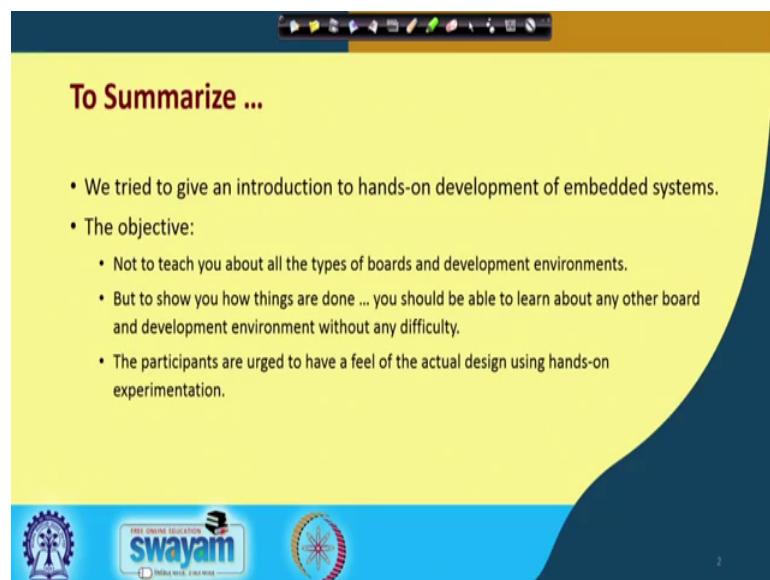


Embedded System Design with ARM
Prof. Indranil Sengupta
Department of Computer Science and Engineering
Indian Institute of Technology, Kharagpur

Lecture – 42
Summarization of the Course

So, we have come to the end of this course on Embedded System Design with ARM. We sincerely hope you have enjoyed this course. So, let me tell a few things about this course before we say goodbye to you.

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To Summarize ...

- We tried to give an introduction to hands-on development of embedded systems.
- The objective:
 - Not to teach you about all the types of boards and development environments.
 - But to show you how things are done ... you should be able to learn about any other board and development environment without any difficulty.
 - The participants are urged to have a feel of the actual design using hands-on experimentation.

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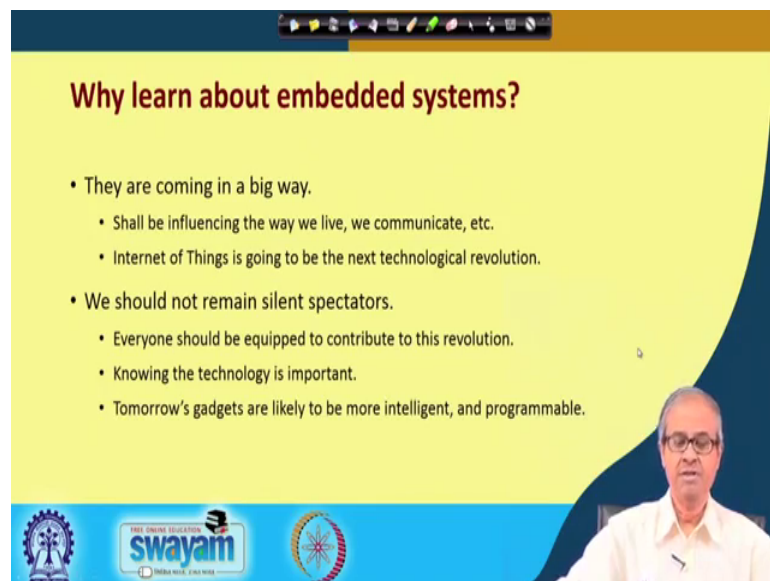
So, let us try to summarize. Now, in this course, we have tried to give you a some kind of broad introduction to the hands-on development of embedded system design. So, as we have seen we have talked very little about the theoretical aspects on the subject. There are other courses, there are very nice textbooks on the subject which dwell with the underlying theory behind the design of embedded systems, how do you do, how do carry out various kinds of trade off, how do design software, how do design hardware, how do you carry out something called hardware-software code design, but we have basically tried to give an introduction to hands-on developmental aspects.

The objective of this course was not to teach you about all the kinds of boards that are available in the market, to tell you about all the kinds of software development systems which are available, but rather we have taken a couple of examples only. We have talked

about the STM 32 board; we have talked about the Arduino board which are very popular development boards. And with the help of those we try to demonstrate that it is quite a simple task to interface devices and build some systems which work according to some requirements, some we are going to say algorithmic requirements.

So, designing such an embedded system is not at all a difficult task, it is very simple in fact. Now, we hope that the participants were with us they were also involved in the actual hands-on demonstration with some of the systems that are available to them, because without hands-on sessions, you really cannot appreciate the beauty and simplicity of this process. There was a time where hardware design was really very cumbersome, but today people are talking about open source hardware design. You buy these modules for the market these modules are really trivial to interface with these boards as I have already seen. They are very simple to interface. And you write a program no longer necessary to write programs in assembly language or machine language, you can write in a high level language like C that we have seen ok.

