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Optimization of Electronic Automobile Urgent Cabin Climate Control System (EAUCCCS)

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Abstract: - The high cabin air temperature for vehicle parked at a location exposed to day long sunlight often causes thermal heatstroke to inside passengers and a negative effect on the cars air-conditioning systems. This work focuses on the design of the urgent cabin climate control system and develop microcontroller program to monitor and control the temperature and weight inside the parked vehicle to serve and adjust the cabin conditions. The system consists of three individual circuit boards that work together to build and form an overall system. The proposed microcontroller program will control on actuators which receives signals from several sensors at different positions inside the vehicle cabin. The work was carried on chosen parked switched off and under sunlight vehicle of TOYOTA Corolla, 2006 (E120) with 1.6 Liter of engine displacement.

Keywords: - Cabin air temperature, vehicle heat stroke, thermal comfort, design patterns.
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1 Introduction

The intensity of solar energy density in some hot countries causes uncomfortable event called greenhouse effect within the cabin parked vehicles under the hot sun. Considerable rise in temperature within the vehicle cabin was achieved when parked under the day sun light. Gaurav Kumar Jaiswal, et al. [1], and Mezrhab and M Bouzidi, [2]. During summer seasons, a very high temperature rises within the range of 55ºC – 78ºC may be observed inside the cabin of the vehicles and which may cause heatstroke. Under the hot conditions, parents and others should take care of the children when leaving them inside the vehicle's cabins. Furthermore, even on normal days with considerable temperatures, the thermal condition inside a parked vehicle can achieve harmful levels within a short time and causes high effect on small children health left inside vehicle.

A condition of human body overheating is called heatstroke. This phenomenon is happening when the human body exposes to high temperature rises up to 41.6oC or higher for a long time. Furthermore, the body cells will damage when the body temperature increases more than the above temperature and finally leads to death. As a matter of fact, the children's systems of Thermoregulatory are not effective as an adult because of warming their body temperature 3 to 5 times faster than an adult.

Again, in summer seasons, the shortwave radiation of the suns is warmed little the window of the car due to its transparency. While, the energy of shortwave will often heat the objects inside the vehicle cabin such as a dark dashboard, steering wheel and car seat temperatures in the range of 82ºC up to over 93ºC.

Asaf Degani1, et al. [3], analyzed and designed an automotive system through a formal approach interaction between a human machine and behavior of a generic climate control system.

Topic of design parameter and model were defined and some design parameters were explored and explained. K. GalatsisW, Wlodarski [4], studied prime source pollution under conditions of exhaust entered the cabin and causing diver discomfort and adverse health effects. According to sensors communication systems between the engine and body management of vehicle, they suggested excite effective action to avoid driver exhaustion.

Kim N., et al. [5] explored ventilation setting system based on vehicle carbon monoxide.

Portable monitors installed within the vehicle to record the concentrations of carbon monoxide. The results showed that the, the concentration was function of year season, while highly dependent on initial inside vehicle concentration. Furthermore, the mean concentrations of carbon monoxide inside the vehicle for ventilation with recirculation were mainly higher than when the windows were open or new air.

Tong-Bou, et al. [6], investigated the condition of carbon dioxide inside the cabin of the vehicle. The effect of out-door ventilation rate on the vehicle inside cabin air quality for each passenger was simulated using CFD model. The results showed that, by using 2.5 lit. /s per person of outside air as recommended by ASHRAE Standard 62.1, the mean concentration inside the cabin was found to be 2850 ppm. While, using 4 lit. /s per person of outside air, the mean concentration inside the cabin was improved and found to be 1810 ppm.V. Ramya1 and B. Palaniappan [7], fabricated built-in system in vehicle cabin, which senses the concentration of oxygen and carbon-monoxide gases. The system monitored the concentration of each gas within second intervals and informed the authorized user via GSM. The results showed the benefit of this system in fast diffusion due to the proper and fast detection time compared with the normal techniques. Rajesh Kumar1 and Hari Parshad [8] showed how to simulate the pollutants inside a car. Through finding out the pollutants present inside the car with their concentration. The flow parameter of pollutants was measured at different positions inside the car. The results of simulation showed that inside pollutants affect the driver and passengers up and the car engine conditions played an important role in emission of pollutants so parameters related to car engine.

