IoT−based tire pressure monitoring system for air and temperature pressure using MPX5500D and LM35 sensor

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***Abstract*—Research has been carried out to monitor vehicle tires before they are used and can reduce damage, including overcoming vehicle fuel waste because air pressure is continuously monitored. This research aims to utilize the MPX5500DP sensor as an air pressure device, the LM35 sensor as a temperature reader, and a buzzer based on IoT to build a tire pressure monitoring system (TPMS). The MPX5500DP and LM35 sensor inputs to the Arduino Uno microcontroller are distributed by the NodeMCU, fitted with a Wi-Fi module. The Blynk application sends and displays the data on a smartphone using the IoT-based. Based on this research, data on the percentage of errors in monitoring air pressure and tire temperature on vehicles were obtained by comparing the data to the pressure gauge and thermometer: 1—the results of the average reading of the sensor error value. MPX5500DP air pressure against pressure gauge is 5.3%. 2—the average reading of the LM35 sensor error value on the temperature thermometer is 6.8%. With this research, the air pressure and temperature in the tires can be monitored in real-time via a smartphone using the IoT-based.**

Keywords—air pressure, Arduino Uno, Blynk, piezoelectric buzzer, temperature, TPMS.

I. Introduction

The increased need for motorized vehicles became significant to support all daily community activities [1]. Safety and comfort aspects when driving are often neglected [2]. Bad lighting, poor road condition or structure, and bad behavior are the most common causes of road crash in Indonesia [3]. Besides, the most priority road safety factors are human behavior, vehicle condition, road condition, environment [4], and equipment [1]. According to the KNKT (National Transportation Safety Committee of Indonesia), it is stated that 80% of road accidents involving tire bursts are due to a lack of tire pressure, one of the parts of the vehicle [5]. For that condition, the role of tire pressure is essential for safe riding in Indonesia. In addition, not suitable air pressure can affect tire to burst [6]. Make sure the tire pressure is the standard level to make safe riding.

Today, the Internet of Things (IoT) was increased, a feature of the industrial revolution 4.0 [7], including in the field of safety transportation [7], [8]. Recent technological developments make it possible to build tools to monitor tire pressure remotely [9], also with fuzzy [10], with linear regression technology [11], and wireless [12], monitor tire failure [13], monitor tire friction [14], assess the road condition [15], analyze the flexibility and vibration of tire and road [16], and temperature. Based on IoT, it is easier for drivers to determine the tire pressure and temperature size. Unfortunately, a limited study does not attach the tire temperature to the analysis factor. This air pressure and temperature of tire monitoring device based on IoT become the research gap for this paper.

II. Literature Review

A. Vehicle Tires

Tires are essential components of vehicles used to reduce vibrations caused by irregularities in the road surface, protect the wheels from wear and damage, and provide stability between the car and the ground to increase acceleration and facilitate movement [17]. Tires are classified into three structures: bias, radial, and belted. For temperature and air pressure resistance, it is adjusted to the type and size of the tire according to the vehicle's needs. This study used *Bridgestone* tires with a size of 195/50 R16 inches with an average temperature resistance of −60 to 175°C with normal usage [18].

B. MPX5500D Sensor

The MPX5500D (Fig. 1) was an air pressure sensor that can measure pressures from 0 to 500 kPa and has an analog output voltage of 0.2 to 4.7 V. This sensor has a maximum tolerance of 2.5% accuracy at temperatures between 0 to 125°C. This sensor type was a differential that measured the difference in air pressure from each side [6]. This characterization is suitable for fulfilling the air pressure sensor requirement.

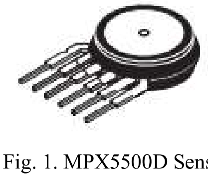

Fig. 1. MPX5500D Sensor (*Source: [19]*).

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C. LM35 Sensor

The LM35 temperature sensor (Fig. 2) was an electronic component that converted temperature into electrical quantities in voltage. In principle, the sensor would sense when the temperature changed every 1°C and would show a voltage of 10 mV. This sensor range started from −55 to 150°C [20]. The suitable tire temperature is between −60 to 175°C with normal usage [18], and the LM35 sensor has a temperature range near the tire temperature.

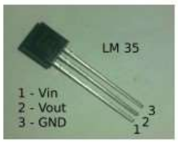

Fig. 2. LM35 Temperature Sensor (*Source: [21]*).

