Development of Portable Electronic Sensor Trainer (PEST) for Teaching and Learning Purpose

Wan Nor Shela Ezwane binti Wan Jusoh
Politeknik Tuanku Sultanah Bahiyah
Kulim Hi Tech Park
09000 Kulim Kedah
+60193404629
shela@ptsb.edu.my

Md Razak bin Daud
Politeknik Tuanku Sultanah Bahiyah
Kulim Hi Tech Park
09000 Kulim Kedah
+60165097432
razak@ptsb.edu.my

ABSTRACT

Portable Electronic Sensor Trainer (PEST) is a training kit for teaching and learning. PEST comes with the breadboard, relay, solenoid, LCD, Arduino Nano and other electronic components. The PEST has been created to assist lecturers and students especially during their practical work on the subject of Industrial Electronics. PEST is developed starting with problem statement, idea exploration and then designed using Inventor. Inventor is a software that can be used to produce 2D and 3D views. It can also be drawn in orthographic drawings complete with dimensions. Once the design drawing is completed, Arduino programming begins with 15 different sensors to allow students to learn the functions and connections of each sensor. PEST also comes with a QR code where students can access the lab sheet as well as circuit connections. In addition, PEST also uses HP Reveal as a medium that allows students to understand demonstrations carried out by their lecturers by simply through scanning the sensor images and video of the connecting circuit that will be displayed on their smartphones. This PEST development involves processes of etching, drilling, soldering and component assembly. The results obtained are in terms of circuit connectivity and output of each sensor.

***Keywords**: Arduino, Sensors, QR Code, Inventor, HP Reveal.*

1. INTRODUCTION

Portable Electronic Sensor Trainer (PEST) is a portable sensor training kit. PEST is a complete set of electronic circuits with 15 types of different sensors that can be connected by students to create a circuit connection according to the applications provided. PEST is convenient and user-friendly. PEST is created primarily for Industrial Electronics subject and Project 1, to help students to identify sensors that could be used perfectly for their final project. PEST is built with reference to the syllabus where it can conduct laboratory experiments consisting of Switch, Relay, Solenoid, and Sensor. PEST can be used for all Malaysian Polytechnics especially in Diploma in Mechatronics Engineering program.

There are 15 types of sensors used to carry out the practical work namely touch sensor, rain sensor, alcohol sensor, smoke sensor, gas sensor, pressure sensor, temperature sensor, flame sensor, Hall Effect sensor, sound sensor, LDR light sensor, ultrasonic sensor, PIR motion sensor, vibration sensor, and colour sensor. One sensor will be used in one practical period using PEST. To enable PEST to be used on all sensors, the development of PEST will be described in more detail in the methodology section. PEST is also developed using a QR code where students can access the code provided and all sensor-related notes, as well as the lab sheet, will display on the smartphone. In addition, PEST is connected to the Hp Reveal apps which will allow students to easily visualize the circuit connection by simply scanning the sensor image and the video will display on the smartphone. This will facilitate lecturers during demonstration sessions as the theory and practice can be clearly understood.

PEST has been registered under the Intellectual Property Corporation of Malaysia (MyIPO) with registration number LY2019005673 for the purpose of copyright security. PEST has also been used throughout the semester for the June and December sessions. It has received positive feedback from the lecturers, students and top management. In addition, PEST has won Gold in departmental and polytechnic innovation competitions while winning Silver in international innovation competitions. PEST is also able to reduce the cost of the department's assets as it is cheap and has the internal expertise to do troubleshoot or maintenance.

2. PROBLEM STATEMENT

One of the major problems faced by students and lecturers in teaching and learning of engineering subjects is the lack of equipment to do practical works. Despite the lack of equipment, practical activities still can be done to ensure that students get the best results. Engineering Departments have limited equipment to enable students to practice their hand-on skills. Therefore, the development of PEST is a lecturer's initiative to ensure that all students are able to perform in hand-on work more efficiently and skillfully. In addition, the teaching and learning of the theories using slides cause students to lose focus. So this PEST comes with a manual video in which the lecturer prepare a guiding video that explains how to connect the circuit and students can easily access it by just scanning of the sensor image. Therefore, teaching and learning are more interactive and students are more engaged. Theoretical explanations and practical methods need to be in line to optimize students' understanding.

