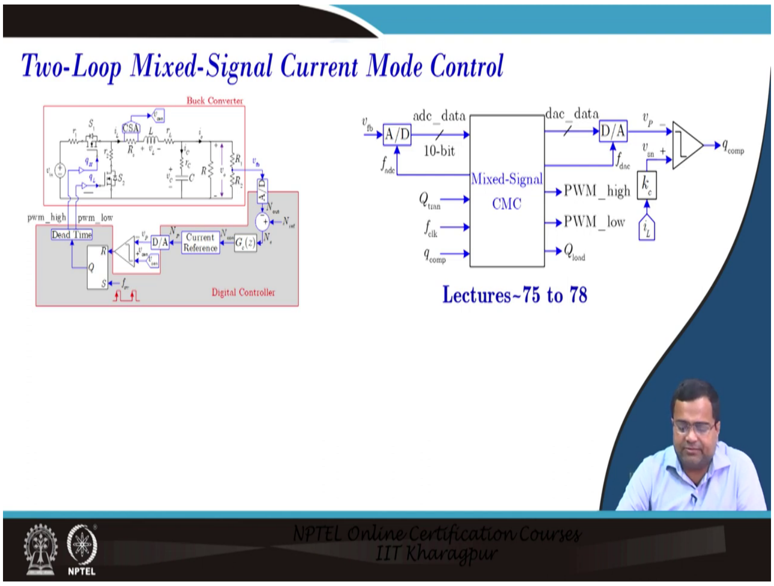

Then we discussed two loops of mixed-signal current mode control and we developed this digital control using Verilog HDL synthesized code we also prototyped using FPGA in lectures 75 to 78.

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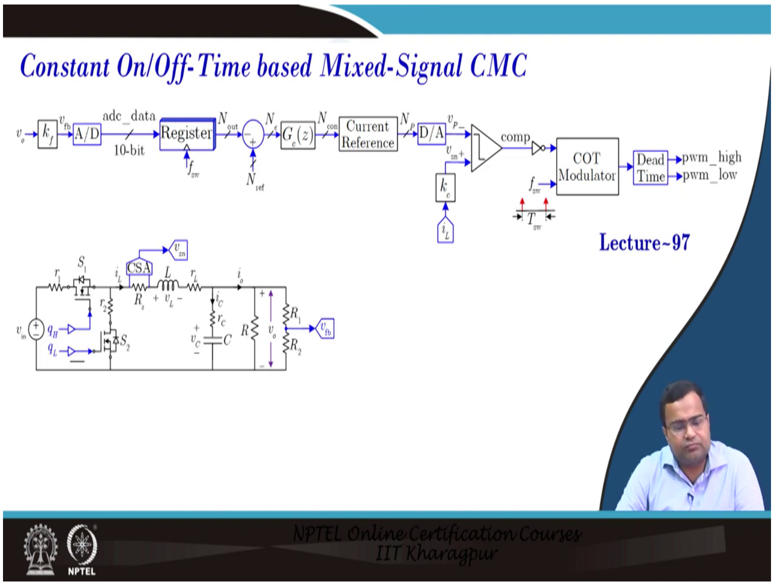

Then we have also discussed constant on-off time mixed signal current mode control and the architecture exploration and we have discussed this aspect in lecture number 97 with the hardware demonstration.

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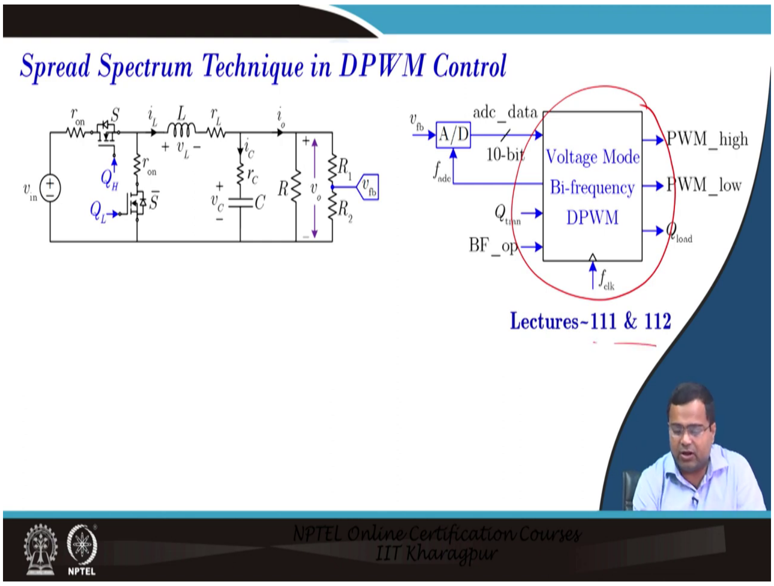

And we developed this core architecture using Verilog HDL, then we also discussed the spread spectrum technique in digital pulse skip modulation control we developed the Verilog HDL synthesize code and we have done we did FPGA implementation in lectures 111 and 112.

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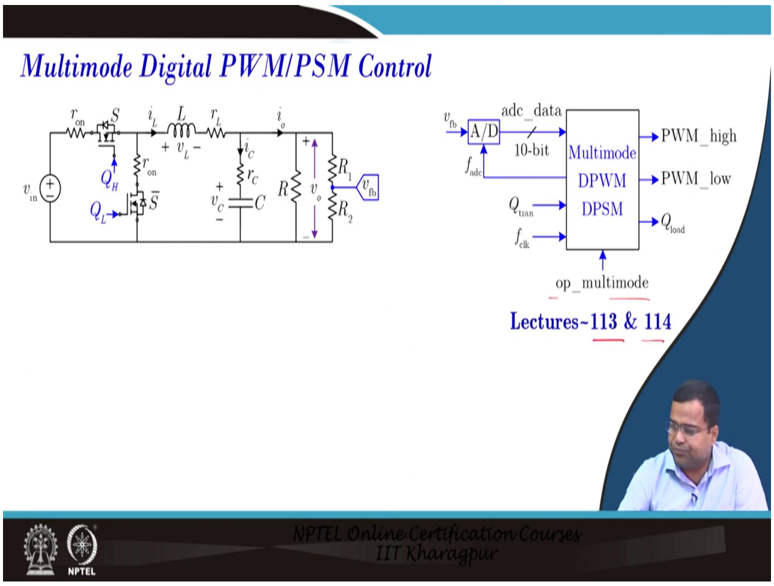

Then we have also discussed multimode digital control PWM and PSM which is a voltage base, you can do also the current base. And we have synthesized this multimode digital control using Verilog HDL and prototype using FPGA in lectures 113 and 114.

