Digital Control in Switched Mode Power Converters and FPGA-based Prototyping
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Module - 09
Digital Control Implementation using Microcontroller
Lecture - 81
STM32 Overview and STM32G4x ecosystem

Hello, welcome to Digital Control in Switched Mode Power Converters and FPGA-Based Prototyping course, I am Akshat Jain working in the SRA Department of ST Microelectronics India.

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In this lecture, we will be discussing about digital power based on an STM32 microcontroller we will be covering the following topics. We will be starting with the STM32 overview and the digital SMPS overview which is the switched mode power supply, then we will be moving to the STM32 microcontroller selection for the digital power applications. Here we will be covering the various peripherals that are the main requirements for the digital power supply in terms of the microcontroller.

Then we will be focusing mainly on the STM32G4x series microcontroller that is mainly developed for digital power applications, it is internal architecture what are the software tools, what are the hardware solutions that are built around STM32G4x for the development of the digital power supply. And in the end, we will be focusing on the complete ecosystem that is being provided by STMicroelectronics for digital power supply applications.

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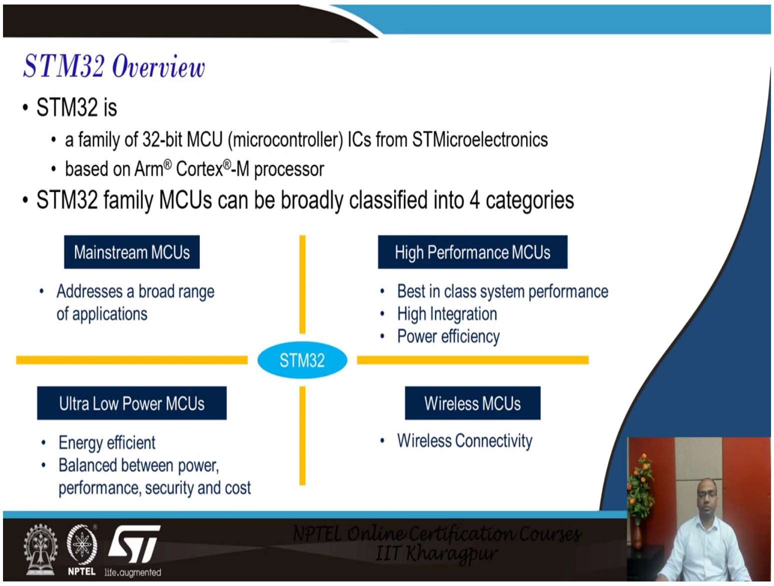

It is a family of a 32-bit microcontrollers from STMicroelectronics these microcontrollers are based on an Arm Cortex-M processor, there are a large number of microcontrollers that is being present in the STM32 family depending on our end applications and the user requirement we need to select the right microcontroller for our requirement.

STM32 family can be broadly classified into 4 categories the first one is the Mainstream MCUs from which we can target all sorts of industrial applications which say digital power, motor control, or any sort of appliances.

From High-Performance MCUs we can target multiple cores or high-speed applications, the third one is the Ultra Low Power MCUs, in which we can target the battery-operated applications where power consumption is the main concern, the 4th one is the Wireless MCUs in which the dedicated module for the wireless connectivity is also present.

