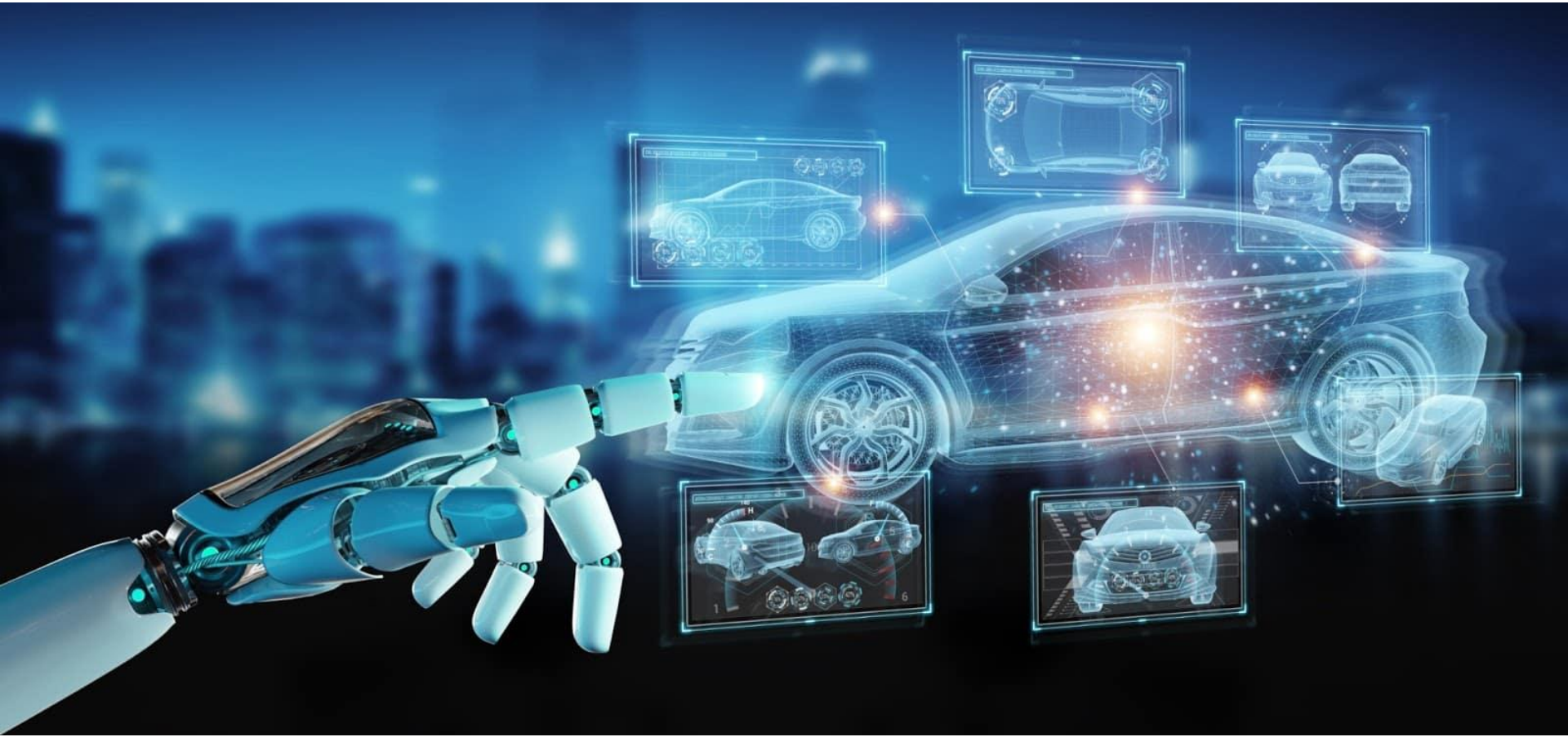
Joint Development Project: Automotive Electronics and Sensors



David Barón-Vega, Matthias Berger, Daniel Forta, Ines Hornung, Lukas Reiling,
Sandro Rogowski, Laxmi Shankar, Hadi Syed, Hibah Syed, Roy Taylor

Outline

- Project Overview
- Team
- Hardware Connections
- System Architecture
- System Components
  - Schematics
  - PCB
  - Sensors
  - GSM
- Bill of Materials
- Software
- Testing
- Demonstration

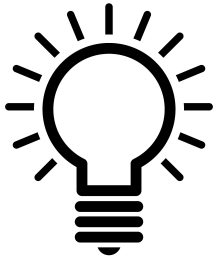
Project Overview

Problem:

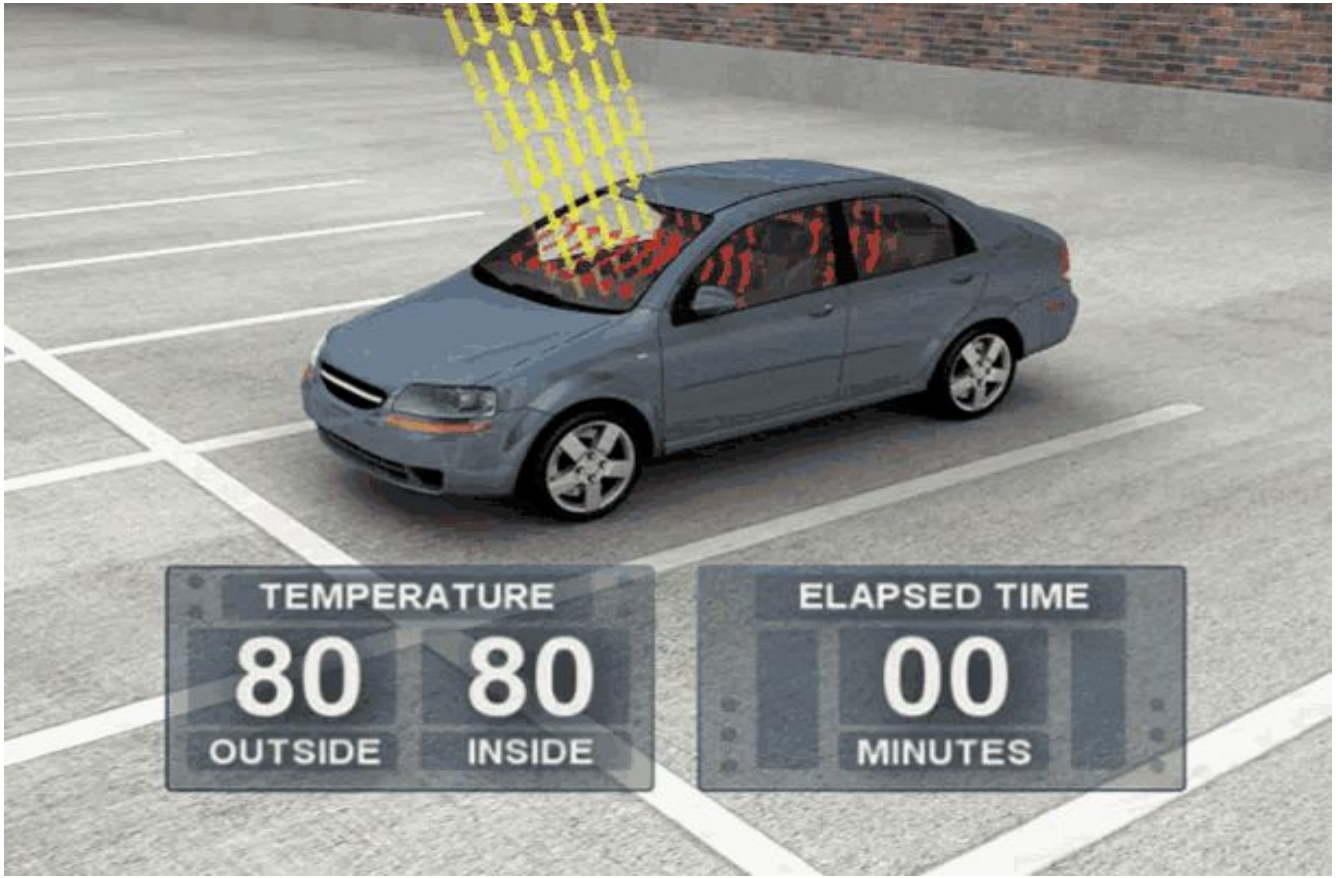
- Children trapped in a locked car at risk of heatstroke death

Solution:

- An intelligent emergency system detects child presence, monitors cabin temperature, and alerts car owner and authorities when critical temperature is reached



Dangers of Car Overheating



Why do children get left behind in cars?

COIL Team Leads

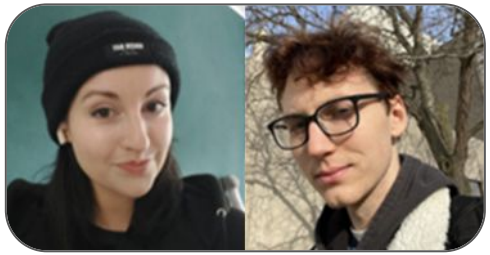
Project Leaders:
Prof. Dr. Alazzawi,
Prof. Dr. Thelen

Wayne State University
ECE Chair:
Prof. Dr. Ismail

Teaching Assistants:
Jonas, Erik, Leila, Jan

COIL Team

Project Managers: Ines, Roy



Quality and Test Managers: Matthias, Hibah

Hardware Developers: Daniel, Lukas

Software Developers: David, Sandro, Laxmi, Hadi

Hardware Connections

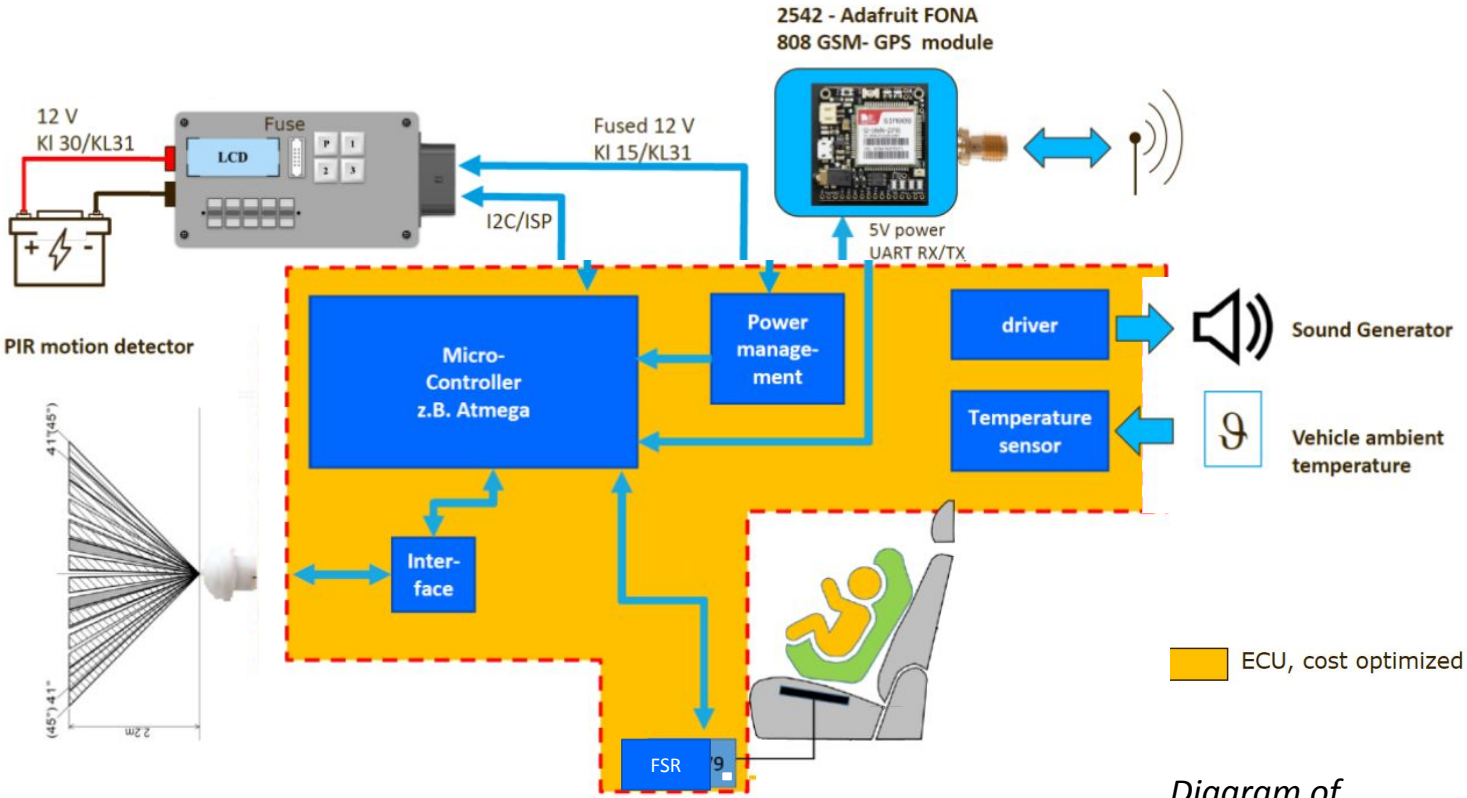
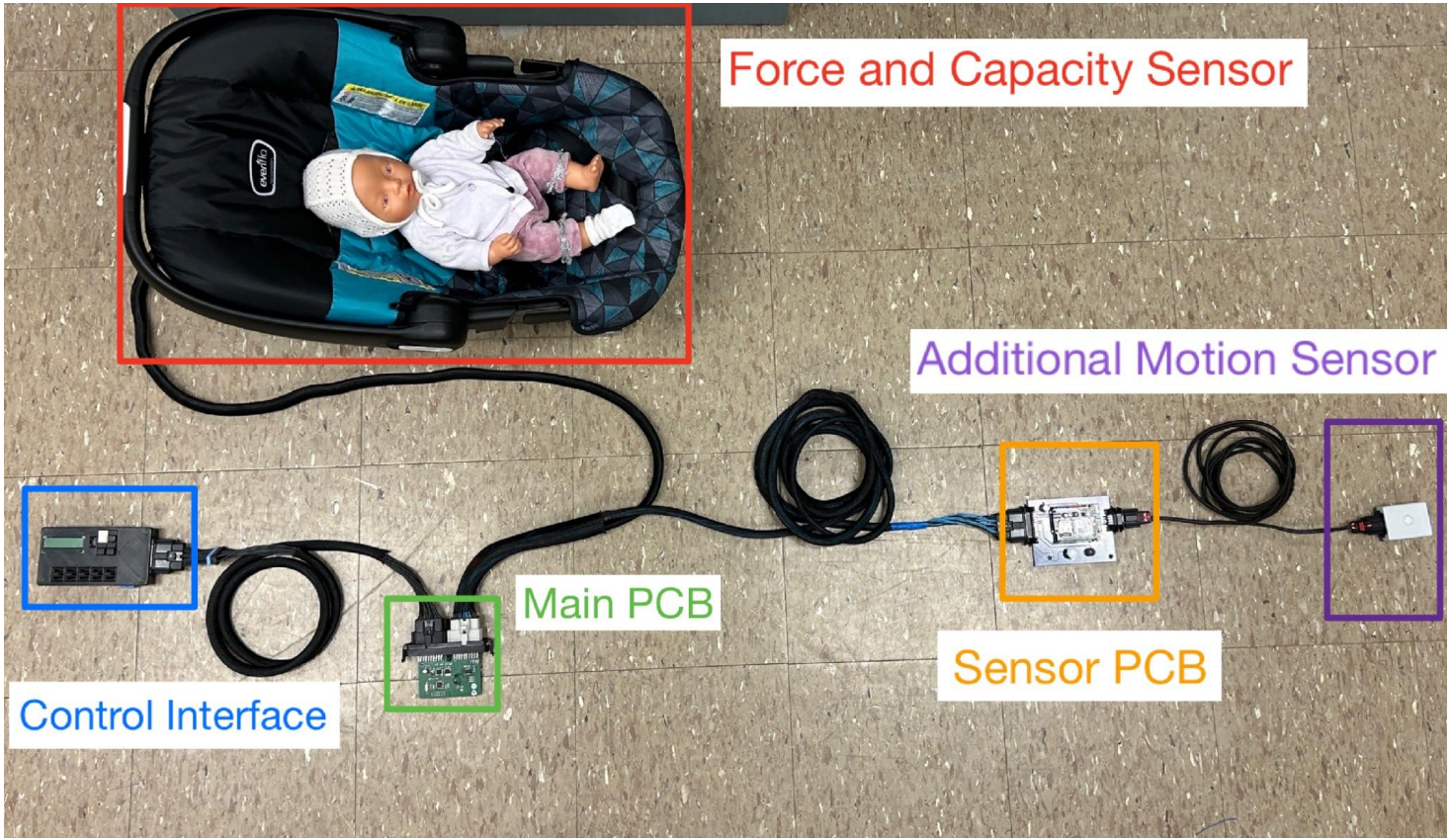
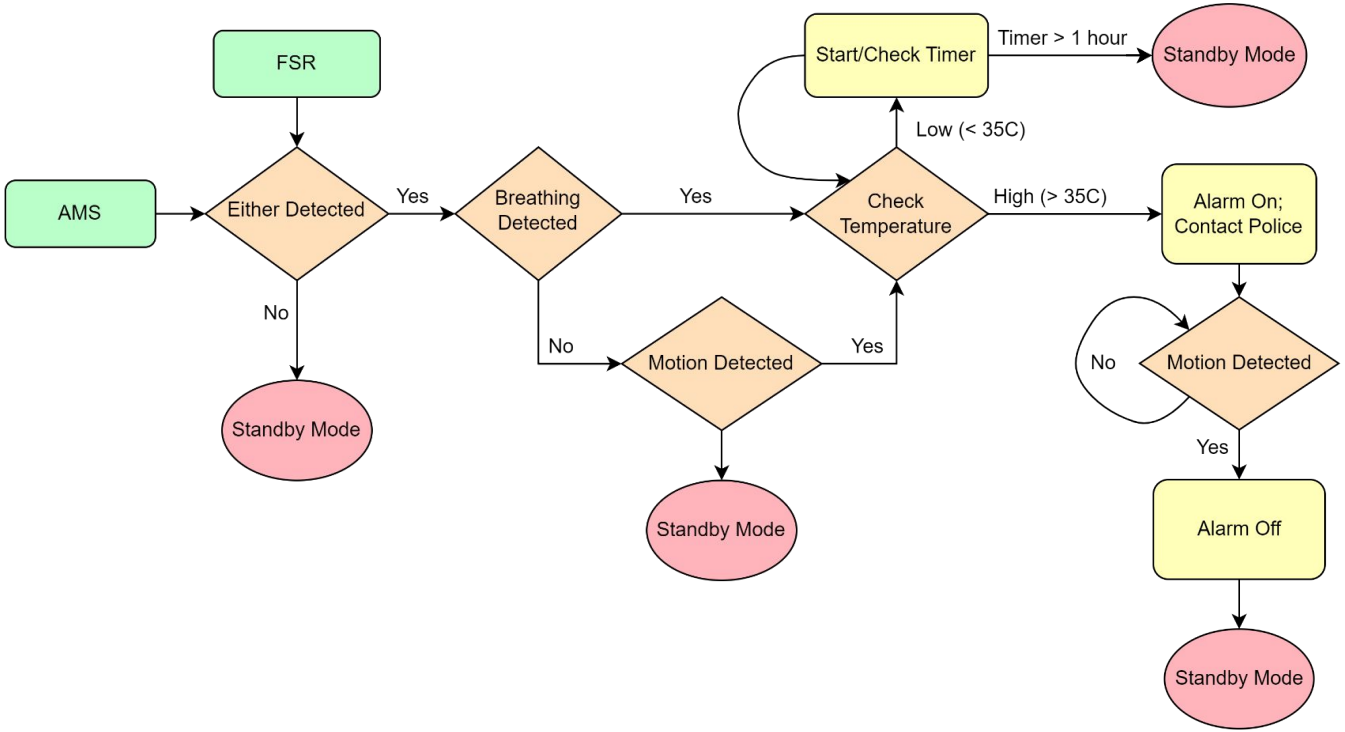