Catherine [9], measured the rise and rate of temperature in different ambient temperatures under condition of windows "cracked" open. The results showed that, the rate of temperature rise inside the vehicle independent to the outside environment temperature. Also, during the first 30 minutes, an increase of 3.2^{o}F per 5 minutes interval was recorded in average mean temperature. In addition, an average temperature increase of 40oF inside the cabin was measured during the ambient temperature within the range of 72 to 96^{o}F. Finally, no effect of open cracking windows was observed.

S.R. Janani1 [10], proposed study of monitoring techniques for bus monitoring at various location, accident detection, alerting system, fuel monitoring system and an overview about the proposed methodology.

Sudhir, et al. [11], investigated inside pattern of temperature for cabin of a parked Sedan car under the day sunlight by measuring the temperature inside the cabin. Two fans were used for ventilation system. Experimental measurements showed a high nearly 22^{o}C in inside cabin temperature compared with ambient temperature under bright sunlight. While, with proposed ventilation system, an approximate of 50% reduction in temperature of the cabin was observed.

Johannes Horak [12], developed a model by using three meteorological parameters, ambient temperature, solar radiation and wind velocity for simulation of cabin temperature.

Based on exposure time, the model was capable to calculate and evaluate the amount of heat stress for cabin passengers. This technique assisted to identify whether the calculated heatstroke was lethal or not. Alahmer, A. [13], investigated the influence of inside cabin relative humidity on the passenger thermal comfort. The results showed that, the air conditioning efficiency was improved by changing dry bulb temperature along with relative humidity. This was due to reduction in heat removal and consequently, the passenger thermal comfort became better. Alexis D. [14], designed safety system to observe the temperatures of ambient and load on an infant seat. The smart seat system was consisted of three individuals normalize integrated circuit boards that work unity to form comprehensive system.

This study focuses on the development of microcontroller programmer system based on design of urgent cabin climate control system to control the temperature and seat conditions inside the cabin of vehicle to serve and adjust the conditions accordingly. The proposed microcontroller programmer will control on actuators which receives signals from several sensors at different positions inside the cabin for totally closed parked vehicle and switched off under the sunlight.

2 EAUCCCS Design

The procedures of designing the loop of urgent cabin climate control system are introduced and shown in Figure 1. Designing procedures depend on analysis of the surrounding environment in order to find a way that the system must react with it. For proper work of EAUCCCS, the design requirements and consequently the components of the system will be specified.

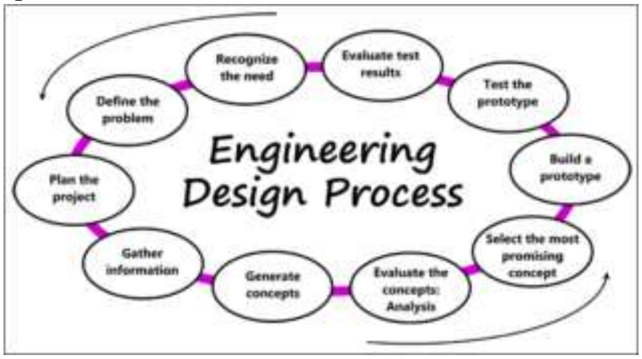

Fig.1 Designing loop

3 Requirements

The required action to prevent the heatstroke while the vehicle locked and parked is supplying the vehicle cabin with a fresh air (comfort temperature and an acceptable degree of humidity). This requirement can be accomplished by using an air conditioning system with a control system to detect the variables (temperature of the cabin and force that acting on the rear passenger seats) as input to the system and finally to take actions (starts the engine, operates the A/C system and contact with driver) as output to the system as shown in Figure2.

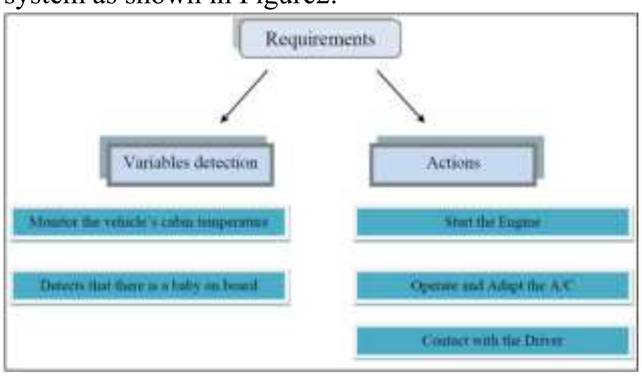

Fig.2 Input and output of the system

A closed loop system as a control system is used to manage command regulates the behavior of other devices or systems as shown in Figure 3.

