A Novel Vehicular Heatstroke Prevention by Smart HVAC System Model

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Abstract. Today, automobile safety has become one of the paramount focus areas by car manufacturers. The vehicles of today have increasingly grown more intelligent to keep passengers safe on the road. Apart from traffic safety, non-crash safety issues progressively turn out to be another prime concern. Currently, vehicular heatstroke deaths in parked vehicles are one of the major focuses in the non-crash safety domain. 2018 saw a total of 52 American children died while 90% out of 8290 calls to RSPCA concerned trapped dogs in scorching cars. Thus, we proposed a prototype system with the capability to monitor vehicle conditions and take appropriate actions to save a life. The objective of this work is to reduce the possibility of uninformed passengers, especially children, the elderly, and the pets, from unnecessary deaths or suffering from trapped car-related heatstroke. This prototype can be further enhanced to smartly communicate with other Electrical Control Units (ECUs) inside the vehicle via an in-vehicle communication network, i.e. CAN bus to further improve vehicle safety.

1. Introduction

Heatstroke is a condition due to body overheating, mostly due to a result of prolonged exposure to or physical exertion in high temperatures. This most serious form of heat injury, heatstroke, can happen when the body temperature rises to 104°F or higher [1].

Two different heatstroke definitions are in use worldwide. Bouchama defined heatstroke as a core body temperature exceeding 40°C, accompanied by hot dry skin and central nervous system abnormalities, i.e. delirium, convulsions, or coma, resulting from exposure to high environmental temperature or strenuous exercise. Japanese Association for Acute Medicine (JAAM) classified heatstroke patients exposed to the high environmental temperature as exhibiting either the central nervous system impaired consciousness with a Japan Coma Scale score of ≥ 2 or hepatic or renal dysfunction or coagulation disorder [2].

In 2018, 52 children died from heatstroke in cars, the highest cases in more than 20 years per Jan Null’s incident tracking [3], and increases over the years [4] [5]. The number of pets suffering from in-vehicle heatstroke is equally high since it takes six minutes for a dog to perish in a blistering hot automobile.
Many pet owners are ignorant of their dogs’ reactions to heatstroke, given the fact that only 50% of dogs survive if the internal temperature goes above 105°F.

Many caregivers lack the competence in handling rapid temperature elevation even in ambient temperature outside the car. The vehicle’s interior’s materials and colors, i.e. the leather installation, the black-color dashboard, and the enclosed environment absorb and trap the heat. Furthermore, the black-color exterior, transparent windows, and the wide windscreen contribute to the heat by exposing the interior, turning the car into a greenhouse. The in-car temperature takes only 30 minutes to reach 104°F, effectively almost doubling the outside temperature of 70°F on an ordinary sunny day.

Table 1 shows the estimated vehicle interior air temperature vs elapsed time, which is showing the severity of the rising temperature inside the vehicle. Temperatures inside vehicles can reach up to life-threatening levels, even during mild or cloudy days. It could not be further emphasized that, to begin with, the children, the elderly, and the pets should never be left unattended inside a vehicle by responsible adults.

| Elapsed time | Estimated Outside Air Temperature (°F) | Estimated Interior Air Temperature (°F) |
|--------------|----------------------------------------|----------------------------------------|
|              | 70 | 75 | 80 | 85 | 90 | 95 |
| 0 minutes    | 70 | 75 | 80 | 85 | 90 | 95 |
| 10 minutes   | 89 | 94 | 99 | 104 | 109 | 114 |
| 20 minutes   | 99 | 104 | 109 | 114 | 119 | 124 |
| 30 minutes   | 104 | 109 | 114 | 119 | 124 | 129 |
| 40 minutes   | 108 | 113 | 118 | 123 | 128 | 133 |
| 50 minutes   | 111 | 116 | 121 | 126 | 131 | 136 |
| 60 minutes   | 113 | 118 | 123 | 128 | 133 | 138 |
| > 1 hour     | 115 | 120 | 125 | 130 | 135 | 140 |

Between 1998 and 2018 timeframe, more than 800 minors’ vehicular heatstroke-related deaths were registered with a 24% occurrence in employer parking lots while the caregivers were at work. Three primary factors resulting in children’s deaths in the hot vehicle are:

- Caregivers forgot their children in vehicles
- Children gaining unauthorized access to the vehicles
- Knowingly leave children in the vehicles
Figure 1 shows the circumstances resulting in children’s heatstroke in a vehicle.

