**ADAPTIVE INFOTECH**
*New No.304, Old No.88*
*East Perumal Maistry Street*
*Madurai 625 001. Tamil Nadu. India.*
*www.adaptit.co.in Ph.: +(91)452-2330521*

# Fundamentals of Embedded Systems

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## Course Outline

- Introduction to Digital Circuits and Analog Circuits
  - Number Systems, Binary Arithmetic, Boolean Algebra
  - Logic Gates, Combinational Circuits and Switching Circuits
  - ADC and DAC Architectures, Sampling, Quantisation, Encoding
  - Diode, Transistor
  - Clocks, PLL, DLL
  - RLC Characteristics and Circuits, OpAmps
  - Analog System Measurement, Sensors, Potentiometers, Buzzers
  - Real-time concepts and design issues
- Microcontroller
  - Architecture
  - CPU (Control Unit, ALU), RISC
  - Pin Descriptions, Electrical Characteristics
  - Bus interface, Harvard and Von Neumann Architectures
  - Timing Diagrams
  - Memory map
  - Registers (General Purpose, Pointers, IO Port, Serial/Parallel, PC, SP, Status)
  - Instruction Execution Process, Pipelining
  - Interrupts, DMA
  - Clock, Timer/Counter, Analog Comparator
  - Serial Communication and Parallel Communication
  - DTP, Parity Detection
  - GPIO, I2C, SPI, USART
  - Watchdog
- Memory
  - Volatile / Non-volatile, Program / Data
  - SRAM, DDRAM, EEPROM, Flash, Cache
- Peripherals, Interfaces, and I/Os
  - Button, Keypad, LED, LCD, UART, SPI, IIC, PWM, Relay, Motors, Connectors, Headers
- Instruction Set
  - Machine Instructions, Instruction Decoder, OpCodes
  - Memory addressing modes
  - ALU operations, Register transfers
  - Bit addressing / manipulation and flags
  - Stack / Heap operations
- Electronic Circuit Design and Drawing

- ☐ Power and clock speed considerations
- ☐ Schematic capture
- ☐ Bill of Materials
- ☐ Flow Charts

❖ Printed Circuit Board Design
- ☐ OrCAD, Allegro
- ☐ IC Packages, Footprint / Library creation
- ☐ Components placement
- ☐ Layout design and verification
- ☐ Design rules check
- ☐ BOM
- ☐ Gerber creation

❖ Components Soldering Techniques
- ☐ Solder, Flex (solid, liquid), IPA, temperature settings, tools
- ☐ PTH component soldering / desoldering
- ☐ SMD component soldering / desoldering
- ☐ Problems due to bad soldering, identifying and rectifying them

❖ Embedded C Programming
- ☐ Data types, variables, operators, pointers, keywords
- ☐ Control flow, loops, functions, macros, expressions
- ☐ Arrays, strings, storage class
- ☐ I/O Handling (Scanf, Printf), Malloc, Dealloc, Heap, Stack, Floating point data
- ☐ Bitwise operations, enums, structures, and unions
- ☐ Exception handling
- ☐ Pre-processor directives, Libraries
- ☐ Compiler, linker, assembler

❖ Low Level Firmware / Drivers
- ☐ Peripherals and Interfaces
- ☐ GPIOs
- ☐ Direct Memory Access
- ☐ Power Management and Sleep Modes

❖ Hardware / Software Debugging
- ☐ Power-on-reset, Oscillator
- ☐ Clocks, Advanced Timers/Counters, PWM
- ☐ Negative Feedback Control, Audio Message Playback
- ☐ ISRs (Internal and External Interrupts)
- ☐ Peripherals and Interfaces
- ☐ Sensors and Calibrations

❖ Real Time Operating System
- ☐ Tasks, context, priority
- ☐ Interrupts, DMA
- ☐ Semaphore and Mutex
- ☐ Time-slicing, priority pre-emption
- ☐ Memory management

