**Prototype I for the “Hot Car Emergency”**

**Deliverable F**

**Project Group B2**

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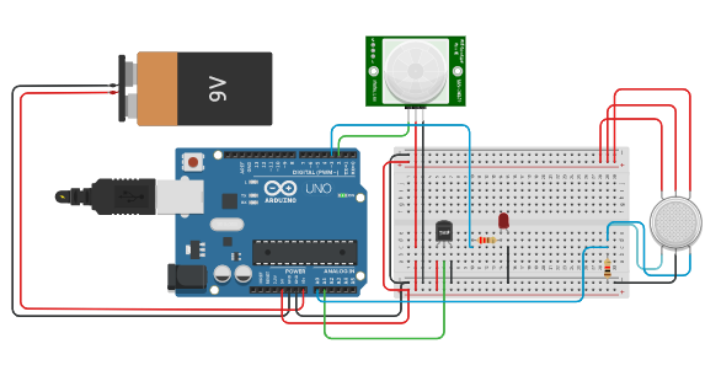
# 1.0 Introduction

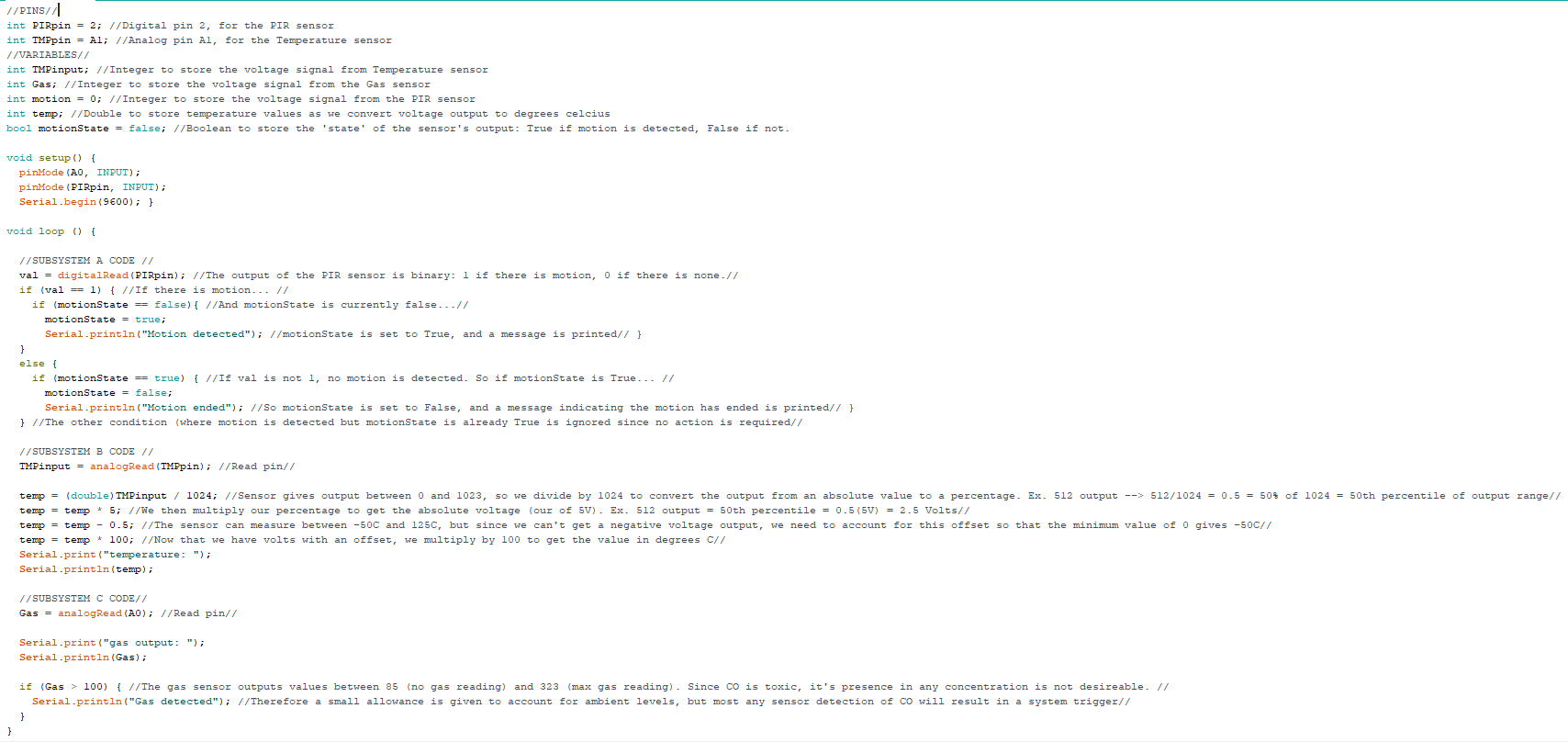
The previous deliverable outlined the direction in which the group is going with regards to the device and its prototype. Since then, many changes have been made to optimize the device and its cost, thus producing a new prototype and bill of materials, both of which are presented in this deliverable. The prototype featured in this deliverable is entirely simulated, and is meant to be a proof of concept, as well as a platform on which the following prototypes will be built. The group thoroughly explains the components of this system, as well as the feedback generated from the client from the meeting a few weeks ago and friends and family in order to advance the iterative process.

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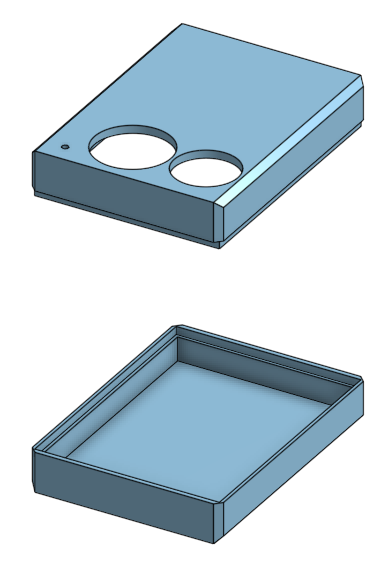
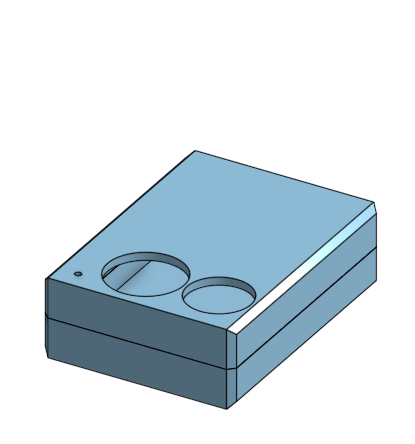
# 2.0 Prototype and Explanation

The first prototype operates in it’s simulated environment with a relatively simple circuit. The sensors for subsystems A, B and C are connected in parallel to a breadboard where they receive their input from, and relay their output to, the arduino control board. The circuit diagram for the sensor array and it’s accompanying C++ software are available below (figures 1 and 2). The codebase is also available in Appendix 1, which has been provided alongside this document. The 3D printed device case is designed to be compact and robust, with most of the internal components housed within the plastic shell - only the sensor contact surfaces are exposed to the environment. The device itself is to be placed on the center console of the vehicle (see fig.4), in order to optimize the angle for the PIR motion sensor’s field of view, and to avoid direct sunlight (like you would see on the dashboard) which could alter the temperature sensor’s readings.

