

LEVEL 4 ASSESSMENT SPECIFICATION

Student name:	Libby Sheldon	Student ID number:	1810506
Programme:			
Module:	Embedded Systems		
Module code:	PCEE4004	Contribution to Overall Module Assessment (%):	100%
Lecturer:	Sarah Williams	Internal Verifier:	
Assignment Title:	Office Environment Monitor	Word count (or equivalent):	2000
Submission deadline:	10th May 2019	Return date of provisional marks & written feedback:	24th May 2019
Submission method:	All written assessments, where practical and possible, must be submitted via Turnitin unless otherwise instructed by the Lecturer. (Please DO NOT put this assessment specification into Turnitin or it will match many similarities with other students' submissions.) Alternative submission method (if applicable): Late submission of the assessment will result in a late penalty mark. Penalties for late submission: Up to one week late, maximum mark of 40%. Over one week late, 0%. Only the Extenuating Circumstances Panel may approve a change to submission dates.		
Academic honesty / referencing:	Academic honesty is required. In the main body of your submission you must give credit to authors on whose research and ideas your work is based. Append to your submission a reference list that indicates the books, articles, etc. that you have used, cited or quoted in order to complete this assessment.		

STUDENT FEEDBACK FORM

This section details the *extent* to which the assessment criteria are demonstrated by you, which in turn determines your mark. The marks available for each category of skill are shown. Lecturers will use the space provided to comment on the achievement of the task(s), including those areas in which you have performed well and areas that would benefit from development/improvement.

Generic Assessment Criteria	Marks available	Marks awarded
1. Engagement with Literature Skills		
Evidence of wide range of independently sourced research provided.	10	6
2. Knowledge and Understanding Skills		
Evidence of planning and consideration of components to use, justification of decisions made included. Hardware and software design provided, using standard conventions and demonstrate sound understanding of the topic area, however there is an additional path on the flowchart that should not be there on the too hot path, looping back on itself.	20	14
3. Cognitive and Intellectual Skills		
Evidence is provided to show that the system has been tested effectively and demonstrated as working as required in class. Also further discussion provides valid ways in which the system might be further developed.	25	19
4. Practical Application Skills		
Circuit developed gives a range of ways temperatures can be reported to the user and effectively allows for the user to identify when the temperature is within acceptable ranges, and when outside. Code is annotated. Code reflects flowchart provided at design stage, and makes use of constants, however you could have considered the boundaries of temperatures as constants also. Overall the project demonstrates a very good deployment of both practical programming and electrical circuit design and construction.	35	21

5. Transferable Skills for Life and Professional Practice		
Work is well formatted and presented, however you ensure it is proof read before submission.	10	6

Assessment Mark (Assessment marks are subject to ratification at the Exam Board. These comments and marks are to give feedback on module work and are for guidance only until they are confirmed.)	Late Submission Penalties (tick if appropriate)		66%
	Up to 1 week late (40% Max)		
	Over 1 week late (0%)		

GENERIC ASSESSMENT CRITERIA

Level 4

In accordance with the Framework for Higher Education Qualifications, at the end of Level 4 students will be expected to have demonstrated knowledge of the basic underlying concepts and principles of a subject, and an ability to evaluate and interpret these within the context of that area of study. They should be able to present, evaluate and interpret qualitative and quantitative data in order to develop lines of argument and make sound judgements in accordance with basic theories and concepts of their subject(s) of study. They will have learned how to evaluate different approaches to solving problems, and will be able to communicate the results of their study/work accurately and reliably, and with structured and coherent arguments. They will be able to undertake further training and develop new skills within a structured and managed environment and will have the qualities and transferable skills necessary for employment requiring the exercise of some personal responsibility.