Diagram of proposed project setup.

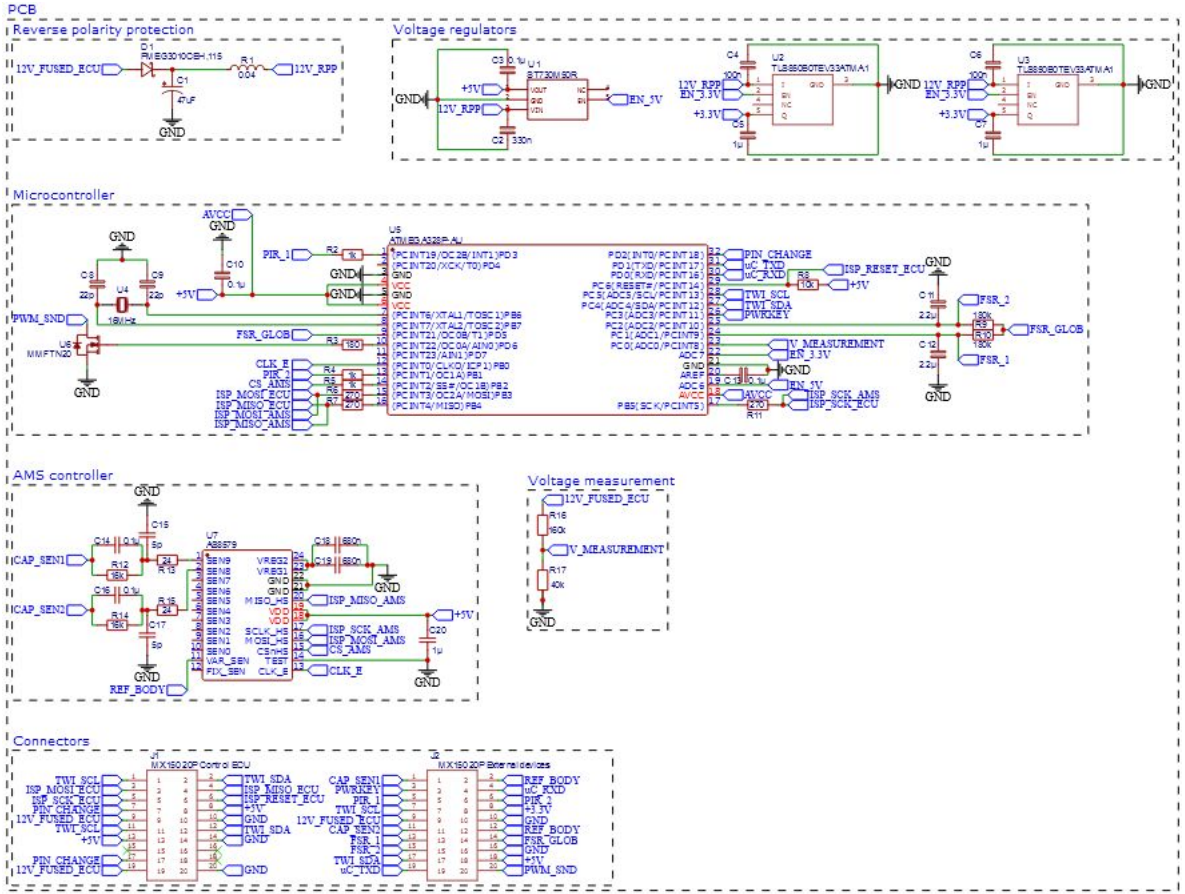
Hardware Connection




FSR
AMS
Either Detected
Yes
No
Standby Mode
Breathing Detected
Yes
No
Motion Detected
Yes
Standby Mode
Start/Check Timer
Timer > 1 hour
Standby Mode
Low (< 35C)
Check Temperature
High (> 35C)
Alarm On; Contact Police
No
Motion Detected
Yes
Alarm Off
Standby Mode

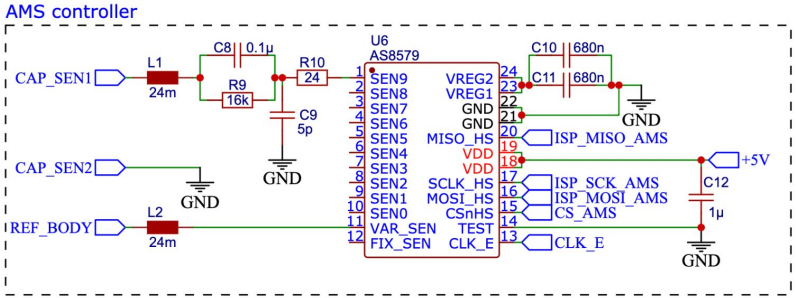
System Components

Main PCB Schematics

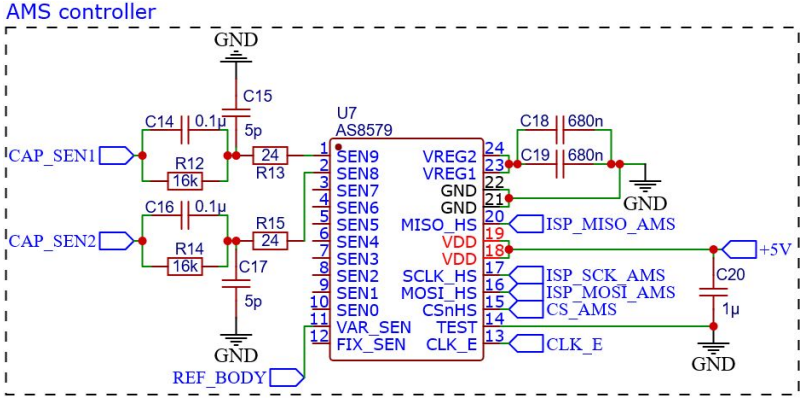


Main PCB Schematics

Version 1

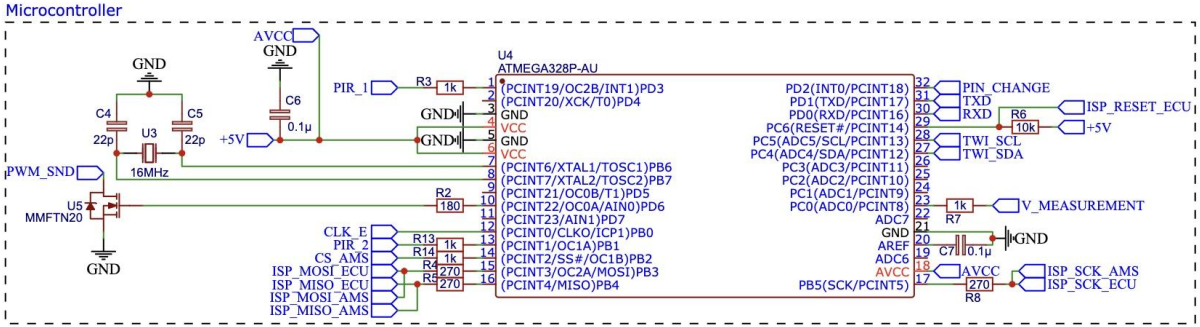


Version 2



Main PCB Schematics

Version 1



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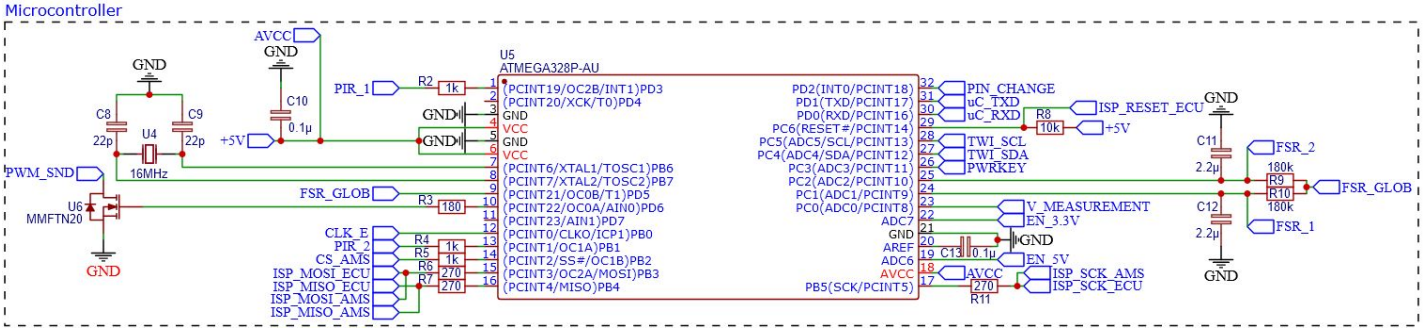
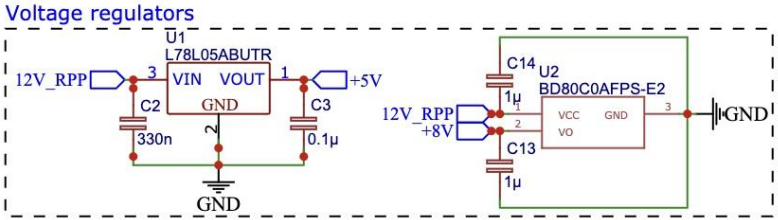