*Figure 1: TinkerCAD circuit*

*Figure 2: TinkerCAD code for the function of the motion, temperature, and CO sensors[[1]](#footnote-0)*

*\* Ctrl+ to properly see code*

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*Figure 3: OnShape prototype device case render*

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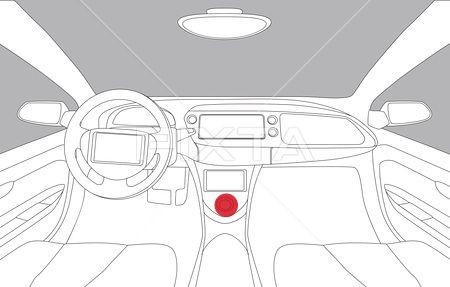


Figure 4: device location

## 

## 2.1 Analysis of Critical Components and Systems

| **Subsystem** | **Functionality** | **Technical description** |
| --- | --- | --- |
| A | Occupant detection | We’ll determine the presence of occupants by monitoring movement inside the vehicle. If there is continual movement detected, it can be assumed that there is an occupant (human or otherwise). Motion will be detected by the HCSR-501 PIR motion detection module. |
| B | Temperature detection | A thermistor will be used to measure the interior temperature of the vehicle. A danger threshold of 30 degrees celsius will trigger the alarm and message systems. |
| C | CO level detection | The MQ7 Carbon-monoxide deduction module will be used to detect the CO levels within the vehicle. Symptoms of CO poisoning first become apparent at levels of 70ppm, so a danger threshold of 50ppm will trigger the alarm and message systems. |
| D | Batteries & power supply | Two 1.5V AA batteries will be put in series to create adequate voltage for the control board. |
| E | Mobile connectivity | For mobile connectivity, our plan is to use Pushbullet to enable push notifications when CO or temperature levels become too high. Pushbullet is an internet service capable of sending sms messages, notifications and files to mobile devices via an app available on IOS and android. The signal from the sensors will be sent to the arduino, and if the conditions are too high, notifications will be sent to the guardians phone. |
| F | Alarm | The client requested the main focus of the prototype to be on alerting the vehicle owner of the presence of an occupant in the car. As a result, the bystander alarm will be minimalist, taking the form of a simple blinking LED light on the device. This LED will be connected directly to the arduino control board. |

*Table 1: Subsystem descriptions[[2]](#footnote-1)*

| **Part** | **Justification** |
| --- | --- |
| HCSR-501 | This will be the basis for our motion-detection subsystem, which will detect whether there are occupants in the vehicle. |
| NTC | The thermistor will be used to detect the temperature within the vehicle, to determine if conditions are dangerous. |
| MQ7 | This is the gas-sensing module we'll use to determine if the carbon monoxide levels in the car are dangerous |
| ESP8266 module | Our push-notification subsystem will use an open-source sms sending and notification management service called *pushbullet*. The device requires an internet connection for the push notification system to function, and the ESP8226 module will facilitate wifi connectivity as well as having a built-in control board. |
| AA Batteries | According to the Arduino website, the nano can be run on unregulated external power supplies from 6v to 20v without a voltage regulator. Four 1.5 volt AA batteries will be put in series to create the adequate voltage output to power the board. |

*Table 2: Part justifications¹*

# 3.0 Prototyping Test Plan

The testing for the first prototype has been completed in a simulated environment, and therefore we are bound to virtual testing. This was achieved via TinkerCAD and it’s built-in functionality. Below is the prototype test plan created to ensure we properly move forward with our iterative prototyping process.

| **Test** | **Part & Subsystem** | **Objective** | **Test Method** | **How Results will be Recorded** | **Date** |
| --- | --- | --- | --- | --- | --- |
| **Prototype I: Analytical Focused on Circuitry Virtual Prototype** | | | | | |
| **1.1** | PIR Motion Sensor (HCSR-501) Code and Circuit Test (Virtual via TinkerCAD)  Occupant detection | Establish the viability of the circuit design to provide adequate power input and to return adequate voltage output from the sensor. Establish the viability of the codebase to accurately collect and interpret output | Experimental verification through TinkerCad | Results will be recorded through the serial monitor in TinkerCad | Oct 28 - Nov 4 |
| **1.2** | Thermistor Sensor (NTC) Code and Circuit Test (Virtual via TinkerCAD)  Temperature detection | Establish the viability of the circuit design to provide adequate power input and to return adequate voltage output from the sensor. Establish the viability of the codebase to accurately collect and interpret output | Experimental verification through TinkerCad | Results will be recorded through the serial monitor in TinkerCad | Oct 28 - Nov 4 |
| **1.3** | CO Sensor (MQ7 Probe) Code and Circuit Test (Virtual via TinkerCAD)  CO level detection | Establish the viability of the circuit design to provide adequate power input and to return adequate voltage output from the sensor. Establish the viability of the codebase to accurately collect and interpret output | Experimental verification through TinkerCad | Results will be recorded through the serial monitor in TinkerCad | Oct 28 - Nov 4 |
| **1.4** | Vehicle placement | To identify and fully define what limitation (if any) are imposed on the system due to its location in the vehicle | The field of view was simulated and overlaid on the interior of a car to verify blindspots | Results were recorded in a figure  (appendix 4) | Oct 28 - Nov 4 |
| **Prototype II: Physical Circuit with Pushbullet** | | | | | |
| **2.1** | Pushbullet device connection  Mobile connectivity | A key portion of this project is notifying a parent/guardian/car owner that a child is present in the vehicle during dangerous conditions. This test will isolate the feasibility of doing so. | Sample information and notifications will be sent to team member’s phones | Screenshots of the shared sample information and notifications will be recorded from the phones | Nov 9 - Nov 12 |
| **2.2** | Pushbullet multiple device connection  Mobile connectivity | One of the feedback given to us, presented in section 5.1, is that the device should push to multiple phones. This test aims to see if that is possible. | Sample information and notification will be sent to several phones simultaneously | Screenshots of the shared sample information and notifications will be recorded from the phones | Nov 9 - Nov 12 |
| **2.3** | PIR Motion Sensor (HCSR-501) Code and Circuit Test (Physical Circuitry)  Occupant detection | To verify the circuit and sensor assembly to ensure adequate function | Objects will be placed in front of the device at ½ meter increments until it’s operating range. These objects will be moved at varying speeds at different times to test the sensor’s speed and accuracy | Sensor response times, object distances and velocities, and sensor outputs will be recorded in a spreadsheet | Nov 5 - Nov 8 |
| **2.4** | Thermistor Sensor (NTC) Code and Circuit Test (Physical Circuitry)  Temperature detection | To verify the circuit and sensor assembly to ensure adequate function | The sensor will be placed in an environment with a controlled temperature. The temperature will then be incrementally increased from 0 degrees celsius until the upper bound of the thermistor’s operating range. | Sensor outputs will be recorded in a spreadsheet and compared with control values. | Nov 5 - Nov 8 |
| **2.5\*** | CO Sensor calibration sequence | To verify the viability of the part, and to ensure proper calibration of the probe. | The sensor calibration procedure, as outlined in the module’s technical documentation, will be completed. CO samples will be measured at different concentrations to verify proper function | Sensor reactant membrane temperature will be plotted against gas concentration, and compared with control values from the technical documentation | Nov 5 - Nov 8 |
| **2.6** | CO Sensor (MQ7 Probe) Code and Circuit Test (Physical Circuitry)  CO level detection | To verify the circuit and sensor assembly to ensure adequate function | Smoke from paper and wood burning will be introduced to the sensor, to test its ability to detect CO in its environment | Sensor output values will be compared with Stoichiometrically determined theoretical CO concentrations | Nov 5 - Nov 8 |
| **2.7** | LED Array or Buzzer System[[3]](#footnote-2) Code and Circuit Test (Physical Circuitry)  Alarm | To verify the circuit and sensor assembly to ensure adequate function | Buzzers will be placed at incremental distances from a microphone to determine their relative power | The volume of each buzzer will be measured in decibels and compared with each other to establish relative usefulness and volume | Nov 5 - Nov 12 |
| **Prototype III: Updates from Prototype III TBD** | | | | | |
| *TBD as the iterative design process continues* | | | | | |

*Table 3: Preliminary Prototyping Test Plan*

## 

## 3.1 Expansion on Objectives

To date, we have met with the client a total of 2 times. Once during his presentation, and another where we presented to him our preliminary concepts. So far, the main objectives remain relatively similar to before; a) identify that there is a child present in the vehicle; b) detects for dangerous conditions of CO and temperature; *c) takes actions to lower temperature*; makes sure the child gets to safety in the *quickest* way possible (e.g. alarms of notifications to a parents phone); d) simple to use and affordable for the average customer.

