**Course Plan**

**T.E. (ECS) (Semester VI)**

Embedded Systems and Real Time Programming

Subject code: ECC 601

Teacher-in-charge: Dr. Sapna Prabhu Academic Term: January-April 2023

|  |  |  |  |
| --- | --- | --- | --- |
| **Module**  **No.** | **UnitNo.** | **Contents** | **Hrs.** |
| **1** |  | **Introduction to Embedded Systems** | **03** |
| **1.1** | Definition, Characteristics, Classification, Application |
| **1.2** | Design metrics of Embedded system and Challenges in optimization of metrics |
| **2** |  | **Embedded Hardware Elements** | **13** |
| **2.1** | Features of Embedded cores- µC, ASIC, ASSP, SoC, FPGA, RISC and CISC cores. Types of memories. |
| **2.2** | Case Study: ARM Cortex-M3 Features, Architecture, Programmer’s model, Special Registers, Operating Modes and States, MPU, Memory map and NVIC. |
| **2.3** | Low power: - Need and techniques. Case study of Low Power modes in Cortex-M3. |
| **2.4** | Communication Interfaces: Comparative study of Serial communication Interfaces (RS-232, RS-485), SPI, I2C, CAN, USB (v2.0), Bluetooth, Zig-Bee. (Frame formats of above protocols are not expected) |
|  | **2.5** | Selection criteria of Sensors and Actuators |  |
| **3** |  | **Embedded Software** | **12** |
| **3.1** | Program Modelling concepts: DFG, CDFG, FSM. |
| **3.2** | Real-time Operating system: - Need of RTOS in Embedded system software and comparison with GPOS, Task, Task states, Multi-tasking, Task scheduling, and Algorithms-Preemptive SJF, Round-Robin, Priority, Rate Monotonic Scheduling, Earliest Deadline First. Inter-process communication: Message queues, Mailbox, Event timers. Task synchronization: Need, Issues - Deadlock, Race condition, live Lock, Solutions using Mutex, Semaphores. Shared data problem, Priority inversion. |
| **4** |  | **Introduction to Free RTOS** | **03** |
|  | Free RTOS Task Management features, Resource Management features, Task Synchronization features, Event Management features, Calculate the CPU Utilization of an RTOS, Interrupt Management features, Time Management features. |
| **5** |  | **Testing and Debugging Methodology** | **02** |
| **5.1** | Testing & Debugging: Hardware testing tools, Boundary-scan/JTAG interface concepts, Emulator |
| **5.2** | Software Testing tools, simulator, debugger. White-Box and Black-Box testing. |
| **6** |  | **System Integration (Case Studies)** | **06** |
| **6.1** | Embedded Product Design Life-Cycle (EDLC)- Waterfall Model |
| **6.2** | Hardware-Software Co-design |
| **6.3** | Case studies for Automatic Chocolate Vending Machine, Washing Machine, Smart Card, highlighting i) Specification requirements (choice of components), ii) Hardware architecture iii) Software architecture |
|  | **Total** | **39** |

**Course Pre-requisites:**

Digital Electronics (ECC 303)

Microprocessors and Microcontrollers (ECC 404)

**Course Objectives:**

1. To study concepts involved in Embedded Hardware and Software for System realization.

2. To learn the concepts of modern microcontroller cores like the ARM-Cortex

3. To learn Real-time programming to design time-constrained embedded systems

**Course Outcomes:**

After successful completion of the course students will be able to:

1. Identify and describe various characteristic features and applications of Embedded systems.

2. Analyze and select hardware for Embedded system implementation.

3. Evaluate various communication protocols for Embedded system implementation.

4. Compare GPOS and RTOS and analyze the concepts of RTOS.

5. Evaluate and use various tools for testing and debugging embedded systems

6. Design a system for different requirements based on life-cycle for the embedded system, keeping oneself aware of ethics and environmental issues