3. RESEARCH OBJECTIVES

After reviewing the problem, PEST was developed with a few objectives in consideration. The first objective is to design a teaching tool is to facilitate lecturers and students to do practical work effectively based on the syllabus set by the Department of Polytechnic and Community College. The second objective is to help students to identify the function and operation of various sensors so that it can assist students in the final semester to create more innovative projects. The third objective is to know the output of each sensor types, the connection of the sensor circuit and to further develop the student's hands-on skills.

4. LITERATURE REVIEW

The literature review for the development of PEST revolves around studies on different types of sensors. A detailed study of sensor functions, sensor applications as well as how to program the sensor in accordance with the application requirements. Gas Sensor MQ5 module is useful in domestic and industrial gas leakage detection. It is appropriate for H2, LPG, CH4, CO, and Alcohol detection. The measurements can be taken as soon as possible due to their high sensitivity and fast response time. The sensor's sensitivity can be changed using the potentiometer [1]. Nevertheless, the light-emitting portion and the light-receiving portion for detecting the smoke and the explosion-proof container containing the circuit board are isolated from each other in the photoelectric smoke sensor using optical fiber, and the photoelectric smoke sensor cannot be prevented being larger in size [2].

The presence of LPG, Butane, Propane, Methane, Alcohol, and Hydrogen can be detected using smoke sensor MQ2. Depending on the type of gas the sensor resistance is different. The smoke sensor has an integrated potentiometer that allows the user to change the sensor sensitivity to the degree to which the user wishes to detect gas [3]. A touch sensor system includes a touch panel with at least one multiple touch sensing area, a multiplexer, and a touch controller. The touch controller contains a set of pins connected to the multiplexer via a plurality of touch control wires and touches sensing wires for control of touch driving and sensing on the touch panel, in which each pin is connected to one of the touch control wires or touch sensing wires. Each touch detection cable transmits driving signals to a corresponding multiplexer from the touch controller to drive on one of the touch detection areas and transmits sensing signals from the touch detection area to the touch control. The touch controller controls the multiplexer by activating the touch control wires in a specified order to perform touch driving and sensing in a specific order on the touch sensing areas [4].

The TTP223 is an IC touch-pad detector that provides 1 touch key. The touching detection IC is designed to replace a diverse pad size with a traditional direct button key. The key contact features for DC or AC applications are low power consumption and wide operating voltage [5]. A module rain sensor is an easy tool for detecting rain. It can be used as a switch when raindrop falls through the raining board and also to measure the intensity of the rainfall. The module features a rain board and the separate control board and for more convenient, an LED power indicator and a potentiometer are installed to indicate adjustable sensitivity [6]. The MQ3 Alcohol Sensor is an alcohol sensor used to detect the concentration of alcohol in your breath. This sensor produces an analog resistive output dependent on the concentration of the alcohol. When the alcohol gas occurs, the conductivity of the sensor is higher along with the rising gas concentration. It is suited to detecting alcohol at different concentrations for various applications. Domestic alcohol gas alarm, commercial alcohol gas alarm, and portable alcohol detector are commonly used [7]. Ultrasonic sensors work by radiating sound waves at an unreasonably high recurrence for listening people. Trust the sound will be reflected back at that point, computing separation depending on the time needed. This is like how radar estimates the time it takes for a radio wave to return in the aftermath of hitting an item [8].

PIR sensor detects a human being moving around within a range of about 10 m. This is an average value since the actual range of detection is between 5 m and 12 m. PIR is essentially made of a pyroelectric sensor capable of detecting levels of radiation in the infrared. For various important tasks or objects that have to be discovered when a person has left or entered the field. The PIR sensors are amazing, flat control and minimal effort, have a wide range of lenses and are easy to work with. Nowadays, this is one of the widely used sensors and can be found in many home security systems. Passive Infrared Detectors look at changes in the level of infrared energy caused by moving objects like humans and animals [9]. This module of vibration sensors produces logic states that are dependent on the vibration and external force applied to it. This module gives a logic LOW output when there is no vibration. If it feels vibration then this module's output will go to logic HIGH. This circuit's working bias lies between 3.3V to 5V DC. The sensor frame is constructed using simple shafts and springs, which demonstrates a conceivable direction in achieving nonlinear semi-zero solidity and thus allowing broadband without vibration point for direct estimation of the removal in vibrational stages. The theoretical investigation of the impact on the bioinspired sensor framework of different structure parameters is conducted to achieve an amazing seclusion property and thus to understand an exceptional exhibition of estimations [10].