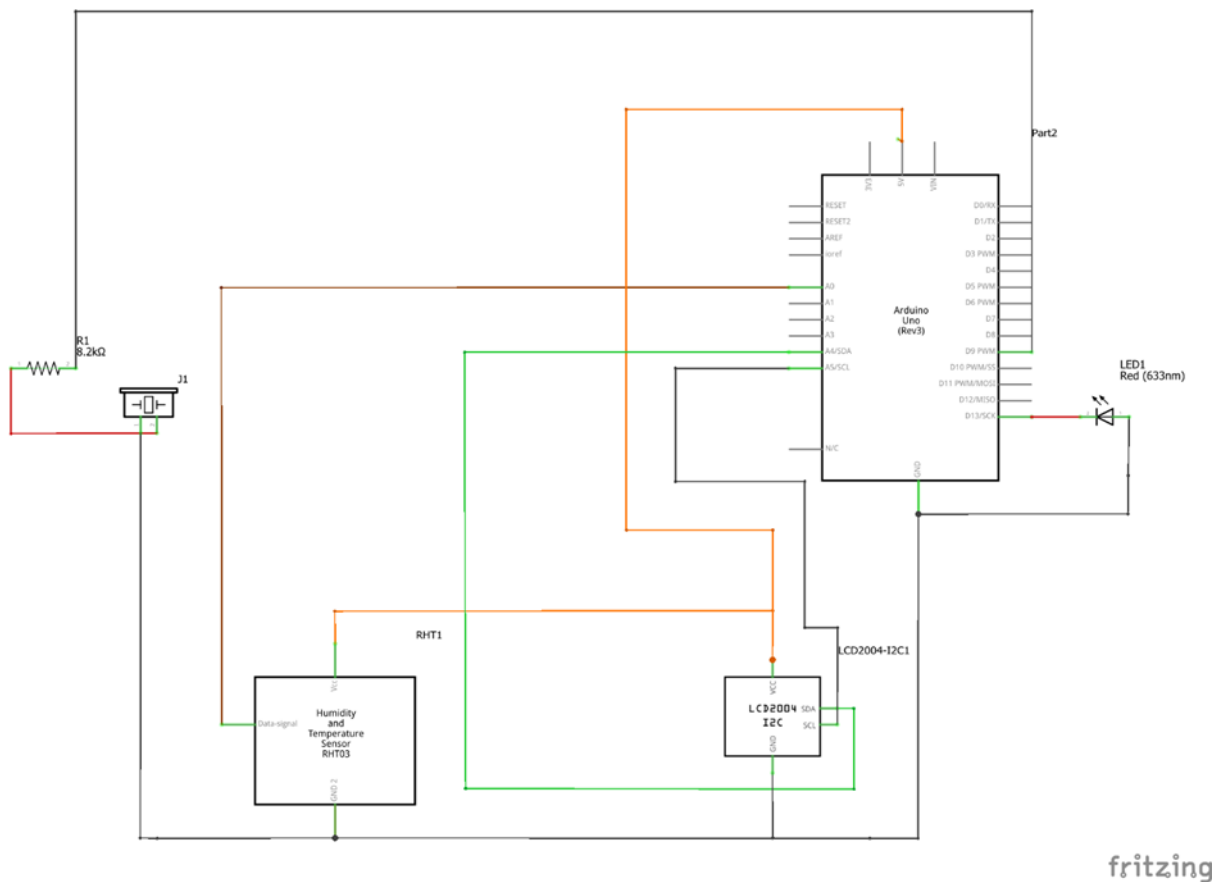
Level 4	FAIL	MARGINAL FAIL	SATISFACTORY (3 rd / Pass)	GOOD (2.2 / Pass)	VERY GOOD (2.1 / Merit)	EXCELLENT (1 st / Distinction)	EXCEPTIONAL (1 st / Distinction)
Category	0-29%	30-39%	40-49%	50-59%	60-69%	70-84%	85-100%
Engagement with literature (including reading, referencing, academic conventions and academic honesty)	Little or no evidence of reading and/or reliance on inappropriate sources. Views and findings mostly unsupported and non-authoritative. Referencing conventions used incoherently or largely absent.	Poor engagement with essential reading. No evidence of wider reading. Reliance on inappropriate sources, and/or indiscriminate use of sources. Heavily reliant on information gained through class contact. Inconsistent and weak use of referencing.	Engagement with a limited range of mostly relevant and credible sources but with some reliance on information gained through class contact. Some omissions and minor errors. Referencing conventions evident though not always applied accurately or consistently.	Engagement with an appropriate range of literature, including sources retrieved independently. Some over-reliance on texts rather than other sources. Referencing may show minor inaccuracies or inconsistencies.	Engagement with a wide range of literature, including sources retrieved independently. Selection of relevant and credible sources. Generally sound referencing, with no/very few inaccuracies or inconsistencies.	Engagement with an extensive range of relevant and credible literature. Consistently accurate application of referencing.	Exceptional engagement with an extensive range of relevant and credible literature. High-level referencing skills consistently applied.
Knowledge and understanding (Knowledge of the basic underlying concepts and principles of a subject.)	Major gaps in knowledge and understanding of the basic underlying concepts and principles of the subject matter. Inclusion of irrelevant material. Substantial inaccuracies.	Gaps in knowledge of the basic underlying concepts and principles, with flawed or superficial understanding. Some significant inaccuracies and/or irrelevant material.	Limited knowledge and understanding of the basic underlying concepts and principles within the subject area. Some elements may be missing.	Knowledge of the basic underlying concepts and principles is accurate with a good understanding of the field of study but lacks depth and/or breadth.	Competent knowledge of the basic underlying concepts and principles. Exhibits very good understanding.	Excellent knowledge and understanding of the basic underlying concepts and principles of the subject.	Exceptional, detailed knowledge and understanding of the basic underlying concepts and principles

Level 4	FAIL	MARGINAL FAIL	SATISFACTORY (3 rd / Pass)	GOOD (2.2 / Pass)	VERY GOOD (2.1 / Merit)	EXCELLENT (1 st / Distinction)	EXCEPTIONAL (1 st / Distinction)
Category	0-29%	30-39%	40-49%	50-59%	60-69%	70-84%	85-100%
Cognitive and intellectual skills (Evaluate underlying concepts and principles of a subject and interpret qualitative and quantitative data in order to develop lines of argument and make sound judgements.)	Wholly or almost wholly descriptive work. Little or no evaluation of the underlying concepts and principles. Failure to develop arguments, leading to illogical or invalid judgements. Minimal or no use of evidence to back up views.	Largely descriptive work, with superficial evaluation of the underlying concepts and principles. Weak interpretation of data, flawed development of arguments and judgements. Information accepted uncritically, uses generalised statements made with scant evidence and unsubstantiated opinions. Ideas sometimes illogical and contradictory.	Limited attempt at evaluation of the underlying concepts and principles, tending towards description. Can interpret qualitative and quantitative data but with some errors. Some evidence to support emerging arguments and judgements but these may be underdeveloped or with a little inconsistency / mis-interpretation.	Good evaluation of the underlying concepts and principles. Can interpret qualitative and quantitative data, with minor errors. An emerging ability to use evidence to support the argument. Mostly valid arguments and logical judgements.	Sound evaluation of the underlying concepts and principles. Can interpret qualitative and quantitative data accurately. Ability to devise arguments using evidence to make mostly appropriate and valid judgements.	Excellent evaluation of the underlying concepts and principles. Can interpret qualitative and quantitative data accurately and with some insight. Excellent ability to devise arguments using evidence and make appropriate and valid judgements.	Exceptional evaluation of the underlying concepts and principles based evidence. Outstanding interpretation of qualitative and quantitative data. Exceptional ability to devise arguments using evidence and make wholly appropriate and valid judgements.
Practical skills (Different approaches to solving problems in particular contexts.)	Limited or no use of taught, basic methods, materials, tools and/or techniques. Little or no appreciation of the context of the application. Very weak evidence of different approaches to problem-solving in particular contexts.	Rudimentary application of taught, basic methods, materials, tools and/or techniques but without consideration and competence. Flawed appreciation of the context of the application. Weak evidence of different approaches to problem-solving in particular contexts.	An adequate awareness and mostly appropriate application of basic methods, materials, tools and/or techniques. Basic appreciation of the context of the application. Can identify problems in particular contexts and propose basic alternative approaches or solutions though there may be errors.	A good and appropriate application of basic methods, materials, tools and/or techniques. Clear appreciation of the context of the application. Good evidence of different approaches to problem-solving in particular contexts and proposes mostly appropriate solutions.	A very good application of a range of basic methods, materials, tools and/or techniques. Very good consideration of the context of the application. Very good evidence of different approaches to problem-solving in particular contexts and proposes appropriate solutions.	An advanced application of a range of taught, basic methods, materials, tools and/or techniques. The context of the application is well considered, and insightful. Excellent evidence of different approaches to problem-solving in particular contexts and proposes appropriate solutions.	Exceptional levels of application and deployment skills in particular practical contexts. Outstanding identification of problems in particular contexts and formulation of wholly appropriate, thoughtful solutions / different approaches.