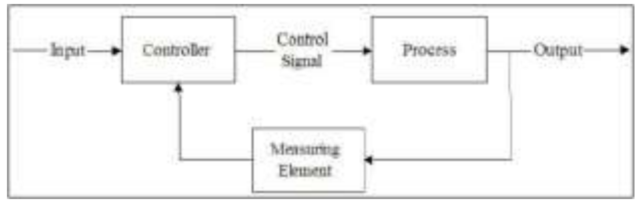

Fig.3 Closed control systems

4 Variables detections

The detected variables indicate the state and the environment of the vehicle cabin and are considered as input to the system.

Two kinds of thermistors, negative temperature coefficient and positive temperature coefficient as temperature sensors with average working range from (10ºC to 70ºC) are used for detection of cabin temperature as shown in Figure (4a and 4b).

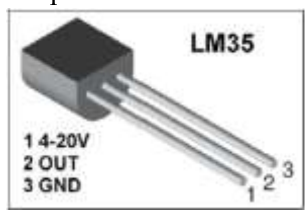

Fig.4 (a) LM35 Temperature sensor

Fig.4 (b) 5D-11 Temperature sensor

The second input variable, force that acting on the rear passenger seats is detected by motion and weight sensor as shown in Figure 5.

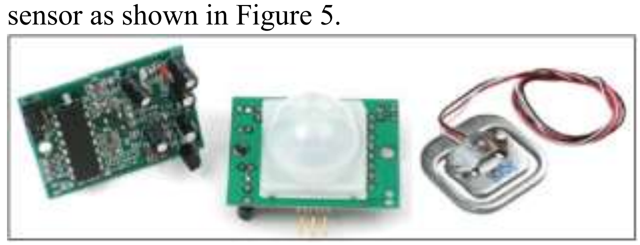

Fig.5 Motion and weight sensor

5 Actions

There are three main actions the EAUCCCS must response and are as follows:

- Starting the engine:

It is the first action, starting the engine classifies as a sensitive case because the (EAUCCCS) will supply the accessories with a 12 volt to active the Engine ECU or Power Control Module (PCM), then operates the starting motor by connecting the start switch to the ground. EAUCCCS must determine the time needed to crank the engine by receiving two signals from sensors of oil pressure switch and engine speed sensor.

Operate the air condition system:

This is the most important process, it's the first step to solve the problem, so the EAUCCCS will operate the A/C after the controller ensure that the engine started and running well. The A/C system is activated by controlling the blower speed and connects the A/C switch. After the A/C activated and worked the EAUCCCS will chose an appropriate temperature that can refresh the climate in the vehicle's cabin.

- Contacting with the driver:

This process is to remind the driver that there is a passenger on board. The EAUCCCS deals with this process through a modern microcontrollers and peripherals which allows to interact with the cell phones, by using the Global System for Mobile Communications (GSM) network which was developed by the European Telecommunications Standards Institute (ETSI) as shown in Figure 6.

Fig.6 GSM Logo

The EAUCCCS will remind the driver by calling the driver on his mobile phone and the system plays a voice message recorded, then the system will send a saved message to make sure that the driver will react with the message as shown in Figure 7.

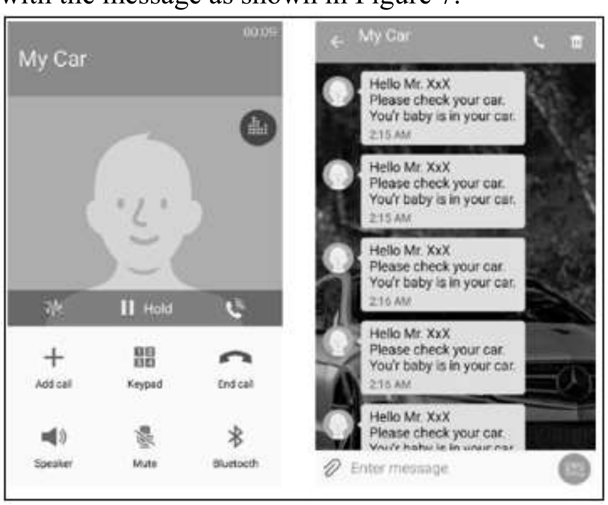

Fig.7 Call and message reminder

6 UCCC Input Devices and Sensors

After the designing and specifying the requirements of the system, the next step is determining the components of EAUCCCS. The system comprises the following components:

6.1 Temperature sensor

AMT1001 temperature sensor is used in EAUCCCS as shown in Figure 8.

Fig.8 AMT1001 sensor

This sensor gives the system an indication that the cabin climate state and measures the cabin air temperature. The module with high accuracy, reliability consistency and temperature compensation are used to ensure long-term stability with the following characteristics: Low power consumption, small size, with temperature compensation single-chip calibration, linear output, fully interchangeable, ultra-long distance signal transmission and precise calibration, [13].

- Voltage supply: DC (4.75 ~ 5.25) V
- consumption current: about (2) mA
- Temperature operating range: (0 ~ 60) ºC
- Temperature detection range: (0 ~ 60) ºC
- Temperature storage range: (0 ~ 60) ºC
- Humidity detection accuracy: (± 5%) (conditions: at 25 ºC and 60% RH)
- Temperature detection accuracy: (±0.5)ºC (conditions: at 25 ºC)

The response of the resistance versus temperature in AMT1001 sensor is shown in Figure 9.

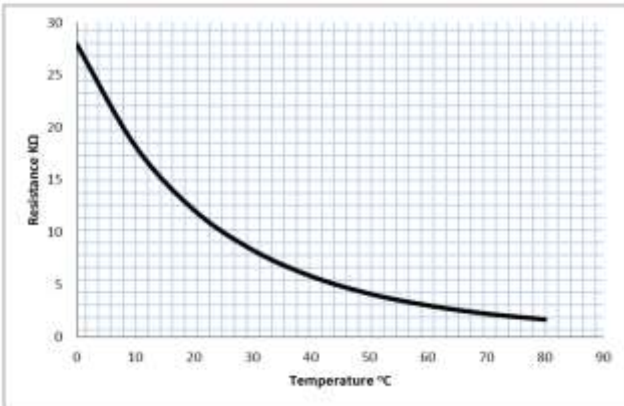

Fig.9 Resistance versus temperature

6.2 Passive infrared", "Pyro electric", or "IR motion" sensors

PIR sensors permit the EAUCCCS to detect sense for motion and also used to detect whether a human within sensors range or not. These sensors are small in size, cheap, low-power consumption, easy to use and don't wear out. Therefore, they are widely used in home appliances and gadgets or businesses as depicted in Figure 3.

6.3 Force sensitive resistor:

Force sensitive resistor is that third sensor gives the EAUCCCS an indication if there is baby on its seat, to ensure that the baby in the vehicle as shown in Figure 10. Force sensing resistor (FSR) consists of a variable resistance depends on applied pressure. In this direction, the term “force sensitive” will be misleading. Therefore, a more suitable term should be “pressure sensitive”. Because the output of the sensor's depends on the area to which the force will be applied.

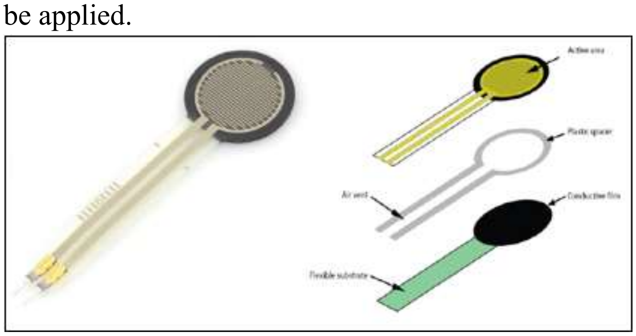
Fig.10 Force sensitive resistor

There are additional inputs such as:
1- Engine oil pressure switch.
2- Engine speed sensor (crank shaft position sensor).
3- Door lock switch.