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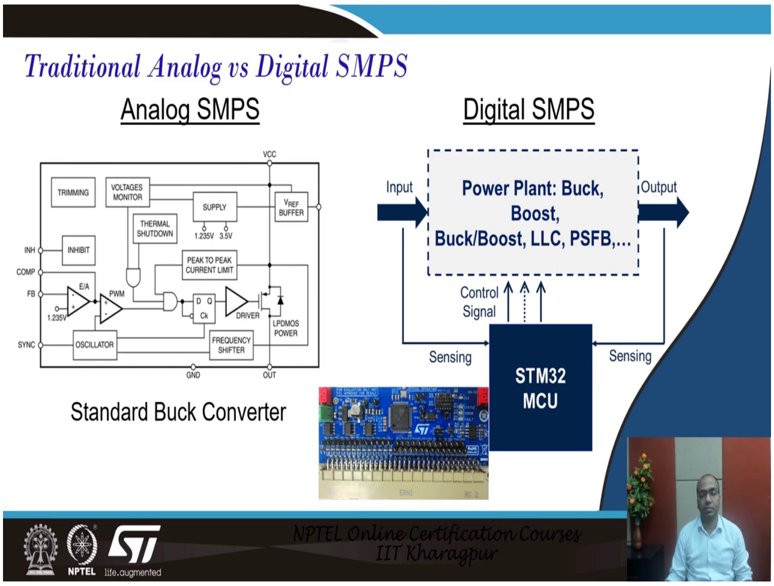

Before moving forward let us discuss the difference between Analog SMPS and Digital SMPS, in the analog SMPS section we have highlighted the internal architecture of a standard buck converter; where the output voltage is sensed at the feedback pin of the controller and then compare it with the set reference value and correspondingly the PWM signal is being controlled. While in digital SMPS the output voltage is being sensed at the ADC pin compared with the internal set reference value correspondingly the PWM signal is being controlled to control the output voltage.

Consider a first case if you want to change the output voltage, in analog SMPS the set reference value is fixed. So, we need to change the external hardware resistors to change the output voltage, while in digital SMPS we only need to change the set reference value that can be easily changed in the firmware, and correspondingly our output voltage can be changed.

Consider a second case if you want to change the operating frequency, though many analog SMPS is fixed frequencies even if they provide the frequency change we need to change the external hardware resistor. While in the case of digital SMPS, we can easily reconfigure the timers to change or operate our topology on a desired frequency. Consider a third case if you want to explore the different topologies for the analog solutions we need to have a dedicated IC for the dedicated topology.

So, the complete controller will be changed for the different topologies. While in digital SMPS only the power plant will be changed while the controller will remain the same. So, the single controller can able to manage various topologies. So, this is the STM32G4x control card which can be considered as a single digital controller that can be used for exploring various topologies.

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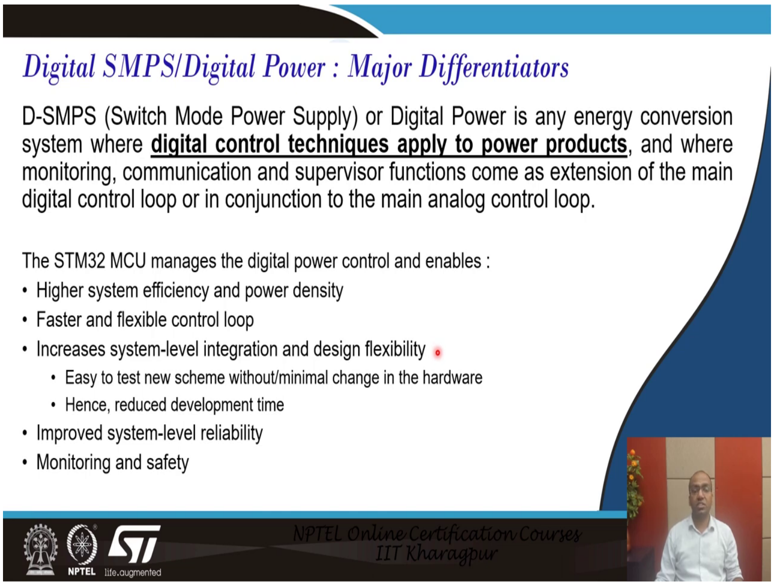

The digital switched mode power supply or we can say that the power supply which is controlled by the microcontroller, not only controls the power control loop but also had additional features like various parameters monitoring and communication etcetera.

