THE UNIVERSITY OF MELBOURNE

Semester 2 Assessment, 2021

Department of Electrical and Electronic Engineering
ELEN90066 Embedded System Design

Reading time: 15 minutes
Writing time: 180 minutes
Scanning and submission time: 30 minutes

TOTAL time: 225 minutes

This paper has 8 pages (including this cover page).

Authorised materials:
This is an open book, hand-written exam and the following materials are permitted:

- Any material loaded onto Canvas as part of the subject content.
- Notes (printed, hand-written and digital/electronic).
- Online books and materials.
- Language dictionaries.
- Calculators (any model), computers, electronic tablets, pens, rulers, etc.

Instructions to students:

- Attempt **ALL** questions.
- The questions carry weight in proportion to the marks in brackets after the question numbers. These marks total **105 marks**.
- All answers on this exam must be handwritten (whether using pen and paper or a tablet).
- All working must be scanned and submitted before the end of the exam time. Ensure your student number is written on each answer page that you upload.
- Submission time is reserved for scanning and uploading. It is your responsibility to submit within the allocated submission time and late submissions will attract a penalty. If you have difficulties in submitting your answers, inform your Subject Coordinator immediately.
- **Any late submissions after the 30 minutes Scanning and submission time will incur a penalty of 5% per minute (with 100% reduction for a 20 minutes late submission) and no submission will be accepted after the 20 minutes.** There will be no exceptions!
- Any updates to the exam will be made via Canvas announcements during the examination time.
- **Collusion is not allowed under any circumstances and can attract serious penalties**. Collusion includes, but is not limited to, talking to, phoning, emailing, texting or using the internet to communicate with other students. Similarly, you cannot communicate with any other person via any means about the content of this exam during the examination time. If another student contacts you during the examination period, you must inform the subject coordinator immediately.
- **Plagiarism, through the use of sources without proper acknowledgment or referencing, is not permitted and can attract serious penalties**. Plagiarism includes copying and pasting from the Internet without clear acknowledgement and paraphrasing or presenting someone else's work as your own. Note that this definition also applies to work completed during the semester as part of a group. All responses to this exam paper must be entirely your own work, unless otherwise acknowledged.

Question 1 [20 marks]

In this question, you will develop a cruise control system, which ensures that a car moves at a set speed without the driver needing to keep their foot on the accelerator. This system has multiple inputs:

- `switch:pure`: a pure signal that turns the cruise control system on if it was off and off if it was already on;
- `inc:pure`: a pure signal that indicates a desire to increase the cruise control speed by 5km/h;
- `dec:pure`: a pure signal that indicates we must decrease the cruise control speed by 5km/h;
- `initial_speed:`$\mathbb{N}$: a positive-integer-valued signal indicating the initial speed that the driver can request.

The cruise control system has only one output:

- `speed:`$\mathbb{N}$, which is a positive-integer-valued signal indicating the speed reference that the car must follow. Note: The set $\mathbb{N}$ denotes the set of positive integer numbers, i.e., $\{1, 2, 3, \dots\}$.

Assume (unrealistically) that the input `initial_speed` is always present and takes the value that the driver wants, e.g. it is set using a knob and its value can be read at anytime. This assumption reduces the number of transitions that you may need.

a) Draw a Finite State Machine diagram, i.e., a state-transition diagram, for the cruise control system. What is the number of reachable states? **[7 marks]**

b) Modify the Finite State Machine diagram in part (a) to impose a speed limit on the cruise control system such that the output speed of the cruise control system must never surpass the maximum speed limit of Australia, 130km/h. Assume that the input `initial_speed` is restricted to be $\{1, 2, \dots, 130\}$. Draw the modified state machine. What is the number of reachable states? **[4 marks]**

c) After redeveloping your plans for part (b), the car company has made a final request to integrate a pause mode into your cruise control system. The system must accept another pure signal as input, `pause:pure`, which puts the cruise control system on pause if it was active and reactivate it if it was already on pause. Note that when paused, the system remembers the state that it was in before pause. They have instructed you use hierarchical finite state machines to incorporate your design in part (b) into the new system easily.

   Draw a hierarchical Finite State Machine diagram for the cruise control system with pause. Explain your choice of semantics for the hierarchical finite state machine. **[4 marks]**

d) Draw the flattened Finite State Machine that captures the semantics of the hierarchical Finite State Machine in part (c). **[5 marks]**

Question 2 [22 marks]

