DESIGN OF TIRE PRESSURE MONITORING SYSTEM USING A PRESSURE SENSOR BASE

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Abstract -- Currently, the Tire Pressure Monitoring System (TPMS) only monitors the condition of a tire pressure. However, there are no particular reactions taking place after the value of its tire pressure is discovered. In fact, the value of a tire pressure determines driving comfort and safety Therefore, this research proposed a method to integrate a TPMS and a Pressure Sensor Base (PSB) with a particular reaction required to fulfill tires automatically. The proposed TPMS has an electronic device unit directly attached to a tire's valve. This unit includes pressure sensors, microcontrollers, Bluetooth transmitters and batteries. An alert system is generated whenever tire pressure exceeds the maximum or minimum safe pressure level. Moreover, if the pressure measured is below the lowest level of the desired pressure, it will automatically activate the compressor. Several experiments have been carried out to analyze the proposed system. The integrated TPMS has proven to be able to be an alternative tool for the automotive sector to keep maintaining the tires and to improve a driving comfort and safety.

Keywords: TPMS: Bluetooth: Microcontroller; Compressor; PSB.

INTRODUCTION

Nowadays, digital technology has been developed and applied in various fields such as computer, mobile and controller technology. One of its uses is the Pressure Sensor Base (PSB) technique meant to be a tool that maintains a vehicle's prohibition and balance performances. The TPMS (Tire Pressure Monitoring System) was first introduced in the 1980s in the European countries, generally as an additional feature since it was safe, friendly, and environmentally friendly (Srinivasan, 2018; Kolodgie et al., 2017; Javheri et al., 2017; Zaharia & Clencie, 2013).

Some researchers and manufacturers define TPMS as a vehicle's safety device to maintain a vehicle's safety and check its condition, especially its tire pressure condition. TPMS (Tire Pressure Monitoring System) is broadly divided into two methods, namely WSB (Wheel Speed Base) and PSB (Pressure Sensor Base). The WSB (Wheel Speed Base) system compares the speed difference between the tires through an ABS wheel speed system on a vehicle to achieve its purposes of monitoring the tires, so the main weakness part in this system cannot be a decision maker when more than two wheels are under a normal pressure, too. A big mistake will occur when the speed exceeds 100 km / hour. Only when the wheel speed reaches a certain limit can this system be achieved. Meanwhile, the PSB

system is a system where the pressure sensor installed on each tire is aimed at calculating the tire pressure directly and monitoring the pressure on each tire (Shout & Yanez, 2017; Sabatini et al., 2017; Liu et al., 2012).

Tire pressure directly affects a vehicle's behaviors such as its stability, maneuverability and fuel consumption. A low tire pressure often makes the tires damaged and therefore can result in some fatalities in several cases. By using digital technology, monitoring the condition and balance of the wheels can be more easily done. From time to time, the monitoring system has progressed as technology becomes more and more advanced. One instance of this technological advancement is the use of microcontrollers which has been developed increasingly fast for its application in terms of monitoring. The monitoring system is carried out to monitor all activities that occur at a time deemed important to be safeguarded. Therefore, it is necessary for us to be informed about the tire pressure to ensure the vehicle's safety performance at a high velocity. Another advantage that we obtain is that it allows communications between the sensor and the mini compressor, so when the tire pressure is lower than that of the compressor, it will automatically charge the wind when the vehicle stops moving during the charging process. The basic concept of a tire pressure monitoring system on a wireless

motorized vehicle consists of a sensor module mounted on a vehicle's tire valve and an attached receiver module. This sensor module is responsible for monitoring the pressure on the tire; afterwards, the tire pressure data is sent to the receiver module wirelessly through Bluetooth. Meanwhile, the receiver module serves as the recipient of the data which are subsequently processed in order that it can be displayed on the LCD screen to inform the user. Therefore, in this research, the thesis raised the process of charging tire wind automatically (Tongbin & Shien, 2017; Hou et al., 2017; Jiang et al., 2011).

