

**T Level Technical Qualification in
Engineering and Manufacturing –
Design and Development for
Engineering and Manufacturing**

**8714-322 Electrical and Electronic
Engineering Occupational Specialism
Grade Standard Exemplification Material
Distinction - Summer 2025**

Version and date	Change detail	Section	Question
v1-0 31 st October 2025	First published		

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Introduction

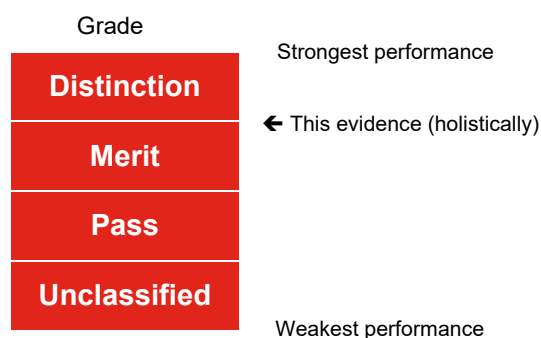
Summer 2025 Results

This document is aimed at providers and learners to help understand the standard that was required in the summer 2025 assessment series to achieve a distinction grade for the 8714-322 Electrical and Electronic Engineering Occupational Specialism (OS).

The Grade Standard Exemplification Material (Grade SEM) evidence provided for the distinction grade displays the holistic standard required across the tasks to achieve the distinction grade boundary in the Summer 2025 series.

The aim of these materials is to provide examples of knowledge, skills and understanding that attested to distinction competence in Summer 2025. It is important to note that in live assessments a candidate's performance is very likely to exhibit a spikey profile and standard of performance will vary across tasks.

The Occupational Specialism is graded Distinction, Merit, Pass or Unclassified.



The distinction grade boundary is based on a synoptic mark across all tasks. The materials in this Grade SEM are separated into two sections as described below. Materials are presented against a number of tasks from the assignment.

Task

This section details the tasks that the candidate has been asked to carry out. What needs to be submitted for marking and any additional evidence required including any photograph/video evidence. Also referenced in this section are the assessment themes the candidates were marked against when completing the tasks within it. In addition, candidate evidence that has been included or not been included in this Grade SEM has been identified within this section.

In this Grade SEM there is candidate evidence from:

- Task 1 Design
- Task 2 Manufacture and test
- Task 3 Peer review
- Task 4 Evaluation and implementation

Candidate evidence

This section includes exemplars of candidate work, photographs of the work in production (or completed) and practical observation records of the assessment completed by centre assessors. This was evidence that was captured as part of the assessment and then internally marked by the centre assessor.

The Occupational Specialism brief and tasks can be downloaded from [here](#).

Important things to note:

- We discussed the approach to standard setting/maintaining with Ofqual and the other awarding organisations before awarding this year. We have agreed to take account of the newness of qualifications in how we award this year to recognise that students and teachers are less familiar with the assessments (<https://www.gov.uk/government/publications/ofqual-guide-for-schools-and-colleges-2025/ofqual-guide-for-schools-and-colleges-2025#grading>), whilst also recognising the standards required for these qualifications.
- The evidence presented, as a whole, was sufficient to achieve the distinction grade. However, performance across the tasks may vary (i.e. some tasks completed to a higher/lower standard than distinction grade).

Grade descriptors

To achieve a distinction, a candidate will be able to:

Demonstrate a comprehensive use of software/ technologies to model, evaluate and produce electrical and electronic engineering diagrams and simulations that meets the requirements of the brief.

Demonstrate excellent technical skills when developing models and prototypes, resulting in a prototype that is fully functional.

Apply comprehensive knowledge and understanding of testing processes, resulting in a prototype that has been tested against all of the design criteria.

Critically interpret information to plan, assess risk, follow safe working practices and apply the technical skills to practical tasks and procedures to an exemplary standard in response to the requirements of the brief, producing an excellent quality of work.

Apply comprehensive knowledge and understanding of the design principles required for electrical and electronic engineering resulting in proposals and solutions that meet all requirements of the brief.

Work safely and make well founded and informed decisions on the selection and appropriate use of tools, materials and equipment within the environments that they are working in, resulting in tasks that are carried out to a high degree of accuracy.

Use accurate industry and technical terminology consistently in both written and verbal contexts.

Task 1 Design

Assessment number (eg 1234-033)	8714-322
Assessment title	Electrical and Electronic Engineering Occupational Specialism

Candidate name	<first name> <surname>
City & Guilds candidate No.	ABC1234

Provider name	<provider name>
City & Guilds provider No.	999999a

Task(s)	1
Evidence title / description	Design specification Design calculations, including all workings Selected sensors with justifications Circuit diagram and wiring diagram PCB layout Outcomes of the virtual modelling of the proposed circuit design, either as screen captures or printouts Record of outcome of testing the functionality of the physical model of the circuit Bill of materials, with justifications Any notes produced of research undertaken including citation of sources and internet search history
Date submitted by candidate	DD/MM/YY

Task 1

Assessment themes:

- Health and Safety
- Design and Planning
 - Documents
 - Drawings and diagrams
 - Virtual modelling

You must:

- produce a design specification that builds on the design criteria for the circuitry, including any references to research used
- generate a suitable design for the circuitry, including:
 - selection of appropriate sensors with justifications
 - calculations of the values required for successful operation, including the power required by the circuitry, values for at least two different types of components
 - configuration of the circuitry, including a circuit diagram and wiring diagram
 - printed circuitry board (PCB) layout for the circuitry.
- simulate the performance of the proposed design using CAD software
- assemble a physical model of the circuitry and test its functionality
- produce a bill of materials (BoM) listing all of the parts required in the final design proposal, with justifications.

Additional evidence of your performance that must be captured for marking:

None

Candidate evidence

Task 1 – Design

A) Design Specification

Purpose

The purpose of this design specification is to assist the development for a circuit to ensure the optimal efficiency and running of a server room. The server room's temperature must be monitored (and displayed through various visual indicators) as there is a risk that the server room may overheat / freeze, causing damage to the server racks and in turn damaging the reputation of the business. Therefore, it is vital that all design requirements are adhered to, in order to prioritise the safety of the servers, aswell as health and safety of all staff nearby.

Requirements

- Lighting in the server room must turn on when motion is detected inside the room via a sensor. Lighting must subsequently turn off within 20 seconds of motion not being detected.
- Motion must be able to be detected within the whole server room.
- There must be a sensor on the door to detect if the door is open.
- There must be a sensor within the room monitoring the current temperature.
- There must be a blue light within the facilities control room to display when temperature within the server room is below 18 degrees celsius.
- There must be a red light within the facilities control room to display when temperature is above 24 degrees celsius.
- An audible output must be placed within the control room to alert staff of when the temperature is out of range.
- There must be controlled lighting within the server room.
- All input and output devices should be connected to the circuitry.

Design / Work Considerations

There is a fundamental requirement across all tasks to design and produce a circuit. This presents numerous health and safety hazards, which will need to be controlled. I will therefore be abiding by numerous regulations, for example;

Control of Substances Hazardous to Health (2002)

I will maintain adequate storage of all hazardous substances in the manufacturing process, for example soldering equipment and hazardous chemicals used in etching will need to be stored appropriately and safely to ensure no health and safety risk. Solder fumes will also be extracted through the use of the appropriate solder fume extraction equipment, in order to prevent long term health damage through inhalation of solder fumes.

Provision and Use of Work Equipment Regulations (1998):

Prior to use of electrical equipment, I will ensure that any equipment has been PAT tested. I must also make sure that all manufacturing equipment has been regularly and effectively maintained, such as maintenance / servicing of the CNC milling machine and regular tinning of soldering tips. I will only use equipment which I have been adequately trained on, to prevent accidental damage to myself, others or the equipment itself.

HSE Guidance on Risk Assessments:

Before I begin any tasks which pose a risk, I will complete a relevant risk assessment and ensure that controls are in place to reduce the likelihood of damage. All risk assessments that I complete will follow the HSE's guidance on risk assessments.

Step 1: Identification of hazards

Step 2: Assessing the risks (likelihood and severity scores) Step 3: Implementation of controls

Step 4: Recording of findings

Step 4: Regular reviewing of risk assessments and controls

Risk assessments are to be regularly reviewed and updated in case of new hazards and risks which may have emerged, and in case of any accidents. In case of any accidents, I will make sure that I am aware of the relevant emergency procedures and where to go / who to report to.

I will also ensure that I am adequately trained on any machinery or equipment before making use of these systems, for example using a CNC milling machine or soldering equipment. During production of the breadboard / circuit, I will be following the IET's wiring regulations. I acknowledge that I have a duty to ensure proper use of PPE, as outlined in PPER.

The design

Detection Methods

- 1) Ultrasonic Distance Sensor (HC-SR04). This sensor can be used to measure distances, but it can also be used as a simple detector. It is a simple sensor to use and can be easily programmed using a microcontroller. However, they can be effected by temperature and humidity due to the sound waves that the sensor uses to measure distances.
- 2) Infrared Obstacle Avoidance Sensor (KY-032). This sensor is simply used as a detector. It stays on a HIGH signal, until an object is detected and it sends a LOW signal to the microcontroller. It is more stable than the ultrasonic distance sensor in the readings that it gives, however it has an extremely limited range.
- 3) PIR Sensor (HC-SR501). This sensor is used to detect motion. It is cost-effective and efficient with energy. They are heavily reliable, and even work in conditions with very little light, or complete darkness. However, they are less sensitive than other sensors.

For the server room I will be making use of a PIR sensor, due to the range at which it can operate (more than the 7 m specified). It can detect motion effectively, which is important as the brief explicitly states the need to detect motion. It is also easily available in my workshop.

Temperature Detection

It is a vital requirement to monitor the temperature of the server room. Therefore, I will be using a temperature sensor, specifically model MCP 9700A-E/TO. It is an accurate sensor with a tolerance of 1 degree +/- from 0 degrees to 70 degrees celsius (worst case 2 degrees +/-). It can measure from -40 to 125 degrees

celsius, giving me a vast range of measurements to read from.

Visual Indicators / Outputs

Across this project there are multiple lights which will need to be implemented into the system. For these lights I will be using standard LED's to alert staff of the temperature within the room, and to also light up the room in case motion is detected.

Audible Output

There is a requirement that staff are alerted audibly if the temperature within the server room exits the permitted range. A simple passive buzzer will provide the appropriate audio output required in the brief.

Server Room Door

I will be using a small 4.8V micro servo to represent the door (as a larger servo would be far too costly). It is reasonable to assume that a servo of this size will pull a current of 0.5A. Servos require pulse-width modulation to drive, so I will keep this in mind when virtually / physically simulating the circuit and when routing the PCB. The PWM period required should be a pulse of around 1-2ms every 20ms. This is what changes the direction of the servo, with a 1.5ms pulse moving to the middle position, 2ms all the way to the right and 1ms all the way to the left.

I must also detect when the door is left open. This will be demonstrated through the use of a push button, representing a pressure switch which will be toggled when the door has shut. There will also be a pushbutton to open the door.

LCD Display

I will include an LCD display in the control room, to display if the door is currently opened / closed. This display will also include the exact temperature, as well as displaying when motion is detected within the server room.

Inputs and Outputs

Currently there are 4 inputs and 6 outputs in my design:

2 x Pushbuttons (input)

Temperature sensor (input)

PIR Sensor (input)

Buzzer (output)

Micro-servo (output)

LCD (output)

3 X LEDs (output)

Bibliography at bottom of document.

B) The Design of The Circuitry

Design Calculations

LED Resistance

LEDs are nominally 2V devices. They often draw a current of around 10 - 20mA which my microcontroller (Arduino Uno R3) is capable of supplying. The Arduino supplies a voltage of 5V.

Therefore, we must take into account the voltage drop when connecting a resistor.

$$(5-2)V / 20mA = 150 \text{ Ohms}$$

$$(5-2) / 10mA = 300 \text{ Ohms}$$

I will assume a maximum current draw of 20 mA. The nearest resistor value to 300 ohms is a 330 ohm resistor, which I will be using to protect the LED from long-term damage.

Pushbutton Resistance

The pushbutton that I am using draws a current of 500uA, the Arduino Uno R3 can supply 5V.

$$500uA \times 5V = 10K \text{ ohms.}$$

I will be using a 10K resistor to ensure safety for the pushbuttons

Servo Power

As mentioned earlier, I will be using a micro-servo. The servo needs a voltage of 4.8V. As assumed earlier, it will draw a current of around 0.5A.

Therefore, using Watts Law:

$$P = I \times V$$

$$P = 0.5A \times 4.8V$$

$$P = 2.4W$$

Justification of Design Options for the Sensors

Configuration of Circuitry

There are three main methods of control which could be used:

- 1) Discrete electronics. This method utilises components such as transistors accompanied with logic gates. This would require no coding, as all the code which would be produced in software is replicated by the components in the form of hardware. However, the building of a discrete circuit would be far too complex, and any issues in the system would take far too long to find and rectify.
- 2) PLC control. This would simplify the programming of the circuit, as the modules would take care of many of the tasks which I would encounter. PLCs are rigid and tougher to break down than a microcontroller based system. However, they are inflexible and costlier than discrete electronics and microcontroller based systems.

- 3) A microcontroller based system. This is the most affordable and practical method which could be used to implement this system. Microcontrollers are capable of handling multiple tasks at once due to the code it has been programmed to execute. They're much smaller than both of the other options and offer a lot more flexibility. However, they have limited processing power which may effect certain tasks.

