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Drowsy Driver Detection via Steering Wheel

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Abstract: The main purpose of this project is to produce a safety system especially for fatigue car driver so as to prevent from accidents. The statistic on road fatality shows that human error constitute of 64.84 % road accidents fatality and 17.4 % due to technical factors. These systems encompassed the approach of hand pressure applied on the steering wheel. The steering will be installed with pressure sensors. At the same time these sensors can be used to measure gripping force while driving. *Copyright © 2010 IFSA.*

Keywords: Safety system, Hand pressure, Pressure sensor.

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1. Introduction

Nowadays, many of technologies approaches was implement to car for improving safety system such as safety belt for rear and front passenger, Automatic Break System (ABS), Air Bag, Finger Print technology to activate car, Distance Sensor and much more [1]. All of this equipment was design to prevent an accident due to the increasing of accidents from year to years that reported by the National Highway Traffic Safety Administration.

One of the factors that cause increasing an accident is sleepiness during driving. In United States, The Council determined that increased awareness of the relationship between sleepiness and motor vehicle crashes is needed in order to promote the health and safety of drivers and highway users. They say physicians can contribute by encouraging good sleep habits, recognizing and treating sleep-related problems, and counseling patients about the risks of driving while sleepy [3].

The Council reports that approximately I percent to 3 percent of all motor vehicle crashes in the United States are caused by driver sleepiness. The National Highway Traffic Safety Administration estimates that sleepiness is a causative factor in about 100,000 police reported crashes each year and about 4 percent of all fatal motor vehicle crashes each year [3, 5].

Driver plays important role during driving to make sure that they never take any risk that cause an accidents. For examples, the driver should take some rest before and during driving for long journey, bring assistant driver to change with the first driver if they getting fatigue or tired, and activated audio system during driving also help the driver for felt bored and then tends to feel fatigue [2].

2. Problem Statements

Sleepy drivers risk injury and death, not only from falling asleep while driving, but also from loss of attention or slowing of reactions during critical driving tasks or maneuvers. Sleepy drivers are at particular risk for motor vehicle crashes because they may not perceive a potential crash threat or react quickly enough to take evasive action. The characteristic of sleepy driver should be study to implement this project to be succeeded [2, 6].

During getting sleepiness most of the driver tries to lose their hand from hold the steering and here some sensor should be installed around the steering to measured tighten of hands to make sure that the driver under normal condition during driving. The calibration of force of hand for normal driver should calibrate. If the force act on to the steering is out of the calibration range, the vibration system and sound system will be activated to notification the driver from sleepiness.

Car steering involve in motion to rotate the rudder to give direction of the car during on road. So, if the wire transmission is used to transmit the data from steering to the main system it will look fibred and not compatible to implement this system. To counter this situation, wireless transmission should be getting involved.

Involvement of driver in traffic jam is most unwanted situation, especially who lived in the main city like Kuala Lumpur. Every day, facing with traffic jam is usually situation that cannot be avoided. Trapped in traffic jam give some influence to the style of driving for the most drivers [4]. The drivers tend to loss their hand from steering at the moment because getting some tiredness and feeling bored. If this situation occurred, both of the sound and vibration system will activate, it’s not convenient to the driver and the system made it function less. To overcome, the system need to function in some range of speed and decide that if the speed of car less than 40 km/h, overall system is in off mode.

3. System Concept

The system basically based on two systems that are transmitter module circuit and receiver module circuit. Transmitter module circuit also known as main system for this research were contains the main brain that process all data that receive from the sensors and then need to transmit the data processing to the second module known as receiver module circuit as shown Fig. 1. Generally, this second module functions to activate motor vibrator inside seat driver by using wireless communication. The types of sensor that will be use in this project are HotPot membrane potentiometer sensor and Rotary potentiometer. Hotpot membrane potentiometer will measure the hand force act on the steering and rotary potentiometer to detect the speed of car base on fuel pedal press.