Transferable skills for life and professional practice (Communicate the results of their study/work accurately and reliably, and with structured and coherent arguments; the qualities needed for employment requiring the exercise of some personal responsibility within a structured and managed environment.)	Work is poorly structured, disorganised, inaccurate and/or confusingly expressed. Very weak use of language and/or very inappropriate style. Failure to work effectively individual or as part of a group. Little or no evidence of the skills for employment requiring the exercise of some personal responsibility.	Work is poorly presented in a disjointed manner. It is loosely, and at times incoherently, structured, with information and ideas often poorly expressed. Weak use of language and/or inappropriate style. Flawed approach to individual or group work, meeting only partial obligations to others. Limited evidence of the skills for employment requiring the exercise of some personal responsibility.	Mostly ordered presentation and structure in which relevant ideas / concepts are reasonably expressed. Work may lack coherence and/or accuracy in places. Can work as part of a group, meeting most obligations to others but perhaps with limited involvement in group activities. Demonstrates the basic skills for employment requiring the exercise of some personal responsibility, with some areas of minor weakness.	Mostly coherent, organised and accurate work, in a suitable structure and is for the most part clearly expressed. Can work effectively independently and/or as part of a team, with clear contribution to group activities. Demonstrates the skills for employment requiring the exercise of some personal responsibility, with some areas of strength and some of minor weakness.	Work is accurate, coherent, fluent, well-structured and organised. Can work effectively independently and/or as part of a team, with very good contribution to group activities. Demonstrates very good skills for employment requiring the exercise of some personal responsibility, with just occasional minor weakness.	Work is coherent, very fluent and is presented professionally. Can work effectively independently and/or as part of a team, with an excellent contribution to group activities. Demonstrates excellent skills for employment requiring the exercise of some personal responsibility with an appetite for further development.	Work is accurate, exceptionally coherent, very fluent and presented well. Can work effectively independently and/or as part of a team, with an exceptional contribution to group activities. Demonstrates exceptional skills for employment requiring the exercise of some personal responsibility with an appetite for further development.
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HNC Instrumentation Engineering

Office Environment Monitor



Module: Embedded Systems

Lecturer Name: Sarah Williams

Learner Name: Libby Sheldon

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Introduction

The purpose of this assignment is to create a simple device that will report if the environment temperature in the workplace is within the normal working conditions. According to health, safety and welfare regulations 1992, it suggests that the temperature in the workplace should be within 16°C-24°C to be classed as 'normal', therefore in this assignment 16°C and under is referred to as 'too cold' and 24°C and above is referred to as 'too hot'. For more information on working temperature <http://www.hse.gov.uk/temperature/law.htm> (07/05/19).

The assignment requires a design using a microcontroller-based system the system will indicate that the working conditions are not within the accepted range whether this is above or below. The system will include a buzzer, LCD (liquid crystal display), LED (light-emitting diode) and DHT11 (digital humidity and temperature sensor).

Hardware Design

An embedded system is a combination of computer software and hardware, which is either fixed in capability or programming. A processor is the brain of an embedded system, there is the option of the system hardware being microprocessor or microcontroller based. A microcontroller is a compact integrated circuit which is an independent system with a processor, memory and general-purpose input output pins. According to <https://www.maxfizz.com/components-of-embedded-system/> (07/05/19) 'the input may be provided by the user or by some sensor. Sometimes some systems need input or output, so the processor selection will be based on I/O.'

In daily life these types of embedded systems are used for washing machines and refrigerators. For this assignment the microcontroller used is the orange pip. Figure 1 shown in the appendix illustrates the orange pip, image retrieved from <https://www.orangepipboards.com/> (11.04.19).

A processor comes in different architectures for example 8-bit, 16-bit, and 32-bit all depending on the performance and speed required for the system. According to <https://www.orangepipboards.com> (11.04.19) "The high performance AT mega 8-bit AVR RISC- based microcontrollers give orange pip users enough power and memory to store and run complex code multiple times- the kona328 and segments328 being designed for beginners and Mega2560 for intermediate users."