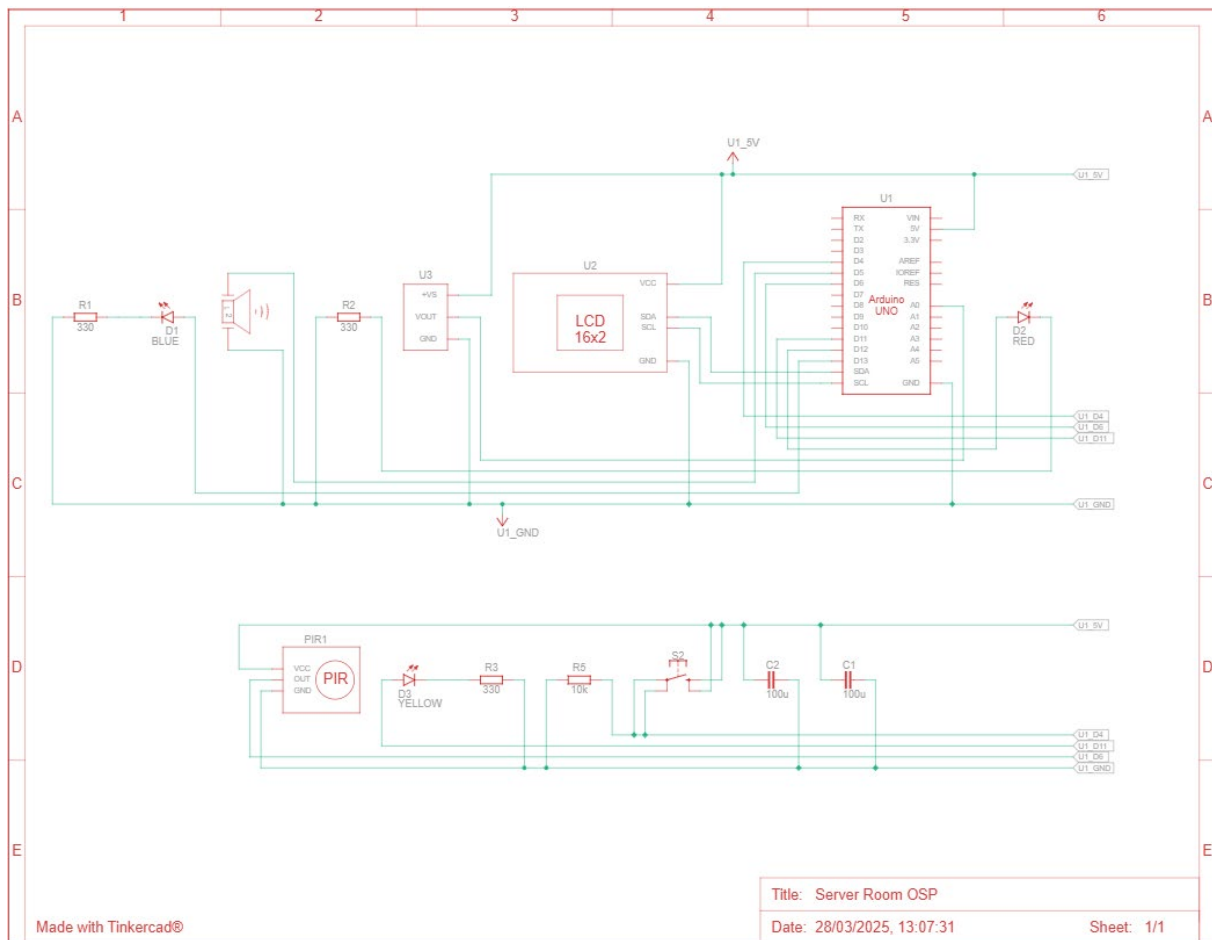
For this task I will be using an Arduino Uno R3 microcontroller due to it being the most accessible method to me. This microcontroller has 14 I/O pins (each with a DC current of 20mA), 6 of which are capable of Pulse-Width Modulation functionality. PWM is important to drive the servos and specify which angle they should move to. The servo that I am using has a 1-2ms duty cycle and a 20ms PWM period.

The microcontroller also offers 6 analog inputs. For this project I will be using an analog input in order for the temperature sensor to function correctly.

I will be using a USB connection to supply power to the Arduino. Unfortunately the Arduino can often suffer from the effects of noise from the sensors. Due to this, I will be making use of two 100uF capacitors in order to stop noise effecting the functionality of the circuit.

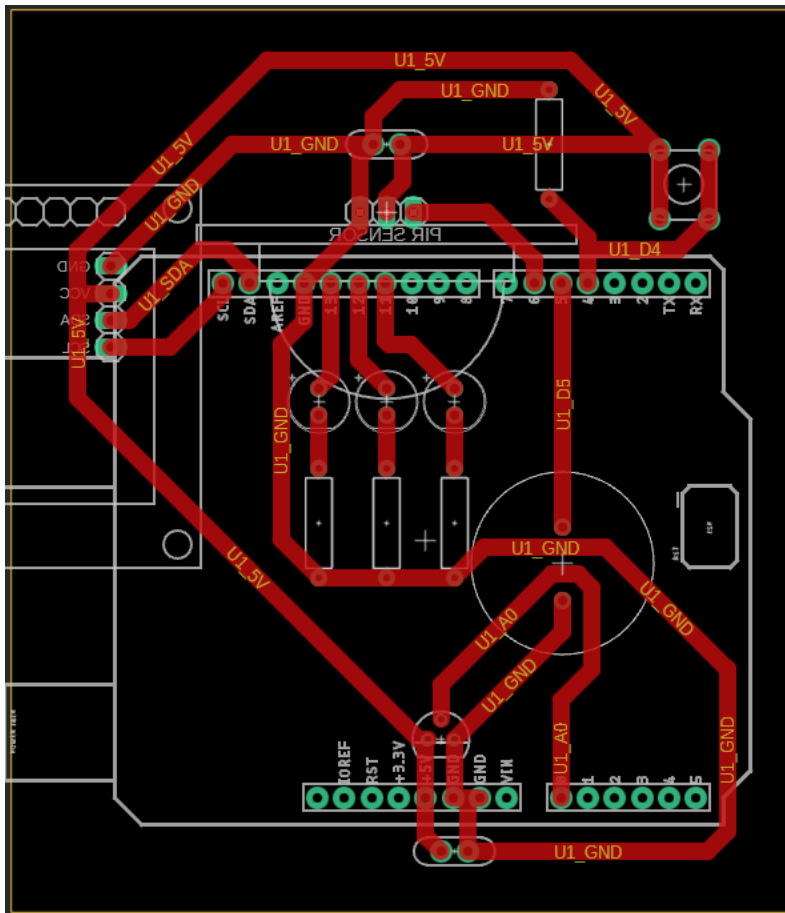
I will be able to make full use of an I2C LCD due to the Arduino having SDA, SCL and I2C functionality. However, it is important to remember that I cannot use pins A4 or A5 whilst the LCD is on, due to the I2C protocol needing these pins to function. Pins 0 and 1 are also unavailable due to the use of the Serial Monitor. I will be using Serial Monitor to count upto 20 seconds before the lights turn off within the server room.

Wiring Diagram



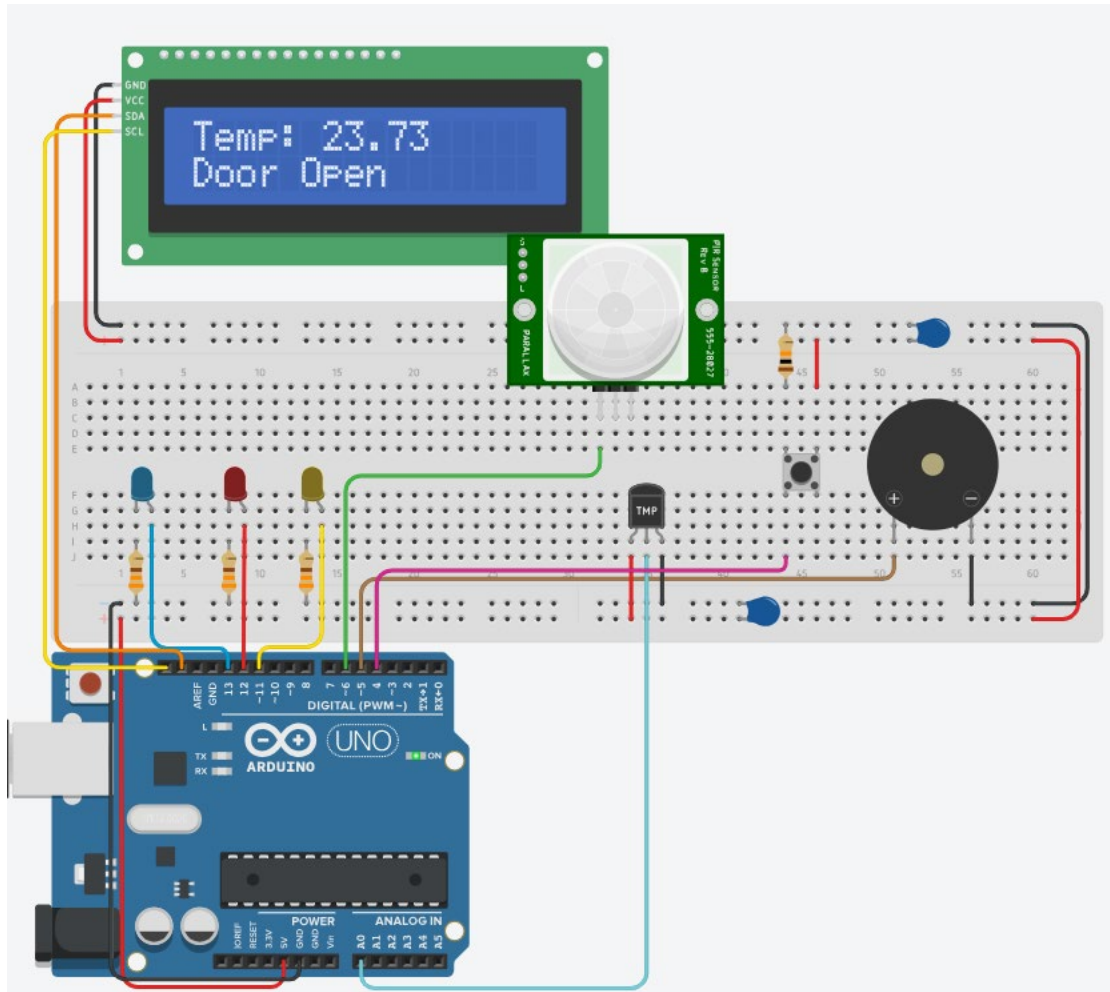
My wiring diagram was generated through Tinkercad, based on my virtual breadboard. I looked over this to ensure that the software had not made any mistakes, as I am aware that sometimes Tinkercad misses out wiring connections, and these must be manually rectified.

PCB Layout



I ported my virtual circuit from Tinkercad to Fusion 360. I have ensured to place components in places which make sense for the functionality of the circuit. For example, the LEDs are all nearby each other in the same orientation. The track width is 60mm to allow ease of soldering later on in the manufacturing process of the PCB. I have also made sure to keep sufficient space between tracks, to reduce the likelihood of continuity issues. At the same time, I have tried to design my PCB to be as small as possible, in order to reduce wastage and the time that it takes to manufacture the PCB.

