**Birla Institute of Technology & Science, Pilani**

**Work Integrated Learning Programmes Division**

## **Digital Learning** **Handout**

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| Course Title | Real Time Systems |
| Course No(s) | BITS ZG553/ ES ZG553/MEL ZG553/SS ZG553 |
| Credit Units | 5 |
| Credit Model | Theory + Lab Assignments |
| Content Author | Prof. K R Anupama |
| Instructor-In-Charge | KONERU GOPALAKRISHNA |

**Course Description:**

Fundamentals of real time systems- Typical real time systems, Hard and soft real time systems; A reference model of real time systems- processors and resources, periodic task model, precedence constraints; commonly used approaches to real time scheduling- clock driven approach, priority driven approach- various scheduling algorithms; resource and resource access control; hardware considerations in real time systems; Multiprocessing and distributed real time systems; Real time operating systems.

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| **COURSE OBJECTIVES** | |
| **LO1** | To introduce the issues and challenges in developing software for Real Time / embedded systems |
| **LO2** | To introduce Real Time Scheduling in uni-processing, multi-processing and distributed RTS |
| **LO3** | Introduce concepts of Real Time Operating Systems (RTOS) to the students. |

**Text Book(s):**

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| **T1** | Liu, Jane W.S., Real Time Systems, Pearson Education, 2000 |
| **T2** | Laplante, Phillip A., Real-Time Systems Design and Analysis, WSE, 4th Ed., 2012. |

**Reference Book(s) & other resources:**

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| **R1** | C.M.Krishna, K.G.Shin, *Real Time Systems,* McGraw Hill Education,2010 |
| **R2** | Phillip.A.Laplante, S.J.Ovaska, *Real Time System Design and Analysis,* 4th edition,2012\* |
| **R3** | Shaw, Real-Time Systems and Software, John Wiley & Sons Inc., 2001. ISBN 0-471-35490-2\* |
| **R4** | H. Kopetz, *"Real-time Systems,"* Design Principles for Distributed Embedded Applications 2nd edition, Springer, 2011\* |
| **R5** | Sivamurthy, G. Manimaran, *Resource Management in Real-Time Systems and Networks ,*PHI, New Delhi,2005 |

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| **COURSE OUTCOMES** | |
| **LO1** | Ability to Design and Analyze Scheduling Algorithms for Single Processor Embedded Real Time Systems |
| **LO2** | Ability to Design and Analyze Scheduling Algorithms for Single Processor Embedded Real Time Systems |
| **LO3** | Ability to design , build Real Rime Embedded Systems |
| **LO4** | Knowledge about both theoretical and practical aspects of Real Time Operating Systems (RTOS). |

**Experiential Learning Components:**

1. Introduction to Cheddar simulation Environment to analyze Scheduling Algorithms for single processor real time systems and example of RTOS (<https://www.keil.com/demo/eval/armv4.htm>)

**Content Structure:**

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| **Contact Hour** | **List of Topic Title** | **Sub-Topics** | **Reference** |
| 1-2 | Introduction to Real time system | * Typical Real-Time Systems * Dependability * Fault Tolerance * Hard Vs Soft Real Time Systems | T1 Ch1, T2 Ch1, T1 Ch 2 |
| 3-4 | A Reference Model of Real-Time Systems | * Processors and Resources * Temporal Parameters of Real-Time Workload * Periodic Task Model * Precedence Constraints and Data dependency * Functional Parameters * Resource Parameters   Feasibility, Optimality and Performance Measures | T1 Ch 3 |
| 5-6 | Scheduling Algorithms – An Introduction, Commonly used Scheduling Algorithms | * Clock-Driven Approach * Round-robin and Weighted Round-robin Approaches * Priority-Driven Approach   Effective Release Times and Deadlines | T1 Ch 4 |
| 7-8 | Commonly Used Approaches to Real-Time Scheduling | * Off-line vs On-line Scheduling * Different Scheduling Algorithms   + EDF Algorithm   + LRT Algorithm   LST Algorithm   * Static Timer Driven Scheduler * General Structure of Cyclic Schedules   Cyclic Executives | T1 Ch 5 |
| 9-10 | Clock Driven Scheduling | * Scheduling Aperiodic Jobs * Scheduling Sporadic Jobs * Practical Considerations * Pros and Cons of Clock-Driven Scheduling | T1 Ch 5 |
| 11-12 | Priority-Driven Scheduling of Periodic Tasks | * Fixed-Priority vs Dynamic-Priority Algorithms * Well-known Fixed-priority Scheduling Algorithms   + RM (Rate-Monotonic) Algorithm   + DM (Deadline-Monotonic) Algorithm * Well-known Dynamic-priority Scheduling Algorithms * EDF (Earliest Deadline First) Algorithm * LST (Least-Slack-Time-First) Algorithm | T1 Ch 6 |
| 13-14 | Priority-Driven Scheduling of Periodic Tasks  Priority-Driven Scheduling of Periodic Tasks, Scheduling Aperiodic and Sporadic Jobs in Priority-Driven Systems | * Maximum Schedulable Utilization of Different Scheduling Algorithms * Time Demand Analysis for Fixed Priority Systems | T1 Ch 6 |
| 15-16 | Buffer/ Review |  | - |
| 17-18 | Scheduling Aperiodic and Sporadic Jobs in Priority-Driven Systems | * Assumptions and Approaches * Deferrable Servers * Deferrable Servers | T1 Ch 7 |
| 19-20 | Scheduling Aperiodic and Sporadic Jobs in Priority-Driven Systems | * Scheduling of Sporadic Jobs | T1 Ch 7 |
| 21-22 | Resource and Resource Access Control | * Resource and Their Usage * Effect of Resource Contention and Resource Access Control | T1 Ch 8 |
| 23-24 | Resource and Resource Access Control | * Basic Priority Ceiling Protocol * Basic Priority Inheritance Protocol | T1 Ch 8 |
| 25-26 | Hardware Considerations in Real-Time Systems | * CPU * Memory * Peripheral Devices | T2 Ch3 |
| 27-30 | RTOS  Review | * Inter-task communication and synchronization * Memory Management   Storage & File System   * Review | Lecture Notes |
| 31-32 | Multi- Processing and Distributed Systems | * Priority-driven Preemptive Scheduling, Static Table-Driven Scheduling, Dynamic Plan-based Scheduling, Integrated Scheduling of Hard and QoS - Degradable Tasks, Real-Time Scheduling with Feedback Control * Resource reclaiming in Multi-Processor RTS * Fault-Tolerant task Scheduling in Multiprocessor RTS - Fault Classification, Fault Tolerance in RTS, Fault-Tolerant Scheduling Algorithms for Multi-Processor Systems, Scheduling of Real-Time Imprecise Computations | Lecture notes |