The program Arduino IDE is what is used to create and transfer the code onto the microcontroller for this assignment. The computer language used on Arduino is 'C'. C is a high-level compiler language. The aim of this code is to deliver an informal and easy way of giving a program of instructions to a computer. The language has been equipped with features that allow programs to be organised in a logical way. In his work in C programming tutorials Mark Burgess explains 'A C program is made by running a compiler which takes the typed source program and converts it into an object file that computer can execute.' (1999, p9).

The power supply for the microcontroller is the computer via USB. The microcontroller includes 14 digital input/output pins, which all have a different function. All microcontrollers have connections for power they are seen as GND and Vin. However, modules like Arduino and orange pi also have voltage regulators, a regulated voltage output is seen as 5V and 3.3V, an unregulated voltage input will be seen as Vin. The power Pins are shown in the appendix as figure 1.

The Analog pins for the board used are labelled A0-A5, these are used to provide Analog inputs in the range of 0-5V. the input/output pins on this microcontroller-based system are shown with digital output pins labelled 0-13, the top right of figure 1 shows these pins. 0-13 pins can be used as input or output pins. The SCL pin will be used for clock synchronization between the microcontroller and the LCD, the details of this arrangement are seen on the schematic diagram in the appendix (figure 3). SDA (serial data) pin is a data logging Pin also used as a component of the LCD.

System Explanation

The purpose of this assignment is to create a simple device that will report if the environment temperature in the workplace is within the normal working conditions. According to health, safety and welfare regulations 1992, it suggests that 'the temperature in the workplace should be within $>16^{\circ}\text{C}-24^{\circ}\text{C}$ to be classed as 'normal'', therefore in this assignment under 16° is referred to as 'too cold' and above 24° is referred to as 'too hot'. For more information on working temperature <http://www.hse.gov.uk/temperature/law.htm> (07/05/19).

The assignment requires a design using a microcontroller-based system, the system is programmed to identify when the working conditions are not within the accepted range whether this is above or below, or in between the both. The system will include a buzzer, LCD, LED and DHT11 all of which have a different function for when a different temperature is detected.

The DHT11 RUNS a program that reads the temperature and humidity and outputs the readings to a serial monitor. The serial monitor is a pop-up element found on Arduino IDE, the serial data is sent over by USB cable (which is attached to the microcontroller as seen in figure 4), the command 'Serial.Begin(9600)' is stated in the code, this starts the serial communication between the serial monitor and the DHT11. A setpoint which is specified in the code is 'baud rate' this means how fast the data is sent, the value is set as '9600'.

The serial monitor can be used on Arduino as a debugging tool. Debugging is an essential part when working on the code, it helps locate the bugs (the problems). There isn't a particular function on Arduino IDE to debug the code therefore the serial monitor can be used in assistance. As <https://www.circuito.io/blog/arduino-debugging/> (09/05/19) explains 'if your code fails when you try to run your sketch, you need to start debugging your code. Think and define which parameters to print and use the serial monitor to monitor them on screen. The aim is to print an overview of the current state of the program. As such: Inputs – sensor readings, Prints that indicate the programs flow, like inside an 'if' statement to see whether the condition was met, Outputs – e.g. PWM values before writing them to the pin.'

In the DHT11 there is a basic chip inside that does an analogue to digital conversion, this splits out a digital signal with the temperature and humidity. In this system the

temperature sensor is used the DHT11 is capable of monitoring the temperature between 0-50° reading with $\pm 2\%$ accuracy. The serial monitor does also receive the humidity reading, the range the DHT11 reads is between 20-90% RH. However, the change in humidity doesn't influence a reaction to the other components.

Another Component used for this system is an LED. An LED is a semiconductor device. LED devices are used in many applications but mostly for indication purpose. Electrons in a semiconductor recombine with electron holes, this releases energy in form of photons, this effect is called electroluminescence. All diodes emit photons however only certain types of diodes emit that electromagnetic energy as light instead of heat. An LED is able to generate light, this is due to the semiconductor materials that are between the electrodes. In this system the LED function is used throughout, when the temperature is detected between $>16^{\circ}\text{C}$ and 24°C the LED which is connected to I/O PIN 13 and GND, stays on HIGH meaning LED continues to emit light whilst temperature is within normal limits. When temperature is detected at 24°C and above the LED will blink. Blink means the LED will flash on and off with a delay of one second, this process will continue until temperature goes back into normal temperature limits. If the temperature is 16°C and below the LED will turn off. The LED used for this system emits a red light, seen in figure 4 in the appendix.

Also used for this system is an LCD. Unlike an LED, an LCD consumes much less power, this is because the way they function means they work on the principle of blocking light rather than emitting it. The program created will write text to an LCD, this code can be adjusted to suit a required output, therefore in this case to show the temperature is above or below limits. This function is used throughout the system, when the temperature is $>16^{\circ}\text{C}$ but 24°C the LCD displays 'Temperature fine', this is displayed until the temperature increases or decreases the 'normal' working temperature. If the temperature reaches or exceeds 24°C the display screen will clear with a one second delay and then read 'Too Hot'. If the temperature drops below 16°C , then the LCD will again clear for a second and read 'Too Cold'. The LCD is connected to the microcontroller, the schematic shown in the appendices shows this connection. To set up the LCD, an address needs to be specified for the bus of the orange pin to allow communication this could be either 0x27 or 0x3F.