5. RESEARCH METHODOLOGY

Firstly, the researcher will explain how to use the Portable Electronic Sensor Trainer (PEST) during laboratory experiments, there are several procedures to be implemented. First of all, identify the components to be used as the components that are built-in or the components that will be used during the process. The built-in components are relays, solenoids, LEDs, LCDs, potentiometers, Arduino nano, and voltage regulators, while the components to be connected and tested are 15 types of sensors to be used during the experiment. PEST is started by connecting it to a power supply using a 12V adapter. The rocker switch is then turned on to ensure that PEST is in standby mode. When the training kit has been turned on, the LCD display will light up and display the "Portable Electronic Sensor Trainer". Turn on the scanner and scan the QR code provided in the training kit to get the lab sheet and view the selected sensor circuit connections. Then download the application shown after the scan, the page will navigate to the PEST home screen. If it does not connect, retry the previous process. The next step is to select the sensor to use for the experiment and run the experiment in accordance with the component layout and circuit connections shown in the application screen. Connect the jumper wire, electronic components, and sensors on the breadboard according to the layout specified in the lab sheet. If the input does not match, the student can troubleshoot to get the proper output. When the output matches, the LED will produce a green light and the LCD will display the data. Once the data are received, unplug the jumper wire and turn off the rocker switch.

Secondly, the author describes how to develop PEST. The development of PEST began with the design of PEST using Inventor Software to draw 2D and 3D drawings to obtain the PEST rough shape with the appropriate size to be developed.

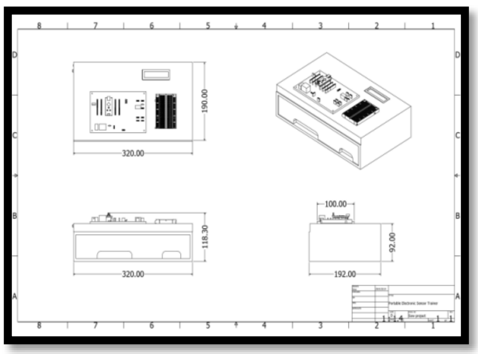

Figure 1 (a) 2D Drawing

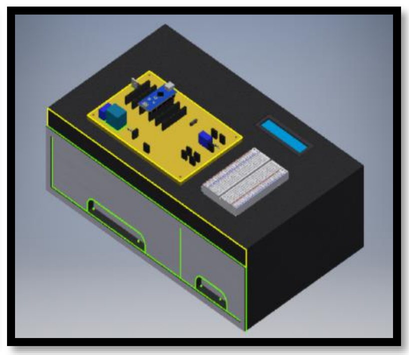

Figure 1 (b) 3D Drawing

Next stage is constructing the circuit using Proteus Software [11]. The process starts with click the “New Project”, enter the project name which is PEST and click into create a PCB layout from the selected template and chose default. Selecting components and starting to draw in schematic capture, Proteus can also be used to perform simulations to make sure the circuit is built correctly. After that the circuit needs to be drawn in the form of PCB layout to produce PCB board.