Main PCB Schematics

Version 1



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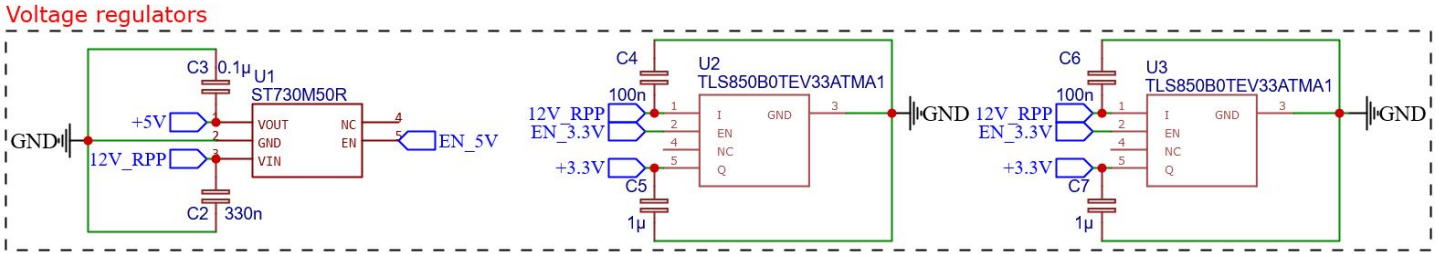
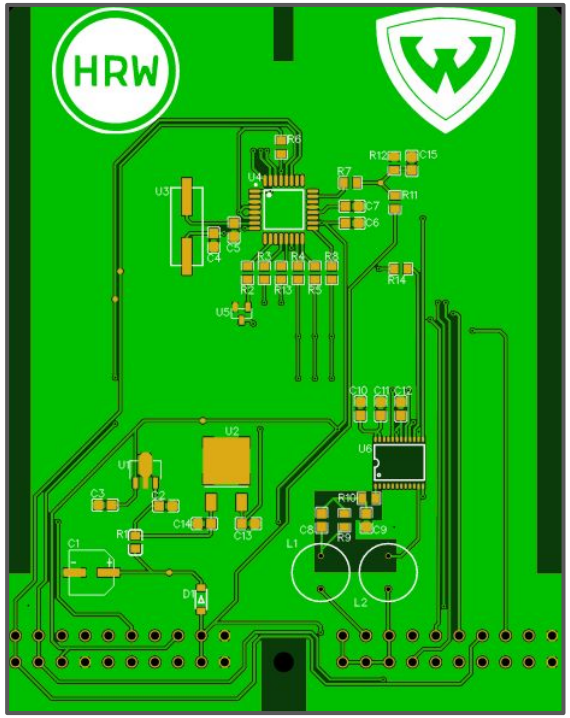
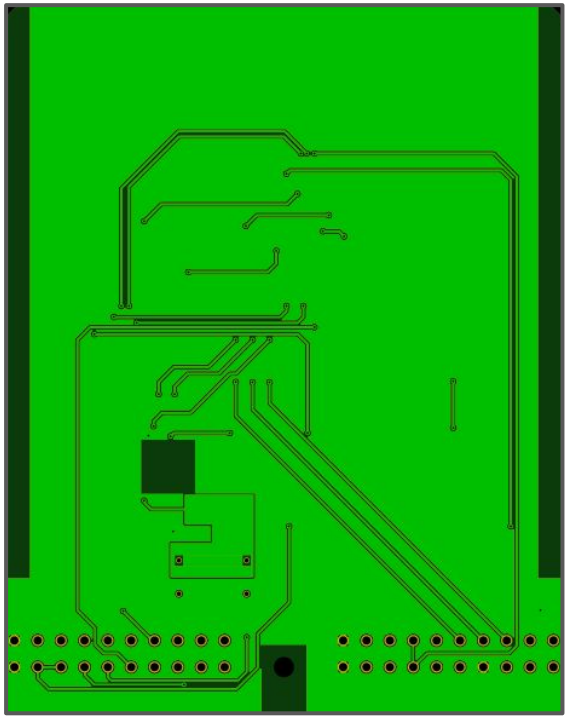