![Figure 1](image1)

**Figure 1.** Circumstances resulting in pediatric vehicular heatstroke deaths (1998-2018). [3]

Although people leaving children unattended in vehicles is considered a society’s unacceptable behavior, statistics continue to show alarming trends in vehicular heatstroke-related deaths with U.S. children death data in Figure 2 [6].

![Figure 2](image2)

**Figure 2.** Pediatric Vehicular Heatstroke Deaths [6]

The data illustrates the urgency for in-vehicle technology to safeguard the children, the elderly, and the pets, who for unknown reasons, left unattended in hot vehicles. This system must be smart enough not only to detect but also to take action to save a life.

This paper demonstrates a heatstroke prevention system using smart **Heating**, **Ventilation**, and **Air Conditioning** (HVAC) system. Due to coordination limitations with the car manufacturer, a stand-alone proof of concept system is being developed with the ability to sense moving life objects or animals, monitor the in-car temperature, and take necessary actions to save a life.

The paper is organized into the following sections. Section 2 provides an overview of existing product and technology implementations. Section 3 discusses the limitations of existing solutions. Section 4 presents the proposed methodology. Section 5 includes the prototype under development. Section 6
discusses the adoption obstacles. Section 7 discusses future research directions. Finally, Section 8 covers the project conclusions.

2. Existing products and technologies
In this section, existing vehicular implementations are discussed. A survey shows that there are several systems currently in the market to trigger caregivers’ attention to taking care of unattended living beings in cars.

Pressure/force-based systems – the detection concept is by pressure applied to the sensor located at the existing vehicle seats, or separately-installed child restraint. This concept is to detect the weight of the object occupying the car seats. For the pre-installed under-the-car-seat concept, the vehicle’s alarm will be triggered after some time if the door closed and the car’s ignition is off. This indicates that the car driver has left the vehicle, but there is still an object detected in the car’s seat. There are several off-the-shelf aftermarket products such as ChildMinder ePad System [9], SafeBABI [10], etc., equipped with a key chain type alarm system which will trigger when it is detected that the driver and the child (in the vehicle) separated for a certain distance.

Buckled chest clip system – this system replaces the child restraint’s chest. There is a battery-powered key-chain alarm system which is placed with the car key. The alarm will be triggered if the caregivers are away from the car for a certain distance and a certain time if the caregivers do not un-clip (deactivate the alarm) the system. The device available in the market is the Child Minder Smart-Clip System [11].

Reminder system when ignition switched off – this system reminds caregivers to check for any rear passengers before leaving the vehicle. This system with a “voice” message will be activated when the ignition switches off. This system is typically implemented in school buses and vans. The product is available in the market such as Kiddie Voice Child Reminder System [12].

Some other sensing systems are using a wireless feature that makes use of the pressure/force-based system and an accelerometer. The accelerometer is used to detect whether the vehicle is moving or idle. This system is designed without the need for any wiring, by using plain Bluetooth communication to smartphone protocol [3].

3. Limitation of existing solutions
In consideration of section II, these different products leveraging various technologies aimed at protecting children by triggering caregivers still have room to improve. The known limitations are:

- Battery-powered key-chain type alarm potentially catch caregivers off guard when the battery runs flat without notification
- Since these systems are separate from the car’s standard installation, if vehicle owners’ self-installation is not properly done according to specifications, they are vulnerable to malfunction
- False alarms may trigger unnecessarily as the sensor depends solely on pressure/force on the seat. The pressure/force applied on the seat may not necessarily due to children or pets, but it may be a piece of luggage with sufficient weight to trigger the sensor
- The implemented solution was not designed to save a life but only to alert caregivers
- The device can be intentionally deactivated or ignored by the caregivers, based on 18.6% of caregivers’ Knowingly Left data in Figure 2

Based on the above-mentioned solution limitations, significant effort is required for caregivers to install the devices in the car. The caregivers must also ensure that younger children are not misusing the
devices. Extra precaution is also required for the alarm system’s batteries to be frequently changed. The detection distance may vary from device to device due to the sensor calibration capability.

The pressure/force-base detection method may be impractical due to driver habits unintentionally placing unrelated objects of considerable weight at the rear seat, causing a false alarm. Some of the children and pets occupying the vehicle will naturally move around inside the vehicle, rendering pressure/force detection to be non-full-proof. Besides, the nature of children and pets not sitting still at their seats will cause the sensor not able to periodically detect and acknowledge the presence of any children or pets in the vehicle.