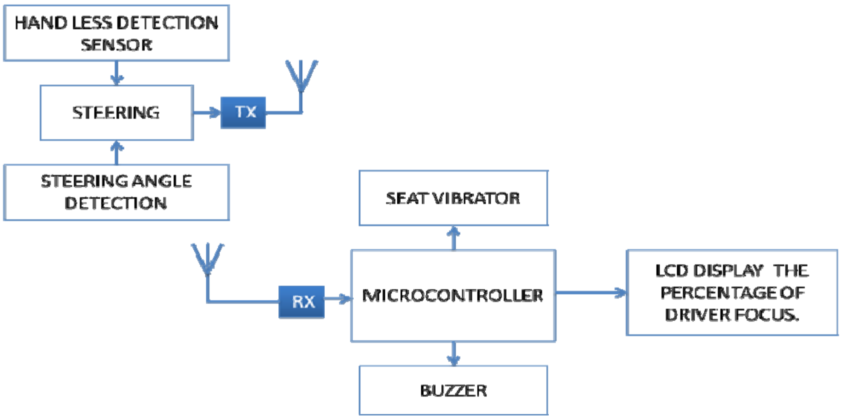

Fig. 1. Concept for the safety system.

4. Hardware Development

4.1. HotPot Membrane Potentiometer

The HotPot Membrane Potentiometer (as shown Fig. 2) single element force sensor acts as a force sensing resistor in an electrical circuit [7]. The sensor strips are 24 inches long and 0.6 inches wide. The active area is 0.25 inches wide. They are polymer thick film (PTF) devices that exhibit a decrease in resistance when pressure is applied on their surface. These thick film devices are printed on a flexible substrate that can be cut, folded, twisted and bent without any damage. When you need to track movement in a volatile environment, HotPot provides a thin and sealed form-factor with operating temperature tolerances of -40 to +85 ^{0}C. The HotPot is the preferred product for industrial and outdoor applications. By pressing down on various parts of the strip, the resistance linearly changes from 100 Ohms to 20,000 Ohms allowing the user to very accurately calculate the relative position on the strip. These potentiometers work great with a finger, or stylus.

Fig. 2. HotPot Membrane Potentiometer.

The Fig. 3 shows the connection of HotpPot Membrane Potentiometer to the amplifier circuit. This type of potentiometer needed to interface with amplifier circuit to gain the signal that generated by this potentiometer due to the low voltage variations. The pin V_{out} will connect to the analog input (RA0) microcontroller.

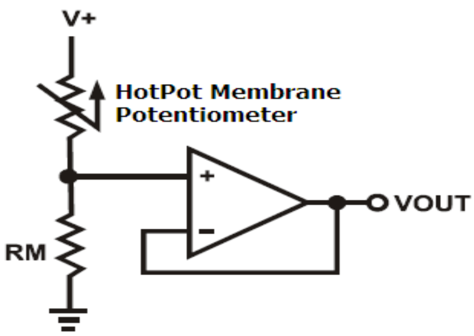

Fig. 3. HotPot Membrane Potentiometer interface with Amplifier.

According to the Fig. 3 the resistor, RM used as the voltage divider and as the result, the voltage drops on this resistor increase when more of forces act on these sensors. The different value of resistor, RM was used to determine the better performance of the sensor response and the results was plotted as shows in Fig. 4.

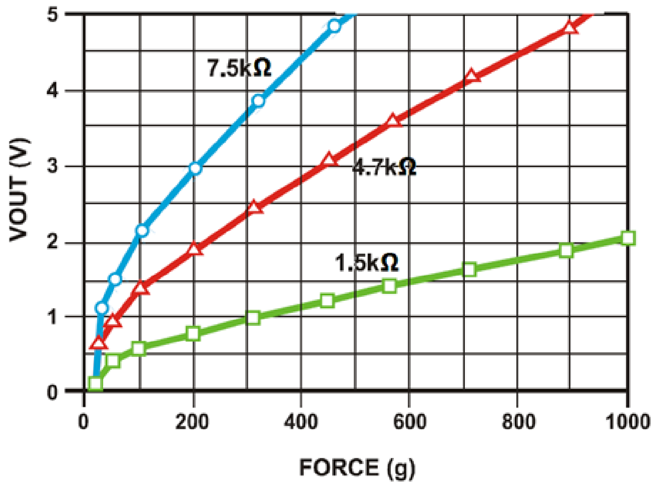

Fig. 4. The graph V_{out} versus hand force.