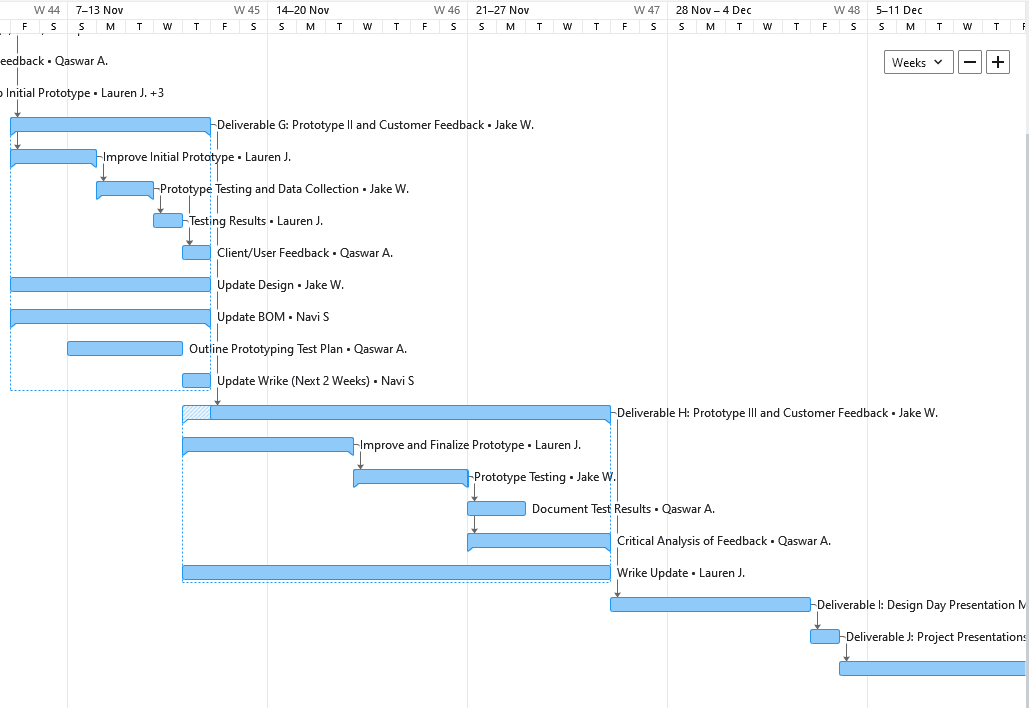
## 3.2 Test Results

| **Test** | **Result summary and analysis** | **Stopping criteria** | **Documentation** |
| --- | --- | --- | --- |
| **1.1** | This test was facilitated by TinkerCad’s built-in sensor input system, which allowed us to drag a particle to test the sensor’s motion detecting capability. This was done 5 times at 5 different distances. | This test was terminated once it was proven able to identify movement 5 times in a row, without failure, from anywhere within its operating radius. | Appendix 1, i and ii |
| **1.2** | This test was facilitated by TinkerCad’s built-in sensor input system, which allowed us to set the ambient temperature for the thermistor directly to verify it’s output. The thermistor was tested at all temperatures within its operating range. | This test was terminated once it was proven able to accurately detect temperatures at every level on the sensor’s operating range | Appendix 2 |
| **1.3** | This test was facilitated by TinkerCad’s built-in sensor input system, which allowed us to drag a cloud of gas to test the sensor’s reactions to varying concentrations of particulates. The outputs were verified for all distances allowed for by the TinkerCad environment. | This test was terminated on it was proven able to return valid voltage outputs for varying (unknown) concentrations of gas within the tinkercad environment | Appendix 3 |
| **1.4** | This test was completed mathematically, to analyze the interior geometry of the standard automobile, to identify potential blind-spots in the motion sensor’s range caused by obstacles in the vehicle. | This test was deemed ‘complete’ once all the relevant considerations pertaining to the interior dimensions of the average family vehicle were taken into account, and the desired calculations completed | Appendix 4 |

*Table 4: Prototype I test results*

## 3.3 Wrike Update

Changes were made in accordance to the feedback given to us this past Tuesday. Tasks should be given to one individual, with others acting as helpers if necessary. Below is the gantt chart for the next two weeks:



*Figure 5: Wrike Gantt Chart for Deliverables G & H with Dependencies*

# 4.0 Updated BOM and Target Specifications

## 4.1 Bill of Materials

| **Part** | **Description** | **Price** | **Store** | **Url** |
| --- | --- | --- | --- | --- |
| HSCR-501 | PIR motion detecting module | $3.00 | Makerspace | <https://edu-makerlab2021.odoo.com/shop/product/pir-sensor-46?category=6#attr=> |
| NTC | Thermistor, for detecting temperature | $2.18 | Makerspace | <https://edu-makerlab2021.odoo.com/shop/product/ntc-thermistor-138?category=6&search=Thermistor#attr=> |
| MQ7 module | CO gas sensing module | $9.95 | Pishop | <https://www.pishop.ca/product/carbon-monoxide-gas-sensor-mq-7/> |
| AA Batteries | Standard AA batteries for power supply | $2.85 | Pishop | <https://www.pishop.ca/product/aa-battery/> |
| Battery holder | Case to house the AA batteries | $1.00 | Makerspace | <https://edu-makerlab2021.odoo.com/shop/product/aa-battery-holder-48#attr=47> |
| ESP8266 ESP-12E v1.0 | Combined control board and wifi module to control modules and send push notifications | $9.95 | Pishop | <https://www.pishop.ca/product/esp8266-esp-12e-v1-0-wifi-cp2102-iot-lua-267-for-nodemcu/> |
| Protoboard | Board to solder circuits | $0.50 | Makerspace | <https://edu-makerlab2021.odoo.com/shop/product/protoboard-51?search=board#attr=53> |
| Resistors  (220Ω,4.7kΩ) | Resistors for the LEDs and the MQ7 module | $0.02  (1¢ \*2) | Makerspace | <https://edu-makerlab2021.odoo.com/shop/product/resistor-6?search=resistor#attr=9> |
| Connection wires | Wires for connecting the various components | $2.50 | Makerspace | <https://edu-makerlab2021.odoo.com/shop/product/wire-5ft-45?search=wire#attr=213,217> |
| **Total:** | **$39.90 After tax** | | | |

*Table 5: Revised BOM with descriptions and URLS. This has received approval.*

## 4.2 Target Specifications

Due to the nature of our prototype, and it’s development since deliverable C, the target specifications have not needed change at all. Below are the user benchmarking and target specifications, respectively, as they were in deliverable C.

| **Company** | **Importance (weight)** | **Kia** | **Nissan** | **GM** | **Tesla** | **Hyundai basic** | **Hyundai premium** | **Hyundai advanced** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Availability** | **2** | **3** | **2** | **1** | **1** | **2** | **1** | **1** |
| **Sensor** | **3** | **2** | **1** | **1** | **3** | **1** | **2** | **3** |
| **Alert** | **1** | **3** | **2** | **2** | **1** | **3** | **3** | **3** |
| **Total** |  | **15** | **9** | **7** | **12** | **10** | **11** | **14** |