Main PCB Design Version 1

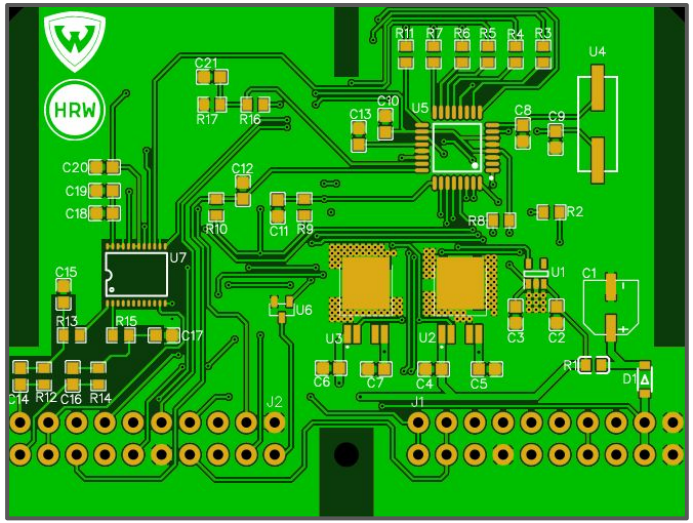


PCB Top Layer

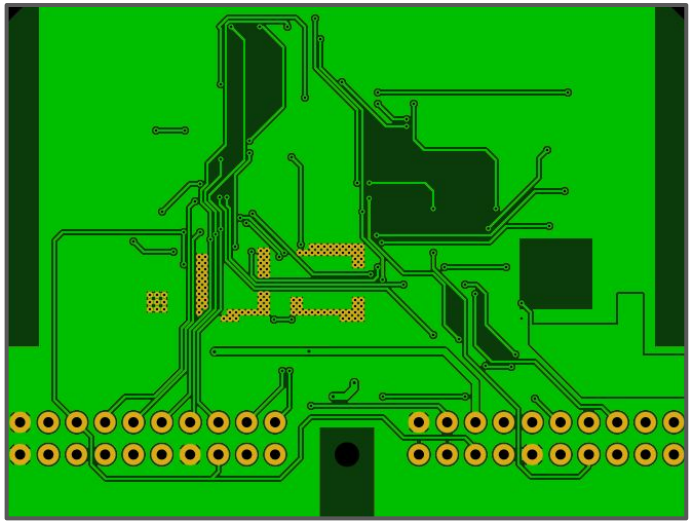


PCB Bottom Layer

Main PCB Design Version 2

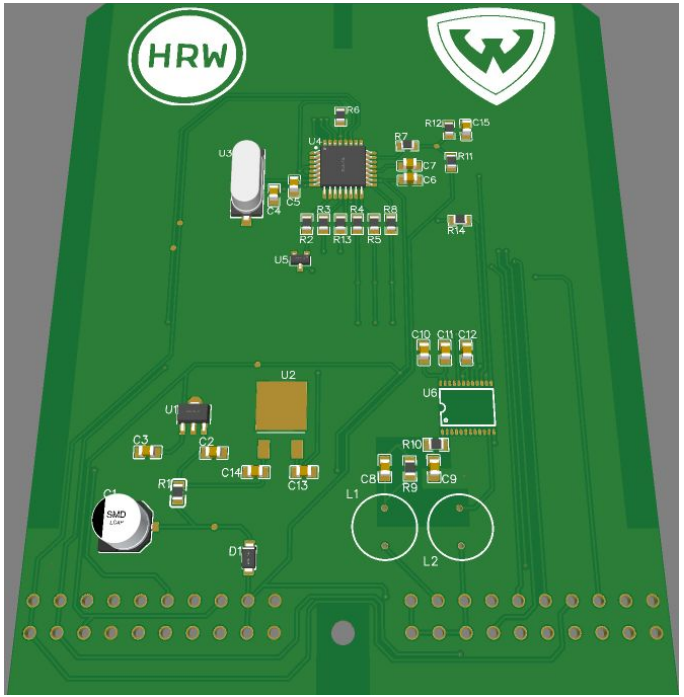


PCB Top Layer

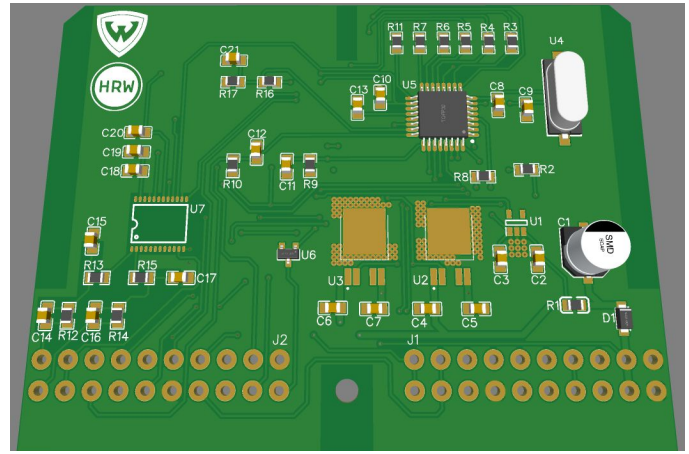


PCB Bottom Layer

Main PCB 3D Design



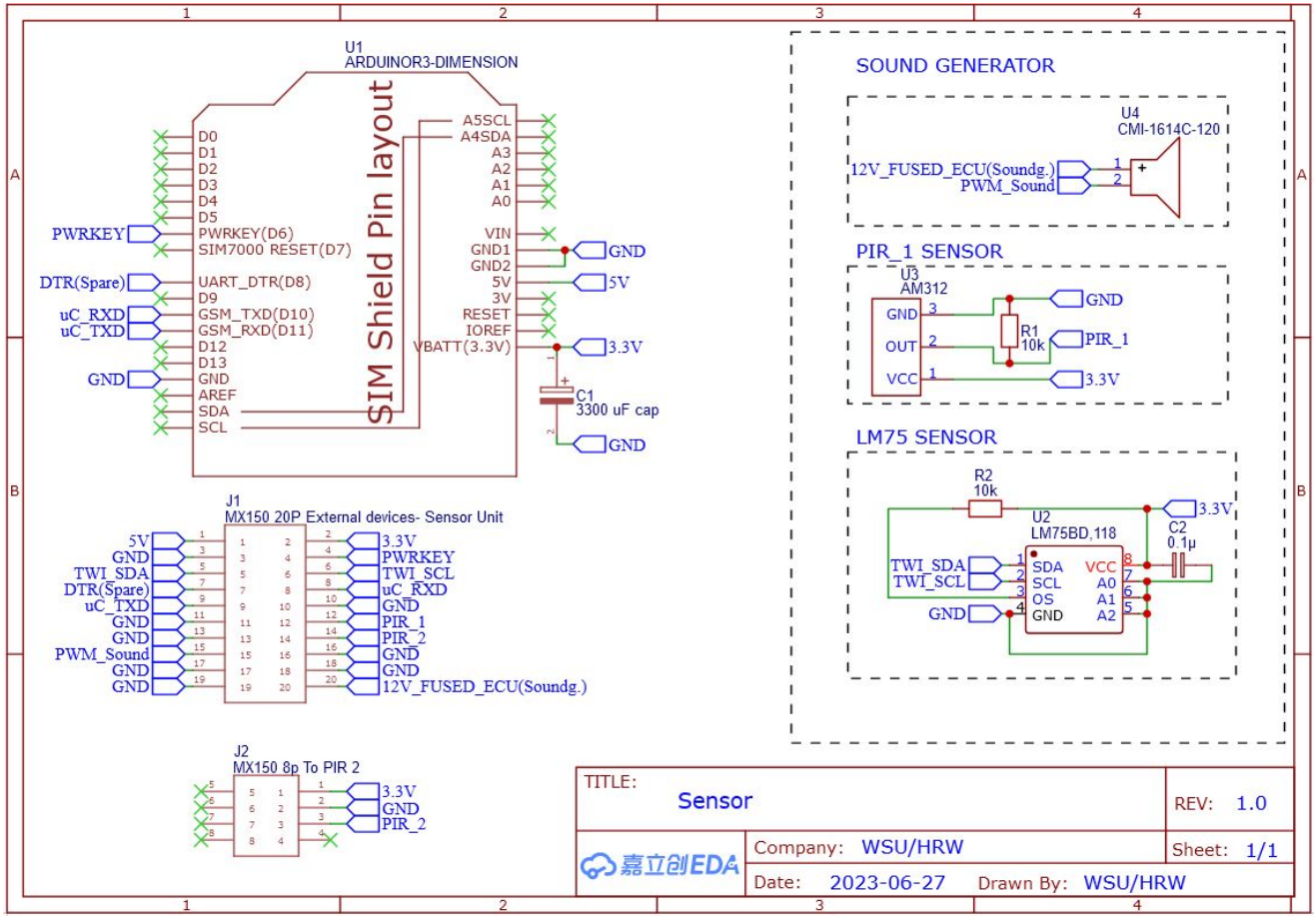
3D Design Revision 1



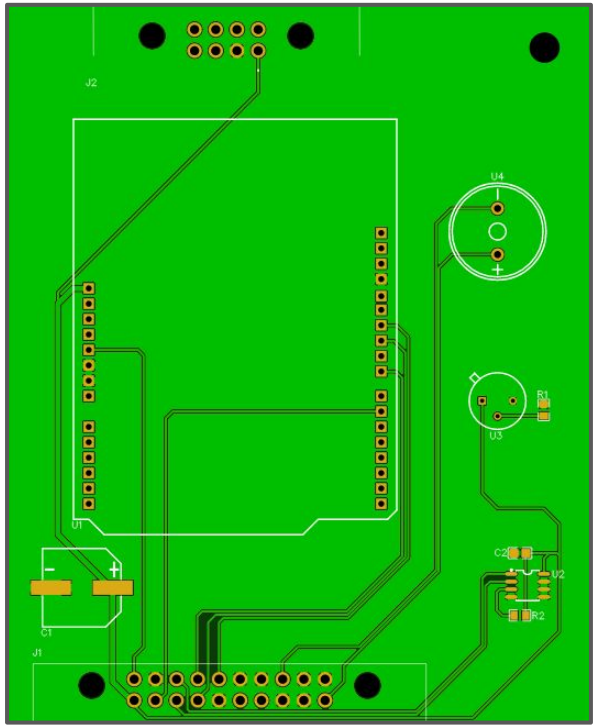
3D Design Revision 2

This version 40% smaller than Revision 1

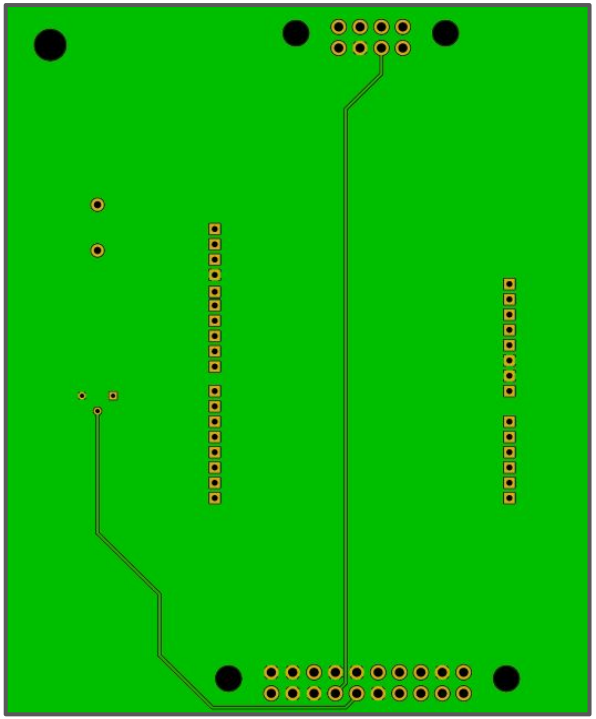
Sensor PCB Schematics



Sensor PCB Design

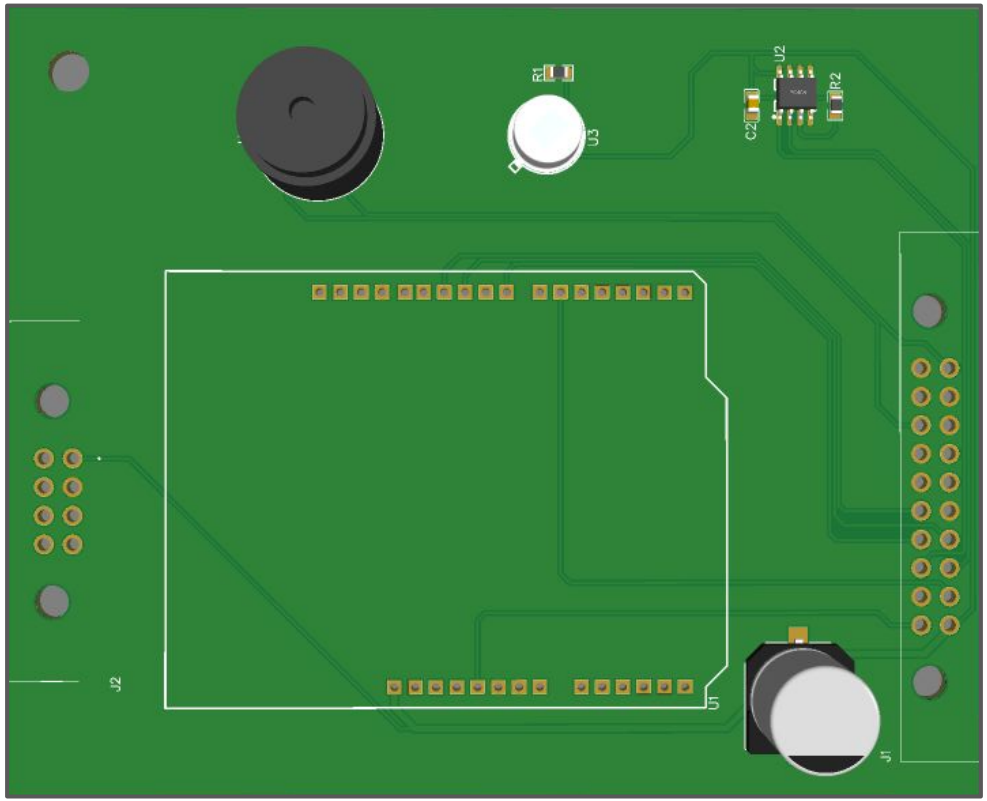


PCB Top Layer



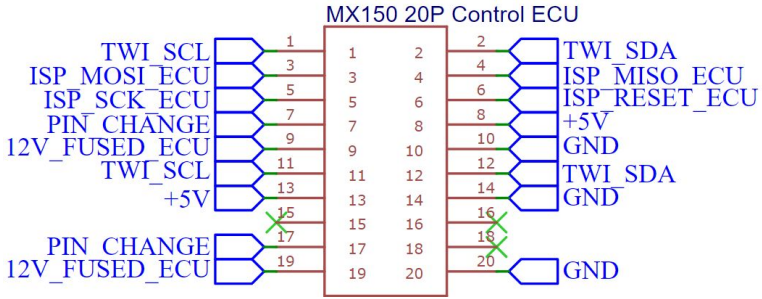
PCB Bottom Layer

Sensor PCB 3D Design



ECU - Control Interface

- 12V power supply
- Protected via blade fuse
- 6-pin ISP header for programming
- MOLEX connector
- Switches:
  - Simulation of terminal 15
  - Go through menu options
- Error handling
  - Displays error codes

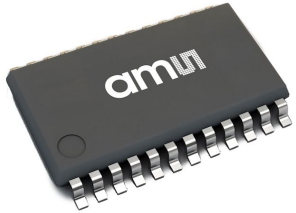


ECU Menu

- [0] Status (Offline/Active)
- [1] System (Detection off/Child detected/No child detected)
- [2] Force
- [3] Breathing FSR
- [4] AMS
- [5] Breathing AMS
- [6] Motion Sensor (Detection off/No motion/Motion detected)
- [7] Temp (Detection off/Out of range/“temp_value”)
- [8] Error Codes
- [9] Detection Status (Dangerous heat/Child left alone/etc.)

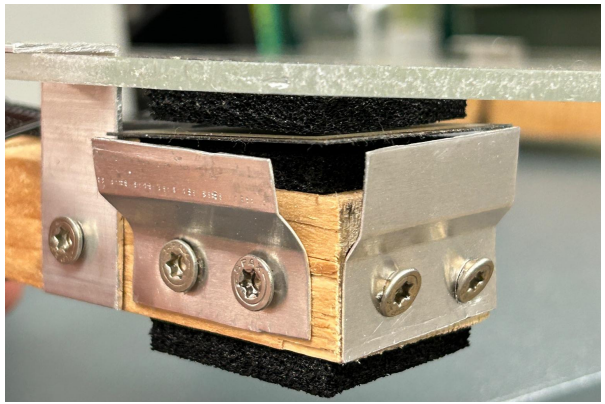
Capacitive Sensor

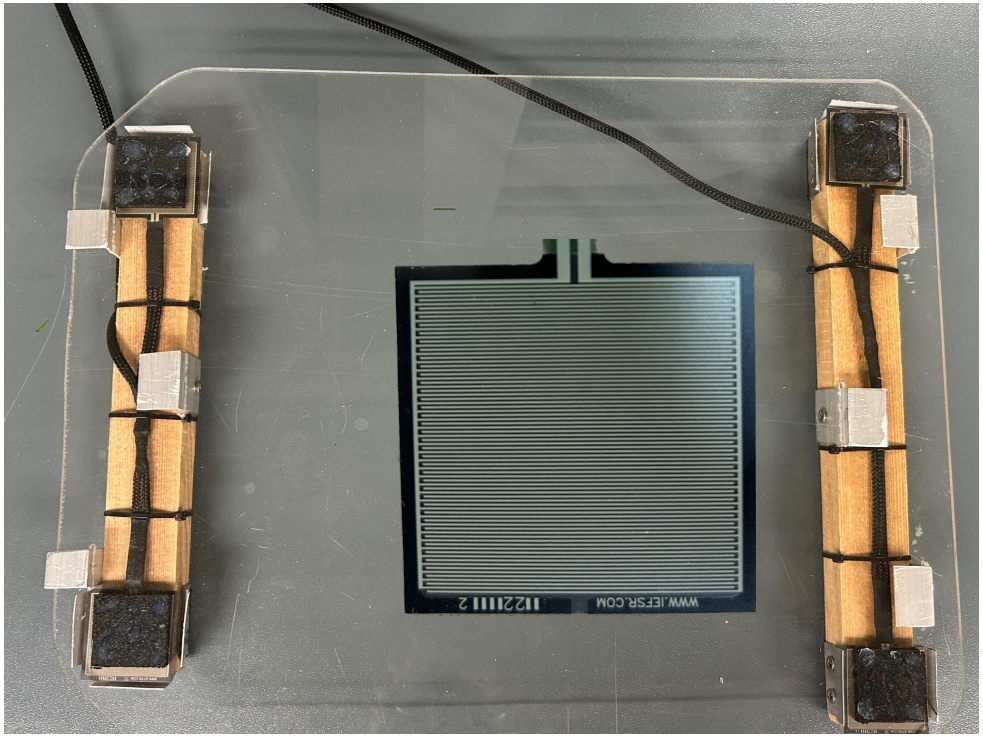
- AS8579 - Automotive Qualified [AEC-Q100]
- Temperature range of -40°C to 125°C
- SPI interface
- Diagnostics available
  - Enables error handling
- Up to 10 independent measurement lines possible
  - 10 SEN lines
- VAR & FIX_SEN function to avoid parasitic influences



Force Sensing Resistor

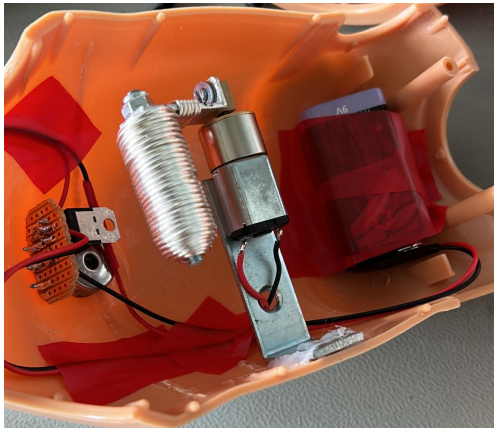
- 4 Sensors (every corner)
- Floating construction
- Detecting child breathing

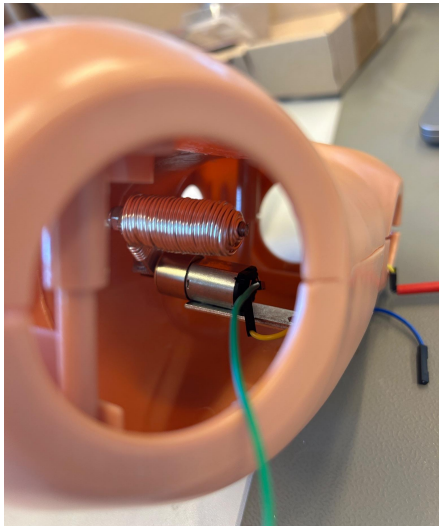


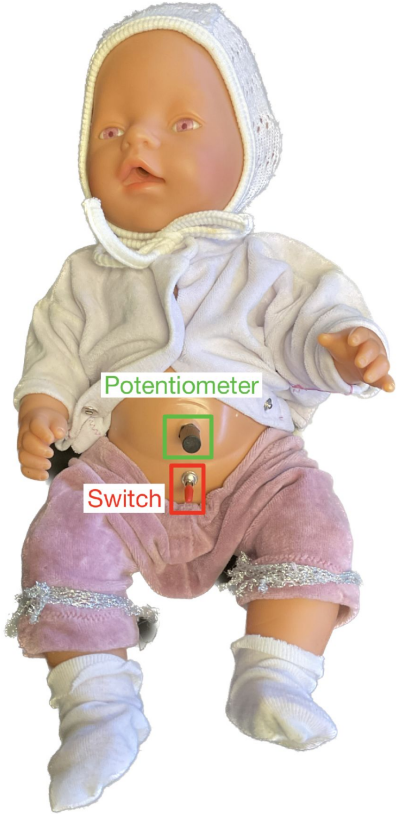


Force Sensing Resistor

- Prepared doll to simulate the breathing
- 85g weight moves around
- Speed change over Poti



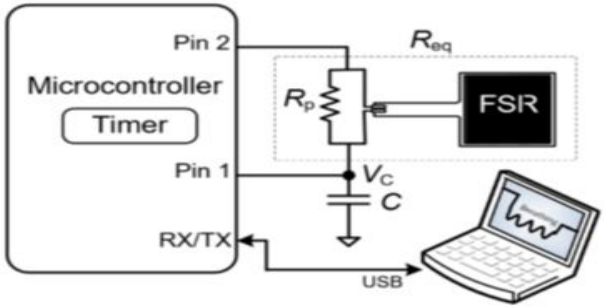




Force Sensing Resistor

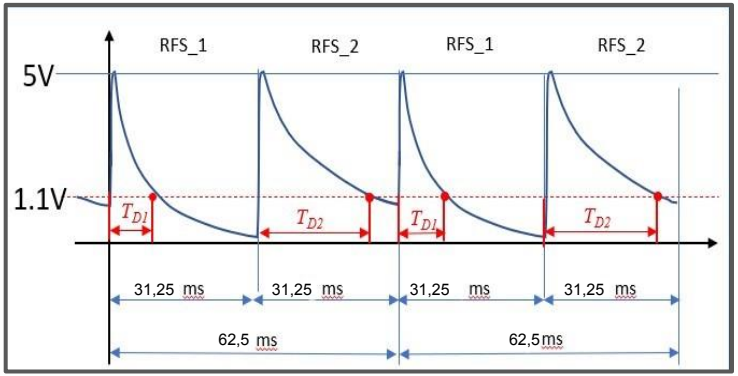
- Steps:
  - Pin 1 charges the capacity
    Pin 2 is floating
  - Pin 1 is now Input and floating.
    Discharges the capacity with force on the FSR
  - Timer measures time with counting

```
ADMUX &= ~(1<<MUX0);                    //Input C4 at AIN1
ADMUX |= (1<<MUX2);                     //Input C4 at AIN1
DDRC |= (1<<1);                         //Pin C1 Output
PORTC &= ~(1<<1);                       //Pin C1 LOW for holding the other capacitor low
DDRD &= ~(1<<5);                        //Pin D5 HiZ
DDRC |= (1<<2);                         //Pin C2 Output
PORTC |= (1<<2);                        //Pin C2 HIGH for loading the capacitor
reset = 1;                              //set temp reset to 1
for (int i = 0; i <= 20000; i++);       //wait 2*10000 system cycles - 2*625us
if (reset == 1)                         //if temp reset value is 1
{
    start_ticks[3] = TCNT1;             //save timer value
}
DDRC &= ~(1<<2);                        //Pin C2 HiZ - Input
DDRD |= (1<<5);                         //Pin D5 Output
PORTD &= ~(1<<5);                       //Pin D5 LOW
```



