Embedded System Design

Course Syllabus

Course Title

Embedded System Design

Course Overview

Embedded Systems are ubiquitous in today's age of digital technology. Its application ranges from home automation, health diagnostics, consumer electronics, telecommunication to automotive and IoT industries. With the advent of robust System-On-Chips (SoC) and its associated software ecosystem, embedded design services is becoming increasingly disruptive and a lucrative career option for engineers interested to carve a niche for themselves in this field.

This course aims at providing the foundation and platform to the participants to get started in this direction. The course is designed to enable the participants to gain an in-depth understanding of embedded systems and its applications. After completion of this course, participants will be able to design, develop, integrate, debug, test and validate embedded systems for real time use cases and solutions

Course Duration

45+ hrs – 14hr Lecture, 16hr Lab Sessions, 15hr Final Project

Course Eligibility

- Pursuing UG/PG in B.E/B.Tech - Electronics and Communication/Instrumentation/Electrical/ Telecommunication/Computer Engineering
- Aspiring graduates seeking job opportunities in the field of embedded design and development
- Professionals interested in up-skilling and re-skilling themselves in the embedded domain

Course Highlights

- Course delivered by seasoned industry experts with more than 17 years of experience in embedded software design and development
- Course contents designed exclusively to groom participants and make them industry "ready" for live projects
- Well-structured and modular program framework to ensure participants gain mastery in embedded system design and development concepts
- Online and interactive sessions with a balanced mix of theory sessions, hands-on lab exercises, assignments and mini-projects

Course Pre-requisites

- Basic knowledge on 8-bit microcontroller
- Programming skills in C and Assembly Language
- Basic Know-How of working with Integrated Development Environment (IDEs) and COTS boards

Course Requirements

- Hardware Board - STM32 Discovery / Nucleo Board
- Software IDE - STM32CubeIDE
- Candidates must have a laptop/desktop with minimum configuration: - 64-bit processor - 8GB RAM - 200GB HDD space - Minimum 2Mbps internet connection

Course Contents

1. Introduction to Embedded Systems
2. Basics of Embedded Hardware
3. Working with Embedded Hardware
4. Embedded System Software
5. Multitasking in Embedded Systems
6. Debugging and Testing of Embedded systems

Module Contents

Module - 1

- **Module Title**
  Introduction to Embedded Systems

- **Module Overview**
  This module provides an overview of real time embedded systems and the typical set of features that characterize an embedded system. The design and development aspects of an embedded system with respect to the hardware and software codesign is discussed in detail. Finally, we cover the various end-user applications of real time embedded systems and its use cases in our day to day lives

- **Module Topics**
  - Introduction to Real-Time Embedded Systems
  - Building Blocks of Embedded System
  - Closed loop implementation in Embedded Systems

- Characteristics of Real-Time Embedded Systems
- Design and Development of Real-Time Embedded Systems
- Applications of Embedded Systems

Module - 2

- **Module Title**
  Basics of Embedded Hardware

- **Module Overview**
  This module provides the details on the internals of embedded hardware including the CPU architecture, Memory subsystems, Interrupt handling, Input/output subsystem of processors including Direct Memory Access concepts. We shall discuss the functions and types of timers and counters and its usage in system reset mechanisms. Finally, we shall discuss the basic communication interfaces available on typical embedded systems to communicate with the external world

- **Module Topics**
  - Processor – CPU internals, Instruction Sets, Addressing Modes, Instruction Pipeline, CISC Vs RISC
  - Memory – RAM, ROM, Cache, Flash, Storage, NVRAM
  - Interrupts – Polling Vs Interrupts, Synchronous & Asynchronous, IVT and ISR, Interrupt Priorities, Masking and Unmasking of Interrupts, Hardware Vs Software Interrupts
  - Input and Output – I/O controllers, I/O Mapped and Memory Mapped I/O, DMA concepts
  - Timers and Counters – Hardware Vs Software timers, Clocks and Cycles
  - Resets - Hard Reset, Soft Reset, Watchdog Reset, Cold and Warm Boot
  - Serial Communication – RS-232, RS-422/485

Module - 3

- **Module Title**
  Working with Embedded Hardware

- **Module Overview**
  In this module we shall discuss the fundamentals of embedded hardware design. This module gives an overview of understanding reference manuals, schematics and input/output ports, memory, and communication interfaces of a sample hardware board. Finally, we shall discuss the standard hardware peripherals, interfaces, and communication protocols in typical embedded processor boards

- **Module Topics**
  - Understanding Hardware Reference Manuals, User Guides, Schematics, Datasheets
  - Case study with a sample hardware board and discussion on component identification, input and output ports, memory interface, communication interface etc
  - Hardware I/O interfaces and peripherals - ADC, DAC, SPI, I2C, PWM, I2S, UART, PCI
  - Communication Protocols – USB, CAN, Bluetooth, WiFi, Zigbee

Module - 4

- **Module Title**
  Embedded System Software

- **Module Overview**
  This module provides an in-depth understanding of embedded system software design. We begin with a discussion on Real time systems and scheduling aspects in embedded system software. We shall discuss the role, features, and services of bootloaders. This module also provides an in-depth understanding of Real Time OS concepts including scheduler, task, kernel, I/O and memory management services

- **Module Topics**
  - Introduction to Real Time Concepts
    - Hard Real-Time Vs Soft Real Time systems
    - Real Time scheduling
  - Bootloaders for Embedded Systems
    - Overview of Bootloader concepts and Services - what is a bootloader, Role of a bootloader, features of a bootloader, Boot sequence, Boot scenarios
  - Basics of Real Time Operating System
    - Scheduler, Tasks, Kernel Services, I/O services, Memory Management

Module - 5

- **Module Title**
  Multitasking in Embedded Systems

- **Module Overview**
  In this module we shall discuss the programming aspects and challenges in multitasking systems. We shall dwell deep into the scheduling, interrupt handling and context switching mechanisms in Real time OSes. The various RTOS support services available for Inter task communication are also covered in detail. This module provides insights into the challenges of developing software for multitasking

systems and the various programming techniques to overcome the same using the underlying RTOS services

- **Module Topics**
  - Scheduling for Real time systems
    - Schedulers and Context switching
    - Interrupt handling
  - IPC and Synchronization in Multitasking systems
    - IPC mechanisms - semaphores, mutex, events, queue, mailbox, buffering
  - Multitasking Challenges
    - Deadlock, Livelock, Race conditions, Starvation
    - Error Handling in Embedded systems

Module - 6

- **Module Title**

  Debugging and Testing Embedded systems

- **Module Overview**

  This module provides a deep understanding of development, debug and testing tools and techniques for embedded systems. We shall start with a discussion on the tools used for developing software for embedded systems. We shall also discuss the various mechanisms for debugging software on embedded hardware using hardware and software debug tools. Finally, we shall cover the testing aspects for testing, verifying, and validating software for embedded systems

- **Module Topics**
  - Challenges and Limitations of debugging Embedded Systems
  - Development tools and techniques
    - Development using Integrated Development Environment (IDE) - Creation of Project, Build Process, Build and Compile Settings
    - Toolchains for embedded software
    - Memory Map, Linker Descriptive File, Object File Format
    - Deploying executable images on embedded target
  - Debug tools and mechanisms
    - Overview of hardware debug tools – Oscilloscopes, Logic Analysers
    - Debugging with LEDS, JTAG, ICE
    - Breakpoints, Watchpoints, Probe Points, Profile Points, Memory window, Register window
  - Testing tools and techniques
    - Hardware verification techniques
    - Software diagnostics
    - Testing software on host and target