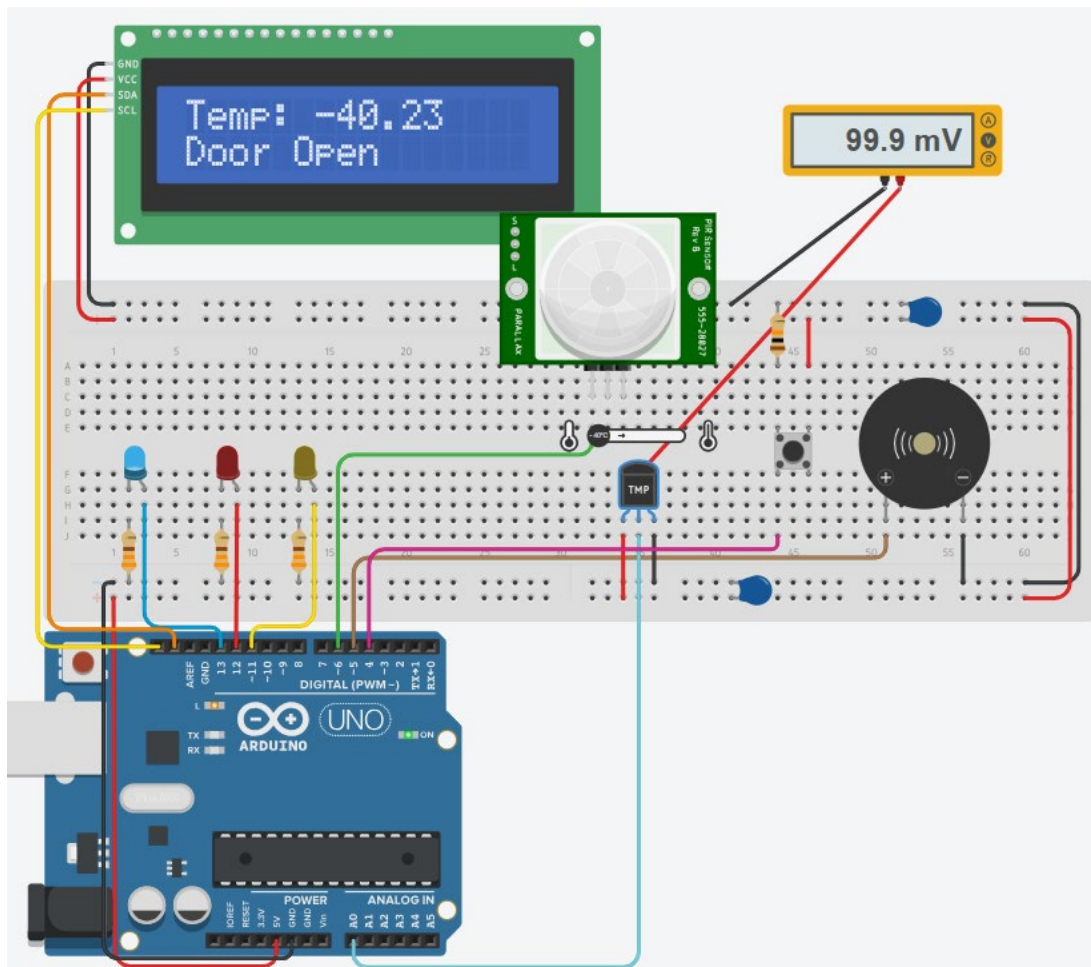
C) Virtual Simulation



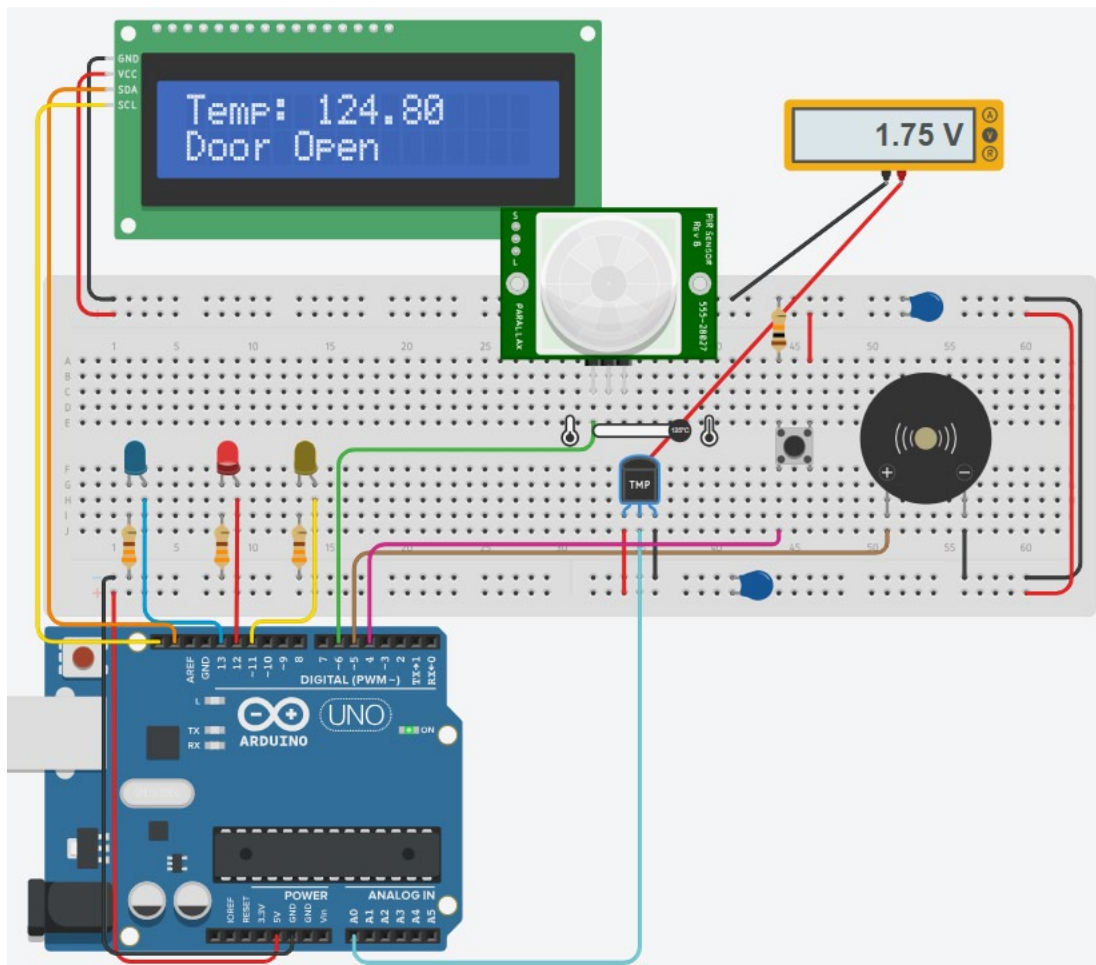
Above is a screenshot of the virtual circuit simulation

This is a simulation of a scenario in which the pressure switch is not pressed, the temperature is <24 and >18 . This proved that in theory, my code should work once taken into a physical form. The temperature sensor was sensing correctly, with the LCD displaying this information. None of the lights were on, as the temperature is in the specified range and no movement had been detected by the PIR yet.

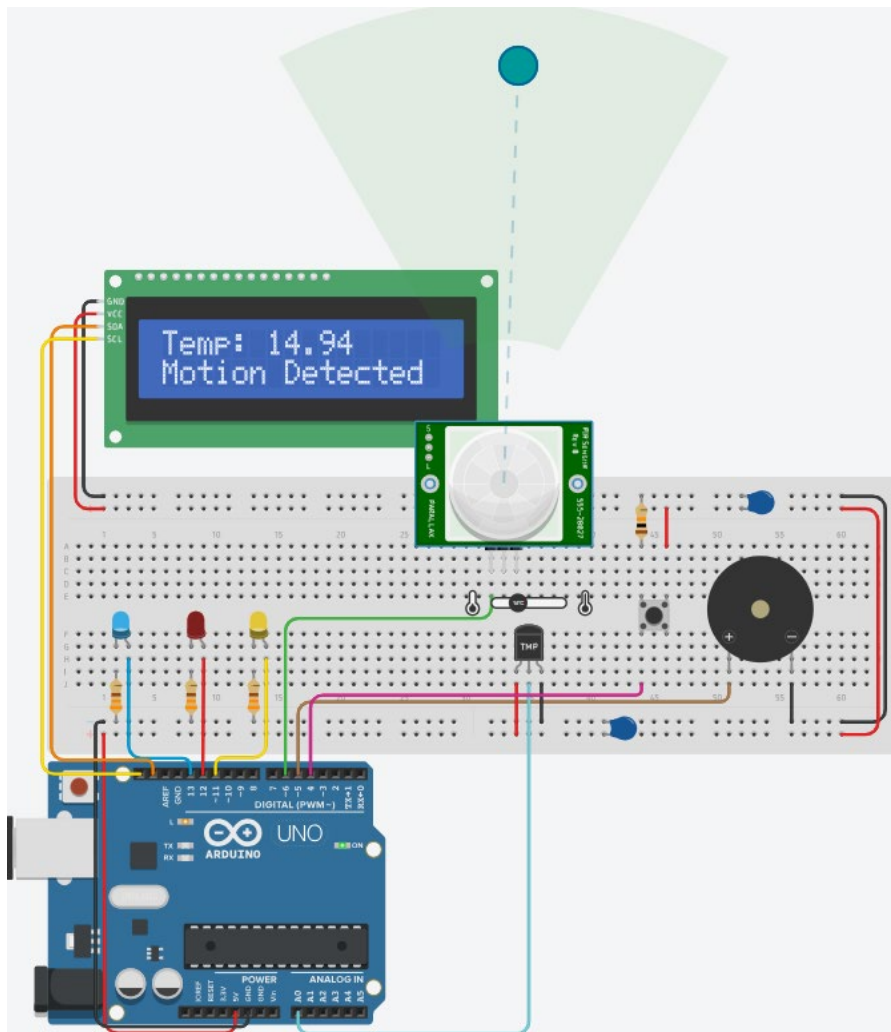
Prior to this, I had realised that due to the noise generated by a servo, my temperature sensor would become extremely unreliable. I had tried to fix this issue both virtually and physically, however I came to the conclusion that my design is better off without a servo and I now have just one button acting as a pressure switch, sensing if the door is opened or closed.



I also used a virtual multimeter to double check that all the components were working as they should, particularly the temperature sensor. When at minimum temperature, the sensor was outputting 99.9mV, compared to 1.75mV at maximum temperature, demonstrating that the sensor was fully functional.



The above is a demonstration of the temperature sensor at maximum temperature.



I then tested out that the PIR was sensing motion, and triggering the yellow LED (representing the server room lighting system). The LCD also conveyed this information on its display. The important thing to ensure was that the motion detection wasn't interfering with the temperature system. To test this out, I put the temperature below 18 degrees, and the blue LED and buzzer were still functioning as expected.

The virtual circuit simulation showed me that the code I had written was working and should in theory, function when made in physical form. However, it is important to note that sometimes there may be a discrepancy between virtual and physical simulations, with physical simulation relying on many different factors which are not encountered in a digital space.

D) Physical Simulation

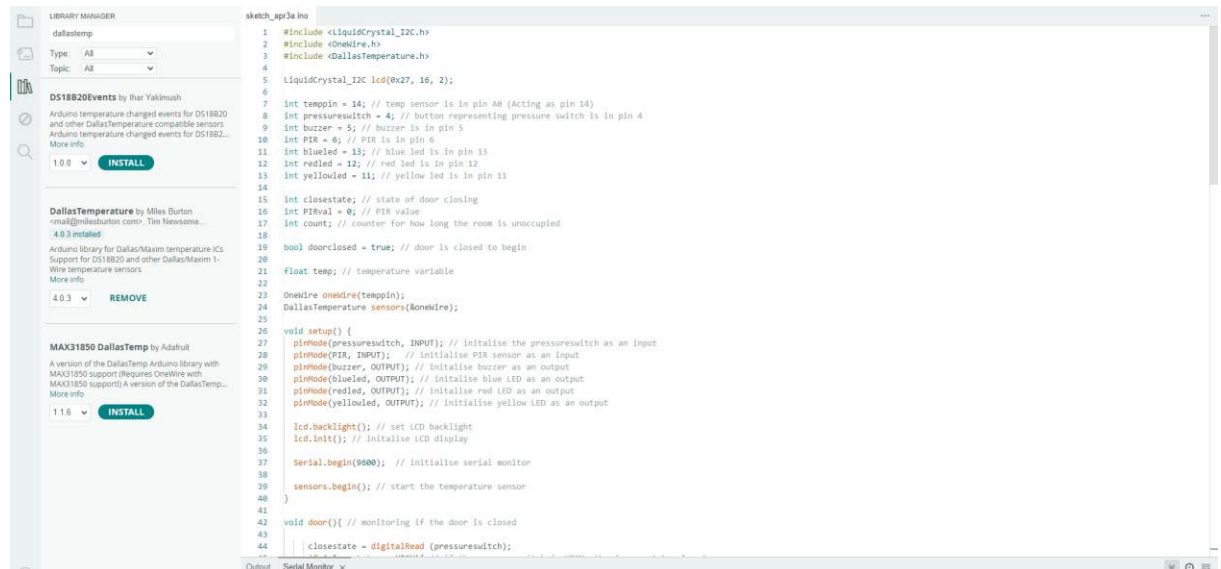
During physical simulation, I had noticed that the temperature sensor was picking up irregular, noisy readings. I quickly realised that this was due to the use of the servo, which has now been removed to reduce noise (one pushbutton has also been removed). However, the temperature sensor was still reading quite irregular temperatures, so I have chosen to change the temperature sensor which will be used. I am now making use of the GX18B20 (identical to the KY-001 module). This sensor acts as a direct substitute to the Dallas temperature sensor DS18B20. The particular model that I am using comes equipped with a resistor, so there is no need for me to change the circuitry, or PCB design. This substitute has greatly increased the accuracy of my circuit, with the temperature sensor boasting an accuracy of around ± 0.4 from -10 to $+70$ degrees Celsius. My code has been adjusted for this sensor's functionality.

I have made sure that all VCC wires are red, and that connections to ground are through a black wire. I have also matched the wires which go to the LEDs with their respective colours. I.e. a blue wire for the blue LED, yellow for the yellow LED and red for the red LED to increase visibility and ensure that I do not make any mistakes with the wiring. Where possible, I have made sure to use the smallest wires possible, to avoid a messy setup and prevent heat / noise distribution.

The PIR sensor initially suffered from noise, however, the 100uF capacitors helped to reduce the faulty inputs. I also made sure to adjust the sensitivity of the sensor in order to expand the range at which it can monitor movement. This may need to be adjusted during the final testing phase in order to monitor a 7m room. The sensor has been adjusted from L mode (no repeat) to H mode (repeat) in order to make sure that the sensor registers movement whenever present.

With the new temperature sensor that I am using I was able to cool down / heat up the sensor to test if the circuit was working as it should. The experiment was a success, with the LEDs and buzzer functioning as expected, with the LCD conveying relevant information. I have also edited the code to function differently, from the virtual simulation seen above. The LCD is now capable of displaying the door state, motion state and temperature simultaneously.