From the previous slide it is very clear that digital control has several advantages over analog control, higher system efficiency, and power density faster and more flexible control loop depending on the input conditions and various load conditions we can easily change the control loop on the go increase system level integration and design flexibility. So, just by changing the power plant we can test or explore various new topologies, and improve system-level reliability monitoring and safety.

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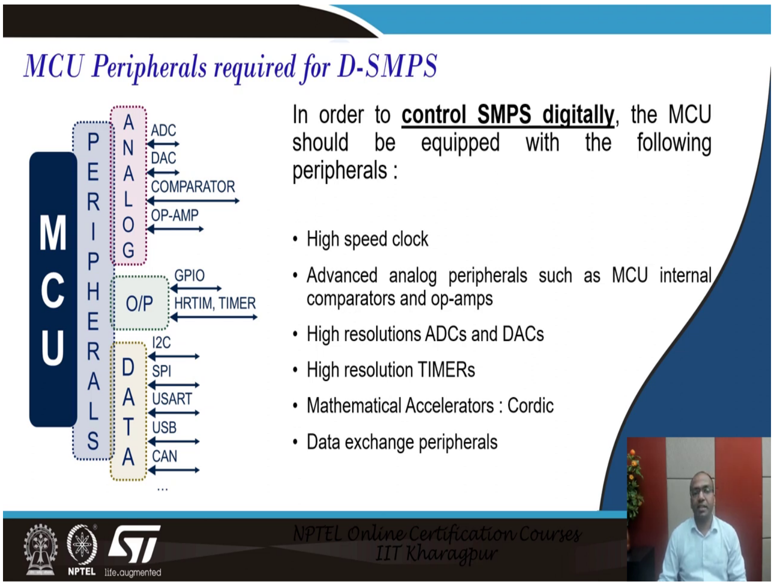

Microcontroller peripherals are required for the digital switched mode power supply. So, to control any SMPS digitally the MCU should be equipped with the following peripherals first one is the high-speed high-speed task, which is written in the application layer and should be executed as fast as possible.

Advanced analog peripherals include a microcontroller internal comparator and OP amps, it is highly desired to have these comparators and OP amps have various thresholds set for the various protections. High-resolution ADCs and DACs to monitor various parameters accurately and set the reference voltages for the various protections, high-resolution timers for various control signals, mathematical escalators for the various trigonometric functions, and data exchange peripherals to communicate with the external world.

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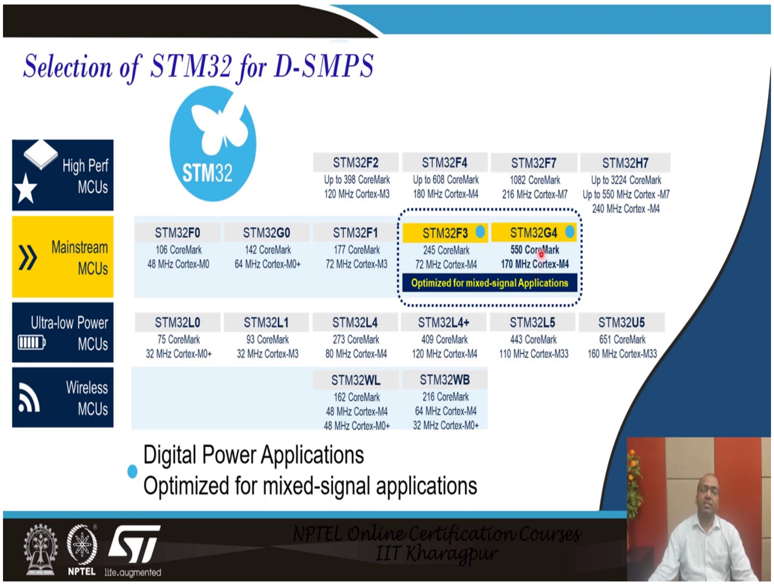

Our next topic is a selection of STM32 for digital switched mode power supply, in the last slide we pointed out the key peripherals required in the microcontroller for digital power applications. The selection of the MCU is very important the MCU selected should not only contain the desired peripherals, but the MCU selected should also be optimized in terms of power consumption, in terms of space when we talk about space we are talking about the package of the microcontroller and it should be also be optimized in terms of cost.

