BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, Pilani
Pilani Campus
AUGS/ AGSR Division

FIRST SEMESTER 2022-2023
COURSE HANDOUT

Date: 25.08.2022

In addition to part I (General Handout for all courses appended to the Time table) this portion gives further specific details regarding the course.

Course No : **EEE G512**
Course Title : **Embedded System Design**
Instructor-in-Charge : **Meetha V Shenoy**
Instructor (Hyderabad) : **Ershad Ahmed**
Lab Instructors(Pilani) : **Sumitra, Anukaran Khanna**
Lab Instructors(Hyderabad): Jisy N K

1. Course Description: Introduction to embedded systems; embedded architectures: Architectures and programming of microcontrollers, DSPs. Embedded applications and technologies; power issues in system design; introduction to software and hardware co-design.

2. Scope and Objective of the Course:
The course intends to cover the design issues involved in embedded systems and system-on-chip technologies. The course also deals with programming techniques, processor architectures, on-chip & off-chip protocols, performance analysis, and optimization techniques used in embedded system development. This course introduces the students to standard Embedded System Development tools and gives hands-on experience in developing various embedded applications.

No	Course Objective
1	Understanding of Hardware and Software Components of a typical Embedded System
2	Understanding the challenges in " System Level Design" and developing system design skills
3	Develop programming skills and practical expertise in designing, debugging, and developing small-scale and medium-scale Embedded systems
4	Introduction to advanced topics of research in the field of Embedded Systems

3. Text Books:
T1. Wolf, Wayne, Computers as Components – Principles of Embedded Computing System Design, Second Edition, Morgan-Kaufmann, 2008.

4. Reference Books:
R1. Vahid, F, and Givargis, T, Embedded System Design – A Unified Hardware/Software Introduction, John Wiley, 2002.
R2. Joseph Yiu,The Definitive Guide to ARM Cortex M3/M4 Processors-Third Edition
R3. James.K.Peckol, Embedded System Design – A Contemporary Design Tool, Wiley Student Edition, 2010
R4. Steve Furber, ARM System-on-chip Architecture, Second Edition, Pearson, 2007
R5. 8051 Reference Manual
R6. Atmel ATMega 128 Reference Manual

R7. ARMv4 Reference Manual
R8. ARMv7 Reference Manual
R9. LPC 23xx Reference Manual
R10. STMF407 Reference Manual
R11. TI DSP 64xx Manual

5. Course Plan:

1. Introduction to Embedded System
   - 1.1. Introduction
     - 1.1.1. Characteristics and Embodiments of Embedded System
     - 1.1.2. Classification of Embedded Systems
     - 1.1.3. Introduction to Hardware and Software Components of an Embedded System
   - 1.2. Hardware Components of Embedded System
     - 1.2.1. Introduction to Processor Architectures
     - 1.2.2. Memory Types Organization, Cache
     - 1.2.3. Interrupts
     - 1.2.4. Basic peripherals like Timers, ADC/DAC
   - 1.3. Software components of Embedded System
     - 1.3.1. RTOS & Tasks
     - 1.3.2. Introduction to SOC design, Embedded System Design Process/Flow
2. Small Scale Embedded System Design
   - 2.1. Problem Specification
     - 2.1.1. User and System Design Requirements
     - 2.1.2. System Block Diagram Development
     - 2.1.3. Selection of Hardware and Software – Considerations
     - 2.1.4. Hardware/Software Design & Testing Considerations
     - 2.1.5. Final System Design
3. Embedded Architecture 1 – RISC ARM Architecture
   - 3.1. Introduction to ARM CPU Architecture
   - 3.2. Programmers Model of ARM CPU
     - 3.2.1. Register Organization
     - 3.2.2. Operating Modes
     - 3.2.3. Pipelining
     - 3.2.4. ARM Exception Handling
   - 3.3. ARM Instruction Set
4. Embedded Architecture 2 –ARM-Based Microcontrollers
   - 4.1. Introduction to ARMv7-Based Microcontrollers
     - 4.1.1. AMBA Bus Architecture
     - 4.1.2. GPIO, Timer, Watchdog
     - 4.1.3. Interrupt Handling -VIC, ADC/DAC
     - 4.1.4. DMAC
   - 4.2. Communication Peripherals- Synchronous & Asynchronous
     - 4.2.1. SPI , I2C , I2S , UART
     - 4.2.2. CAN
     - 4.2.3. USB
     - 4.2.4. Board Design - System Booting related Concepts

5. Embedded Architecture 3 –DSP Processors

5.1. Introduction to VLIW & DSP architectures
- 5.1.1. Fixed and Floating point Datapath
- 5.1.2. DSP Architectures – Characteristics

6. Distributed and Multiprocessor Based System Design

- 6.1.1. Introduction to Multiprocessor, Distributed and Networked Embedded Systems
- 6.1.2. Case Studies – Distributed and Multiprocessor Systems