Accordingly, in this research, the title, "Monitoring and Control Prototype in a Tire Pressure Monitoring System", explained in this thesis is aimed at automatically filling the tire winds when the tire pressure is lower than that of the minimum safety limit, using pressure sensors as a real pressure data time and a compressor as a tool for tire filling so that the results will be obtained in the forms of safe and comfortable tires because the tire pressure has been made standard, and in this Thesis, the prototype can be activated when the vehicle is in a stationary state, so it can be illustrated as follows: when the vehicle moves, the sensor sees the value of the tire pressure; as soon as the tire pressure is below the standard, the relay will be activated and give a warning sign to the driver to stop and the tire filling process is automatically carried out with the compressor active when charging.

MATERIALS AND METHODS
Tire Pressure Monitoring System (TPMS)

The basic concept of a tire pressure monitoring system on a wireless motorized vehicle consists of a sensor module mounted on a motor vehicle tire valve and an attached receiver module. This sensor module is responsible for monitoring tire pressure; afterwards, the tire pressure data is sent to the receiver module wirelessly through Bluetooth. Meanwhile, the receiver module serves as the recipient of data which is subsequently processed, so it can be displayed on the LCD screen to inform the user. Tire pressure directly affects a vehicle's behaviors such as its stability, maneuverability and fuel consumption. Low tire pressure often makes the tires damaged and can result in fatalities in if the cases are severe. Therefore, it is necessary for us to be informed about the tire pressure to ensure the vehicle's safety performance at a high speed (Hasan et al., 2011).

TPMS, according to some researchers and manufacturers, is defined as a vehicle's safety device to maintain the vehicle's safety and check the vehicle's condition, especially its tire pressure

condition. Hasan et al. (2011), in his paper, proposed a method for carrying out TPMS (Tire Pressure Monitoring System) tasks on vehicles to measure the air pressure in a pneumatic tire that has an electronic device unit directly attached to a tire valve (Hasan et al., 2011). Fig. 1 shows the proposed TPMS.
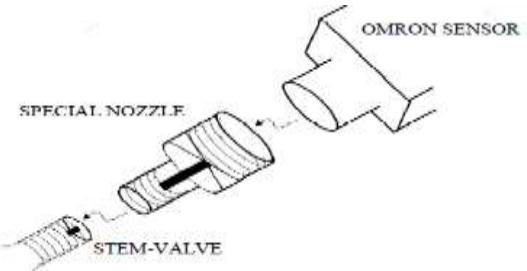
Figure 1. Valve Stem and Sensor are connected using a special nozzle (Hasan et al., 2011)

In his paper, Jiang et al. (2011) introduced the development situation of TPMS (Tire Pressure Monitoring System) where in this case, tire pressure directly affected a vehicle's behaviors such as its stability, maneuverability, and fuel consumption. A low tire pressure often resulted in a tire failure, and it could even result in fatalities for severe cases. Therefore, it was necessary to be informed about the tire pressure and the temperature to ensure the vehicle's safety performance in real time (Jiang et al., 2011).

Meanwhile, in his paper, Liu et al. (2012) when elaborating the trend of TPMS applications (Tire Pressure Monitoring System) mainly introduced the basic principles of TPMS transmitters (Tire Pressure Monitoring System), system structures, and the components' main features where focusing was located on the software process to achieve a low power's consumption and steps from the detection process (Liu et al., 2012). Fig. 2 depicts the proposed TPMS.
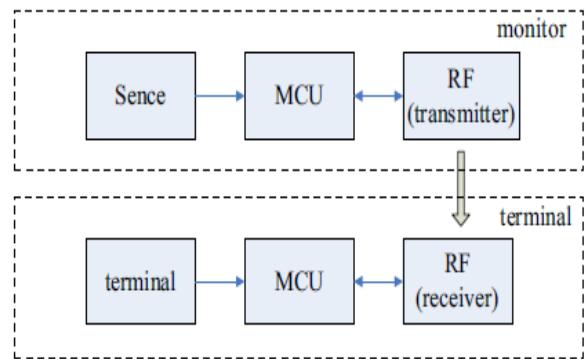
Figure 2. Principle of TPMS (Liu et al., 2012)