In the current slide, all four categories of microcontroller within the STM32 family has been highlighted, correspondingly various series of microcontroller associated with the particular category has also been highlighted the STM32F3 and STM32G4 series of the mainstream MCU is particularly meant for the digital power applications. In the subsequent slides, we will be focusing on the STM32G4 microcontroller and understanding more about it.

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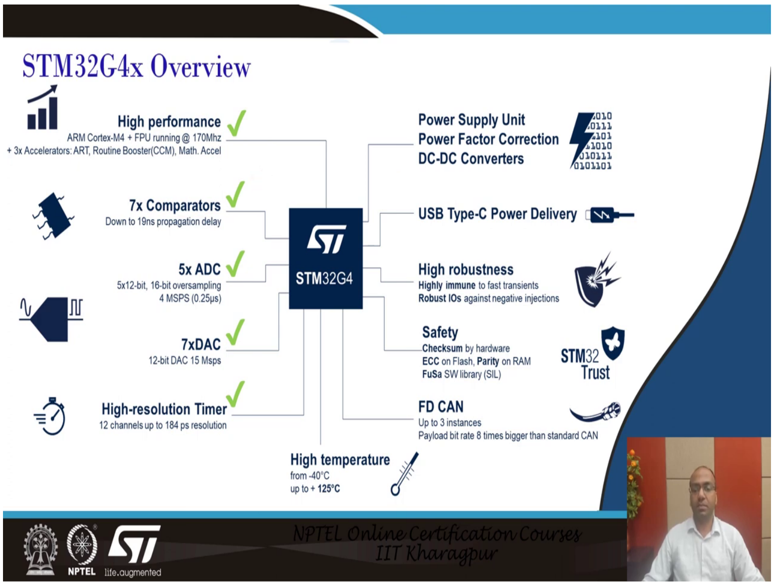

STM32G4 overview the STM32G4 is one of the advanced microcontroller series for digital power applications, on the left side we have highlighted the key differentiating peripherals along with the technical specifications related to STM32G4. While on the right side, we have highlighted the safety and reliability aspects of STM32G4. The STM32G4 can easily target various topologies for AC-DC and DC-DC power conversion.

There have been several hardware boards and several software examples available which we will be covering in the later part of the slides, also STM32G4 is available in various packages depending on the peripherals requirement, depending on the pin count requirement the end user can select the desired package from the available portfolio.

One key feature worth mentioning about the STM32G4 peripherals, any internal event of any peripheral or any external event can be made to synchronize with other peripherals just by the configuration. So, this makes the small section of the code work as an independent state machine, this part we will be understanding more deeply while we will be doing the STM32G4 configuration in STM32G4x.

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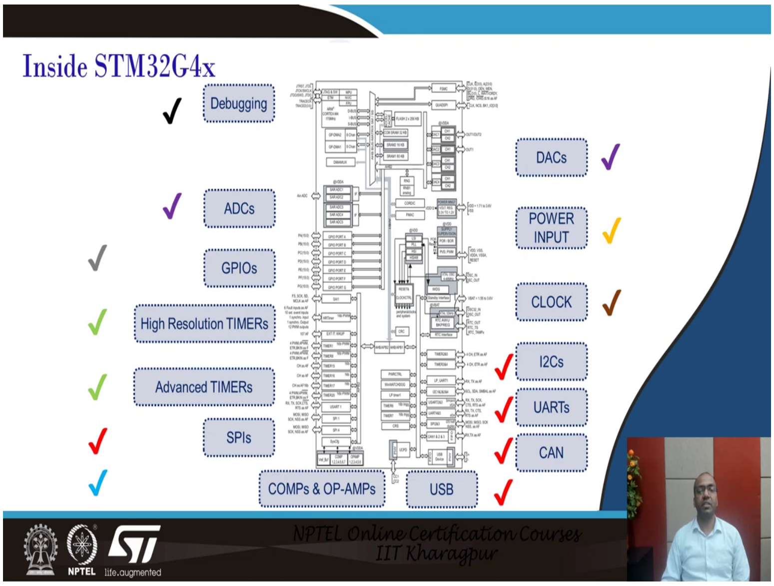