Below is a screenshot of the Arduino IDE Software that I am using to programme my circuit:



Transcript of Full Code:

```
#include <LiquidCrystal_I2C.h>
```

```
#include <OneWire.h>
```

```
#include <DallasTemperature.h>
```

```
LiquidCrystal_I2C lcd(0x27, 16, 2);
```

```
int temppin = 14; // temp sensor is in pin A0 (Acting as pin 14)
```

```
int pressureswitch = 4; // button representing pressure switch is in pin 4
```

```
int buzzer = 5; // buzzer is in pin 5
```

```
int PIR = 6; // PIR is in pin 6
```

```
int blueled = 13; // blue led is in pin 13
```

```
int redled = 12; // red led is in pin 12
```

```
int yellowled = 11; // yellow led is in pin 11
```

```

int closestate; // state of door closing

int PIRval = 0; // PIR value

int count; // counter for how long the room is unoccupied


bool doorclosed = true; // door is closed to begin


float temp; // temperature variable


OneWire oneWire(tempPin);

DallasTemperature sensors(&oneWire);


void setup() {

    pinMode(pressureswitch, INPUT); // initialise the pressureswitch as an input

    pinMode(PIR, INPUT); // initialise PIR sensor as an input

    pinMode(buzzer, OUTPUT); // initialise buzzer as an output

    pinMode(blueled, OUTPUT); // initialise blue LED as an output

    pinMode(redled, OUTPUT); // initialise red LED as an output

    pinMode(yellowled, OUTPUT); // initialise yellow LED as an output

    lcd.backlight(); // set LCD backlight

    lcd.init(); // initialise LCD display


    Serial.begin(9600); // initialise serial monitor

}

```

```
void door(){ // monitoring if the door is closed
```

```
    closestate = digitalRead (pressureswitch);
```

```
    if (closestate == HIGH){ // if the pressureswitch is HIGH, the door must be closed
```

```
        doorclosed = true;
```

```
    }
```

```
    else{ // if the pressure switch is LOW, the door must be open
```

```
        doorclosed = false;
```

```
    }
```

```
}
```

```
void display(){ // controlling the LCD display
```

```
    lcd.clear();
```

```
    lcd.print("Temp: ");
```

```
    lcd.print(temp); // print the current temperature
```

```
    lcd.setCursor(0,1);
```

```
    lcd.print("Door ");
```

```
    if (doorclosed == true){
```

```
        lcd.print ("Closed"); // if the door is closed, display this
```

```
    }
```

```
    else {
```

```
        lcd.print ("Open"); // if the door is open, display this
```

```
    }
```

```

    delay(100);

}

void temperature(){ // measuring the temperature

    sensors.requestTemperatures(); // measure the temperature

    temp = (sensors.getTempCByIndex(0)); // assign value to temperature variable

    Serial.print(temp);

    Serial.println(" Degrees Celsius"); // display current temperature in the Serial Monitor

    if (temp > 24){ // if temperature is above 24 degrees

        digitalWrite(redled, HIGH); // if temp is above 24 degrees, red LED must turn
on
        digitalWrite(blueled, LOW); // blue LED turns off

        tone (buzzer, 50, 100); // buzzer turns on, as temperature is out of range

        delay(100);

    }

    if (temp < 18){ // if temperature is below 18 degrees

        digitalWrite(blueled, HIGH); // blue LED must turn on

        digitalWrite(redled, LOW); // red LED turns off

        tone (buzzer, 50, 100); // buzzer turns on, as temperature is out of range

        delay(100);

```

```
}
```

```
if ((temp >= 18) && (temp <= 24)){ // if temperature is within range
```

```
digitalWrite(blueled, LOW); // blue LED off
```

```
digitalWrite(redled, LOW); // red LED off
```

```
}
```

```
delay(1000); // wait one second
```

```
}
```

```
void motion(){
```

```
PIRval = digitalRead(PIR);
```

```
count = 0;
```

```
if (PIRval == HIGH){ // if motion is detected
```

```
while (count <21){ // while counter is within 20 seconds
```

```
Serial.println (count);
```

```
digitalWrite(yellowled, HIGH); // turn lights on in server room
```

```
count++;
```

```
temperature();
```

```
lcd.clear();
```

```
lcd.print("Motion "); // display that motion was detected within the room
```

```
lcd.print(" Temp: ");
```

```
lcd.print(temp); // display current temperature
```

```
lcd.setCursor(0,1);
```

```
lcd.print("Door "); // display door state
```

```
closestate = digitalRead (pressureswitch);
```

```
if (closestate == HIGH){ // if the pressureswitch is HIGH, the door must be  
closed
```

```
lcd.print("Closed");
```

```
}
```

```
else{ // if the pressure switch is LOW, the door must be open
```

```
lcd.print("Open");
```

```
}
```

```
delay(1000);
```

```
PIRval = digitalRead(PIR);
```

```
if (PIRval == HIGH){ // if motion is still detected, reset the counter to 0
```

```
count = 0;
```

```
}
```

```
}
```

```
}
```

```
digitalWrite(yellowled, LOW); // when counter goes above 20, the lights in the  
server room turn off
```

```
}
```

```
void loop(){
```

```
temperature(); // temperature monitoring
```

```
door(); // monitoring if the door is closed or open
```

```
motion(); // checking for motion inside of the server room
```

```
display(); // displaying the key information on the LCD display
```

```
}
```

E) Bill of Materials

Name	Description	Part Number/Value	Quantity	Cost per unit in £	Total Cost
U1	Arduino Uno R3	A000066	1	15	£15
U2	16 x 2 I2C LCD	FNK0079A	1	7	£7
U3	Temperature Sensor	GX18B20	1	0.75	£0.75
D1	Blue LED	5mm	1	2	£2
D2	Red LED	5mm	1	2	£2
D3	Yellow LED	5mm	1	2	£2
R1, R2, R2	Resistor	330 Ohm	3	0.30	£0.9
R5	Resistor	10K Ohm	1	0.30	£0.90
C1, C2	Capacitor	100uF	2	0.35	£0.70
PIEZO1	Passive Buzzer	TP124005-2	1	0.62	£0.62
PIR1	PIR Sensor	HC-SR501	1	2.19	£2.19
S2	Pushbutton	BG-YM-91570	1	4.50	£4.50

	Single-Sided Copper Clad Board	1.5mm thick	2	0.46	£0.92
	Dupont Jumper Wire Pack	Pack of 120	1	6	£6
	Male Pin Headers	Pack of 50	1	8	£8
	Lead Free Solder Wire	0.8mm dia (20 grams)	1	4	£4
	Lead Free Soldering Flux	Gruiqrd (50 grams)	1	4	£4
	Lead Free Tip Thinner	TMT-TC-2 (20 grams)	1	6.50	£6.50
			22	Total	£67.38

Justifications:

All of the components / materials in my BoM have been thought out and listed in the appropriate quantities.

Components have been carefully selected based on their functionality and suitability for this project. Where possible I have tried to budget, but not to the detriment of my circuit. A few of the components may be purchased in bundles, for example the LEDs may be purchased in a multi-coloured LED pack, saving a lot of money.

Additional materials have been listed, such as the copper board needed to produce the PCB. (I have listed 2, as one will be manufactured as a backup PCB in case anything goes wrong with the soldering of the first board). Dupont jumper wire packs almost always come in packs of 120 (there are a plethora of examples on amazon). The solder wire and flux have been listed in appropriate quantities and are enough to get through the manufacturing / soldering process without running out of consumables. My workshop has previously bought the same exact solder wire, flux and tip thinner as listed. Amazon is the primary supplier of my chosen components, materials and consumable products (with limited exceptions).

The 'Name' of components refers to their name on the my wiring diagram.

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Task 2 Manufacture and test

Assessment number (eg 1234-033)	8714-322
Assessment title	Electrical and Electronic Engineering Occupational Specialism

Candidate name	<first name> <surname>
City & Guilds candidate No.	ABC1234

Provider name	<provider name>
City & Guilds provider No.	999999a

Task(s)	2
Evidence title / description	Completed risk assessment Test records for the results of testing the circuitry Assessor observation Photographic evidence
Date submitted by candidate	DD/MM/YY

Task 2

Assessment themes:

- Health and Safety
- Manufacturing
 - Prototype/model
 - Developing
 - Testing
- Reports
 - Implementation
 - Record/reports

You must:

- produce and complete a risk assessment for the production of the PCB and the construction of the soldered prototype
- produce the PCB for the design
- build a soldered prototype working circuitry from your design
- test the operation of the circuitry.

Additional evidence of your performance that must be captured for marking:

- assessor observation of:
 - the production of the PCB
 - building of the soldered prototype
 - testing of the circuitry.
- photographic evidence which shows:
 - unassembled PCB clearly showing the track layout
 - back of the assembled PCB showing all soldered joints
 - front of the assembled PCB showing positioning and fitting of components.

Candidate evidence

Task 1

Hazard(s)	Risk(s)	Control(s)	Likelihood	Severity
Pre-work checks				
Messy, unprepared workspace	Slips, trips and falls Sharp waste, debris and flammable material leftover from previous work. Leftover water may pose a significant electrical fire hazard	Physical inspection of workspace. Appropriate storage of tools and equipment to prevent tripping hazard. Alert other of all operations to be undertaken in the workshop. Keep all water sources isolated from electrical equipment. (Clean spillages and distribute wet floor signs if applicable.) Ensure full understanding of fire drill's and make sure that all fire exits are kept clear at all times.	1	2

Manual handling of tools and equipment	Back injury.	Do not exceed maximum lifting limit. Request assistance with large handling operations when appropriate.	1	1
Faulty electrical equipment / components	Overheating of faulty electrical components / equipment may cause burns / thermal injury. Use of faulty electrical equipment may results in electric shocks.	Only use electrical equipment and components which you have been trained on prior to beginning any work. Check all electrical equipment for PAT testing. Use ESD wrist straps to prevent components being damaged and becoming faulty. Isolate electrical equipment.	2	2

Manufacturing of PCB				
Use of developer solution for PCB chemical etching	Hazardous solutions used in PCB etching may risk a variety of health and safety issues such as skin irritation and eye burn.	Ensure appropriate storage of all substances deemed hazardous to health, as outlined by COSHH Only use solutions which you have received appropriate training on. Use appropriate PPE to protect from chemicals, such as overalls, goggles, gloves and mask. (outlined by COSHH.) Remember to wipe down surfaces which may have come in contact with chemicals. Thoroughly wash hands after handling solutions.	2	3
CNC Milling machine				
	Mechanical injury caused by rotating parts. Flying debris could enter eye. Dust from cutting material may	Use of machine guards to prevent flying debris causing harm. Ensure use of the appropriate PPE such as goggles, overalls and gloves.		

CNC milling machine	enter eyes / respiratory system. Flammable material poses a significant fire hazard. Electrical faults may cause fires / electric shocks. Noise generated by CNC Milling machine may potentially exceed noise limit.	Only reach into the machine whilst no operation is running and gloves are worn, as well as a mask to protect from dust. Vacuum all dust after operating the machine. Clean and visually inspect the cutting tools after use. Ensure that use of flammable material is prevented and fire exits are kept clear at all times. Make sure you have a full understanding of all emergency procedures and that the emergency stops are clear and available at all times. Check PAT testing of machine prior to use. Wear noise cancelling equipment (if possible) whilst machine is running.	2	3
	Flying debris.	Always file away from yourself, and into bin.		

Filing of PCB	Sharp waste and debris may cause cuts / abrasions. Dust may enter eyes / respiratory system. Sharp filing tool may cause cuts / abrasions.	Dispose of all leftover waste and debris appropriately. Wear PPE such as mask, gloves, goggles and overalls. Only use filing tool if you have received appropriate training. Check tool for any visual damage after use.	1	1
Soldering of PCB				
Use of soldering equipment	Use of hot soldering iron may cause burns / thermal injury. Soldering spillage may cause scalds. Soldering iron poses fire hazard.	Ensure appropriate use of PPE such as goggles, overalls and mask. Use soldering mat to prevent spillage. Do not leave soldering iron on when unattended. Ensure maintenance of soldering equipment according to manufacturer recommended intervals. Make sure that you understand all emergency procedures and that fire exits are kept clear and accessible at all times.	2	2

Soldering fumes	Build-up of soldering fumes may cause toxicity within respiratory system. Can be especially dangerous for those with breathing issues E.g. Asthma. Lead solder can pose a higher risk than alternatives, due to increased toxicity.	Ensure use of high quality fume extraction. Ensure that the workpiece is directly under fume extraction and that fumes are directed away from the individual. Where possible, prevent the use of lead solder in favor of a less toxic soldering material. Check PAT testing for all fume extractors prior to use. Immediately report any signs of illness.	2	2
Use of sharp hand tools to aid soldering	Sharp hand tools may cause cuts / abrasions. Flying debris.	Ensure use of appropriate PPE such as goggles, overalls and gloves. Cut away from self. Remove waste and debris to reduce hazards later on. Store tools after use, as appropriate.	1	1

Wiring of PCB	Accidentally reversing the polarity of electrical components can cause overheating, resulting in potential burns / thermal injuries. ESD may cause failure of electrical parts.	Only use components which you have received training on. Make use of component datasheets. Refer to documents / drawings to ensure correct wiring before supplying power to the PCB. Use ESD wrist strap to prevent ESD from affecting components / equipment.	2	2
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Likelihood		Severity	
1	Very unlikely to happen	1	Minor injury
2	Unlikely to happen	2	Major injury
3	Possible to happen	3	Loss of limb
4	Likely to happen	4	Death of an individual
5	Very likely to happen	5	Multiple deaths

B) Production of PCB

My PCB was manufactured via CNC milling machine. I used fusion to push my PCB track layout to a 3D PCB. Following this, I selected the machine that I would be using (Roland mdx-50) and set the dimensions for my PCB. I then setup each operation which the machine would undergo (milling the tracks, drilling the holes and milling out the PCB.) Whilst the machine was running, I followed my risk assessment and wore the appropriate PPE such as; overalls, gloves, goggles and also my mask whilst reaching into the machine. After the

manufacturing of my PCB I also vacuumed the machine and cleaned the tools, to prevent future damage.

