Microcontroller managed module for automatic ventilation of vehicle interior

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Abstract – In order to mitigate overheated interior of a vehicle parked in the hot summer sun and thereby to make the entering into the vehicle more comfortable, microcontroller managed module for automatic ventilation of vehicle interior is made. The module is implemented using a microcontroller as a central logical unit and a series of sensors which provide sufficient data to ensure functional, but also efficient, reliable and safe ventilation. The ventilation process is performed by opening vehicle windows slightly, which enables air to circulate. Microcontroller controls the position of the windows autonomously and independently of the driver's presence, following predefined algorithm that uses sensors data obtained from the vehicle's surroundings. Besides temperature, the most important factors to ensure quality implementation of ventilation are detected movements around the vehicle, the presence of precipitation and other. This paper shows the components, their purpose and capabilities, advantages and disadvantages, as well as potential implementations and upgrades. The test results give insight into utilization options of this module and its usefulness.

Key words – automatic ventilation of vehicle interior, microcontroller, sensors, temperature, controlling position of vehicle windows.

I. INTRODUCTION

Closed area without air circulation and directly exposed to sunlight heats up much faster and reaches significantly higher temperatures than the open space where air circulates freely – so-called "greenhouse effect". That is exactly what happens in a vehicle parked in the hot summer sun, which later represents a problem when entering such overheated vehicle.

The basic idea of this project is to prevent or at least mitigate overheating of the vehicle interior in order to facilitate entering into the vehicle.

The problem can be solved by leaving the vehicle windows partially opened so air can circulate, which reduces the heating of the vehicle interior. However, as the ventilation process takes place in a parked vehicle, without human presence, and the vehicle is exposed to external influences, such as precipitation or potential burglary, it is unreliable and unsafe. Consequently, it is necessary to automate the ventilation process.

According to [12], the complete automatic ventilation process is managed by microcontroller default algorithm, considering input signals read using various sensors. The temperature sensor measures the temperature inside the vehicle. If it exceeds predefined level of "comfortable temperature", microcontroller automatically lowers the power windows to enable air circulation which alleviates aforementioned "greenhouse effect".

The automatic ventilation process must be reliable and not affect the safety of the vehicle. For this reason, additional sensors are used, whose task is to annul dangers appeared with this ventilation method. Before all, these are precipitation sensor that makes the ventilation process reliable, and motion sensors that make it safe. There are also other sensors whose implementation gives additional quality, but these are the most important of them. Together with temperature sensor, they meet the minimum requirements to perform automatic function of ventilation, without endangering the vehicle.

Following chapters show components and technologies used, operation modes, advantages and disadvantages, capabilities and potential upgrades of the module, as well as ability of integration with existing automatic systems within the vehicle. Results of testing the module in real conditions are presented and analyzed.

II. COMPONENTS AND MODULE ARCHITECTURE

According to [12], the module's task is to control the ventilation process autonomously in order to facilitate vehicle utilization, i.e. providing conditions to make the entering into the vehicle parked in the sun more comfortable. In order to meet all the criteria of quality ventilation, the module has to collect enough data from the vehicle's immediate environment and, based on that data, it has to decide whether it is necessary to lower the windows and thus start the ventilation process. Accordingly, the module can be divided to three logical units: peripheral unit - collects data, control unit - manages module operations, and switching unit – adjusts signals. Figure 1 shows logic diagram of module.

The switching unit exclusively receives commands, which makes it the output unit. The control unit, or microcontroller, receives, processes and sends signals which makes it the central logical unit, while peripheral

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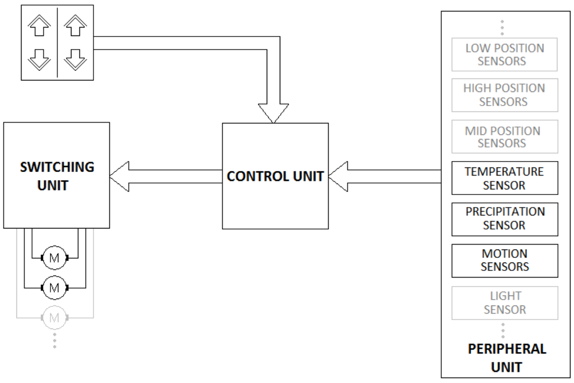

Figure 1. Logic diagram

unit exclusively collects data and sends it to control unit, which makes it the input unit.

