MEC302: Embedded Computer Systems

Lecture 11 – Concluding session

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Outline

- Overview of covered materials;
- Exam & exam paper introduction – types of questions to expect;
- Generalized feedback on Assignment 2;
- Q&A session.

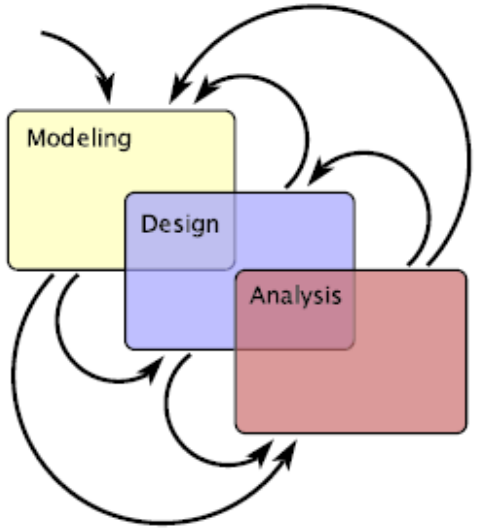
Overview of covered materials

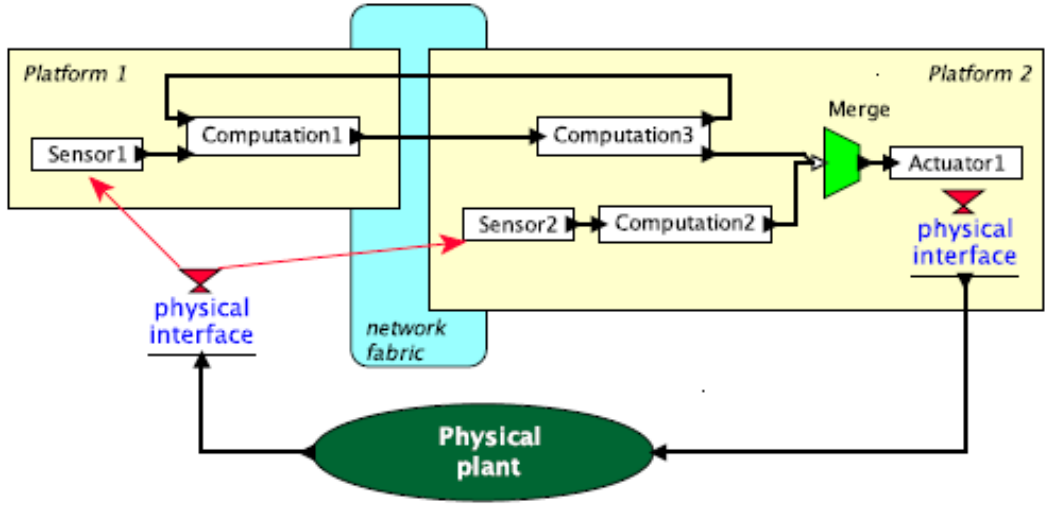
0. Introduction to embedded computer systems
I. Modeling Dynamic Behaviors
   - Continuous and discrete dynamics;
     - ODEs, IEs, DDEs, state machines and hybrid systems.
II. Design of Embedded Computer Systems
   - Sensors and actuators; Embedded processors;
   - Input, output and peripheral devices:
     - Embedded C for programming microcontrollers;
   - Memory architecture; Multitasking; and Scheduling.
III. Analysis and Verification of Embedded Systems
   - Invariants and Temporal Logic