My practical observer will submit some images of my manufacturing process as evidence.

C) Soldering of PCB

I made use of a variety of equipment / consumables across the soldering task, such as soldering iron, fume extractor, solder mat, solder, tip tinner and flux. I also ensured the use of appropriate PPE such as; overalls, safety goggles and an ESD wrist strap. However, one of the most important tools that I used was actually an oscilloscope. I used this to check the continuity of my PCB prior to soldering. After soldering each joint I used the oscilloscope to check that the PCB had not been short circuited (continuity testing.) The oscilloscope was also useful when testing for waveforms.

My practical observer will submit some images of my manufacturing process as evidence.

D) Testing of PCB

Design Criteria	Testing Method	Test Outcome
Lighting in the server room must turn on when motion is detected inside the room via a sensor. Lighting must subsequently turn off within 20 seconds of motion not being detected	Motion test (Moving hand in front of PIR sensor) Repeat before 20 seconds is up and check serial monitor to see if counter has reset and lights stay on Make sure lights turn off after 20 seconds of no motion	I swept my hand past the PIR sensor from a small distance within the server room rig. Serial monitor confirmed that the counter had started, and I could also physically see the yellow LED turn on. I waited 20 seconds without moving in front of the sensor, and the LED turned off. Test passed

Motion detection must cover the whole server room.	Motion test beyond the door of the test rig, to see if motion detection covered past the room, subsequently meeting the design criteria.	I swept my hand past the room and the yellow LED turned on, confirming that motion will be detectable within the full vicinity of the room. Test passed
The input and output devices should be connected to the circuitry	Simple pressure test on components to ensure that they are fully soldered, stiff and will not detach from PCB.	I performed slight pressure tests on all soldered components; pin headers, resistors, capacitors, LEDs and the pushbutton. Vast majority of components were soldered to an acceptable degree. Loose components were further soldered and loose joints were corrected. Test passed

Inputs to circuitry		
A sensor on the door to detect if the door is open.	Check LCD display whilst button is unpressed / pressed to see if the door state message changes.	I pressed the pushbutton, and the LCD showed the "Door closed" message. Test passed

A sensor to detect if there is movement in the server room, to keep the light on.	Motion test to see that the PIR sensor is working as expected.	I swept my hand past the PIR sensor from a small distance within the server room rig. Serial monitor confirmed that the counter had started, and I could also physically see the yellow LED turn on. I waited 20 seconds without moving in front of the sensor, and the LED turned off. Test passed
A sensor to monitor the temperature of the server room.	Use ice cube / hand to test if temperature sensor detects change in temperature. Visual check of LCD display / Serial monitor to ensure correct temperature is shown.	I used my hand to heat up the temperature sensor and the LCD / Serial monitor displayed the correct temperature. I also held an ice cube near the sensor, and an accurate reading was shown. Test passed

Outputs from circuitry		
A visual indicator (blue light) inside the facilities control room to show when the temperature is below 18°C.	Hold ice cube nearby sensor to check for accurate new reading, and ensure (blue LED) visual indicator turns on.	When the temperature reading was below 18 degrees, the blue light activated as expected. Test passed
A visual indicator (red light) inside the facilities control room to show when the temperature is above 24°C.	Hold temperature sensor to check for accurate new reading, and ensure (red LED) visual indicator turns on.	When the temperature reading was above 24 degrees, the red light activated as expected. Test passed
An audio output inside the facilities control room to indicate when the temperature is out of range.	Whilst temperature is out of range conduct audible test.	When temperature reading was <18 degrees or >24 degrees the buzzer activated. Test passed
A controlled lighting system in the server room	Motion test (Moving hand in front of PIR sensor) Repeat before 20 seconds is up and check serial monitor	I swept my hand past the PIR sensor from a small distance within the server room rig. Serial monitor confirmed that the counter had started, and I could also physically see the yellow LED turn on.

	to see if counter has reset and lights stay on Make sure lights turn off after 20 seconds of no motion	I waited 20 seconds without moving in front of the sensor, and the LED turned off. Test passed
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As well as the functional testing methods mentioned in the table, I conducted a plethora of various other tests throughout both the manufacturing and soldering processes respectively.

For example, before operating the CNC milling machine, I virtually simulated the manufacturing process on Fusion to ensure there would be no damage to machinery, tools, the copper board and people nearby. I did this for each operation separately (milling the tracks, drilling the holes and milling the board out.) After individually simulating each operation, I also simulated the whole process in one go to double check that everything would run smoothly.

I also conducted tests during the soldering process, in the form of the oscilloscope, as mentioned before. This method of testing came in handy multiple times, as there were a few continuity issues along the way. For example, I found out that two tracks were inadvertently connected from a small piece of copper between them. I then used the appropriate hand tool to scrape away the copper, retested for continuity and the problem had been resolved.

Along with this, I also noticed that I was getting a short circuit across a specific track for a few seconds when initially touching it with the prongs, and then reversing the prongs. At first, I was very confused as to why this was happening, and I decided to start soldering on a backup PCB. However, I ran across the same issue with that PCB. As soon as the exact same issue occurred, I figured out that it had to be because of a component. After investigating further I realised that it was a capacitor storing the current from the prongs, and I continued work on the original PCB.

Whilst wiring my PCB I decided to wire / test one component at a time, to speed up fault finding if any problems were to occur. Thankfully no issues were found, and all circuitry

worked during the first attempt. After successful wiring, I setup my components onto the test rig and conducted functional testing. The code that I developed for task 1 was used for this, as it was already input into the Arduino.

I used the Arduino IDE software to check the Serial monitor. I did this for the motion sensor counter and the temperature readings. This verified that the motion counter was working as expected and that the counter would reset after motion was detected. I let the counter reach 20 seconds and the yellow LED turned off as anticipated. The Serial monitor also displayed the current temperature correctly.

My practical observer will submit evidence of testing. (A scaled down mock of the server / control room were developed and used as test rigs.)

Full PPE during the production and manufacturing (HS)



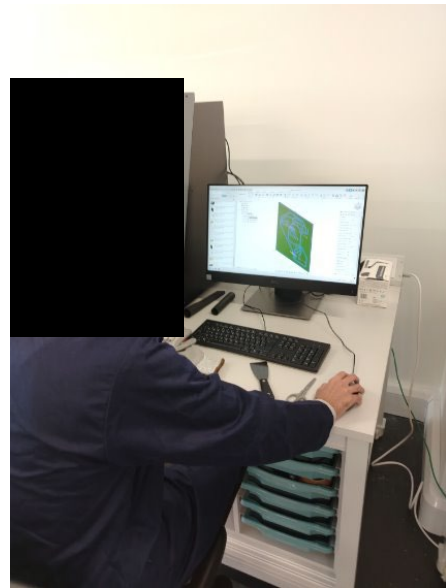
Appropriate selection and use of tools, equipment and processes for PCB production. E.g. etching and milling (M)



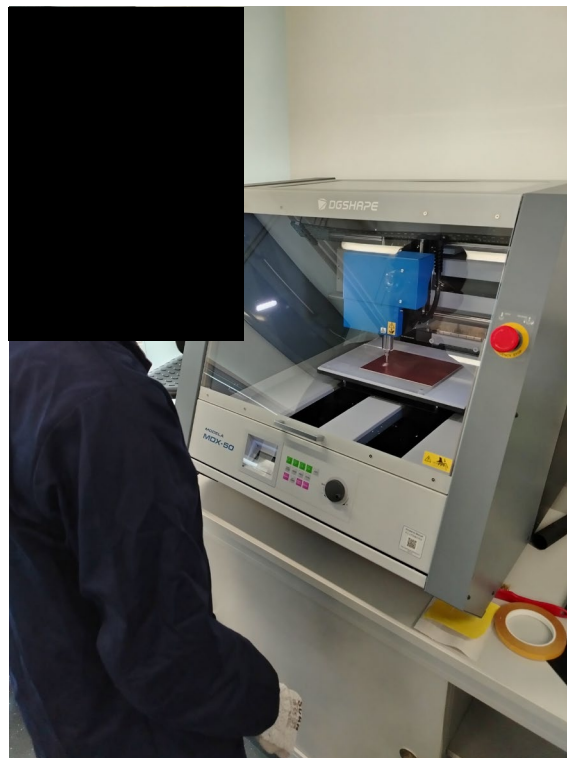
Appropriate selection and use of tools, equipment and processes for PCB production e.g. Cutting the PCB Board (M)



Appropriate selection and use of tools, equipment and processes for PCB production e.g. Capturing the circuit layout from the software. (M).

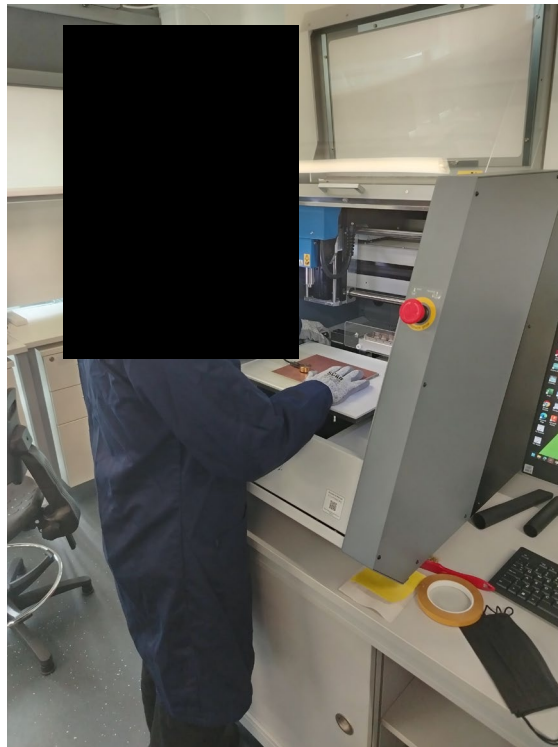


Appropriate selection and use of tools, equipment and processes for PCB production. E.g. Using the milling machine tool and developing the Track (M).

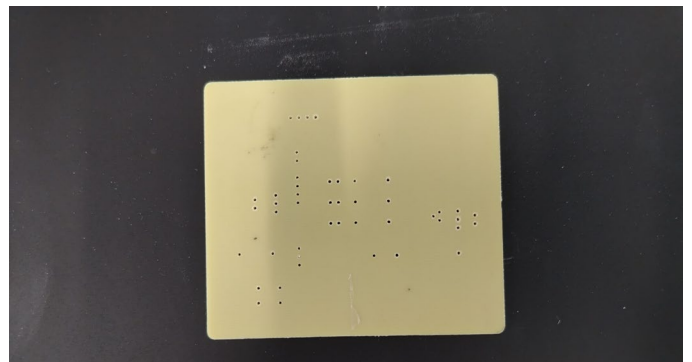
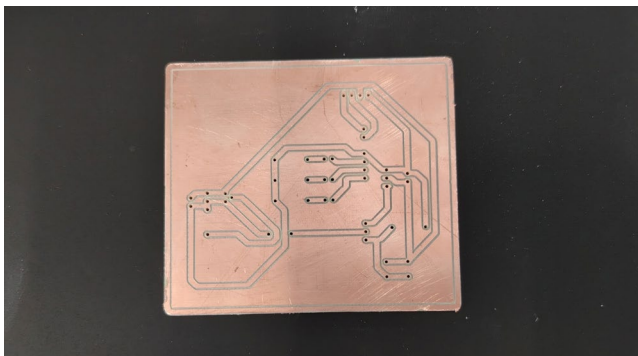


Appropriate selection and use of tools, equipment and processes for PCB production. Eg.