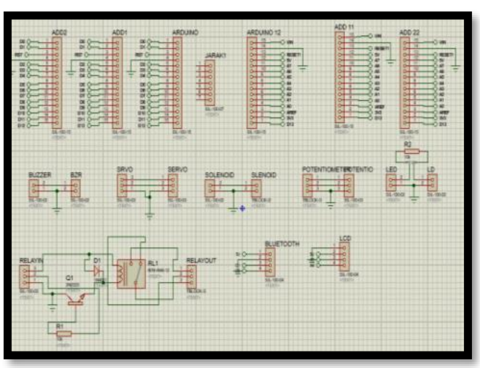

Figure 2 (a) Schematic Capture

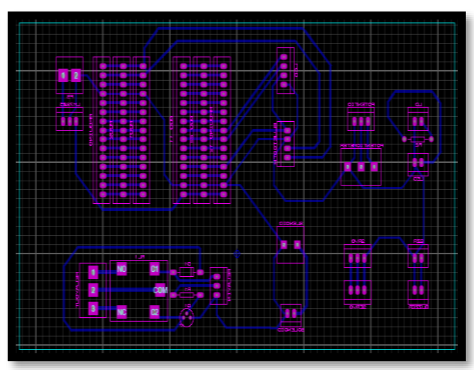

Figure 2 (b) PCB Layout

After complete sketching in PCB layout is ready, the sketching is printed on a transparent paper sheet using a laser printer then the printed sketch is placed into the circuit in UV imaging frame. Next, place the PCB board into the etching solution and agitate for 25-30 minutes or until all the copper has dissolved around the design. After etched PCB board complete, drill the holes on the

PCB board by using PCB driller and then drill the size hole corresponding to the width of the pins of components used. Solder the components and test using multimeter in continuity mode to check if all the connections are continuous.

Figure 3 Process to Produce PCB Board

Next, programming is written using Arduino software to enable PEST to function as it should. The program code should be compatible with the function of each type of sensor to obtain accurate data. Once the program is written, the interface is designed using MIT software to enable students to access the lab sheet using QR code. MIT software also uses block type programming and can generate QR code as a reference for students to obtain sensor circuit connections. To obtain sensor connectivity videos using PEST, students can upload the HP Reveal application in the Google Apps Store and scan on the desired sensor image, then the sensor circuit connection will be displayed on the smart phone.

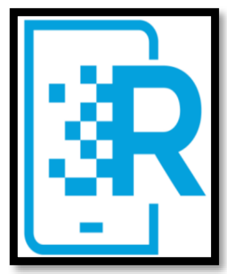

Figure 4 (a) QR Code Figure 4 (b) Hp Reveal

6. RESEARCH FINDING

PEST is connected to the Portable Smart Fan (PSF) project to obtain data for testing ultrasonic sensors and temperature sensors. The test for ultrasonic sensors is to analyze the distance to detect an object or human. The data are measured in terms of radius readings as well as distances where the test is conducted to determine which radius or distance is best detected by the ultrasonic sensor. From these data, readers can determine the appropriate distance and radius for them to use in developing their innovation projects.

Table 1 (a) Radius Accuracy

Radius (Degree)	Accuracy
80°	Sufficient
85°	Good
90°	Excellent
95°	Good
100°	Sufficient

Table 1 (b) Distance Accuracy

Distance (cm)	Accuracy
200	Sufficient
100	Good
80	Good
60	Excellent
30	Excellent

For the temperature sensor, it is to analyze automatic temperature control speed and also to analyze power consumption. Data obtained is to determine the voltage, current, fan speed and motor. The tested temperature is more than 32 degrees and less than 32 degrees (32 degrees is a randomly selected value for testing purposes only). In the programming code, the researcher has set the temperature level according to two conditions, i) if the temperature is less than 32 degrees, the fan will automatically turn on at speed 1, ii) while if the temperature exceeds 32 degrees, the fan will automatically change the speed level from speed 1 to speed 2 . Table shown below is for the reader to see the changes in the values of voltage, current and motor readings.

Table 2 Temperature condition

Temperature	Voltage (V)	Current (A)	Fan Speed	Motor (rpm)
<32°	9	1.1	1	699.8
>32°	12	1.8	2	1274.2

7. DISCUSSION

The findings of the study showed that it is an interactive teaching and learning that allows students to construct circuit well and gained correct output. Therefore, the objectives of this research are achieved. PEST has also been a necessity for students in performing practical work as it enhances student engagement in circuit connectivity as well as enhances student hand-on skills. After completing the PEST programming, the installation of casing has been done to ensure that the training process is completed. In this process, a complete casing is assembled with the two boxes to make it as a compartment to store the jumper wires and sensors. The casing is designed with complete labeling to ensure the PEST is easy to use. Figure 5 shows the PEST with its specifications. The results obtained are in terms of sensor circuit connections.