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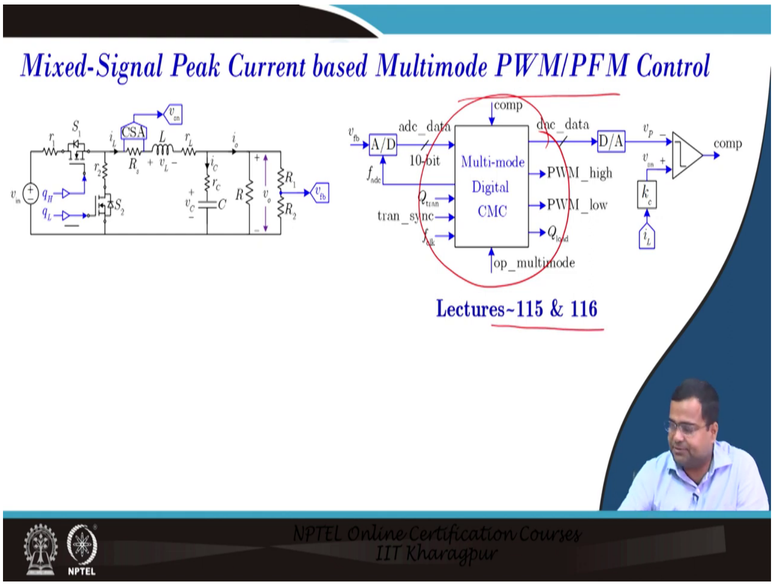

And we have shown also experimental results. We have also discussed mixed signal peak current-based multi-mode PWM and PFM control and we have developed this architecture and synthesized using Verilog HDL we have presented FPGA prototyping with experimental results in lectures 115 and 116.

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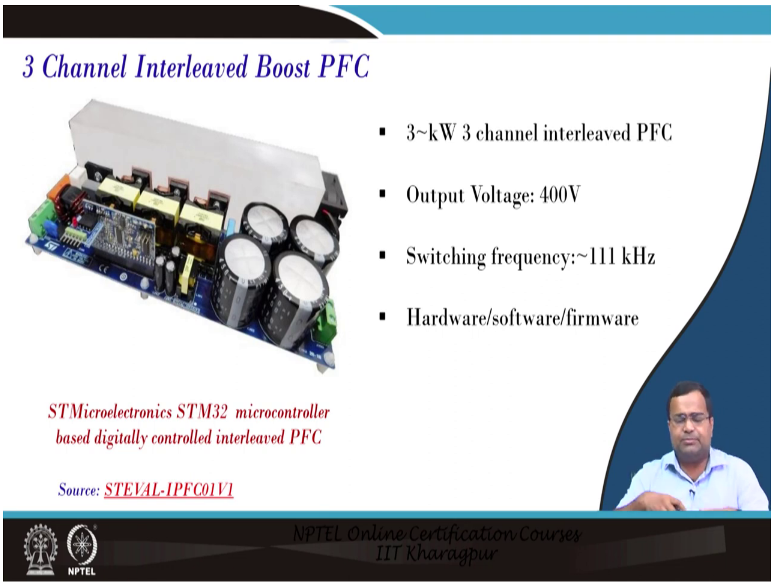

So, with this understanding of the key architecture that we have discussed and we have also developed their Verilog HDL synthesize file and have a prototype with this concept it is reasonable to link with some of the commercial products. So, one example is the 3 level 3 channel interleaved boost PFC which is from ST microelectronics this is a 3 kilowatt I am not going to discuss this because one can get detail with this part number.

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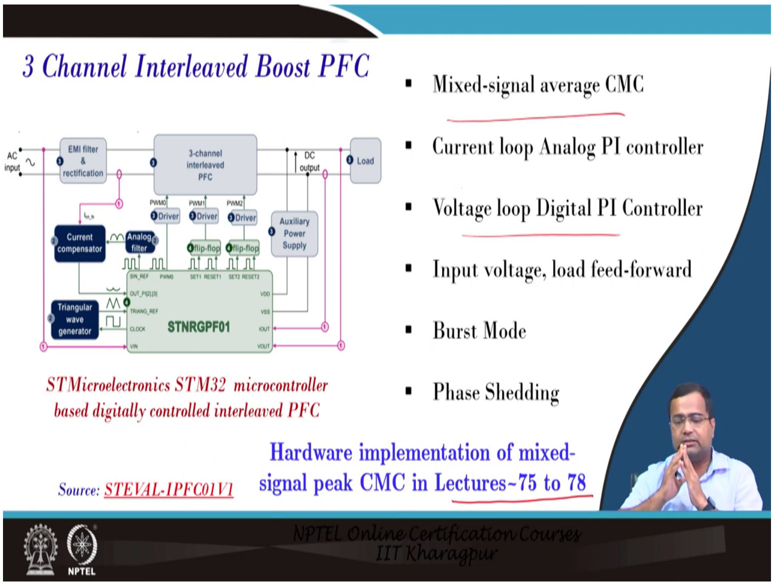

Now, in this part it is mentioned that mixed signal average current mode control with current loop analog, voltage loop digital. In our course, we have discussed the mixed signal peak current mode control in lectures 75 to 78. I think this lecture can be a basic very helpful to understand what might be there because in most commercial products the detail of the control logic may not be available explicitly in the public domain.

But, with the knowledge of this course particularly the mixed signal current mode control architecture, one can think about what could be the solution here or come up with a new solution.

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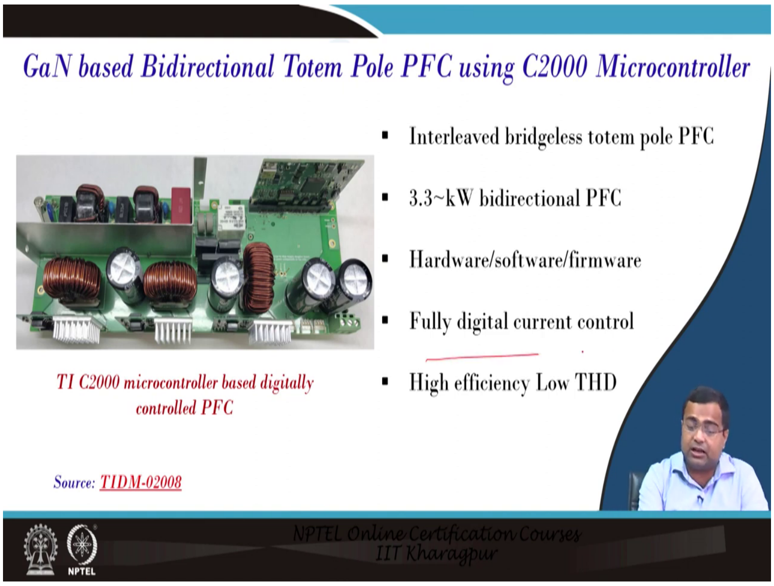

Another aspect is a GaN-based totem pole you know PFC interleave PFC which is like a using C2000 microcontroller. This architecture was considered with a small hardware demonstration in this course in week 9.