**CO-PO/PSO mapping**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **PO1** | **PO2** | **PO3** | **PO4** | **PO5** | **PO6** | **PO7** | **PO8** | **PO9** | **PO10** | **PO 11** | **PO 12** | **PSO1** | **PSO2** |
| **ECC 601.1** |  | 2 |  |  |  |  |  |  |  |  |  |  |  |  |
| **ECC 601.2** |  | 2 | 3 |  |  |  |  |  |  |  |  |  | 2 |  |
| **ECC 601.3** |  | 2 | 2 |  |  |  |  |  |  |  |  |  |  |  |
| **ECC 601.4** |  |  |  | 2 | 3 |  |  |  |  |  |  |  | 2 | 2 |
| **ECC 601.5** |  |  |  |  | 3 | 2 |  |  |  |  |  |  |  |  |
| **ECC 601.6** |  |  | 3 |  |  |  | 2 | 2 |  |  |  |  | 2 |  |

**CO-PO Mapping:(BL – Blooms Taxonomy, C – Competency, PI – Performance Indicator)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **CO** | **BL** | **C** | **PI** | **PO** |
| **ECC 601.1** | 2 | 2.1 | 2.1.1 | PO2 |
| **ECC 601.2** | 4 | 2.1 | 2.1.2 | PO2 |
| 3.3 | 3.3.1 | PO3 |
| **ECC 601.3** | 4 | 2.1 | 2.1.2 | PO2 |
| 3.3 | 3.3.1 | PO3 |
| **ECC 601.4** | 4 | 4.1 | 4.1.2 | PO4 |
| 5.1  5.2 | 5.1.1  5.2.1 | PO5 |
| **ECC 601.5** | 4 | 5.1 | 5.1.1 | PO5 |
| 6.1 | 6.1.1 | PO6 |
| **ECC 601.6** | 6 | 3.1  3.2  3.3  3.4 | 3.1.1  3.2.1  3.3.1  3.4.1 | PO3 |
| 7.1 | 7.1.1 | PO7 |
| 8.1 | 8.1.1 | PO8 |

**CO Assessment Tools:**

|  |  |  |
| --- | --- | --- |
| ***Course Outcomes*** | ***Indirect*** | |
| Unit Tests | | | Assignment | Class discussion/ Other class activities | End Sem Exam | Course exit survey |
| 1 | 2 | |  |  |
| **ECC 601.1** | 20% | -- | | -- | 20% | 60% | 100% |
| **ECC 601.2** | 20% | -- | | -- | 20% | 60% | 100% |
| **ECC 601.3** | -- | 20% | | -- | 20% | 60% | 100% |
| **ECC 601.4** | 20% | -- | | -- | 20% | 60% | 100% |
| **ECC 601.5** | -- | 40% | | -- | - | 60% | 100% |
| **ECC 601.6** | -- | 10% | | 10% | 20% | 60% | 100% |

**Rubrics for assessing Course Outcome with each assessment tool:**

|  |  |  |  |
| --- | --- | --- | --- |
| **Rubrics** |  |  |  |
| **Assignment** | **Timeline(4)**  On time -4  One day late-2  Later than one day -0 | **Level of content(4)**  Excellent-4  Good -3  Satisfactory-2 | **Neatness(2)**  Neat -2  Else-0 |
| **Case Study** | **Level of content(5)**  Excellent-4  Good -3  Satisfactory-2 | | **Presentation (5)**  Excellent-4  Good -3  Satisfactory-2 |

**Curriculum gap:** Discussion on ARM 7 architecture

**Content beyond syllabus:** Lectures/videos on ARM 7 architecture

**Text Books:**

1. Dr. K. V. K. K. Prasad, “Embedded Real Time System: Concepts, Design and Programming”, Dreamtech, New Delhi, Edition2014.

2. Rajkamal, “Embedded Systems: Architecture, Programming and Design”, McGraw Hill Education (India) Private Limited, New Delhi, 2015, 3rd Edition.

3. Sriram Iyer, Pankaj Gupta, “Embedded Real Time Systems Programming”, Tata McGraw Hill Publishing Company ltd., 2003.

4. Joseph Yiu, “The Definitive guide to ARM CORTEX-M3 & CORTEX-M4 Processors”, Elsevier, 2014, 3rd Edition.

5. [www.freertos.org](http://www.freertos.org)

**Reference Books:**

1. David Simon, “An Embedded Software Primer”, Pearson,2009.

2. Jonathan W. Valvano, “Embedded Microcomputer Systems – Real Time Interfacing”, Publisher - Cengage Learning, 2012 3rd Edition.

3. Andrew Sloss, Domnic Symes, Chris Wright, “ARM System Developers Guide Designing and Optimising System Software”, Elsevier, 2004.