7. Embedded Software Design

7.1. System Modeling
- 7.1.1. Hardware-software partitioning

7.2. Compilers, Assemblers, and Debuggers for Embedded Sytems

7.3. Embedded C Programming
- 7.3.1. Memory Management, Shared Memory
- 7.3.2. System Initialization

8. Embedded Software

8.1. Tasks & Task management, Context Switching

8.2. RTS –Task Scheduling Concepts, Semaphore, Mutex, Deadlocks

8.3. Multitasking using ARM Cortex M Architectures – Introduction to RTOS Design/ Study on RTOS

9. Advanced Embedded System Concepts

9.1. Performance Analysis and Optimization

9.2. Accelerated Embedded System

9.3. Fault Tolerance and Reliability

5.1 Lecture Plan

Lecture No	Topic	Reference	Learning outcomes
1	Introduction to Embedded Systems, Characteristics of Embedded System, Course Overview	T1-Chapter 1 + Class Notes	Motivation , Understanding the challenges in " System Level Design" , Develop system design skills
2-3	Performance Metrics, Challenges in Embedded System Design, Embedded System Design Process. Introduction to Hardware and software components of Embedded systems.	T1- Chapter 2 ,3, 4 &7	
4-5	Introduction to Processor Architectures in Embedded Systems- Instruction level, Data Level & Thread-level parallel Architectures (Scalar/Superscalar/VLIW etc) Structural units in a processor and Processor Selection	R2 - Chapter 3 and 4. T1- Chapter 4	Understanding of Hardware and Software Components of a typical Embedded System- How to select components of an embedded system for a given application.
6-7	Memory Devices and Selection, Interfacing Processor Memory + I/O Devices, Introduction to Cache organization	T1,R2,R4	

8-13	Introduction to ARM (RISC) architecture, Programmers Model, Operating Modes, Exception Handling, and Instruction Set(ARMv4 and ARMv7). Introduction to CISC architecture	R2,R4	Detailed understanding of Embedded Architectures, impact on system development, design of the embedded system
14-15	AMBA Bus Architectures	R4, Programmers Manual	Understanding the Impact of the on-chip bus on system design, How to select an embedded architecture for an application.
16-17	Embedded System Clocking, Low Power Modes	Lecture Slides+ DataSheets	System Design, Optimization
18-22	I/O Devices- Interrupt Servicing- Timing and Counting devices, GPIO, ADC, DAC, DMA Interrupt Servicing, Interrupt Servicing Mechanism, Context and Periods of Context Switching, Latency.(Study will be based on a microcontroller based on ARM Cortex M4 architecture as an example architecture)	Lecture Slides+ Data Sheets	Understanding of on-chip & off-chip peripherals, bus standards, and Interfacing external components.
23-25	Bus Standards & Architectures - I2C, Microwire, CAN, I2S, UART, SPI, SSP		
26	Case Studies Example-Small/Medium Scale Embedded System Design	Lecture Slides	System Design concept through on-paper design
27-28	Memory Management, Virtual Memory	T1,R4	Impact of Memory System on overall system performance
29-31	Introduction to RTOS for Embedded Systems - Tasks & Task Management, Context Switching.IPC, Resource Sharing – Semaphores, Deadlock ,Locks, Mutexes. RTS & RTOS – Basic Scheduling Strategies. RTOS support features in ARM-Cortex M4. RTX RTOS- Case Studies	R3	Introduction to Real Time Systems & Real Time Operating Systems- Designing Embedded Systems with RTOS
32-33	Embedded System modeling, Hardware Software Partitioning, Compiler, Assemblers, Debuggers for Embedded Systems .	R3	Advanced Embedded C concepts
34-35	Introduction Multiprocessor, Distributed,	Supplementary	Case Studies

	and Networked Embedded System (Including IoT Systems)	Notes will be provided	
36	Introduction to Advance Architectures, VLIW & DSP Architectures –Processors Data Path	Lecture Slides+ Data Sheets	Introduction to DSP
37	Power Issues- CPU Power Consumption and optimization(Covered through other lectures as well)	Supplementary Notes	System Design, Optimization
38	Embedded System Booting	R3	System Start-up considerations, System Design
39-40	Reliability, Fault-tolerant, and Safety Critical Embedded System Design. Accelerated Embedded System. [The topic might change depending on the student's interest].	Supplementary Notes, Published Papers	Introduction to advanced areas of study & research in Embedded Systems

6. Evaluation Scheme:

Component	**Duration**	**weightage (%)**	**Date & Time**	**Nature of component (Close Book/ Open Book)**
Mid-semester Exam	90 mins	25	As per time Table	CB
Lab Tasks, Design Project	TBA	30	Continuous Evaluation	OB/OL
Study on Advanced Topics *	For 6 weeks	10	To be Announced	OB/OL
Comprehensive Examination	3 hours	35	As per time Table	Part A- CB + Part B – OB/OL

• Students in groups will have to refer to published papers in their chosen area and deliver two seminars and submit abstract/term paper (Details will be provided **). Marks are also reserved for interaction and participation in seminars. It is mandatory to attend the presentation of all student groups.

Lab Tasks, Design Project- Will be announced separately for Pilani & Hyderabad Campus.

7. Chamber Consultation Hour: Students can meet me after requesting an appointment via email: **meetha.shenoy@pilani.bits-pilani.ac.in**

8. Notices: All notices regarding the course will be put up on the course website.

9. Make-up Policy: In general, Make-up will not be granted without prior permission. If the student is unable to appear for the Mid-Semester Test/ Comprehensive Examination due to genuine exigencies, the student must refer to the procedure for applying for Make-up.

10. Note (if any): It shall be the responsibility of the individual student to be regular in attending lectures and the lab sessions as per the schedule announced in time table.

Instructor-in-charge:
Dr. Meetha V Shenoy
Course No. EEE G512