NO.	CRITERIA	SPECIFICATION
1.	Arduino	• 8-bit microcontroller ATmega328
2.	DC Power Requirements	• 5Vdc 200A • Power Adapter 9Vdc 1A
3.	AC Power Requirements	• 240VAC 6 A
4.	Host/ Salve Communication	• Bluetooth Module HC-05
5.	Digital Output	• Maximum quantity:11 • Operating Voltage: 5Vdc 20mA

Figure 5 Portable Electronic Sensor Trainer and its specifications

Experiment 1 - Determine the output of Ultrasonic Sensor.

Ultrasonic sensor is an instrument that measures the distance from one object to another using ultrasonic sound waves. An ultrasonic sensor uses a transducer to send and receive ultrasonic pulses that relay back information about an object's proximity [8]. Ultrasonic sensors work by emitting sound waves at a frequency too high for humans to hear. Next, they wait for the sound to be reflected back and calculating distance based on the time required. What equipment needed for application of this ultrasonic sensor are loop control, full detection and robotic detecting [12].

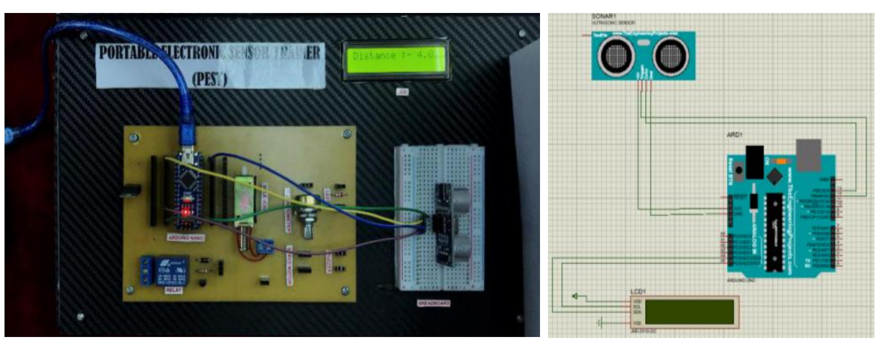

Figure 6 Circuit Connection of Ultrasonic Sensor

The analysis had been constructed from the experiment as shown on the circuit connection (trainer) which had been connected to all components based on the figure shown in the schematic circuit connection using pin connectors. For the purpose of this research, the VCC pin was connected to the pin 5V power supply, ECHO pin to pin D13, TRIGGER pin was to pin D12, GND pin to GND, DO pin to a pin digital I/O pin and the AO pin connected to the analogue output pin. The pin number will be based on the actual program code. After all the pins are connected all the pin, the data would appear on the LCD screen when the Arduino is connected to a computer or power bank using a USB cable.

Experiment 2 - Determine the output of Vibration Sensor.

Vibration Sensors used to measure vibration come in three basic types which are displacement, velocity, and acceleration. Displacement sensors measure changes in distance between a machine's rotating element and its stationary housing (frame). The features are digital output, the default state of the switch is close and supply voltage 3.3V-5V [13]. Application of this vibration sensor are from the machine shafts and bearings to hard disk performance, vibration causes machine damage, early replacement, low performance, and inflicts a major hit on accuracy [10].