The EAUCCCS needs these new inputs to determine the followed conditions:
Engine state, working or switched off.
The doors are close or open.
Output Devices and Actuators:
CG05SZ-009 relay module
EAUCCCS needs relays to control the engine starting and switching off, the A/C system and remind the driver. CG05SZ-009 relay module of high-quality module comes with 5 volt 4-channel interface board, durable RF4 material, strong anti-intermission performance, and LED indication lights for showing relay output status is used in EAUCCCS as shown in Figure 11 is used. This relay module helps the controller to drive the engine and the A/C system easily and safely.

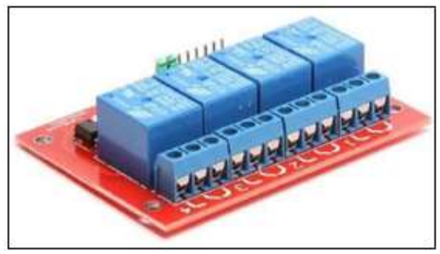
Fig.11 CG05SZ-009 relay module

7 GPS GSM GPRS SIM808 Modules:

SIM808 module comprises GSM and GPS, those two functions in single module. GSM/GPRS is supported by Quad-Band network and combines GPS technology with satellite navigation. This module connects the EAUCCCS with the driver by the GSM network to remind the driver when an urgent situation happens with two ways by calling and messaging, Figure 12.

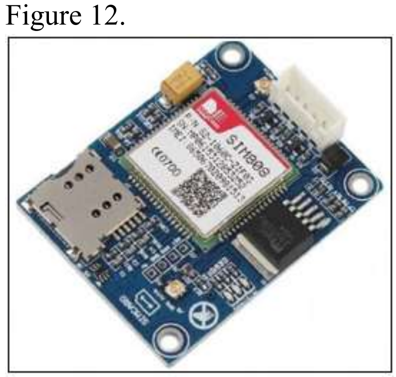

Fig.12 SIM808 GSM Module

7.1 Microcontroller Selection

The proper selection of microcontroller depends on the inputs and based-on its pre-programming. The perfect microcontroller for performing this mission should characterize with some properties and should be offered by this controller such as:
1-Offering an analogy input.
2- Offering digital inputs.
3- Average speed of its internal processor unit.
4- Large ROM and Ram.
5- Offering a Pulse Width Modulation (PWM) outputs.
6- Low electric power consumption.
Based on above specifications, Arduino Mega 2560 R3 as shown in the Figure 13 is utilized for this mission.
With the following features:

Operating voltage	**5V**
Input voltage (7-12) V (recommended)	Input voltage (7-12) V (recommended)
Input voltage (limit) (6-20V)	Input volta (6-20) V (limit)
DC current per (input/output) Pin	20 mA
	50 mA
Digital (input/output) Pins	54 (of which 15 provide PWM output)
Analog input Pins	16
Flash memory	256 KB of which 8 KB used by boot loader
SRAM	8 KB
EEPROM	4 KB
Clock speed	16 MHz

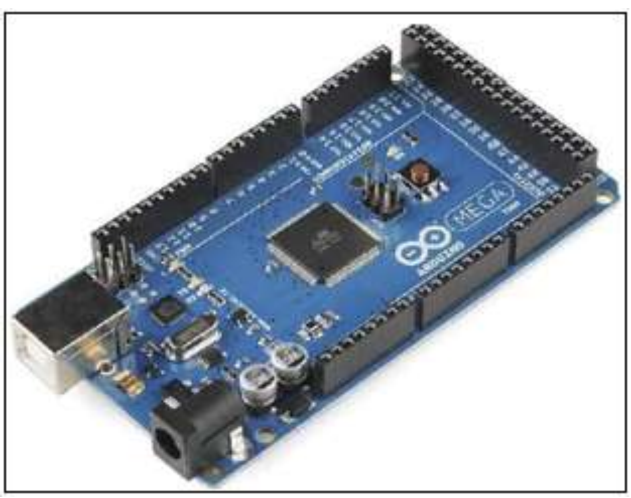

Fig.13 Arduino Mega 2560 R3

8 EAUCCCS Block Diagram and Wiring

Figure 14 shows a block diagram for the general arrangement of the EAUCCCS components and wiring.

