Digital Control in Switched Mode Power Converters and FPGA-based Prototyping
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Module - 01
Introduction to Digital Control in SMPCs
Lecture - 05
Introducing Basic Digitization in Power Electronic Converters

Welcome. So, in this lecture, we are going to Introduce some Basic Digitization in Power Electronics Converter.

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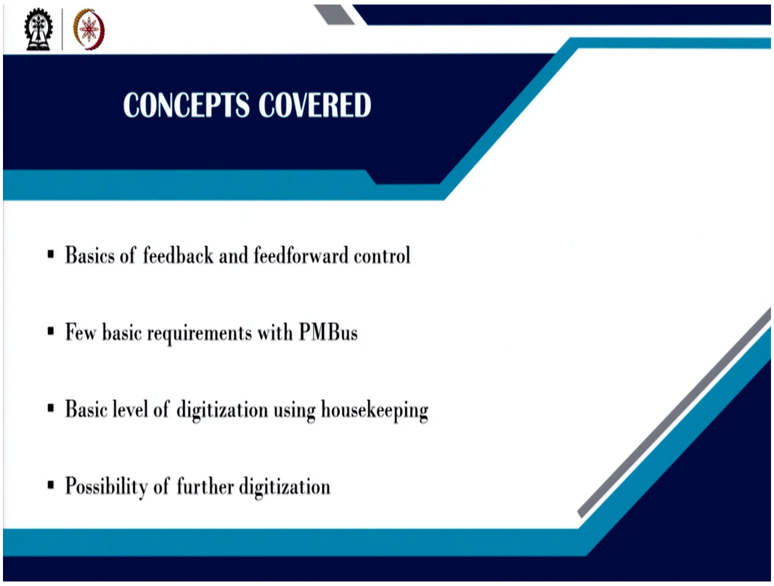

So, in this course in this lecture we will talk about basic feedback and feedforward control, then a few basic requirements with power management bus, and then the basic level of digitization using housekeeping and the possibility of further digitization.

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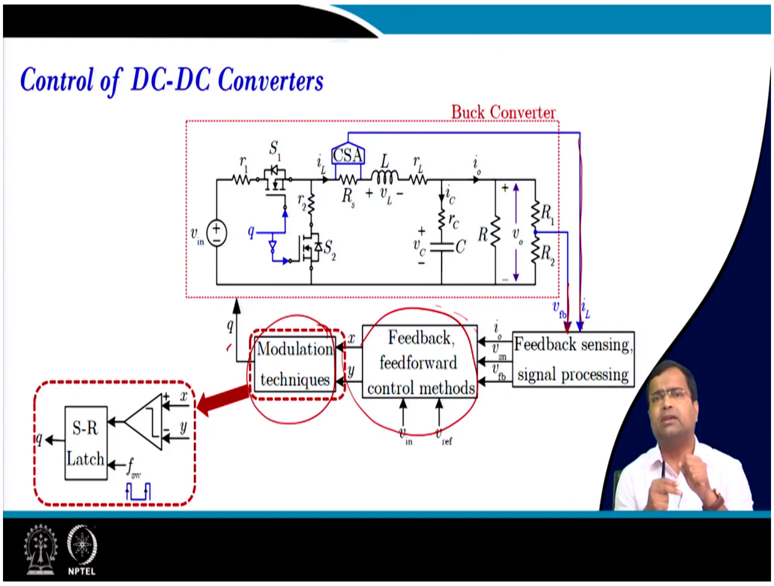

So, first, we will talk about the control of the DC-DC converter. So, here I am just showing a DC-DC buck converter, but you can have any switching power converter that you can replace. So, where we are sensing here let us say the output voltage we are sensing is my feedback voltage we are taking the resistive divider, and then we have a current sensor also. So, whether the current sensor is not mandatory or it may be optional based on whether you know whether you are using current mode control or voltage mode control you may or may not use.

Then after this block, it is a sensing block and the signal processing then goes to the feedback control; that means, what is the control structure? Are you going to the standard current mode control? Or are you going to the state feedback control? Are you going to use the output feedback control like only the voltage mode control? Are you going to use ripple-based control hysteresis control? So, many possibilities exist.

But ultimately at the end of this feedback control, we need to have a modulation technique because this will generate our duty ratio or the gate signal. And these gate signals are nothing, but on-off time; that means, they will generate on-and-off times. So, one such example that is a PWM latch; that means we are talking about fixed frequency modulation pulses width modulation. Where we compare two signals.