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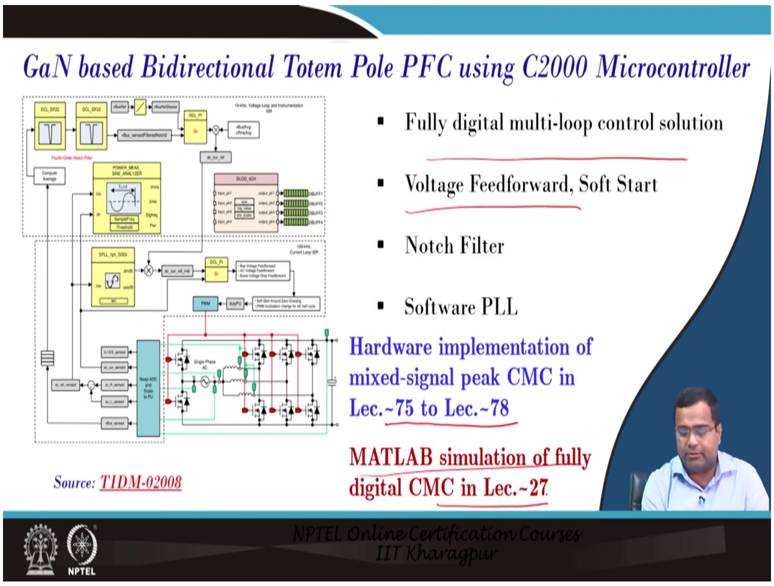

And in this course, it is a 3.3-kilowatt converter and it is fully digital current control the other feature of this controller it uses a fully digital multi-loop control solution and it also has a feed-forward soft start. Now if we recall our digital current mode control architecture we have discussed in lectures 75 to 78 mixed signal, how to implement digital current mode control using a mixed domain approach.

We have synthesized this architecture with Verilog HDL and we have also prototyped with FPGA. For fully digital we have carried out MATLAB simulation and developed the model in lecture number 27. So, this concept may be useful to link what is there inside or come up with an alternative solution.

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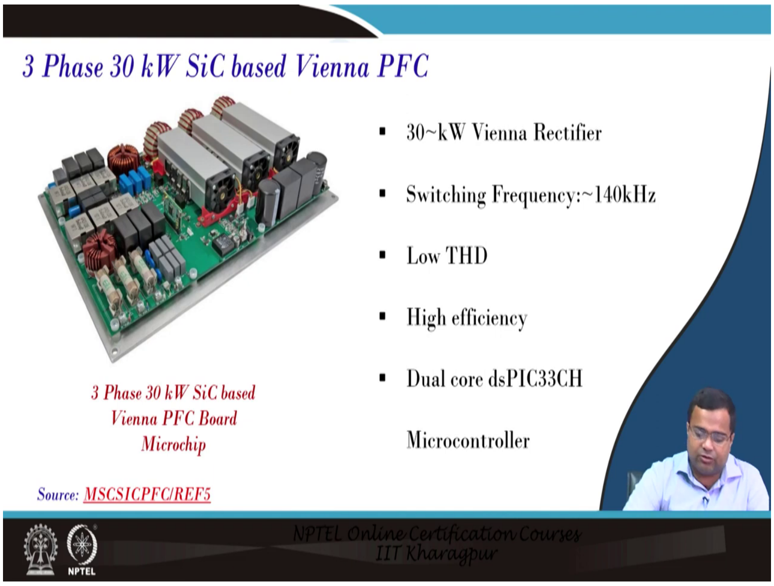

If you go for 30 kilowatts 3 phase SiC based I know Vienna rectifier. This is coming from microchip technology.

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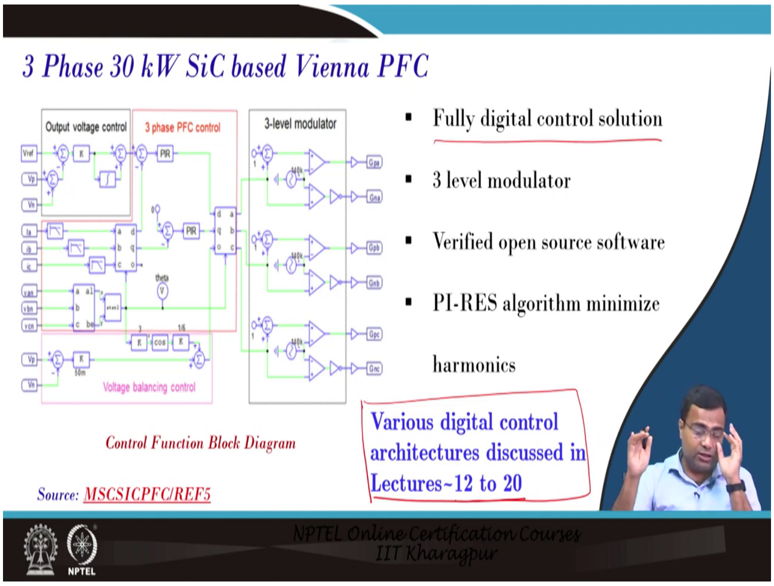

As you all the digital control solution may not be readily available, but it says about digital control solution which means the digital control is very much used for this particular high power converter we have discussed in detail from lectures 12 to 20, the different digital control architecture some of this architecture may be useful to link with this what is there inside or maybe thinking alternative solution, because the digital architecture may not be publicly available.

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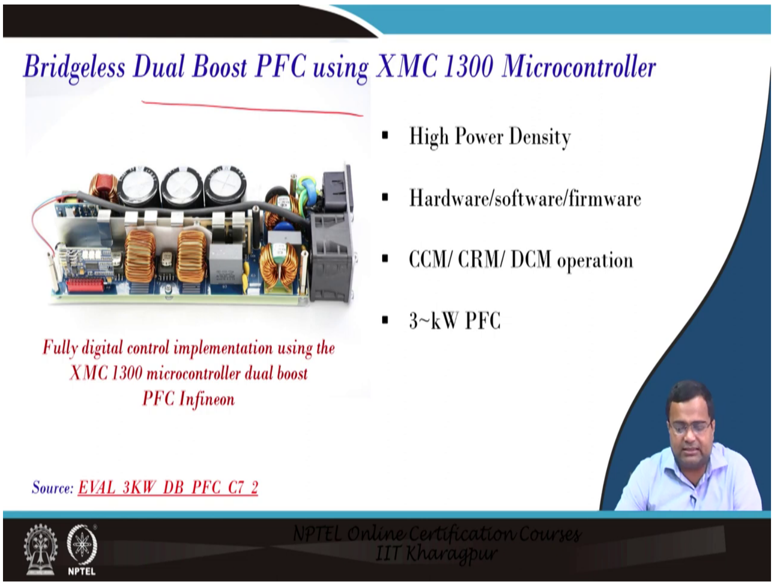