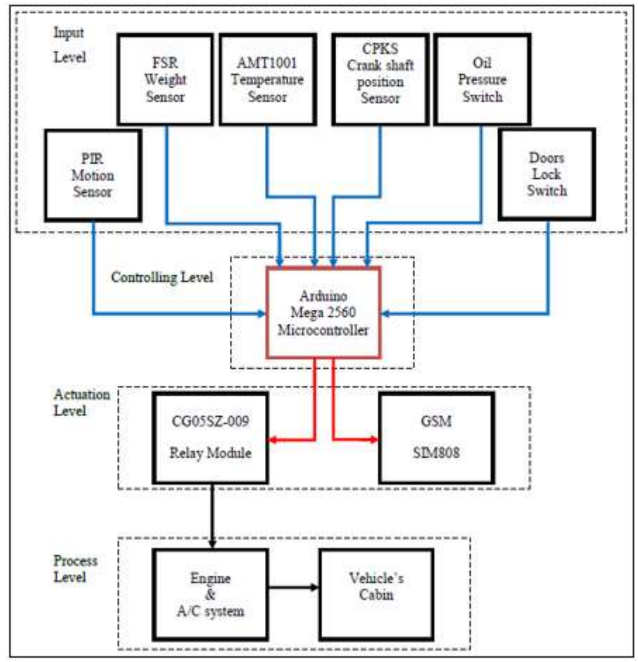

Fig.14 EAUCCCS block diagram and wiring

8.1 Wiring Connection System

The wiring connection system is accomplished individually for each component in EAUCCCS.

8.2 AMT1001

The wiring starts with the most important component in the system which is AMT1001 (Temperature sensor). The sensor has four terminals as shown in Figure 15.

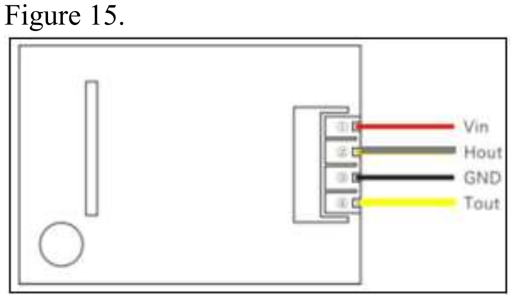

Fig.15 AMT1001 terminals

Red terminal is the input voltage; this terminal connects to the 5-volt source taken from the Arduino Mega 2560 microcontroller. The second terminal is black this terminal connects to the ground (zero volt), which taken from the common ground pin in the microcontroller. Finally, the yellow terminal is the output temperature signal; this terminal must connect to an analog input pin in the microcontroller to give the controller a specific voltage at every change in the surrounding temperature.

8.3 PIR motion sensor

The second component is the PIR motion sensor, terminals shown in Figure 16.

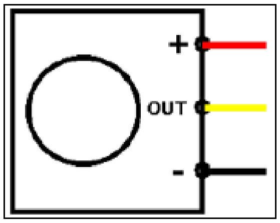

Fig.16 PIR motion sensor terminals

8.4 Force Sensitive Resistor

It's the third input element in EAUCCCS. The sensors with blue terminal is connected to the digital input in Arduino Mega 2560 microcontroller for detecting any force acting on it caused by weight, and the red terminal connected to the 5-volt source as shown in Figure 17.

Fig. 17. Force sensitive resistor.

8.5 GPS GSM GPRS SIM808 module terminals

SIM808 module has five terminals one of them is ignored, the other terminals are Rx, Tx, Vin, GND.
Tx green terminal will connect to the Rx1 of Arduino Mega 2560, Rx blue terminal of sim808 module connect to the Tx of microcontroller, then the power source will be connected to the Vin terminal with the red colour, and finally, the GND will be connected to the ground pin of controller as shown in Figure 18.

