Ho Chi Minh City University of Techonology
Faculty of Computer Science and Engineering

– CO3009 - Microprocessors-Microcontrollers –

A Smart Low Temperature Dehydration System

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1 Introduction

Low Temperature Dehydration or LTD is one of the most common techniques for dry food to be preserved for a longer duration and is less susceptible tp spoilage caused by the growth a bacteria, molds and insects. In this microprocessors-microcontrollers course, I want to deliver a proposal in building a Smart LTD System that serves the efficiency, reliability, availability, scalability as well as affordability to users.

An LTD normally includes three fans, a heater, a heat-pump/dehydration machine and LTD controller which can sense the temperature and humidity inside the room and control machines adaptively. The proposal suggest a list of different hardware components, several solutions that provide the users with wide range of choices correspond to the property of their needs like quality, range of the system, and price, etc...

2 Block Diagram

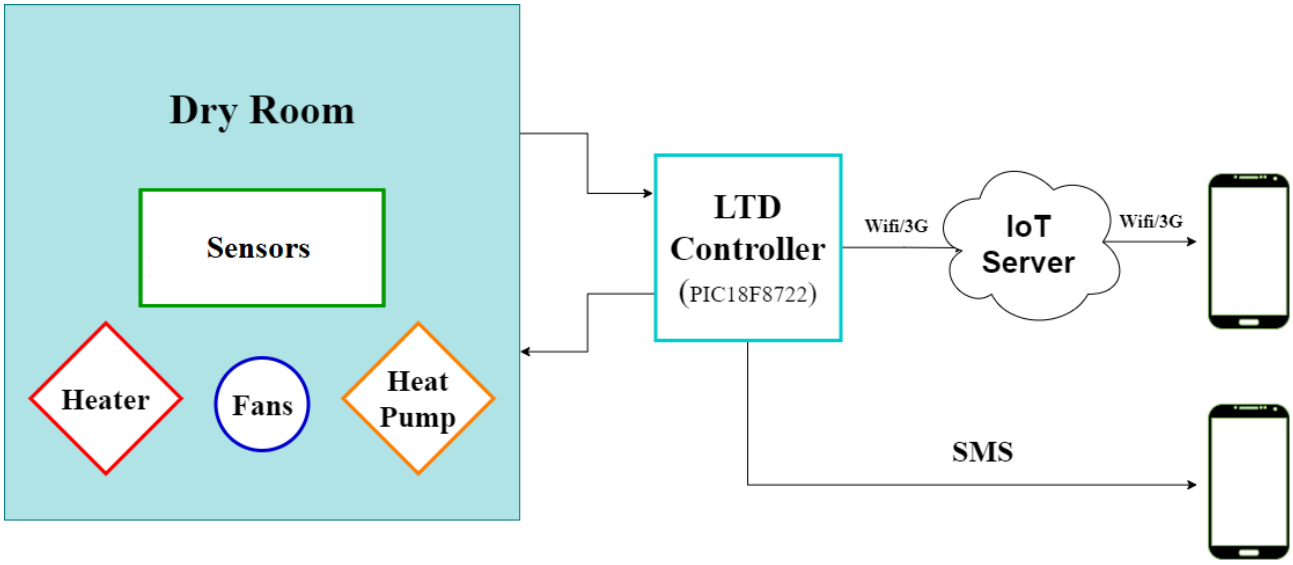


Figure 1: A Smart LTD System

3 Design

3.1 Materials

3.1.1 Hardware Components

- **List of machines and devices:**

No.	Name
1	Fan
2	Heater
3	Heat Pump/Dehydration
4	LTD Controller
5	Temperature and Humidity Sensor
6	Current Sensor
7	Real-Time Module

Table 1: Devices and machines used in the LTD System

- **LTD Controller:**

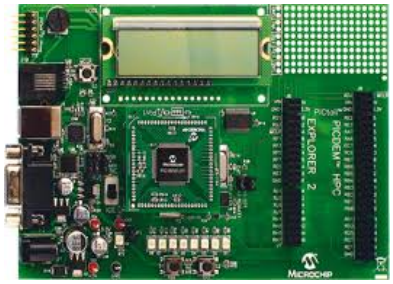
For the main processor of the LTD system, I used PIC18F8722 microcontrollers which is a electronic circuit that can be programmed to carry out a vast range of tasks. It can be programmed to be a timer to control a production line which can be used in alarm systems, computer control systems etc [1]. Description of PIC18F8722 microcontroller is shown below:

Name	Value
Operating Voltage	2 V - 5.5 V
Program Memory Type	Flash
Program Memory Size	128 KB
CPU Speed	10
SRAM	3396 KB
EEPROM	1024
Digital Communication Peripherals	2-UART, 2-SPI, 2-I2C2
Timers	2 x 8 bit, 3 x 16 bit

Table 2: Features of PIC18F8722

For the simulation of the LTD System, the project involves using PIC18 Explorer Board with the integrated PIC18F8722 microcontroller as a main processor. The PIC18 Explorer Board also supports dozens of general purpose PIC18 families using various processor Plugin-In Modules. The board also provides debugger for a full featued, PIC18 environment development. Also an LCD 16x2 is supported within the board in order to help users keep track of information or display information. [2]

(a) PIC18F8722



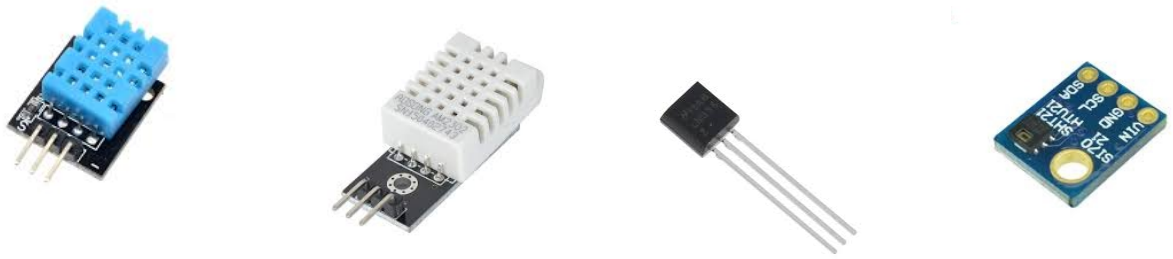
(b) PIC18 Explorer Board

Figure 2: PIC18F8722 and PIC18 Explorer Board

- **Temperature / Humidity sensors:**

	DHT11	**DHT22**	**LM335**	**HTU21D**
Type	Temp/Humid	Temp/Humid	Temperature	Temp/Humid
Output Signal	Digital	Digital	Digital	Digital
Operating Voltage	3 V - 5V	3.3 V - 6 V	2.92 V - 3.04 V	1.5 V - 3.6 V
Operating Range	0°C - 50°C	-40°C - 80°C	-40°C - 100°C	-40°C - 125°C
Maximum Load	0.014 W	0.01 W	0.0152 W	0.018 W
Sensitivity	± 2°C	± 0.1°C	± 2°C	± 0.3°C
Response Time	1 s	2 s	-	10 s
Price	1 $	6 $	2 $	4 $

Table 3: Features of Temperature/Humidity sensors



(a) DHT11 (b) DHT22 (c) LM335 (d) HTU21D

Figure 3: Temperature / Humidity sensors

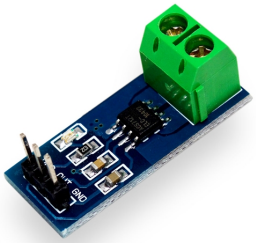
- **A brief description of each sensor:**
  - + **DHT11** is a basic, ultra low-cost digital temperature and humidity sensor. It output a digital signal on the data pin. Overall, it is fairly simple to use, but it requires careful timing to receive the data. [3]
  - + **DHT22** is almost similar to DHT11 which is a basic, ultra low-cost digital temperature and humidity sensor. Compared to DHT11, DHT22 is more precise, more accurate and works in a bigger range of temperature/humidity, but it is more larger and expensive. [4]
  - + **LM335** is a precision, easily-calibrated integrated circuit temperature sensor. It works in a larger range of temperature in compared with DHT22 but the output error is 2 degree Celsius. On the other hand, the price of the LM335 sensor is reasonable. [5]
  - + **HTU21D** is a digital and humidity sensor which is dedicated humidity and temperature plug and play transducers for OEM applications where reliable and accurate measurements are needed. It is designed for high volume and cost sensitive applications. [6]

- **Build the Temp/Humid based-sensor system:**
  - + Users can choose what kind of temperature/humidity sensor that suitable for the system's demand and requirements since each sensor has its own advantages and disadvantages.
  - + The system is one of most important part in the entire LTD System because LTD Controller gets the temperature and humidity measured by sensors. In order to improve its efficiency and reliability, there will be at least three sensors will be used and connected in series.
  - + The purpose of this method is that we can compare the result of each sensor, for example, if we only have one sensor then we do not know if the data is accurate or not meanwhile with three more sensors available we can compare the result of each one and get a more precise data.