*Table 6: Technical benchmarking competitor general evaluations*

| **Design Specification** | **Relation** | **Value** | **Units** | **Verification Method** |
| --- | --- | --- | --- | --- |
| **Functional Requirements** | | | | |
| **Thermistor** | **=** | Yes | °C | Test |
| **Carbon Monoxide Detector** | **=** | Yes | PPM | Test |
| **Functions Under High Temperatures** | **=** | Yes | N/A | Test |
| **Child Sensor** | **=** | Yes | N/A | Test |
| **Bystander Alarm** | **=** | Yes | N/A | Test |
| **Mobile Communication** | **=** | Yes | N/A | Test |
| **Constraints** | | | | |
| **Cost (Prototype)** | **<** | 50 | CAD | Given |
| **Cost (Final Product)** | **>** | Unlimited | UAE dirham | Given |
| **Materials** | **=** | 3D Printing PLA plastic |  | Test |
| **Time to Complete** | **<** | 4 | Months | Given |
| **Non-Functional Requirements** | | | | |
| **Easy Setup and Installation** | **<** | Yes | N/A | Test |
| **Heat Resistant** | **>** | Yes | N/A | Test |
| **Battery Powered** | **=** | Yes | N\A | Design |
| **Volume** | N/A | 20x10x5 | cm | Design |
| **Compatibility to varying vehicles** | = | Yes | N/A | Design |

*Table 7: Target specifications*

Due to our limited budget of $50.00, we are limited in our access to materials and premade components. Compared to the industry manufacturers, our team is not equipped with as many of the resources, or indeed the expertise, required to produce a system like this. Thus, it can be said that we are meeting the target specifications that we have outlined in Deliverable C to a predictable and realistic extent. In fact, our functionality is superior to existing and forecast devices because none of them measure internal temperature or carbon monoxide concentration, our device therefore provides an added layer to assess poor conditions in the vehicle.

# 5.0 Feedback and Comments

Group members isolated one or more individuals in their running circles to ask their thoughts on the prototype and its various mechanisms. This is to seek further insight into what a potential user and/or customer would find attractive or unattractive in a product like this.

## 5.1 Individual 1: Working class, licensed driver, parent

Since a physical prototype has not yet been materialized, the concept diagrams were shown to this individual, as well as a detailed description of its estimated functions. This individual has no education background in circuitry or engineering, and thus those aspects were not overly discussed.

Their thoughts:

* *Overall a good idea that addresses a serious issue.*
* *It would be really useful and important that the notifications push to multiple phones in case the person who owns the car doesn’t have their phone with them when they leave the car.*
* *It’s probably hard to distinguish the difference between the alarm for this and a normal car alarm. This is something that probably has to be standardized.*
* *What is the incentive for someone to actually buy this? No one thinks they are going to be the ones who forget their child in the car.*
* *Sensors seem good.*
* *Would this also work for dogs? Dog owners are crazy and would probably buy this more than parents.*

## 5.2 Individual 2: Engineering student at Carleton, licensed driver, with a younger sibling

Concept and circuit designs, as well as a thorough description of the concept was outlined to this individual. This individual is more likely a potential user than a customer.

Their thoughts:

* *Physical design is just fine. Nothing special.*
* *How reliable is the battery system? I would not trust a device like this that runs just on AAs. It should be rechargeable. I would not buy this because of that.*
* *It seems complex for no reason. Why do you need a motion sensor? Why not just always detect for harsh conditions?*

## 5.3 Individual 3: Civil Engineer, licensed driver, parent

Their thoughts:

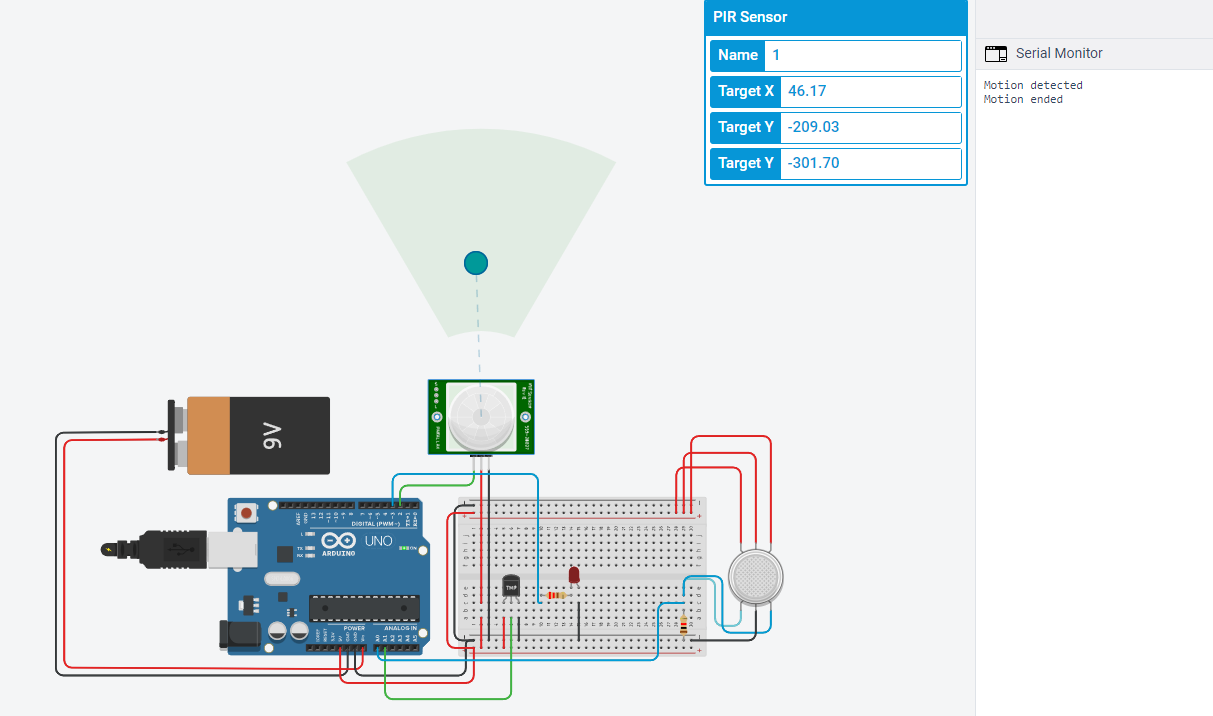
* *The design concept features some good ideas.*
* *Where will the device be placed? And how will you secure it so that it does not move in the car?*
* *I think there should be an additional way to contact the parent, since sometimes there is no internet connection.*
* *An LED to alarm people around the car is not enough, you should add some type of sound alert such as a speaker or a buzzer.*

This feedback will be considered when making changes for prototype II and its respective components.