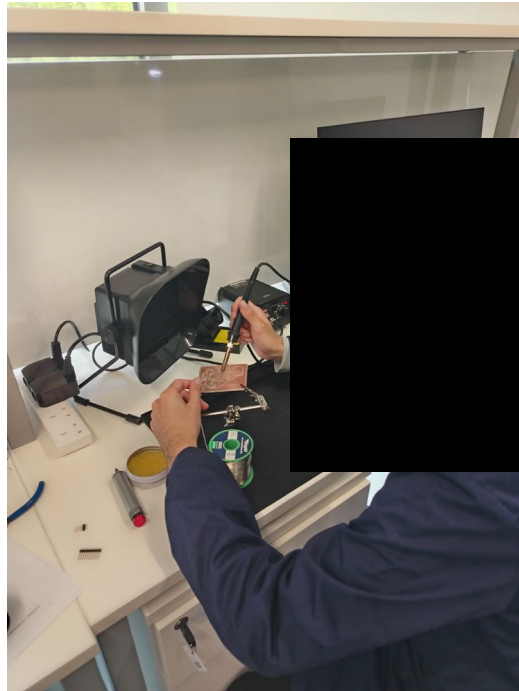
The overall developing process of the PCB (M)



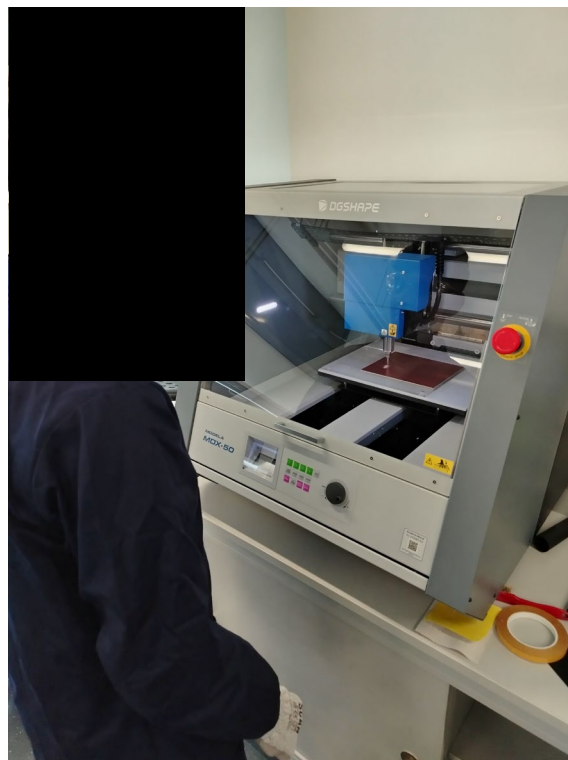
Front and back of the Manufactured PCB: Copper side and component side. (Without component and Soldering) (M)



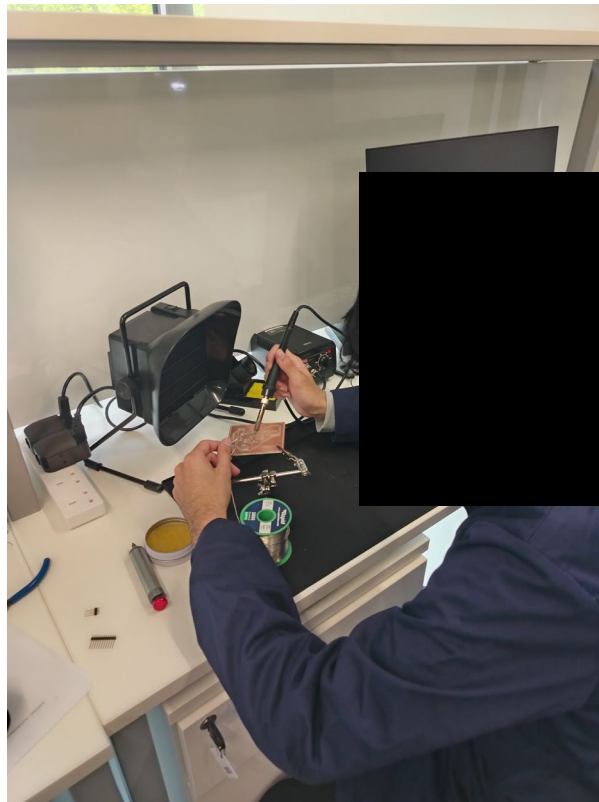
Safe construction and assembly of the PCB (HS) eg PPE used during the soldering



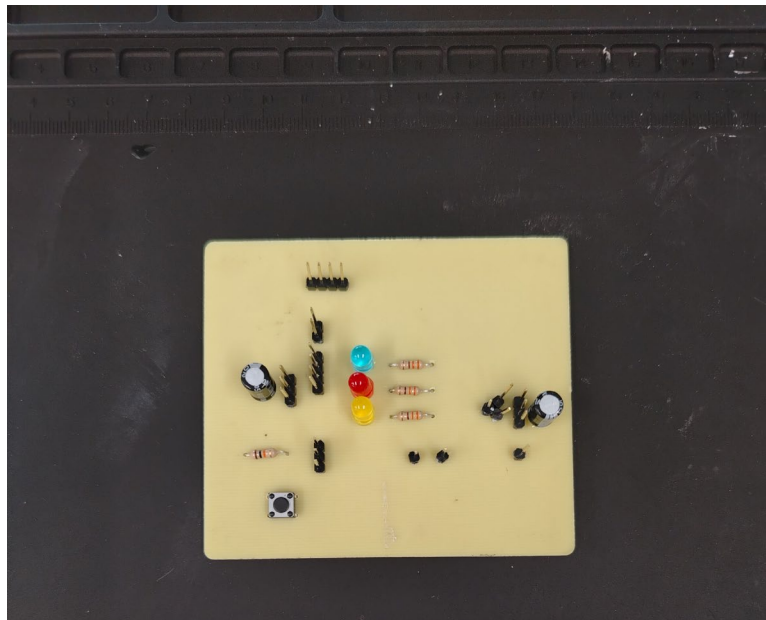
Safe construction and assembly of the PCB (HS) e.g Drilling the hole by drill – Holes drilled using CNC correctly as observed



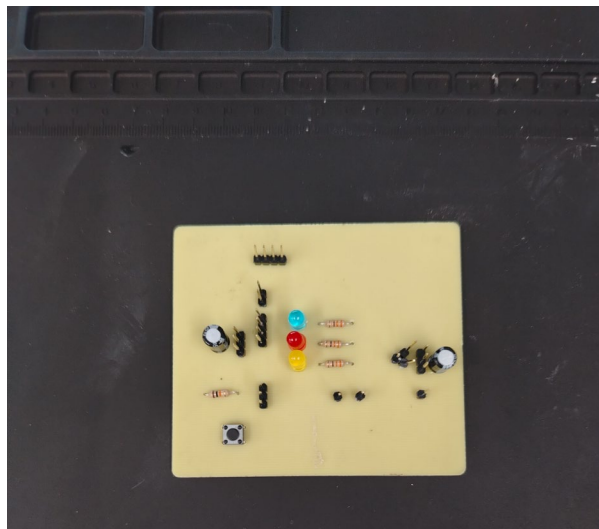
The candidate's selection and use of tools, equipment and processes to manufacture and assemble the PCB e.g measuring and cutting of components, soldering of components (M)



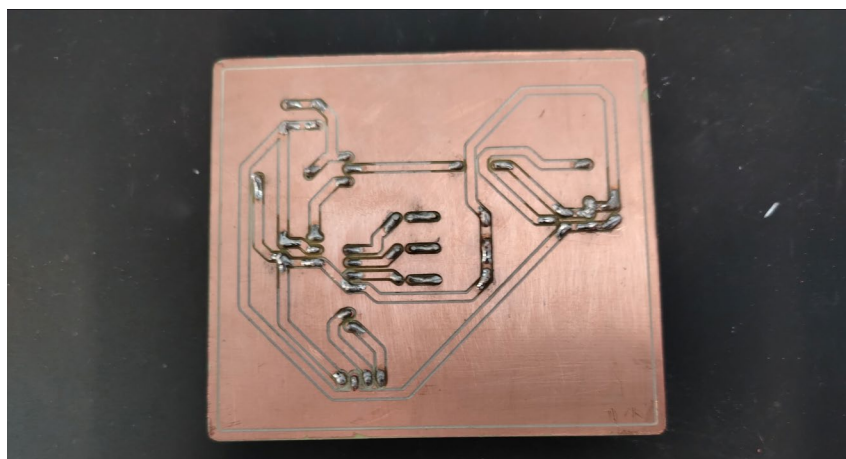
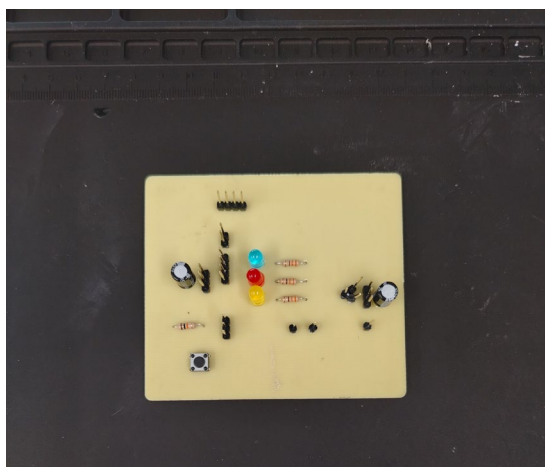
Selection of components for PCB assembly (M) e.g. Components going to use in the PCB



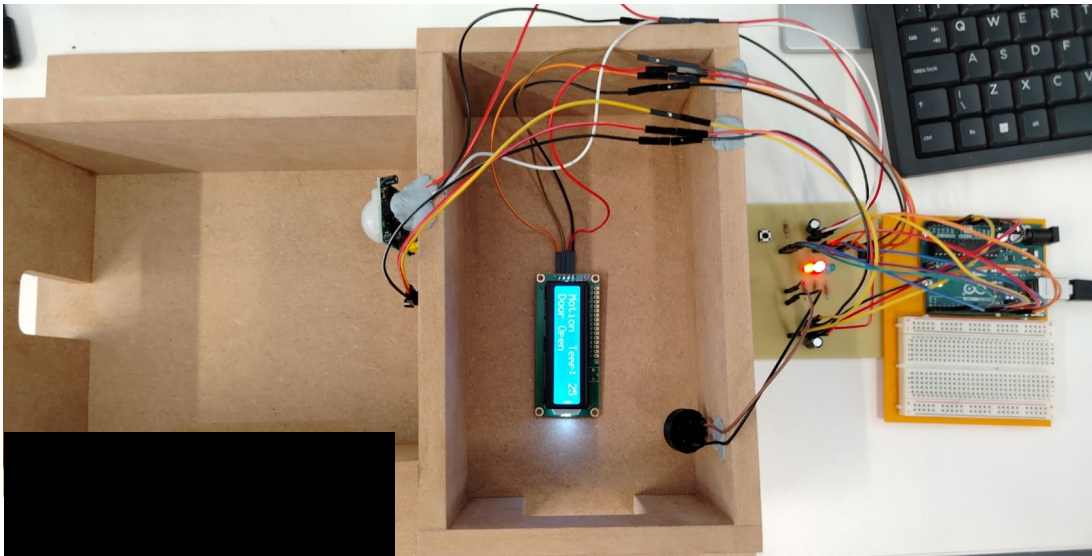
Positioning and fitting of components (M)



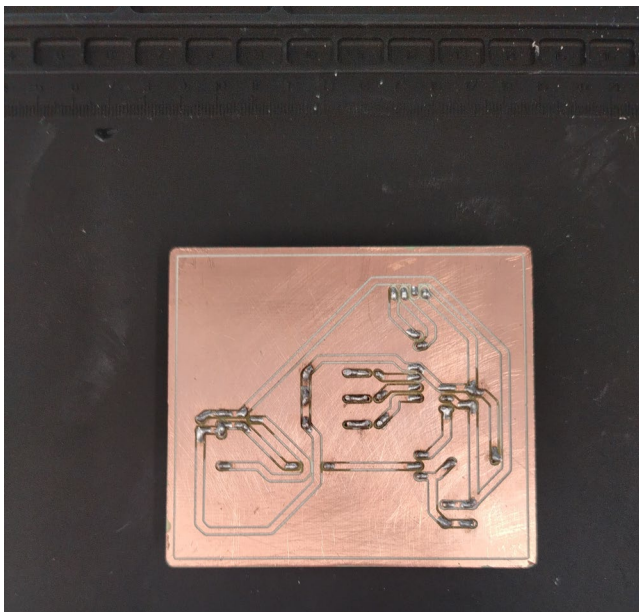
The candidate's PCB assembling skills (M).



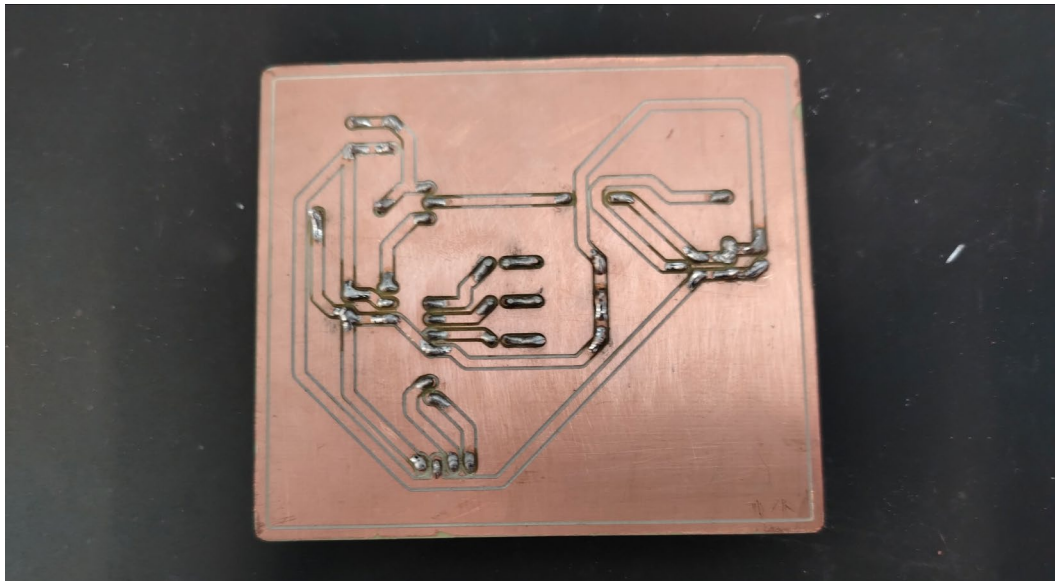
The candidate's hand skills e.g. wiring, fitting input, process and output devices (M)