D. NodeMCU ESP8226 and IoT

NodeMCU ESP8266 (Fig. 3) was a microcontroller in the form of an electronic board with an ESP8266 chip with the ability to run microcontroller functions and a Wi-Fi internet connection. The NodeMCU has several I/O pins, so this microcontroller became famous for monitoring and controlling applications in IoT systems. NodeMCU can be programmed with the Arduino compiler, named *Arduino IDE Software*. NodeMCU was a USB port for easy programmed [20]. Internet of Things (IoT) is a network of objects connected by the internet and communicates independently without human intervention. The capabilities include sharing data and remote control [27],[28]. The module was also compatible with IoT features.

TABLE I. SPECIFICATIONS OF NODEMCU ESP8266*.

No.	Specification	NodeMCU
1	Microcontroller	ESP8266
2	Board Size	57 mm x 30 mm
3	Input Voltage	3.3 – 5 volts
4	GPIO	13 pins
5	PWM channel	10 channels
6	Flash memory	4 MB
7	10-bit ADC pin	1 pin
8	Clock Speed	40/26/24 MHz
9	Wi-Fi	IEEE 802.11 b/g/n
10	Frequency	2.4 GHz – 22.5 GHz
11	USB Port	Micro USB
12	Card Reader	Unavailable
13	USB to Serial Converter	CH340G

*Note: details adopted from [22].

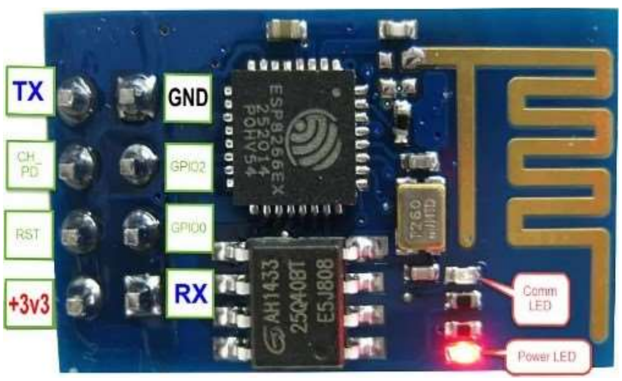

Fig. 3. NodeMCU ESP8266 module (*Source: [23]*).

E. Piezoelectric Buzzer

Piezoelectric (piezo) was a type of buzzer that used the piezoelectric effect to produce sound. The electric voltage applied to the piezoelectric material would cause mechanical movement. The movement was then converted into sounds that the human ear used diaphragm and resonator. For ultrasound applications, a piezo buzzer would work well in produced frequency in the 1–5 kHz to 100 kHz range. Typical ASP-H119 piezo buzzer-operated voltage recognized capacities from 3 to 12 Volt (Fig. 4) [24].

Fig. 4. ASP-H119 piezoelectric buzzer (*Source: [24]*).

F. Blynk App

Blynk was a new platform that allowed you to rapidly build an interface for controlled and monitored hardware projects from iOS and Android [25]. The Blynk application controls and monitors remotely, provided the microcontroller must be connected to the internet network with a stable connection [26].

III. METHOD

The research used is Development Research and Development (R&D) method. R&D is a research method used to produce specific products, assess the effectiveness of products, and deliver these products requires analysis [29].

A. Flowchart

This research begins with a literature study to get a research gap. Design is done to design a prototype. The results of the design are continued by programming the tool testing application. If the prototype is successfully synchronized, data collection is carried out, but if not, the research process returns to the coding and wiring stage. After the data was obtained, the discussion continued to get conclusions from this research. After the decision is reached, the study is finished.

B. Wiring

The process of wiring all sensors (MPX5500D and LM35), piezo buzzer, and NodeMCU assembled into one connected unit. This study also wired the Arduino-uno module for connection to all sensors, and the main module is NodeMCU wired to Arduino-uno. In our opinion, combining two modules between NodeMCU−Arduino-uno can make the monitoring process more robust. Because of the recent study that used two combined-module for performance maximum IoT monitoring [30] and in some cases, several sensors are only compatible with the Arduino-uno module [31]. An illustration of this prototype wiring can be seen in (5).

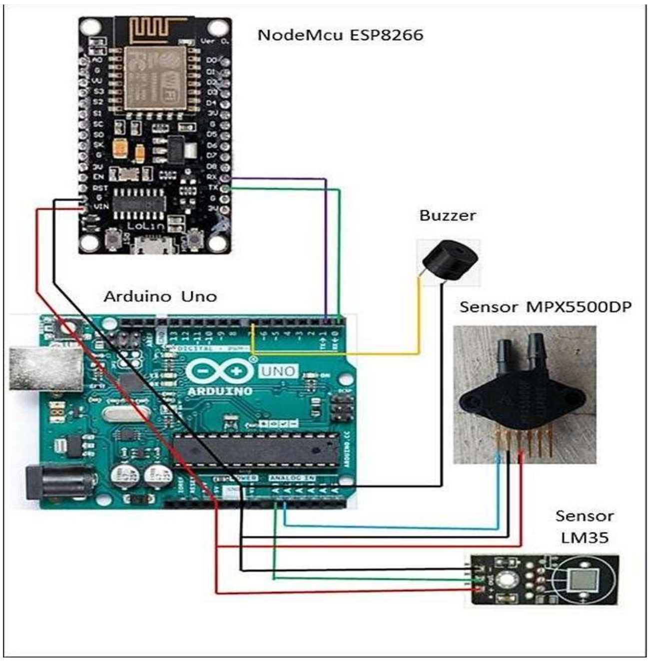

Fig. 5. Prototype schematic diagram.