In his paper, Savic et al. (2014) evaluated TPMS aimed at a traffic management by presenting a simple TPMS simulation model based on empirical investigations in order that the simulation results obtained were the number of detected vehicles and the detection range, the sensor transmission period and low congestion (low traffic) (Savic et al., 2014). Fig. 3 depict this TPMS.
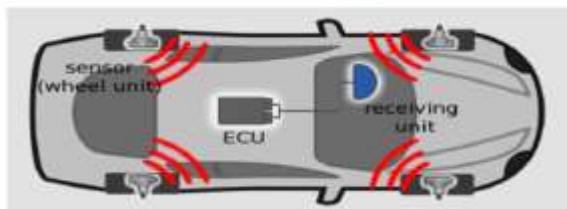
Figure 3. TPMS Structure (Savic et al., 2014)

Moreover, Vasantharaj & Krishnamoorthy (2016) introduced a tire pressure monitoring system using a system on the chip and Bluetooth transmission. That system increased the driver's safety by automatically detecting the tire pressure and the temperature and subsequently sending a warning signal to the driver to measure it so as to prevent accidents (Vasantharaj et al., 2016). Fig. 4 shows the TPMS using that wireless telecommunication system.
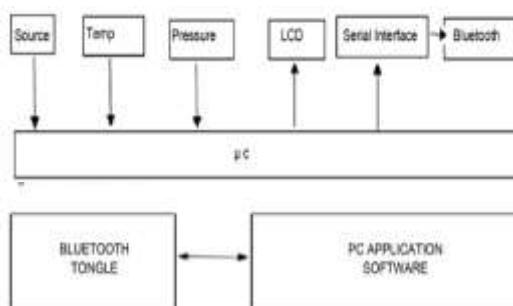
Figure 4. Block Diagram Transmitter and Receiver (Vasantharaj & Krishnamoorthy, 2016)

TPMS plays an important role in the driver's safety and the fuel consumption. Vehicles moving with a low tire pressure will consume a lot of fuel. Things like tire leakage will not be detected, and it can result in a serious problem during the trip. In addition to recording tire pressure in real-time, the TPMS can also maintain and provide warnings when the tire is in a nonstandard state. Therefore, to ensure the driver's safety, we have to provide a pre-warning system for the drivers and the passengers. This then makes the TPMS divided into two types namely a direct TPMS the instance of which is: PSB attaching the pressure sensors on each tire to directly calculate the tire pressure

in real-time, and an indirect TPMS (indirect) the instance of which is: WSB (Wheel Speed Base) comparing the speed difference between the tires through a wheel speed sensor on an ABS (Automated Brake System) type of vehicle so as to monitor the tire pressure (Miclaus et al., 2016).

Methods

This device generally consists of two parts, namely the transmitter and the receiving device. In general, the overall system block diagram can be shown in Fig. 5.
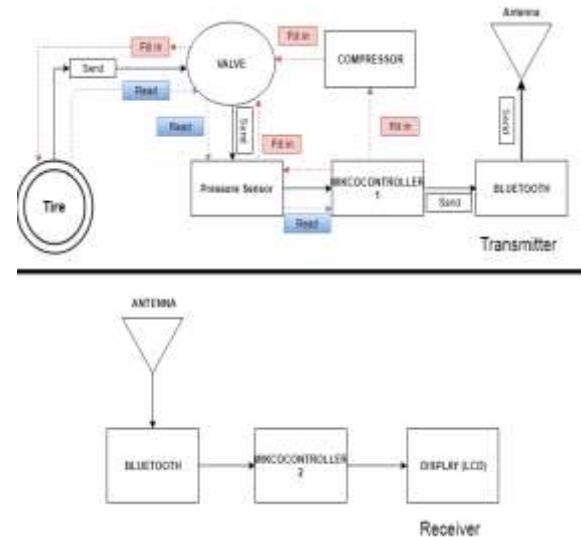
Figure 5. Block Diagram Prototype Monitoring & Control TPMS

Each tire of the vehicle has a transmission unit that is uniquely identified by the recipient through its ID. This unit can measure the tire pressure of the vehicle when they are still stationary. All units are activated "ON" and they attached to the valve stem. When the unit is attached to a valve, the pressure switch is activated. Pressure sensors can directly sense the tire's air pressure. The tire pressure generates voltage and output voltage sensors. The following block diagram on the transmitter is shown in Fig. 6.
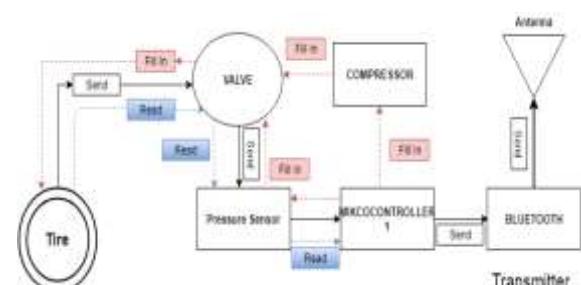
Figure 6. Block Diagram Transmitter Prototype Monitoring & Control TPMS

