



## SIZING, POSITIONING AND AIR DUCTING ANALYSIS FOR SOLAR-BASED CAR VENTILATOR

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### ABSTRACT

This paper presents a study on solar based car ventilation system by observing its effectiveness in reducing the temperature inside the car that is parked unroofed under the sun. The performance of the motor, power produced from the solar panel, airflow rate effect, tilt angle effect and air duct effect were investigated. A commercially available ventilator and a redesigned ventilator have been used to benchmark the analysis. The present study shows that the commercial ventilator only provided 6.86% of reducing interior temperature inside a car compared to without ventilator. Size of solar panel, placement and position angle as well as air duct became contributing factors that affect the performance. A redesigned ventilator that considers those factors is developed and analysed. From result, a redesigned ventilator provided at least 19.83% better result of reducing the interior temperature inside the parked car as compared to the existing ventilator.

**Keywords:** car ventilation system, solar panel.

### INTRODUCTION

In Malaysia most people prefer to drive cars to go from one place to another. From statistic, on average about 545218 cars have been registered in Malaysia every year within year 2005 to 2013[1]. While using their vehicles, sometimes the car has to be parked directly under the sun due to limited roofed parking area. Under hot weather conditions, vehicle's interior temperature can increase very quickly. Study by [2,3] have shown that an average of 4.4 °C increase in the temperature inside the car for ambient temperature spanning from 22.2 °C to 35.6 °C. Rise in temperature levels inside the car can be attributed to convection (volume of air inside), conduction (various metals and heat absorbing materials inside) and radiation (from the glass and body of the car), of which the most influencing factor in such heating is radiation [4,5]. As to reduce the heat inside the car, some drivers open a small gap of the car windows to provide some ventilation. However, study from [2] shows that the practice had minimal effect and it does not really improve the situation. That practice will also lead to safety and security issue due to theft and robbery.

Thus, there is a need to have a proper ventilation system inside a parked car. There are several tools that have been developed to assist the ventilation problem inside a parked car either via battery powered system or solar based system [3], [5], [6], [7], [8]. The use of solar based ventilation system sounds promising to be employed in Malaysia due to our present weather and sun radiation condition. In spite of the commercially available solar based car ventilation kit in the market, analysis is important to study the efficacy of having the system. Contributing factors such as sun radiation, position of solar panel, size of solar panel, tilt angle of solar panel and area of air duct are important to be observed. This will be the key contribution of the paper.

Overall this paper will be presented as follow. The next section will discuss on system requirements. This

includes knowledge and information required from the selected components and configuration. Then the implementation based on commercially available ventilation system (Refer to as Type A) as well as the redesigned system (Refer to as Type B) will be shown. The setup for data collection for the purpose of analysis and observation will be also highlighted. Later the result and analysis from the finding are discussed. Finally the paper ends with conclusion supporting with recommendation for further research development.

### SYSTEM REQUIREMENTS

#### Solar radiation

Malaysia is a country that is suitable for photovoltaic implementation. It is good to consider the use of photovoltaic because Malaysia is possible to have six hours of direct sunlight with solar radiation between 800 W/m<sup>2</sup> and 1000 W/m<sup>2</sup>. From April to October, Malaysia has a tropical climate. From October to February, it has a northeast monsoon season. It can be seen that the maximum distribution of average hourly solar radiation as well as the temperature is higher from 7.00 am until 1.00 pm and lower from 2.00 pm until 7.00 pm (morning to late evening). At 12.00 pm, the solar radiation reaches the peak values [9].

#### Solar panel

There are two sizes of solar panels under investigation in this study. The first size is a custom made from the commercially available car ventilator kit (Type A) and the second size is the panel that will be used in the redesigned system (Type B). The photo of those solar panels and its specifications are shown in Figure-1 and Table-1, respectively.



Figure-1. Solar panel.

### Solar cell module tilt angle

The suitable place or area for photovoltaic (PV) integration is an important point to estimate the potential generating of solar cell modules. Local climate, load consumption temporal profile and latitude are the factors of photovoltaic inclination and orientation optimization. Generally, a surface with tilt angle equal to the latitude of a location receives maximum insolation. The power density of the solar cell module is equal to the incident power density when the sun's array is perpendicular to the absorbing surface. However, as the angle between the sun and the absorbing surface changes, the intensity of the light on the surface is reduced. The intensity of the light essentially falls to zero when the solar cell module is parallel to the sun's array. Therefore, at any given instant, an array will generate maximum output when pointed directly at the sun [10].

