# STM32L412KB Nucleo-Based Cold Storage Controller with GSM/Serial & RTC Interface, SD Card Logging, and Intelligent Actuator Control

Abstract:

This project aims to design and implement a **Cold Storage Controller** using the **STM32L412KB Nucleo microcontroller** as the central processing unit. The system will acquire a **temperature setpoint** through either a **UART-based GSM module** or a **serial terminal**, enabling flexible remote configuration. A **DS1307 RTC (I2C)** provides accurate real-time data, while a **PT100 sensor (with signal conditioning)** and an **I2C-based humidity sensor** continuously monitor environmental conditions inside the chamber. The logged temperature and humidity data are stored on an **SPI-based SD card module** for record-keeping and analysis.

A **16x2 LCD display** is used for real-time visualization of parameters, and a **4x1 keypad** enables local user input for essential configuration. On the actuator side, the system controls a **hot air valve** and **cooling fan** via relay drivers, while a **PWM-controlled servo motor** operates the **coolant valve** for fine control of cooling. Together, these elements create a reliable and flexible **closed-loop temperature and humidity control system**, tailored for cold storage applications.

Block Diagram:
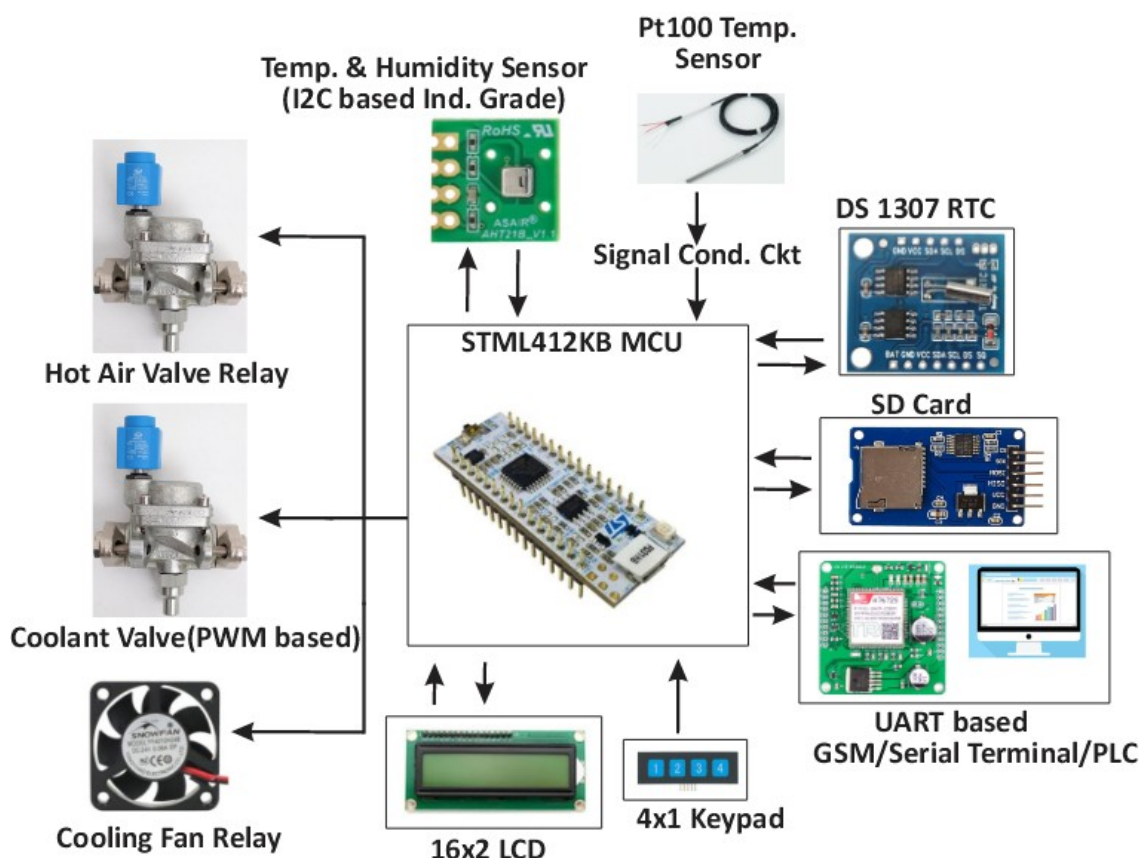
Advantages:

- **Low-power STM32L4 MCU** ensures high efficiency and long-term reliability.
- **Multiple communication options** (GSM / Serial) for flexible parameter setting and remote monitoring.
- **Data logging with SD card** for historical analysis and compliance with regulatory standards.
- **Closed-loop precision control** using PT100 and humidity feedback for accurate temperature maintenance.
- **User-friendly interface** with LCD and keypad for on-site operation.
- **Scalable design** that can be extended to multiple sensors and actuators for larger cold storage chambers.

Applications:

- **Cold storage chambers** for food preservation (fruits, vegetables, dairy, meat).
- **Pharmaceutical cold chain monitoring** for vaccine and medicine storage.
- **Agro-based storage** for sensitive crops such as saffron, mushrooms, or flowers.
- **Industrial environmental control** in warehouses and storage units.
- **Research laboratories** requiring controlled temperature and humidity chambers.