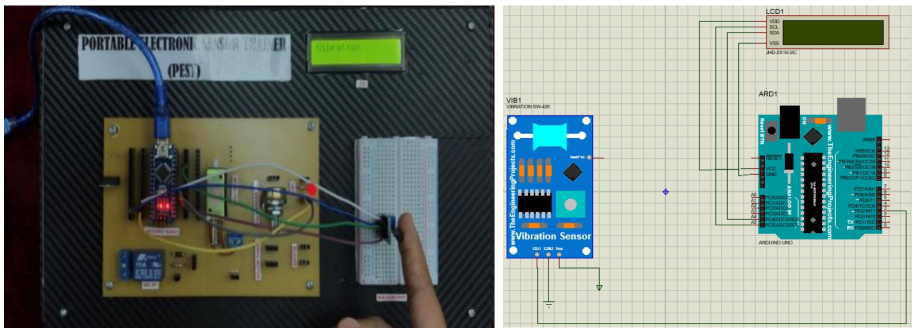

Figure 7 Circuit Connection of Vibration Sensor

The analysis constructed from experiment as shown on the circuit connection (trainer) that had been connected with all the components based on the figure shown in the wiring diagram using pin connectors. VCC pin was connected to the 5V power supply pin, DO pin to a digital D3 pin and the AO pin connected to the D9 pin. Pin number will be distinguished based on the actual program code. After connecting all the pins, data would appear on the LCD screen when Arduino is connected to a computer or power bank using a USB cable.

Experiment 3 - Determine the output of Colour Sensor.

The TCS3200 colour sensor as shown in the figure below uses a TAOS TCS3200 RGB sensor chip to detect colour. It also contains four white LEDs that light up the object in front of it. By selectively choosing the photodiode filter's readings, able to detect the intensity of the different colours [14]. The sensor has a current-to-frequency converter that converts the photodiodes' readings into a square wave with a frequency that is proportional to the light intensity of the chosen colour. The features are single-supply operation (2.7V to 5.5V), power down feature and support LED lamp light supplement control. The application of this TCS3200 colour sensor is RGB LED consistency control, Industrial process control, and medical diagnostic equipment [15].

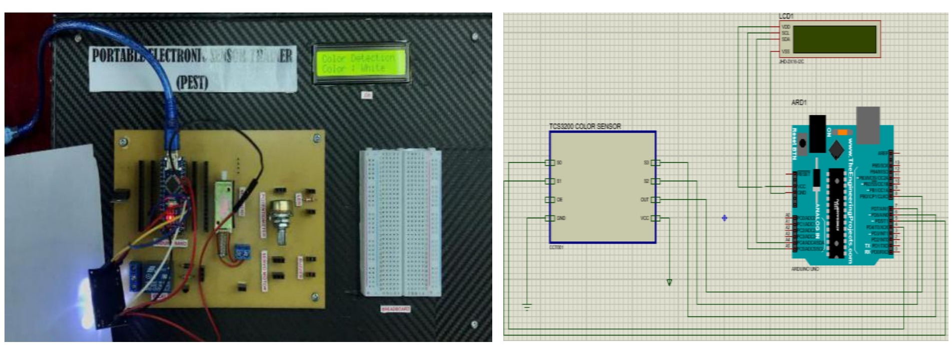

Figure 8 Circuit Connection of Colour Sensor

The analysis constructed from the experiment as shown on the circuit connection (trainer) that had been connected with all the components based on the figure shown in the wiring diagram using pin connectors. VCC pin is connected to the 5V power supply, OUT pin to pin D8, S2 pin to the pin D7, S3 pin to pin D6, GND pin to the GND, S1 was connected to the pin D5, S0 pin to pin D4, DO pin connected to a digital I/O pin and the AO pin to the pin analogue output pin. The pin number will be based on the actual program code. once all the pins are connected, the data would appear on the LCD screen when the Arduino is connected to a computer or power bank using a USB cable.

8. CONCLUSION

In conclusion, the researcher conclude that PEST is well-represented throughout the institution as it is relatively inexpensive and can help in meeting the syllabus's requirement. However, it is still undergoing research for improvements in the use of LCDs as it can be replaced by touchscreen displays, while sensor testing can be added to more than 15 types, more compact designs and other requirements. The first objective is to develop a trainer kit that able to use during laboratory experiments or learning sessions in teaching and learning purposes. The trainer built is portable and is user-friendly. Students will find it easy to use because it is not very complicated and students can learn using the training kit very quickly. Thus, it will make the lecturer easy to be taught and ease the learning process. The trainer kit also looks attractive and futuristic which attract students to use it. Therefore the first objective of this research is fulfilled.