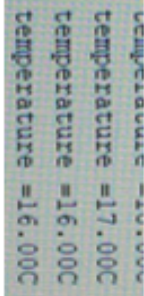
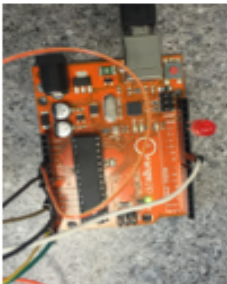
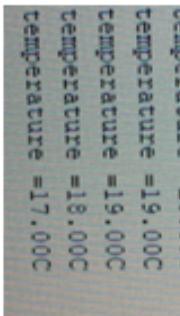
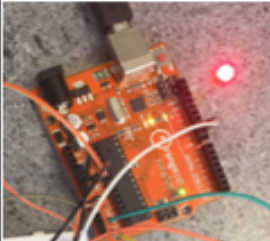
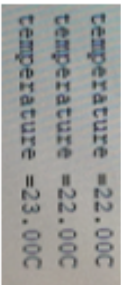
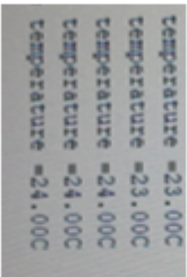
The final component used in this system is a buzzer. The buzzer demonstrates the pulse width modulation (PWM) capabilities of the board. PWM allows a digital signal to be converted to an analogue signal. The buzzer requires additional components including a bread board and an 8.2kohm resistor. The buzzer is connected to a GND pin, the resistor is added to digital pin 9, to connect the other end of the resistor and buzzer, a bread board was required. 'A bread board is a solderless plugboard that is used for prototyping in electronics.' A definition of a breadboard given by <https://uk.rs-online.com/web/c/pcb-prototyping/printed-circuit-boards-pcb/breadboards/> (07/05/19). The breadboard and all over components are shown clearly in the appendix by figure 4.

Software Design

A flow chart was used to design the initial idea of what the program would do. A flow chart helps breakdown the problem and determine the order of code. As shown in the appendix the flow chart is labelled as Figure 2, the Flow chart shows what the code should translate to. The flow chart was produced on a software called Auto CAD.

A schematic Diagram is shown in the appendix labelled as figure 3. A schematic diagram is used to represent the elements of the system without using real images. Figure 3 gives a clear identification on where the components are connected to the microcontroller. Figure 5 in the appendix is the 'C' code used for this system, Functions are defined below to allow the program to be easily readable.

Testing

Test Temp	Serial Output	LCD output	LED output	Buzzer	Pass or fail
16°			 LED Off	Buzzer on once every other second.	pass
17°			 On without flash whilst within 'normal' temp range	Off	pass
23°			On without flash whilst within 'normal' temp range	Off	pass
24°			On with flash 24° and upwards	Off	pass

Discussion, Evaluation and conclusion

As shown on page 10 all tests carried out for the system were successful. The tests were focussed around the boundary limits, for example the first test temperature being 16°C, at this temperature the normal working conditions go from 'fine' to 'cold' therefore the LCD screen was programmed to change, as well as the LED turning off and the buzzer beginning to sound. At 17°C the working conditions return to 'Normal' until 24°C (24°C being too hot). There was also test carried out at 23°C which is the boundary between 'fine' and 'hot'.

The tests were completed to gain valuable information about the programme's quality. Although the system is sufficient and is programmed to meet the specification, modifications could be made to improve the system. One modification could be expanding the use of LED's, there is one red LED used throughout, having three LEDs which are different colours may be an improvement for an outsider to understand. An example could be red LED to light for too hot, Yellow LED for temperature fine and a Blue for too cold.

The requirement of this assignment is to monitor normal working conditions. Normal is stated as >16°C-24°C< according to the Health and safety Executive (HSE) <http://www.hse.gov.uk/temperature/law.htm> (09/05/19), however the HSE does also comment that this is not an absolute legal requirement but just a recommendation, therefore the employer of each company has the duty of defining reasonable comfortable temperature for whichever the circumstance of the workplace is. For a more accurate assumption of normal working temperature for this assignment a survey could have been carried out by those in the workplace. Expanding on this a component that could be added is a keypad. the program would read the button pressed on the keypad and output a letter or number corresponding to this letter. The code would require adjustments to suit the keypad, this could be used to change the temperature setpoints.

A way to make the system more consistent could be using the humidity detection as well as temperature sensor. Although the code reads humidity and it comes onto the serial monitor the components only change if the temperature does. The DHT11 detects water vapour by measuring the electrical resistance between two electrodes.

As air temperature increases, the water vapour/ moisture increases, fundamentally meaning an increase in air temperature.

The humidity sensing component is a moisture holding substrate with electrodes applied to the surface. The change in the resistance between the two electrodes is proportional to the relative humidity, higher relative humidity decreases the resistance between the electrodes, while the lower relative humidity increases the resistance between the electrodes. However, to measure the temperature the DHT11 uses a surface mounted NTC temperature sensor which is built into the unit.

Having the humidity readings to influence the other components can be a backup if the temperature sensor failed. Although the temperature accuracy is $\pm 2\%$ and the humidity $\pm 5\%$, the humidity detection could be used as a secondary temperature detection device.

To conclude the code functioned without an error throughout. The test results on page 10 illustrates that the components reacted accurately when there were fluctuations in the temperature. Overall meaning the system meets the requirements in the specification as the microcontroller-based system monitors room temperature and gives an indication if temperature is outside of normal working conditions.