It is worse for caregivers who knowingly left their children, the elderly, and the pets inside the vehicle. The caregivers intend to think that it might be safe to partially open the windows, but they might not realize the gravity of rapid temperature upsurge in the vehicle.

4. Proposed Smart HVAC system
By comprehending the heatstroke hazards in the vehicles, and current solutions limitations, a solution is developed not only to detect, monitor, and trigger the alarm but also to proactively save a life. This solution has the required intelligence designed to bring down the temperature in the vehicle without human intervention. Hypothermia is out of scope for this model.

The solution we develop is based on Internet-of-Things (IoT) and real-time system methodology, consists of:

- Sensors:
  - Temperature sensor to monitor the temperature in the vehicle
  - Motion sensor to detect moving objects such as pets which will naturally move around inside the vehicle
  - Microphone sensor to sense sounds detected in the car. When faced with an abnormal situation, such as when the car interior gets too hot, children and pets will naturally create noise, with the baby starts crying and the dog barking

The motion and microphone sensor combination precludes any false alarms by validating real living beings in the vehicle.

- Actuators:
  - The alarm will be triggered if the sensing conditions are met. The alarm is used to trigger surrounding people to save lives in trouble in the vehicle
  - Hazard lights will also be triggered to highlight extra attention to bystanders for help during night time
  - The exhaust fan is the key element for saving lives. An exhaust fan is used to exhale the in-vehicle heat out so that the vehicle’s temperature will consequently drop
  - SOS system will be triggered to make an alert call to an emergency call center, such as eCall 112 for Europe [14] and eCall 911 for the USA [15]. This is a safety net in case no one rescues the left-over children/pets in the heated vehicle and the temperature keeps rising to the danger level.

- Xilinx Zynq-7000 board, also known as the Zybo board, will be strictly targeted for the proposed development platform for the prototype. This board, together with the related electronic parts, is reasonably affordable and can be easily sourced from any electronic shop. This prototype should eventually integrate into existing in-car sensors, actuators, and HVAC system during vehicle production to proactively avoid mechanic installation issues and caregivers’ negligence.
• FreeRTOS, a Real-Time Operating System (RTOS) with the pre-emptive kernel option to be used to assign highest priority levels to mission-critical tasks to respond to hard deadlines to avoid any catastrophic consequences
• Vehicle’s components’ motion in terms of doors, windows, and ignition statuses. Doors and windows are additional required checks since the temperature will rise rapidly if the doors and windows are closed. In most cases, the temperature will rise even with windows partially open. In this case, the exhaust fan will be activated to purge the heat out of the vehicle as long as the system detected real living beings in the vehicle

The proposed design consists of motion sensors detection and pre-calibrated microphone using general-purpose I/Os. The temperature sensor, based on analog to digital conversion method, is software-configurable (Figure 3).

![Figure 3. The Proposed Vehicular Heatstroke Prevention System Diagram](image)

The exhaust fan, hazard light, and alarm are activated using general-purpose I/Os. As demonstrated in Figure 3, the exhaust fan plays a crucial role in this system. Hazard light and alarm are the actuators to trigger for help from nearby onlookers. The exhaust fan will be intelligently activated to lower the temperature while waiting for help. With this proposed design, the objective is to save a life whether the children, the elderly, or the pets are left intentionally or unintentionally in the hot vehicle. SOS system acts as a safety net by triggering an emergency call if the temperature continues rising to a dangerous level.

The approximate cost of the prototype system is listed.

| No | Items                                           | Cost Per Unit |
|----|-------------------------------------------------|---------------|
| 1  | Zybo-7000 ARM/FPGA Board                        | RM808.64      |
| 2  | Arduino Temperature Sensor                      | RM2.30        |
| 3  | Sound Sensor                                    | RM6.00        |
| 4  | PIR Motion Sensor                               | RM8.30        |
| 5  | 5V Piezo Buzzer C/W Wire                        | RM1.00        |
| 6  | Mini Cooling Fan -5V                            | RM7.00        |
|    | **Total**                                       | **RM833.24**  |
5. Prototype

Figure 4 shows the prototype implementation. The prototype consists of a buzzer to represent an alarm system and LEDs to represent hazard lights. The whole implementation is powered up by a 5V source, which is easily drawn from the vehicle battery supply. Doors, windows, and ignition status are simulated using the Zybo board’s dip switches. The DC motor fan represents a car exhaust fan. Figure 5 is the real use case block diagram for Vehicular Heatstroke Prevention by Smart HVAC.