- ☐ Inter-process communication
- ☐ Finite State Machine

❖ Mini Project – Embedded Systems
- ☐ Code walkthrough
- ☐ Atmel AVR, ATMega328P, Microchip PIC, ARM, Cortex-M
- ☐ Arduino, Raspberry Pi
- ☐ Peripherals and Interfaces: Matrix Keypad, GPIO, SPI ADC, I2C memory, LCD/TFT Display, USART, Timer
- ☐ CPLD, FPGA, VHDL / Verilog
- ☐ LED blinking, ASCII Chart, ISO/IEC 8859
- ☐ Combining C/C++ and Assembly
- ☐ Control System and feedback
- ☐ Socket programming, data logging, cloud integration, and automation
- ☐ IDE installation and project creation
- ☐ Embedded code debugging, ICE, JTAG
- ☐ Bluetooth, Zigbee, WiFi, RFID
- ☐ Sensors: PIR, IR, Ultrasonic, Temperature, Pressure, Humidity, MEMS, Gyro
- ☐ Robots
- ☐ Speech Recognition
- ☐ Computer Vision, Real-time video surveillance
- ☐ IoT Architecture and applications, Smart Home System
- ☐ Motion detection and DC motor control using relays and interrupts
- ☐ Designing and implementing an embedded system project

## Benefits of the Course

- ❖ Job opportunities in innovative startups working in embedded space
- ❖ IoT devices development
- ❖ Robotics development
- ❖ Empowers you for building DIY projects with ease and confidence
- ❖ Foundational course pre-requisite for advanced system design using embedded linux
- ❖ Course completion certificate

## Students will learn

- ❖ Explain the basic concepts about how microcontrollers operate
- ❖ Basics of entire life cycle of an embedded system design
- ❖ Basics of Digital and Analog circuits design
- ❖ Usage of Design Tools
- ❖ Microcontroller architecture
- ❖ Assembler, Compiler, and Linker
- ❖ Firmware and Software development and debugging using tools

- Usage of multimeter, oscilloscope, and logic analysers
- AT Commands
- Features and Benefits of Real Time Operating System, Finite State Machines for modularising/simplifying the programs
- Schematic design, PCB layout
- Soldering of Components, Usage of tools
- Peripherals and Interfaces
- Real Time Clock and Timer Services
- Exception Handling
- Direct Memory Access
- Battery Power Optimisation
- Input keys and Output displays
- Key debouncing / de-glitching techniques using FSMs
- Implementation of alpha numeric codes using matrix limited keypad
- Sensor and Module Integrations
- Implement and debug basic program in C using flow control, logical operators, and variables
- Design and develop mini project - sensor and actuator integration, smart door locks
- Implement program to use UART of microcontroller to communicate with PC/serial terminal/keyboard
- How to connect sensors to microcontroller through analog signal interface
- How to do time management in microcontroller programs
- Summarise the fundamental concepts of public and private variables and functions.
- Summarise the fundamentals of relay modules and use them to control DC motor.
- Develop programs to get and manage interrupts with the embedded system board
- Summarise how LEDs are connected and used in electronic circuits.
- Describe how to connect a PIR sensor to the embedded system board using a digital input
- Implement time management on embedded systems using microcontroller timers
- Generate an audio message using Pulse-width modulation
- Develop a simple negative feedback control system
- Implementation of PWM to control the brightness of an RGB LED
- Control the Siren and Strobe Light using PWM
- Describe how an embedded system project can be developed following an ordered process
- Design and implement a prototype of an embedded system, including its hardware and software
- Summarise the fundamentals of the concepts of verification and validation
- Develop programs that are organised into modules and are separated into different files for maintainability and increasing productivity.
- How to connect LCD (character and graphical) Display using GPIOs, I2C, and SPI buses.

- Gas, Temperature, Motion Sensors, IR Sensor, Light Sensor, Ultrasound Sensor, Water/Moisture Sensor
- Alarm generation, Gate control, Solenoid valve
- SAR ADC, Resistor Divider DAC
- Tolerance and size coding of components.
- The libraries/APIs that are used by the modules (i.e. a set of .h files)
- Declarations of definitions, data types, variables, and functions
- The implementation of public and private functions
- Use of PIR sensor as an intruder detection alarm
- IoT based Smart Street Lighting
- Smart City Bike Lights
- Software and Hardware modules of the irrigation system

## Instructor: Rishikeshlalbabu S Ramiya

https://www.linkedin.com/in/rishikeshlalbabu

## Instructor's Training Expertise

- On behalf of AdaptIT, signed an MoU with Dhanalakshmi College of Engineering, Chennai to jointly deliver various technical programmes such as training, final year projects guidance, etc.