Appendix

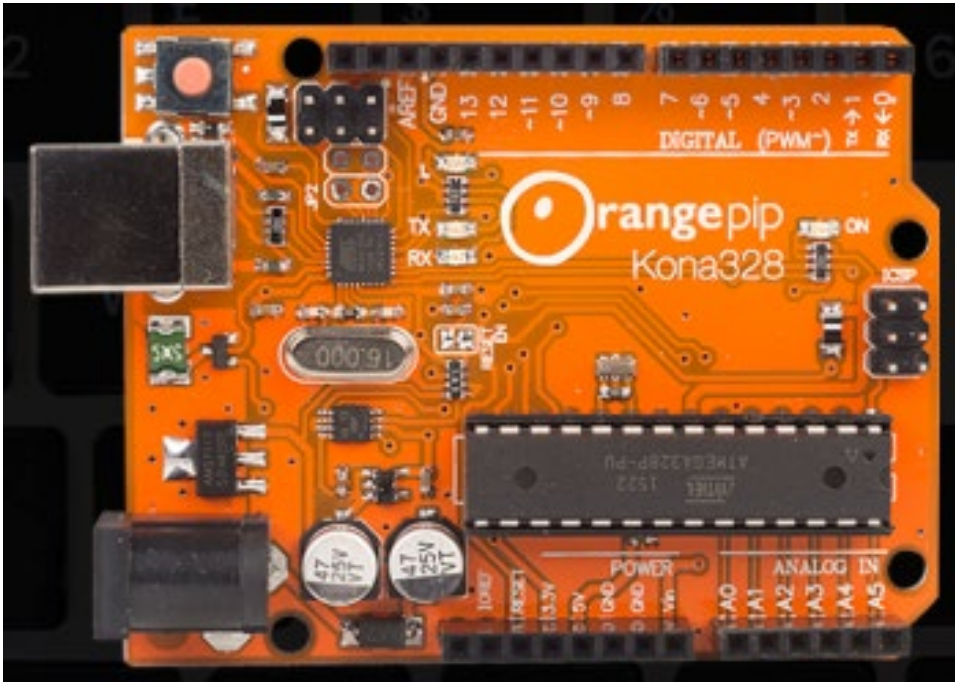


Figure 1

Figure 2