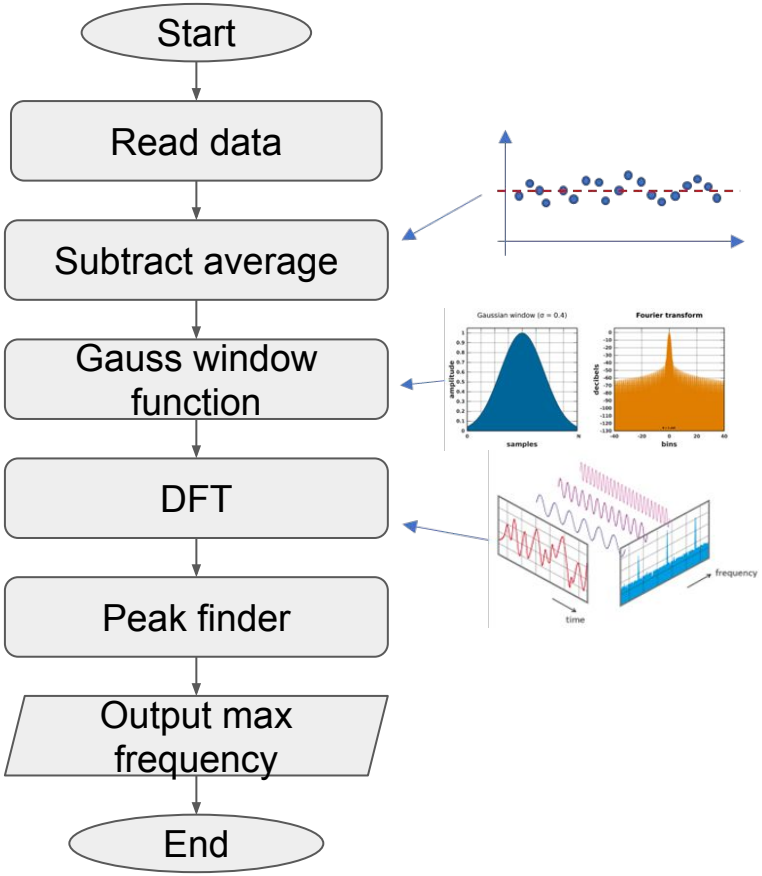
Force Sensing Resistor

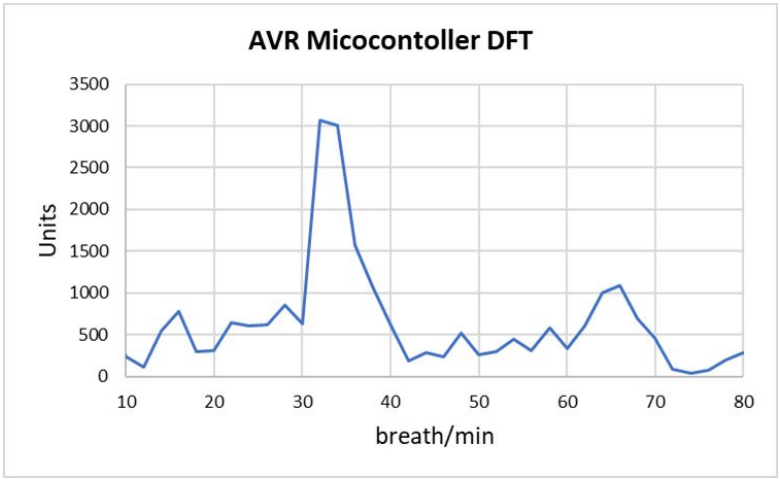
- 4 Measures every 125 ms
- Building difference of FSR1 and 2
- Adding the two differences
- Dividing by two
- This average values are used for DFT



$$T = |T_{D1} - T_{D2}|$$

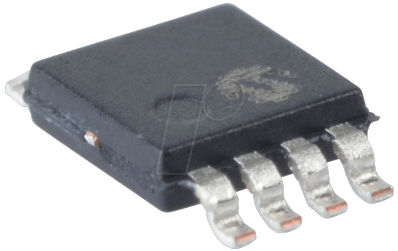
DFT Calculation

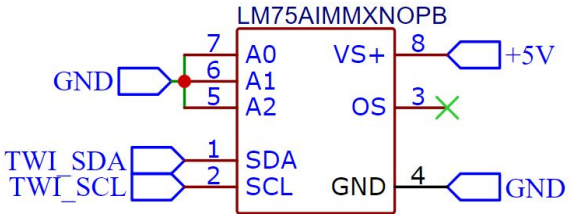




Temperature Sensor

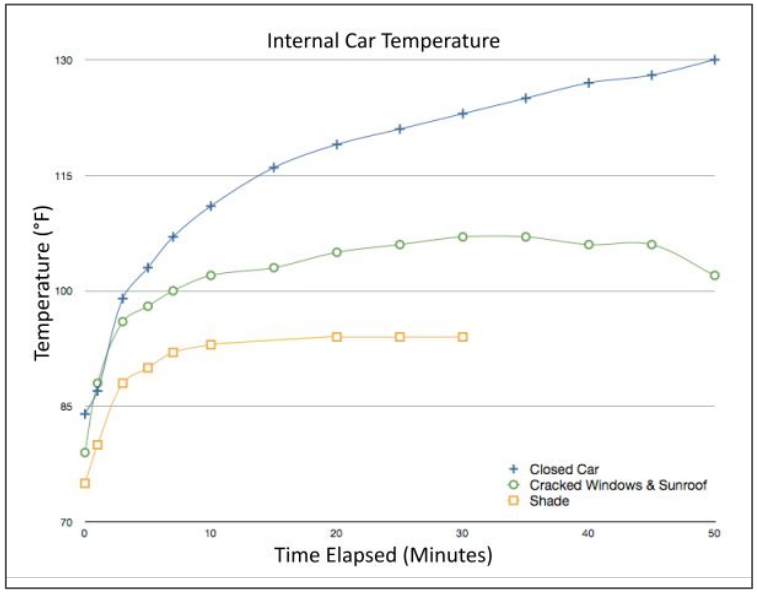
- LM75
- Measure the temperature within the vehicle
- Temperature accuracy of:
  - ±2 °C from −25 °C to +100 °C
- I²C bus interface
- Displays temperature value on LCD
- High temperature threshold: 35°C





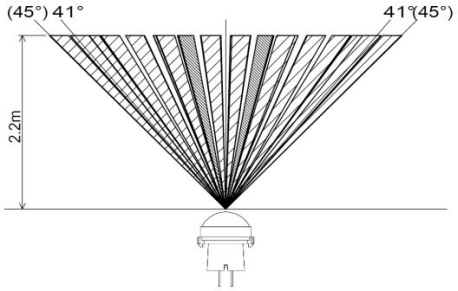
Temperature Research

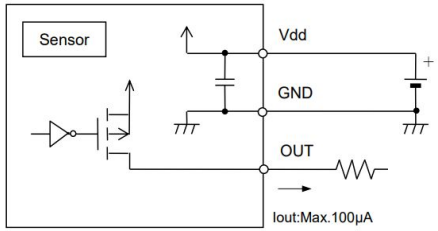
- What temperatures are dangerous?
  - Uncompensable temp is 37°C (98.6°F)
  - 40-42°C (104-107.6°F) causes cardiac organ failure and neurological damage

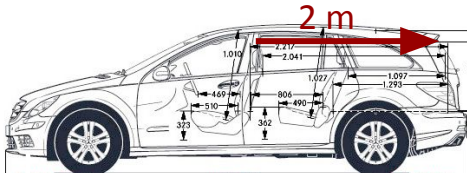


Motion Sensor

- Detection range: 2.2m
- Able to withstand heat up to 80°C
- 12uA of consumption when active
- Sends a high or low signal

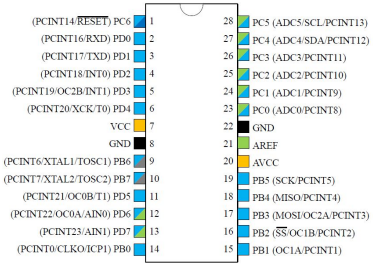


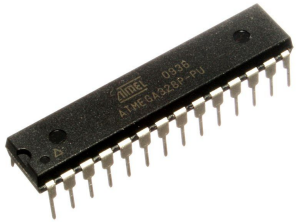




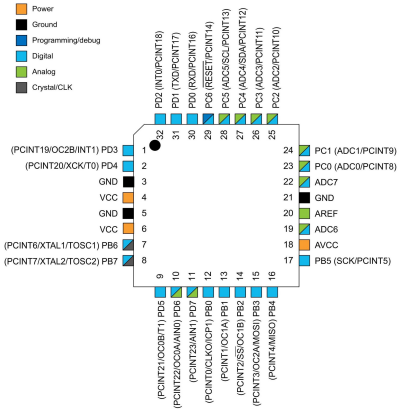
ATmega

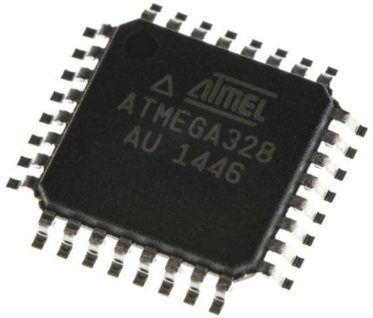
28-Pin ATmega328 contains 6 ADC ports





32-Pin ATmega328 can handle two extra ADC ports

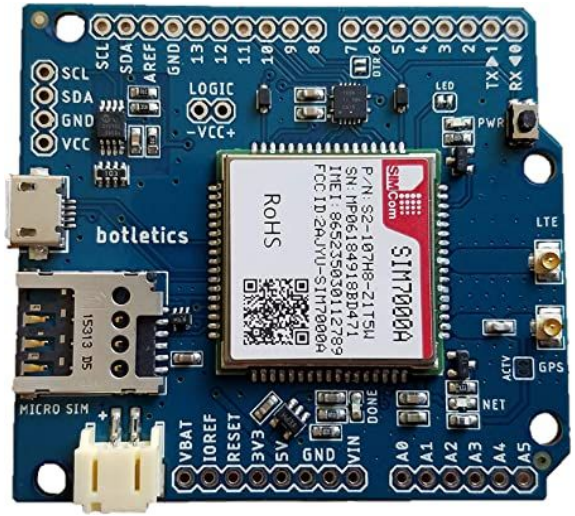




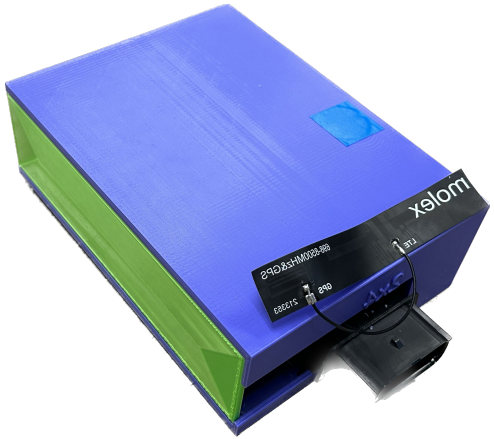
GSM/SIM Module

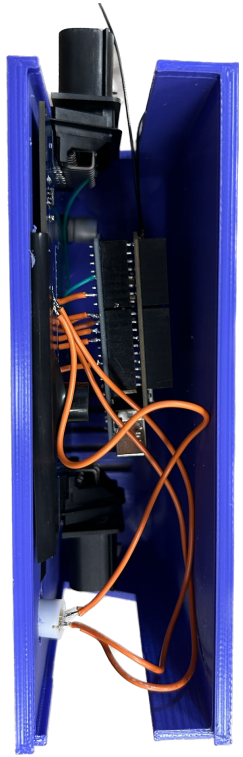
- Power-saving mode
- Communicates over UART
- AT commands
- HTTP and MQTT Protocols
- GPS data capabilities
- Usage of T Mobile/Telekom IOT sim card

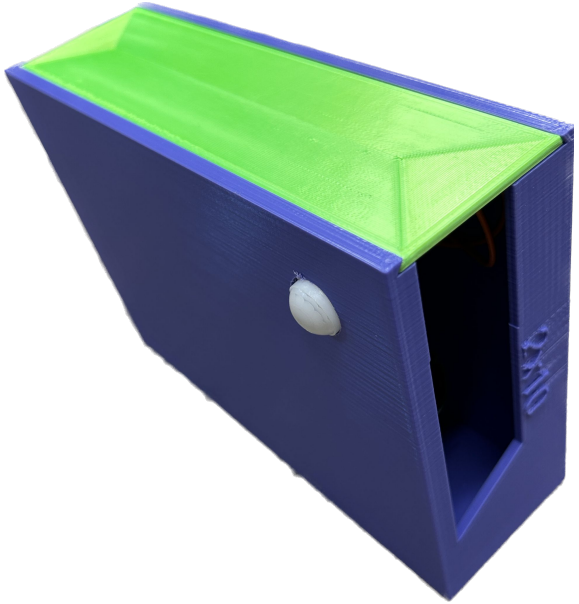
SIM7000A GSM shield:



Sensor PCB Housing

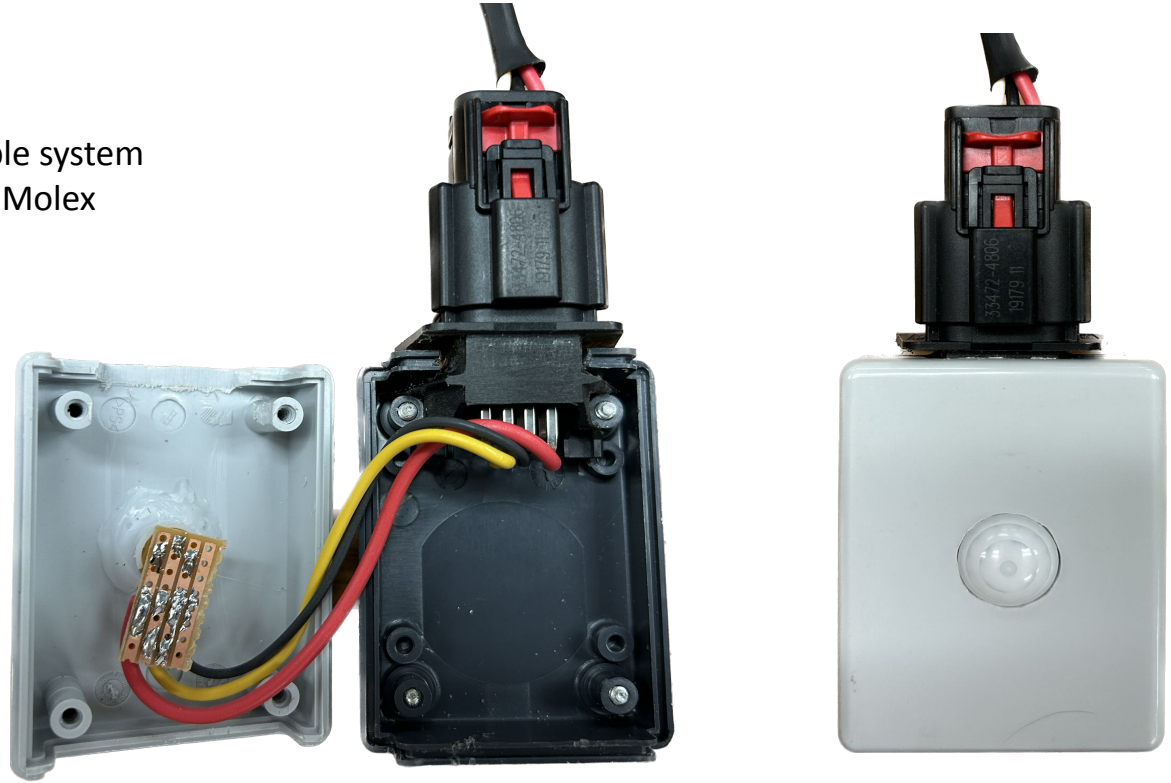






PIR Sensor with Housing

- Example for a scalable system
- Connected via 8 Pin Molex



Quiescent Current

Number of pieces	Part Number	Component	Quiescent Current (µA)
1	1	Atmega 328P AU	30
1	2	LM75B	0.2
1	4	NMOS (SOUND)	1
1	7	Voltage regulator (5V)	10
2	8	Voltage regulator (3.3V)	1
1	9	Voltage measurement	60
1	10	PIR	12
		Sum	114.2