- **Current sensors:**

	ACS712	**ACS764**	**AK3102**
For Measuring	AC/DC	DC	AC/DC
Operating Voltage	5 V	3 V - 3.6 V	4.5 V - 5.5 V
Operating Range	±30 A	±32 A	±40 A
Maximum Load	0.07 W	0.05 W	0.1 W
Total Output Error	±1.5 %	±1 %	±1.5 %
Price	3 $	1.6 $	4 $

Table 4: Features of Current sensors



(a) ACS712

(b) ACS764

(c) AK3102

Figure 4: Current sensors

- **A brief description of each current sensor:**

  + **ACS712** provides economical and precise solutions for AC or DC current sensing in industrial, commercial and communication systems. The device consists of a linear Hall sensor circuit with a copper conduction that generate a magnetic field when there is a current flowing through this copper and converted into a proportional voltage. [7]
  + **ACS764** is a fully integrated Hall-effect current sensor IC is designed for application that needs digital current sensing and report the result on the I2C bus. User can also select the coarse sensitivity and fault level in order to meet the demands of diagnostic applications. [8]
  + **AK3102** is an open-type current sensor using a Hall sensor which outputs the analog voltage in proportion to AC/DC current. The AK3102 current sensor is ultra low noise because it has a sensitive semiconductor Hall element and signal processing technology. It is often used to detect current in high resolution such as motor control. [9]

- **Build the based-sensor current checking system:**
  + Depending on the users demands and the system's requirements, each current sensor has different characteristics that may be suitable or unsuitable for the system.
  + There will be at least three current sensors that are connected in series with temp/humid sensors and maybe other devices and machines. Current sensors will measure the current passing through the machines and devices in order to make sure that every time they are turned on by direct or remote, they will actually work.
  + As a result, users can be notified as soon as possible in case of broken machines or devices happens.
  + Nevertheless, current sensors can help to check how efficient the system works and notify users to replace those that do not work on maximum efficiency or predict at a specific period of time that it may broke down.
  + Current sensors help to improve the ability to handle exceptions, errors as well as the efficiency and reliability and maintainability of the LTD system.

- **WiFi modules:**

	ESP8266	**ESP32**	**WT8266-S1**
Operating Voltage	2.5 V - 3.6 V	2.3 V - 3.6 V	3.3V
Maximum Load	0.61 W	0.86 W	0.7 W
Typical Frequency	80 MHz	160 Mhz	80/160 MHz
Flash Memory	4 MB	4 MB	16 MB
Distance	200 m	240 m	400 m
Price	4 $	6 $	10.35 $

Table 5: Features of suggested WiFi Modules

(a) ESP8266

(b) ESP32

(c) WT8266-S1

Figure 5: WiFi Modules

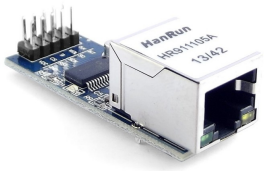
- **A brief description of each Wifi module:**
  + **ESP8266** is a low-cost WiFi microchip with full TCP/IP stack and microcontroller capability manufactured by Espressif Systems. The ESP8266 is capable of either hosting an application or offloading all WiFi networking functions from another application processor. [10]
  + **ESP32** is a series of low-cost, low-power system on chip microcontrollers with integrated WiFi and dual-mode Bluetooth which is also manufactured by Espressif Systems. Compared to the ESP8266, the ESP32 has some better characteristic, for example, the ESP32 is dual core 160MHz whereas ESP8266 is a single core which runs at 80MHz. Moreover, the ESP32 adds an extra CPU core, faster WiFi, more GPIOs and supports Bluetooth 4.2. [11]
  + **WT8266-S1** WiFi module is a low consumption, high performance embedded WiFi network control module designed by Wireless-Tag. It can meet the IoT application requirements in smart power grids, building automation, security and protection etc. The module's core is based on the ESP8266 but the working range of the module is slight wider and the flash memory is larger as well in comparison to both the ESP32 and the ESP8266. [12]

- In case of the place that we are in now does not have WiFi available or in thunderstorm weather the ESP8266, ESP32 and WT8266-S1 WiFi modules do not operate properly which decreases the efficiency and accuracy. Therefore, Quectel EC20 and ENC82J60 Ethernet are suggested to solve the mentioned problems:

	Quectel EC20	**ENC82J60 Ethernet**
Operating Voltage	2.5 V - 3.6 V	2.3 V - 3.6 V
Maximum Load	0.61 W	0.86 W
Communication Method	Wireless	SPI
Price	31.64 $	2.5 $

Table 6: Features of Quectel EC20 and ENC82J60 Ethernet

(a) Quectel EC20



(b) ENC82J60 Ethernet

Figure 6: GSM Modules

- **A brief description of Quectel EC20 and ENC82J60 Ethernet:**
  + **Quectel EC20** is a new generation of Quectel module. It delivers 100Mbps downlink and 50Mbps uplink data rates. It is compatible with existing GSM/GPRS networks, ensuring that it can be connected even in remote areas devoid of 4G or 3G coverage. [13]
  + **ENC82J60 Ethernet** is a stand-alone Ethernet controller with an industry standard Serial Peripheral Interface (SPI). It is designed to serve as an Ethernet network interface or any controller equipped with SPI. Communication with the host controller is implemented via two interrupt pins and the SPI with data rates up to 10Mbps. [14]

- **GSM modules:** For an alternative method to connecting WiFi modules to LTD System, GSM modules can be used to interact with users via SMS message which are based on wireless network configuration.

	SIM5320E	**SIM7000E**
Operating Voltage	3.3 V - 4.2 V	3 V - 4.3 V
Maximum Load	2 W	2 W
Frequency	850 MHz	900 MHz
Sensitivity Tracking	157 dBm	162 dBm
Price	79.95 $	40.3 $

Table 7: Features of GSM modules

(a) SIM5320E

(b) Shield SIM7000E

Figure 7: GSM Modules

- **A brief description of GSM modules:**
  + **SIM5320E** is a quad-band GSM/GPRS/EDGE and dual-band UMTS/HSDPA that works on frequencies GSM 850 Mhz which supports HSPDA up to 3.6Mbps for downlink data transfer. It provides much flexibility and ease of integration for many applications, for example, Tracker, AMI, Health Care etc. [15]
  + **SIM7000E** is a Tri-Band LTE-FDD and Dual-Band GPRS/EDGE module solution in a SMT type which supports LTE CAT-M1(eMTC) and NB-IoT up to 375kbps data transfer. It is designed for applications that need low latency, high performance, and flexibility such as tracking, remote monitoring, Health Care etc. [16]

3.1.2 Software Components

- **List of software programs:**

No.	Name
1	MPLAB X IDE
2	MQTT Protocol
3	MIT App Inventor

Table 8: Software Programs

- **MPLAB X IDE:**

MPLAB X Integrated Development Environment (IDE) is an high configurable program that provides tools to develop, debug and qualify embedded applications for Microchips's microcontrollers and digital signal controllers. MPLAB x IDE works seamlessly with the MPLAB development ecosystem of software and tools, many of which are completely free. [17]

- **MQTT Protocol:**

MQTT (Message Queuing Telemetry Transport) is an open OASIS and ISO standard lightweight, publish-subscribe network protocol that transports messages between devices.

The MQTT protocol defines two types of network entities: a message broker and a number of clients. An MQTT broker is a server that receives all messages from the clients and then routes the messages to the appropriate destination clients. An MQTT client is any device (from a micro controller up to a full-fledged server) that runs an MQTT library and connects to an MQTT broker over a network. [18]

- **MIT App Inventor:**

MIT App Inventor is a web application integrated development environment. The software applications programmed by MIt App Inventor can operate on two operating systems: OS and iOS. Its servers store your work and help users keep track of their projects. MIT App Inventor support two modes which are Designer and Blocks Editor.

In Designer mode, users can select the component they want to be displayed on the app. In Blocks Editor mode, users assemble program blocks that specify how the components should behave. When users are done, it will produce a stand-alone application to install. [19]

3.2 Must Have Features

- The sensor-based system measures the temperature and humidity both inside and outside the dry room then return the data to the LTD controller to operate machines and devices.
- The heater will be turned on to warm the dry room until the temperature reaches the user-defined maximum value. When the heater is on, fan2 will be on as well to distribute the air evenly inside the dry room.
- When the heater is off, the heat pump is on to absorb heat from a cold space and releases heat into the dry room. Moreover, fan3 is also turned on to help the heat pump work better. Noticeably, if the heater is on then the heat pump is off vice versa.
- If the humidity inside the dry room is greater than the user-defined maximum humidity, fan 1 will be turned on to transfer the humid air outside. The speed of fan1 can be controlled by output an analog signal.
- The user can set the timer so that the operation of the heater and heat pump can be processed periodically. Each operation has a timeout in case of errors.