And the output of the comparator goes to the latch circuit and then the latch generates the gate signal, but it is not mandatory that we need to use PWM we can use various implementations. In fact, in this course we will be using apart from fixed frequency also will be using variable frequency architecture.

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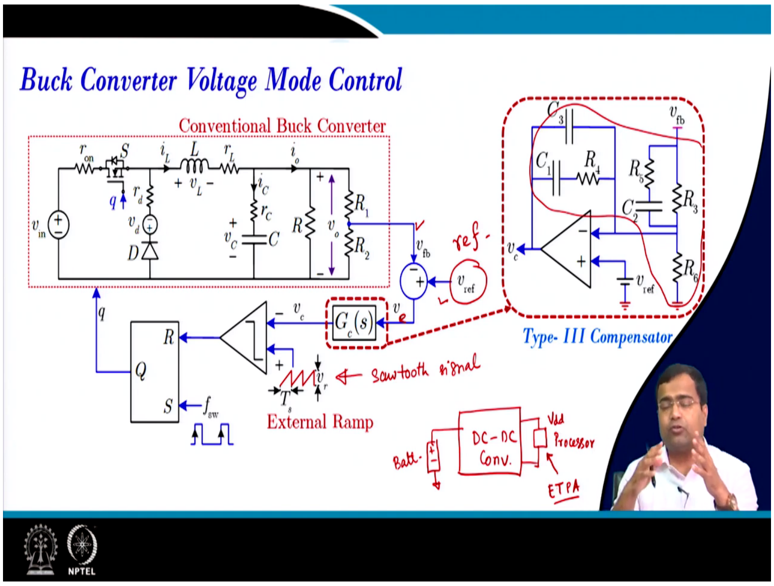

Now, here I am talking about a basic voltage mode control. So, in the voltage mode control, we have a feedback loop and then it is compared to the reference voltage. And then the error voltage this is the error voltage it goes to the compensator. And the output of the compensator is compared with the sawtooth waveform.

So, this is our sawtooth waveform our sawtooth signal and then the comparator output goes to the latch circuit ok. So, here it is a pure analog control; there is no digital part and the compensator typically used in voltage mode is a type three compensator and you can see such a compensator if you are talking about up to a few megahertz.

So, for most of the commercial products, this part will be the off-chip product; that means, we have to put it from outside separately because their values are large and you may not be able to put it inside the IC. So, depending upon the technology, if you go for a very very high switching frequency may be this IC when the capacitor size will come in the range of pico farad then only you can put it inside the IC ok.

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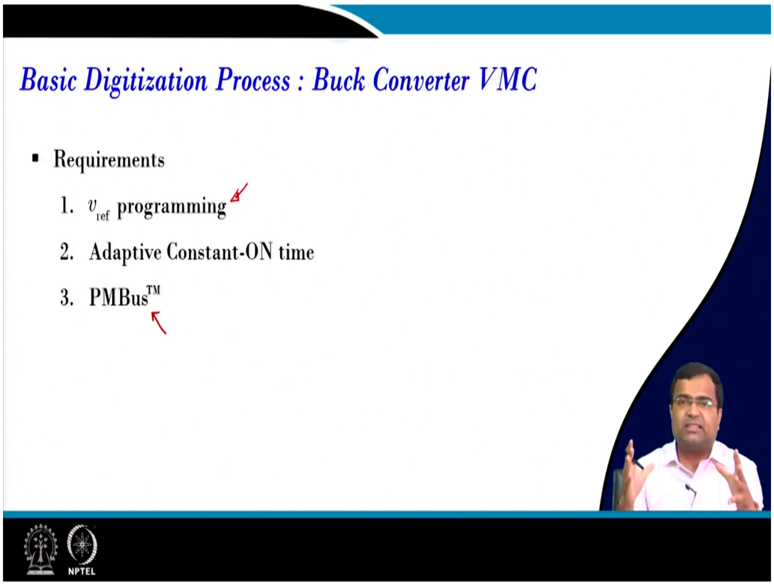

Now, how do you start with basic digitization? So, first of all, if you look at this feedback control. So, this is our reference voltage ok. Now, this reference voltage should be programmable why because when you are talking about the dynamic voltage scaling application or if you are talking about envelope tracking application because if you are talking about this DC-DC converter suppose this is your DC-DC converter where is the input is like you know battery. So, it is a battery.

So, the input is just a battery and the output let us say is driving a processor may be a small processor it is a processor. And the processor voltage V dd of this processor may have to be adjusted based on the tax requirement that is one scenario. This can be also the envelope tracking power this can be envelope tracking power amplifier because power amplifier means which is used for example, for our antenna right.

