CSE 321 Project 3

Temperature and Humidity Alarm

Jayaprakash Ginjupalli, junior

Department of Computer Science and Engineering

School of Engineering and Applied Sciences

University at Buffalo

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Contents

1 Project Overview

1.1 Introduction

The goal of this project is to develop a device that monitors a home's humidity levels, displays them, and issues an alarm when they rise to dangerous levels. Until the user manually mutes it or the levels recover to ideal levels, the alarm will keep going off. Too much or too little humidity can lead to a variety of issues for a residence. High concentrations can destroy furniture, harm paintwork, grow mold and mildew, and cause structural damage to homes. On the other side, low humidity can lead to skin and eye dryness, accelerate the spread of infections and viruses, and harm wood. The ultimate goal is the development of an alarm system that enables householders to stop the potentially harmful consequences of low or excessive humidity levels by forewarning them before they happen.

1.2 Overview of features and specifications

Software Requirements:

- MBED RTOS
- Use of a synchronization technique.
- Appropriate configuration of watchdog timer.
- Direct bitwise driver configuration.
- Critical section protection for entire implementation.
- At least 1 interrupt configured.
- Use of threads/tasks.

Hardware Requirements:

- Nucleo-L4R5ZI
- DHT11 Sensor
- Buzzer Audio Module
- 18x2 LCD display
- Breadboard
- At least 10 Male to Female jumper wires
- At least 20 Male to Male jumper wires
- USB A to Micro USB B
- Resistors

Specifications:

- Displays humidity percentage.
- Displays the state of humidity levels.
- Humidity levels are:
    - Harmful at greater than 70% or lower than 25%

    - Fair between 60 – 70% or 25-30%.
    - Ideal at 30-60%
- Audio alarm activates when state becomes harmful.
- User button B1 will mute the alarm

1.3 Explanations of how the required internal features are integrated

Explanation of thread/tasks and how it was incorporated

The humidity alarm requires 3 threads to function. Each thread is responsible for controlling the behavior of the three external peripherals, the threads that are incorporated are:

Thread 1: thread_sense

- Controls the DHT11 sensor behavior.
- Calls the function “sense()”.
- Senses every 2.5 seconds.
- Puts humidity data (int) to the queue “display_humidityque”.
- Puts state (string) to the queue “state_que”.

Thread 2: thread_display

- Controls the LCD display
- Calls the function “display()”
- Waits for data to be available in “display_humidityque”, and “state_que”.
- Updates the global variables “humidity” and “state”.
- Prints data to serial monitor and LCD.
- Kicks the watch dog.

Thread 3: thread_audio

- Controls the buzzer audio module.
- Calls the function “audio”
- Continuously monitors the global variable “state” and “muted”.
- Writes to the global variable “muted”.

Explanation of synchronization technique and how it was incorporated

To provide synchronization between the input peripheral and the output peripherals, two queues are used. The LCD waits until the data is ready in the queue before obtaining the humidity information that was detected by the DHT11. This prevents concurrent access by the two threads to shared global variables.

Explanation of bitwise driver control and how it was incorporated

Bitwise driver control was incorporated for the LCD, Buzzer module, and DHT11 sensor. The following code snippets show how each driver is configured using bit masking.

- The RCC is enabled for ports B and C.

```
RCC->AHB2ENR |= 0x6;
```

- Port B holds the pin mappings for the output peripherals, the mode is set to output (01) for pins PB_8 (SCL), PB_9(SDA), and PB_15 (Buzzer module).

```
GPIOB->MODER &=~(0x800A0000);
GPIOB->MODER |= 0x40050000;
```

- Port C holds the pin mappings for the input peripherals, the mode is set to input (00) for pins PC_6 (DHT11 sensor) and PC_13 (User Button).

```
GPIOC->MODER &=~(0x300c000);
```

- The DHR11's input data register is enabled in the main function to allow for input. It is enabled with:

```
GPIOC->IDR |= 0x4000;
```

- The buzzer module's output data register is set to output on an active low signal. The buzzer is disabled in the main function before any threads start executing. This is also controlled in the "audio ()" function which is responsible for buzzer behavior.
    - It is disabled with:

```
GPIOB->ODR |= 0x4000;
```

    - It is enabled with:

```
GPIOB->ODR &= ~(0x4000);
```

Explanation of critical section protection and how it was incorporated

Critical section protection was incorporated with the use of the two queues "display_state_que", and "display_humidityque". This avoids the need for the "thread_sense" and "thread_display" threads to access the global variables "state" and "humidity" at the same time.