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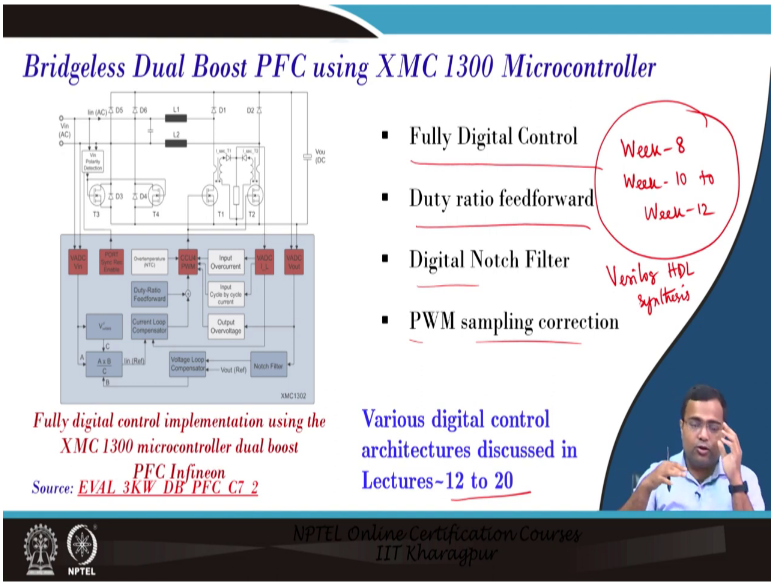

Then we are talking about a bridgeless dual boost PFC and this is for Infineon technology, where you know it talks about high power density 3 kilowatt PFC, and it takes it to consider fully digital control and which has a duty ratio feed-forward notch filter and sampling, but all details of this control architecture may not be publicly available.

But, we have learned from lecture number 12 to 20 about all digital control architecture. In fact, from week I would say week 8 then week 10 to week 12 we discussed a lot of Verilog HDL synthesis of multiple digital control architectures including voltage mode current mode architecture, fixed frequency variable frequency architecture then multi-mode digital control architecture. Then we discussed spectral spreading. So, this architecture will be helpful either to understand this concept what might be or to find an alternative solution.

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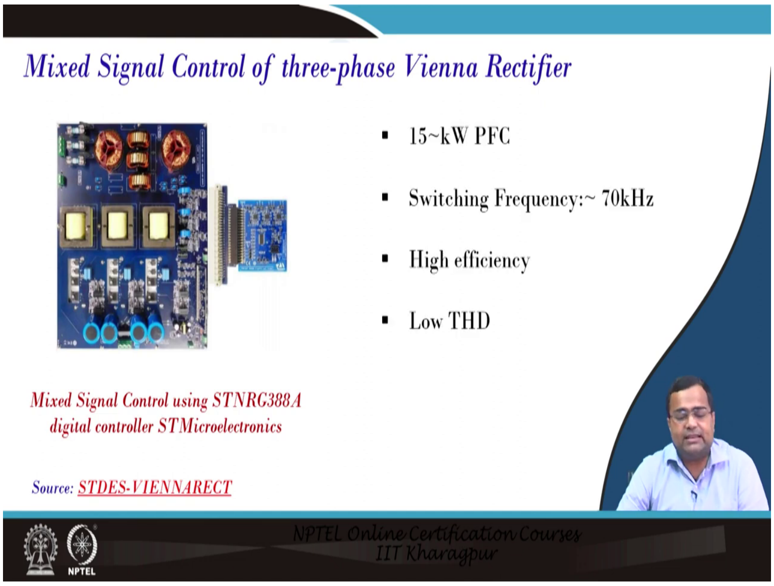

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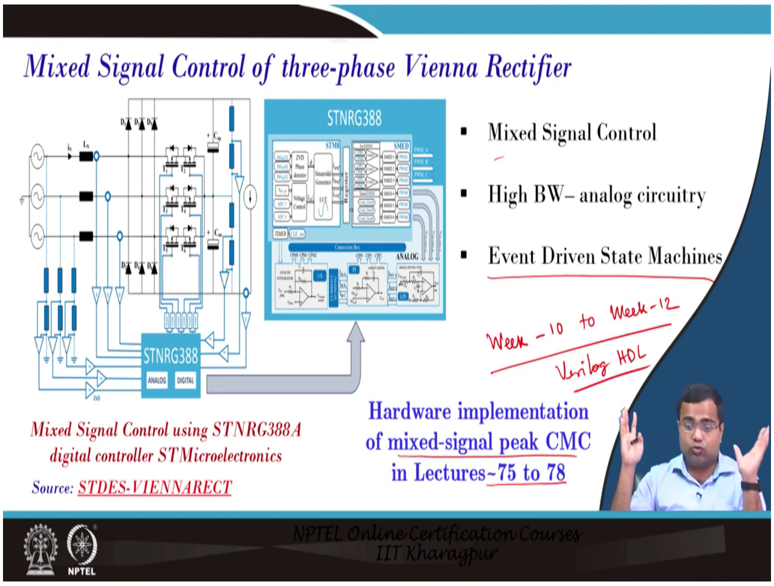

So, this is another one from ST microelectronics the 3-phase Vienna rectifier where it is a mixed signal control, and the inside of all these control logics are not available, but it said that the event-driven state machine is using a mixed signal control.

So, if you go to the mixed signal current mode control in 75 to 78 as well as if you go to week 10 to I think week you know week 12 we have discussed a lot of Verilog HDL coding and synthesis of the digital control architecture for various digital voltage current mode control. So, this will be useful.

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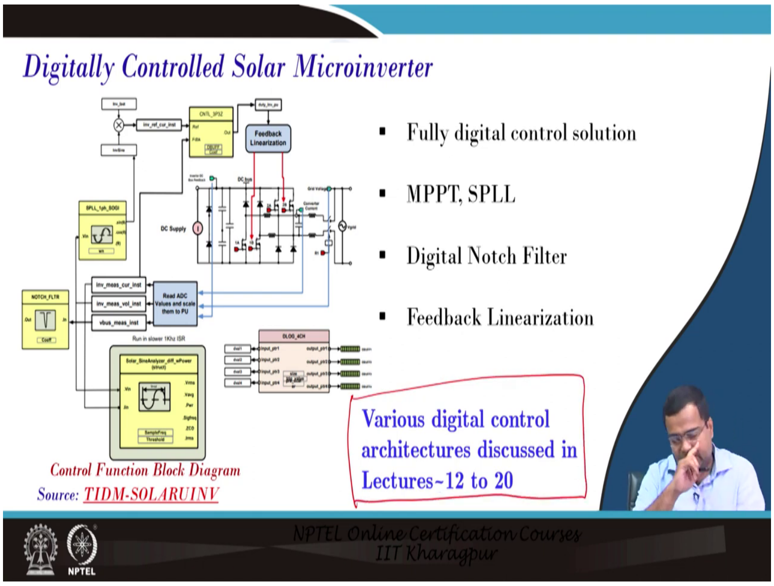

Now, digitally controlled solar microinverter, so this is from a Texas instrument that it uses for micro inverter and all these MPPT algorithms it is a fully digital control solution and you will get the idea of the basic digital control architecture voltage mode current mode architecture in lecture 11 to 20 and we have also discussed details in week 10 week 11 week 12 various architecture. Some of this architecture may be helpful to come up with an alternative solution for digital control solar micro-inverters.

