Industrial Automation and Robotics

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NAME:

UNIVERSITY ID NUMBER:

SIGNATURE: ─────────────────────────────

Warnings

- This file consists of **8** pages (including cover).

- During the exam you are not allowed to exit the room for any other reason than handing your work or withdrawing from the exam.

- You are not allowed to withdraw from the exam during the first 30 minutes.

- During the exam you are not allowed to consult books or any kind of notes.

- You are not allowed to use calculators with graphic display.

- Solutions and answers can be given **either in English or in Italian**.

- Solutions and answers must be given **exclusively in the reserved space**. Only in the case of corrections, or if the space is not sufficient, use the back of the front cover.

- The clarity and the order of the answers will be considered in the evaluation.

- At the end of the test you have to **hand this file only**. Every other sheet you may hand will not be taken into consideration.
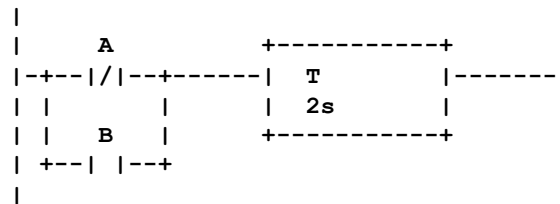
EXERCISE 1

Consider the dynamic system described by the following equations:

$$\begin{aligned}
\dot{x}_1 &= x_2 \\
\dot{x}_2 &= -3x_1 - 4x_2 + u \\
y &= 2x_1 + x_2
\end{aligned}$$

1. Find the expression of the transfer function $G(s)$ from the input u to the output y.

2. Find the values of the type, dc gain and time constants of the transfer function previously obtained.

3. Discuss the stability of the transfer function.

4. Without going through the numerical computation, explain how it would be possible to obtain the expression of the output, after an initial transient, when the input takes the following expression: $u(t) = 4\sin(2t)$.
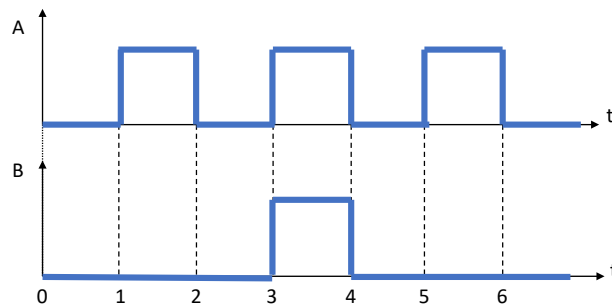
EXERCISE 2

1. Consider the Ladder Diagram programming language for PLCs. Explain what is a normal timer, how it works and how it is reset.

2. Making reference to the following Ladder Diagram code:

```
|                                        |
|      A                +-----------+    |
|-+--|/|--+------|  T          |-------|
| |       |      |  2s         |         |
| |   B   |      +-----------+    |
| +--| |--+                              |
|                                        |
```

assume that the Boolean inputs A and B have the time histories depicted in the following plots:

Sketch the plot of the Boolean variable T associated to the (simple) timer, commenting the answer.

3. Consider now a Sequential Function Chart (SFC). Explain what is a transition in a SFC and what is meant with the expression "a transition is superable".

4. Consider the following piece of code in SFC, where A and B are mutually exclusive conditions. Explain whether any issue can occur in using such code.
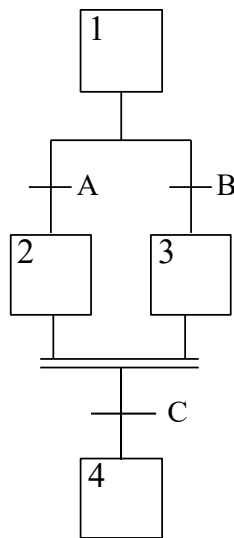
EXERCISE 3

1. Consider the following robot manipulator with 3 joints (rotational, prismatic, and prismatic):
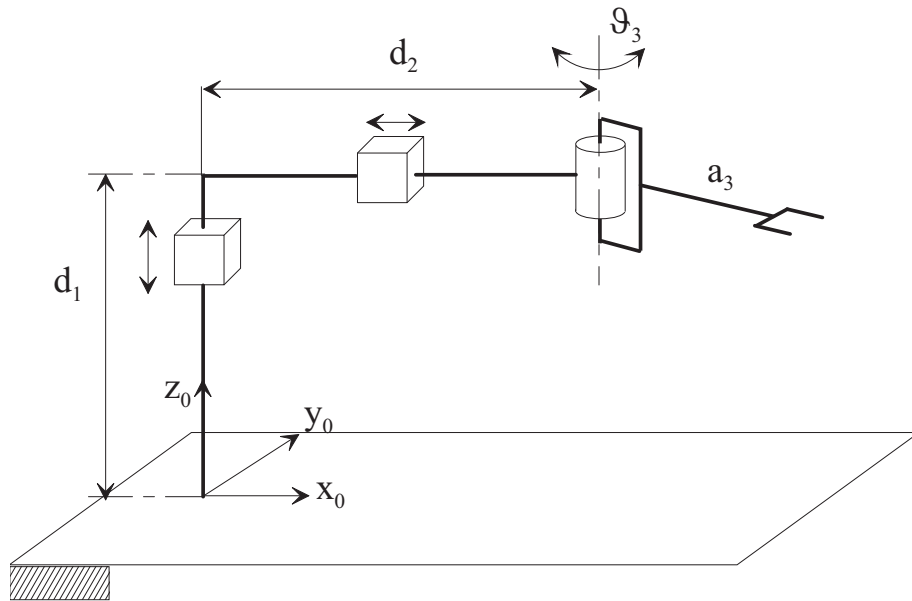
Find the expression of the direct kinematics of the robot, in terms of the position coordinates of the end effector with respect to the joint variables d_1, d_2, and ϑ_3.

2. Write the expression of the Jacobian of the manipulator of this exercise.

3. Characterize the singularities of the manipulator of this exercise.

4. Consider now the safe interaction between a robot and a human. Explain what are the interaction modes allowed by the safety standards. Out of such standards, is there any one that is specific for cobots?