There is a single receiving unit on the onboard for the transmission unit. Once activated, it will turn on the LCD and will subsequently start receiving packets from the RF receiver. The controller will only receive packets in a certain order (the same order as that of the transmitter unit). After receiving the package, it will then search for errors. If an error is detected in any package, the controller will wait for the packet it receives from the next transmitter unit. After receiving the packets from the successful tires, the tire pressure is calculated. It will then display the tire pressure of all tires on the LCD. If the calculated tire pressure is lower than the specified limit, the warning screen pressure will turn on the "Low Tire Pressure" sign as well as the number of the corresponding tires and it will make the buzzer active; then, the compressor will light up and fill in the tire air. The following block diagram on the transmitter is shown in Fig. 7.
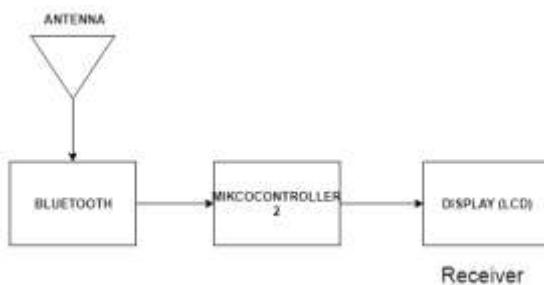
Figure 7. Block Diagram Receiver Prototype Monitoring & Control TPMS

There is a wind charging unit for the transmitter unit. After the system is activated, the compressor will automatically be in the standby position. It will then start receiving information from microcontroller 1. After receiving the information, it will then search for any errors. If an error is detected, the control will wait for the information to be sent to the next pressure sensor. After receiving the information from the successful pressure sensor, the tire pressure will be calculated. If the calculated tire pressure is below the pressure limit, the active compressor will fill the pressure until it achieves the desired value and no longer fills the tire air if it already meets the tire filling criteria. Fig. 8 shows the block diagram of the tire filling process.
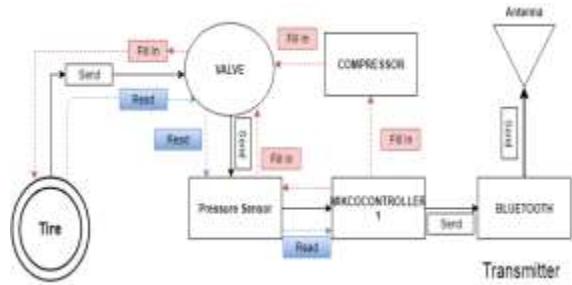
Figure 8. Block Diagram Tire Charging Prototype Monitoring & Control TPMS

RESULTS AND DISCUSSION

The device created in this thesis is in the forms of hardware. This device serves a signal sender from the MPX5500 pressure sensor input processed by the microcontroller. The valve closure and activation are adjusted to the MPX5500 pressure sensor that detects tire pressure. Moreover, during the charging, the compressor is activated and the filling process is carried out by a half-a-second delay to fill and measure the pressure value until it reaches the safe limit of the tire pressure.

The output of the microcontroller then goes to the LCD circuit. The signal is then transmitted via Bluetooth. The received signal that has been processed in the receiver section will bring up the display on the LCD screen in the forms of the measured tire unit information.

A tool calibration testing was aimed at determining the output pressure generated by the circuit that has been made with the pressure aids in the market. Calibration testing and results are shown in Fig. 9.

Figure 9. Calibration Results between the Protypes with a Comparison Tool: Digital Tire Pressure Gauge

Figure 9. (a). The results of the comparison between the TPMS Prototype and a 10 PSI Digital Tire Pressure Gauge Tool

Figure 9. (b). The results of the comparison between TPMS Prototype and Digital Tire Pressure Gauge Tools worth 15 PSI

Figure 9. (c). The results of the comparison between the TPMS Prototype and the Digital Tire Pressure Gauge Tool worth 18 PSI

Hence, based on the results of the calibration between the Monitoring Prototype and the Control on a Tire Pressure Monitoring System with a comparator: Digital Tire Pressure Gauge, it reaches the same value as shown in Fig. 10.