4. FrankVahid, Tony Givargis, “Embedded System Design – A Unified Hardware/SoftwareIntroduction”, John Wiley & Sons Inc., 2002.

5. Shibu K V, “Introduction to Embedded Systems”, Tata McGraw Hill Education Private Limited, New Delhi,2009

**Lesson Plan**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **CLASS** | | | | | | | | | TE (ECS) | | | | | |
| **Academic Term** | | | | | | | | | January-April 2023 | | | | | |
| **Subject** | | | | | | | | | Embedded systems and RTOS | | | | | |
| ***Periods (Hours) per week*** | | | | ***Lecture*** | | | | | |  | | | | |
| ***Practical*** | | | | | |  | | | | |
| ***Tutorial*** | | | | | |  | | | | |
| ***Evaluation System*** | | | |  | | | | | | ***Hours*** | ***Marks*** | | | |
| Theory examination | | | | | | 3 | 80 | | | |
| Internal Assessment | | | | | | -- | 20 | | | |
| Practical Examination | | | | | | -- | -- | | | |
| Oral Examination | | | | | | -- | -- | | | |
| Term work | | | | | | -- | -- | | | |
| Total | | | | | | -- | 100 | | | |
|  | | | | | | | | | | | | | | |
| ***Time Table*** | | | | ***Day*** | | | | | | ***Time*** | | | | |
| Monday | | | | | | 12.15 pm-1.15 pm | | | | |
| Wednesday | | | | | | 11.15 am-12.15 pm | | | | |
| Friday | | | | | | 12.15 pm-1.15 pm | | | | |
| ***Course Content and Lesson plan*** | | | | | | | | | | | | | | |
| **Lecture**  **No.** | | **Date** | | | | | | **Topic** | | | | |  | |
| **Planned** | | | | **Actual** | |  | | | | | **Remarks**  **(If any)** | |
|  | | | | | | | | | | | | | | |
|  | 1 | | 10/1/23 | | 10/1/23 | | Introduction | | | | |  | | | | |
| 2 | | 11/1/23 | | 11/1/23 | | Definition, Characteristics, Classification Application | | | | |  | | | | |
| 3 | | 13/1/23 | | 13/1/23 | | Design metrics of Embedded system and Challenges in optimization of metrics | | | | |  | | | | |
| 4 | | 17/1/23 | | 17/1/23 | | Real-time Operating system: - Need of RTOS in Embedded system software and comparison with GPOS | | | | |  | | | | |
| 5 | | 18/1/23 | | 18/1/23 | | Task, Task states, Multi-tasking | | | | |  | | | | |
| 6 | | 20/1/23 | | 20/1/23 | | Interrupt Latency | | | | |  | | | |
| 7 | | 23/1/23 | | 23/1/23 | | Task scheduling, and Algorithms-Preemptive SJF, Round-Robin, Priority, Rate Monotonic Scheduling, Earliest Deadline First. | | | | |  | | | |
| 8 | | 25/1/23 | | 25/1/23 | | Numericals on RMS | | | | |  | | | |
| 9 | | 31/1/23 | | 31/1/23 | | Inter-process communication: Usage of semaphores | | | | |  | | | |
| 10 | | 2/2/23 | | 2/2/23 | | Message queues, Mailbox, Event timers. | | | | |  | | | |
| 11 | | 3/2/23 | | 3/2/23 | | Task synchronization: Need, Issues - | | | | |  | | | |
| 12 | | 6/2/23 | | 6/2/23 | | Deadlock, Race condition, live Lock, | | | | |  | | | |
| 13 | | 8/2/23 | | 8/2/23 | | Solutions using Mutex, Semaphores. | | | | |  | | | |
| 14 | | 10/2/23 | | 10/2/23 | | Shared data problem, Priority inversion. | | | | |  | | | |
| 15 | | 13/2/23 | | 13/2/23 | | Program Modelling concepts: DFG, CDFG, FSM. | | | | |  | | | |
| 16 | | 15/2/23 | | 15/2/23 | | Program Modelling concepts: DFG, CDFG, FSM. | | | | |  | | | |
| 17 | | 17/2/23 | | 17/2/23 | | Free RTOS Task Management features, Resource Management features | | | | |  | | | |