For powering our you know; that means, the RF transmission right or the signal transmission while transmission. So, we need to provide sufficient power to the antenna. So, the power amplifier is used and to power to provide sufficient you know V dd then we need to use a DC-DC converter and the voltage of the DC-DC converter has to adaptively vary according to the envelope of this power amplifier and then you need to change the reference voltage. For such an application, how do you change v ref?

So, v ref programming is one requirement another requirement we know is constant on-off time modulation. So, for example, constant on-time control. We need to adaptively vary on time ok. So, how do you adapt the on-time ok, that is one possibility. Another possibility is the power management bus. Suppose we are talking about that different many converters are connected to a common bus and they are sharing data and the clock.

Then for this communication, it is digital communication, but your basic converter is a loop analog.

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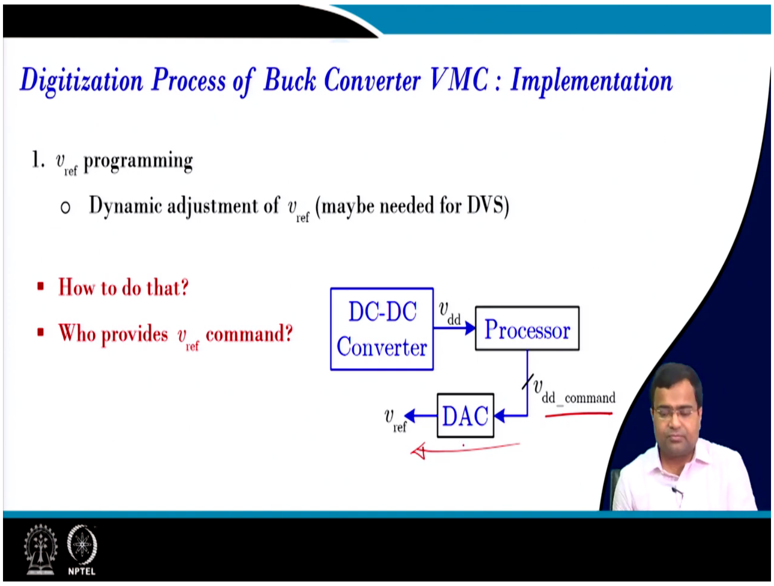

So, how to deal? The first level of v ref programming, how to do that? So, as I said this DC-DC converter is supplying a processor, but the processor task based on the task it will ask for a required v dd and that is a vdd comment and that is nothing, but your reference voltage, and this comment come from the processor as a digital number.

It is just a number and you have to convert it to an analog voltage because this reference voltage is the reference for the voltage mode control and this whole control is analog. So, we need a d to a converter.

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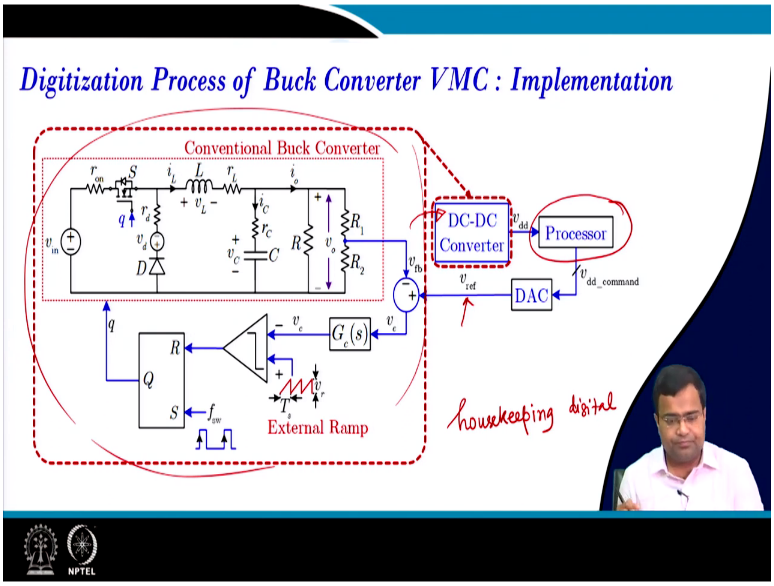

So; that means, the overall system looks like this. So, this is the processor it is supplied by the DC-DC converter and the processor is asking for a certain voltage we need to program this v ref accordingly and this whole loop is in analog. And you can see this DC-DC converter is nothing, but this one which is supplying the processor.