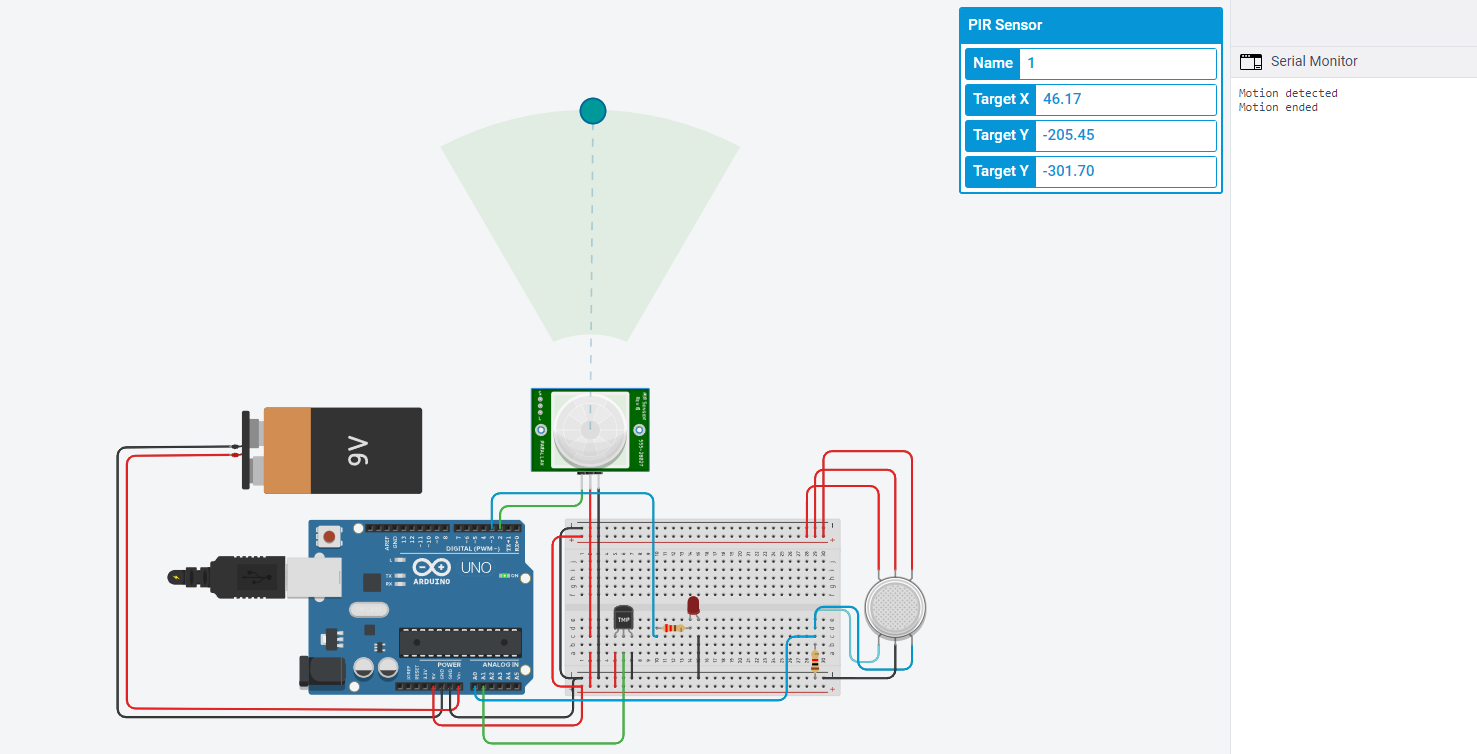
# 6.0 Conclusion

Due to a late approval for the bill of materials, paired with group member conflicts, the prototype presented in this deliverable is virtual and very conceptual. An updated prototype test plan was created to compensate for this issue. Preliminary virtual prototype testing was conducted on 3 subsystems of the concept, motion, temperature, and CO detection. This allowed the group to verify code before the physical parts arrived. We also reached out to potential customers and/or users and acquired feedback that will be translated into prototype II.