- The system has at least three temperature sensors and three humidity sensors connected to three pins of a processor in terms of improving the accuracy and reliability of the system. If one sensor fails, the operation will not be stopped due to errors when receive data from sensors.
- Current sensors are used to detect whether the machines or devices are broken or they are not working efficiently anymore so that the user can replace it as soon as possible. Similarly to the temp/humid sensors, there will be at least three current sensors to increase the accuracy and efficiency.
- The LTD controller can also interact remotely with users through an IoT server in real time via Wifi/3G connectivity. It sends the temperature and humidity to the server for users can easily monitor without having to be nearby.
- The IoT server can also store the information about the current status of the system as well as the temperature and humidity in case of emergency shut down or loss of power source. In case there is no Wifi/3G, the LTD system can backup the data in a SD Card Memory.
- Users are provided with an mobile application to keep track the operation of the system which will be notified if there is a broken machine or device. The users themselves can turn on or off devices and machines.
- The LTD system can send a SMS to the user's phone as well using a GSM modules to help users keep track the status of all machines and devices and alert if some issues occur to the system in order for the users to replace them as soon as possible.

4 Implementation

4.1 Flow Chart

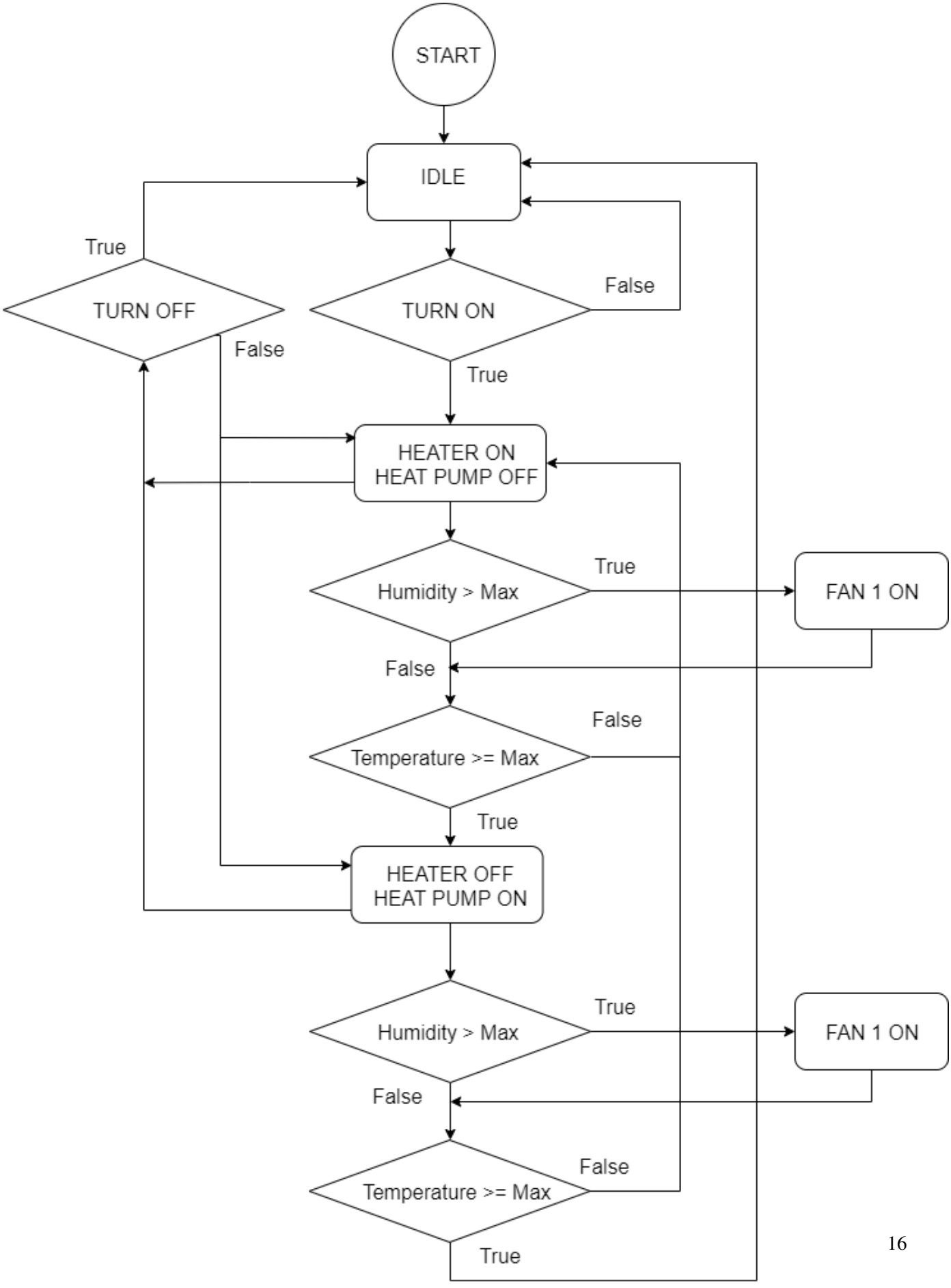


Figure 8: How the LTD System operates

4.2 Description of Operation Flow

- For simulation purpose, the heater, heat pump, fan1, fan2 and fan3 is displayed by LEDs and real-time modules are not implemented. The system operates through three states which are Idle state, Heater state and Heat Pump state.
- Idle state:
  - The LTD system is in IDLE state until there is a signal to change state into working which is the button RA5. In Idle state, both heater and heat pump are off.
  - In Idle state, the LTD controller also checks for the changes of temperature in the dry room and can automatically change to Heater state.
  - Each operation state is set a timeout and then back to Idle state because in case of an error happens to the LTD system, for example, a machine or device breaks down then the operation will not hung completely but instead it will back to Idle state. Setting up a time out can improve the safety and maintainability of the system.
- Heater state:
  - Whenever the system changes state to Heater state, the heater is turned on as well as fan2. During this state, LTD controller will periodically check for the humidity and temperature of the dry room.
  - If the humidity exceeds the user-defined maximum humidity then fan1 will be turned on to transfer the humidity air to outside. If the temperature exceeds the user-defined maximum temperature then the heater is off and the system changes to Heat Pump state