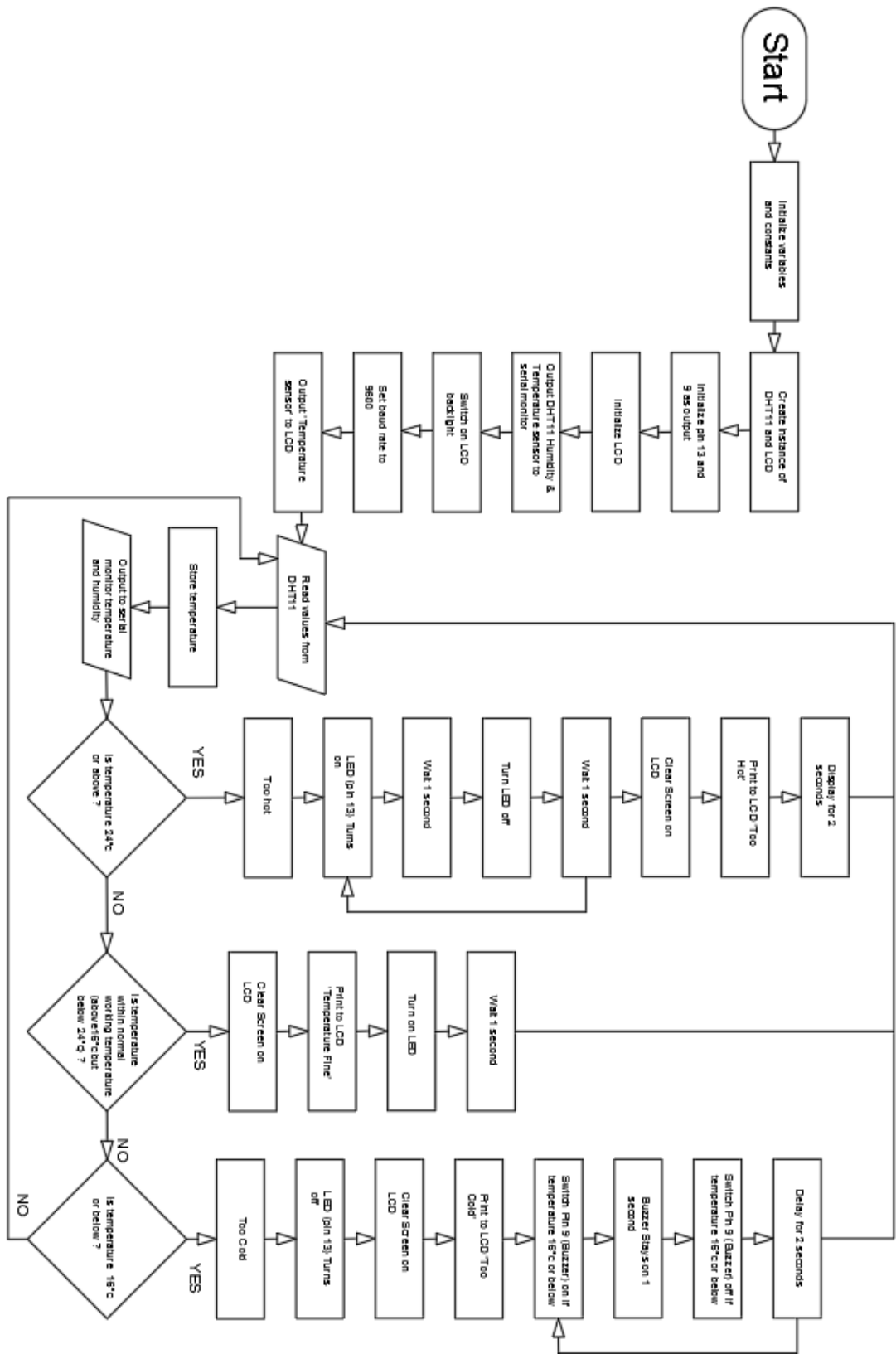
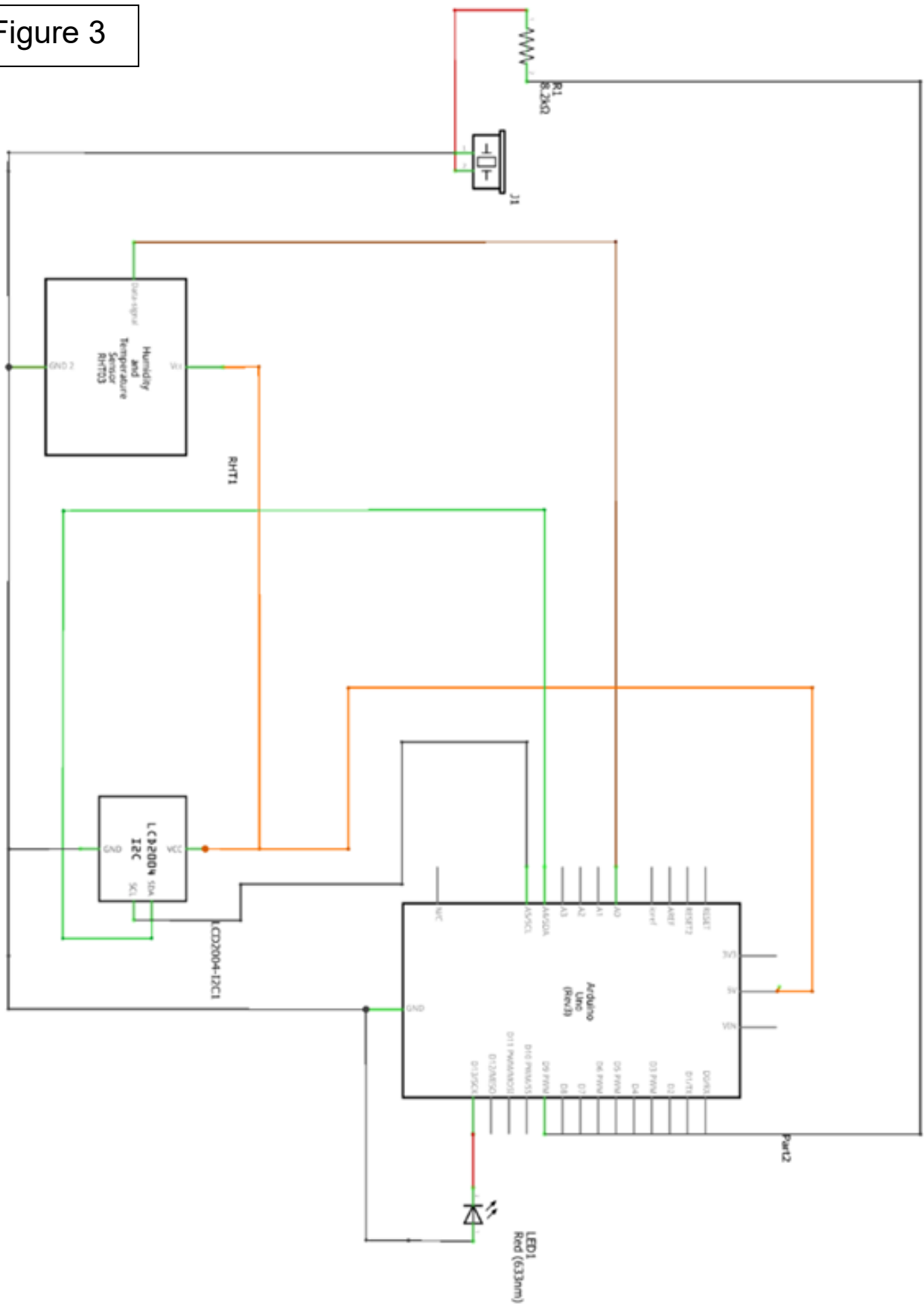