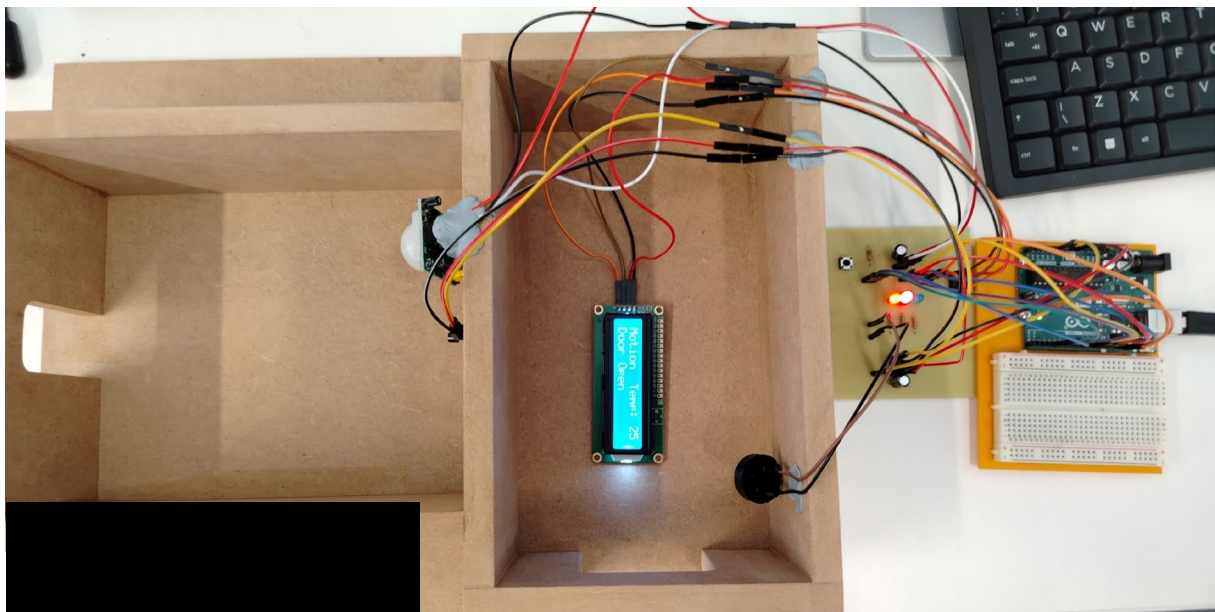
Back of the assembled PCB showing all soldered joints (M) overall picture of the soldering joints



The quality of the formed soldered joints (M) Close up picture of the soldering joints

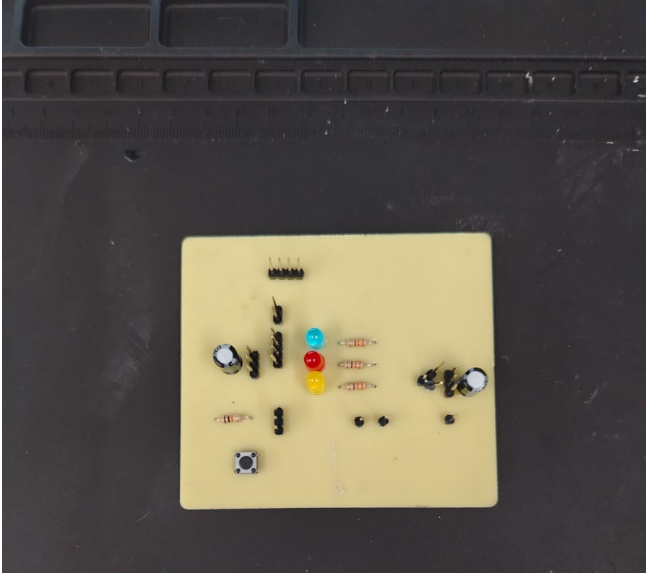


Appropriate use of colour coding of wiring (M)
e.g. + and -ive power supply wires colour/any other relevant colour wires used.



Appropriate circuit protection methods (M)

Use of power rail decoupling capacitors to protect against electrical noise and the use of an earth strap (to protect against static electricity) and a rubber mat in the building of the prototype.



Task 3 Peer review

Assessment number (eg 1234-033)	8714-322
Assessment title	Electrical and Electronic Engineering Occupational specialism

Candidate name	<first name> <surname>
City & Guilds candidate No.	ABC1234

Provider name	<provider name>
City & Guilds provider No.	999999a

Task(s)	3
Evidence title / description	Peer review feedback form Feedback record form
Date submitted by candidate	DD/MM/YY

Task 3

Assessment themes:

- Reports

You must:

- prepare to present your design verbally using annotated sketches and diagrams.
- present and explain your design.
- peer reviewers will now have time to reflect on your design.
- discuss feedback from the group on your design presented in part b.
- peer reviewers will now complete the peer review feedback form.

Additional evidence of your performance that must be captured for marking:

None

Candidate evidence

Peer Review Form

Assessment ID	Qualification number
8714-322	8714-32
Candidate name	Candidate number
<first name> <surname>	ABC1234
Provider name	Provider number
<provider name>	999999a
Date	Series

Question	Feedback
Explain how well the diagrams/drawings meet the design criteria.	The drawings / diagrams meet all of the design criteria. The LEDs light up as is specified in the design criteria. The wires on both the drawings and the prototype are colour-coded. The add on of an LCD is a good improvement on the brief as well as the use of capacitors for smoothing out signals.
Explain how well the diagrams/drawings meet the specification criteria.	The drawings meet the specification criteria to a high standard, all the requirements are satisfied by the proposed design. They improved on the brief by adding a liquid crystal display (LCD) which displays the motion in the room, the door status (open or closed), and the live temperature reading.
Explain how well the diagrams/drawings conform to the relevant conventions.	The diagrams / drawings are compliant to the IET wiring regulations. The prototype complies with the Institute of Printed Circuits (IPC) Regulations. The components used

	were appropriate and fit for purpose, as all worked as expected.
Explain how the system could be optimised/improved.	The circuit could be improved by increasing the tone of the buzzer to be more noticeable. An additional start / stop button could be implemented. On the LCD displaying degrees Celsius to clarify. Pin headers could be added to certain tracks to be used as testing stations. Changing the pressure switch to a hall effect may be a good idea, as buttons wear-down over time.

Feedback Record Form

Assessment ID	Qualification number
8714-322	8714-32
Candidate name	Candidate number
<first name> <surname>	ABC1234
Provider name	Provider number
<provider name>	999999a
Date	Series

Candidate's notes
The potential improvements which my peers have identified are mainly minor adjustments, such as changing the tone of the buzzer to increase the distance at which it can be heard. Most of the feedback that I received was positive, and only minor adjustments were identified with the only major adjustments being a start / stop button, testing station and using a hall-effect instead of my pushbutton. All my peers liked the information that was included on the LCD, with the minor issue of the degrees Celsius symbol not showed on the display. They particularly liked how I had managed to fit all of the critical information onto the display despite the limited characters that the LCD allows to be shown at one time. Originally, I left out the degrees Celsius symbol due to the limited spacing, however I will investigate this further later and see if it is possible to display this whilst keeping all the crucial information on the display. In terms of how the PCB itself was manufactured, everybody thought that the soldering was neat and tidy with no spillages or excessively soldered joints visible. They also thought that

the PCB was a sensible size with the layout resulting in minimal waste, whilst sensible spacing between joints to allow for an ease of soldering.

All the components used were deemed fit for purpose, and they liked that I had used capacitors to smooth out signals and prevent noise. They thought that I could add a start / stop button to quickly and easily stop and start the system. Whilst they thought that all the components used were fit for purpose, they still recognised that I could have used a hall effect sensor instead of a pushbutton for the door. This is not a major issue; however, I will be further examining this to see what can be done as I recognise this as a legitimate improvement on the current system.

Overall, I am extremely happy with the feedback received, as no major issues were identified and all the possible improvements, I have received are appropriate for the system.

Task 4 Evaluation and Implementation

Assessment number (eg 1234-033)	8714-322
Assessment title	Electrical & Electronic Engineering Occupational specialism

Candidate name	<first name> <surname>
City & Guilds candidate No.	ABC1234

Provider name	<provider name>
City & Guilds provider No.	999999a

Task(s)	4
Evidence title / description	Outcomes of virtual modelling Revision control document/report Evaluation and implementation report
Date submitted by candidate	DD/MM/YY

Task 4

Assessment themes:

- Health and Safety
- Design and Planning

You must:

- update the virtual model of your final design using appropriate software to incorporate any changes made and research completed in response to feedback or as a result of manufacturing and testing
- produce a revision control document/report that is typically 500 words justifying why changes were made or not made as a result of the peer review feedback
- produce a report evaluating the design and development work completed. The report should typically be 800 words. This must include:
 - an explanation of the test methods used, reasons for their use and their limitations
 - a summary of the capabilities of the circuitry
 - an evaluation of the fitness for purpose of the design proposal and its conformance to the design criteria and specification
 - the information necessary for a third party to implement
- an outline of any additional factors that may need to be considered during the implementation, including:
 - cable types to be used to connect the sensors to the circuitry, if appropriate
 - health and safety considerations
 - applicable requirements from wiring regulations
- any further improvements or adaptations required to the prototype, including any reasoning and justifications if adaptations or improvements are not required.

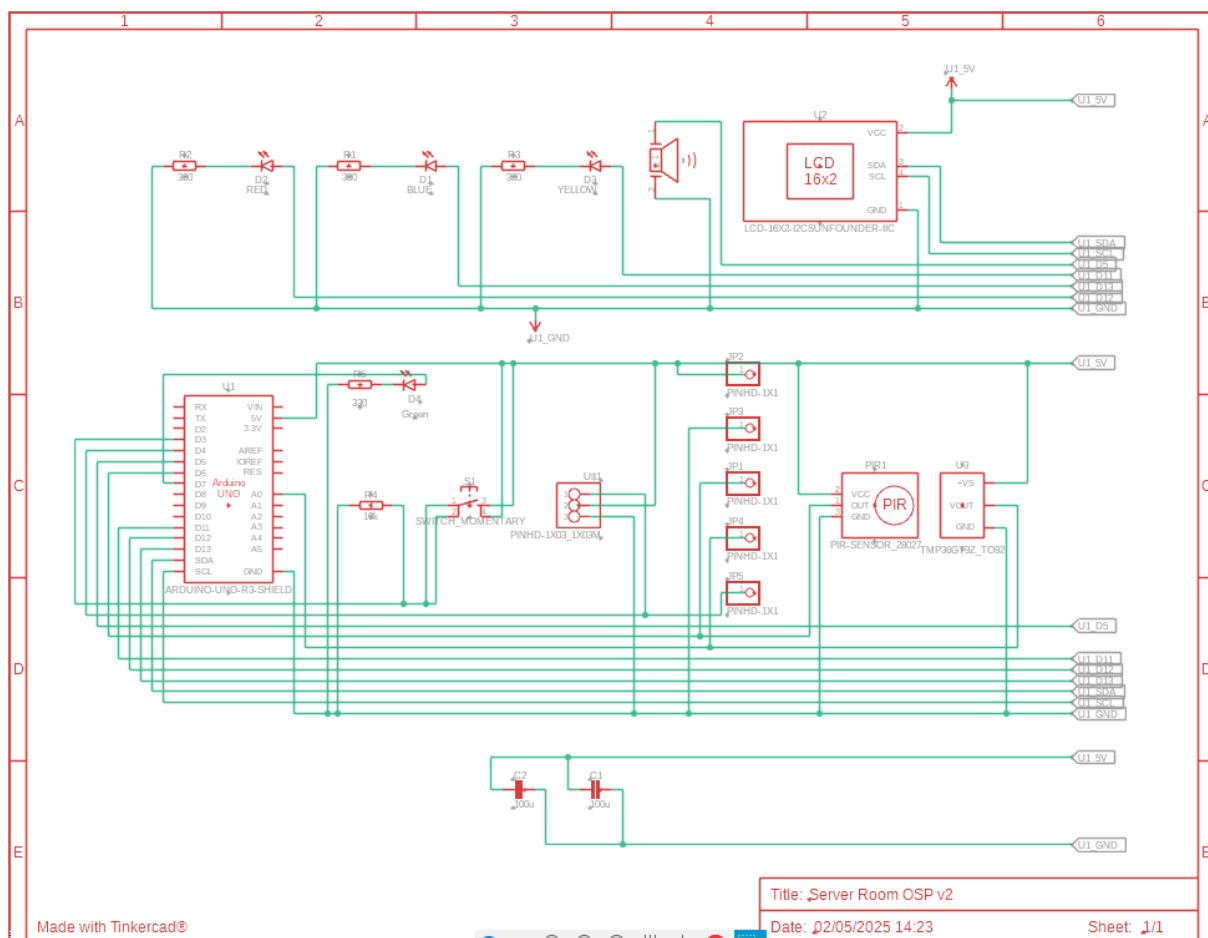
Additional evidence of your performance that must be captured for marking:

None

Candidate evidence

A) Virtual Modelling

Following the improvements which my peers suggested, I have developed a version 2 for my current PCB. I made changes to the breadboard in Tinkercad and exported my design to Fusion, in order to make a few changes and develop a brand new schematic based on the feedback / improvements suggested by my peers. The schematic is seen below:



I have included a 3 pin-header to represent the KY-024 magnetic hall effect sensor. On Tinkercad this is represented by a PIR sensor for testing and simulation purposes, but more importantly due to the fact that Tinkercad does not offer any hall effect modules.

The hall effect sensor offers a much greater longevity as opposed to a pushbutton, as the module is less likely to be damaged over time and the module itself can also be easily replaced instead of having to replace a whole pushbutton, and resolder the circuit.

There are also 5 separate pin headers which I have implemented as testing stations for various signals. An oscilloscope can be used on these to measure signals / waveforms coming from them, and ensure that the circuitry is working as expected. If any issues arise with the PCB it will now be much easier to diagnose faults.

A start / stop button was incorporated into the new design to allow for a much easier method of halting circuitry functions. I have also added a green LED to indicate when the system is running.