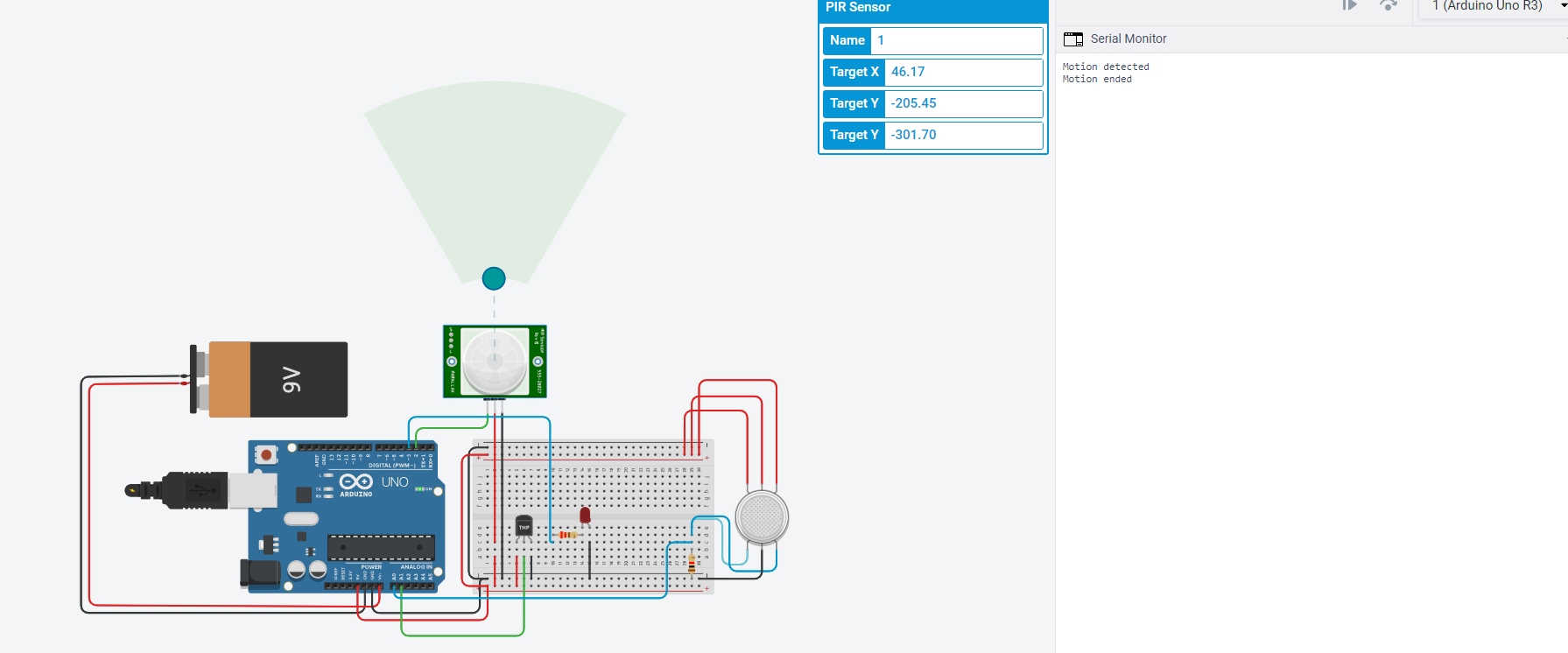
# Appendix 1: Test 1.1 results



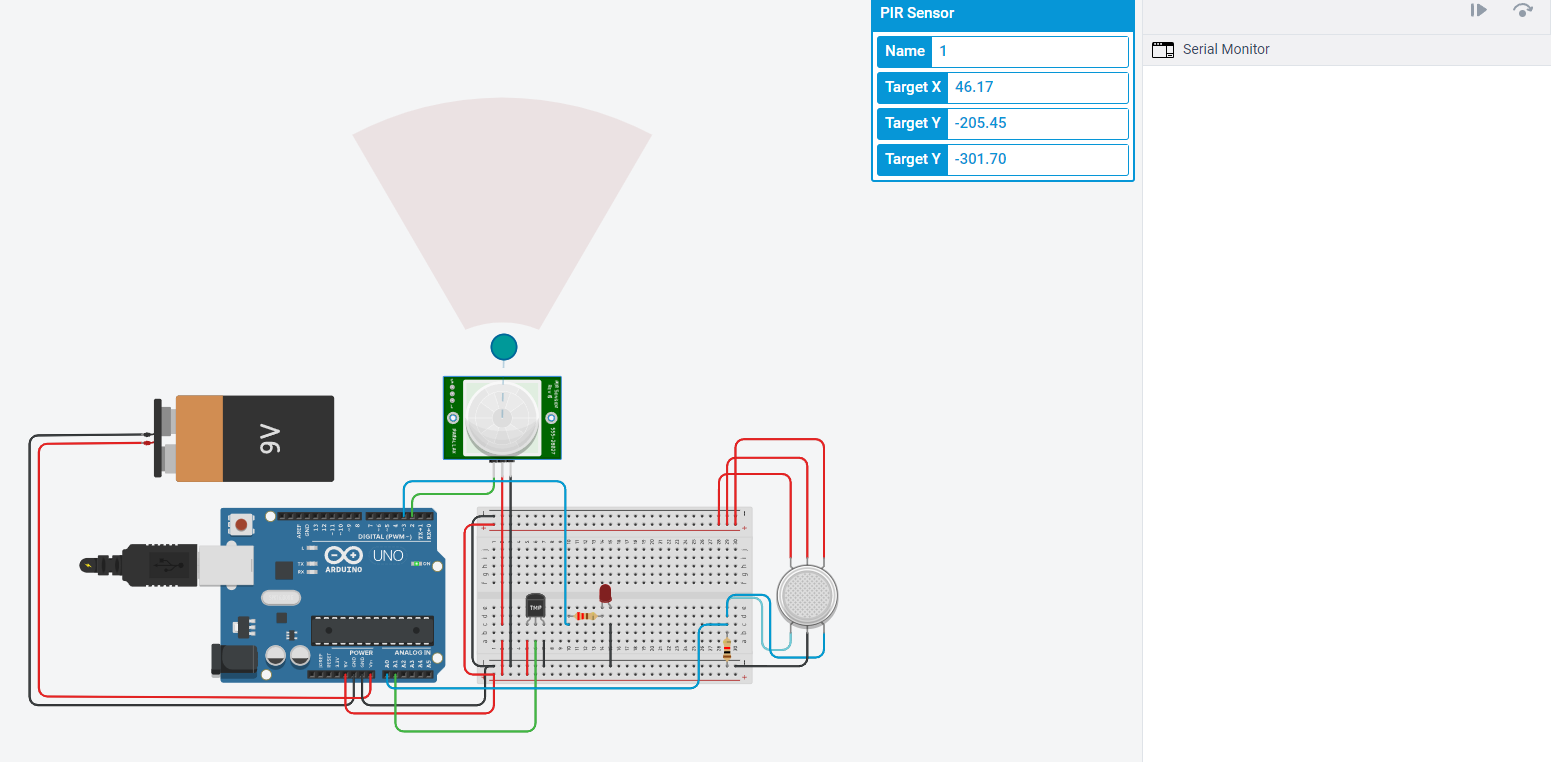
*Figure 6 : PIR module particle test, within range.*



*Figure 7: PIR module particle test, at maximum range*

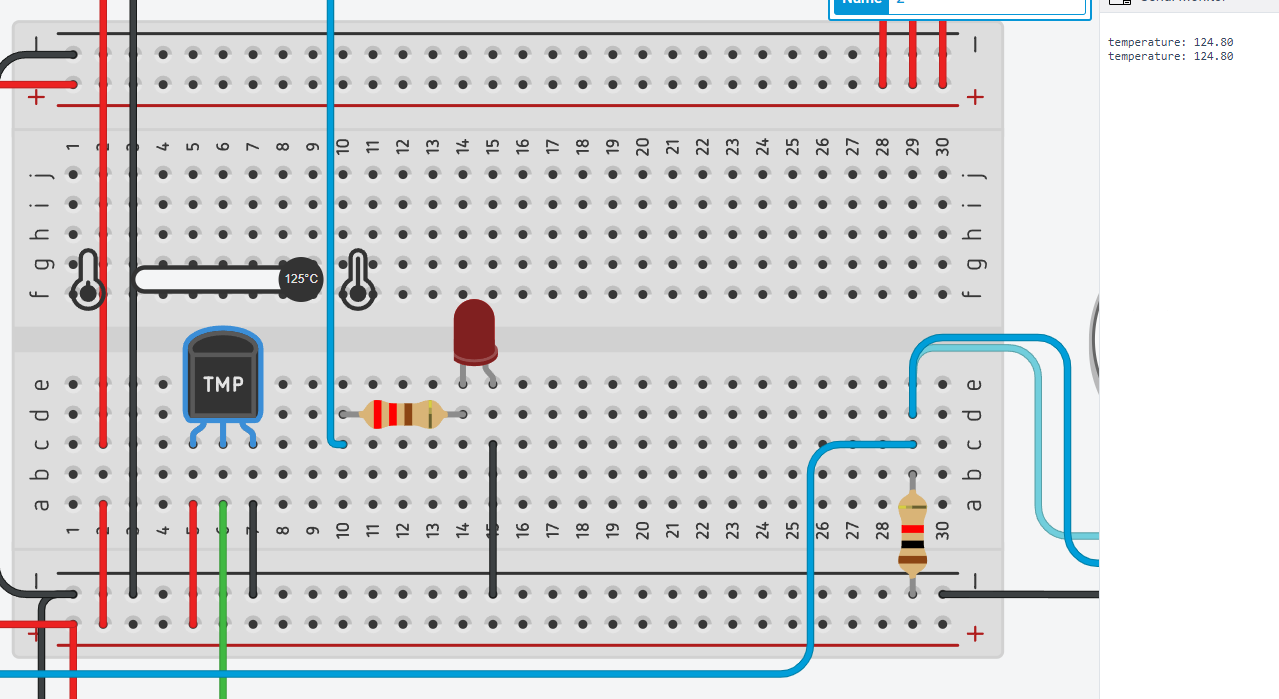
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*Figure 8 : PIR module particle test, at minimum range*

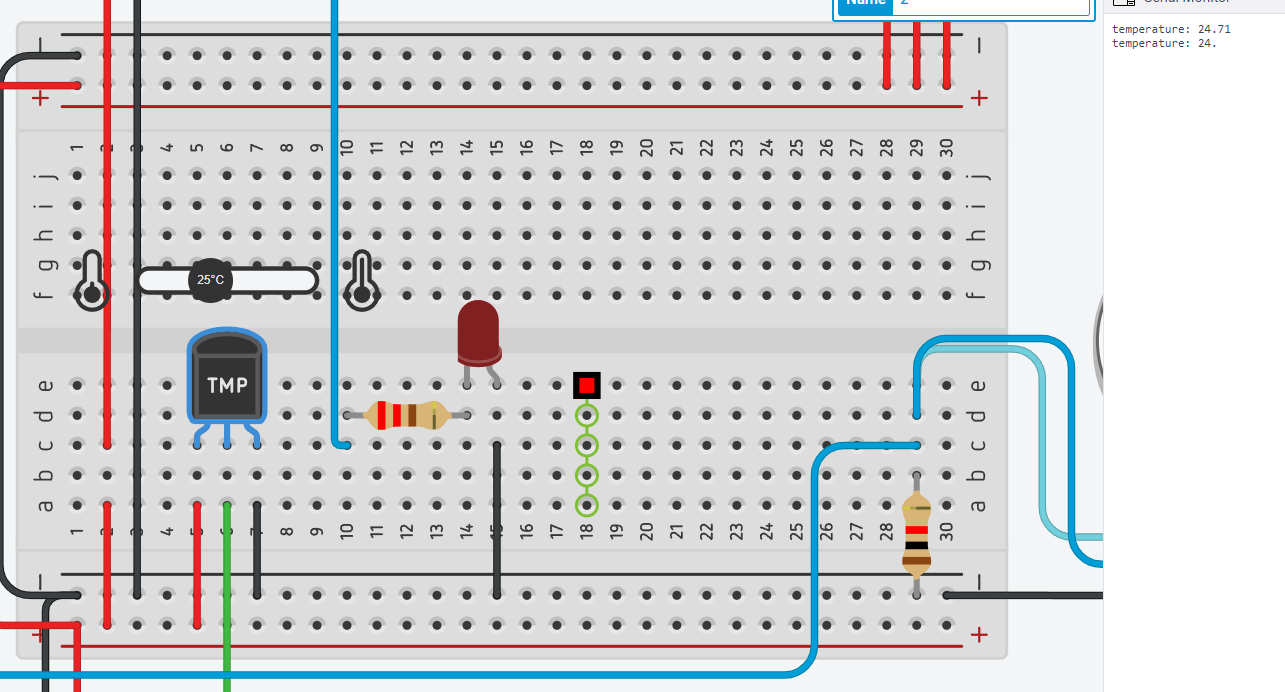
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*Figure 9 : PIR module particle test, outside range. Note the lack of return values*