The purpose of this test was to observe the sensor output voltage to the device used, and the results were as follows:

Figure 10. Results of Voltage Measurement on MPX 5500 Pressure Sensor

Tire wind charging test, the purpose of this test is to observe the output pressure connected to the pressure sensor when the pressure sensor is activated when filling the tire. Fig. 11, Fig. 12, Fig. 13, Fig. 14 and Fig. 15 show voltage measurement results to reach 6 PSI, 10 PSI, 15 PSI, 20 PSI and 25 PSI, respectively.
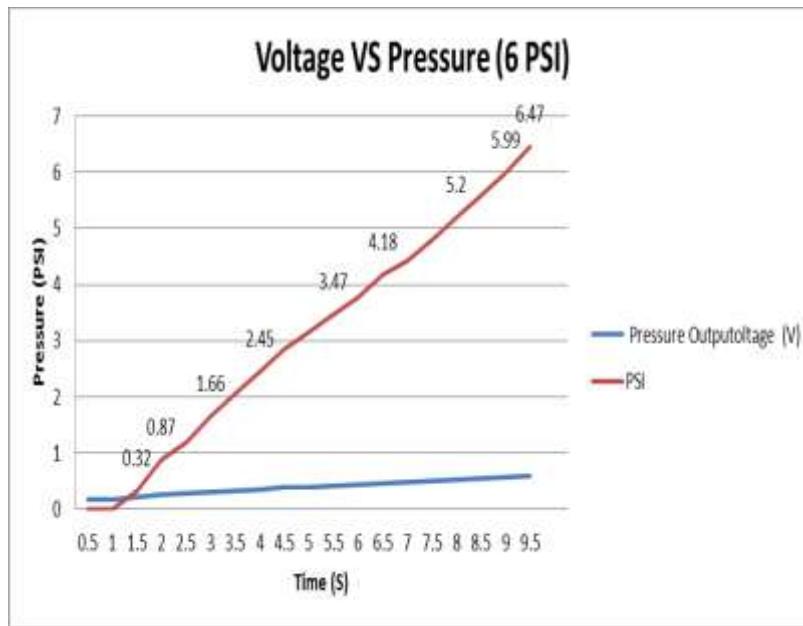
Figure 11. Voltage measurement results to reach 6 PSI
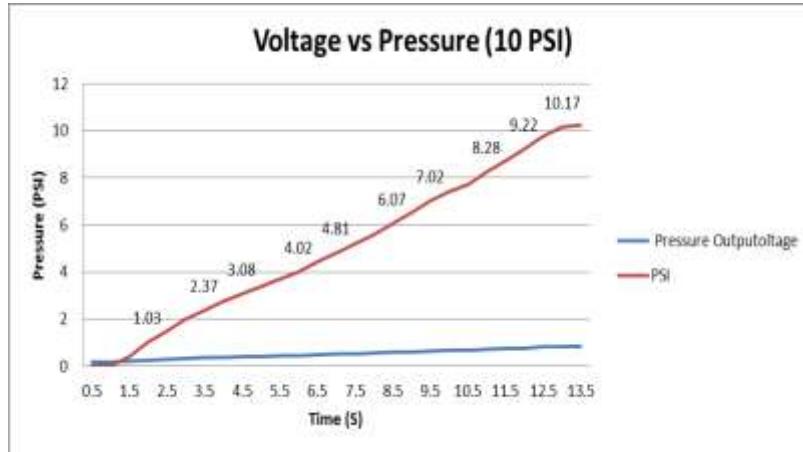
Figure 12. Voltage measurement results to reach 10 PSI