C. *Hardware Design*

In the tool's design, the air pressure drill controller uses the MPX5500D sensor and the LM35 sensor. Only with this module can the air pressure drill controller be built a scheme (Fig. 6).

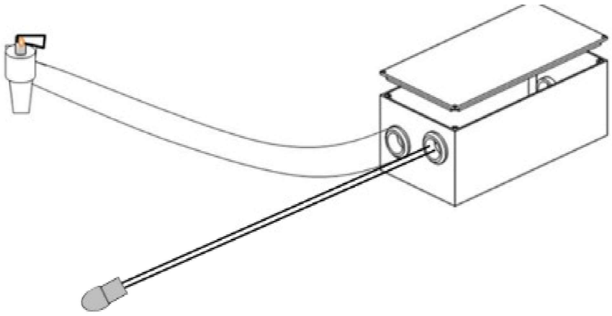

Fig. 6. Hardware design tool.

IV. Results and Discussion

A. *MPX5500DP Sensor Test Results on Blynk Display Against Pressure Gauge*

Testing the pressure gauge using the MPX5500DP sensor on four-wheeled vehicle tires by testing the buzzer response to a predetermined measuring value using several air pressure measurements, with data results that can be seen in Table 2.

TABLE II. TIRE PRESSURE TEST RESULTS ON BLYNK DISPLAY ON PRESSURE GAUGE.

No.	**Tire Air Pressure (kPa)**		**Error (%)**
	Pressure Gauge	***Blynk (MPX5500DP)***	
1	200	194	2.77
2	193	173	10
3	165	152	7.8
4	131	132	0.7
Average			5.3

Based on the assessment in Table 2, the average value shown in Blynk is about 2.998 Psi (1 kPa equal to 0.145038 Psi); this is higher than the previous study that reported an increased tire pressure value between 0.12-0.22 Psi [6]—probably caused by the 5.3% error rate.

B. *LM35 Sensor Measurement Value on Blynk Display Against Digital Thermometer*

Testing the measurement of this measuring value to ensure the error value of the LM35 temperature sensor against the difference in results from the measurement values of other commonly used tools can be seen in Table 3.

TABLE III. LM35 SENSOR MEASUREMENT VALIDATION TEST.

No.	**Tire Temperature (°C)**		**Error (%)**
	Thermometer	***Blynk (LM35 Sensor)***	
1	33.7	32.74	5.7
2	33.7	32.74	5.7
3	35	31.76	2.8
4	35	32.79	6.4
Average			6.8

Based on the assessment in Table 3, the average value of an error is 6.8% higher than other research, with an error rate of less than ±1.15%FS with an overall 23.77 Psi [32]. This study may provide an estimated tire temperature for the monitoring device.

C. *Analysis*

The following are the analysis of the research on measuring air pressure and temperature of vehicle tires using the MPX5500DP pressure sensor and the IoT-based LM35 temperature sensor on the Blynk application display on the pressure gauge and thermometer air pressure gauge:

- The MPX5500DP pressure sensor in the tool functions correctly and can detect air pressure according to the specified limit value according to the program in the *Arduino IDE*.
- The LM35 temperature sensor in the tool is functioning correctly and can measure the temperature according to the temperature set in the *Arduino IDE* program.
- Blynk can be connected to the device and display the actual pressure and temperature sensor readings' actual value with a readable range of about 2–450 cm.
- There is a difference in the reading value of the MPX5500DP pressure sensor with the pressure gauge value of about 0.7~10%.
- There is a difference in the reading value of the LM35 sensor with a different value of about 2.8~6.8%.

V. Conclusion and Future Works

Based on testing, this study uses two different test sources, the air pressure sensor, and the temperature sensor, so it can be concluded that the average reading of the sensor error value MPX5500DP air pressure against the pressure gauge is lower than the LM35 sensor.

We propose that this prototype is used to develop novelty IoT applications for transportation safety purposes, precisely to measure tire air pressure. Because based on our research, this prototype can be further developed to be widely applied to testing vehicle tire standards.

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