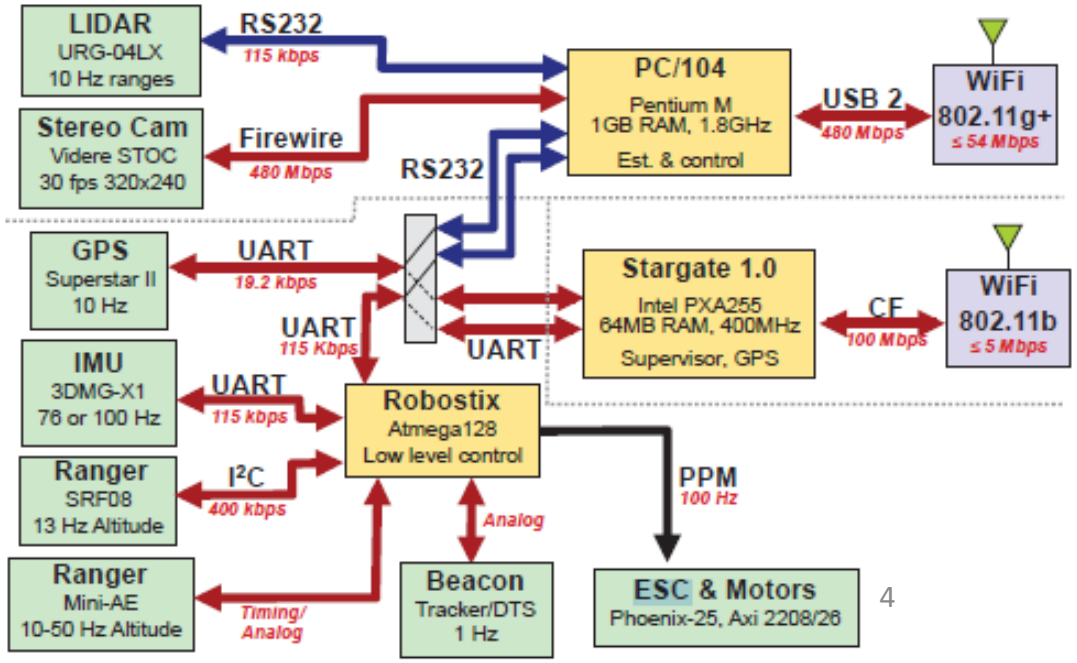
0.Introduction to embedded computer systems

L1: In the introductory session you learnt:

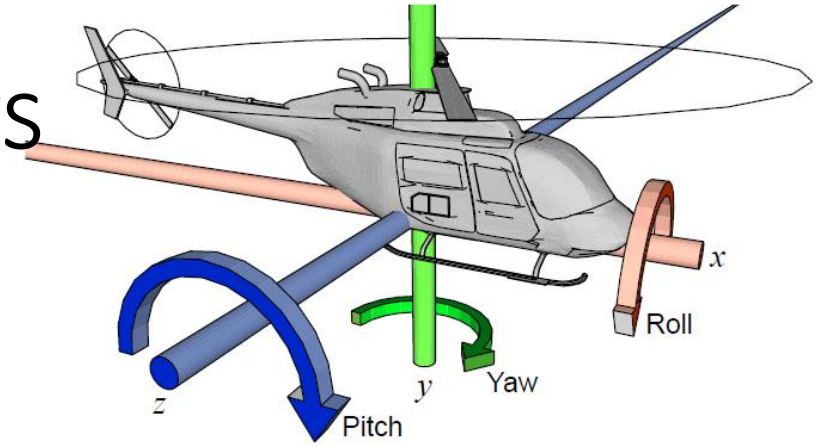
- What is an Embedded Computer System (ECS) and why do you need to study it;
- Basic structure and terms of ECS (i.e., plant, platform, network, control);
- Motivating example of ECS (i.e., STARMAC quadrotor and its architecture);
- Design principles of ECS.







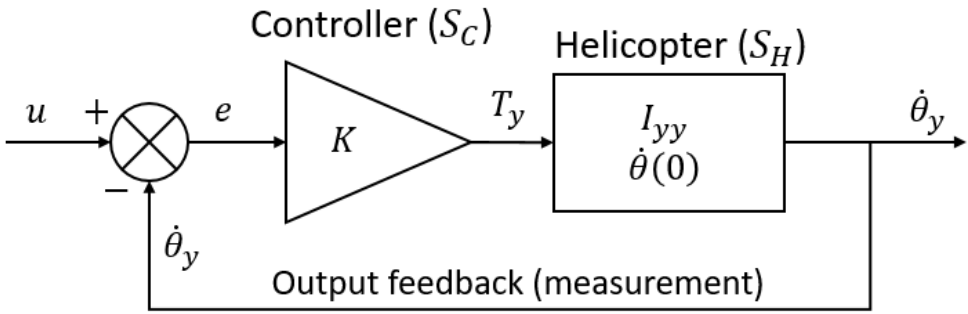
I.Modelling Dynamic Behaviors



L2: Continuous Dynamics:

$$\dot{\theta}_y(t) = \dot{\theta}_y(0) + \frac{1}{I_{yy}} \int_0^t T_y(\tau) d\tau$$

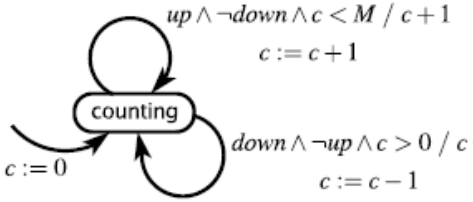
- Mathematical models and their types;
- Continuous dynamics modelling:
  - Newtonian mechanics, Model order reduction, and Actor models;
- Model properties and Feedback control:
  - Solving ODEs.