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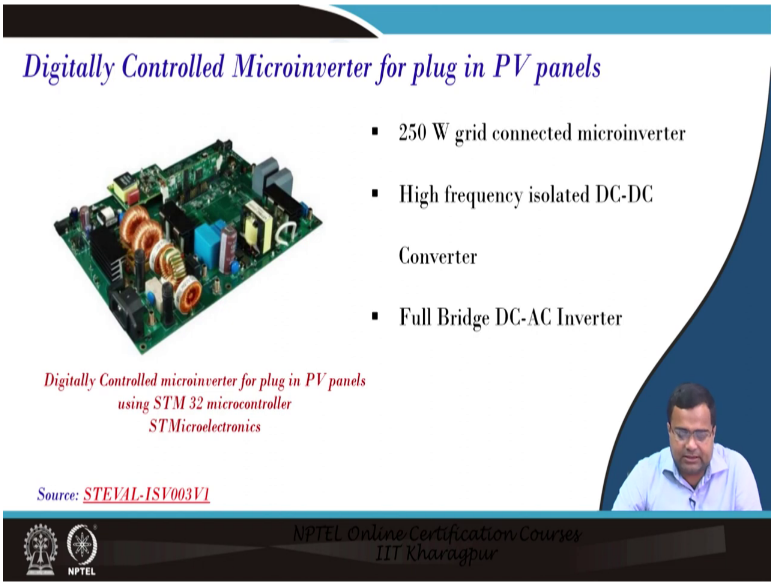

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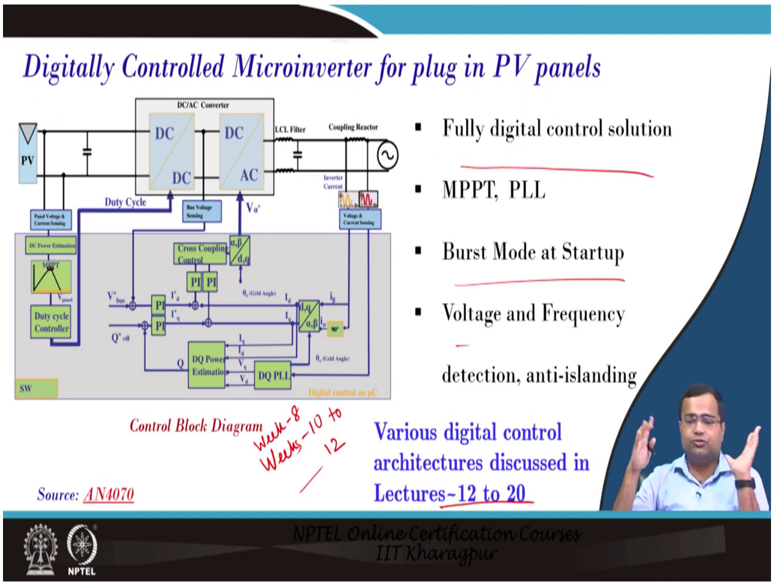

So, then solar microinverter in plug-in PV is for micro ST microelectronics where it also uses you know fully digital control solution and burst mode control for light load efficiency improvement and we have discussed various digital control architecture in lectures 11 12 to 20 and we have also discussed in week 10 week 8 and week 10 to 12.

So, this will be useful for how understanding the implementation of digital control which may be helpful to come up with a digital control solution for the micro inverters.

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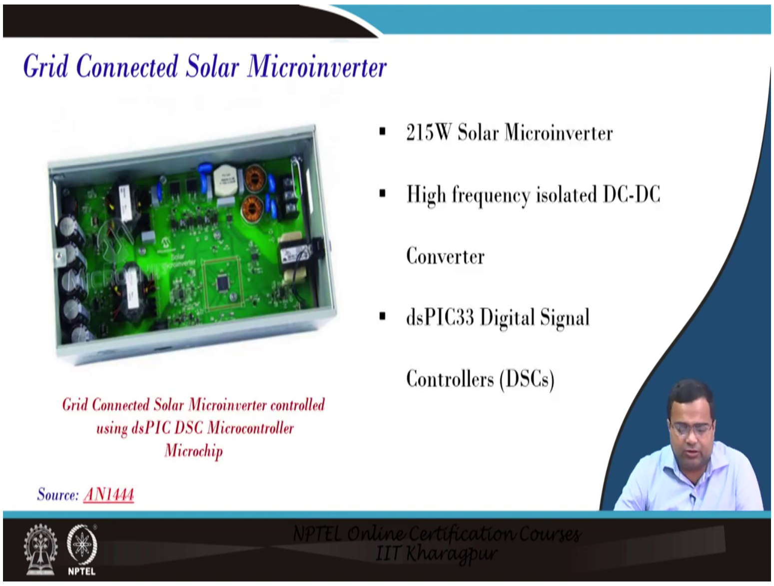

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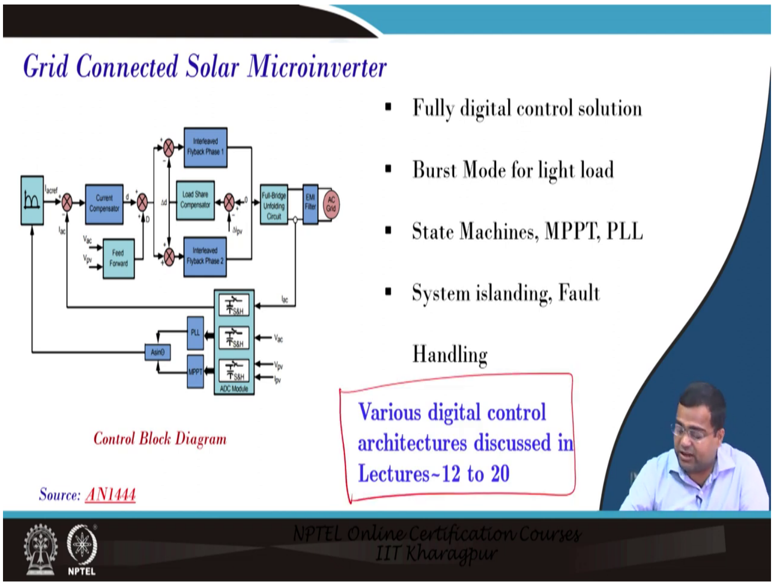

Then solar grid micro inverter from microchip technology also uses digital control and we have discussed this digital control in weeks 12 to 20 and we have this whole lecture on digital control. So, I think if one can understand this lecture very well. I think they can come up with a new or maybe alternative digital control solution.