![Prototype Image](image1)

Figure 4. A Prototype of the system

In other words, Figure 5 is the detailed hardware routing of the design. This prototype has been successfully implemented with the acceptable response from every sensor and all the actuators can act in real-time without delay. This proves that FreeRTOS real-time system and Zybo board can be utilized to successfully develop the smart HVAC system design.

![Use Case Diagram](image2)

Figure 5. Use Cases Block Diagram
6. Result and discussion
In this section, we will illustrate some experimental results based on the use cases. This SMART HVAC SYSTEM design is based on the FreeRTOS Real-Time Operating System (RTOS) with multiple tasks running simultaneously.

The setup 1 use case showed the experimented results with the highest priority task that preempted the low priority task including the semaphore event that passed a specific task ID designed on the use case logic. The setup 2 use case validated the design logic on the Sensor Monitoring task to read the environment data, which included any motion detection from life objects, sound input from MIC input and car ambient temperature, and the use case’s condition to trigger the actuator's output. The setup 3 use case validated the temperature sensor to read the car ambient temperature designed based on the ADC input.

Use Case setup 1: Experimented results on Vehicle Status Monitoring Task get the input parameters and semaphore event pass it to Sensor Monitoring Task (Table 3).

| Input Parameters | Output |
|------------------|--------|
| Door Signal | Window Signal | Ignition Signal | Even Passing to Sensor Monitoring Task |
| 0 | 0 | 0 | No Event Pass |
| 0 | 0 | 1 | No Event Pass |
| 0 | 1 | 0 | No Event Pass |
| 1 | 0 | 0 | No Event Pass |
| 0 | 1 | 1 | No Event Pass |
| 1 | 0 | 1 | No Event Pass |
| 1 | 1 | 0 | No Event Pass |
| 1 | 1 | 1 | Send the semaphore event within 800 milliseconds to Sensor Monitoring Task |

Use case setup 2: Experimented results on Sensor Monitoring Task get the input parameters to send the semaphore events to Action Trigger Task and ON the actuators devices (Table 4).

| Input Parameters | Actuator Output |
|------------------|-----------------|
| Motion Sensor | MIC Input | Temperature Sensor | Exhaust Fan | Buzzer (Alarm) | SOS (eCALL) |
| 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | < 40 °C | 0 | 0 | 0 |
| 1 | 0 | < 40 °C | 1 | 1 | 0 |
| 1 | 1 | < 40 °C | 1 | 1 | 0 |
| 1 | 1 | > 40 °C | 1 | 1 | 1 |

Use case setup 3: Experimented results on Temperature Reading Task to read ADC voltage from the temperature sensor to check is reach the high-temperature limit (Table 5).
With the identification of all these challenges, some strategies to improve users’ adoption have been proposed:

- Increase public awareness on the in-vehicle heatstroke via awareness campaigns
- Increase the knowledge of in-vehicle temperature profile versus outside temperature given the fact that in-vehicle temperature fluctuations are drastically different from that outside of the vehicle
- Propose regulatory measures for the vehicle to be equipped with the children/pets presence detection and triggering mechanisms, including life-saving options
- Propose regulatory measures for car manufacturers to integrate the proposed solution into their vehicles

Table 6 illustrates the comparison between the proposed solutions against currently available vehicular heatstroke prevention systems:

**Table 5. Use Case Setup 3**

| ADC Voltage from Temperature sensor | Ambient Temperature | Temperature Limit          |
|-------------------------------------|---------------------|---------------------------|
| 0.00                                | 0°C                 | 0°C                       |
| 0.238                               | 22°C                | Comfortable Temperature   |
| 0.245                               | 25°C                | Comfortable Temperature   |
| 0.250                               | 27°C                | Comfortable Temperature   |
| ≥ 0.50                              | ≥ 40°C              | Extremely High Temperature|