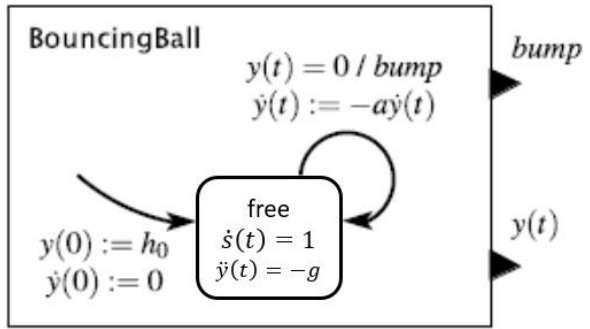


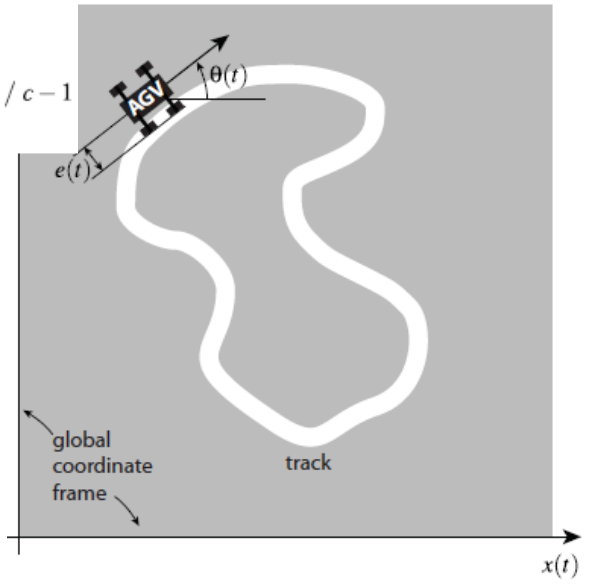
L3: Discrete Dynamics:

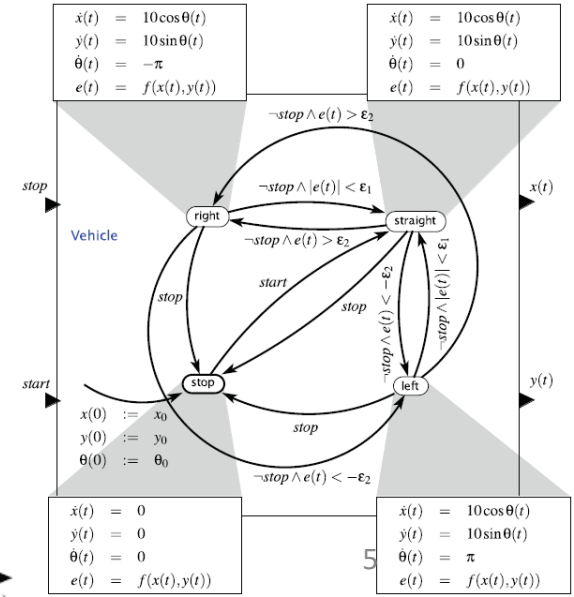
- Discrete system modelling:
  - State machines and their properties;
- Hybrid system modelling:
  - Hybrid systems; Timed automata; Supervisory control.

variable: c: $\{0, \cdots, M\}$
inputs: up, $down$: pure
output: $count$: $\{0, \cdots, M\}$