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Why learn about embedded systems?

- They are coming in a big way.
 - Shall be influencing the way we live, we communicate, etc.
 - Internet of Things is going to be the next technological revolution.
- We should not remain silent spectators.
 - Everyone should be equipped to contribute to this revolution.
 - Knowing the technology is important.
 - Tomorrow's gadgets are likely to be more intelligent, and programmable.

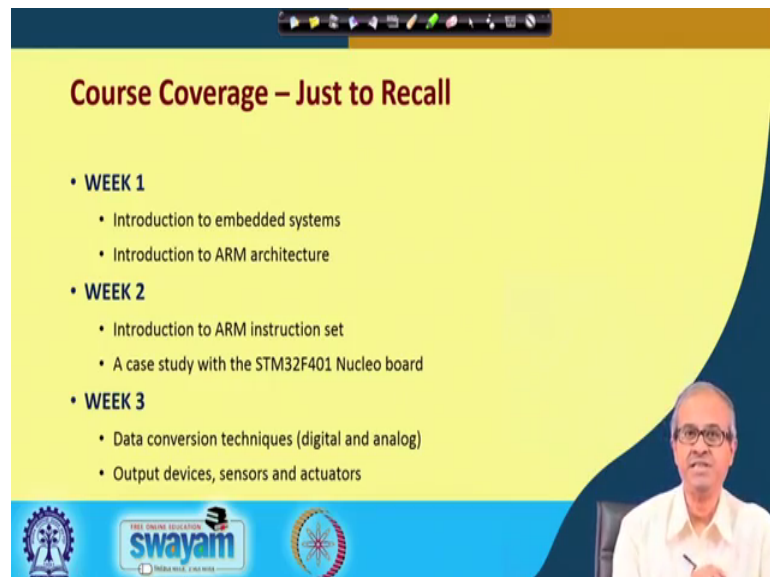
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So, now the question is that why do we need to learn about embedded systems? The first and foremost motivation is that embedded systems are coming to us in a really big way. We have already talked about internet of things, they are spreading like wildfire across every aspects of a life and they shall be spreading we may not be seeing them as yet to that extent, but there are places where they are really spreading very fast. And these

developments shall be influencing the way we live, we communicate that is our daily life ok.

And the point is that we should not remain silent spectators that is why the objective of this course was to try and give you a flavour of the development aspects of embedded system. So, what is the state of their technology with which you can develop such a system today, because tomorrow's gadgets and devices that we will be seeing they will be unlike what we see today. They will mostly be programmable and to program them effectively some knowledge about technology is very important ok.

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The slide is titled "Course Coverage – Just to Recall" and lists the following weekly topics:

- **WEEK 1**
 - Introduction to embedded systems
 - Introduction to ARM architecture
- **WEEK 2**
 - Introduction to ARM instruction set
 - A case study with the STM32F401 Nucleo board
- **WEEK 3**
 - Data conversion techniques (digital and analog)
 - Output devices, sensors and actuators

The slide also features logos for IIT Bombay, Swayam, and IIT Madras at the bottom, and a small video inset of a man in a white shirt in the bottom right corner.

So, very quickly let us go through the weekly coverage what we have covered over the weeks. During the 1st week, we had talked about very introductory aspects about embedded system designs, various tradeoffs and also we talked about the architecture of the ARM microcontrollers. During this 2nd week, we talked about some interesting aspects about the arm instruction set some innovations that were incorporated therein and we took as a case study the STM32 board what are the specific features there. And in a 3rd week, we talked about the AD converter and DA converter designs and various output devices, sensors and actuators. Most of them we actually showed through hands-on demonstrations subsequently in the lab and demonstration sessions.

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- **WEEK 4**
 - Microcontroller development boards and programming environments
 - Interfacing examples with STM32F401 and Arduino UNO boards
 - 7-segment LED and LCD interfacing
- **WEEK 5**
 - Experiments with temperature sensor
 - Experiments with LDR based light sensor
 - Experiments with speaker
 - Experiments with microphone

