



# Digital Twin of a Microcontroller Lab

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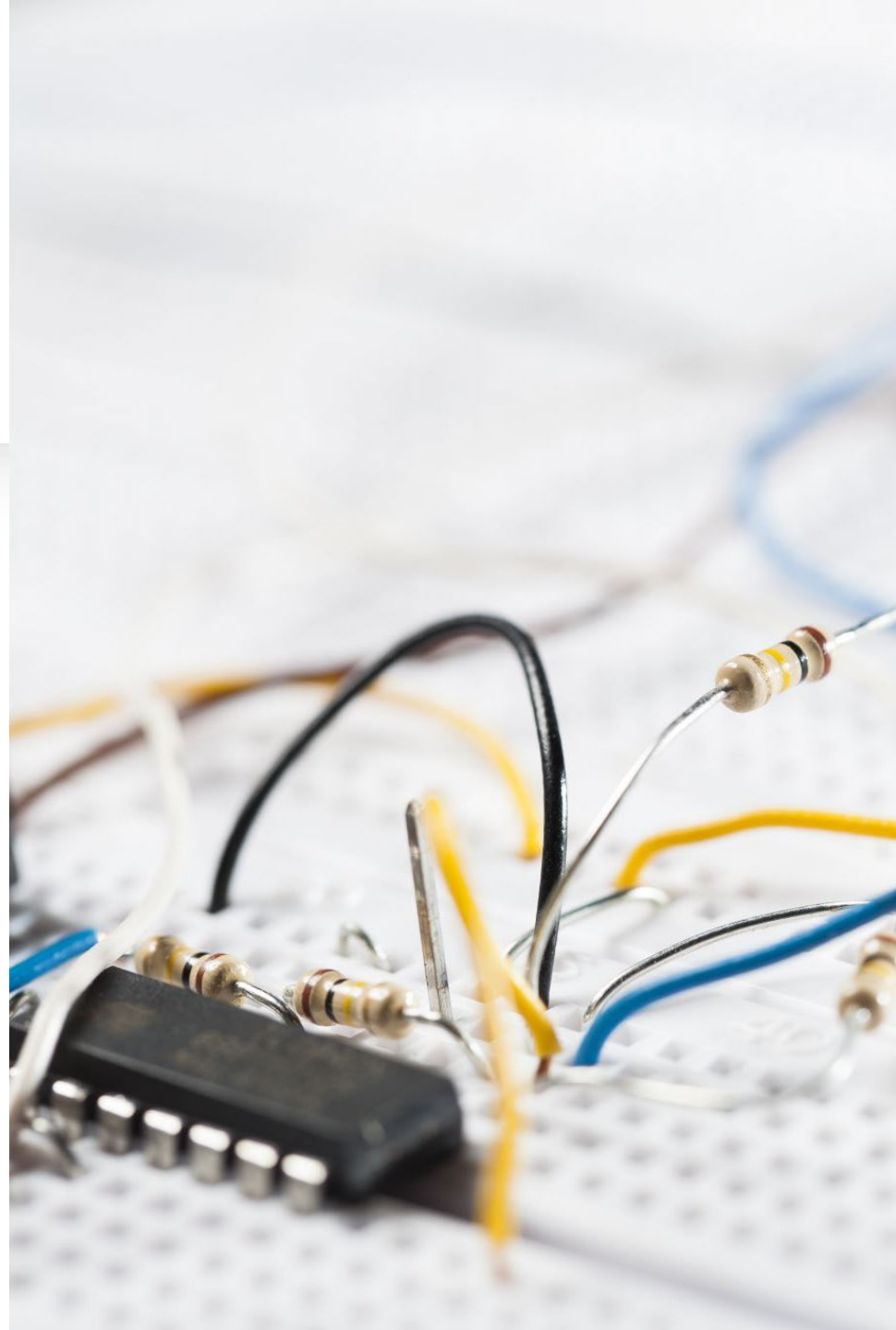
# What is a Digital Twin?