Explanation of interrupt and how it was incorporated

The on-board user button B1 is configured to call the function mute() on a rising edge. When called it will check if the global variable "state" == "Harmful", at which point it will set the global variable "muted" to true. This will cause the thread "thread_audio" to silence the buzzer audio module instantly.

Explanation of watchdog element and how it was incorporated

The detecting interval is set to 3 seconds since the DHT11 sensor can only sense at intervals longer than 2 seconds. The thread t sense enters a 3-second sleep period before sending data to the "state_que" and "display_humidityque" queues. The "t display" thread is set up to wait indefinitely before successfully obtaining data from the queue. The watchdog timer's timeout is set to 2.2 seconds because this process should only take a tiny amount of time longer than the sensing interval to complete.

1.4 Recap of design process

Stage 1: Identify the problem, and constraints.

The initial step in the design process is to identify the problem that needs be addressed with the given specifications and constraints. The specifications were the incorporation of 3 external peripherals,

programmed using a RTOS, and addresses an area of application. The problem was the need for a device that can warn homeowners of unsafe humidity levels in their home

Stage 2: Research the problem

According to research, the best humidity levels are between 30% and 60%, fair levels are between 60 and 70% and between 25 and 30%, while dangerous levels are above 70% or below 25%. Humidity ranges between low and high can lead to structural damage, increased infections, and mold growth, among other things. This device consequently pertains to safety. Most homeowners would want this item due to the negative consequences on their homes and health. This device must make use of bitwise control, threads, interrupts, watchdog timers, and synchronization mechanisms. Threads enable several control flows to occur concurrently, synchronization prevents two threads from trying to use a shared resource at the same time, interrupts notify the occurrence of an event, watchdog timers can be used to detect errors, and so on, and bitwise control uses bit masking to control drivers.

Stage 3: Imagine solutions

The peripherals that must be utilized were a 18x2 LCD, DHT11 sensor, buzzer audio module, and the B1 button. These elements can be used in conjunction to create a humidity sensor, that also functions as an alarm system.

Stage 4: Plan and design

The second stage is picking a design and making a plan to put it into action. The humidity alarm modelled after a smoke alarm was chosen for its design. The DHT11 sensor would be used to determine the humidity level in a space, the LCD would show the humidity level along with its quality level, the buzzer audio module would play an alarm, and the B1 button would silence it. To simultaneously operate each peripheral, the software would make use of many threads. After that, a flowchart and hardware schematic are made.

Stage 5: Implement

The hardware schematic and code can be implemented when all of the planning and designing is finished. Building the design is the first thing to do. All peripherals are linked to the appropriate pin mappings that were selected. The design would then be coded in Mbed using all of the given constraints.