A. Peripheral unit

Since the peripheral unit is also the input unit, it is presented first, for better insight into module operations and modes.

By having to collect many different types of data, the peripheral unit is complex enough as it is. The necessity of placing different sensors in separate locations, in order to achieve data collection, makes it even more complex.

- The temperature sensor is the most important sensor of this module because measuring of the vehicle interior temperature enables this method of automatic ventilation. The sensor is located inside the vehicle, protected from direct sunlight in order to measure the actual temperature of the vehicle interior, not the ostensible temperature (which is slightly higher due to the direct expose to the sun rays). The sensor consists of temperature sensitive resistor - NTC (Negative Temperature Coefficient) as a main part of sensor's electronic circuit with other necessary electronic components. In accordance with temperature change, sensor gives different output value. The control unit processes it and thus receives information about the actual temperature inside the vehicle.

- Precipitation sensor [9] is very important because it makes the automatic ventilation reliable. If precipitation occurs during the ventilation process, sensor detects the new circumstances and sends a signal to the control unit which orders to close the windows immediately. The sensor is situated on the windshield inside the vehicle, above the rear-view mirror in order to detect the falling drops of water on the glass. LED (Light Emitting Diode) or IR (Infra-Red) diode is used as a transmitter that emits light at a certain angle onto the windshield. The light of the expected intensity reflects to the photodiode which is used as a receiver. If droplets appear onto the windshield, the light reflects differently which causes a change in the receiving electronic circuit connected to the microcontroller. That is recognized as the presence of precipitation and windows close. Figure 2 shows precipitation sensor.

- Motion sensors are very important for the vehicle's safety while the ventilation process takes place. If there are movements detected within the vehicle's surroundings, it is classified as a potential danger and the system closes the windows. Commercial motion sensors on the principle of infrared technology - "Velleman PIR416" [10] are used for purpose of this module. The infrared motion sensor works on a similar principle as the precipitation sensor; by detecting the infrared radiation reflected from a moving object within the sensor's range. Infrared sensors have the disadvantage of not receiving signal effectively through the glass, so they should be mounted outside the vehicle, which is aesthetically undesirable. For this reason, microwave motion sensor(s) can be used, such is [11], which will surely detect all motions within the vehicle's surroundings, from inside the vehicle.

The basic function of automatic ventilation inside the vehicle is achieved using temperature sensor. Ventilation inside the vehicle is achieved by method of slightly lowering windows for a few centimeters, which makes it functional, discreet enough, but relatively reliable and safe. By adding the precipitation and motion sensors, the ventilation process becomes reliable and safe, but it opens up the possibility of even better ventilation. That is, now when there is a control system and protection from external impact, the windows can be further lowered to increase air circulation, and more air circulation means more quality ventilation. These critical input units are the most important for stable ventilation process. Other input units which contribute to efficiency and vehicle safety are:

- The light sensor; used for economic reasons. Given that the interior can be heated more than the environment only when the vehicle is exposed to direct sunlight, which does not exist at night, whole ventilation process at night does not make sense, and it is automatically suspended until morning. It results in a more efficient and economical usage of the module. Sensor is placed inside the vehicle, protected from direct

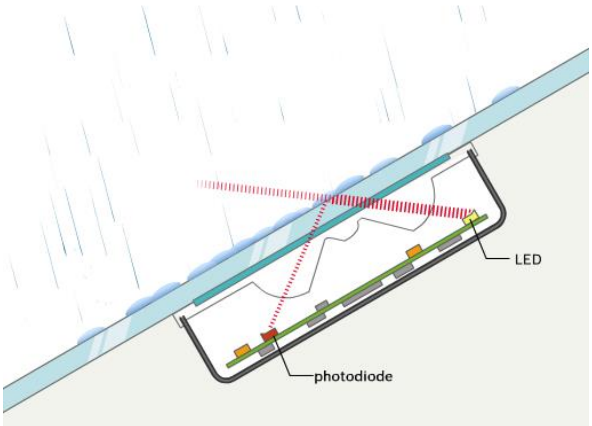

Figure 2. Precipitation sensor

sunlight in order to reduce sudden changes in light intensity readings caused by disruptive factors such as clouds. The sensor itself is actually a photo resistor that has a characteristic of resistance change depending on the intensity of light in the area where it is located. Photo resistor used here has an extremely fast response to changes in light intensity. Resistance changes are large even for the least change of the brightness. Therefore, it is necessary to use additional electronic components that slow down and reduce these rapid and large changes to obtain stable and reliable signal which can then be sent to the control unit for processing. [12]