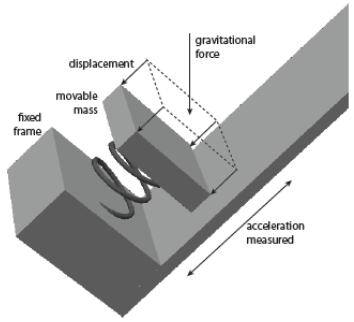


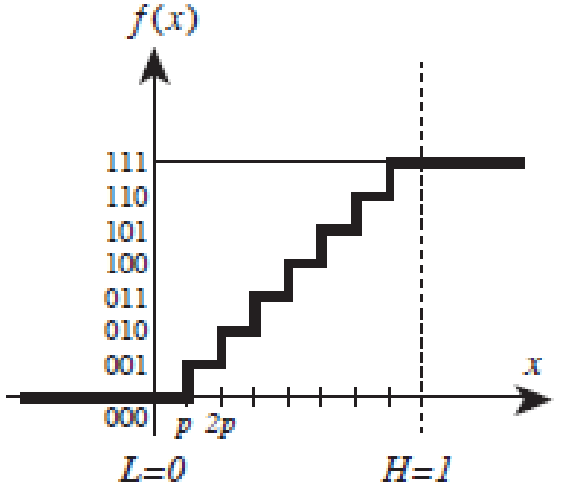


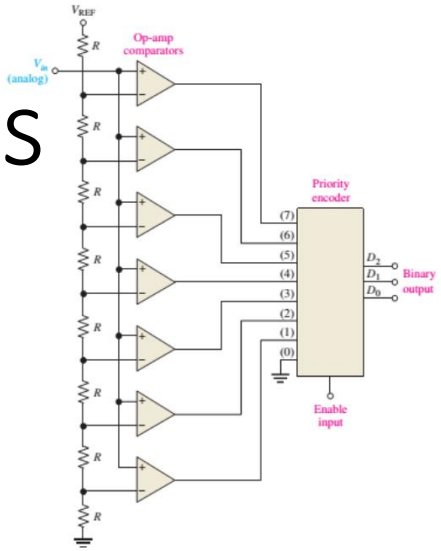
II.Design of Embedded Computer Systems

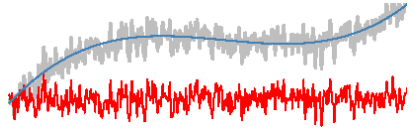
L4: Sensors and Actuators (S&A):

- What are S&A and how they are interfaced with computers/controllers;
- Models and Characteristics of S&A;
- Signal conditioning (i.e., filtering);
- Common sensors and actuators.



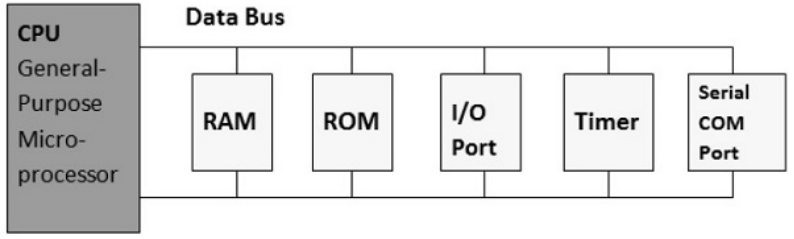


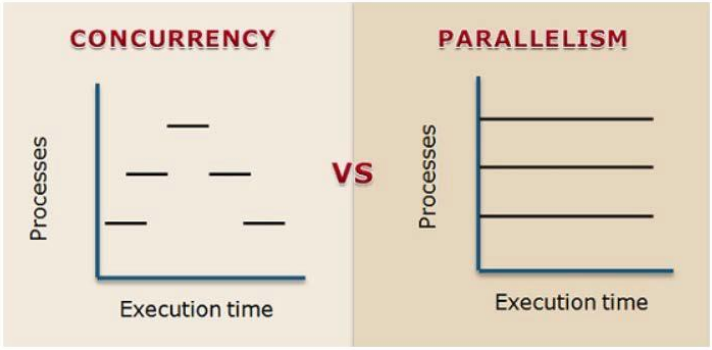


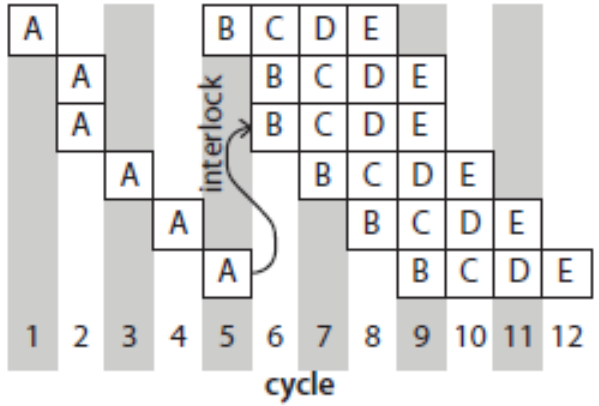


L5: Embedded processors:

- What is microprocessor;
- Main types of embedded processors:
  - µC, DSP, GPU;
- Parallelism and concurrency:
  - Pipelining and command execution cycle;
  - Instruction-level parallelism;
  - Multicore architectures.