So, in this case, everything else is analog, but the reference voltage programming is digital. So, this is a housekeeping arrangement; that means, this is housekeeping you can say that housekeeping is digital; that means, we are not touching the basic analog feedback loop, but we are digitizing some interfacing signals. So, as you know the main loops remain analog.

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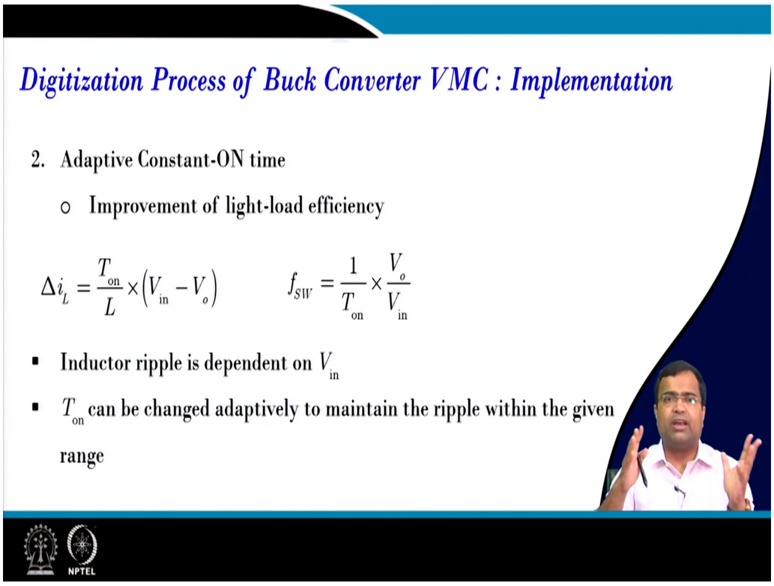

Another application is if we want to adaptively vary on time. So, suppose you know we need to maintain a certain switching frequency. So, how to adaptively adjust on time because we know that constant on time if the input voltage changes ok. Then there will be a change in the switching frequency for fixed on time. So, we need to adapt the on-time in such a way we can regulate the switching frequency.

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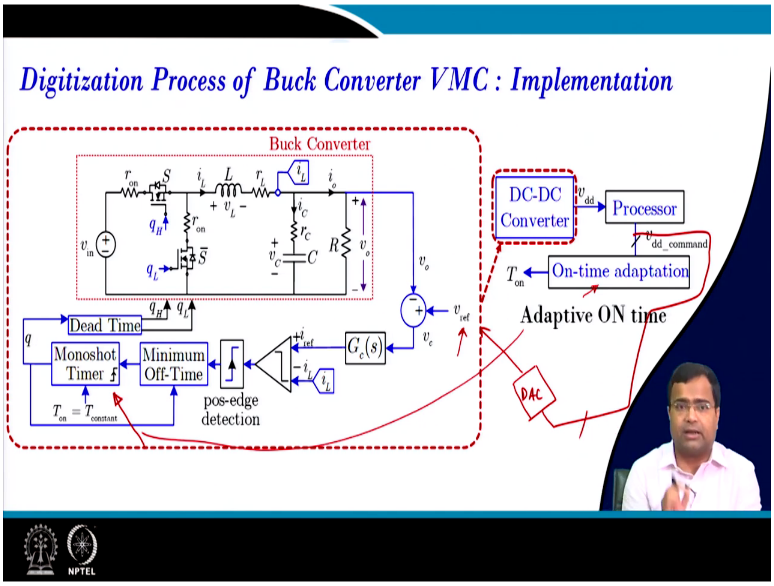

In such an application; so, how do you; that means, this moonshot timer will be loaded with constant on time, but how do update this on time? So, one possibility by beams of v dd; that means, suppose we need to program the vdd of this supply ok so; that means, we can change the reference voltage we have discussed; that means, we will be using a DAC here and DAC will have this information from this.

So, DAC will change the reference voltage, but once the reference voltage changes and if your input voltage is fixed then naturally switching frequency varies. So, in that case, we need to adaptively vary the on-time and that has to be loaded here and this, and this adaptation moonshot timer can be fully digital there was you can just use either counter base or other architecture where you can update the number.