Table-1. Solar panel specification.

	Type A [3]	Type B
Power (W)	1.2	5.0
Operating Temp. (°C)	-40 ~ +85	-40 ~ +85
Type of cell	Polycrystalline	Polycrystalline
Dimension (mm)	54 x 54 x 1	285 x 185 x 18

Research finding such as in [3], [8] adopted the outside car rooftop as a place to position the solar panel. In this study, consideration is made to place the panel inside the car for safety and component precaution due to sudden weather changes. When the location is meant in the automotive area, there will have suitable location to place the solar cell module. It has been observed that the temperature at the front and back dashboard was higher than the side dashboard due to the area of the windows. The area of the front and back windows are wider than the side window. Therefore allowed more sunlight to reach directly to the front and back dashboard.

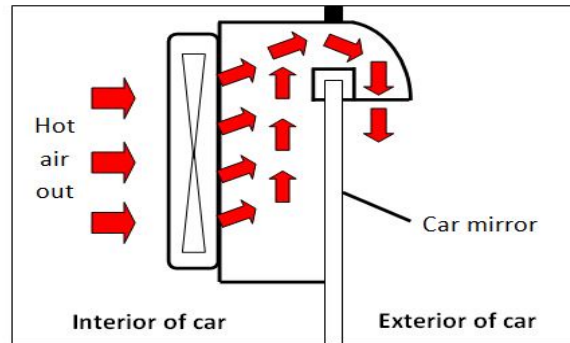


Figure-2. Air flow process.

### Air flow

Simple ventilation system typically used single phase motor with fan to move air. Single phase motor (AC motor) normally operates at a fixed voltage, so their speed varies on the blades of the fan. Volume of air will flow by the fan into the air duct. The efficiency of the system will improve significantly when the air flow rate is maintained at a constant level [11]. While performing similar operation, however, in this project a brushed dc motor is used. The ventilator as shown in Figure-2 fits in the window, making the interior air of the vehicle to flow to the exterior air. The circulation will remove the heat thereby decreasing interior temperature of the vehicle. The faster the air changing between the environments, the more cooling effect would be achieved inside an automobile.

While using the same type of centrifugal blower (Figure-3), the specification of dc motor in used for Type A and Type B is slightly different as shown in Table-2.



Figure-3. Centrifugal blower.

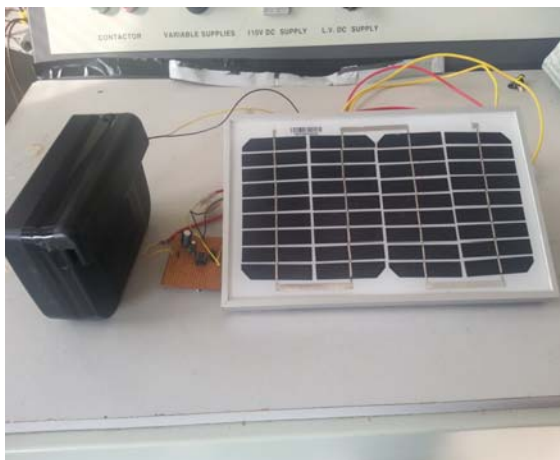
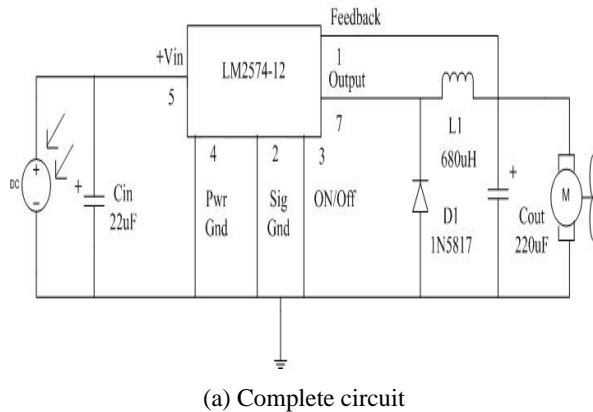
Table-2. DC motor specification.