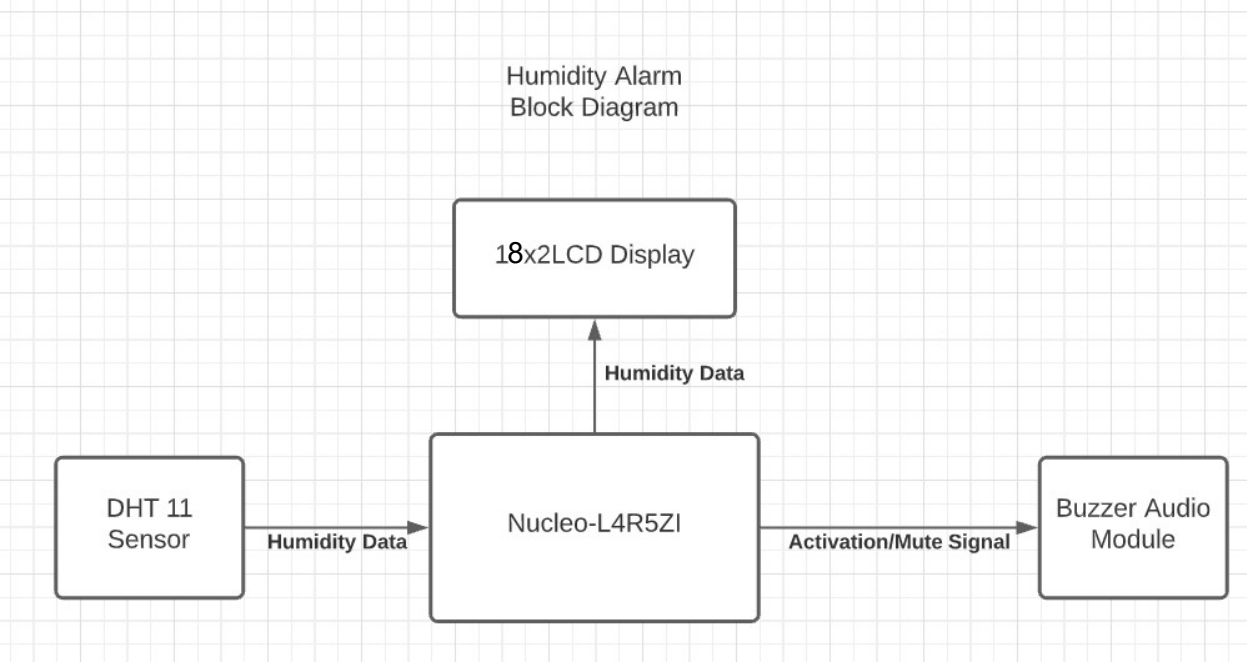
Stage 6: Test

After the implementation of the hardware and software are completed, a testing plan is developed, and the humidity alarm evaluated for correctness.

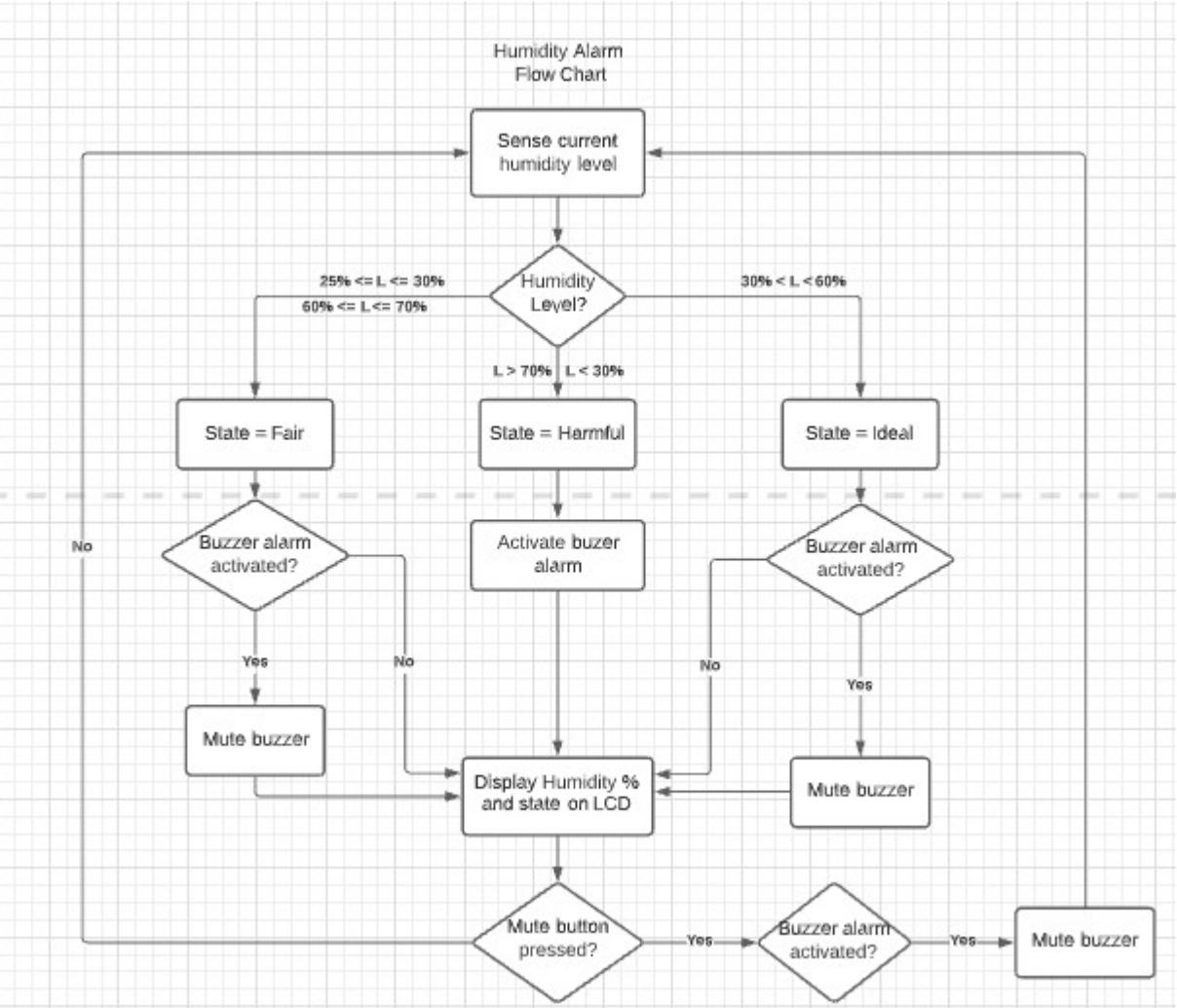
Stage 7: Improve:

The wiring of the device can be simplified, and the color coding of the wires can be improved. An event queue can be incorporated to correctly handle the mute interrupt.

1.5 Block Diagram



1.6 Flow Chart



2 Getting Started

2.1 Bill of Materials

DHT11 Sensor

Description: An external peripheral which can detect humidity levels and temperature

Price: $10.29

Reference: https://components101.com/sites/default/files/component_datasheet/DHT 11-Temperature-Sensor.pdf

Purchase Link: https://www.amazon.com/HiLetgo-Temperature-Humidity-Digital-3-3V5V/dp/B01DKC2GQ0

18x2 LCD Display

Description: An external peripheral that displays text on a 16x2 display.

Price: $8.99

Purchase Link: https://www.amazon.com/SunFounder-Serial-Module-DisplayArduino/dp/B019K5X53O/ref=sxin_13_pa_sp_search_thematic_sspa?cv_ct_cx=LCD+1602&dchild=1&keywords=LCD+1602&pd_rd_i=B019K5X53O&pd_rd_r=533f4e19-cd79-4704-9ea7-4a9b76ea3af5&pd_rd_w=zEW74&pd_rd_wg=txPku&pf_rd_p=3b2adfc6-e3ad-467a-9f38-271e811048b0&pf_rd_r=A14V16SMA0DCWZABFJ5P&qid=1629389281&sr=1-1-a73d1c8c-2fd2-4f19-aa41-2df022bcb241-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEyNzM5N1RLMU1XWDBOJmVuY3J5cHRlZElkPUEwNzU0MTk3M0ZKRDJVQTJGOTY4SiZlbmNyeXB0ZWRBZElkPUEwNjg1NDY1M0hTTDVSTVhZQlNUQyZ3aWRnZXROYW1lPXNwX3NlYXJjaF90aGVtYXRpYyZhY3Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNrPXRydWU=&pldnSite=1

Buzzer Audio Module

Description: An external peripheral which outputs audio signals.

Price: $7.80

Reference: http://tinkbox.ph/sites/tinkbox.ph/file/downloads/5V_BUZZER_MODULE.pdf

Purchase Link: https://www.amazon.com/HiLetgo-Temperature-Humidity-Digital-3-3V5V/do/B01DKC2GQ0

Nucleo-L4R5ZI

Description: The microcontroller which will control the logic of the system.