The measurement has been done by measuring the voltage drop from the output amplifier with the variations of hand forces on the steering wheel. As shown in Fig. 4 the performance for red line is the better compare to the others. The values of resistor, RM which are 7.5 kΩ, 4.7 kΩ and 1.5 kΩ were used to determine the response. As the result, the 4.7 kΩ was selected to be installing for this project circuit because of the performances because the graph approach to be linear and make it easy to do the analysis. The normal range of hand force on the steering is between 250 g and 350 g by referring to the Fig. 4.

4.2. Transmitter Radio Frequency Module

These RF Transmitter Modules (as shown in Fig. 5) are very small in dimension and have a wide operating voltage range (3 V-12 V). The low cost RF Transmitter can be used to transmit signal up to 100 meters (the antenna design, working environment and supply voltage will seriously impact the effective distance). It is good for short distance, battery power device development. The frequency transmission generate by this module is 315 MHz. This module will attach to PT2262 IC's to encode the data.

Fig. 5. Transmitter radio frequency.

4.3. Receiver Radio Frequency Module

These RF receiver modules (as shown in Fig. 6) are very small in dimension. The low cost RF Receiver can be used to receive RF signal from transmitter at the specific frequency which determined by the product specifications. Super regeneration design ensure sensitive to weak signal. This receiver frequency module using frequency 315 MHz for receiving the data and it will attach together with PT2272 to decode the data that received.

Fig. 6. Receiver radio frequency.

4.4. Liquid Crystal Display (LCD)

Recently, a number of projects using intelligence Liquid Crystal Display (LCD) modules have been feature in EPE. Their ability to display not just numbers, but also letters, words and all manner of symbols makes them a good deal more versatile than the familiar 7-segment light emitting diode (LED) display. User can interface it by using PIC microcontroller, which is probably the most popular microcontroller used by the electronics hobbyist. On screen mode this LCD can display 32 character (2x16), 2 lines consist of 16 characters for each line.

4.5. Potentiometer

Potentiometers (as shown Fig. 7) are rarely used to directly control significant power (more than a watt). Instead they are used to adjust the level of analog signals (e.g. volume controls on audio equipment), and as control inputs for electronic circuits. The potentiometer can be used as a voltage divider to obtain a manually adjustable output voltage at the slider (wiper) from a fixed input voltage applied across the two ends of the pot. This is the most common use of pots.

Fig. 7. Potentiometer.

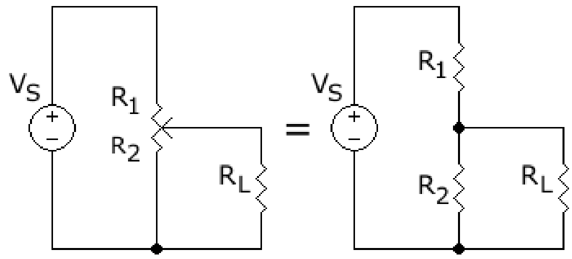

Fig. 8. Voltage divider circuit.

The voltage across R_L can be calculated by:

$$V_L = \frac{R_2 R_L}{R_1 R_L + R_2 R_L + R_1 R_2} \cdot V_s.$$

If R_L is large compared to the other resistances (like the input to an operational amplifier), the output voltage can be approximated by the simpler equation

$$V_L = \frac{R_2}{R_1 + R_2} \cdot V_s.$$

4.6. Microchip PIC18F452 Microcontroller

A microcontroller (also microcontroller unit, MCU or µC) is a small computer on a single integrated circuit consisting of a relatively simple CPU combined with support functions such as a crystal oscillator, timers, watchdog timer, serial and analog I/O etc. Program memory in form of NOR flash or OTP ROM is also often included on chip, as well as a typically small amount of RAM. Microcontrollers are designed for small or dedicated applications.

Since embedded processors are usually used to control devices, they sometimes need to accept input from the device they are controlling. This is the purpose of the analog to digital converter. Since processors are built to interpret and process digital data, i.e. 1s and 0s, they won't be able to do anything with the analog signals that may be being sent to it by a device. So the analog to digital converter is used to convert the incoming data into a form that the processor can recognize. There is also a digital to analog converter that allows the processor to send data to the device it is controlling.

A dedicated Pulse Width Modulation (PWM) block makes it possible for the CPU to control power converters, resistive loads, motors, etc., without using lots of CPU resources in tight timer loops.