- A digital twin is a virtual representation that mirrors a real-world system in real time.
- Physical Asset: Actual lab hardware (controllers, sensors, actuators)
- Virtual Model: Unity-based simulation mimicking real system behavior
- Data Connection: Real-time serial or IoT link for data exchange
- Visualization: Interactive dashboard for monitoring and control



# Challenges in Traditional Labs

- Limited lab access and hardware availability
- Frequent component damage due to wiring mistakes
- High cost and low scalability
- Difficulty distinguishing software and hardware faults
- Restricted to predefined experiments



# Digital Twin Solution



Remote access and control for learners



Safe environment for testing code and logic



Real-time hardware-virtual synchronization

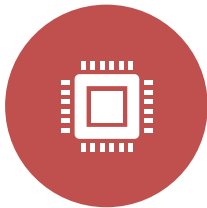


Flexible experimentation and learning pace



Cost-effective and scalable setup

# System Architecture



PHYSICAL LAYER: ARDUINO,  
RASPERRY PI, OR SIMILAR  
CONTROLLERS



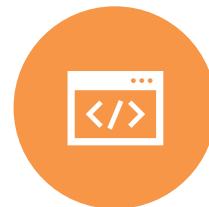
CONNECTIVITY LAYER:  
SERIAL/WIFI INTERFACE  
FOR COMMUNICATION



DATA PROCESSING: LOCAL  
OR CLOUD BRIDGE FOR  
MESSAGE HANDLING



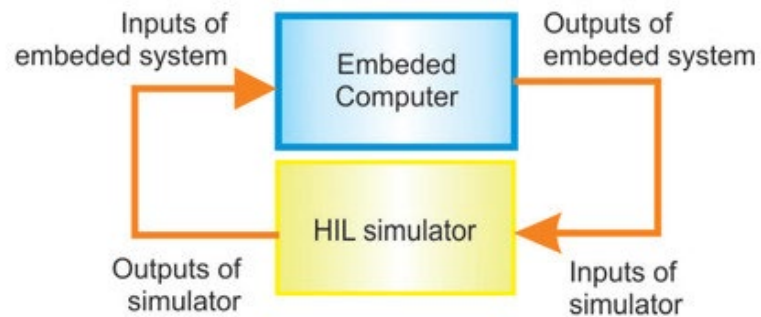
VIRTUAL LAYER: UNITY 3D  
SIMULATION OF  
COMPONENTS



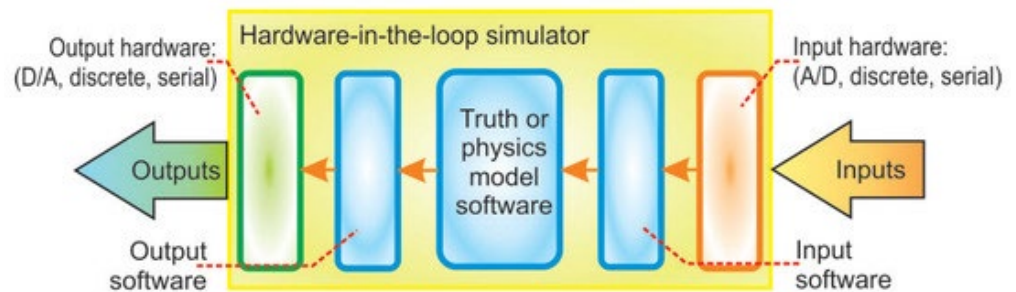
USER INTERFACE:  
GRAPHICAL PANELS FOR  
STUDENT INTERACTION

## Hardware in Loop (HIL)

A testing and validation technique where a real-time digital twin of a system is linked to a physical hardware component



(a)



(b)

# LED Control (Digital Twin)



Arduino sends ON/OFF signals to Unity.



Unity toggles LED emissive material color.