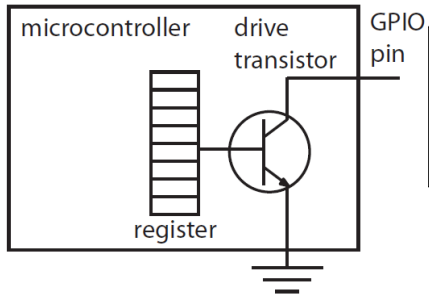
II.Design of Embedded Computer Systems

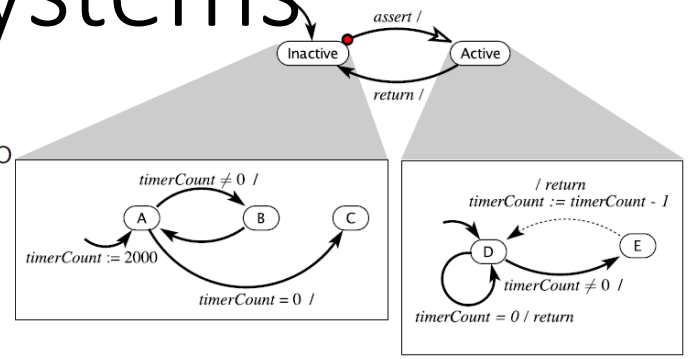
L6: Input, output and peripheral devices:

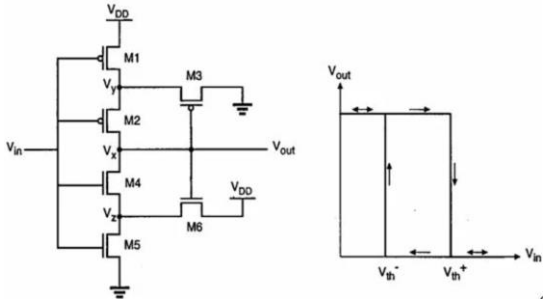
- Input and Output (I/O) Hardware:
  - GPIO, PWM, data interfaces (i.e., serial, parallel, and buses);
- Mechanisms to interact with the external world
  - Interrupts: types, models, and controllers.

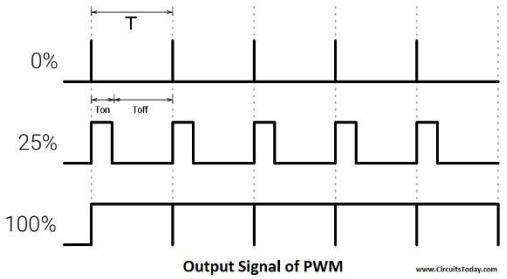
L7: Memory technologies, hierarchy and models:

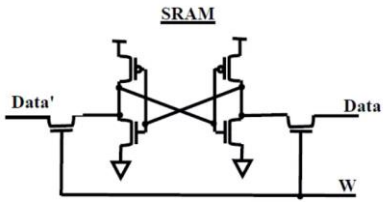
- Memory technologies in microprocessors:
  - Physical realization and distinctive characteristics;
- Memory hierarchy:
  - Register files, scratchpads, caches;
- Memory Models
  - Address space, data types, alignment and allocation of data;
  - Memory model of C.