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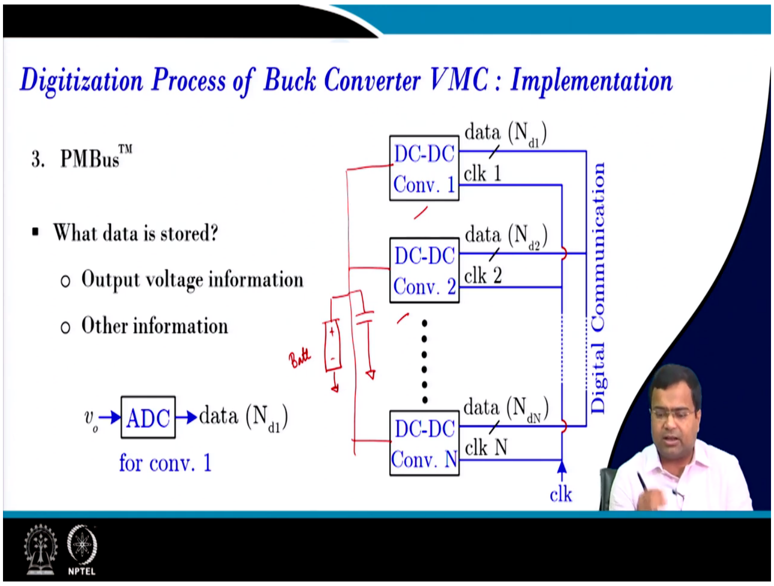

Another level of digitization is the power management bus. What is this? Here multiple converters are connected it is like an interconnected power supply network where we have a DC-DC converter 1 2 N number of converters are there and each converter is sharing data and clock now the clock is common and this will help to synchronize the switching frequency and do another kind of operation suppose if all this converter undergoes the same switching frequency right or it depends depending upon its power stage design.

The switching frequency can be different, but there is scope for optimization suppose each converter is rated almost the same power level and they are operating under nominal power; that means, their switching frequency is more or less fixed then you can shift the clock in such a way we can optimize the ripple parameter of this converter because maybe all this converter may have a common input voltage.

Because in case of our you know mobile phone, it may be a just a battery can be input. So, this input up each converter will have the input capacitor. So, you can reduce the size of the capacitor overall capacitor at the battery terminal using sequencing you know the gate signal or visible switching signal. Similarly, if this converter since is driven by a battery; that means, you can say there is a battery here.

So, this can be a battery and you can also have a cap here you know bank of capacitors here. Now, this battery cannot support a very high current because the battery depends upon the battery technology whether it is a high power density or high energy density, but still, it has a limit in the current both the slew rate as well as the magnitude. But if all converter undergoes transient then if everybody asks for high input current the battery can collapse.

So, there you need to put some kind of sequencing. So, that is why this digital interface helps in any way in the power management bus.

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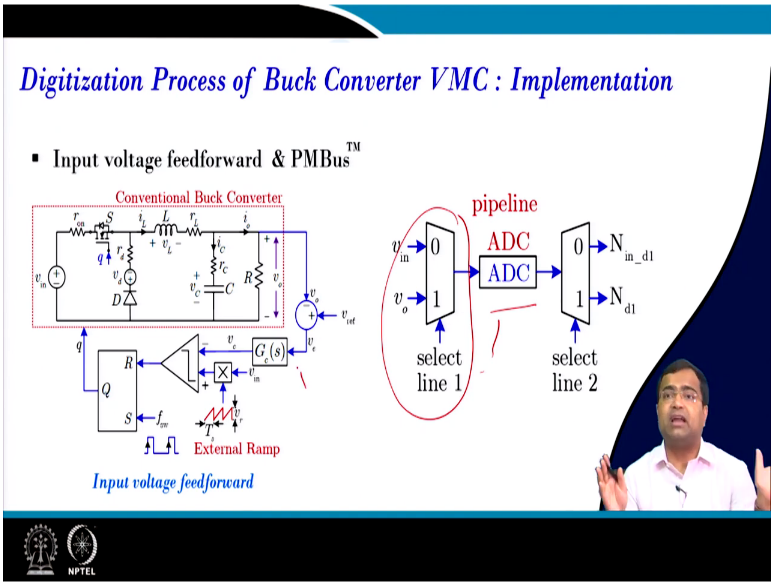

But the question is in this power management bus let us say its converter is running with the analog control pure analog control, but since they have to communicate with the bus. So, they need to digitize suppose you want to send the gates your output voltage information to the other converter.

So, you need to digitize and we need to share the input voltage information. So, you can use a maxing operation, and then you can use a single ADC and do that, but just for communication, this sampling requirement of the ADC may be low because you will just send this data once in many cycles. So, that may not be very fast. So, it may be a low computational ADC which can reduce the power consumption and cost. But the basic loop is analog which can be very high frequency.