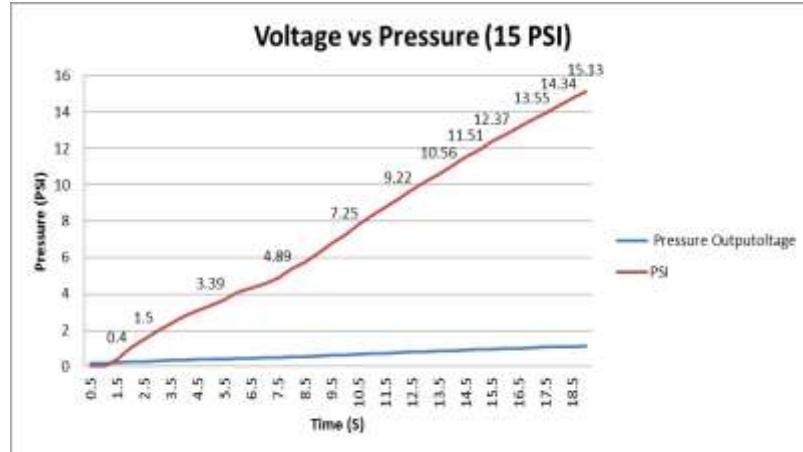
Figure 13. Voltage measurement results to reach 15 PSI
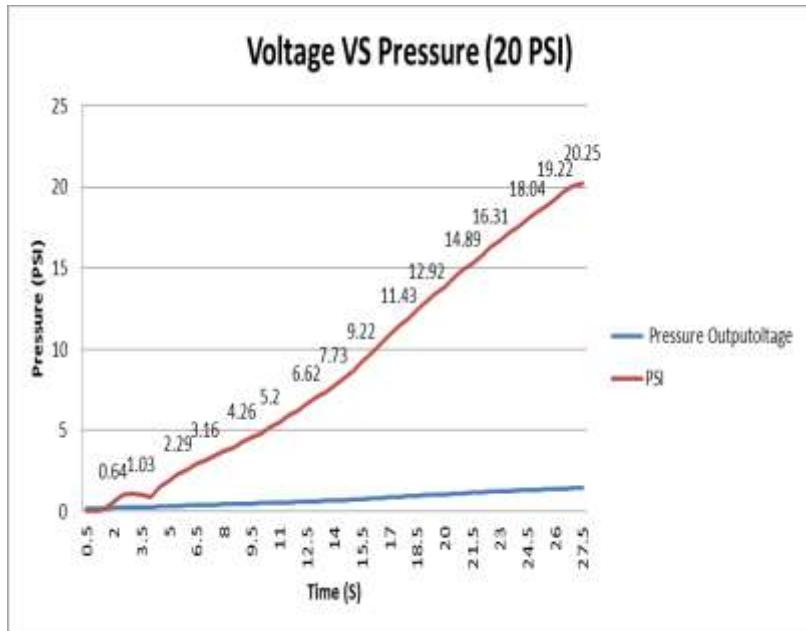
Figure 14. Voltage measurement results to reach 20 PSI
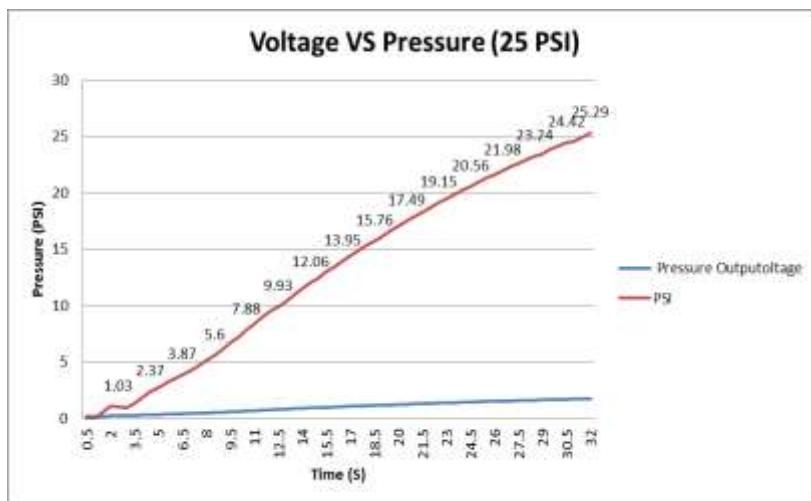
Figure 15. Voltage measurement results to reach 25 PSI

Based on results of the measurement, it can be seen that the wind pressure on a normal tire rises as the voltage increases. At the beginning of charging, the filling process occurs very fast, but when it reaches a higher pressure, there is a back pressure from the tire, so the filling process takes longer due to the condition of the reciprocal pressing -- the compressor filling the tire and the tire sending back the pressure.

