Training Course on Low-Power Embedded System Design for IoT

Professional Development Training Course Outline

Category	Engineering	**Duration**	10 Days
Base Fee	$3,000 USD	**Delivery Mode**	Online / On-site Hybrid

Course Introduction

Introduction

This intensive training course provides a comprehensive deep dive into Low-Power Embedded System Design for IoT, equipping participants with the specialized knowledge and practical skills required to create highly energy-efficient and long-lasting connected devices. Training Course on Low-Power Embedded System Design for IoT focuses on optimizing power consumption across the entire system, from microcontroller selection and software optimization to sensor interfacing, communication protocols, and battery management. Attendees will gain hands-on expertise in crucial concepts such as deep sleep modes, duty cycling, energy harvesting, power gating, and ultra-low power communication standards like LoRaWAN and BLE. This course is meticulously crafted to empower engineers to design IoT devices that can operate for months or even years on a single battery, unlocking new possibilities for remote monitoring, smart agriculture, wearables, and environmental sensing.

The program emphasizes practical application and industry best practices, exploring trending topics like predictive power analysis, TinyML for energy efficiency, advanced battery technologies, and integration with sustainable energy sources. Participants will learn to conduct detailed power profiling, identify energy bottlenecks, and implement highly optimized firmware that intelligently manages power states. By the end of this course, attendees will possess the expertise to architect and implement truly low-power IoT solutions, ensuring extended device lifetimes, reduced maintenance costs, and a significant competitive advantage in the rapidly expanding market for sustainable and autonomous connected devices. This training is indispensable for professionals seeking to innovate in the energy-constrained world of IoT.

Programme Curriculum

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Course Objectives

1. Understand the fundamental principles of power consumption in embedded systems and IoT devices.
2. Select and configure ultra-low-power microcontrollers (e.g., ARM Cortex-M0+, MSP430).
3. Implement and manage various low-power operating modes (sleep, deep sleep, standby).
4. Optimize software for minimal power consumption through efficient coding practices.
5. Design power-efficient sensor interfacing and data acquisition strategies.
6. Choose and apply low-power wireless communication protocols (BLE, LoRaWAN, NB-IoT).
7. Perform accurate power profiling and analysis of embedded systems.
8. Design and implement effective battery management systems (BMS) for IoT devices.
9. Integrate energy harvesting techniques for self-powered applications.
10. Develop duty cycling strategies for periodic data transmission.
11. Optimize TinyML models for ultra-low power inference at the edge.
12. Implement power gating and dynamic voltage/frequency scaling (DVFS) for hardware power control.
13. Troubleshoot and debug power-related issues in embedded IoT designs.

Organizational Benefits

1. Extended battery life of IoT products, leading to lower maintenance and replacement costs.
2. Reduced power consumption across their device fleet, contributing to environmental sustainability.
3. Faster time-to-market for highly energy-efficient IoT solutions.
4. Increased competitiveness in the market for autonomous and long-lasting IoT devices.

5. Lower operational expenses by minimizing site visits for battery changes.
6. Enhanced product reliability by mitigating power-related failures.
7. Greater innovation in developing self-powered or remote IoT applications.
8. Improved ability to meet stricter energy efficiency regulations.
9. Optimized bill of materials (BOM) by reducing battery size or complexity.
10. Development of more attractive products for niche markets requiring extreme power efficiency.

Target Participants

- Embedded Software Engineers
- Hardware Engineers
- IoT Device Developers
- Firmware Developers
- System Architects
- Electrical Engineers focusing on low-power design
- Technical Leads in IoT product development

Course Outline

Module 1: Fundamentals of Low-Power Design

- **Understanding Power Consumption Metrics:** Current, voltage, energy, power states.
- **Sources of Power Consumption:** Active, sleep, leakage currents, switching losses.
- **Trade-offs in Low-Power Design:** Performance vs. Power vs. Cost.
- **Power Budgeting:** Estimating and managing energy resources.
- **Case Study:** Analyzing the power consumption breakdown of a typical coin-cell powered sensor node.

Module 2: Low-Power Microcontroller Selection

- **Microcontroller Architectures for Low Power:** ARM Cortex-M0/M0+, MSP430, RISC-V.
- **Power Modes and Capabilities:** Deep Sleep, Standby, Stop, RTC Wake-up.
- **Peripherals for Low Power:** Low-power UART, ADC, Timers.
- **Core Logic Optimization:** Clock gating, power gating.
- **Case Study:** Selecting the most suitable microcontroller for a low-power, battery-operated smart water meter.

Module 3: Software Optimization for Energy Efficiency

- **Efficient Code Structures:** Avoiding unnecessary loops, optimizing algorithms.
- **Minimizing CPU Wake-ups:** Event-driven programming, interrupt-driven design.
- **Compiler Optimizations:** Impact of optimization levels on code size and speed.
- **Data Handling Optimization:** Efficient data structures, reducing memory access.
- **Case Study:** Refactoring a basic sensor reading application to reduce active CPU time and improve sleep cycles.

Module 4: Low-Power Operating Modes

- **Active Mode Optimization:** Dynamic Voltage and Frequency Scaling (DVFS).
- **Sleep Modes:** Idle, Sleep, Stop, Standby, Deep Sleep.

- **Wake-up Sources:** External interrupts, timers, RTC, communication events.
- **Context Saving and Restoration:** Managing state transitions between modes.
- **Case Study:** Implementing a multi-level power management strategy for a wearable fitness tracker.