In this slide internal block diagram of the STM32G4 microcontroller has been highlighted, STM32G4 microcontroller can be operated from 1.7 volts to 3.6 volts, normally it is operated at 3.3-volt input. It can have a maximum clock of 170 megahertz with both options available of internal RC oscillator or external crystal, it has 7 internal comparators and 6 internal operational amplifiers.

It has 5 ADCs with multiple channels depending on the package we have selected the channel number can be decided accordingly. It has 12-bit DACs 4 are internal while 3 are external when we say internally it is for the internal reference values and when we say the externals those DAC or the analog signals will be present on the pins of the microcontroller. Debugging either we can go for the J tag or SWD cable.

Where SWD stands for the Serial Wire Debugger, GPIOs almost all the pins of the microcontroller can be configured as a GPIO if they are not used for any other peripherals. High-resolution timers though this timer is one in STM32G4, 12 PWM channels can be generated from the high-resolution single timer.

All the different PWM can be synchronized according to our requirements, apart from the high-resolution timer there are advanced timers and basic timers, which can be configured as per our own needs. Apart from that, there have been several communication peripherals like SPI I2C UART CAN and USB, which can be used for communicating with the external world.

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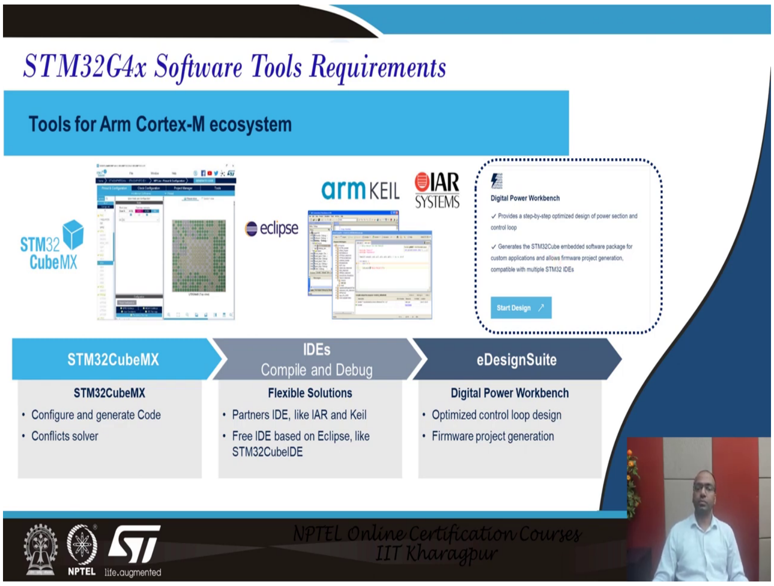

Up till now, we have covered the STM32 family overview, where we found out that there are several series of microcontrollers from which depending on our end applications and the user requirement, the right microcontroller needs to be selected. Then we touch on the digital power overview where we found out that there are some key peripherals required within the microcontroller to achieve the optimized digital power application.

Eventually, we focused our attention on the STM32G4 microcontroller, this microcontroller is being designed for digital power applications. Now application development can be a bit tedious task there are several tools from ST Microelectronics. The first software tool available from ST Microelectronics is STM32CubeMX it is a graphic user interface tool this tool is quite handy in generating the application firmware.