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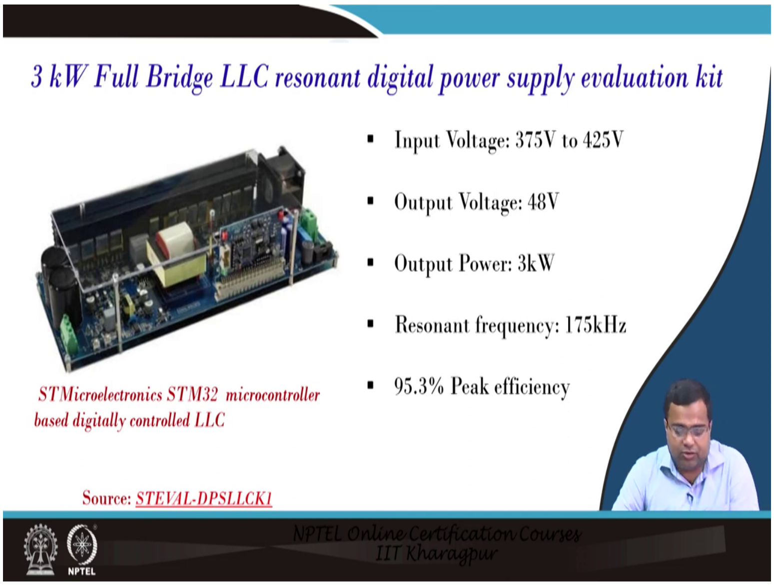

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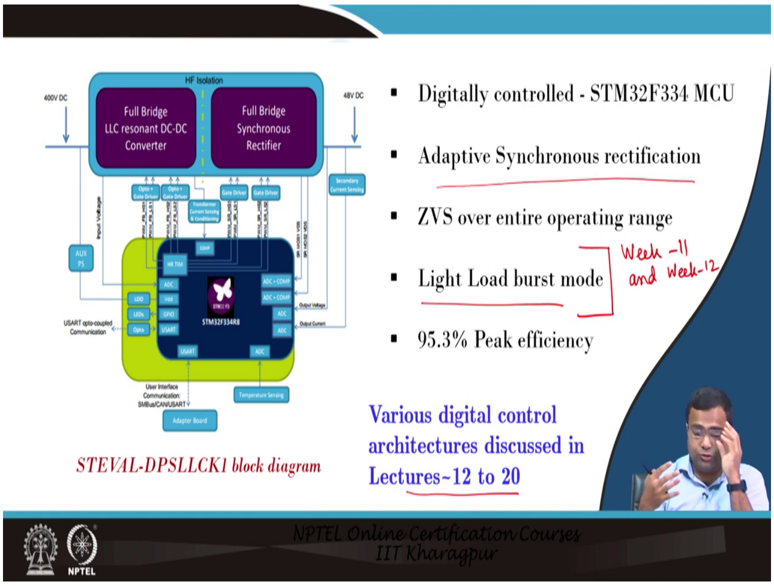

Then this is the 3 kilowatt LLC converter from ST microelectronics, then it uses you know fully digital control solution and adaptive synchronous rectification; that means, you can also do you know burst I mean the dead time optimization.

Then light load control improvement and we discussed lectures 12 to 20 the different architectures and this light load control we have taken week would say 11 and 12. So, which considers extensively light load control technique digital control, how to synthesize? How to implement synthesizing Verilog HDL? How to implement using FPGA? So, this technique will be useful. I am not exactly in burst mode, but we have talked about constant on time. Pulse skipping modulation then you know eruptive on time control technique and also multimode technique.

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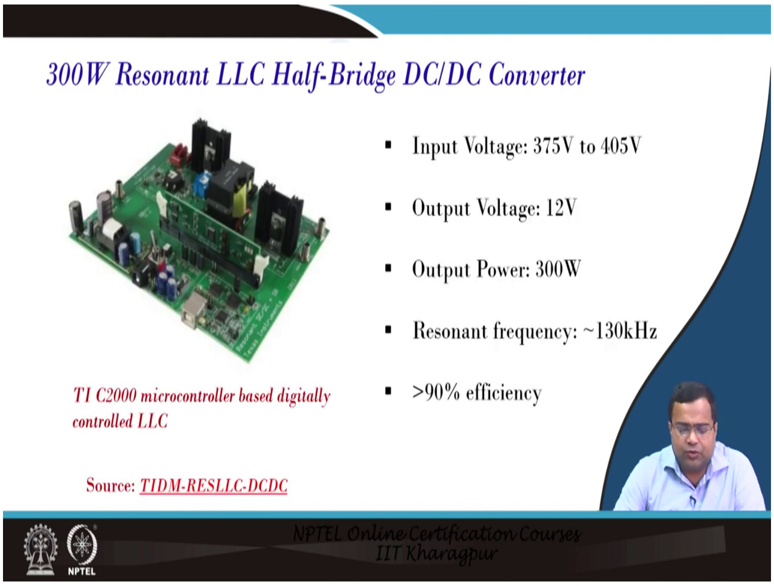

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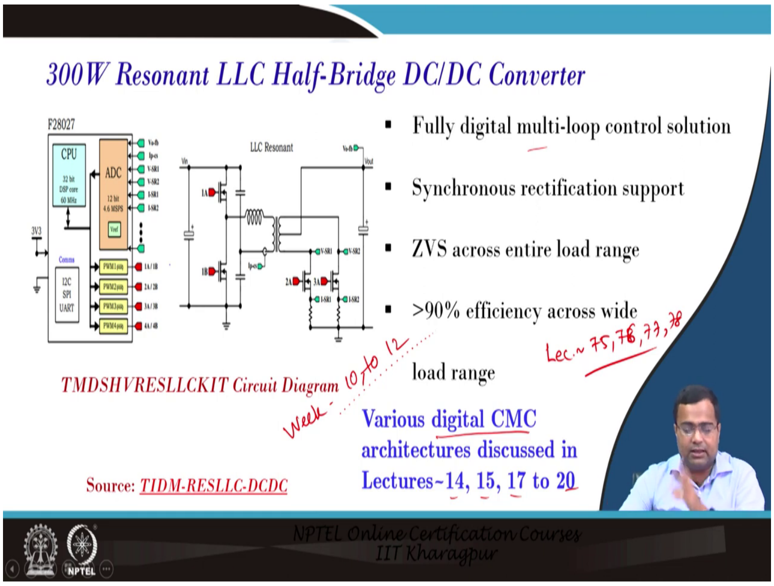

Then this is another resonant converter from Texas instrument which also uses you know fully digital multi-loop control we have discussed digital current mode control in lectures 14, 15, 17, and 20 and then we have also discussed in lectures 75 to 78 you know 75, 76, 77, 78 all the digital current mode control architectures are discussed.