Module 5: Power Profiling and Measurement Techniques

- **Current Measurement Tools:** Multimeters, oscilloscopes, power analyzers.
- **Energy Measurement Tools:** Coulomb counters, dedicated power profilers.
- **Analyzing Power Profiles:** Identifying current spikes, average consumption.
- **Debugging Power Issues:** Locating power leaks and inefficiencies.
- **Case Study:** Using a precision current measurement tool to characterize the power consumption of an IoT device in different states.

Module 6: Battery Technologies and Management

- **Battery Chemistry Overview:** Li-Ion, Li-Po, Alkaline, NiMH, LiFePO4.
- **Battery Characteristics:** Capacity, C-rate, self-discharge, voltage discharge curve.
- **Battery Management Systems (BMS):** Fuel gauging, overcharge/discharge protection.
- **Battery Lifetime Estimation:** Calculating expected device operating time.
- **Case Study:** Designing a battery management circuit for a long-range environmental sensor.

Module 7: Energy Harvesting Fundamentals

- **Types of Energy Harvesting:** Solar, thermoelectric, kinetic (vibration), RF.
- **Energy Harvester Components:** Transducers, power management ICs (PMIC).
- **Storage Solutions for Harvested Energy:** Supercapacitors, small rechargeable batteries.
- **Harvesting System Design:** Matching source to load, power conversion efficiency.
- **Case Study:** Designing a solar-powered sensor node with backup battery for continuous operation.

Module 8: Low-Power Sensor Interfacing

- **Sensor Selection:** Choosing low-power sensors, understanding active vs. sleep current.
- **Powering Sensors:** Using load switches, enabling/disabling sensor power.
- **Efficient Data Acquisition:** Burst reading, single-shot conversions.
- **Sensor Calibration and Compensation for Power:** Impact on processing.
- **Case Study:** Optimizing the power consumption of a multi-sensor array by intelligently powering each sensor.

Module 9: Bluetooth Low Energy (BLE) for Low Power

- **BLE Architecture and Concepts:** GAP, GATT, advertisements, connections.
- **BLE Power Optimization:** Connection intervals, advertising intervals, data packet size.
- **Role of Central vs. Peripheral:** Impact on power consumption.
- **BLE Mesh Networking:** Low-power mesh communication.
- **Case Study:** Developing a BLE beacon and an accompanying low-power BLE peripheral for asset tracking.

Module 10: LoRaWAN for Ultra-Low Power Wide Area Networks

- **LoRaWAN Architecture:** End devices, gateways, network server, application server.
- **LoRaWAN Classes (A, B, C):** Power consumption trade-offs.
- **Adaptive Data Rate (ADR):** Optimizing transmission power and data rate.
- **Message Types and Duty Cycle Limits:** Unconfirmed vs. confirmed messages.

- **Case Study:** Deploying a LoRaWAN sensor node for remote agricultural monitoring with multi-year battery life.

Module 11: Other Low-Power IoT Connectivity Options

- **NB-IoT and LTE-M:** Cellular technologies for low-power, wide-area.
- **Sigfox:** Ultra-narrowband for very low data rates and power.
- **Proprietary RF Protocols:** Custom low-power radio implementations.
- **Considerations for Network Overhead:** Protocol efficiency vs. power.
- **Case Study:** Comparing the power profiles of NB-IoT and LoRaWAN for a specific use case scenario.

Module 12: Duty Cycling and Scheduling

- **Concept of Duty Cycling:** Periodic wake-ups, short bursts of activity, long sleep periods.
- **Event-Driven vs. Time-Driven Duty Cycling:** Choosing the right approach.
- **Synchronization and Coordination:** Scheduling multiple devices.
- **Impact on System Responsiveness and Latency:** Trade-offs.
- **Case Study:** Designing a duty-cycled sensor network for indoor environmental monitoring.

Module 13: TinyML and Edge AI for Power Efficiency

- **Introduction to TinyML:** Running ML models on resource-constrained devices.
- **Model Compression and Optimization:** Quantization, pruning, sparsity.
- **Inference at the Edge:** Reducing data transmission to the cloud.
- **Powering ML Inference:** Choosing efficient ML accelerators.
- **Case Study:** Implementing a low-power anomaly detection model on a microcontroller for predictive maintenance.

Module 14: Advanced Power Management Techniques

- **Power Gating:** Switching off power to unused blocks.
- **Clock Gating:** Disabling clocks to idle modules.
- **Dynamic Voltage and Frequency Scaling (DVFS):** Adapting power based on workload.
- **Voltage Regulators:** LDOs, DC-DC converters for efficiency.
- **Case Study:** Optimizing power consumption in a complex SoC by applying power and clock gating techniques.

Upcoming Scheduled Sessions

Start Date	End Date	Location	Price
23 Nov 2026	04 Dec 2026	Online	$2,000
23 Nov 2026	04 Dec 2026	Physical	$3,000
23 Nov 2026	04 Dec 2026	Physical	$6,000
23 Nov 2026	04 Dec 2026	Physical	$6,000
23 Nov 2026	04 Dec 2026	Physical	$12,000

Start Date	End Date	Location	Price
23 Nov 2026	04 Dec 2026	Physical	$9,000
23 Nov 2026	04 Dec 2026	Physical	$12,000
23 Nov 2026	04 Dec 2026	Physical	$12,000

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