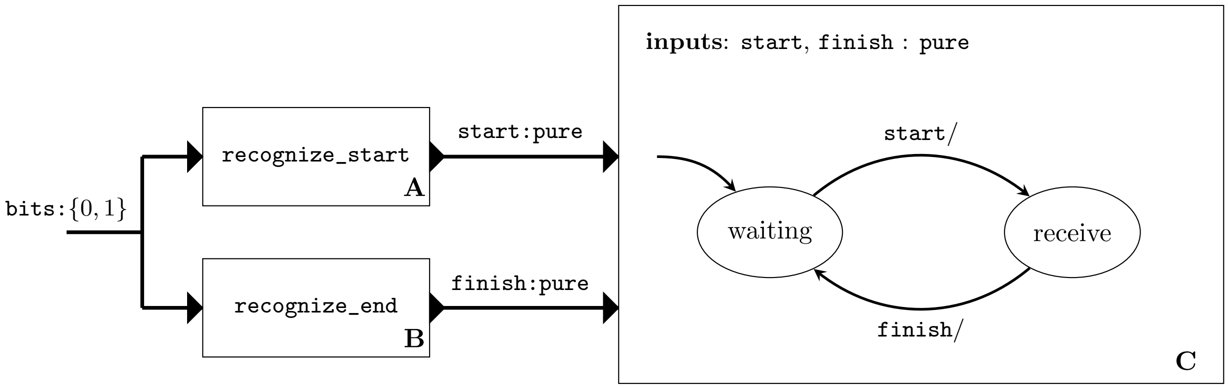


Figure 1: Schematic diagram of some of the actors in our communication protocol.

In this question, we analyze a simple communication protocol. Figure 1 shows schematic diagram of some of the actors in our communication protocol. The system `recognize_start` recognizes a signature sequence of bits, 010, that means the communication has started. When this sequence is detected, `recognize_start` flags the start of communication to the receiver unit shown by Finite State Machine **C**. The system `recognize_end` recognizes a signature sequence of bits, 111, that means the communication has ended. When this sequence is detected, `recognize_end` flags the end of communication to the receiver unit.

a) Draw a Finite State Machine for `recognize_start`. From this point forward, this is denoted by Finite State Machine **A**. **[5 marks]**

b) Draw a Finite State Machine for `recognize_end`. From this point forward, this is denoted by Finite State Machine **B**. **[5 marks]**

c) Draw the flattened Finite State Machine **D** corresponding to synchronous side-by-side composition of Finite State Machines **A** and **B** including any unreachable states. **[5 marks]**

d) How many reachable states Finite State Machines **D** possess? Reduce this FSM to only contain its reachable states. **[2 marks]**

e) Draw the flattened Finite State Machine **E** corresponding to synchronous cascade composition of Finite State Machines **D** (the one reduced to only reachable states) and **C**. **[5 marks]**

Question 3 [15 marks]

Assume there are 7 tasks of $\{\tau_1, \ldots, \tau_7\}$ with following precedence constraints:

- τ_1 precedes τ_3;
- τ_2 precedes τ_3;
- τ_3 precedes τ_5;
- τ_4 precedes τ_6;
- τ_2 precedes τ_4;
- τ_3 precedes τ_6;
- τ_4 precedes τ_7.

All tasks arrive at time 0, have a common deadline of 20, and the following execution times e_i:

	τ_1	τ_2	τ_3	τ_4	τ_5	τ_6	τ_7
e_i	3	2	4	3	2	5	1

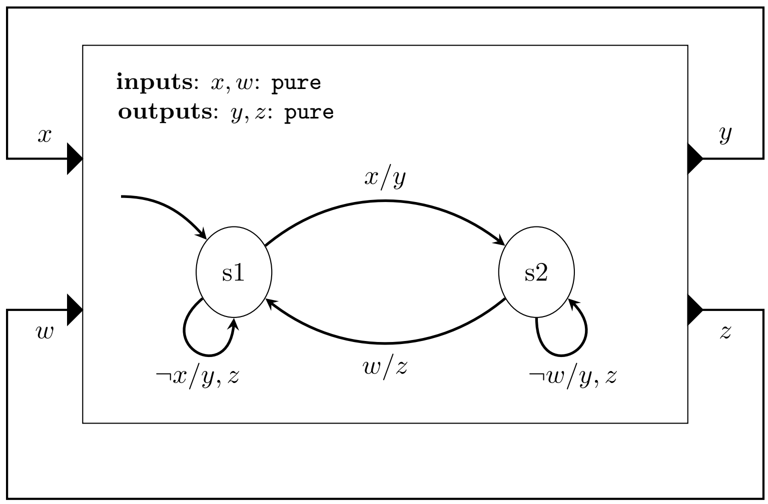
a) Draw the directed acyclic graph representing the precedence of the tasks where a directed edge marks a precedence. **[4 marks]**

b) Does Earliest Deadline First with Precedence (EDF*) yield a feasible schedule? Explain why if the answer is no, and construct the schedule if the answer is yes. You need to provide all necessary computations. **[8 marks]**

c) Assume the additional precedence constraint "τ_5 precedes τ_2". Is there still a feasible schedule for the above task set? Justify your answer. **[3 marks]**

Question 4 [13 marks]

Consider the following Finite State Machine.



a) Prove that the following synchronous model is **well formed**. Is it also **constructive**? Explain your reasoning and provide justification. **[8 marks]**

b) For the model in part (a), give the semantics by giving an equivalent flat state machine with no inputs and two outputs. **[5 marks]**