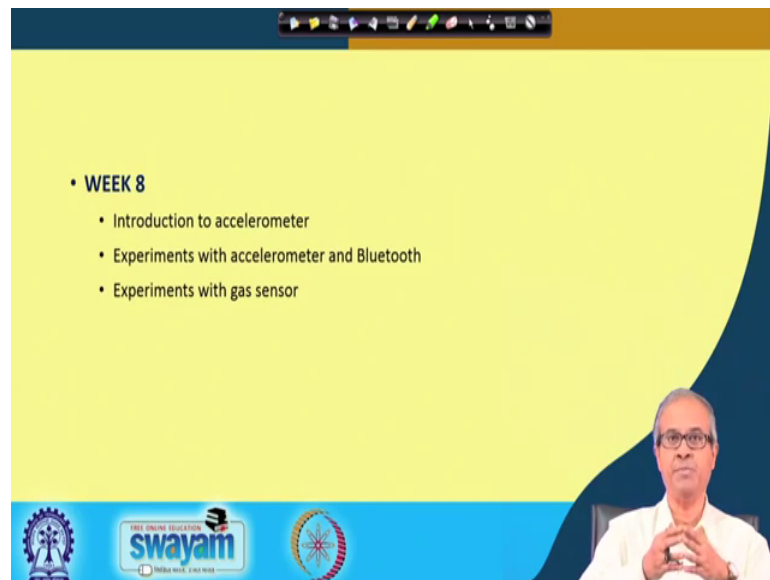
In the 4th week, we talked about the microcontroller development boards and the software development or programming environments. Specifically, we saw the interfacing examples with the two boards I talked about the STM 32 and the Arduino UNO boards. And specifically we had some detailed discussion on 7-segment LED displays and LCD display interfacing. During the 5th week, we talked about experiments with various kinds of sensors like temperature sensors LN 35, light dependent resistors, LDRs, speakers and microphones.

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- **WEEK 6**
 - Introduction to control system design
 - Experiments with relay control
 - Experiments with motor interfacing
- **WEEK 7**
 - Introduction to IoT systems
 - Experiments on home automation using GSM communication
 - Experiments on simple alarm system based on touch sensing

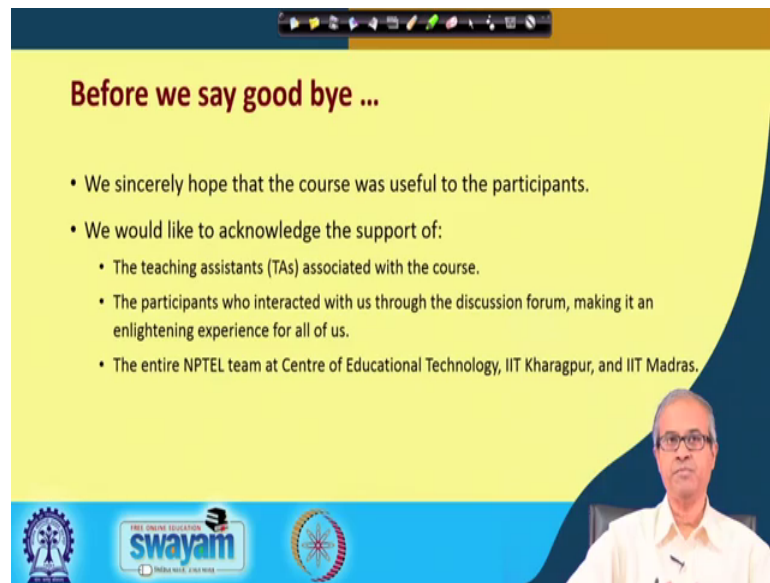
In this 6th week, we very briefly talked about the design of control systems various kind of control algorithms proportional integral on-off control etcetera. Then we saw some experiments using relays and also how we can interface a DC motor to the microcontroller, speed sensing of the motors and so on. So, in the process, we also learned how to use the interrupt system in the STM 32 board. So, we saw that it was really a very simple task for developing this intra based software in this kind of environment. And in week 7, there was a very brief discussion on the internet of things IoTs, then there are some experiments on home automation. Here we also learned about various communication techniques GSM for instance. And also we talked about some simple lm system using some kind of touch sensors and so on.

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And in this last week, we saw how an accelerometer works, what are its various applications. And in particular we had looked at some experiments where you also interfaced such an accelerometer device with Bluetooth technology, where we paired with a mobile phone and some messages were also displayed on the mobile phone screens. And lastly we had some experiments with gas sensors, which is also very important kind of a sensor for many applications.

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Before we say good bye ...

- We sincerely hope that the course was useful to the participants.
- We would like to acknowledge the support of:
 - The teaching assistants (TAs) associated with the course.
 - The participants who interacted with us through the discussion forum, making it an enlightening experience for all of us.
 - The entire NPTEL team at Centre of Educational Technology, IIT Kharagpur, and IIT Madras.

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So, before we end this course and say goodbye to all of you, so I once again sincerely hope myself and also Dr. Komalika Dutta was my co instructor in this course, that the course was useful to you and also it would be very proper to acknowledge the support of various people without which this course recording, the regular day-to-day running would not have been possible. Firstly, the teaching assistants or TAs, who are associated with the course then of course you the participants.

So, the way you interacted with us through the discussion forum, it was really a very rewarding and enlightening experience for all of us. And lastly the entire NPTEL team at the Center of Education Technology here at IIT Kharagpur and also at IIT Madras who are actually running this whole show. They are actually enabling this technology reach to all of you to all of us sharing the knowledge and making this really beautiful and rewarding experience. So, with these few words, we thank you once again, and we hope to see you again in the future.

Thank you.