- Position sensors; contribute to the quality work of module. These are the lower and upper end as well as mid position sensors. They are located in the vehicle doors, that is, the end positions of windows movement range. They signal an entirely opened or entirely closed position of the window. The mid position sensor signals when window reaches position where should be placed in the automatic ventilation mode. Position sensors provide a reliable windows setting in the desired position. This benefits to all aspects of the module quality; provides the reliability and security because the windows will always reach an end position whenever it is necessary, improves efficiency because windows will stop immediately when they reach a target position, preventing unnecessary overload of the electric motors and needles consumption of limited electrical energy, as well as potential danger of blowing electric motors or module is prevented and the vehicle is protected from potential conflagration. Moreover, a very important input information is obtained - direct feedback that informs the microcontroller on the execution of the given commands. All this greatly improves the quality of the ventilation process. Position sensor functionality is achieved using conventional buttons and switches. When reaching the mid or end position, the window carrier press the button/switch that closes the electronic circuit which confirms successfully executed operation to microcontroller. According to [12], various components and methods were considered for this purpose, such are photo and infra-red diodes or instead of using additional components this function is programmable via microcontroller in the form of time circuit. However, classic buttons and switches are the simplest, most reliable and most resistant components that are to be applied for this purpose.

B. *Control unit*

Control, or central logical unit, is the "brain" of the module. By default algorithm and collected input signals, module independently controls power windows in automatic mode - the automatic ventilation inside the vehicle. In manual mode, when a person is present in the vehicle, module just relays human commands onto the windows.

For this purpose is used AVR ATmega32 microcontroller. Since the microcontroller is available as one component, this is seemingly a very simple logical unit. However, it is a highly complex integrated circuit that contains thousands of electronic components inside [8]. All in all, this microcontroller is too powerful for this module. However, as it has an affordable price, and considering the additional module upgrades and extensions, it would be imprudent to limit its potential immediately at start by implementing a microcontroller with fewer features.

The control unit could be implemented even without microcontroller by using some other logic electronic components, however, the module would not be programmable, nor upgradeable or be adaptable to individual vehicles and customer requirements.

C. *Switching unit*

Switching unit is also used as the output unit and is responsible for the stable transmission of the output control signals from the microcontroller and to adjust them for window's electric motors. It consists of several components that are responsible for the conversion of weak control signals from the microcontroller to the strong electric signals that directly drive the electric motors. These are various transistor amplifiers and relays which, in addition to amplifying the weak control signals from the microcontroller, also galvanically isolate logic module's electronic circuit from a strong motor's electric circuit. There are various options of transfer and adjustment of control signals from the microcontroller to the electric motors. In this case, a driver L293NE is used. It turns logic signal from the microcontroller into much stronger electric signal that can directly power the electric motor. Considering that in real circumstances current reaches 1 A, it turns out that this driver component overheats and does not deliver enough power for electric motor to move windows quality enough. Therefore, besides the aforementioned galvanic circuit separation, relays are used to prevent overheating of the driver component, achieving a sufficient power for quality work of electric motors and prevent the flow of large currents within the module, which is not advisable because of the strong magnetic fields that are generated by large currents and their negative effects on sensitive electronic components.

D. Other units

Peripheral unit, control unit and switching unit compose a logical unit that is oriented to the specific module's role - automatic ventilation inside the vehicle. In addition to them, the module includes other components that perform a particular role; voltage converter and stabilizer, integrated connector and a set of components that allow the microcontroller to be programmed directly within the module.

III. ALGORITHM AND MICROCONTROLLER PROGRAMMING

It is mentioned that a microcontroller decides what to do and operates independently. The microcontroller basically just follows the algorithm behavior, predefined program of what to do in a certain situation. Simplified flowchart shows the microcontroller's algorithm of behavior (Figure 3).