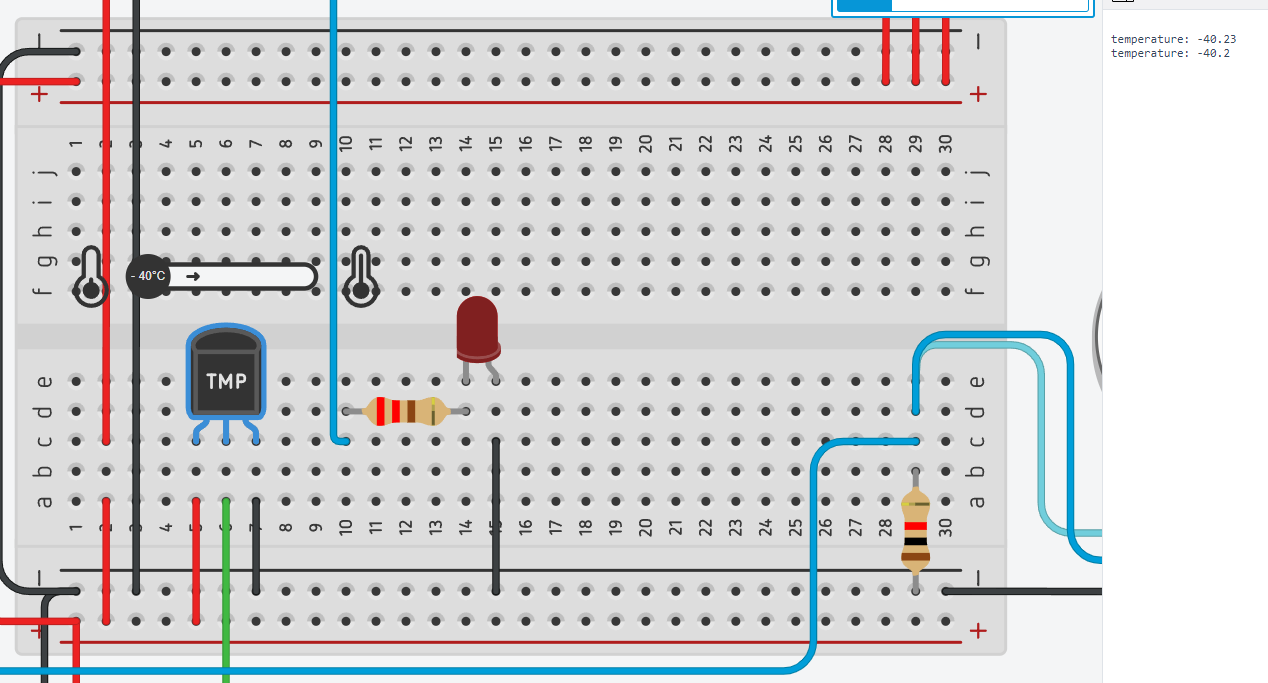
**Appendix 2: Test 1.2 Results**



*Figure 10: TMP sensor test, maximum temperature.*

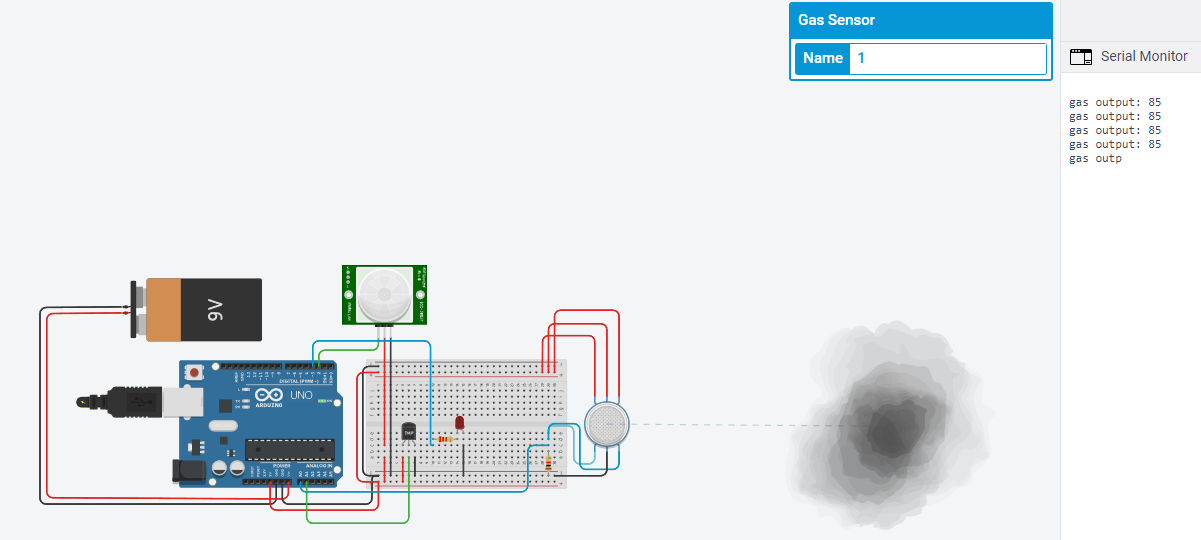
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*Figure 11: TMP sensor test, in-range temperature.*

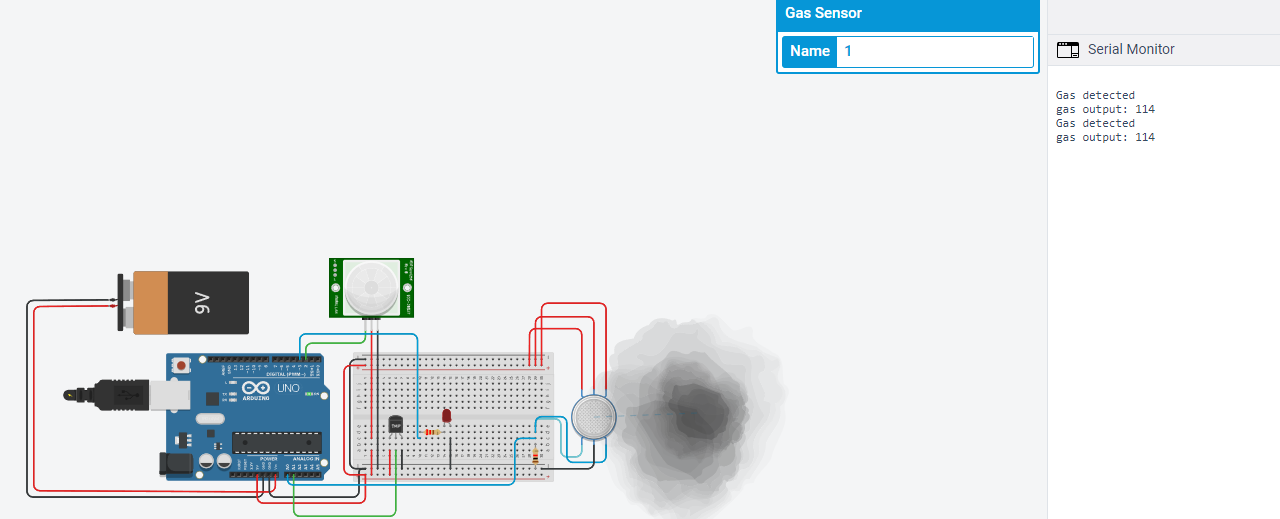
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*Figure 12: TMP sensor test, minimum temperature.*