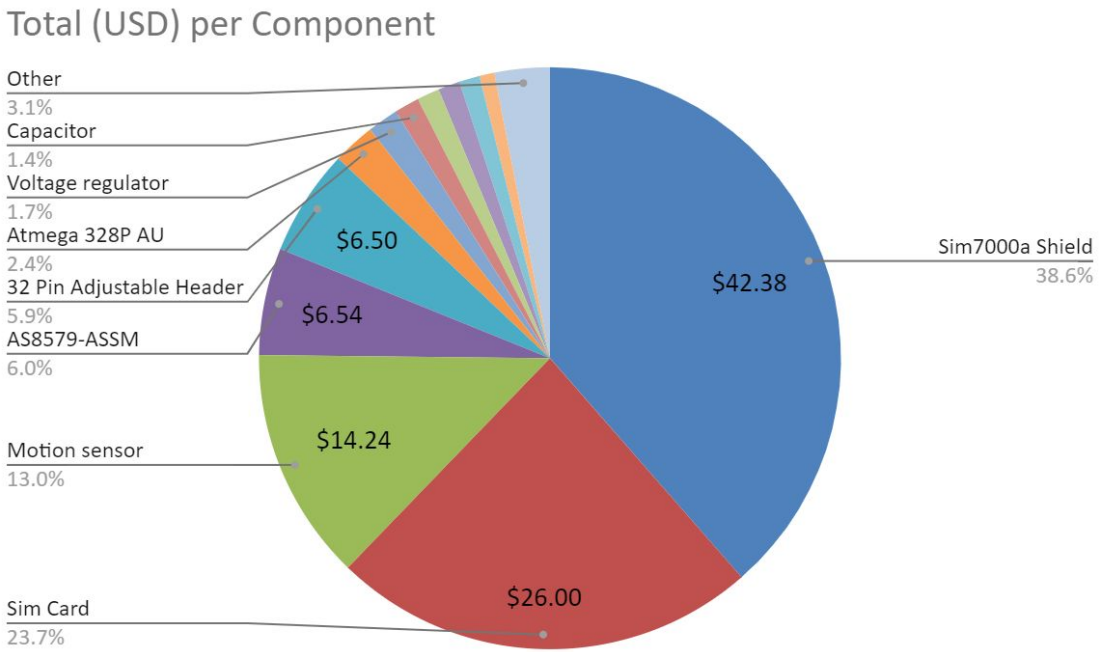
Bill of Materials

Part number	Number of pieces	Component	Value	Component	Dealer	Order number	Order link	Net piece price (price when buying 1000 pieces)	Total (Euros)	Total (USD)
1	1	Sim7000a Shield	-	-	digikey	DFR0763	https://www.digikey.com/en/products/detail/dfrobot/DFR0	37.7182€	37.7182€	$42.38
2	1	Sim Card	-	(30 days) of service: sms, calling, and data	SpeedTalk Mobile	N/A	https://speedtalkmobile.com/pay-as-you-go-phone-plans/	23.1400€	23.1400€	$26.00
3	2	Motion sensor	-	-	digikey	EKMC1603113	EKMB1393113K Panasonic Electric Works | Sensors, Transd	6.3368€	12.6736€	$14.24
4	1	AS8579-ASSM	-	Controller capacitive sensor	Mouser	985-AS8579-ASSM	https://www.mouser.de/ProductDetail/ams-OSRAM/AS857	5.8400€	5.8400€	$6.54
5	1	32 Pin Adjustable Header	-	-	digikey	N/A	D01-9923246 Harwin Inc. | Connectors, Interconnects | Dig	5.7850€	5.7850€	$6.50
6	1	Atmega 328P AU	-	Microcontroller	Farnell	1715486	https://de.farnell.com/microchip/atmega328p-au/mcu-8bit	2.3100€	2.3100€	$2.59
7	2	Voltage regulator	-	GPS/GSM module	Mouser	726-TLS850B0TEV33ATM	https://www.mouser.com/ProductDetail/Infineon-Technolo	0.84 €	1.6840€	$1.89
8	1	Capacitor	100µ	-	Mouser	80-A784MS107M1JLAS28	https://www.mouser.com/ProductDetail/80-A784MS107M1	1.3528€	1.3528€	$1.52
9	2	Capacitor	0.1µ		Mouser	80-C0805Y104J5RAUTO	https://www.mouser.com/ProductDetail/80-C0805Y104J5R	0.6141€	1.2282€	$1.38
10	1	Sim Card (LTE Cat-M capable)	-	-	SpeedTalk Mobile	N/A	https://www.amazon.com/dp/B07933LMZW?ref_=cm_sw_	1.1837€	1.1837€	$1.33
11	2	Coil	24mH	-	Mouser	530-DRC-V-123K	https://www.mouser.de/ProductDetail/Bel-Signal-Transforn	0.5600€	1.1200€	$1.25
12	1	Temperature Sensor	-		Mouser	771-LM75BD118	https://www.mouser.com/ProductDetail/771-LM75BD118	0.8099€	0.8099€	$0.91
13	2	Resistor	10k	Thin film resistor	Mouser	603-RP0805FRE0710KL	https://www.mouser.com/ProductDetail/603-RP0805FRE07	0.3115€	0.6230€	$0.70
14	1	Piezo transducers	-	Sound generator	Mouser	490-CEM-1212S	https://www.mouser.de/ProductDetail/CUI-Devices/CEM-1	0.4480€	0.4480€	$0.50
15	1	Voltage regulator	-	Microcontroller	Mouser	511-ST730M50R	https://www.mouser.com/ProductDetail/STMicroelectronic	0.45 €	0.4460€	$0.50
16	1	LM75BD	-	Temperature sensor	Mouser	LM75BD118	https://www.mouser.de/ProductDetail/771-LM75BD118	0.3540€	0.3540€	$0.40
17	1	NMOS	-	Driver sound generator	Mouser	637-MMFTN20	https://www.mouser.de/ProductDetail/Diotec-Semiconduct	0.1650€	0.1650€	$0.18
18	1	Quarz	16MHz	Microcontroller	Farnell	2467728	https://de.farnell.com/abracon/abls2-16-000mhz-d4y-t/cry	0.1450€	0.1450€	$0.16
19	3	Capacitor	1µ	-	Farnell	1458907	https://de.farnell.com/yageo/cc0805zky5v9bb105/kondens	0.0440€	0.1320€	$0.15
20	2	Capacitor	680n	Controller capacitive sensor	Farnell	2522227	https://de.farnell.com/tdk/cga4j3x7r1e684k125ab/kondens	0.0479€	0.0958€	$0.11
21	1	Capacitor	0.33µ	-	Farnell	3581154	https://de.farnell.com/murata/gcj219r71h334ka12d/konde	0.0900€	0.0900€	$0.10
22	1	16 MHz Crystal Oscillator	16MHz	-	digikey	AS-16.000-18	https://www.digikey.com/en/products/detail/raltron-electr	0.0890€	0.0890€	$0.10
23	1	Diode	-	Reverse polarity protection	Farnell	3440039	https://de.farnell.com/nexperia/pmeg3010ceh-115/schottk	0.0716€	0.0716€	$0.08
24	5	Capacitor	0.1µ	-	Farnell	3013476	https://de.farnell.com/samsung-electro-mechanics/cl21b10	0.0113€	0.0565€	$0.06
25	2	Capacitor	5p	-	Farnell	1759184	https://de.farnell.com/multicomp/mc0805n5r0c500ct/kond	0.0246€	0.0492€	$0.06
26	1	Capacitor	47µ	Onboard filter	Farnell	4061829	https://de.farnell.com/aishi/emk1em470e83d00r/kondensa	0.0476€	0.0476€	$0.05
27	2	Capacitor	2.2µ	-	Mouser	187-CL21A225KAFNNNE	https://www.mouser.com/ProductDetail/Samsung-Electro-I	0.02 €	0.0440€	$0.05
28	2	Capacitor	22p	Microcontroller	Farnell	2310684	https://de.farnell.com/multicomp/mc0805n220j500ct/kond	0.0211€	0.0422€	$0.05
29	3	Resistor	270	-	Farnell	1576451	https://de.farnell.com/multicomp/mchp05w4f2700t5e/dick	0.0065€	0.0195€	$0.02
30	3	Resistor	1k	-	Farnell	2446904	https://de.farnell.com/multicomp/mcwr08x1001ftl/dickssch	0.0053€	0.0159€	$0.02
31	2	Resistor	16k	-	Farnell	2073652	https://de.farnell.com/multicomp-pro/mcmr08x1602ftl/ker	0.0079€	0.0158€	$0.02
32	1	Ferrit	0.2	HF ferrit	Farnell	4141776	https://de.farnell.com/abracon/afbc-q0805h-301-t/ferritpe	0.0148€	0.0148€	$0.02
33	2	Resistor	180k	-	Mouser	279-1623126-1	https://www.mouser.com/ProductDetail/TE-Connectivity-H	0.01 €	0.0120€	$0.01
34	1	Resistor	40k	-	Farnell	3975002	https://de.farnell.com/vishay/crcw080540k0fkea/widerstar	0.0116€	0.0116€	$0.01
35	2	Resistor	24	-	Farnell	2447615	https://de.farnell.com/multicomp/mcwr08x24r0ftl/dickssch	0.0036€	0.0072€	$0.01
36	1	Resistor	160k	-	Farnell	2073655	https://de.farnell.com/multicomp-pro/mcmr08x164-jtl/ker	0.0062€	0.0062€	$0.01
37	1	Resistor	10k	-	Farnell	2446870	https://de.farnell.com/multicomp/mcwr08x1002ftl/dickssch	0.0053€	0.0053€	$0.01
38	1	Resistor	180	-	Farnell	2446900	https://de.farnell.com/multicomp/mcwr08x1800ftl/dickssch	0.0049€	0.0049€	$0.01
								sum	97.86€	$109.60

Bill of Materials

Can be cheaper:

- Sim card (via wholesale deal with supplier)
- Motion sensors

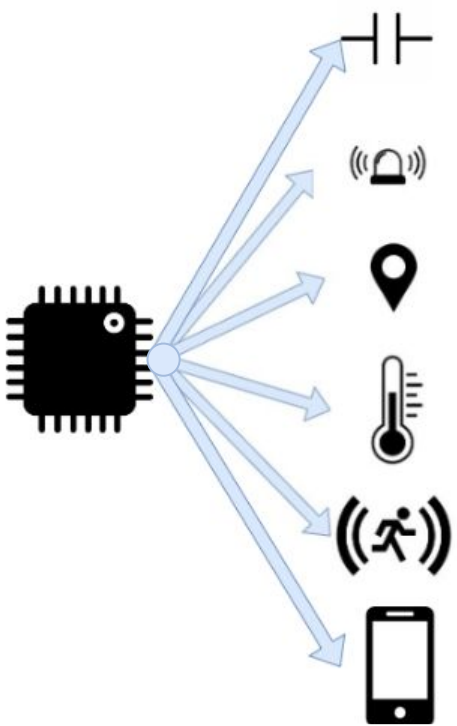


Software Scope

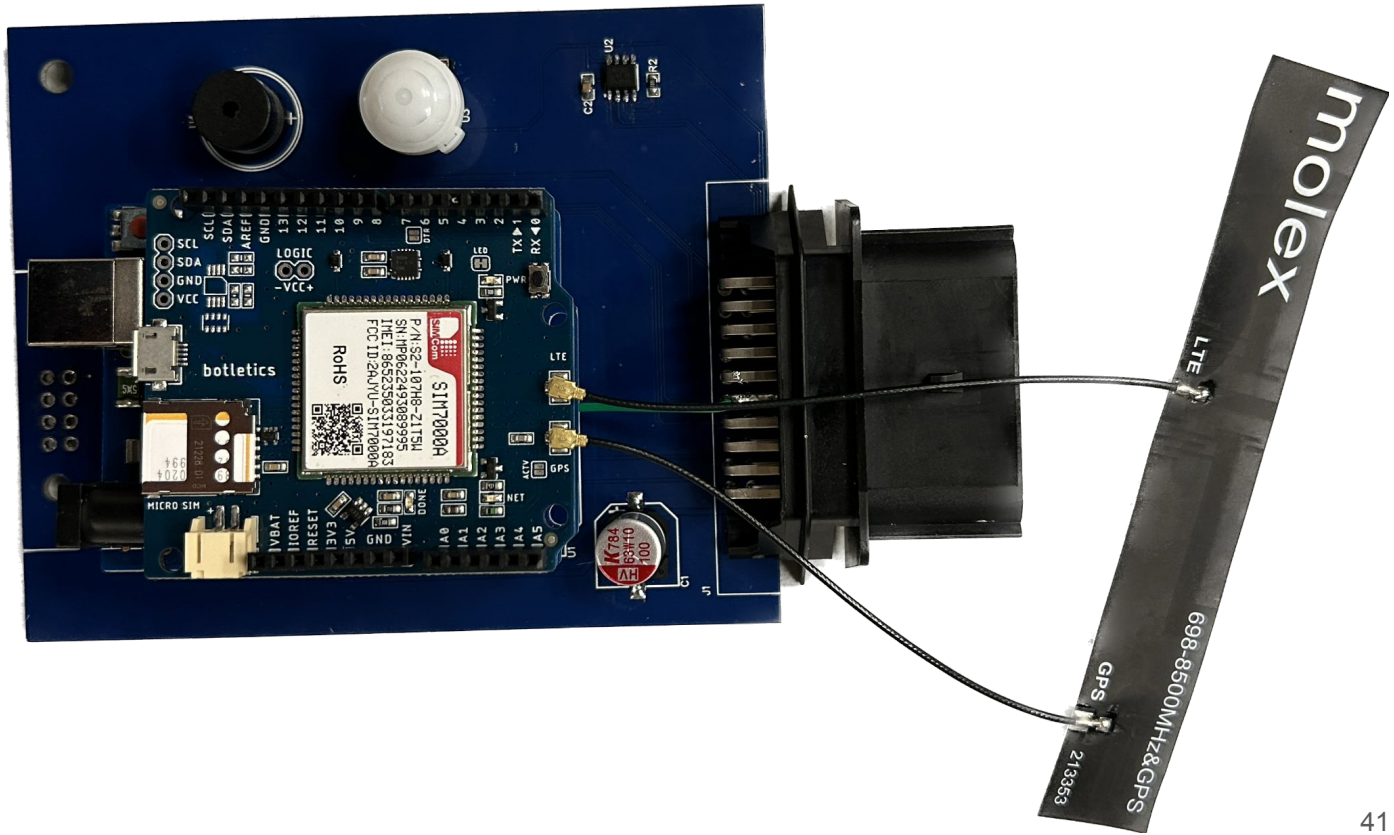
Goal: Read conditions car environment, record those in a database, and communicate that to vehicle owner