	Type A	Type B
Rated voltage (V)	5	12
Rated current (A)	0.21 A	0.12 A
Rated speed (rpm)	3000 rpm	6500 rpm
Diameter (mm)	12	25
Length (mm)	34	40



### Redesigned circuit

The circuit of solar panel, dc-dc converter and motor fan is shown in Figure-4.

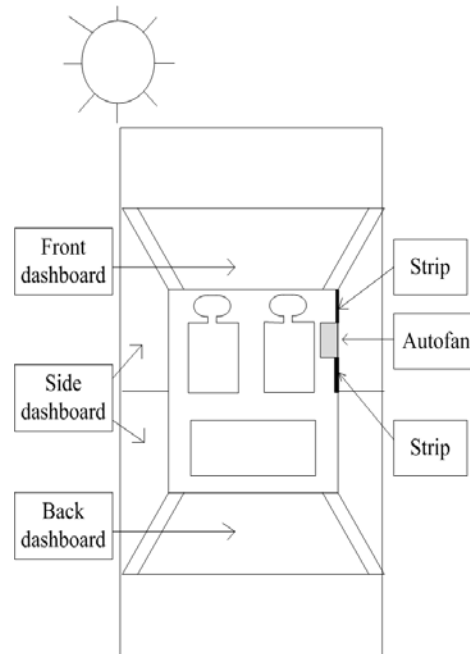


**Figure-4.** Redesigned circuit Type B.

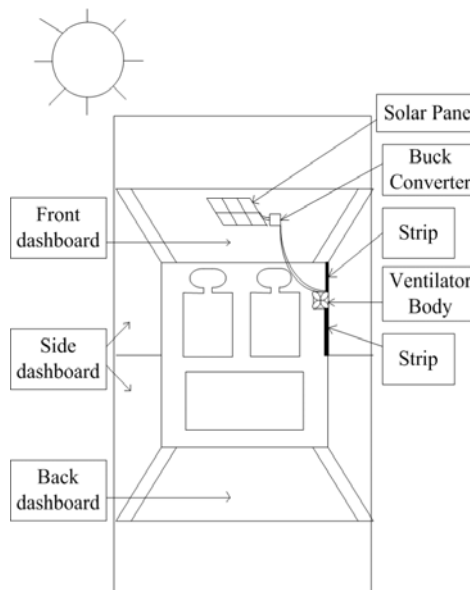
## IMPLEMENTATION

### Sizing

From the max power as shown in Table-1, it is worth mentioned that the performance of Type B panel is expected to be better due to higher power configuration. As such, the use of higher than 5 W solar panel, will provide better performance too. However, the size of the panel and its cost will increase too.



**Figure-5.** Type A ventilation system.



**Figure-6.** Type B ventilation system.

### Positioning

#### Case 1: Car without ventilation system

This test is conducted on a normal car that is parked under the sun without having any ventilation system installed.

#### Case 2: Type A – side window position

Test is run for the commercial ventilator as shown in Figure-5. The PV tilt angle is approximately at 90°.



### Case 3: Type B – Front dashboard position (0°)

Test is run using the redesigned circuit having the blower fan on the side window. The solar panel is placed at PV tilt angle = 0° as shown in Figure-6.

### Case 4: Type B – Front dashboard position (30°)

Similar to Case 3, however at this time the solar panel is placed at PV tilt angle = 30°.

### Air ducting

In order to observe the effectiveness of air duct to the system, the modification has been done to the original housing by providing wider air duct cross sectional area. The modification is shown in Figure-7.

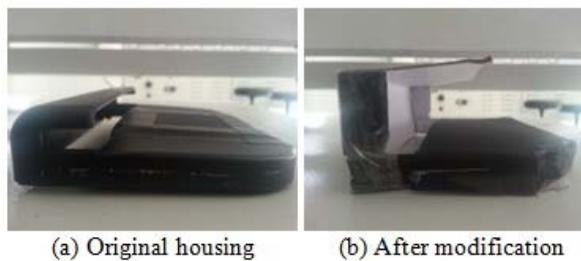


Figure-7. Improvement on ventilator's body.