This tool helps since the microcontroller selection configuring various pins of the microcontroller, initializations of the peripheral and eventually generating the first level of code for 3 different IDE; that is IAR Keil and STM32Cube IDE. The next session will be dedicated to STMCubeMX, where we will be focusing on the initializations of various peripherals the MCU pins configurations, and eventually generating the code.

The second software tool requirement is the IDE, where the IDE stands for Integrated Development Environment STM32CubeMX generates the initial workspace in 3 different IDEs IAR systems Keil and eclipse IAR system is a paid version while Keil is free for evaluation purposes only, while the eclipse is a freeware available from ST.

Now, ide is required for the application development its more of a customized thing that is required for the end applications and debugging purposes. For digital SMPS applications, there is a new tool called digital power workbench under the (Refer Time: 12:18) of design suite is available on the ST website this tool assists in the application development one step ahead as it provides a step-by-step optimized design of power section and control loop.

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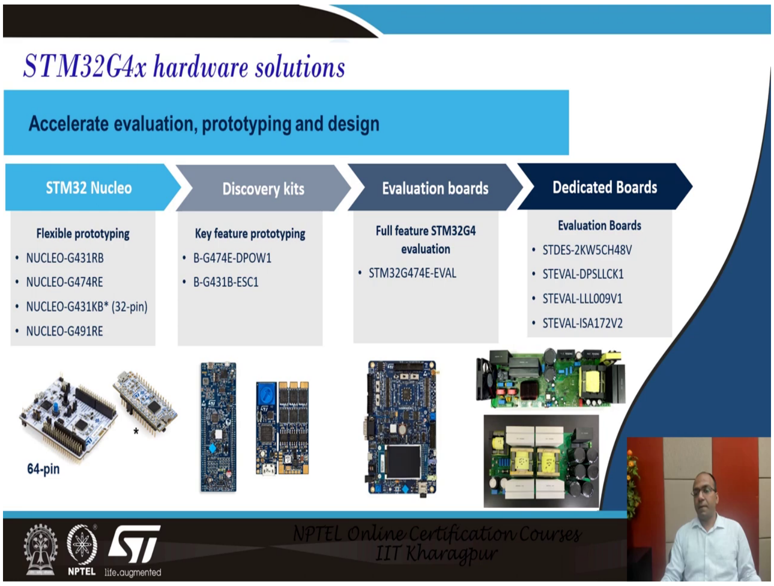

There are several hardware platforms available for STM32G4 microcontroller evolutions, the first category is the STM32 Nucleo boards these are very cost-effective general-purpose boards in which the microcontroller is in the center. While all the GPIO pins are available at ST morpho connectors and some of the pins are available at Arduino Uno connectors these boards do not require any external debugger as the debugger is mounted on top of it.

All the STM32G4 Nucleo boards are listed here also in STM32CubeMX, there are several examples based on Nucleo G4 series boards that can be evaluated, and based on the end user applications those examples can be modified. Also, several x Nucleo boards can be mounted on top of these Nucleo boards and our end applications can be realized accordingly.

In hardware solutions the second category belongs to the discovery kits, this discovery kit has been designed and developed to evaluate specific applications. The first board has been designed and developed to evaluate the USB type C connector interface and to evaluate the buck-boost converter application. The complete hardware and the firmware application details are already present on the ST website, while the second board has been dedicated to motor control applications MOSFET and its related gate drivers are already mounted on it.

The third category of hardware evaluation tools belongs to the evaluations board; this eval board is a complete demonstration and development platform. The full range of hardware features available on the board helps the user to improve application development and to evaluate all the peripherals available on STM32G4. The last category belongs to the evolution boards or the reference board from ST microelectronics these boards can be considered as a complete system.

In the digital switched mode power supply domain, several boards have been designed and developed for evaluating several applications it can battery charging applications, it can be for EV infrastructure, it can be for motor control, and many other several applications. There is a large number of boards and only some of them have been listed here.