Question 5 [20 marks]

a) Assume that φ and ψ are atomic propositions. Is $\varphi \mathbf{U} \psi = \psi \vee (\varphi \wedge \mathbf{X}(\varphi \mathbf{U} \psi))$ true? If yes, prove this. If no, provide a counter example. **[10 marks]**

b) Consider a robot that can visit a set of 6 important locations $\{\ell_1, \ldots, \ell_6\}$. Note that there are other locations that the robot can visit. Let φ_i be an atomic proposition that holds true if and only if the robot visits location ℓ_i. Give LTL formulas specifying the following tasks:

b.1) The robot must eventually visit at least one of the 6 locations. **[2 marks]**

b.2) The robot must eventually visit all 6 locations, but in any order. **[2 marks]**

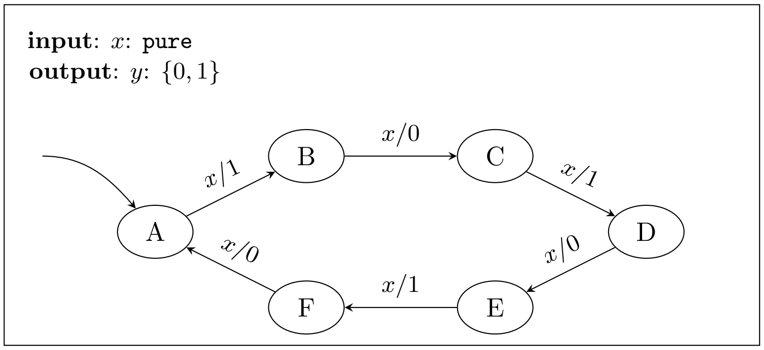
b.3) The robot must eventually visit all 6 locations in the order $\ell_1, \ell_3, \ell_5, \ell_2, \ell_4, \ell_6$. **[2 marks]**

b.4) The robot must visit ℓ_5 in 4 steps. **[2 marks]**

b.5) If the robot visits ℓ_3, it must either visit ℓ_5 immediately afterwards or never visit ℓ_5. **[2 marks]**

Question 6 [7 marks]

Consider the Finite State Machine in the figure below. Find a bisimilar finite state machine with fewer states, and give the bisimulation relation.



Question 7 [8 marks]

a) In this question, you will model a sensor for measuring CO2 concentration to ensure a healthy working environment. The output voltage of the sensor versus the concentration of CO2, measured in particles per million (ppm), is illustrated in Figure 2. Assuming an affine model for the sensor, estimate the bias and sensitivity parameters of the sensor. Provide all calculations. **[4 marks]**

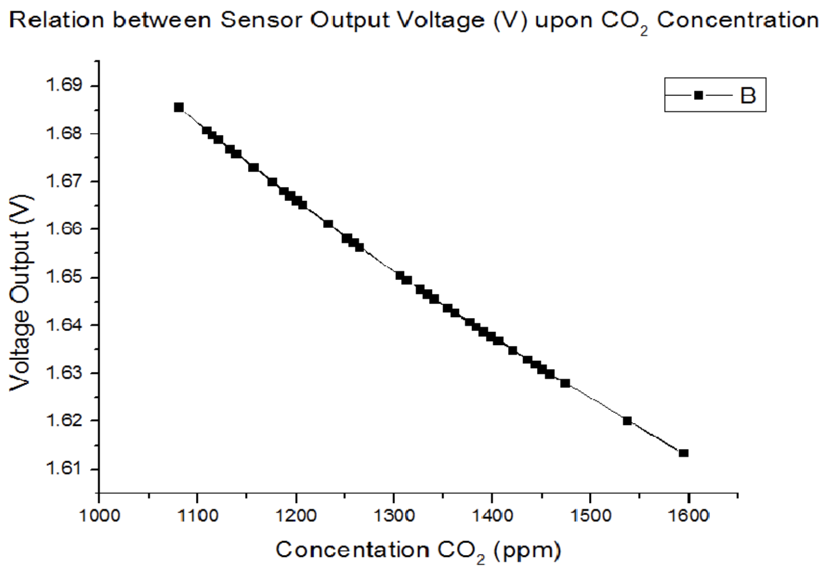


Figure 2: Output voltage of sensor versus concentration of CO2.

b) Assume that the output terminal voltage of the sensor can range between 1.5V and 1.7V. The output signal from the sensor is converted to a 4-bit binary number via an Analog to Digital Converter by dividing this voltage range into equally spaced voltage steps. What is the precision and dynamic range (dB) of the sensor? Provide all calculations. **[2 marks]**

c) Assume that the output voltage can be noisy. The noise is modeled as an additive term similar to the textbook. The measurement noise has root mean square of 0.1V. The typical CO2 concentrations is assumed to be close to 1300ppm corresponding to a voltage of 1.65V. What's the signal-to-noise (SNR) ratio at a concentration of 1300ppm? Provide all calculations. **[2 marks]**

END OF EXAMINATION