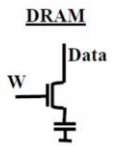


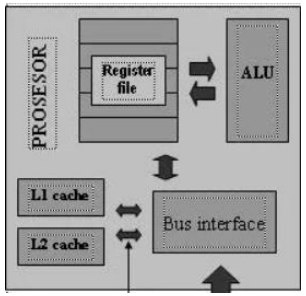


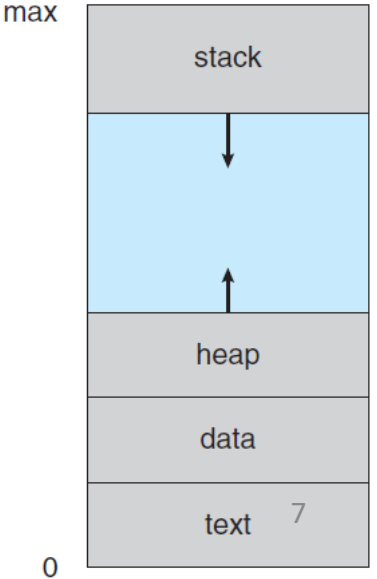








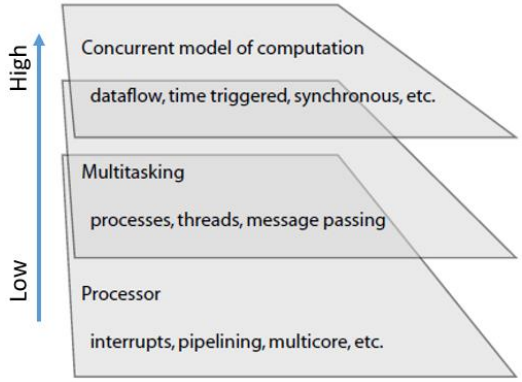


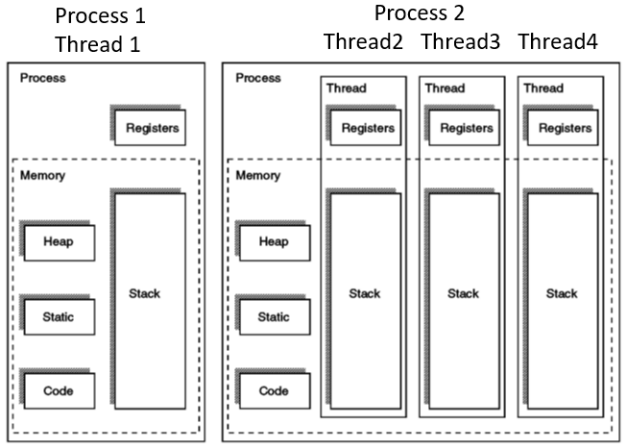


II.Design of Embedded Computer Systems

L8: Multitasking:

- What is multitasking & its mechanisms;
- Threads:
  - Memory consistency models; mutexes; deadlocks;
- Processes:
  - Communication between processes.



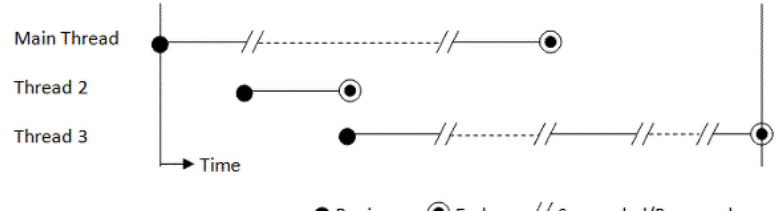


#Consider example:

1. w, x, y, z = 0;

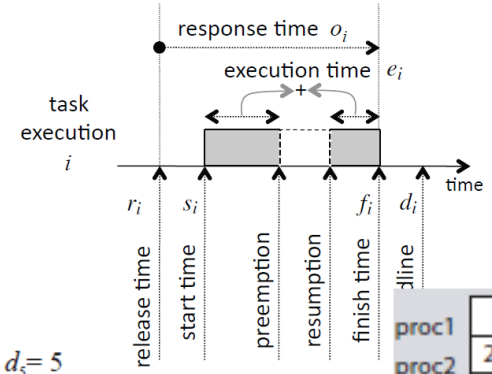
Thread A:
- ❑ x = 1;
- ❑ w = y;

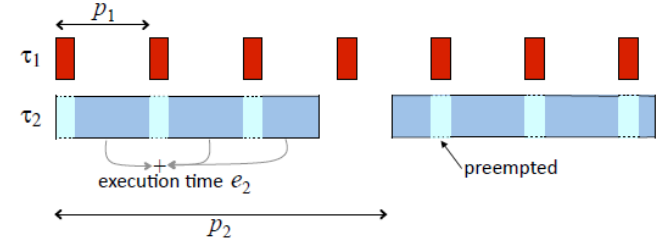
Thread B:
- ❑ y = 1;
- ❑ z = x;

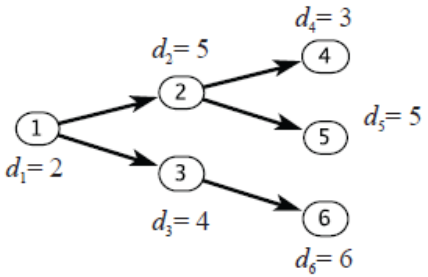


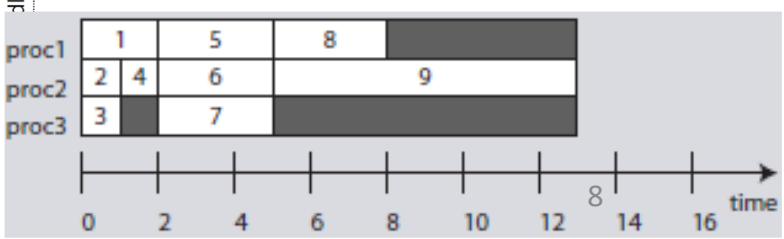
L9: Scheduling:

- Basics of scheduling:
  - Implementation; Scheduling decisions; Task model; Metrics;
- Scheduling strategies:
  - Single & multiprocessor scheduling;
- Scheduling anomalies.