One of my peers brought up the point that the °C symbol was not present on my LCD display. This has been rectified and the symbol is now present, ensuring no confusion.



It was also mentioned that the buzzer was quite hard to hear, however this was a simple and easy coding fix:

Old code:

```
tone (buzzer, 50, 100); // buzzer turns on, as temperature is out of range delay(100);
```

New code:

```
tone (buzzer, 50, 100); // buzzer turns on, as temperature is out of range delay(50);
```

```
tone (buzzer, 75, 150); delay(50);
```

```
tone (buzzer, 100, 175); delay(50);
```

The use of multiple tones / pitches has resulted in a more noticeable sound.

B) Revision control document

Design Description
This circuit has been developed to monitor / convey the temperature of a server room, if the door to the server room is open / closed and turn lights on if motion is detected within the room. The temperature inside of the server room should not dip below 18°C, nor exceed 24°C. If the server room temperature is deemed to be outside of this specified range, an audible output will be sounded, alerting staff. This audible output is sounded within a facilities control room,. The control room is also equipped with a blue light and red light to indicate if temperature is out of bounds (blue light is displayed when temperature is <18°C, red light is displayed when temperature is >24°C.) The control room is equipped with an LCD display to convey critical information, such as temperature, if the door is open or closed and if motion is detected within the server room. The server room has a PIR sensor to detect movement, and automatically turn lights on if motion is detected. The door of the server room is monitored via a push button.
Changes to system
I have incorporated each one of the improvement points mentioned in the peer review in my improved design. The audible output is louder now due to the change in tone / pitch that I have coded in. This was an important and significant improvement on the original buzzer, as I must admit it was originally hard to hear due to the monotone pitch that I had chosen. I have also added a start / stop button (and a green LED to indicate when system is running) which greatly increases the convenience of stopping the system, as previously power supply to the arduino had to be cut off to halt system functionality. The °C symbol is now clearly on the LCD, ensuring that there is no confusion as to what the number on the LCD is actually displaying. My PCB is now much more convenient for fault finding and testing with the addition of testing stations spread across the tracks. This will allow various testing equipment to easily read values, allowing for issues to be identified much faster. The addition of a hall-effect sensor on the door will improve the longevity of components, compared to the simple pushbutton in version 1.
Changes to technical documentation
All technical documentation / drawings will need to be updated so that they are representing version 2 of my PCB. I have already changed the schematic so that it is now showcasing the latest version (this is also represented in the title as it clarifies that the schematic is version 2). Any technical manuals will need to be updated and changed so

that they are in line with the new circuitry. The PCB layout will also need to be amended so that the new PCB can be developed and manufactured as appropriate. Due to the increased number of components my bill of materials from task 1 will also need updating so that the correct components can be purchased in their correct quantities.

Any SOPs developed for the manufacturing process will need amending, as the manufacturing process for the PCB has changed. This also means that the risk assessment that I developed at the start of task 2 must be updated to include any new potential risks which may be encountered. If any new hazards or risks are identified then controls must be put in place to prevent accidents.

New tests and testing methods will need to be developed, implemented and documented to ensure that all the new components are working as expected and that they do not interfere with the functionality of the circuit.

C) Evaluation and implementation report

Testing

I used both software and hardware testing throughout various stages of the project. Prior to assembling the breadboard, I used Tinkercad to develop a design for my circuit including which components I was going to use. I then virtually simulated the circuit to make sure that all the components were wired correctly and that my coding would allow for the appropriate functions and applications of the circuitry.

After virtually simulating the code, I physically built the breadboard. Virtual simulation and physical simulation did show some disparities. The main difference which I found between virtual simulation and physical simulation was the noise encountered when I had physically built my circuit. This led to me removing the servo motor which was originally planned to represent the door.

Whilst removal of the motor did make a significant improvement, there was still a large amount of noise being encountered with the temperature sensor. At first, I decided to add capacitors in the hope that this would reduce the noise and allow the sensor to operate at an appropriate level. The noise encountered was significantly reduced, and for the most part dealt with. However, I was still not happy with the operation of the sensor, as I was worried

that it may not sense the temperatures required to a consistent level due to the spikes that it was receiving.

I then decided it was time to look for a new sensor. The sensor kit available in my workshop had a temperature sensor (GX18B20) which acts as a direct substitute to the Dallas temperature sensor. I then researched this module to see if the tolerance and general operation would be better than the one I was already using (model MCP 9700A-E/TO). Eventually after researching the new sensor I decided to use it instead of the old model, as it provided much greater accuracy. After updating my code and wiring it into the breadboard, I was relieved to see that this sensor was giving me accurate readings. Ultimately, the GX18B20 was used in my PCB and after switching to it I have encountered no issues with temperature readings.

This situation was a great example of the differences between virtual testing and physical testing. Whilst my circuit worked with no issues virtually, I had to make multiple significant changes to my physical circuit in order to ensure correct functionality. It is crucial to always follow up virtual testing with physical testing, as problems like noise and sensor tolerance are often not encountered within a virtual space.

After confirming that the physical and virtual simulations were working as expected, the next testing that I did was in task 2.

Prior to manufacturing my PCB, I virtually simulated the manufacturing operations using Fusion. This allowed me to watch each operation in depth, with the ability to zoom in, and slow down the speed of each process to carefully ensure that all operations were running correctly.

After successfully manufacturing my PCB I tested for continuity using an oscilloscope. This came in handy, as two of my tracks had a small piece of copper lodged between them. After I removed this, I retested for continuity and all tracks were separated as intended. I then ran across something which initially confused me, as two certain tracks were initially carrying a voltage through the oscilloscope probes. After repeated testing, I decided to manufacture a second PCB as I could not get this to stop. I then ended up with the same situation as before, with the same two tracks with the exact same issue.

Eventually I realised that this was due to the capacitors storing the charge from the probes of the oscilloscope, not a short circuit. I then continued work on my original PCB, with no significant issues to report.

Whilst using an oscilloscope is a fundamental part of electronics, it is important to fully understand the functions of components and equipment prior to use in order to reduce misunderstandings.

After successfully soldering my PCB with the help of the oscilloscope, it was time to test the functionality of my circuit.

I used a pre-manufactured test rig to replicate the situations which were likely to be encountered within the server and control rooms. I believe with the testing equipment available to me in my workshop, that I did the best I could.

I used a variety of tests such as a simple motion test for the PIR sensor, which showed me that the sensor was registering motion and turning on the lights in the server room. This was a simple yet effective test which verified that the system was functional.

Another one of the tests which I used was a simple pressure test on soldered components, to ensure that they were all connected to the circuitry and that no components were in danger of coming loose. The vast majority of components were stiff and secure to the PCB, with the loose components using slightly more solder. I believe this test was sufficient and appropriate for the equipment used.

The easiest test that I had done was the pushing of the button. I could see the LCD displaying that the door was closed when the button was pressed. This testing method was fully sufficient, and did not need to be overcomplicated.

The temperature test was another quite simple test. When the temperature was in range, no outputs were triggered. When above 24°C, the red LED turned on, as well as the audio output. I then used plastic icecubes to cool down the sensor, and the blue LED turned on, with the buzzer doing the same. I believe this test was sufficient and showed me that the appropriate outputs were functioning as intended.

Capabilities of circuitry

My design fully incorporates all aspects of the design criteria and brief, resulting in a circuit which meets all requirements.

The circuitry is able to monitor the temperature of the server room, and light up the required LEDs (red and blue). It is also able to turn on the lights within the server room (represented via a yellow LED), when motion is detected through a PIR sensor. Door status is monitored through the use of a push button acting as a pressure switch (this will be changed to a hall-effect sensor). An LCD display conveys all relevant information, such as temperature, door state and motion state.

The design criteria has been fully met, however, the specification will need to be amended to include some of the changes made throughout the project, such as the use of a different temperature sensor and the removal of a servo motor.

Information necessary for a third party to implement my design

Third parties will be provided with a new & improved design specification, including health and safety guidelines to follow. Design criteria is also to be given. All new diagrams / drawings are to be provided, such as the wiring diagram and schematics to allow for correct wiring and installation. New PCB layout is to be provided for manufacturing of PCB. Third parties are to have access to virtual simulation software in order to test circuitry.

Physical testing equipment / components are also to be provided, as results may vary from virtual simulations. The full code is to be provided, so that the circuit can function as needed. Brand new bill of materials is to be given out, to ensure third parties are aware of all components needed and their prices.

A full risk assessment is to be provided, however risks and hazards may depend on third parties workshops and their own methods of producing PCB. Third parties may need to supply training to staff in order to manufacture PCB correctly and safely.

Methods of testing are to be provided, so that third parties may conduct identical testing and ensure same results.

Third parties will need to ensure that they are aware of any relevant standards, such as IET's wiring regulations (BS 7671).

Additional factors of implementation

Cables connected to sensors are to use multi-strand wires. This is to prevent cables from becoming damaged, as the sensors' may be subject to additional stress / strain as they are moved and adjusted as required. Multi-strand wires are more malleable than just a single-strand wire, and offer superior resistance. If a wire is to break, it will not stop the circuit from working, as opposed to a single-strand wire.

Pin headers are also to be used, due to the convenience they offer. Cables connected to pin headers can easily be disconnected, rather than having to unsolder joints, which may damage circuitry.

Health and safety is a priority, and risk assessments are to be adhered to at all times. Correct PPE must be worn during each stage of manufacture and implementation. Standards like COSHH and PUWER are to be followed when appropriate. The HSE's guidance on the 5 stages of risk assessments must be followed whilst creating any risk assessments.

During any wiring, the IET's wiring regulations (BS 7671) are to be adhered to.

I do not believe any further adaptations or improvements are required, other than those suggested in the peer feedback (and the green LED I chose to add myself), as I have fully met the criteria and my specification.

Overall evaluation

I believe I used a plethora of techniques to test and problem solve throughout the production of my prototype (for example, the use of serial monitor to measure the temperature readings). I used testing throughout the whole of the project, to both verify and improve on my work (replacing the temperature sensor).

The manufacturing process went well, as I had identified many risks prior to starting work. I adhered to my risk assessment while undertaking any activities which held risk. This also took the form of using PPE. The use of PPE and soldering equipment resulted in soldering which I believe to be of a high standard and quality. There were no spillages, or damage during the soldering phase and majority of components did not have to be resoldered. As mentioned prior, those that did need more solder worked perfectly after application of slightly more solder material.

I am also happy with the size of my PCB, as I did not want it to be too big and waste material, however I also wanted to keep the tracks far from each other to reduce the likelihood of a short circuit. My PCB was around 2mm thick, 76mm wide and 86mm long which I am satisfied with. For the tracks, I decided to go down 0.7mm as I wanted to keep the likelihood of a short circuit as slim as possible, as mentioned above, however I did not want to go too deep and weaken the PCB.

Overall I am very happy with how my prototype has turned out. I believe my circuit was ultimately fit for purpose and all the components that I chose complimented the system. I am very pleased with the feedback that I received as it allowed me to improve an already fully functional and well working circuit.

Bibliography:

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Principal Moderator Commentary

The candidate has thoroughly analysed the design criteria and demonstrated a comprehensive understanding of design principles methodologies by comparing and analysing a range of contrasting proposals and solutions for each element of the design criteria e.g./detection methods with three different appropriate solutions. The design specification, final evaluation and revision document are written using accurate industry terminology and laid out in a professional manner, as would be expected in industry, with a range of calculations used to identify suitably selected components and an in-depth bill of materials listing all necessary components that are needed. The design brief and criteria has been critically analysed throughout.

A comprehensive use of software technologies are evidenced both in the design specification and revision documents e.g. wiring diagrams, PCB layout and virtual simulations (demonstrating functionality). The candidate has excellent technical skills when developing the model and uses a range of evidence to support this. The candidate reviewed the peer review form and revised and optimised the design using software techniques which demonstrated a comprehensive understanding of the criteria. The revision control document was detailed and outlined all changes required to the system demonstrating a thorough understanding, the candidate considered all changes needed to the technical documentation e.g. wiring diagrams, PCB layout to complement these changes.

There is evidence of outstanding safe working practices and that good housekeeping has been followed throughout. This is outlined in the detailed risk assessment containing all the necessary mitigations as well as the correct use of protective equipment e.g. overalls, goggles and safe use of tools as evidenced in photographs during manufacturing of the PCB. The high quality of the finished prototype is evident, and the candidate demonstrates excellent practical skills when developing models and manufacturing the final model as evidenced in the documented photographs. The candidate discussed methods used for production and development of the printed circuit board in task 2 written documentation, which evidenced a good understanding of the equipment used.

A full and comprehensive list of functional testing is outlined demonstrating a thorough understanding of the design criteria. The candidate understands testing methodology and uses an iterative approach by testing each element of the design criteria e.g. temperature, sound, which meets all the requirements of the design brief and criteria. The design criteria was analysed, the test methods and test outcomes were evident in a table. As well as

functional testing, a meter was used to fault find a short circuit demonstrating analytical skills by the candidate.

The video demonstrated a thorough understanding of the finished prototype by the candidate and shows complete functionality that meets the requirements of the design brief. The candidate could verbally describe the functionality and understood the expectations of the design criteria. The quality of work was outstanding and excellent technical skills were demonstrated which were evidenced with a range of photographic and video footage.

The candidate produced a thorough evaluation by using accurate terminology and language which discussed all main points e.g. testing, cable types, third party implementation. Analysis and reasoning were used throughout the evaluation which evidenced the candidates in depth knowledge. The candidate responded to the peer feedback and made changes to the design, this is discussed thoroughly in the evaluation and revision document.

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