Secondly, the objective is to invent teaching and learning tools to test 15 types of sensors. The trainer has all the 15 sensors programmed. Student have to use jumper wires to connect with the components according to the lab to obtain the result. Students can read notes and control the trainer using the mobile application created by just scanning the QR code provided by the trainer. The second objective is fulfilled. The last objective is to get an output with its application of 15 types of sensors. The training kit has an LCD display installed to display the result obtained from every experiment. It will display the result once the experiment is correctly done. Students can also read and understand the notes in the App created specifically for the trainer. The third objective is fulfilled.

9. ACKNOWLEDGMENTS

Researchers would like to express our heartfelt gratitude to Centre of Technology (COT) Politeknik Tuanku Sultanah Bahiyah and Malaysian Department of Polytechnics & Community College (DPCC) for financial support and assistance throughout this research. Our special thanks also goes to the Mechanical Department of PTSB for providing us laboratory facilities.

10. REFERENCES

[1] Yang Yi-Na, Sun Jing, Wang Ran-Ran, MXenes in Flexible Force Sensitive Sensors: A Review, Journal of Inorganic Materials, January 2019, DOI: 10.15541/jim20190282.

[2] Fenwal Controls Of Japan, Ltd., Japan, 2019: Photoelectric smoke sensor. [Online] Available at: https://patents.google.com/patent/US20180180540A1/en.

[3] Dada Emmanuel Gbenga , Hamit Isseini Hamed, Adebimpe Adekunle Lateef, Ajibuwa Emmanuel Opeyemi, Alcohol Detection of Drunk Drivers with Automatic Car Engine Locking System, Nova Explore Publications, Nova Journal of Engineering and Applied Sciences, DOI: 10.20286/nova-jeas-060104, Nova Journal of Engineering and Applied Sciences Page: 1, Nova Explore Publications, Nova Journal of Engineering and Applied Sciences, DOI: 10.20286/nova-jeas-060104, Vol.6 (1) 2017:1-15.

[4] Novatek Microelectronics Corp., Taiwan, 2019: Touch sensor system and multiplexer thereof. [Online] Available at: https://patents.google.com/patent/US10055049B2/en

[5] L.Angelov, Jörgen Stenarson, Niklas Wadefalk, Erik Kollberg, On the performance of low-noise low-DC-power-consumption cryogenic amplifiers, IEEE Transactions on Microwave Theory and Techniques 50(6):1480 - 1486, July 2002, DOI: 10.1109/TMTT.2002.1006408.

[6] Josep Freixas, Chapter In book: Wiley Encyclopedia of Operations Research and Management Science· February 2011, Universitat Politècnica de Catalunya, DOI: 10.1002/9780470400531.eorms0669

[7] Hironori Wakana, Masuyoshi Yamada, Portable Alcohol Detection System for Driver Monitoring, October 2019, 2019 IEEE SENSORS, DOI: 10.1109/SENSORS43011.2019.8956885

[8] Roderick Burnett (2019) MaxBotix Inc. [Online] Available at: https://www.maxbotix.com/articles/how-ultrasonic-sensors-work.htm

[9] Tarun Agarwal (2017) PIR Motion Sensor. [Online] Available at: https://www.elprocus.com/passive-infrared-pir-sensor-with-applications/ https://www.elprocus.com/pir-sensor-basics-applications/

[10] Huihui Pan (2018) Vibration Sensor. [Online] Available at: https://ieeexplore.ieee.org/abstract/document/8283785

[11] Narasimha (2017). [Online] Available at: http://www.circuitstoday.com/proteus-software-introduction

[12] Ahmed Liyu (2017) An ultrasonic sensor distance induced automatic braking automobile collision avoidance system. [Online] Available at: https://ieeexplore.ieee.org/document/8281927

[13] Ain Zawawi (2017) Vibration Sensor. [Online] Available at: https://tutorial.cytron.io/2017/07/27/getting-started-vibration-sensor-module-normally-off-sn-vibrate-mod/

[14] Hannu L. T. Heikkinen, Developing pedagogical practices under umbrellas of different colours, November 2019, University of Jyväskylä, DOI: 10.12697/eha.2019.7.2.02b.

[15] Amitesha Sachdeva, Development Of Industrial Automatic Multi Colour Sorting and Counting Machine Using Arduino Nano Microcontroller and TCS3200 Colour Sensor, May 2017, DOI: 10.9790/1813-0604025659.