Price: $28.14

Purchase Link: https://www.mouser.com/ProductDetail/511-NUCLEO-L4R5ZI

Wires

Description: Wires allow for the flow of electricity between components.

Price: $3.90

Purchase Link: https://www.mouser.com/ProductDetail/713-110990044

Breadboard

Description: A device upon which electric components are held and connected.

Price: $15.40

Purchase Link: https://www.mouser.com/ProductDetail/854-BB1460

Resistors

Description: Resistors regulate voltage between components.

Price: $0.95

Purchase Link: https://www.mouser.com/ProductDetail/474-PRT-14492

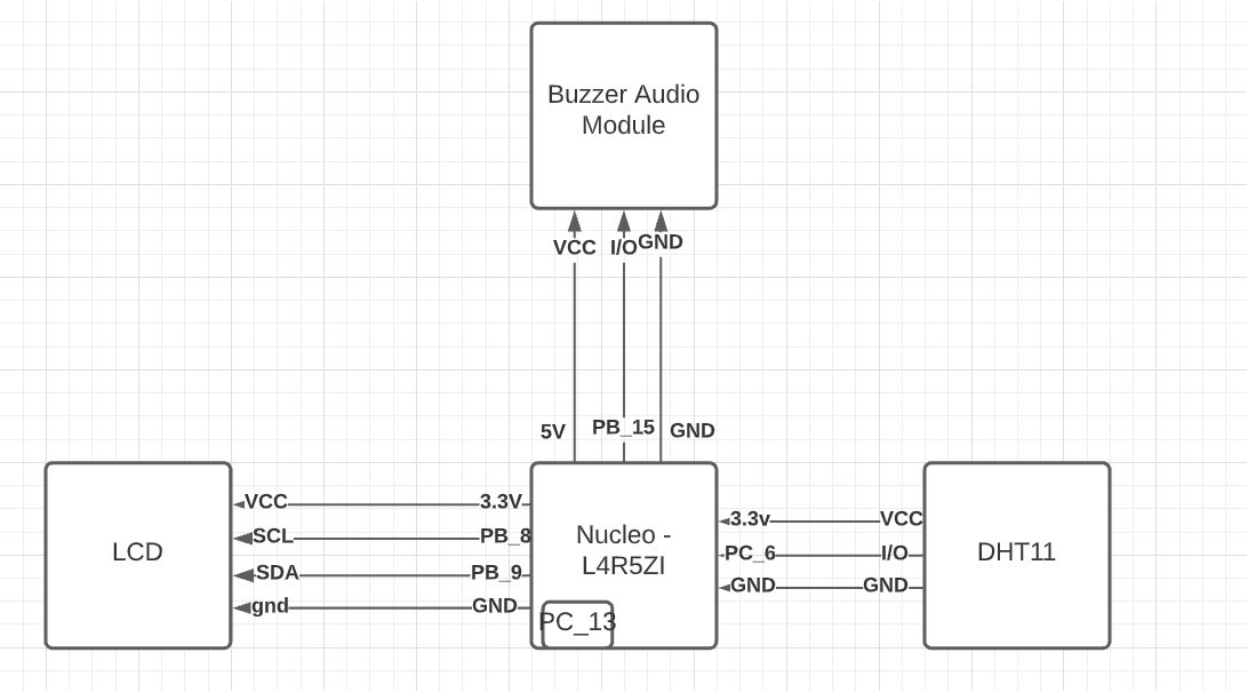
USB A to Micro USB B cable

Description: Cable which will connect the Nucleo-L4R5ZI to a computer.

Price: $7.99

Purchase Link: https://www.bestbuy.com/site/best-buy-essentials-3-micro-usb-to- usbcharge-and-sync-cable-black/6456436.p?skuId=6456436

2.2 Schematic



2.3 How to build

This section will cover the steps required to configure the hardware elements of the device. All resistors used will be 1kOhm.