Universal Asynchronous Receiver/Transmitter (UART) block makes it possible to receive and transmit data over a serial line with very little load on the CPU.

4.7. Installation of Hardware

The HotPot membrane Potentiometer which is installed at the steering wheel will detect the amount of holding pressure of the driver's hand as shown in Fig. 9). The current supply equivalent to 5 V used for this sensor will be from the car battery via a converter. The potentiometer mounted to the fuel pedal will measured the amount of angle when it moved. The LCD panel placed on the dash board makes it easy monitored by the driver while driving. High frequency buzzer placed on the dashboard and opens air that is near from the driver position to make it function effectively and make the sound clear when activated. The two motor vibrator placed inside the seat of driver will make both thigh of driver feel the vibration when driver get fatigue or sleepy during on road.

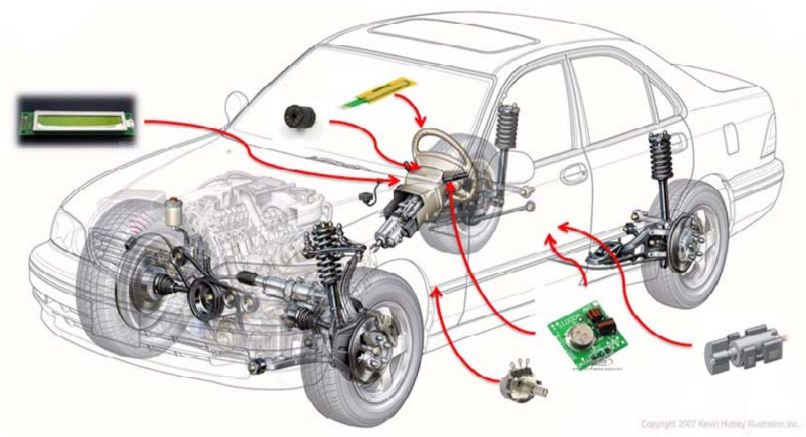

Fig. 9. The position of devices installed in the car.

4.8. Mounting HotPot Membrane Potentiometer

From the Fig. 10 the red line colour indicates the HotPot membrane potentiometer was mounted to the steering. Two pieces of this sensor was used to cover all the outer surface steering wheel. The sensor strips are 24 inches long and 0.6 inches wide. The active area is 0.25 inches wide. They are polymer thick film (PTF) devices that exhibit a decrease in resistance when pressure is applied on their surface. The sensors were connected to a simple amplifier circuit, consisting of a voltage divider, operational amplifier and some additional power stabilizing elements as in Fig. 15.

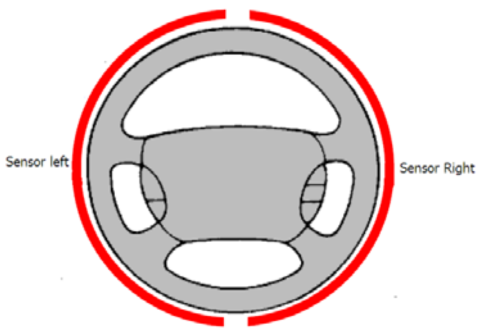

Fig. 10. Sensor location on the steering wheel.

4.9. Vibration System

There is two motor vibrator mounted to the seat driver and 12 V DC power supply needed for the activation. The two red circles at the Fig. 11 indicate that two motor vibrator is mounted. The motor vibrator need to place in the right location that is parallel to the thigh of driver when they drive. The both thigh of the driver will feel the vibration when they getting sleepy. Two wire from the seat will connected to the circuit and the voltage to the motor should not be less than 12 V 1.5 A. The motor vibrator will slowly vibrate if the power supply is less from the requirements.