**Table 6. Proposed Solution Vs Currently Available Vehicular Heatstroke Prevention Systems Comparison**

| Existing Solutions                                                                 | Proposed Solution                                                                 |
|-------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| “ChildMinder” solution requires setting up the alarm to alert the driver. The drawback is if the alarm is not set due to negligence, the consequences will be life-threatening. | The proposed solution able to detect the live object in real-time and without user intervention. And the benefit of this solution able to auto-trigger the SOS call to rescue team. |
| Rear Passenger weight detector. The drawback is the alarm’s unnecessarily false triggering as the sensor depends solely on pressure/force on the seat. The pressure/force applied on the seat may not necessarily due to children or pets, but it may be a piece of luggage with sufficient weight to trigger the sensor. It may cause a car battery drain due to this type of false alarms. | The proposed solution can detect live objects using motion or sound detection while the car engine is off and the live objects are still inside the car to avoid false alarm problems. |
| Baby car seat with battery key chain-powered alarm potentially catches caregivers off guard when the battery runs flat without any advance notification. | The proposed solution is powered by the car battery with very minimum power consumption for operation. And the proposed solution operates during the car engine off mode to detect any live objects inside the car. |
| “Aftermarket systems” are not part of car manufacturers’ standard installation, if vehicle owners’ self-installation is not properly done according to specifications, they are vulnerable to malfunction | The proposed solution is part of the overall car design to ensure the proposed solution maximum co-existence with the car interior design. Will need to work closely with car manufacturers on the most optimal design. |
7. Future research directions

Each figure should have a brief caption describing it and, if necessary, a key to interpret the various lines and symbols on the figure. Even though this work has been successfully implemented, it has its limitations and challenges. One important factor to be taken into consideration is the fact that this is a prototype under development. The intention is to demonstrate the heatstroke prevention concept using existing vehicle resources, like a car horn, hazard lights, microphone, HVAC temperature sensor, and telematics unit. The only additional design element that needs to be incorporated into the car is the motion sensor unit. It is not the final system to be implemented in vehicles.

The final standalone solution may need to be installed by a professional technician. There might be some issues expected during the installation, including taking in the proper signals for the doors, windows, and ignition statuses. Considerable vehicle’s wiring modification might be needed, which might not be within the car owner jurisdiction. This prototype should eventually integrate into existing in-car sensors, actuators, and HVAC system during vehicle production to proactively avoid mechanic installation issues and caregivers’ negligence. Another anticipated barrier might be the car owners’ own willingness to adopt this solution. Base on Figure 2, since the majority of the incidents’ root causes are due to ignorance and negligence, this car owner’s outright unfavorable behavioral traits typically may not convince them to install this system. However, this is still a prototype under development and these issues might need to be addressed in future research.

To effectively drive in-vehicle heatstroke incidents reduction, the best solution would be to impose regulatory measures for car manufacturers to implement the proposed solutions. The solution should complement the existing in-vehicle Electronic Control Units (ECU) to take advantage of the electronic processing capability of the vehicle.

An initial investigation for future research shows that this proposed Zybo board-based system can be connected to a Vehicle OBD-2 (On-Board Diagnostics 2) port, the onboard in-car computer that monitors vehicle-related data, via an OBD Interpreter, which will interpret the vehicle internal communication message, and then send it out to Zybo board-based system over UART interface.

![Figure 6. Future research for Zybo board to connect to Vehicle OBD-2 port via a CAN bus for integration into the vehicle](image)

The reason is that every vehicle internal ECU communication is different, so OBD2 connector on the vehicle will expose all the standard interfaces out to the external world, then external devices such as the OBD2 interpreter will translate the vehicle message to UART interface.
The strategic proposal is for the system to be able to monitor the doors, windows, and ignition status via vehicle communications bus i.e. CAN bus [7]. Doors and windows status can be obtained from the Body Computer Module [8] which will periodically broadcast these statuses. In the same manner, the ignition status can be obtained from the CAN bus or via a hard-wired option.

When Smart HVAC system detects a moving object in the vehicle, presumably the children, the elderly, or the pets in the ignition-off condition, the Smart HVAC requires to turn on the air-conditioning exhaust fan. Smart HVAC should also communicate to ECU to activate the hazard light and alarm to alert the surroundings for help. The vehicle can also be designed to send SOS messages to the vehicle call center or the car owner. All the vehicle’s ECUs need to intelligently communicate with each other and act as necessary without human intervention. Figure 8 is the proposed future in-vehicle solution by car manufacturers. A suggestion is to include this solution together with an in-vehicle HVAC system, to make it able to save lives.

Another anticipated issue concerns noise effects on live subjects in the car due to passing vehicles. Since most modern cars have already been equipped with the high-end microphone with noise suppression features, noise interference might be of minimum impact on the target passengers.