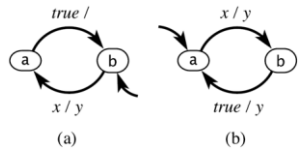
III. Analysis and Verification of Embedded Systems

L10: Invariants and Temporal Logic:

- Specifications;
- Invariants and temporal logic;
- Linear Temporal Logic (LTL);
  - LTL formulas and operators;
- LTL formulas in practice.

- $\phi_1 = \mathbf{F}\mathrm{b}$
- $\phi_2 = \mathbf{G}(x \Longrightarrow \mathbf{F}\mathrm{b})$
- $\phi_3 = (\mathbf{G}x) \Longrightarrow (\mathbf{F}\mathrm{b})$

input: x: pure
output: y: pure



#Consider the following examples of specification requirements:

- *"Whenever the robot is facing an obstacle, it is required to move at least 5 cm away from the obstacle"*:

$$\mathbf{G}(p \Longrightarrow \mathbf{F}q),$$

where p is the condition that the robot is facing an obstacle,

q is the condition where the robot is at least 5 cm away from the obstacle.

- *"Whenever the reset signal is asserted the state machine shall move immediately to the* ErrorReset *state and remain there until the reset signal is de-asserted"*:

$$\mathbf{G}\big(reset \Longrightarrow \mathbf{X}(\mathrm{ErrorReset}\mathbf{U}\neg reset)\big).$$

Other useful (common) **LTL formulas**:

- Infinitely many occurrences: $\mathbf{G}\,\mathbf{F}p$

  "p is *true* eventually" or "p is *true* infinitely often";

- Steady-state property: $\mathbf{F}\,\mathbf{G}p$

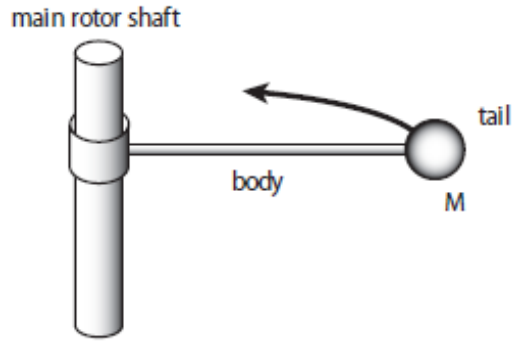
  "eventually p holds globally" or "from some point in the future, p holds at all times";

- Request-response property: $\mathbf{G}(p \Longrightarrow \mathbf{F}q)$

  "a request p will eventually produce a response q".

Practical skills learnt

$$T_y = I_{yy}\ddot{\theta}_y$$

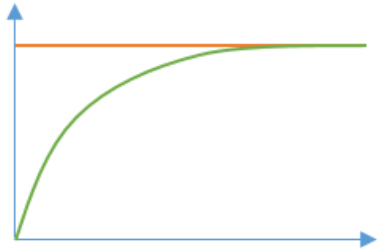


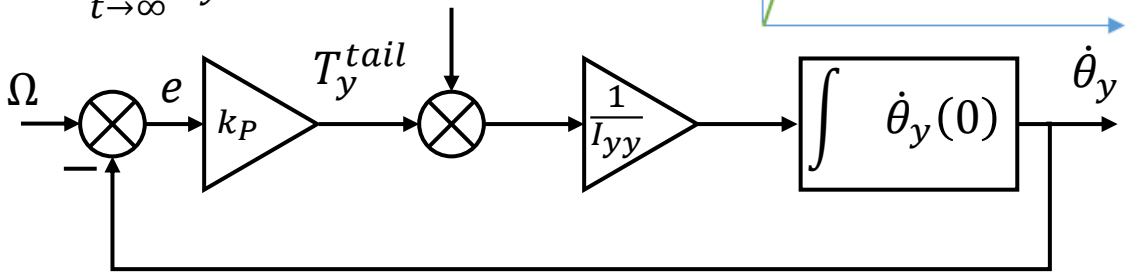
T1, T2, A1: Modelling continuous and discrete dynamics:

- Mathematical modelling (i.e., ODEs, IEs, DDEs), state machines and hybrid systems;
- ODE solution and Computer modelling.

$$\dot{\theta}_y(t) = \dot{\theta}_y(0) + \frac{1}{I_{yy}}\int_0^t T_y(\tau)\,d\tau$$