- Conducted the following Corporate Trainings
  - CDMA (2G and 3G) – Wipro, Bangalore, ElementK(NIIT), Chennai.
  - GSM – ElementK (NIIT), Chennai.
  - Bluetooth (Protocol Layers, Profiles, IOT, Qualification Process) – L&T, Bangalore, Atheros, Chennai.
  - Network Management – Siemens, Bangalore.
  - Telecom & Datacom – Alcatel-Lucent, Chennai.
  - Wireless Communication Implementation Aspects – Tata Elxsi, Chennai, CDAC, Trivandrum
  - High Speed Transceivers (DDR3, CPRI, SRIO, Gigabit Ethernet) – Altera, Malaysia
  - Image and Video Processing – Altera, Malaysia
  - CPRI Version 4.2 – Tata Elxsi, Bangalore
  - VoIP & SIP – MIMOS, Malaysia, Sapura Secure Technologies, Malaysia
  - Linux – American Mega Trends, Chennai.

- Conducted the following Student Trainings
  - Embedded systems
  - Signals and Systems
  - CDMA / WCDMA
  - GSM / GPRS
  - C/C++ Language
  - DTP/Basic Computer Knowledge

## Instructor's Industrial Experience

- Developed the following AdaptIT products
  - Stand-alone GPS product Hardware and Software for Position Data Logging and Speed Sensing Applications
  - Analog data acquisition and wireless transmission by Bluetooth
  - Automotive Glossary of Electrical, Electronic, & Communication terms

- Completed the following Hardware and Software Client Projects
  - Five Wireless Projects – 1. Anti-jam GPS Receiver 2. mm-wave RADAR 3. DSP-based Wireless base band for WiCOMM-T, 4. WiMAX System Controller (IEEE802.16 - MAC/Network Management & MIB), 5. Zigbee (Wireless Sensor Networks) Software development
  - Five Medical Systems Projects – 1. Modernisation of Auto-Perimeter by touchscreen-based Inputs and Outputs 2. Hardware and Software for Toric Marker 3. Hardware development for Needle Positioner – Biopsy device 4. Hardware and Software development for a compact Tonometer 5. Hardware and Software for Auto-Refractometer / Keratometer
  - One Software Project – 1. TI Sitara's (AM5728) processor-based software (Embedded Linux, TI RTOS)
  - Three Auxiliary Projects – 1. Ambe CODEC 4020 2. Neon Programming 3. IMU Sensor ADIS16497
  - Two Automotive Projects – 1. Java based Electronic Spare Parts Catalogue Software 2. Java based Eicher Service Information
  - Several Matlab/Student Projects – 1. Two-sided impacts (Fortran77 to Matlab conversion), 2. Sophisticated Matlab String Utility Functions, 3. Inventory Control (cost/profit/holding time/shortage optimization), 4. Delta-Sigma Modulator, 5. Unmanned Rail-Road Crossing (Gate Module and Train Module), 6. Remote Temperature Monitoring and Power Automation for PBX Server Room, 7. Unit Commitment problem solution using shuffled leap frog algorithm, 8. Image Feature Extraction, 9. Abstracting Keywords from Hypertext Documents using Stemming Algorithm
  - Two Application Development Projects – 1. Java based MP3 Mixer, 2. S60/Symbian Mobile Application for Smart home

- Work experience
  - Nokia Mobile Phones, San Diego. USA.
    - OSE based CDMA Engine Platform for 3G Cellular / PCS Phone
  - Dialogic Corporation, an Intel Company. New Jersey. USA.
    - Computer Telephony and Fax Products (Voice Brick, Chameleon (D82U))
  - Philips Consumer Communication. New Jersey. USA.
    - IS-95 / J-STD-008 CDMA Standard based Cellular/PCS Phone
  - Hughes Software Systems. India.
    - Fixed-point implementation of MM-CELP CODEC
    - Real Time User Terminal for ICO Land Mobile Satellite Communication System
  - Industrial Consultancy and Sponsored Research, IIT Madras. India.
    - DigiCom Experimenter
    - Programmable Power Line Carrier Communication
    - CorDECT Wireless in Local Loop System

## Instructor's Educational Background

- M.S. (Signal Processing)
  - Indian Institute of Technology, Madras. India.
- B.E. (Electronics and Communication)
  - Madurai Kamaraj University, Madurai. India.
- Specialized Certificate in CDMA Engineering
  - University of California, San Diego. CA. USA.
- Several other Signal Processing and Communication Courses from
  - University of California, San Diego. CA. USA.

- Northeastern University, Boston. MA. USA.