| 18 | | 20/2/23 | | 20/2/23 | | Task Synchronization features, Event Management features | | | | |  | | | |
|  | 19 | | 22/2/23 | | 22/2/23 | | Calculate the CPU Utilization of an RTOS, Interrupt Management features | | | | |  | | | |
| 20 | | 24/2/23 | | 24/2/23 | | Time Management features | | | | |  | | | |
| **Unit Test 1 – February 27,2023-March 1,2023** | | | | | | | | | | | | | | |
| 21 | | 3/3/23 | | 3/3/23 | | Features of Embedded cores- µC, ASIC, ASSP, SoC, FPGA, RISC and CISC cores. Types of memories. | | | | |  | | | |
|  | 22 | | 3/3/23 | | 3/3/23 | | Discussion on ARM 7 architecture and features | | | | | **BSA** | | | |
|  | **Guest Lecture: Trends in Embedded Industry** | | | | | | | | | | | | | | |
|  | 23 | | 6/3/23 | | 6/3/23 | | Case Study: ARM Cortex-M3 Features, Architecture | | | | |  | | | |
| 24 | | 8/3/23 | | 8/3/23 | | Programmer’s model, Special Registers, | | | | |  | | | |
| 25 | | 10/3/23 | | 10/3/23 | | Operating Modes and States, | | | | |  | | | |
| 26 | | 13/3/23 | | 13/3/23 | | MPU, Memory map and NVIC | | | | |  | | | |
| 27 | | 15/3/23 | | 15/3/23 | | Low power: - Need and techniques. Case study of Low Power modes in Cortex-M3. | | | | |  | | | |
|  | 28 | | 17/3/23 | | 17/3/23 | | Communication Interfaces: | | | | | **Class Discussion** | | | |
| 29 | | 20/3/23 | | 20/3/23 | | Communication Interfaces: | | | | |  | | | |
| **30** | | 24/3/23 | | 24/3/23 | | Selection criteria of Sensors and Actuators | | | | |  | | | |
| **Cultural Week** | | | | | | | | | | | | | | | | | |
|  | 31 | | 3/4/23 | | 3/4/23 | | Testing & Debugging: Hardware testing tools, Boundary-scan/JTAG interface concepts, Emulator | | | | |  | | | |
| 32 | | 5/4/23 | | 5/4/23 | | Software Testing tools, simulator, debugger. White-Box and Black-Box testing. | | | | |  | | | |
| 33 | | 10/4/23 | | 10/4/23 | | Embedded Product Design Life-Cycle (EDLC)- Waterfall Model | | | | |  | | | |
|  | 34 | | 12/4/23 | | 12/4/23 | | Hardware-Software Co-design | | | | |  | | | |
| 35 | | 12/4/23 | | 12/4/23 | | Case studies for Automatic Chocolate Vending Machine, Washing Machine, Smart Card, highlighting i) Specification requirements (choice of components), ii) Hardware architecture iii) Software architecture | | | | |  | | | |
| 36 | | 15/4/23 | | 15/4/23 | | Revision | | | | |  | | | |
|  | 37 | | 15/4/23 | | 15/4/23 | | Revision | | | | |  | | | |
| **Unit Test 2 –April 17, 2023- April 20,2023** | | | | | | | | | | | | | |
|  |  | | Total | |  | |  | | | | | 37 | | | |

**Examination Scheme**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Module** | | **Lecture Hours** | **Marks distribution in Test (For internal assessment/TW)** | | **Approximate Marks distribution in Sem. End Examination** |
| **Test 1** | **Test 2** |
| 1 | **Introduction to Embedded Systems** | 03 | 05 | - | 05 |
| 2 | **Embedded Hardware Elements** | 13 | - | 10 | 20 |
| 3 | **Embedded Software** | 12 | 10 | - | 25 |
| 4 | **Introduction to Free RTOS** | 03 | 05 | - | 10 |
| 5 | **Testing and Debugging Methodology** | 02 | - | 05 | 10 |
| 6 | **System Integration (Case Studies)** | 06 | - | 05 | 10 |

|  |  |
| --- | --- |
| Submitted By | Approved By |
| Dr Sapna Prabhu | Dr D.V. Bhoir |
| Sign: | Sign: |
|  |  |
| Date of Submission: | Date of Approval: |
|  | |