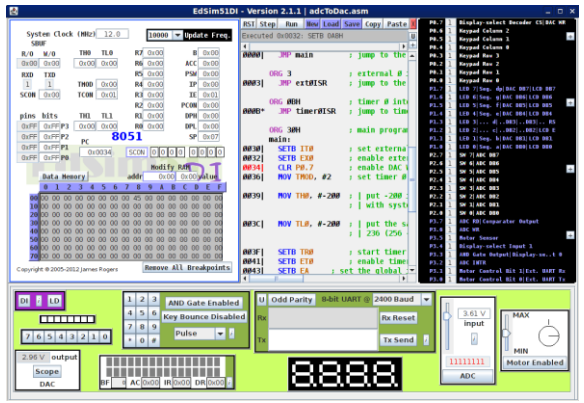
$$\lim_{t\to\infty} \dot{\theta}_y(t) = \infty$$

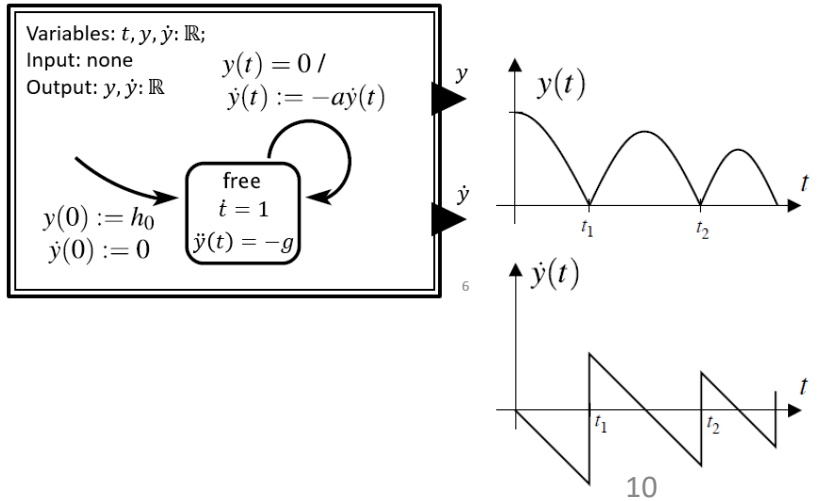




Lab, A2: Programming microcontrollers:

- Input and output:
  - Control: LEDs, displays, switches, motor;
- Other main functions:
  - Timers, counters and interrupts.





Exam

- Start date and time: **May 25, 2023; 14:00;**
- Duration: **2 hours;**
- Place: **Venue specified in your personal calendar;**
- Rules and restriction:
  - All XJTLU policies apply (i.e., Regulations for Conduct of Examinations, Academic Integrity, etc.);
  - Come to the exam room AT LEAST 30 minutes earlier ($t \leq$13:30);
  - Bring your ID with you;
  - Closed-book exam (NO books and NO notes);
  - NO calculators and NO other electronic devices;
  - Only English solutions are accepted;
  - Provide solutions only in the answer booklet (to be provided on the exam);
  - All materials MUST be returned after the exam.

Exam paper and types of questions:

TIME ALLOWED: *2 Hours*

INSTRUCTIONS TO CANDIDATES

1. This is a *closed-book* examination, *which is to be written without books or notes*.
2. Total marks available are 100.
3. This exam consists of *a number of* questions each containing a number of sub-questions (indexed by letters).
4. Answer all questions and sub-questions. There is NO penalty for providing a wrong answer.
5. Only English solutions are accepted. Answer should be written in the answer booklet(s) provided.
6. All materials must be returned to the exam invigilator upon completion of the exam. Failure to do so will be deemed academic misconduct and will be dealt with accordingly.

Question 1 (X marks)

Question 1 task description.

(a) Sub-question (a). **(x_a marks)**

(b) Sub-question (b). **(x_b marks)**

(c) Sub-question (c). **(x_c marks)**

...,

where $x_a + x_b + x_c + \cdots = X$

Question 2 (Y marks)

Question 2 task description.

Question 3 (Z marks)

(a) Sub-question (a). **(z_a marks)**

(b) Sub-question (b). **(z_b marks)**

(c) Sub-question (c). **(z_c marks)**

...,

where $z_a + z_b + z_c + \cdots = Z$

Question ... (... marks)

Notably, $X + Y + Z + \cdots = 100$ **marks**

The end of the paper

Feedback on Assignment 2

To be provided during the session

The end!

That is all from me.

Wish you luck on the exam!

- ***Prepare well***!

All the best in your future endeavors!

! Provide your feedback through Module Questionnaire (MQ) on LM:

- After you done with MQ we can proceed to your questions.