### Case 5: Type B – Improved air duct area

This test is conducted similar to Case 4, however at this time the air ducting system has been modified.

### Temperature measurement

The temperature reading took place at three different locations inside the car (Figure-8). This location is chosen considering the area of passenger's seats. By considering quite similar weather condition of the day, the data is collected for three days from 9.00 am to 12.00 pm.

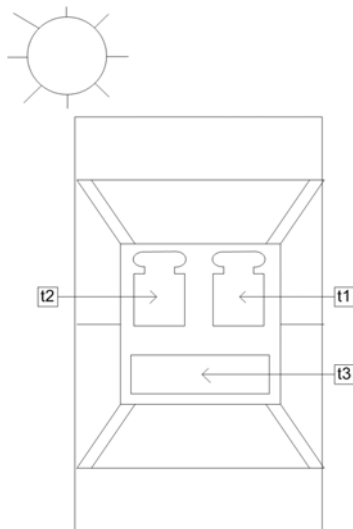


Figure-8. Area for temperature reading.

Without a solar based ventilation system (Case 1), temperature in the car is recorded using thermocouple before the test with a solar based ventilation system is conducted. This data will be treated as Control Temperature. After three hours the car is parked under the sun, the temperature is recorded at 12.00 pm.

### RESULT AND ANALYSIS

Figure-9 shows the result of the output power versus time for the three setting of Case 2, 3 and 4. As expected, the output power from Type B is better. It is seen that solar power of PV tilt angle at 30°, slightly increased over the time period, but solar power of PV tilt angle at 0° fluctuated over the time period. Thus, the solar power of PV tilt angle at 30° shows a good trend of performance overall.

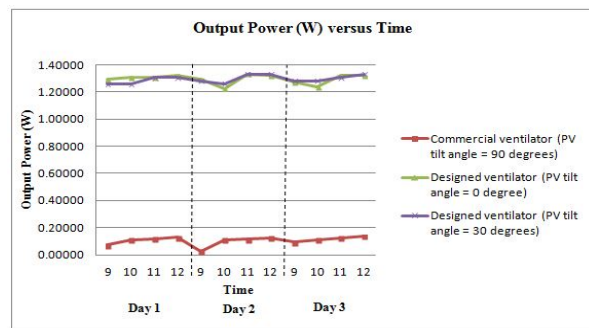


Figure-9. Output power (W) versus time.

The example of data collected for Case 1, 2 and 4 is tabulated in Table-3, 4 and 5 respectively. Finding from Case 3 is omitted in this paper due to similar setup as Case 4 and it is shown that the performance as observed in Case 4 is better. The plot for overall result for Case 1, 2 and 4 is shown in Figure-10.

Table-3. Interior temperature reading for case 1.

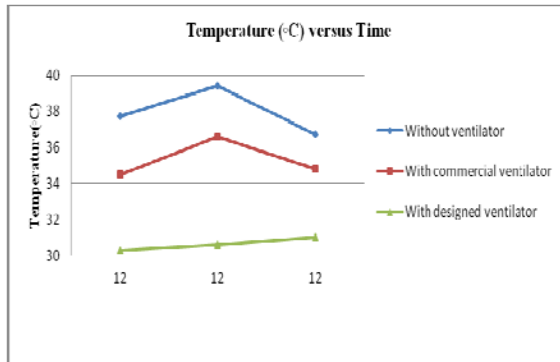
	Time	t1 (°C)	t2 (°C)	t3 (°C)	Avg. (°C)
Day 1	12 pm	37.1	38.5	37.5	37.7
Day 2	12 pm	38.9	39.7	39.6	39.4
Day 3	12 pm	36.3	37.0	36.9	36.7
Total Average					37.9

Table-4. Interior temperature reading for case 2.