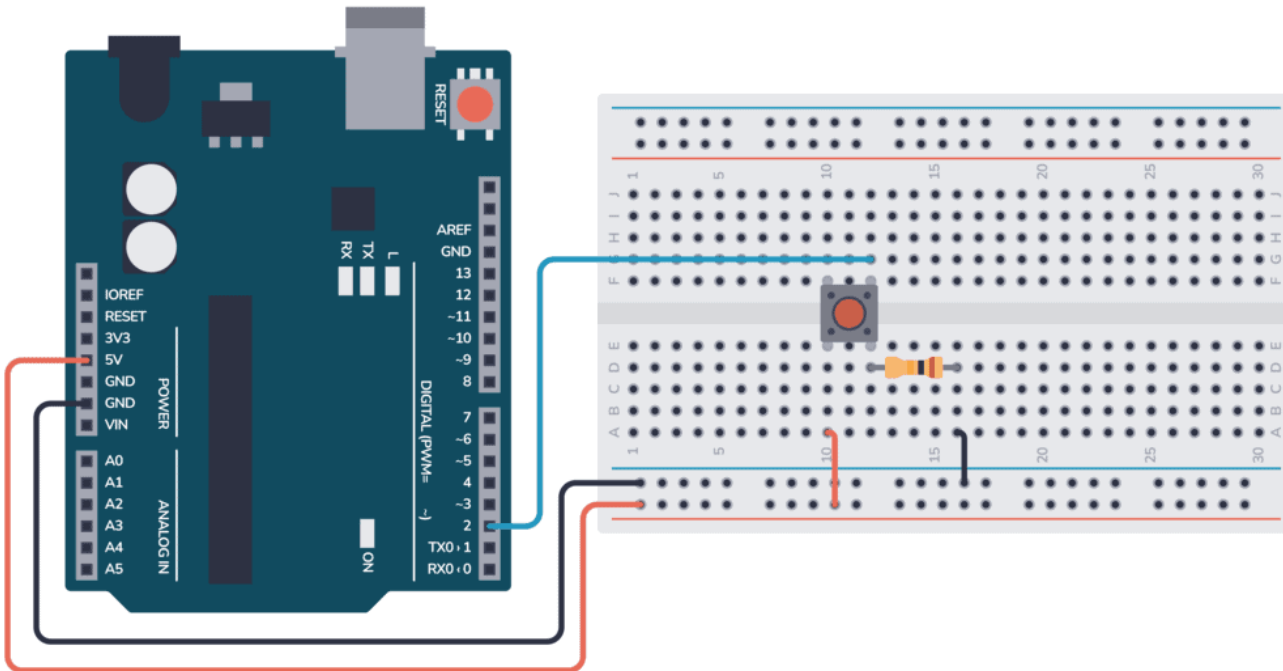
Serial communication:  
COM4 @115200 baud.



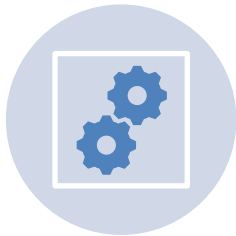
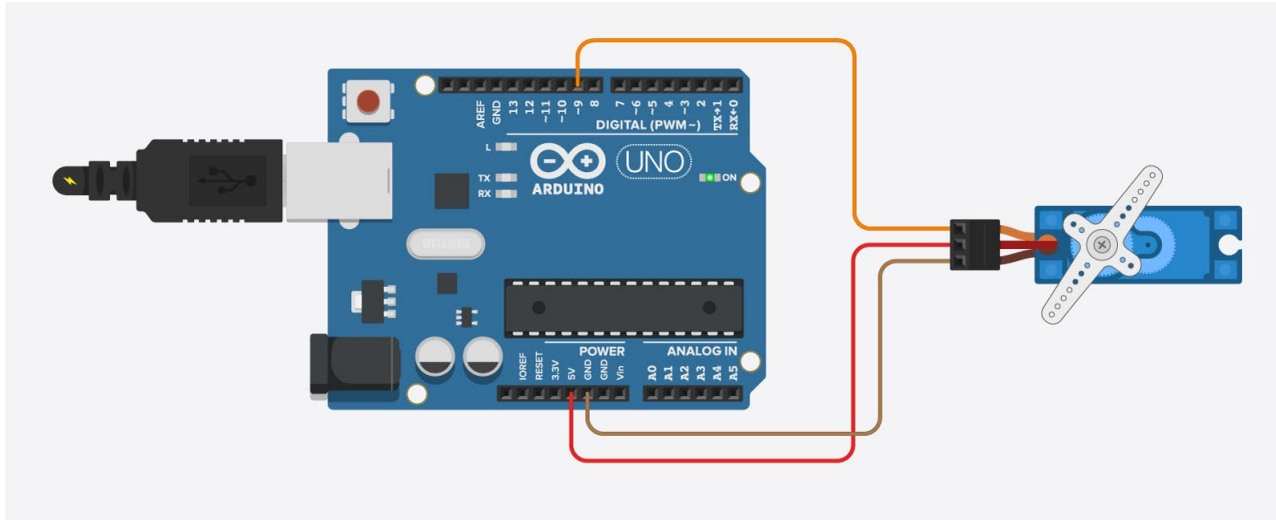
Educational outcome:  
Understand digital I/O  
mapping.