Figure 7. OBD2 Connector and Pin Out

Figure 8. Smart HVAC architecture proposal
Overcome Trauma for Children Alone in Rear Seats Act, H.R.3593) [13] introduced by US Congress on September 15, 2016, hopefully, can be enforced for implementing this system on every vehicle, such as reverse sensor and seat belt. Specifications must be defined to standardize the implementation and communication aspects with regards to all the ECUs in the vehicle. Reliability testing specifications must be created to ensure the implementation fulfills all the requirements. The testing must be carried out in various extreme conditions such as in the arid environments.

8. Conclusion
The vehicular heatstroke statistics showed that the car industry needs to seriously investigate these catastrophes incidents and find solutions. Existing solutions available in the market are still not good enough to resolve the in-vehicle heatstroke issues. This paper focuses on a life-saving system proposal to protect our beloved ones, not limited to children and pets, but also the vulnerable elderly people and those with disabilities. To make the system more intelligent, sensor data can be sent to the cloud for further analysis, more data collection on the temperature data, as well as more in-depth behavioral studies on the caregivers, using cloud-based data.

9. Acknowledgments
The authors wish to thank Universiti Sains Malaysia for providing the Xilinx Zynq-7000 board critical for this research that culminates in the publication of this paper.

10. References
[1] Mehta, S. R., Jaswal, D. S., Heat Stroke. Medical J., Arméd Forces India. vol 59, issue 2 (2003) pp. 140.
[2] Hifumi, T., Kondo, Y., Shimizu, K. et al., Heatstroke. J. of Intensive Care. vol 6, issue 30 (2018) DOI:10.1186/s40560-018-0298-4.
[3] Null, J., Trends and Patterns in Pediatric Vehicular Heatstroke Deaths, 1998-2018. Dept. of Meteorology and Climate Science, San Jose State Univ., (July 2019).
[4] Grubenhoff, J., du Ford, K., Roosevelt, G. E., Heat-Related Illness, Clinical Pediatric Emergency Medicine. vol 8, issue 1 https://doi.org/10.1016/j.e pepm.2007.02.006, (2007).
[5] Guard, A., Gallagher, S. S., Heat-related deaths to young children in parked cars: an analysis of 171 fatalities in the United States, Inj Prev 2005. vol 11, issue 1, 1995-2002.
[6] Howell, D., Talley, S., Seong, S., Smart system to prevent child vehicular heatstroke. Arkansas State University, Future Technologies Conference (FTC), [online document], 29-30 Nov. 2017. Vancouver, Canada, https://saiconference.com/Downloads/FTC2017/Proceedings/144_Paper_296-Smart_System_to_Prevent Child_Vehicular_heatstroke.pdf. [Accessed: Nov. 19, 2019].
[7] Bosch, CAN specification, http://www.bosch- semiconductors.de/media/pdf_1/canliteratur/can2spec.pdf, Version 2.0, September 1991.
[8] Bosch, Body Computer Module, Domain control unit for body electronics functions, https://www.bosch-mobility-solutions.com/en/products-and-services/passenger-cars-and-light-commercial-vehicles/interior-and-body-systems/body-electronics/body-computer-module/
[9] Coxworth, B., ChildMinder reminds drivers not to leave their baby in the car, New Atlas, https://newatlas.com/childminder-pad-baby-car-alarm/23174/, retrieved July 03, 2012
[10] Texas Instruments, “SafeBABI”, https://processors.wiki.ti.com/index.php/SafeBABI
[11] Baby Alert International, “ChildMinder SoftClip System Foto Guide”. Retrieved from https://www.babyalert.info/guides/softclip_files/softclip-system-foto-guide.html#p=1
[12] KiddieAlert, “Kiddie Voice Child Safety Alarm”. Retrieved from http://atwecgrp.com/kiddie-voice-child-safety-alarm.html

[13] Standardized Technical Specification, Bi-Level Passenger Rail Cars for Intercity Corridor Service, HVAC System, Revision C, California Department of Transportation, (2010) ch. 10.

[14] U.S. House. 116th Congress, 1st Session. Subcommittee on Consumer Protection and Commerce, Hot Cars Act of 2019. [Online]. Available: https://www.congress.gov/bill/116th-congress/house-bill/3593. (Jun. 28, 2019).

[15] B. Williams, “European Standardization in support of eCall,” European Committee for Standardization, CEN TC278 WG15, (Oct. 3, 2019).

[16] Oörni R., Goulart, A. In-Vehicle Emergency Call Services: eCall and Beyond. IEEE Communications Magazine. vol 55, issue 1, (Jan. 2017) pp. 159-165.