	Time	t1 (°C)	t2 (°C)	t3 (°C)	Avg. (°C)
Day 1	12 pm	35.3	34.1	34.2	34.5
Day 2	12 pm	36.7	36.3	36.7	36.6
Day 3	12 pm	35.7	34.2	34.5	34.8
Total Average					35.3

**Table-5.** Interior temperature reading for case 4.

	Time	t1 (°C)	t2 (°C)	t3 (°C)	Avg. (°C)
Day 1	12 pm	30.9	30.2	29.9	30.3
Day 2	12 pm	31.0	30.8	29.9	30.6
Day 3	12 pm	32.8	31.5	28.7	31.0
<b>Total Average</b>					<b>30.6</b>

**Figure-10.** Graph of temperature (°C) versus time.

The results for average interior temperature of the parked car without the solar based ventilation system indicate that it is necessary to install the ventilation system in order to obtain more effective ventilation inside the car. It is seen that the commercial ventilator only able to provide small decrement in temperature inside the car. However, the performance of the interior temperature reduction with the designed ventilator is much better than the commercial ventilator. Of course this is mainly due to the size of the solar panel (better power), dc motor (better dc motor), position of solar panel (location at front dashboard is better than side dashboard) and the solar tilt angle (90° angle is not effective in capturing maximum insolation).

With an improvement being made to the air duct area, the result as seen in Table-6 is recorded. It is shown that the modification is able to drop the temperature by another 2.3 °C. This also shows that the proper air duct must be considered in order to provide smooth hot air flow from inside to the outside of the car. Relatively, it can be directly observed from the air flow in cubic meter per minute equation as follow.

$$Q = v \times A \quad (1)$$

$$v = \frac{d}{t} \quad (2)$$

Where,

$d$  = displacement, m

$t$  = time period, sec

$Q$  = air flow in cubic meter per minute, m<sup>3</sup>/min

$v$  = flow velocity, ms<sup>-1</sup>

$A$  = duct cross sectional area, m<sup>2</sup>

From equation, the greater the duct cross sectional area the more air can flow through the ventilator.

**Table-6.** Interior temperature reading for case 5.

	Time	t1 (°C)	t2 (°C)	t3 (°C)	Avg. (°C)
Day 1	12 pm	28.3	28.3	29.7	28.8
Day 2	12 pm	26.7	28.6	28.3	27.9
Day 3	12 pm	28.3	27.7	28.3	28.1
<b>Total Average</b>					<b>28.3</b>

The overall comparative performance of the system under study is shown in Table-7. The Type A ventilator provides 6.86% reduction of the interior temperature compared to the car without ventilation system. However, Type B ventilator able to show an improvement of 13.31%, as compared to Type A. The percentage of the redesigned ventilator compared to without ventilator is about 19.26%. In the other hand, with improvement of the air duct system, the performance of 25.33% can be achieved.

**Table-7.** Thermal performance of case 1, 2, 4 and 5.

	Case 1	Case 2	Case 4	Case 5
Temp. (°C)	37.9	35.3	30.6	28.3
Case 1	0%	6.86%	19.26%	25.33%
Case 2	-6.86%	0%	13.31%	19.83%

From result and analysis, it is clearly seen the importance of equipping car with proper ventilation system. The installation may provide the circulation of air flow inside the car, which indirectly will lower down the temperature inside the car that is parked unroofed under the direct sun. This could also help in reducing the incident of heat stroke to people who accidentally leaving children or pets inside a locked car. Some observations stated as follow are a few points to consider, before installing the car ventilation system.

- Size: From analysis it is shown that higher power solar panel provides better performance. However, this will duly come with cost that will be higher too.
- Position: It is also shown that placing the solar module at 90° angles on the side of the car is not a good idea as the solar energy from sun unable to be efficiently utilized. In consideration that all the ventilation tool must be placed inside the car for safety reason, the recommended placement is on the front dashboard.
- Air duct: Wider duct cross sectional area, better air circulation will be obtained.
- In this study only one ventilator is used for investigation. For better performance, it is recommended to install two or more blowers side to



side of the windows to increase the process of circulating the hot air out.

## CONCLUSIONS

An analysis based on size of solar panel, location of placing the solar panel, position of tilt angle of the solar panel and the air duct system is done in this study. From analysis, it is shown that the size, position and air duct play a role in improving the solar based ventilation system that is installed inside the car that has been parked unroofed under the direct sun. From result, the car with ventilation system able to reduce the temperature of about 25.33% as compared to one without the ventilation. Further study is conducted in realizing the prototype to commercial setup with aim of portability, easy assemble and re-pack for user convenient.

## ACKNOWLEDGEMENTS

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