Method of operation can easily be noticed by the flowchart. At the beginning, initialization of microcontroller and auxiliary variables is performed. After completion of the initialization, program starts checking parameters and thus sets the state of the output. First, it determines whether the vehicle is parked or in use. This is determined by checking whether the key is in the ignition lock, which is not a one hundred percent confirmation, but it is considered satisfactory. Depending on the result, manual or automatic mode is switched on. In manual mode, while a person uses the vehicle, microcontroller only transmits input state to output and thereby has only a minor role in the protection of electric motors from overload. When the automatic mode is on, other preconditions are checked in order of priority; whether it is night, is there precipitation and are there suspicious objects near the vehicle. If the answer to any of these queries is confirmative, it means the ventilation process is not necessary or it could endanger the vehicle and will not even start until the appropriate conditions. If all conditions are satisfied, only then microcontroller checks if the vehicle interior is overheated and, if it is, opens the windows for ventilation. If, at any time during the ventilation process, disturbing factors appear, the windows close, thus suspending the ventilation process until the required conditions are met again. Left and right window can be opened and closed separately in automatic mode. This also provides the efficiency. For example, if in the middle of the ventilation suspicious movements are detected on the right side of the vehicle, only the right window will close which still allows partial ventilation through left window only, which is better than none.

IV. FINAL IMPLEMENTATION

The module is designed and developed for the installation into a one older car without automatic air conditioner and with already existing basic electric mechanism for lowering and raising the windows. The car has two power windows which can be managed. That is why this module prototype manages only two sets of input and output signals for connecting two independent windows. Figure 4 shows the electric scheme of a module prototype. Control unit, switching unit, other units and some of the peripheral units (temperature and light sensors) can be perceived. Since the rest of the sensors cannot be integrated into the module's main electronic circuit, connectors for their signals are located inside the module. However, what is not mentioned so far are a lot of buttons, switches and LEDs that can be seen alongside input and output connectors. With buttons, switches and LEDs, this prototype module becomes the simulator as well – inside the module are simulators of all input and output signals that make this prototype even more convenient for the further development and testing. Although this is just a module prototype, it satisfies all requirements for working in real conditions and can be implemented in any vehicle.

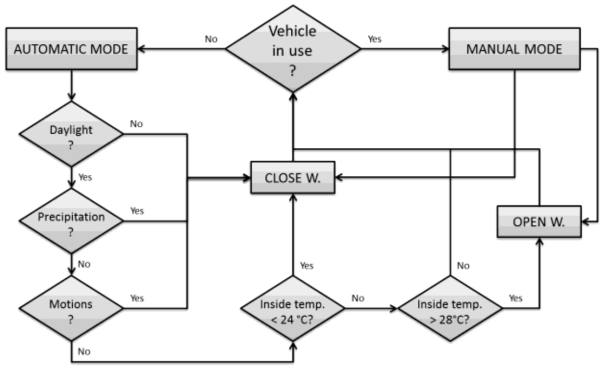

Figure 3. Flowchart diagram

Considering different characteristics of individual microcontroller pins and the various possible upgrades, important criterion was to place and connect components in a logical and calculated order, with respect to all present and possible hardware or software upgrades so it is important to be careful while designing and connecting all electronic circuits, inputs, outputs and electronic components in general. Integration of certain electronic components protects module against different sort of nuisances that exist or could appear in real circumstances. Electronic circuit was developed parallel with the program code to achieve even better congruence between individual components and operations. Besides all the attention that was given in the hardware development, a lot of attention was committed to the software segments that improve quality work of module and protect system against contingent situations. Aesthetic appearance of the assembly was also taken into consideration. Result is a complete product that is ready for real use. Of course, the software can still significantly improve in order to obtain a more "intelligent" and efficient module, but it is efficient enough, functional, reliable and safe to use.