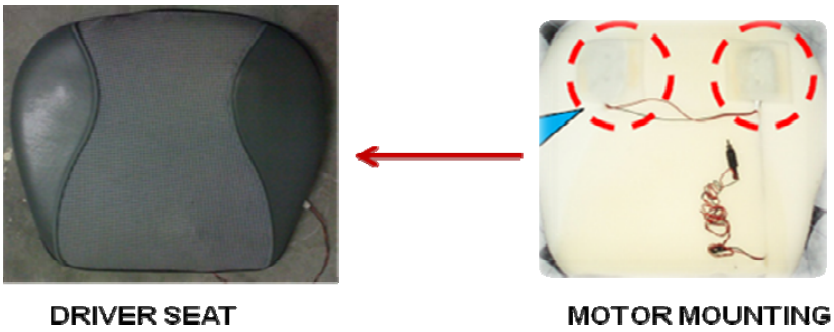

Fig. 11. Motor vibrator mounting to the seat driver.

This is very important because, when the driver gets sleepy or fatigue while driving the driver can not feel the vibration due to the low of power and immediately unwarned the driver. If this situation occurred, it will dangerous to the driver when getting sleepy or fatigue because it will highly risk the driver to get involved in an accident and also make this system function less.

4.10. Circuitry Development

For the circuitry it contains two modules. Generally, first module act as the main of the system where all the sensors like potentiometer and HotPot Membrane Potentiometer were attached. Second module act as the slave for the main system and it act as the output where circuitry for the motor vibrator is placed.

4.10.1. First Module (Main System)

According to the block diagram in Fig. 12, generally, main system supply by four input sensors. The input sensors consist of two HotPot membrane potentiometer, fuel pedal potentiometer and push button act as calibration button. Two Hotpot's membrane potentiometer was mounted around the outer steering surface. Each of this sensor were covered half of the steering surface. Then, the output terminal of the sensor will pass through the amplifier circuit to amplify the lower signal generated by this sensor when some hand forces act on the steering. After that, the output signal that already amplified was connected to the analog input PIC18F452 microcontroller. After the car engine has been started, all the system will automatically activated then the system request the driver to do the hand calibration by pressing the push button placed at the left of the steering.

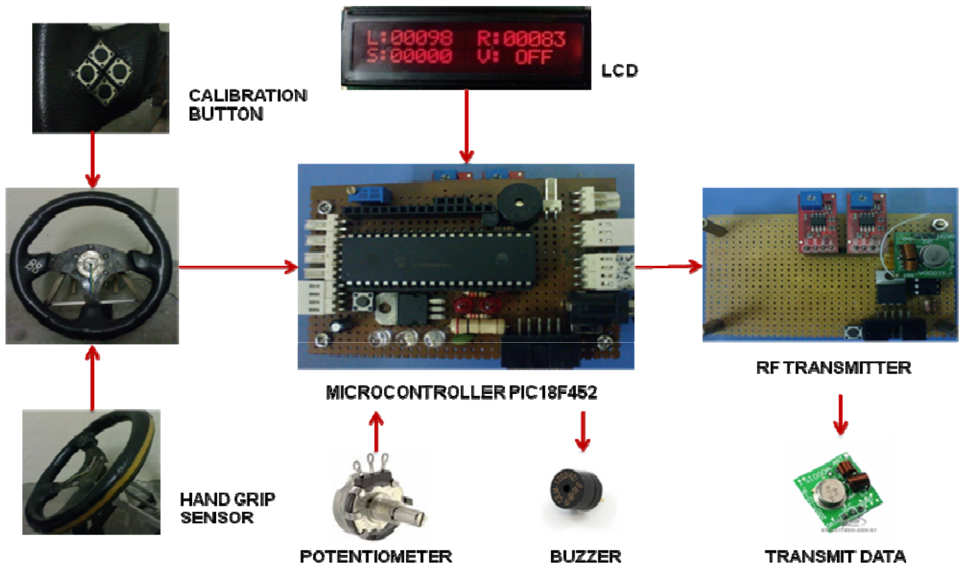

Fig. 12. Complete circuit for main system.

The analog potentiometer was mounted to the mechanism fuel pedal were the rotation occurred. This potentiometer used to measure the angle of the rotation when the driver presses the pedal. When this potentiometer detects the angle means the car make some movement and the angle measured by the potentiometer will be sent to the PIC18F452 microcontroller for the next process. LCD displayed the angle of fuel pedal, force for left hand and right hand of the driver and also vibration status either switch on or switch off.