So, one can get details about this about current mode control because it may be linked with multi-mode or it can be other architecture which is proprietary may not be available, but if we go to our week you know 10 to 12 weeks you will get to know a lot of digital control architecture that may be useful.

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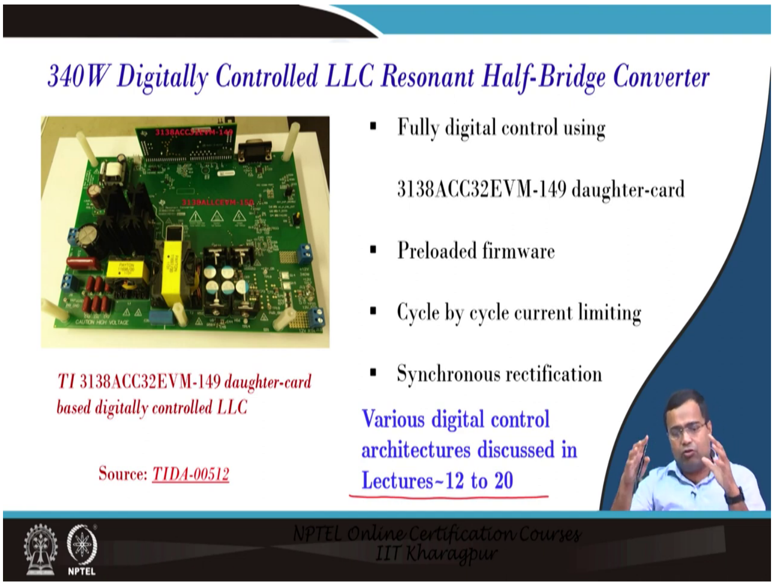

Then digitally control resonant half-bridge converter this is from you know Texas instrument which also uses the fully digital control solution. And we have discussed various architectures of digital control from lectures 12 to 20. So, some of this architecture including extensive implementation from week 8 as well as weeks 10 to 12 will be helpful.

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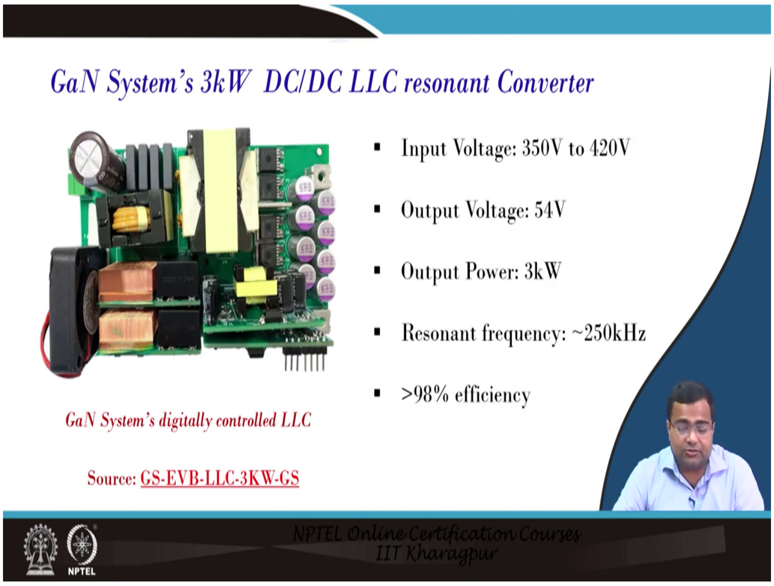

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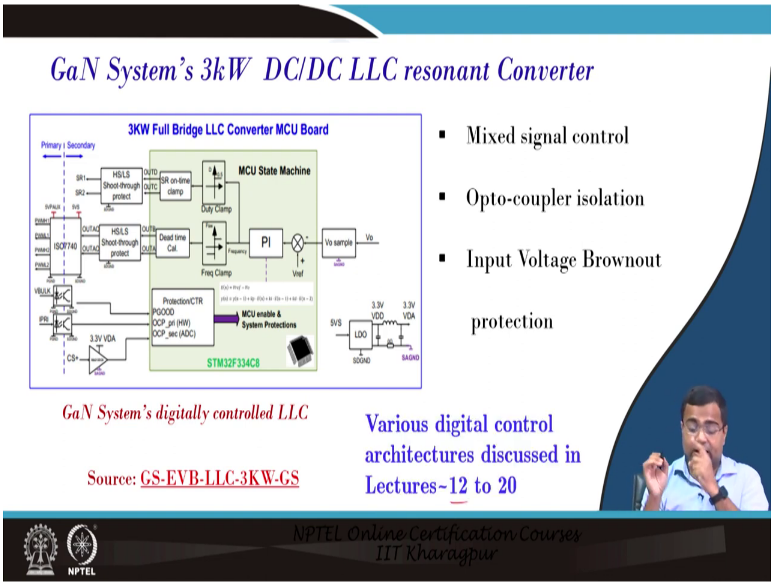

Then GaN-based 3-kilowatt converter you know GaN system this also uses the digital control mixed-signal control and we have discussed lecture 12 to lecture 20 as well as weeks 8 week 10 week 11 week 12. All digital control techniques are implementations are discussed.

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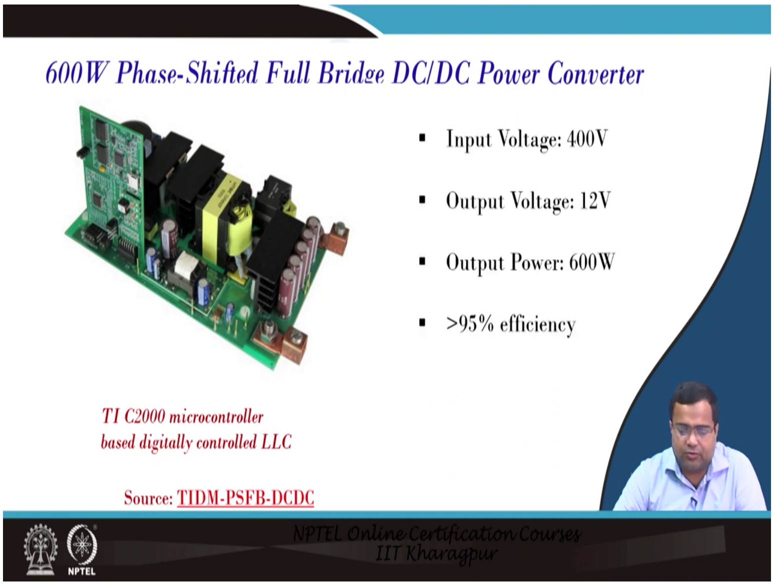