Expected Features:

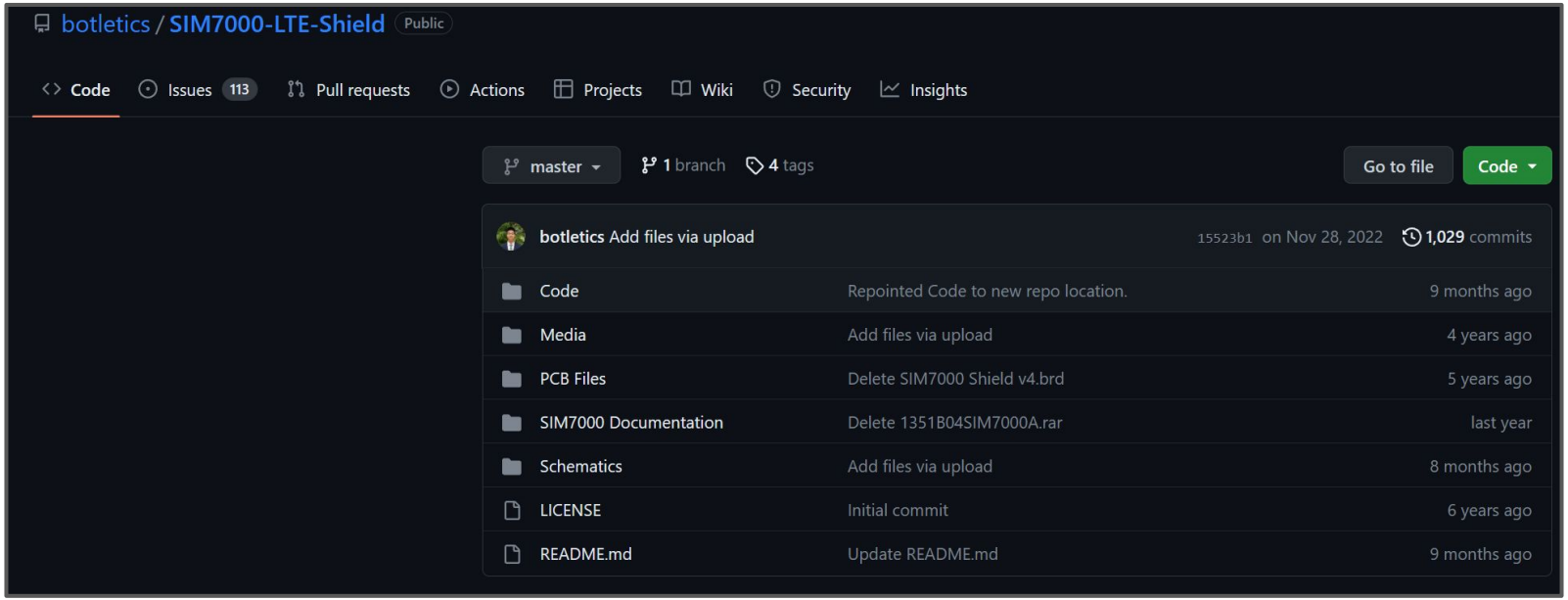
- Integration of FSR
- Alert Child
- Integration of GSM/SIM Module
- Integration of Temperature Sensor
- Integration of Motion Sensor
- Mobile App Features
- Notify Parent and Emergency Services



GSM/SIM Module



GSM/SIM Module



GSM/SIM Module

```
void send_text(char* phone_number, char* message) {
    char at_command[50];
    sprintf(at_command, "AT+CMGS=\"%s\"", phone_number);
    //set to texting mode
    send_AT_command("AT+CMGF=1","OK");
    // send the SMS number wait until response
    send_AT_command(at_command,"OK");
    // send the SMS text wait until response
    uart_send_string(message);
    // send Ctrl+Z
    uart_send_byte(0x1A);
    uart_send_string("\r\n");
    //~fin~

}
```

```
int send_AT_command(const char* at_command,const char* expected_response)
{
    currentExpectedResponse = expected_response;
    // Send the AT command to the GSM module
    currentCommandState = 1;
    uart_send_string(at_command);
    uart_send_string("\r\n");
    timer0reset();
    while ( timer0ms < 1500 || currentCommandState != 1);

    if (currentCommandState == 1)
    {
        // Do nothing, or do other tasks that need to be done
        // The interrupt service routine will handle the arrival of the response
    }
    else if (currentCommandState == 2)
    {
        currentCommandState = 0;
        return 1;
    }
    else if (currentCommandState == 3)
    {
        // Handle the error
        // Reset the state to COMMAND_NOT_SENT to send the next command
        currentCommandState = 0;
    }
    else if (currentCommandState == 4)
    {
        currentCommandState = 0;
    }

    //handle received command back at original function
}     // end of function //
```

UART Programming

```
ISR(USART_RX_vect)
{
    rx_buffer[rx_write_pos] = UDR0;                          // Read the received byte from the UART data register
    rx_count++;                                              // Increment the received bytes counter
    if (UDR0 == '\n')                                        // If a newline character is received,transmission done
    {
        debug_LED_red();
        rx_buffer[rx_write_pos] = '\0';                      // Null-terminate the string
        rx_write_pos = 0;

        if (strstr(rx_buffer, currentExpectedResponse) != NULL) // Check if the response matches the expected response
        {
            currentCommandState = 2;
        }
        else if (strstr(rx_buffer, "ERROR") != NULL)         // Command is an error command
        {
            currentCommandState = 3;
            debug_LED_yellow();
        }
        else
        {
            currentCommandState = 4;                         // Data is garbage
        }
    }
    else
    {
        rx_write_pos++;                                      // Store the received byte in the buffer
        if (rx_write_pos >= RX_BUFFER_SIZE)                  // If we've reached the end of the buffer
        {
            rx_write_pos = 0;
        }
    }
}
```

UART Programming

```
void handle_received_command()
{
    free(parameters);
    char *at_command;
    char **parameters = NULL;
    int param_count = 0;

    // Check if command is a query or a set command
    if (strstr(rx_buffer, "OK") != NULL) {
        // The received message is "OK"
        return;
        }
        else if (strstr(rx_buffer, "ERROR") != NULL)
        {
        // Command is an error command
        //error handling with pass of ERROR and the *command
        }
        else if (strchr(rx_buffer, '=') != NULL)
        {
        // Command is a set command
        at_command = strtok(rx_buffer, "=");
        char *param_str = strtok(NULL, "=");

        // Tokenize the parameters based on commas
        char *token = strtok(param_str, ",");
        while (token != NULL)
        {
            parameters = realloc(parameters, sizeof(char*) * (param_count + 1));
            parameters[param_count] = token;
            param_count++;
            token = strtok(NULL, ",");
        }
        }
```

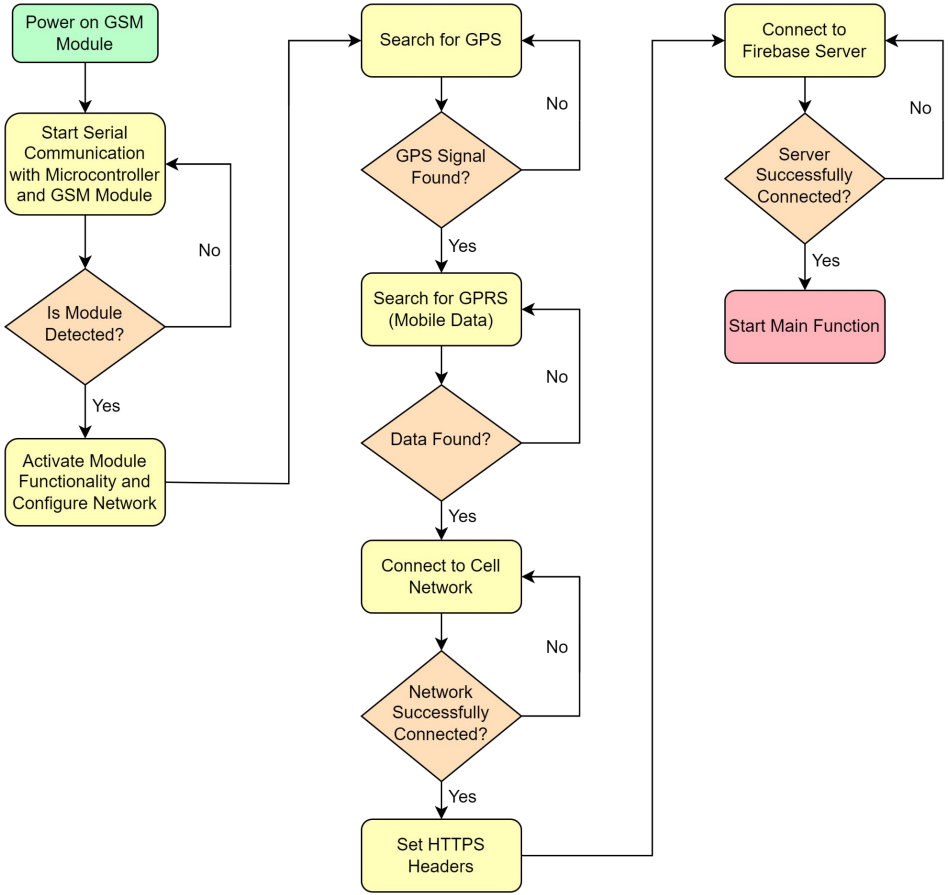
```
else if (strchr(rx_buffer, '?') != NULL)
{
// Command is a query
at_command = strtok(rx_buffer, "?");
parameters = NULL; // No parameters for a query command
}
else
{
// Command is a basic command with no parameters or query
at_command = rx_buffer;
parameters = NULL;
return;
}
```

GSM/SIM Module

Sent UART information to GSM:

```
AT+CMGF=1
AT+CMGS="5862224507"
This is the message text
□AT+CMGF=1
```

GSM/SIM Module Initialization

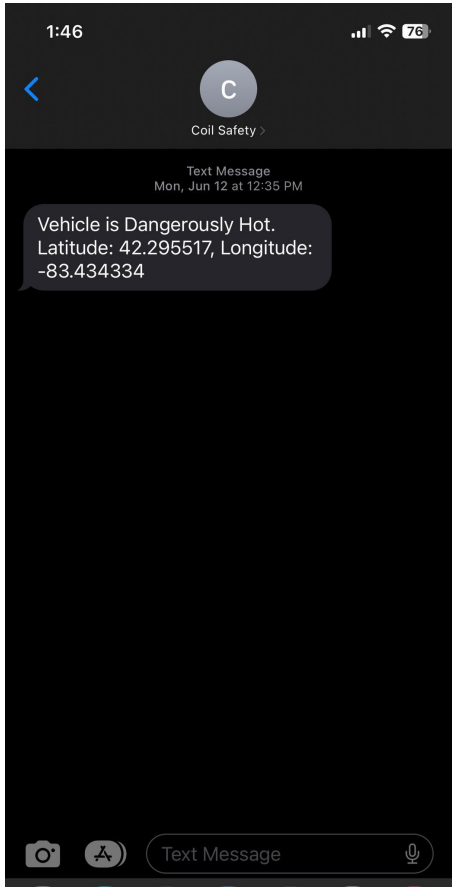


GSM Texting:ATCommands

Command:

```
---> AT+CMGF=1
<--- OK
---> AT+CMGS="7342624678"
<--- >
---> Temperature: 90F
```

Result:



GSM GPS: ATCommands

ATCommand:

```
---> AT+CGNSINF
<--- +CGNSINF: 1,1,20230607191508.000,42.295815,-83.434215,212.600,0.00,0.0,1,
```

Result:

```
Latitude: 42.295814
Longitude: -83.434219
Speed: 0.00
Heading: 0.00
Altitude: 212.60
```

GSM HTTP: ATCommands

```
---> AT+CBC
<--- +CBC: 0,74,3969
---> AT+SHDISC
<--- ERROR
---> AT+CSSLCFG="sslversion",1,3
<--- OK
---> AT+SHSSL=1,""
<--- OK
---> AT+SHCONF="URL","https://fir-test-93ea5.firebaseio.com"
<--- OK
---> AT+SHCONF="BODYLEN",1024
<--- OK
---> AT+SHCONF="HEADERLEN",350
<--- OK
---> AT+SHCONN
<--- OK
---> AT+SHSTATE?
<--- +SHSTATE: 1
---> AT+SHCHEAD
<--- OK
---> AT+SHREQ="/PhoneNumber.json",1
<--- OK
<--- +SHREQ: "GET",200,12
```

```
HTTP status: 200
Data length: 12
        ---> AT+SHREAD=0,12
        <--- OK
        <--- +SHREAD: 12
        <--- "7342624678"
        ---> AT+SHDISC
        <--- OK
```

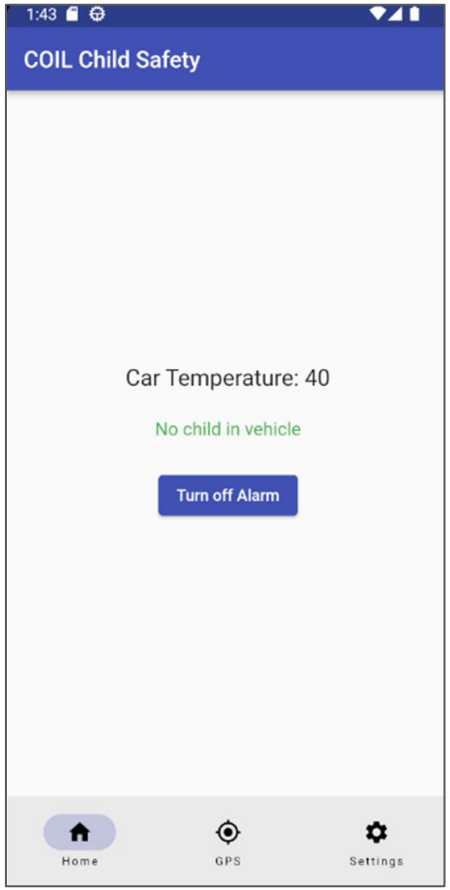
Server Values:

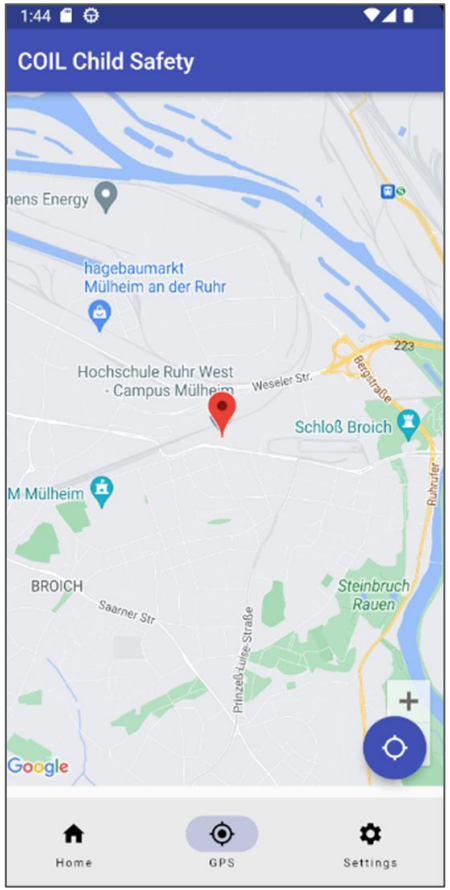
https://fir-test-93ea5.firebaseio.com

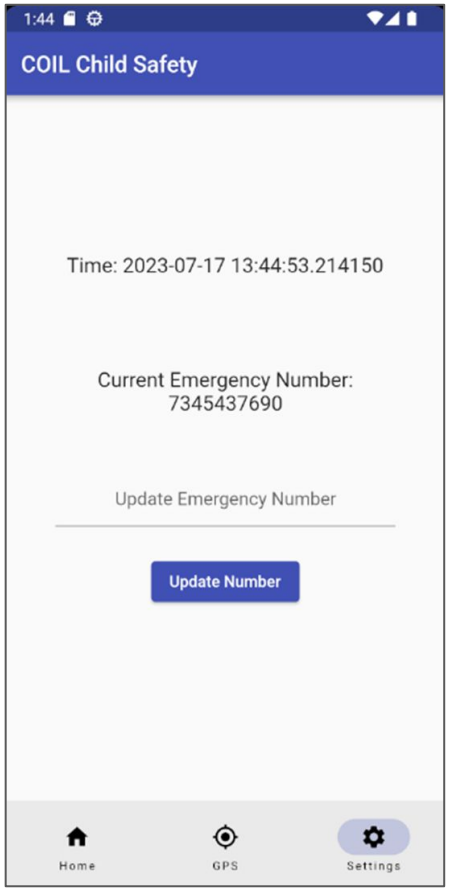
https://fir-test-93ea5.firebaseio.com/

- Alarm: false
- Latitude: 33
- Longitude: 112
- PhoneNumber: "7342624678"
- State: 3
- Temperature: 70

Flutter Mobile App

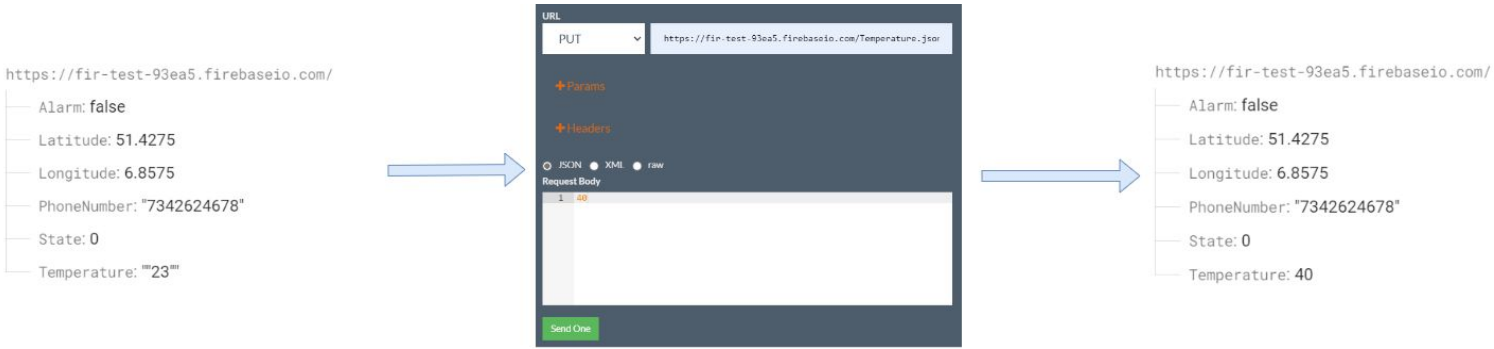






GSM HTTP Protocol and Limitations

- Continuously running HTTP slows the sim module to a halt.
  - A more sophisticated HTTP client is necessary. Possible solution: SBC
  - Instead of continuously updating server, sending texts from temperature and position
  - SSL certificate in modern day secured HTTP services contribute to the delay
- On the ATmega328 HTTP Request Times
  - Server connection: 22 seconds
  - HTTPs GET: 34 seconds
  - HTTPs POST: 53 seconds



Testing

Test Summary

ID-TST 75		ID-VLH 63		It contains a SIM card slot and is compatible with EU and US GSM and GPS standards	GD	GD	GD
ID-TST 76		ID-VLH 64		sound generator should be connected with an automotive compatible connector to the wiring harness	GD	GD	GD
ID-TST 77		ID-VLH 65		use SIM7000E NB-IoT/LTE/GPRS/GPS Expansion Shield	NT	NT	NT
ID-TST 78		ID-VLH 66		specifications of the C-style guide [2] must be followed	NT	NT	NT
ID-TST 79		ID-VLH 67		diagram of programm sequence of alarm system should be used	NT	NT	NT
ID-TST 80		ID-VLH 68		diagram with statistics of heatstroke death of children in vehicel in USA	NT	NT	NT
ID-TST 81		ID-VLH 69		(optional) open windows of the car by 2.5cm if it is too hot inside the car	NP	NP	NP
ID-TST 82	ID-BLH 1			create a prototype of an ECU	NT	NT	NT
ID-TST 83	ID-BLH 2			development of an ECU designed for use with the vehicle components	NT	NT	NT
ID-TST 84	ID-BLH 3			investigated accordingly and documented by suitable functional tests	NT	NT	NT
ID-TST 85	ID-BLH 4			control unit must not exceed standby current consumption with passive module (300 µA)	NP	NP	B
ID-TST 86	ID-BLH 5			control unit should contain the latest electronic components that are freely available on the market	NT	NT	NT
ID-TST 87	ID-BLH 6			ATMega should be used as controller	B	B	B
ID-TST 88	ID-BLH 7			component selection must be made with the best possible cost/benefit ratio	NT	NT	NT
ID-TST 89	ID-BLH 8			all critical values of electronic components are to be designed under "worst case"	NP	NP	NP
ID-TST 90	ID-BLH 9			control unit designed to ensure its full functionality over at least 10000 cycles of operation	NT	NT	NT
ID-TST 91	ID-BLH 10			Proof of compliance with all requirements	NT	NT	NT
ID-TST 92	ID-BLH 11			system must be designed for operating temperatures between -20°C and +80°C	NP	B	B
ID-TST 93	ID-BLH 12			operating voltage range is 9 V - 16 V.	NT	NT	NT
ID-TST 94	ID-BLH 13			control unit must be designed with reverse polarity protection	NP	NP	P
ID-TST 95	ID-BLH 14			control unit measures supply voltage at regular intervals (error entry when range is exceeded or below)	NP	NP	P
ID-TST 96	ID-BLH 15			control unit must be fully functional after the drop test	NP	NP	P
ID-TST 97	ID-BLH 16			parts for actuators selected so that temp increase compared to the ambient temp is limited to 30 K	B	B	B
ID-TST 98	ID-BLH 17			housing for protection against moisture IP54 shall be used for the control unit	B	B	B
ID-TST 99	ID-BLH 18			connectors waterproof versions are to be used	NT	NT	NT
ID-TST 100	ID-BLH 19			control unit´s weight needs to be documented	NT	NT	NT
ID-TST 101	ID-BLH 20			control unit must be designed in such a way that mounting in the higher-level component is possible	NT	NT	NT
ID-TST 102	ID-BLH 21			EMC requirements result from the standard tests	NT	NT	NT
ID-TST 103	ID-BLH 22			measures for the next maturity level are to be presented	NT	NT	NT
ID-TST 104	ID-BLH 23			software is to be versioned	B	B	P
ID-TST 105	ID-BLH 24			documents in table (4.1) to be created/updated for each maturity level	NT	NT	NT
ID-TST 106	ID-BLH 25			product specifications describe how requirements of user requirement specifications are implemented	NT	NT	NT
ID-TST 107	ID-BLH 26			all requirement IDs listed in the product specification	NT	NT	NT
ID-TST 108	ID-BLH 27			all tests mentioned in the test specification are to be listed	NT	NT	NT
ID-TST 109	ID-BLH 28			A complete circuit diagram is created for each maturity level	B	B	P
ID-TST 110	ID-BLH 29			software is documented exclusively as source code	NT	NT	NT

Example Screenshot shows only 40/145 TEST IDs

- BLH: Basic Requirement Specification
- VLH: Model Requirement Specification
- NRM: Standard Test

B	passed
BL	passed last time
P	planned
PN	planned but not carried out
NP	not performable
NT	no test needed
F	failed
GD	grounded by design

Hardware Component Tests

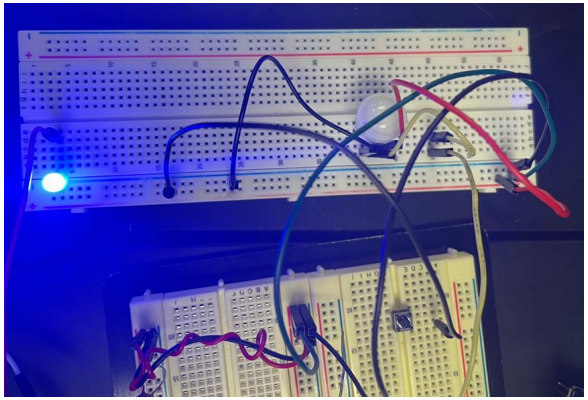
- Testing the capacitive sensor to detect the breathing
- Respiration is not measurable

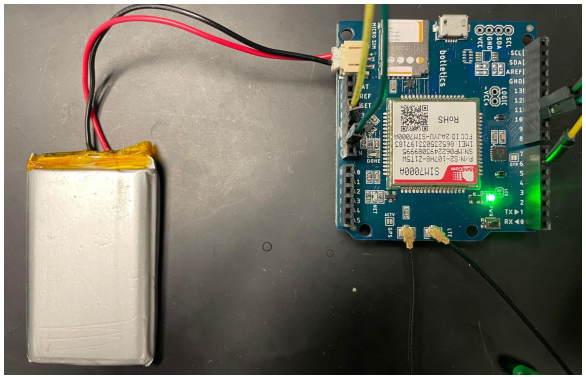
Hardware Component Tests

- Seat belt fastened
  - No detection
- Measurement on level ground
  - Respiration measurable

Hardware Component Tests

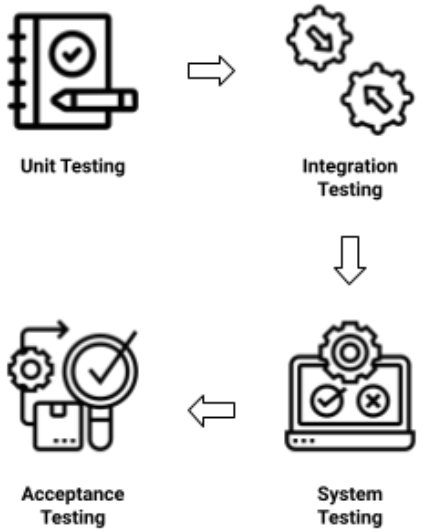
- GSM Module (VLH 33-36)
  - SIM card slot
- Temperature Sensor (VLH 46-51)
  - Room air temperature, connected to the ECU
  - Measurement range
- PIR Sensor (VLH 52-56)
  - Motion in the car
  - Detection Range





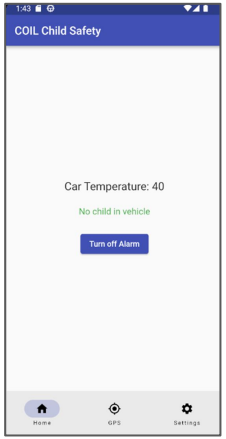
Software Functionality Tests

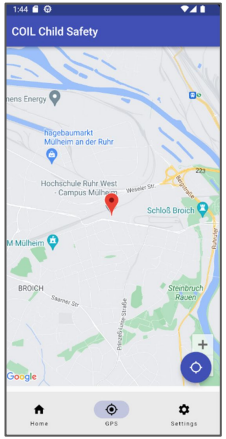
- Tests conducted on Mobile App
  - ID-NRM 13: Unit testing
  - ID-NRM 12: Integration testing
  - ID-NRM 14: Functional testing
  - ID-NRM 16: Regression testing
  - ID-NRM 17: Stress testing
  - ID-NRM 11: Acceptance testing
  - ID-NRM 18: Usability testing
- Test conducted on GSM
  - ID-NRM 14: Functional testing
  - ID-NRM 17: Stress testing
  - ID-NRM 19: Network Reliability

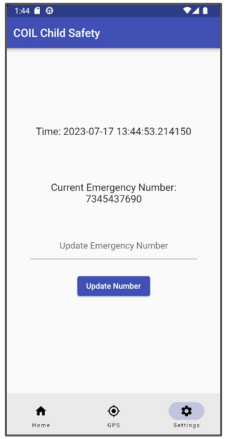


Software Functionality Tests

- Example Tests conducted on Mobile App
  - ID-NRM 13: Unit testing







- Example Test conducted on GSM
  - ID-NRM 19: Network Reliability

```
---> AT+CGREG?
<--- +CGREG: 0,5
Network status 5: Registered roaming
```

Future Ideas

- Connect to car to open windows when child is detected in critical temperature
- More sophisticated HTTP client: SBC
  - App integration
- Consider other sensor technologies for improved detection

Demonstration

References

- Jennifer K. Vanos, Ariane Middel, Michelle N. Poletti & Nancy J. Selover (2018) Evaluating the impact of solar radiation on pediatric heat balance within enclosed, hot vehicles, Temperature, 5:3, 276-292, DOI: 10.1080/23328940.2018.1468205
- Heat Stress in Motor Vehicles: A Problem in Infancy K. King; K. Negus; J. C. Vance; Pediatrics (1981) 68 (4): 579–582.; https://doi.org/10.1542/peds.68.4.579
- Gibbs LI, Lawrence DW, Kohn MA. Heat exposure in an enclosed automobile. J La State Med Soc. 1995 Dec;147(12):545-6. PMID: 8543892.
- alguth, Posted by, and Kutukamus Says: “On the Heating of Parked Cars.” *Doing Science To Stuff*, 18 July 2013, blog.doingsciencetostuff.com/2013/07/18/on-the-heating-of-parked-cars/.

Questions?