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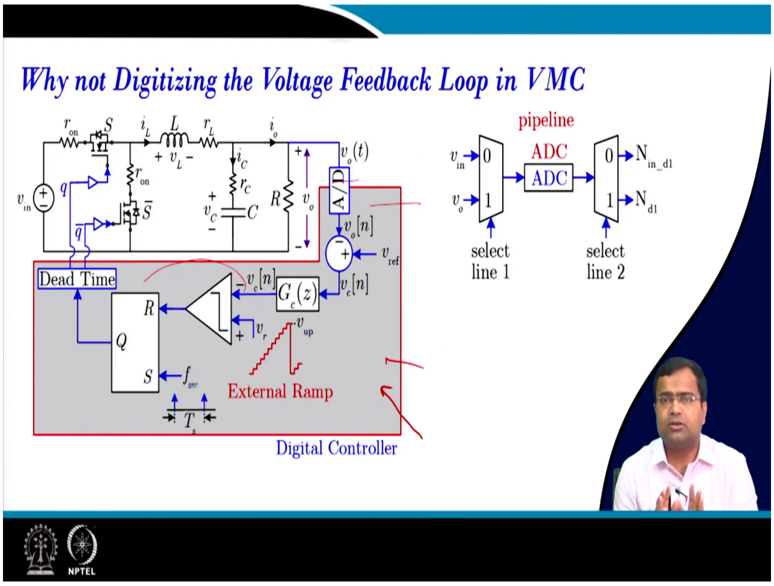

But since you are using this ADC. The next question why do not you digitize the whole loop; that means, why not you digitize the voltage as well? If you digitize the voltage then this information is already available. So, you can selectively send this information to the PMBus. So, PMBus solution where we have a digital interface for multiple converters connected.

Then for such a case if you slowly go into digital that will further enable you to take the advantage of smart communication as well as the information system and we can implement even many other different types of algorithms and optimize. Because suppose you want to play with the switching frequency suppose you are using this DC-DC buck converter it is a voltage mode digital control. And if you want to input the line load efficiency.

Then you need to reduce the switching frequency or you need to go for some other control. So, you can simply change the control logic inside the digital platform, no significant changes are required. So, those can be easily acquired. So, the next question; that means, in you know subsequent lectures we will be slowly digitizing the feedback loop. So, this is a starting point.

So; that means, in the process of digitization we can start with the housekeeping which is a very nominal level of digitization around the analog loop that we have discussed and in the subsequent lecture we will slowly digitize the feedback loop. Here we are talking about only a voltage loop single loop. If there is a two-loop control, should we digitize the two loops or only one loop analog and one loop digital? So, depending upon the there will be various architecture.

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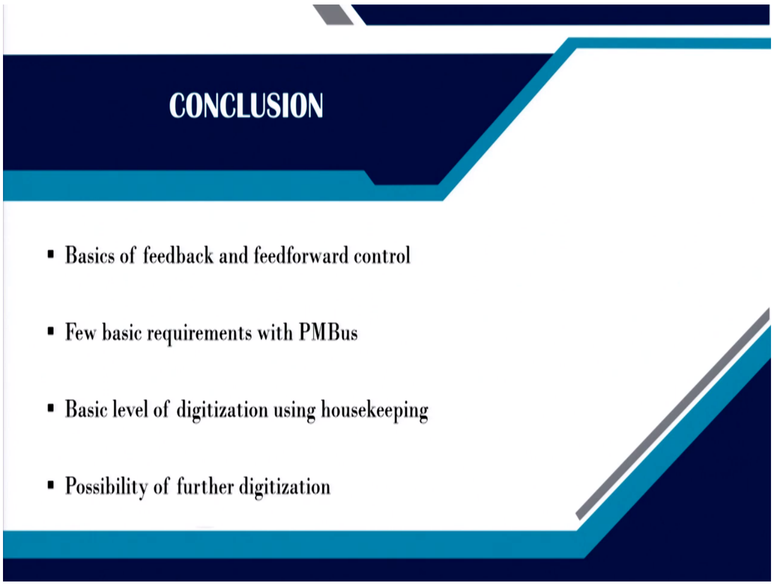

So, that will be discussed. In summary, we have discussed basic feedback and feedforward control we have you know identified basic requirements in the case of a power management bus. Then what are the basic levels of digitization using housekeeping I have also discussed and the possibility of further digitization is also discussed. That is it for today.

So, thank you very much.