  - If the button RB0 is pressed during the process, the system will return to Idle state.
- Heat Pump state:
  - Whenever the system changes state to Heat Pump state, the heat pump in turned on as well as fan3. Similarly to Heater state, LTD controller will periodically check for the humidity and temperature in the dry room.
  - If the humidity exceeds the user-defined maximum humidity and fan 1 has not been turned on in Heater state then fan 1 is on. If the temperature in the room remains stable which exceeds the user-define maximum temperature then the system backs to Idle state otherwise it will changes to Heater state and heat pump is turned off.
  - If the button RB0 is pressed during the process, the system will return to Idle state.

4.3 Operating Modes

- **Periodically Task Scheduling:**
  - Heater state and Heat Pump state are set up for LTD system to switch between two states periodically using an integrated interrupt timer to manage and execute tasks. Also, other tasks like temperature checking, humidity checking can be set to run periodically after a period of time.
  - In order to manage and make sure that the order of each task is executed correctly, I use a linked list data structure implemented by array which provide several functions like add task, delete task and update task.
  - The default mode of the LTD system is periodic task scheduling.
- **Manual Adjustment:**
  - The purpose of this mode is mainly to simulate and test for all features by manually increasing the temperature and humidity.
  - When the LTD systems is working in either Heater state or Heat Pump state, users can press button RA5 to enter manual adjustment mode. Press the button RB0 to increase both the temperature and humidity and the LTD controller will based on that simulated temperature and humidity to operate. To exist the mode, press the button RA5 again.

5 Conclusions

In the research, our target is to build a smart LTD system that support checking for the operation of machines and devices, for example, are they broken or not, also how long they can operate at maximum efficiency and predict the period of time which machines or devices will be broken, as well as real-time monitoring for the users. Users are provided with list of temperature and humidity sensors, current sensors, WiFi and GSM modules to support all the features mentioned above. Moreover, some methods of how to build the sensor system and current checking system in order to improve the reliability, efficiency, accuracy and maintainability of the LTD system.

The simulation of LTD system is only partial with only basic features but the operation of the simulation is almost the same as the smart LTD system. In the future, I will build a complete system with real-time monitoring through a self-made application for the users.

The source code of the simulation can be found at GitHub: https://github.com/NhanNgocThien/LTD_System_MCU

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