# Button Interaction

- Physical button → Unity trigger input.
- Unity simulates button press visually.
- Code maps HIGH/LOW states to animation.
- Reinforces pull-up resistor concepts.



# Servo Motor Simulation



ARDUINO OUTPUTS  
PWM SIGNAL TO  
CONTROL SERVO.



UNITY ROTATES 3D  
SERVO HORN  
ACCORDINGLY.



DATA STREAMED OVER  
SERIAL BRIDGE.



DEMONSTRATES  
CONTROL SYSTEMS &  
SIGNAL TRANSLATION.

# 7-Segment Display Twin



ARDUINO SENDS DIGITS (0-9) TO UNITY VIA SERIAL.



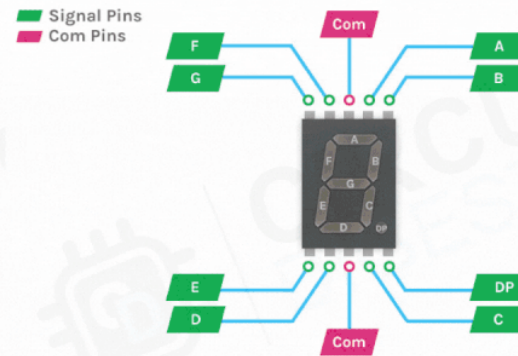
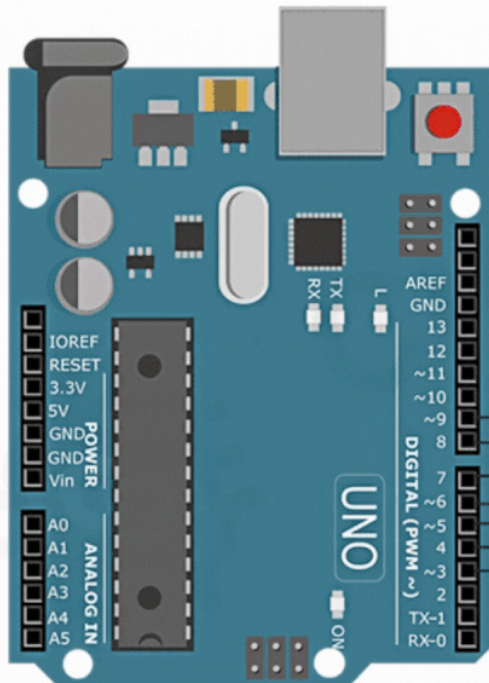
UNITY ILLUMINATES CORRECT LED SEGMENTS DYNAMICALLY.



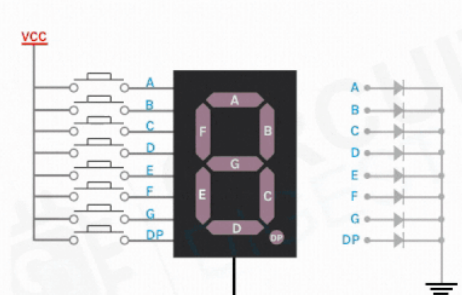
ERROR HANDLING PREVENTS THREAD LOCKING.



STUDENTS VISUALIZE NUMERIC ENCODING (BINARY → SEGMENTS).