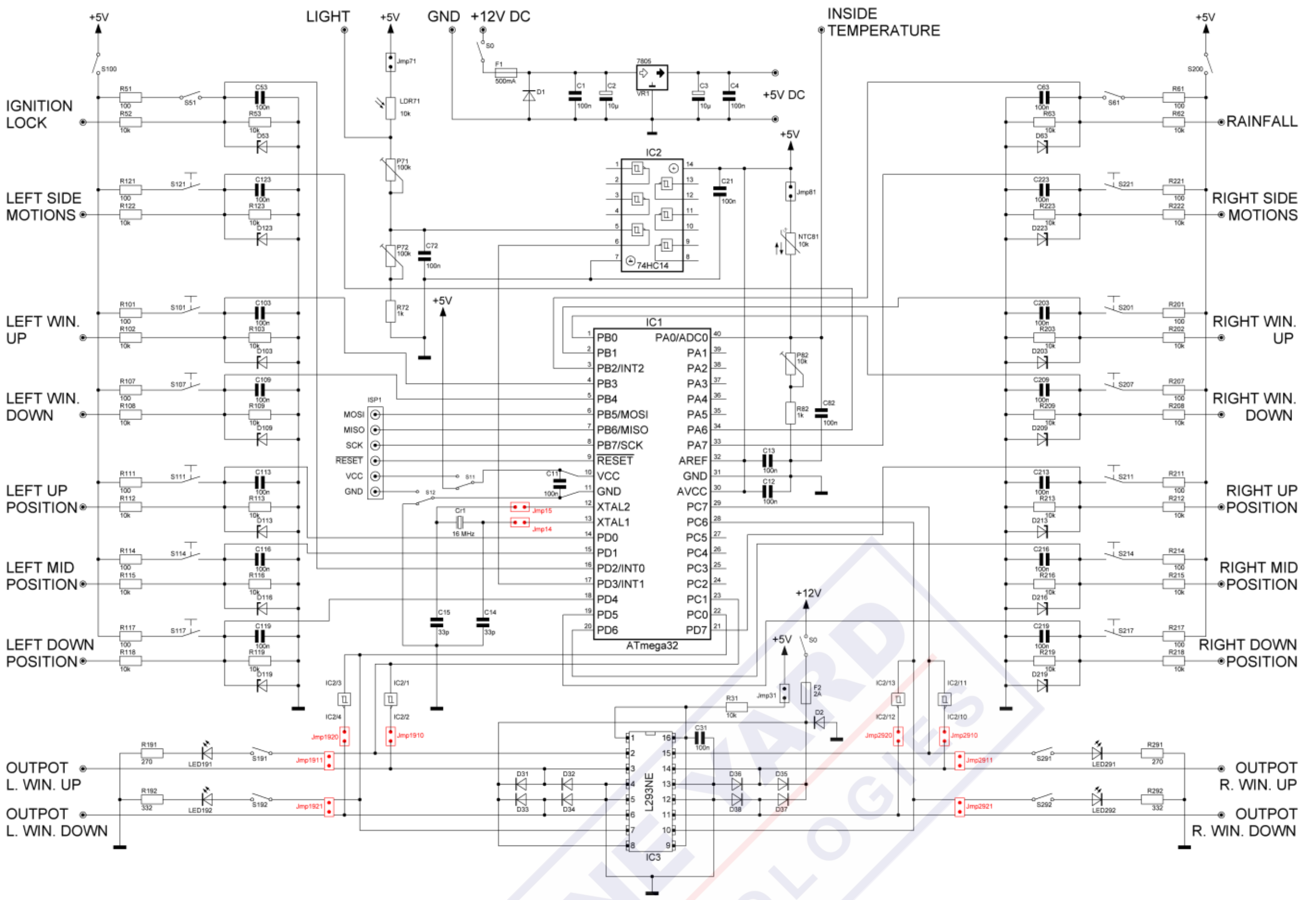

Figure 4. Electric scheme

The module is assembled using DIP (Dual In-line Package) electronic components, primarily due to the ease of making, testing and changing the hardware, which is quite important since it is a prototype that will spend most of the time in simulation instead of operating into the real world. Figure 5 shows the final implementation of printed circuit board.

Necessity of placing sensors around vehicle interior is already presented, but it is good to emphasize it again because it directly disables implementation of this module as one physical unit, which triggers other aggravating effects for easy installation and minimum costs.

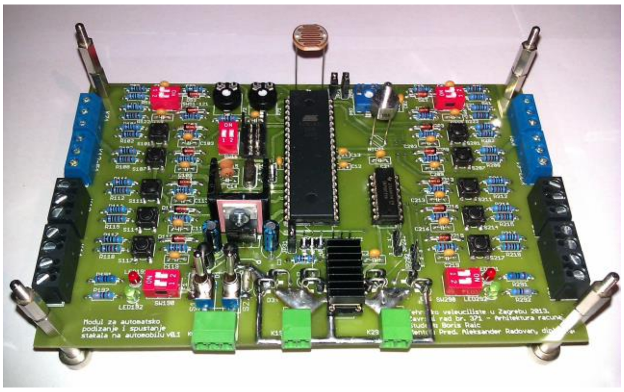

Figure 5. Final implementation

V. TEST RESULTS AND DISCUSSION

Module has been tested under real operating conditions in few vehicles on outside temperatures in range of 21 °C to 27 °C. Mid position sensors were set on few different levels. Also, temperatures inside vehicles while fully opened/closed windows were measured for better comparison. Measured temperatures are presented by Figure 6. The samples were collected during longer period of time. Comparing measured inside temperatures it is concluded that slightly opened windows (up to 5 cm) do not get satisfying results. To achieve quality ventilation it was necessary to lower windows at least 10 to 15 centimeters. Of course, more opened windows, and finally completely opened windows gives the best results, but 15 to 25 centimeters is optimal regarding inside temperature drop, energy consummation and safety concerns.