1. Acquire all hardware elements as described in the BOM.
2. Connect the Nucleo-L4R5ZI to a computer with a USBA to Micro USB.
    a. Ensure a proper connection has been made, the Nucleo-L4R5ZI should appear in the device manager.
3. Set up the buzzer audio module.
    a. VCC to +5V, add a resistor.
    b. GND to GND
    c. I/O to PB_14
4. Set up the 18x2 LCD display.
    a. VCC to +3.3V, add a resistor.
    b. GND to GND.

    c. SCL to PB_8.
    d. SDA to PB_9
5. Set up the DHT11 sensor.
    a. VCC to +3.3V, add a resistor.
    b. GND to GND
    c. Data to PC_5

3.4 How to use

This section will detail how to operate the humidity alarm. Make sure the steps described in section 3.3 are completed before continuing.

1. Once the device is connected to a power source the LCD should display “Humidity Level: __%” on the 1st row and “State: ____“on the 2nd row.
2. The device will automatically detect and update the display with the current humidity and state every 2.5 seconds.
3. The state indicates the quality of the current humidity. The alarm will sound if state becomes “Harmful” and will automatically mute once levels become “Ideal” or “Fair”.
    a. Ideal: This indicates optimal humidity %
    b. Fair: Humidity % isn’t optimal, but not harmful.
    c. Harmful: Humidity is too low or too high, consider addressing this to avoid negative effects.
4. If the alarm becomes activated, the user button B1 may be pressed to mute it.
    a. Once muted, it cannot be unmuted unless state changes to “Fair” or “Ideal” and back to “Harmful” again.

3 Analysis

3.1 Test Plan Instructions

This section details the purpose, inputs and expected outputs of each test case.

Test 1: Test behavior of low harmful humidity

Test 2: Test behavior of high harmful humidity

Test 3: Test behavior of low fair humidity

Test 4: Test behavior of high fair humidity

Test 5: Test behavior of ideal humidity

Test 6: Test behavior of buzzer when going from harmful state to fair.

Test 7: Test behavior of buzzer when going from fair to harmful.

Test 8: Test mute button functionality.

Test #	Humidity %	State	Expected LCD Display	Buzzer activation?
1	23	Harmful	Humidity Level: 23% State: Harmful	Yes
2	80	Harmful	Humidity Level: 80% State: Harmful	Yes
3	25	Harmful	Humidity Level: 25% State: Fair	Yes
4	65	Fair	Humidity Level: 65% State: Fair	No
5	50	Ideal	Humidity Level: 50% State: Ideal	No
6	71% ➔ 69%	Harmful ➔ Fair	Humidity Level: 69% State: Fair	Yes ➔ No
7	69% ➔ 71%	Fair ➔ Harmful	Humidity Level: 71% State: Harmful	No ➔ Yes
8	72%	Harmful	Humidity Level: 71% State: Harmful	Yes ➔ No

3.2 Outcome of Implementation

Test 1: Pass, buzzer activates, and the LCD updates appropriately.

Test 2: Pass, buzzer activates, and the LCD updates appropriately.

Test 3: Pass, buzzer isn't activated, and the LCD updates appropriately.

Test 4: Pass, buzzer isn't activated, and the LCD updates appropriately.

Test 5: Pass, buzzer isn't activated, and the LCD updates appropriately.

Test 6: Pass, the buzzer disables immediately after the state transitions and the LCD updates appropriately.

Test 7: Pass, the buzzer activates immediately after the state transitions and the LCD updates appropriately.

Test 8: Pass, the buzzer disables immediately after the button is pressed.

3.3 Future Considerations

The design can be expanded to also include an option to switch the device from a humidity alarm to a thermometer with the use of a new input peripheral. Additionally, critical section protection is not fully implemented as can be seen with the mute interrupt. The mute interrupt writes to a global variable "muted" when pressed, however, the audio thread also writes to this variable when switching from a

harmful state to fair/ideal. Now, no issues have been found because of this, although a potential solution may be to use an event queue

3.4 Development Timeline/Revision History

11/16/2022 - Design and planning steps completed

11/21/2022 – Hardware elements built.

11/23/2022 – Program and function headers written

11/19/2022 – Main, sense, audio, and display functionality completed.

11/24/2022 – Mute functionality completed.

11/30/2022 - Fixed interrupt bounce bug.

12/13/2022 – Code finalized.

12/14/2022 – Report Finalized