**HydroFarmIoT: An IoT-Integrated Vertical Hydroponic System**

***Graduation Project Summary – Department of Computer Systems Engineering, MSA University (2024/2025)***

**Abstract**

The rising demand for food, driven by global population growth and urbanization, is placing significant pressure on traditional farming methods, which depend on cultivable land and abundant water resources. As these resources become increasingly scarce due to urban expansion, climate change, and water scarcity, hydroponic systems offer a sustainable alternative, enabling soil-less agriculture with reduced water consumption. However, many existing systems lack automation and still require labour-intensive manual management. HydroFarmIoT: IoT-Integrated Hydroponic Vertical Farming System addresses these issues by utilizing IoT technology to automate the monitoring of key parameters such as pH, nutrient levels, temperature, and water level. Through sensors and actuators in a vertical farming setup, the system autonomously maintains pH level conditions. This project aims to enable year-round cultivation in urban environments, providing a scalable and sustainable solution for addressing food security challenges in urbanized regions.

**System Overview**

**Architecture:**

* **Controller:** ESP32 microcontroller
* **Sensor Suite:** pH, TDS, temperature (DS18B20), water level sensor (Ultrasonic)
* **Actuators:** Water pump, solenoid valve(x2), grow lights
* **Software Stack:** Arduino-based firmware; Node-RED for orchestration and dashboard interface
* **Power Supply:** 5V & 12V Power Adapter.
* **Display Unit:** 16x2 l2C LCD

**Engineering Methodology:**

* Followed a modular and incremental development approach.
* Individually tested each sensor before full integration.
* Calibrated pH sensor using standard buffer solutions (pH 4 and 7).
* Verified TDS readings using nutrient-enriched water.
* Mapped ultrasonic distance to water level in the tank.
* Designed and tested rule-based pH automation logic.
* Developed a custom Node-RED dashboard for real-time monitoring and control.
* Used MQTT protocol with local broker and topic prefix **hydrofarmiot/.**
* Built a compact 6.5 cm × 5 cm PCB for neat wiring and stability.
* Housed all sensors and actuators in a junction box attached to the hydroponic tower then deployed in hydroponic setup for final testing.

**Key Contributions**

* Achieved full automation of hydroponic crop management with real-time monitoring via Node-RED.
* Reduced pH solution waste by automatically dosing only when readings exceeded defined thresholds..
* Developed a portable and reproducible system using open-source tools and readily available hardware components.
* Delivered a fully documented implementation, including schematics, source code, and sensor calibration procedures.

**Academic and Applied Relevance**

HydroFarmIoT serves as a practical demonstration of how embedded systems and IoT can be integrated into sustainable agriculture. By automating pH control and enabling real-time monitoring of water quality and environmental conditions, the system offers a scalable foundation for small-scale smart farming. The project highlights the applicability of open-source tools and low-cost components in solving real-world agricultural challenges. Its modular architecture and documented workflow make it a relevant reference for future research in precision irrigation, pH regulation techniques, Node-RED-based control systems, and hydroponic system optimization

**Available Documentation**

* **Full technical thesis**
* **System and circuit diagrams**
* **Annotated source code**
* **Bill of Materials (BOM)**
* **Field test logs and performance analysis**
* **Extension roadmap for research-driven variants**