System testing is done to find out the performance of the tools that have been made. The measurements are carried out by activating the transmitter and receiver alternately, up to 25m. This test is aimed at observing how far Bluetooth can be employed, as shown in Fig. 16.
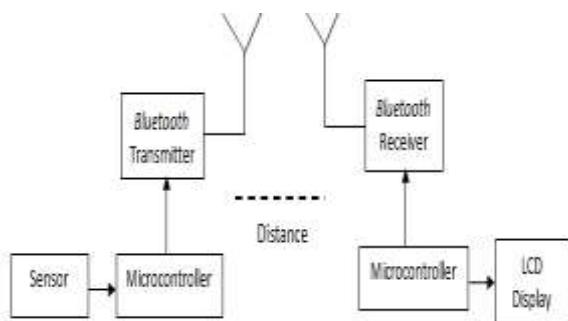
Figure 16. Block Diagram Prototype Monitoring & Control TPMS

Table 1. Results of Measurement of Distance between the Transmitters and the Receivers

Tx		RX				
gap (m)	gap (m)	Status LOS	Status Glass	Status Plastic	Status Aluminum	Status Wall
1	1	Connected	Connected	Connected	Connected	Connected
5	5	Connected	Connected	Connected	Connected	Connected
10	10	Connected	Connected	Connected	Connected	Connected
15	15	Connected	Connected	Connected	Connected	Disconnected
20	20	Connected	Connected	Connected	Disconnected	Disconnected
25	25	Connected	Connected	Connected	Disconnected	Disconnected
30	30	Disconnected	Disconnected	Disconnected	Disconnected	Disconnected

Pursuant to Table 1, it found out that the distance between the transmitter and receiver would be optimal up to 10 meters. If it is given obstacle / disturbance to the wall, the maximum distance in aluminum would be up to 15 meters, and the obstacle / interference on glass and plastic reached 20 meters, and when compared with Vasantharaj & Krishnamoorthy (2016) research, where the measurement results were also different in terms of the use of sensors, where the study used two sensors namely pressure sensors and temperature sensors and they were carried out in the simulations; however, in this thesis, we only used the pressure sensors and directly applied them to real objects namely the vehicles. Overall the design of this prototype would be allowed up to 72.5 PSI, but in the measurement process, the charging only reached 25 PSI, due to the back pressure between the compressor and the tire. Moreover, in Suharmanto & Musafa (2013) research, the results of the design used an on-off control system, where the system will control the fill valve and the exhaust valve would open or close based on the data input pressure that needed to be entered. Meanwhile, in this thesis, the input data was already built-in in the program set on the minimum limit value and maximum tires. Furthermore, in (Wahyu et al., 2011), the results of his research focused on the compressor control systems ready to be used at all times, as a vehicle tire air conditioner, while in this thesis, the results of the first research were to calculate the current pressure value and if the pressure was below the desired lowest limit, the compressor would be automatically activated to fill the tire.

CONCLUSION

The purpose of this thesis was to design an automatic tire filling system using sensors to monitor the tire conditions and to fill the air pressure if tire conditions were below the standard. The existence of a prototype wind pressure automation system designed with a Bluetooth system used in the TPMS (Tire Pressure Monitoring System) provided simpler design results. Accordingly, an in-depth analysis was already carried out and its performance was compared, such as measuring the tire pressure working at a high or a low pressure in both situations. Based on the results of the analysis in this thesis, we made a conclusion that first the longest optimal system capability was 15 meters. Secondly, the capability of a compressor that has a small strength made the wind filling denied to achieve the optimal pressure. Thirdly, this tool worked with a Bluetooth system. Fourthly, we could set up the pressure of this tool depending on the desired tire pressure. In the future for further research, not only will there be pressure sensors but we will incorporate more new features due to increased safety standards in the automotive industry. We can achieve this situation in a number of ways such as adding more sensors to the TPMS (Tire Pressure Monitoring System) module, providing data other than pressure, temperature, wheel alignment, puncture indications, heavy vehicle loads, etc, or combining various information sources such as a more effective TPMS integration communication (Tire Pressure Monitoring System) with other parts of the vehicle. Finally, the system performance will be tested and run by using an Arduino software provided as a real time application.

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