Mastering ESP32 Development: From Basics to IoT Applications

Course Description

This course offers a deep dive into developing Internet of Things (IoT) applications using the ESP32 microcontroller. From environment setup to advanced IoT protocols like MQTT and ESP-NOW, participants will gain practical skills through hands-on modules covering various aspects of ESP32 development. Whether you're a novice or an experienced developer, this course provides the knowledge and tools to create robust IoT solutions

Audience

- Electronics enthusiasts eager to delve into IoT development.
- Embedded system engineers seeking to expand their skill set.
- Software developers interested in building IoT applications.
- Students pursuing degrees in computer science, engineering, or related fields.

Pre-requisite Knowledge/Skills

Basic understanding of programming concepts and familiarity with C programming language

Course Objectives

- Master the setup and configuration of ESP32 development environments.
- Understand different types of ESP32 microcontrollers and their applications.
- Learn essential programming techniques for IoT applications using C and FreeRTOS.
- Gain proficiency in working with various peripherals such as GPIO, I2C, SPI, UART, and more.
- Explore different storage options and memory management techniques for ESP32.
- Establish internet connectivity and develop REST APIs for IoT applications.
- Build and deploy MQTT and ESP-NOW protocols for efficient communication.
- Develop Bluetooth Low Energy (BLE) applications for sensor networks and wearable devices.
- Create and host web servers on ESP32 for remote monitoring and control of IoT devices.

Course Outline

Module 1: Course Introduction

- Course Introduction
- Overview of Development Boards

Module 2: Environment Setup

- Introduction to Environment Setup
- Installing the ESP-IDF on Windows
- Configuring VS Code for ESP32 Development
- Project Walkthrough
- Managing Multiple IDF Versions

Module 3: ESP32 Types

- Introduction to ESP32 Types
- Comparing Different ESP32 Variants
- Configuring ESP32 Targets in VS Code

Module 4: A First Look - Introduction

- Introduction to Basic ESP32 Programming
- Logging and Debugging Techniques
- Utilizing Delays and Random Number Generation
- Blinking LEDs
- Handling Keyboard Input
- Exploring Example Projects

Module 5: Working with C

- Introduction to C Programming for ESP32
- Understanding Structures and Pointers
- Exploring Function Pointers

Module 6: Headers, Components, and Libraries

- Referencing Header and Source Files
- Understanding ESP32 Components

- Integrating External Components
- Registering Libraries in the IDF Component System

Module 7: Fundamentals in FreeRTOS

- Introduction to FreeRTOS
- Exploring FreeRTOS Resources
- Working with FreeRTOS Tasks
- Utilizing the Second Core
- Understanding Task Notifications, Mutexes, Semaphores, Queues, Event Groups, Timers, and High-Resolution Timers

Module 8: Debugging with OpenOCD

- Introduction to Debugging with OpenOCD
- Manual Debugging Techniques
- Overview of OpenOCD
- Debugging Walkthrough
- Configuring FT2232 for Debugging
- Introduction to QEMU

Module 9: Configuration and Menuconfig

- Introduction to Configuration and Menuconfig
- Basics of Menu Configuration
- Customizing Configuration Options
- Managing Menu Defaults

Module 10: Understanding Memory

- Introduction to Memory Management on ESP32
- Understanding SRAM Allocation
- Working with Dynamic Memory Allocation
- Managing Stack Memory
- Utilizing PSRAM
- Flash Partitioning Techniques

Module 11: Storage

- Introduction to Storage Options on ESP32

- Loading Files Directly into Flash Memory
- Working with Non-Volatile Storage (NVS) for Simple Data
- Customizing NVS Partition and Structured Data
- Introduction to SPIFFS (SPI Flash File System)
- CRUD Operations with SPIFFS
- Implementing Wear Leveling and Read-Only Operations with FAT File System
- Working with SD Cards via SPI and MMC

Module 12: GPIO

- Introduction to General-Purpose Input/Output (GPIO)
- Configuring GPIO Pins for Output
- Reading Input from GPIO Pins
- Handling Interrupts on GPIO Pins
- Implementing Debouncing Techniques
- Configuring GPIO Modes for DAC, ADC, LEDC, PWM, Hall Sensor, and Touch Inputs

Module 13: I2C, SPI, UART

- Introduction to Bus Systems: I2C, SPI, and UART
- Setting up Bluetooth Logging with JDY-31
- Implementing Basic UART Echo Functionality
- Establishing UART Communication with PC
- Utilizing UART Queue for Buffered Communication
- Working with I2C Devices: LM75A Temperature Sensor
- Introduction to SPI Communication
- Wiring and Communicating with SPI Devices
- Displaying Data on SPI-Compatible Displays

Module 14: Sleeping

- Introduction to Power Management and Sleep Modes on ESP32
- Overview of Sleeping Techniques
- Implementing Light Sleep with Timer and GPIO Wake-Up
- Utilizing Deep Sleep with Timer Wake-Up
- Configuring Deep Sleep with External Wake-Up Sources (EXT0, EXT1)
- Understanding Hibernation Mode

Module 15: Internet Connection

- Introduction to Internet Connectivity on ESP32
- Establishing Wi-Fi Connection: Examples and Techniques
- Implementing NTP Time Synchronization
- Handling Wi-Fi Connection Events
- Configuring ESP32 as a Station (STA) or Access Point (AP)

Module 16: Internet REST Client

- Introduction to RESTful APIs
- Sending Simple HTTP GET Requests
- Handling Chunked Data Transfer
- Implementing HTTPS Communication
- Sending and Receiving Large JSON Data
- Creating JSON Data for Sending Emails

Module 17: Internet Server

- Introduction to Creating Internet Servers on ESP32
- Implementing Multicast DNS (MDNS) for Device Discovery
- Toggling an LED with HTTP POST Requests
- Introduction to Websockets
- Implementing Websockets for Real-Time Communication

Module 18: Website on Chip

- Introduction to Hosting Websites on ESP32
- Creating and Flashing Webpages
- Serving Static and Dynamic Webpages
- Implementing MIME Types for Web Content
- Developing React-Based Web Applications

Module 19: MQTT

- Introduction to MQTT Protocol
- Setting up MQTT Test Client
- Establishing MQTT Connection and Subscription
- Publishing and Receiving Data via MQTT
- Implementing Retained Messages and Last Will Testament

Module 20: ESP-NOW

- Introduction to ESP-NOW Protocol
- Implementing Basic ESP-NOW Communication
- Automating Device Registration with ESP-NOW
- Utilizing ESP-NOW for Push Button Applications
- Implementing Encrypted Messages with ESP-NOW

Module 21: Bluetooth BLE

- Introduction to Bluetooth Low Energy (BLE)
- Understanding BLE Stack and Communication Protocols
- Implementing BLE iBeacon and Eddy Stone
- Exploring BLE Generic Access Profile (GAP) and Generic Attribute Profile (GATT)
- Reading and Writing Characteristics in BLE GATT
- Implementing BLE Battery Service
- Handling BLE Events and Descriptors
- Creating BLE Central and Peripheral Applications