**Laboratory Component (Self Study- Lab manual will be provided ):**

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| Exp No. | Experiment Title | Reference to handout module/section |
| 1. | Introduction to Cheddar Simulation Environment/ Building a new project | An Introduction, Commonly used Scheduling Algorithms |
| 2. | Implementing LST/RM/DM algorithms | Priority driven Algorithms |
| 3. | Implementing user defined scheduling algorithms | Priority driven Algorithms |
| 4. | Implementation of PIP and PCP protocol | Resource and Resource Access Control |
| 5. | Introduction to RTOS on STM32 | <https://www.keil.com/demo/eval/armv4.htm> |

**Evaluation Scheme:**

**Legend:** EC = Evaluation Component; AN = After Noon Session; FN = Fore Noon Session

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| Evaluation Component | Name | Type | Weight | Duration | Day, Date, Session, Time |
| EC - 1 | Quiz-I | Online | 10% | 30 min | February 19-28, 2024 |
| Quiz-2 | Online | 10% | 30 min | March 19-28, 2024 |
|  | Quiz-3 | Online | 10% | 60min | April 19-28, 2024 |
| EC - 2 | Mid-Semester Test | Closed Book | 30% | 2 hours | Friday, 15/03/2024 (FN) |
| EC - 3 | Comprehensive Exam | Open Book | 40% | 2.5 hours | Friday, 17/05/2024 (FN) |

Syllabus for Mid-Semester Test (Closed Book): Topics in Contact Hours: 1 to 16

Syllabus for Comprehensive Exam (Open Book): All topics

Syllabus for Quiz-1/2/3 (Sessions completed till date)

Important links and information:

Elearn portal: https://elearn.bits-pilani.ac.in

Students are expected to visit the Elearn portal on a regular basis and stay up to date with the latest announcements and deadlines.

Contact sessions: Students should attend the online lectures as per the schedule provided on the Elearn portal.

Evaluation Guidelines:

1. EC-1 consists of either two Assignments or three Quizzes. Students will attempt them through the course pages on the Elearn portal. Announcements will be made on the portal, in a timely manner.
2. For Closed Book tests: No books or reference material of any kind will be permitted.
3. For Open Book exams: Use of books and any printed / written reference material (filed or bound) is permitted. However, loose sheets of paper will not be allowed. Use of calculators is permitted in all exams. Laptops/Mobiles of any kind are not allowed. Exchange of any material is not allowed.
4. If a student is unable to appear for the Regular Test/Exam due to genuine exigencies, the student should follow the procedure to apply for the Make-Up Test/Exam which will be made available on the Elearn portal. The Make-Up Test/Exam will be conducted only at selected exam centres on the dates to be announced later.

It shall be the responsibility of the individual student to be regular in maintaining the self-study schedule as given in the course handout, attend the online lectures, and take all the prescribed evaluation components such as Assignment/Quiz, Mid-Semester Test and Comprehensive Exam according to the evaluation scheme provided in the handout.

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