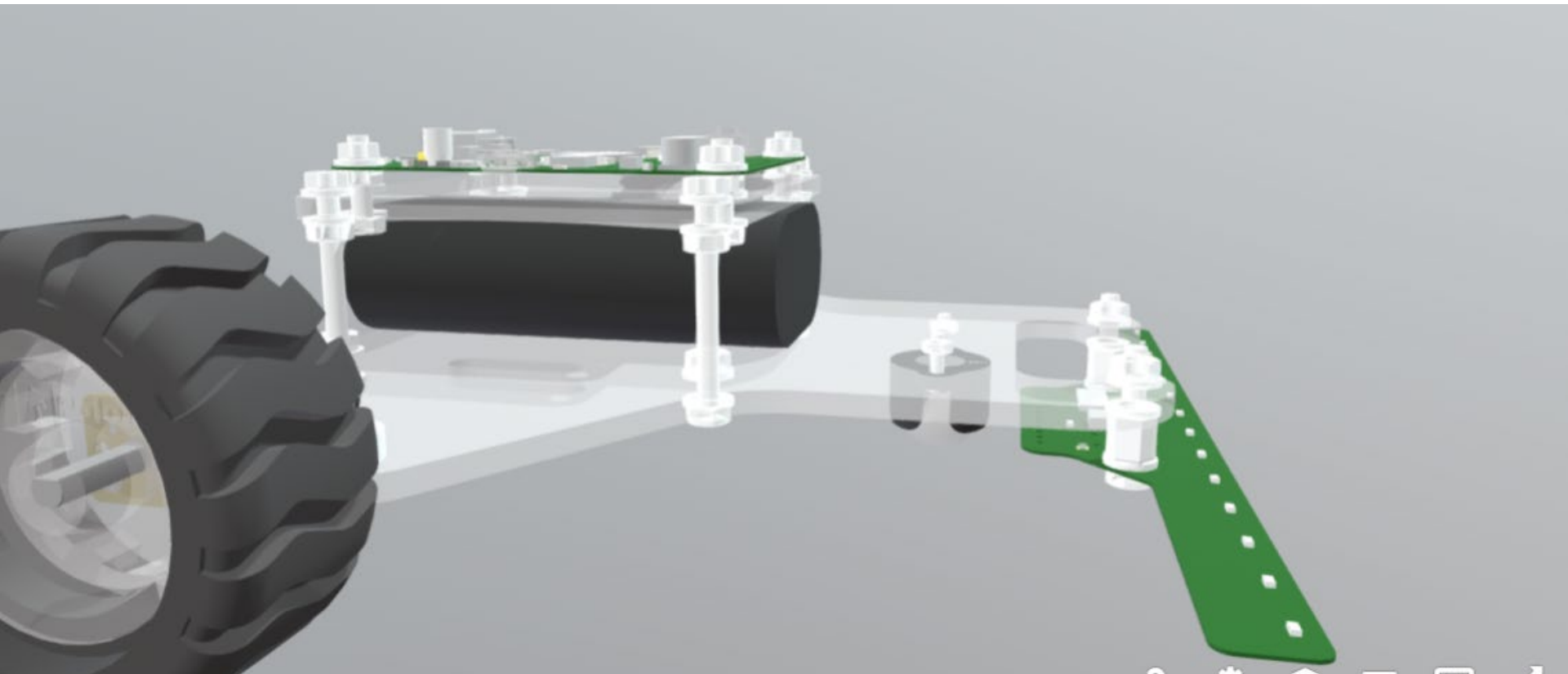


7 Segment Display PINOUT

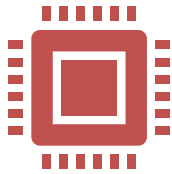


# Line-Following Robot

- Robot uses 2 IR sensors to detect line contrast.
- Unity simulates movement and sensor response.
- Wheel colliders replicate motor torque.
- Illustrates feedback control in robotics.



# Summary and Takeaways



Students experience safe, interactive microcontroller experimentation.



Unity + Arduino bridges physical and virtual learning.



Supports scalable, remote, and immersive education environments.



Thank You!