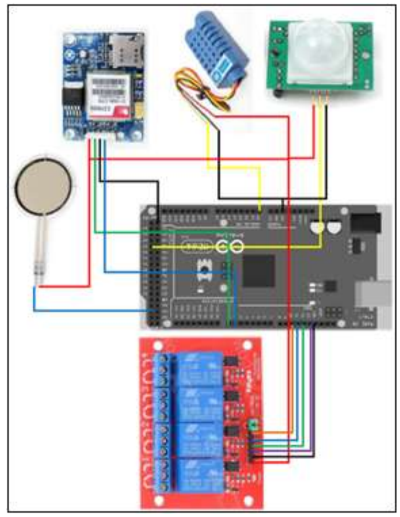

Fig.18 EAUCCCS block wiring

8.6 CG05SZ-009 module terminals

This module has six low current inputs and four high current outputs. Every single relay has three controlling terminals, one of them connects to the microcontroller and the second one is connected to the common 5 volts, while the third terminal is connected to the common GND as shown in Figure 18.
The CG05SZ-009 module is considered to be the main output module that controls the vehicle's engine. Figure 19 shows the wiring connections of vehicle's ignition switch to start the engine. First relay is connected to the terminal 5 and 6 when these terminals are connected together, the ECU will supply with 12 volts, then the second relay will connect the terminal 5 with the 4 terminals, this makes the motor to start.

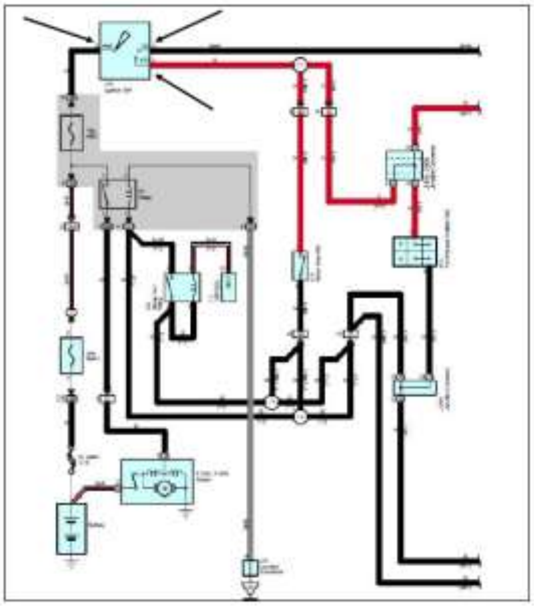

Fig.19 Ignition switch wiring

To control and activate the air conditioning system, the other two relays will do this mission. First relay is connected to the terminal 6 and 5 and these terminals will activate the low speed of blower and the A/C request. The second relay will connect the terminal 4 with terminal 5 (GND), to speed up the blower at the maximum speed as shown in Figure 20.

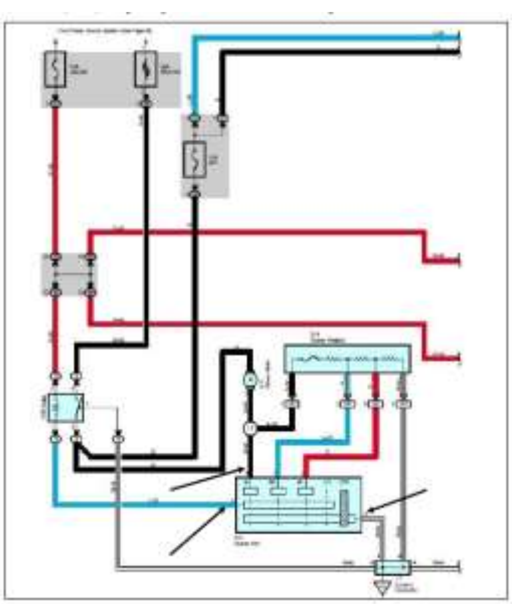

Fig.20 Blower speed connector.

9 Conclusions

1- This Control System can solve the problem of the heatstroke situation and even prevent it, but this does not mean that there isn't a main responsibility on parents or driver.
2- This design developed a smart urgent cabin climate control system to alert the driver that there is a passenger on board.
3- A modern microcontroller is used which allow to interact with the driver's cell phone by using a GSM communication network.
4- EAUCCCS will start the internal combustion engine preparing it for the next action.
5- Using this design, the A/C will be turned ON after ensuring that the engine is started and running well.
6- This System can be developed by the manufacturers of vehicles and integrate it with vehicle's ECUs.
7- A feature can be added to this system, is that the driver can control vehicle's Engine and Air-conditioning system, when he/she at his/her home or during shopping and vehicle parked out.

10 Acknowledgment

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