One thing worth mentioning here all the STM32 Nucleo boards, discovery kits, and evaluation boards are available for purchase directly from the ST website and also from the distributor website. While only a few evaluation boards or reference boards are available for direct purchase. But for all the evaluation boards or the reference boards, the complete schematic or the design details including the magnetics and the firmware application is present on ST dot com.

In the subsequent lectures, we will be focusing on these two particular boards the first board is the STDES-2KW5CH48 volts. It is a 2.5-kilowatt charger board it can take input from 85 volts to 265 volts and the output is for 48-volt battery charging applications.

The front end is the continuous conduction mode PFC while the DC-DC is full bridge LLC and subsequently the rectification while the other boards are the high voltage full bridge LLC converter. In the subsequent lectures, we will be focusing on testing various waveforms which are going to be interesting.

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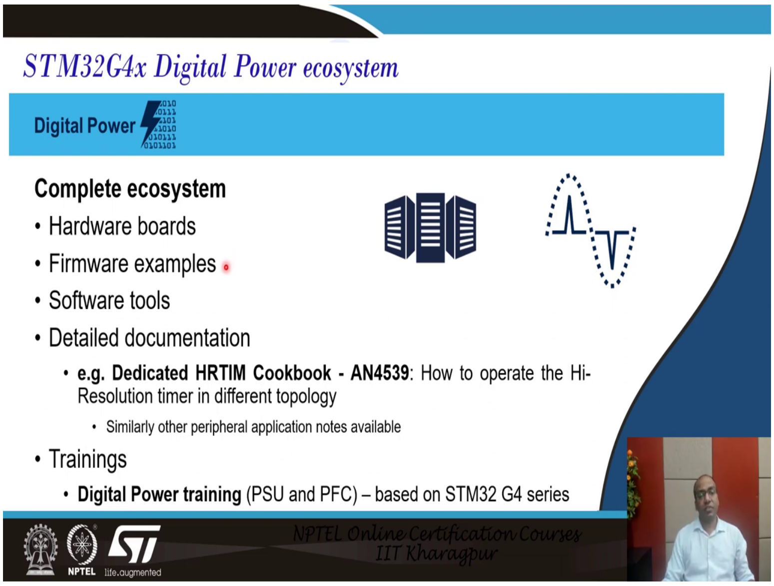

STM32G4 digital power ecosystem in the last couple of slides we have discussed several software tools STM32CubeMX which not only helps in MCU selection MCU pin configuration clock management but also assists in generating the initial workspace with all peripherals initialized. Then we discussed several ideas for a digital power workbench also there are several hardware boards like STM 32 Nucleo boards, discovery boards, and evaluation boards.

Several firmware examples are being developed for STM32 Nucleo boards and discovery boards. Evaluating those examples it does not only assist in understanding the peripherals or the application working but also reduces the time of the final product development.

Apart from that, there is detailed documentation, and there are several application nodes that help in understanding the various peripherals. For example, there is a dedicated HRTIM which is a high-resolution timer cookbook. That helps us in understanding how to use a high-resolution timer for various topologies. Apart from that, there have been several videos on STM32G4 available on the ST website under the category of digital power training.

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Concepts covered in this session several industrial consumer and automotive applications that require AC -DC and DC-DC converters in several topologies. Those converters not only require high integration high efficiency and high reliability but also requires the flexibility to reconfigure. It can be a challenge to the analog solutions, but not for the digital solutions, this we have understood in comparison between analog SMPS versus digital SMPS.

We also had an overview of the STM32 family and STM32 digital power ecosystem, there are several hardware and software tools to support and accelerate the development of digital power applications. In the next module, we will be covering the STM32CubeMX tool and try to capture and learn every feature of it, also we will be covering the various firmware examples developed for STM32 Nucleo and STM32G4 evaluation board in the STM32CubeMC tool which enables a very quick start to real-time code and firmware writing.

Thank you let us meet again in the next session.