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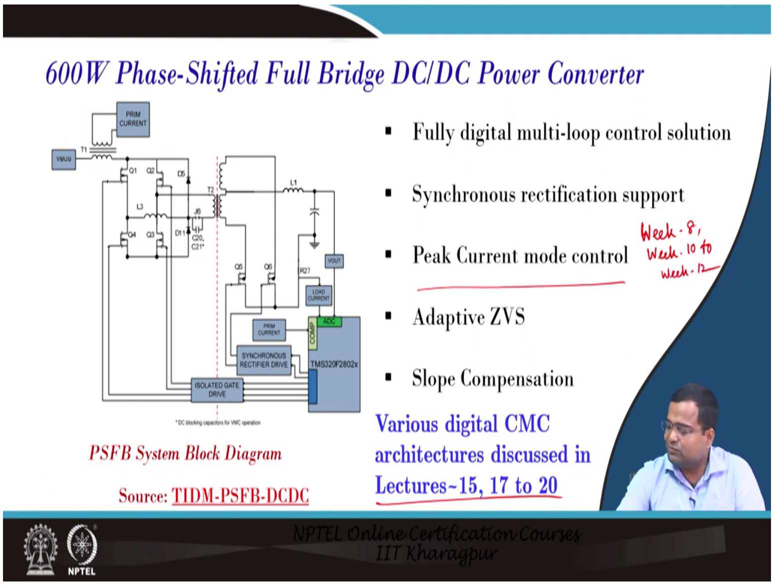

Then this is a phase-shifted full bridge converter from Texas instrument which also uses fully digital control multi-loop and again we have discussed multi-loop digital control both fixed frequency variable frequency as well as keep peak current mode control. We implemented this thing in week 8 then from week 10 to week 12 different architecture.

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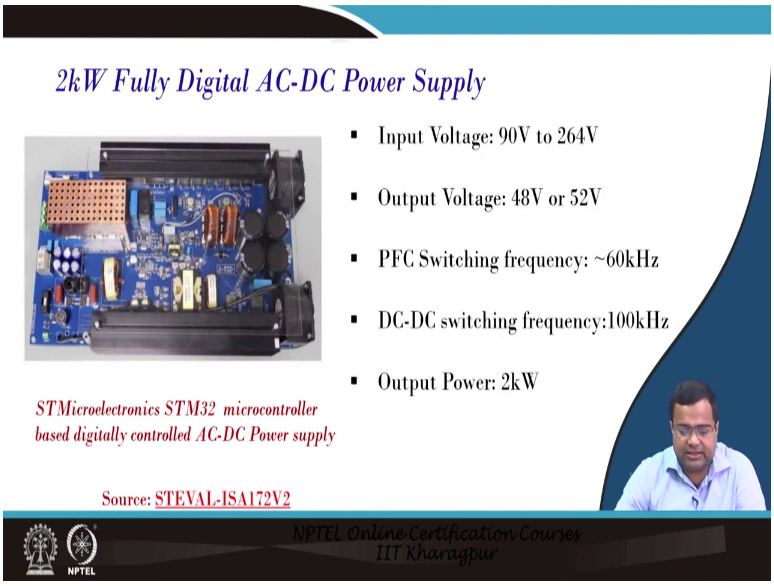

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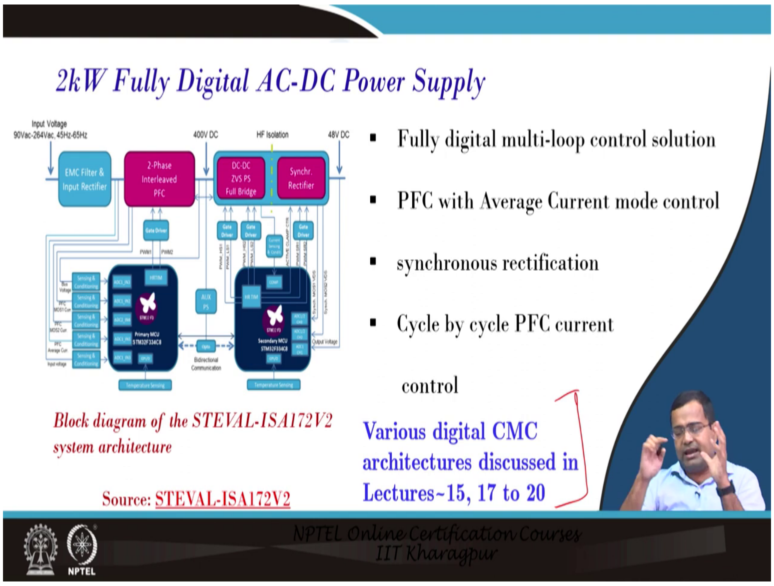

So, this may be more helpful than another fully digital AC DC power supply from ST also use a digital control solution and various digital control architectures we have discussed, and in week 8 week 10 week 11 week 12 we have synthesized various control architectures that may be useful for PFC converter.

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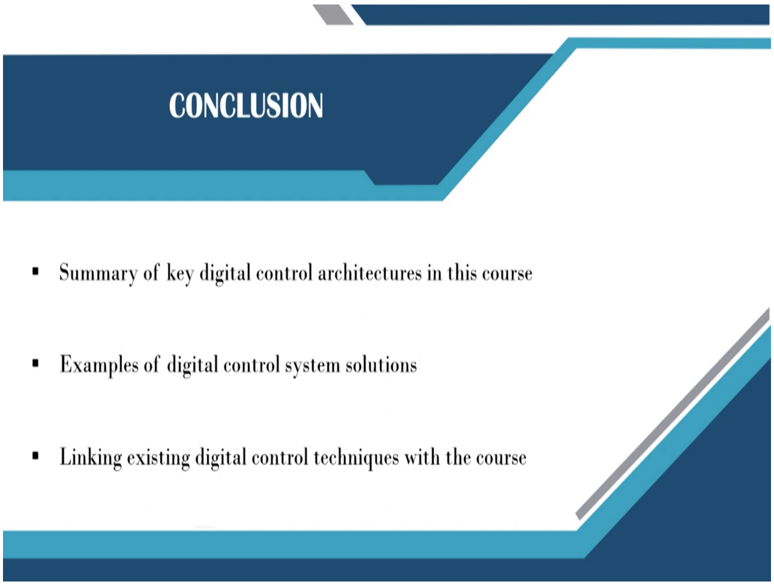

So, what we wanted to say is we have shown all the digital control system solutions to show there is an increasing trend of digital control for high power converters for power factor corrector converters, LLC converters, electric vehicle EV chargers then EV power trains then solar micro-inverter DC grid so then LED driver.

So, this increase in (Refer Time: 12:24) I would say our summary of digital control architecture in this course would be very helpful to understand that architecture as well as come up with a new architecture for future this commercial product. So, we have taken many examples of digital control system solutions and we try to link the knowledge that we gain in this course with this existing system that is it for today.

Thank you very much.