Figure 3



fritzing

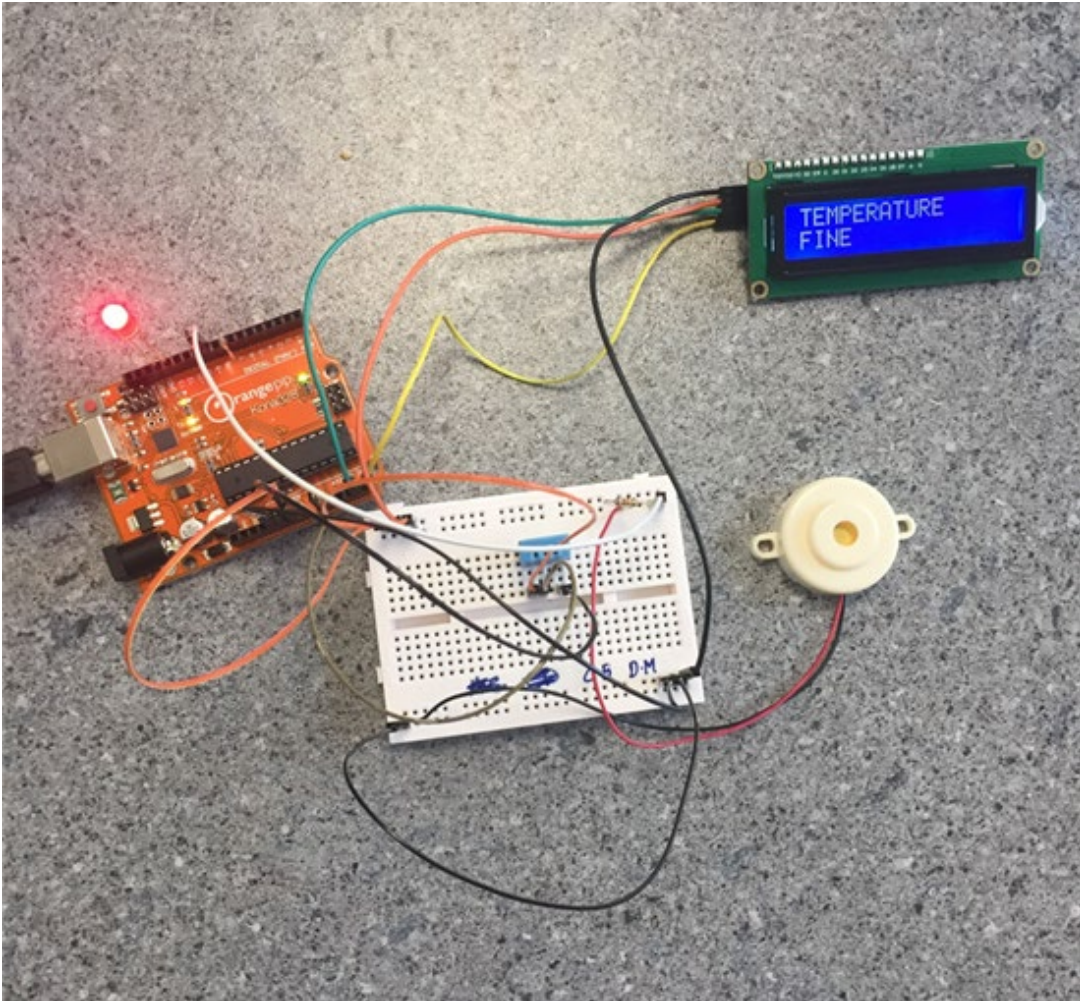


Figure 4

Below illustrates the C code produced to implement the system (Figure 5)

```

#include <Wire.h> //Include LED to system
#include <LiquidCrystal_I2C.h> //include LCD to system
#include "dht.h" //include dht11 to system

#define dht_pin A0 //Analog pin sensor is connected to
#define LED_PIN 13 // pin 13 is analogue pin LED connected to
#define IC2_ADDRESS 0x3F // new address located for LCD

dht DHT;
LiquidCrystal_I2C lcd(IC2_ADDRESS,16,2);
const int buzzerPin=9; //buzzer connected to analogue pin 9
void setup() {
    // put your setup code here, to run once:

    Serial.begin(9600); //set baud rate to 9600
    delay(500); //delay to let system boot
    Serial.println("DHT11 Humidity & temperature Sensor\n\n");
    delay(1000); //wait before accessing sensor

    pinMode(LED_PIN, OUTPUT) ; //pin
    pinMode(buzzerPin,OUTPUT); //pin 9 is set as output

    lcd.init(); // initialise number of characteristics, lines
    lcd.backlight();
    lcd.print("TEMPERATURE"); //print to LCD
    lcd.setCursor(0,1); // move to next line
    lcd.print("SENSOR"); //print to LCD
}
void loop() {

```

```

// main code is here to run repeatedly:
DHT.read11(dht_pin);
float temperature= DHT.temperature;

Serial.print("Current humidity =");
Serial.print(DHT.humidity);
Serial.print("% ");
Serial.print("temperature =");
Serial.print(DHT.temperature);
Serial.println("C");

if(temperature>=24){
digitalWrite (LED_PIN, HIGH) ;

lcd.clear(); // clears screen on LCD
lcd.print("TOO"); //print to LCD
lcd.setCursor(0,1); // move to next line
lcd.print("HOT"); //print to LCD

delay(2000); // display for 2 seconds
}
else if (temperature >16 &&temperature <24){

lcd.clear(); // clears screen on LCD
lcd.print("TEMPERATURE"); //print to LCD
lcd.setCursor(0,1); //move to next line
lcd.print("FINE"); //print to LCD

digitalWrite (LED_PIN, HIGH) ; //turn LED on
                                //HIGH is voltage level

delay(1000); //wait 1 second

```

```
digitalWrite (LED_PIN, LOW) ; //turn LED off
                                //LOW is voltage level

delay(1000); //wait a second
}
else
{

  lcd.clear(); // clear LCD screen
  lcd.print("Too"); //Print to LCD
  lcd.setCursor(0,1); // move to next line
  lcd.print("COLD"); //Print to LCD

  digitalWrite (buzzerPin,HIGH); //switch pin 9 on if temperature >16
  delay(1000); // buzzer stays on 1 second
  digitalWrite(buzzerPin,LOW); //switch pin 9 off if temperature >16
  delay(2000); // 2 second delay
}
//delay(5000); // 5 second delay
}
```

Reference Page

Books

- Noergaard T. Embedded Systems Architecture: A Comprehensive Guide for Engineers and programmers. 2nd Edition. Newnes (2013)
- Ganguly AK. Embedded Systems: Design, Programming and applications. Alpha Science International Ltd. (2014)
- Lewis D, W. Fundamentals of Embedded software. Prentice Hall. (2002).
- Burgess, M. C programming Tutorial. Fourth edition, Faculty of engineering: Oslo College.
- Barr, M. Programming embedded systems, O'Reilly Media, Inc.
- Banzi, M. Getting started with Arduino. Second edition, O'Reilly Media, Inc.

Websites

- <https://www.orangepipboards.com/> (11/04/19)
- <http://www.hse.gov.uk/temperature/law.htm> (07/05/19)
- <https://internetofthingsagenda.techtarget.com/definition/embedded-system> (07/05/19)
- <https://www.circuito.io/blog/arduino-debugging/> (09/05/19)
- <https://www.maxfizz.com/components-of-embedded-system/> (07/05/19)
- <https://uk.rs-online.com/web/c/pcb-prototyping/printed-circuit-boards-pcb/breadboards/> (07/05/19).