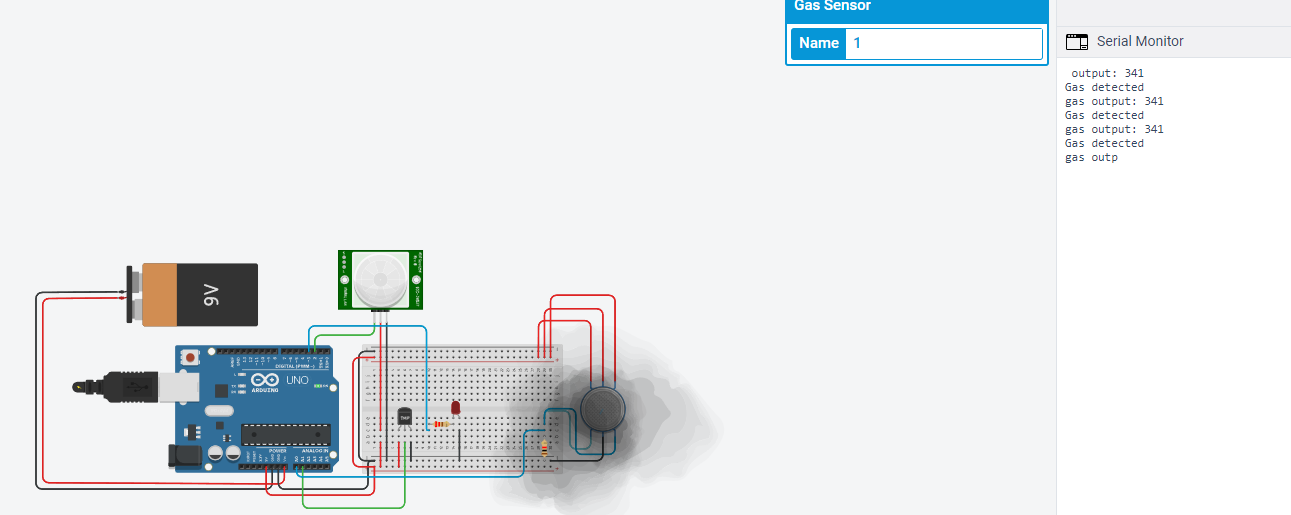
**Appendix 3: Test 1.3 results**

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*Figure 13: Gas module test, Minimum output value. Note the lack of notification*

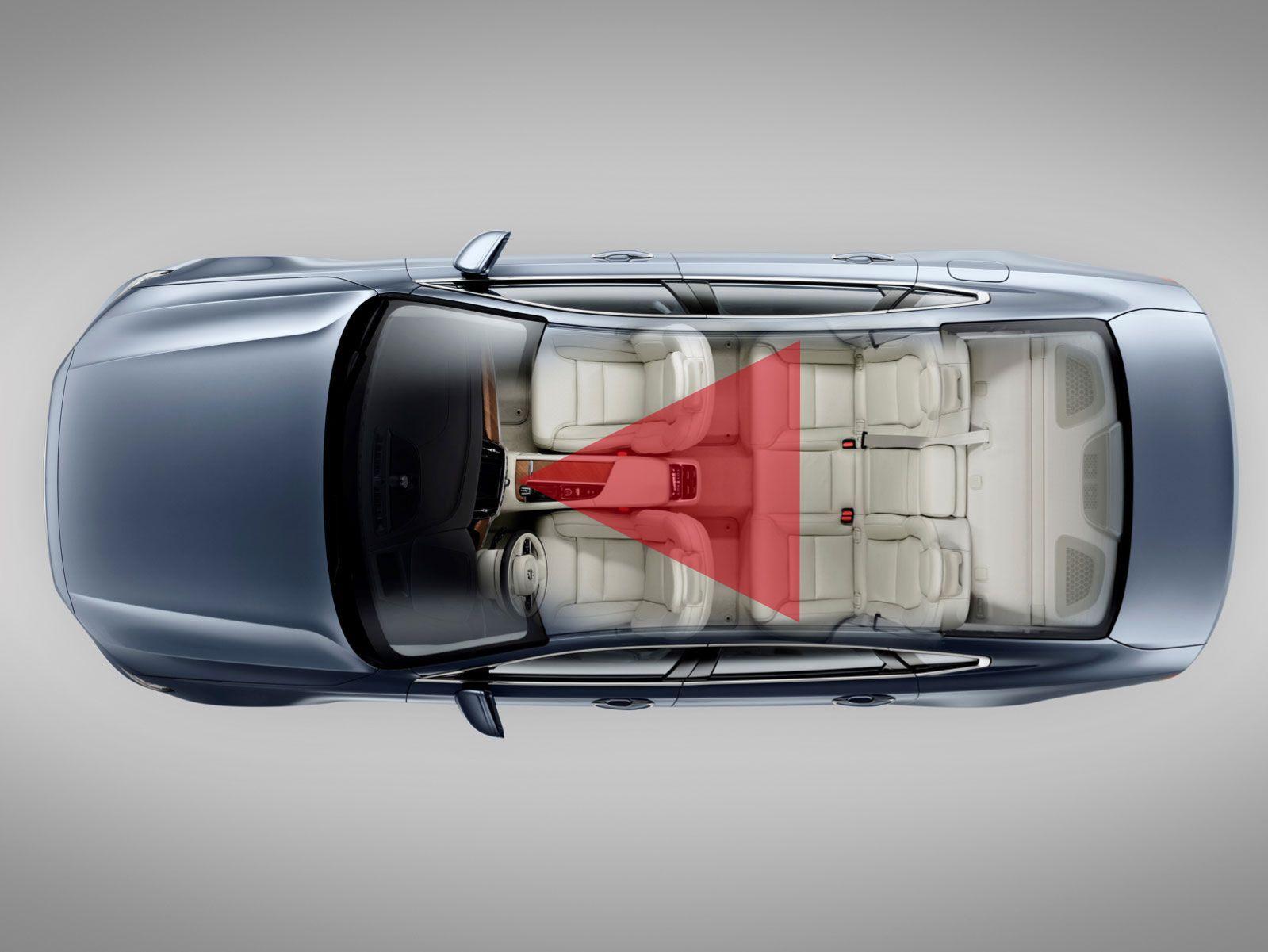
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*Figure 14: Gas module test, intermediary output value*

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*Figure 15: Gas module test, Maximum output value*

**Appendix 4: Test 1.4 documentation**

This image outlines the field of view of the PIR motion sensor on the interior of the car. Blind spots have been identified behind both of the front seats, but this has been deemed acceptable, as a view of the entire object is not necessary to detect movement.

*Figure 16: PIR motion sensor range*

1. This code had been sent in it’s own document [↑](#footnote-ref-0)
2. These tables were present in the updated BOM emailed to the PM and TA on Wednesday, November 3rd. [↑](#footnote-ref-1)
3. One or both will be conducted to decide the most optimal buzzer solution (if possible within the given budget) [↑](#footnote-ref-2)