Presented results should be taken into consideration as informative since measurements were not taken in exactly the same weather conditions for each individual vehicle so there are visible disrupting effects. It can be remarked that many different factors, besides obvious direct sunlight, outside temperature and windows position directly affect ventilation process; weather conditions have significant influence on the ventilation process – e. g., wind noticeably accelerates and enhances ventilation. Further, size of the vehicle, even vehicle body color and vehicle orientation relative to the sun makes noticeable difference.

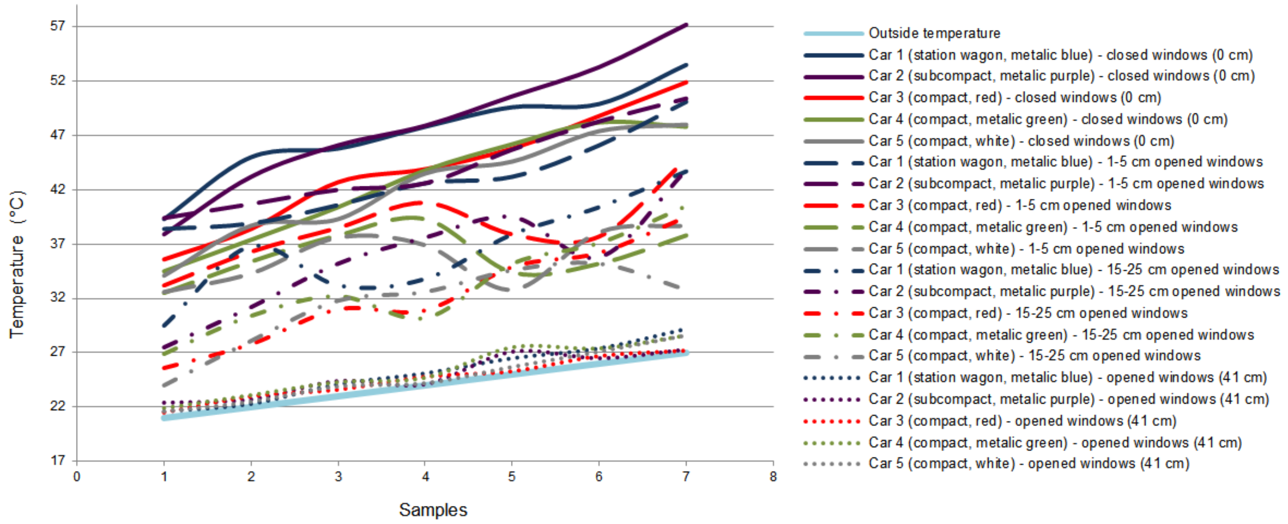

Figure 6. Measured temperatures

Except module proved to be safe, reliable and efficient, satisfactory results of the ventilation function were achieved. Without the module and with closed windows (or slightly lowered windows), temperature inside of the vehicle parked in the sun on light spring temperatures of 25 °C can reach over 50 °C. In summer, inside temperature rises even more drastically. While lowering windows for at least 10 to 15 centimeters to enable quality ventilation process, inside temperature becomes much bearable. Considering the fact that this ventilation process is a passive method of cooling overheated interior, it accomplishes very good results.

VI. Conclusion

It can be summarized that this module, although only a prototype, is completely functional device that performs its function safely, reliably and efficiently. Possibility of application is not limited only to the vehicle ventilation. The module is extremely expandable in both ways: it is upgradeable for new tasks as well as compatible for integration into some existing systems. Nearly every component can be used for several other functions, which can be achieved only by software upgrade. Upgrading hardware opens even greater possibility to upgrade the software and there are countless capabilities. Despite all the positive sides of this module, the question remains whether it can find its application in the market. Since the module is impracticable as a physical unit (because of peripheral unit), it is necessary to adapt it to any individual vehicle. Thus its individual installation is not cost-effective. It could find its purpose and economic efficiency if it would be serially mounted in same type of vehicle.

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