There is three outputs system for this module, buzzer, LED and encoder for wireless transmission. The high frequency buzzer was used in this project because it can interrupt the attentiveness of driver when him/her getting sleepy or fatigue while driving. So, the driver's will put lots of attention while driving to prevent this buzzer from activated. Bright LED used in this system to interrupt driver vision by provided bright light to makes the driver eyes dazzling. The chip PT2262 will encode the data before it will send to the second module by using wireless communication.

4.10.2. Second Module (Slave System)

The slave system it contains four important blocks as shown in Fig. 13. The four important blocks are Radio frequency (RF) receiver module; chip PT2272, Relay and also vibration system. RF receiver module received the data from transmitter module located at main system then the data will pass through the decoder chip PT2272. At this stage the data received was decoded to acknowledge the motor vibrator either switches on or vice versa. Next, the data were acknowledge from the decoder chip PT2272 will connected to the relay and should must through the transistor between them. This transistor act as internal switch to activated the coil inside the relay when the transistor sense 5 V at the base terminal. Motor vibrator connected to the relay and only activated when the driver getting sleepy or fatigue during on wheel.

For slave system, it requires at least 12 V DC and 1.5 A because the load of motor vibrator drains much power when vibrated. There is power resistor installed in this slave system that act as protection for the circuit system when the current supply over the limit. This protection circuit prevented the circuit cause damage when the current over the limits. The power source from the smoke heater will used to supply the power for this slave system because the voltage and current is follow the requirement and also easy to mount when this safety system available in the market.

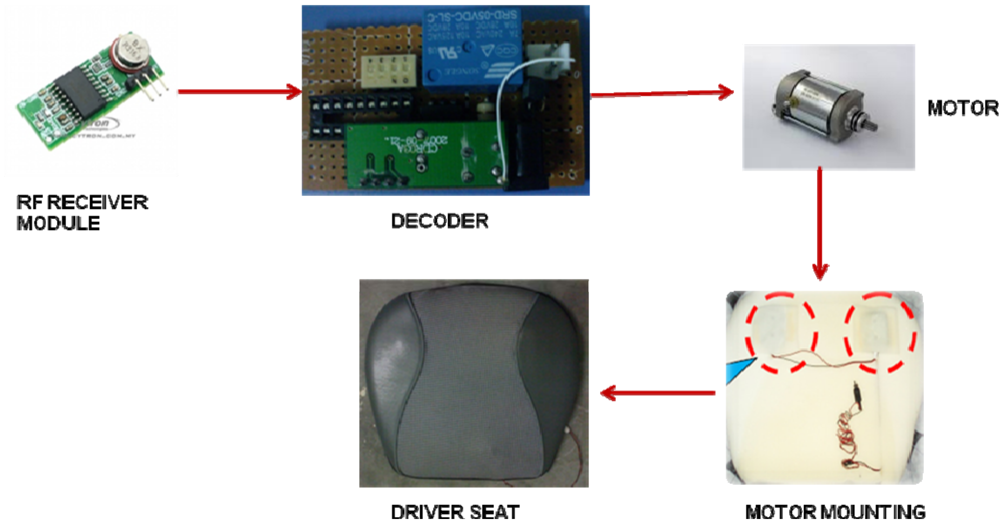

Fig. 13. Complete circuit for slave system.

This slave system also provided security code system that can only received the signal from the main system. The unpredicted signal may affected the data that received by the RF receiver module If this security code system not been installed. The DIP switch connected to the chip PT2272 allows the user to set the 4-digits combination of password for protection aspect.

4.11. Flow Chart for Complete System

The overall system will automatically activate when the driver start the car engine as shown in Fig. 14. The LCD will display the instruction that ask the driver to do the calibration. At this moment, drivers need to press calibration button just a second and immediately they need to grip the steering wheel with both their hands in normal gripped. At this stage the system will do the calibration by taking the average value that read from the sensor in 4 seconds time interval. Then the system will automatically set the range based on the average value calibrated. This calibration step should be done by the driver because each of them gets different hand forces act on the steering wheel.

When the calibration is done the LCD will display "calibration complete" and buzzer will beep one time. The LCD will display "calibration failed" and the buzzer continuously beep when the driver not properly doing the calibration. So, the drivers need to press reset button that is near of the calibration button to reset/restart the system and do again the calibration. After the calibration has been fulfilled, the driver can begin their journey. When the driver start to press the fuel pedal, the potentiometer will do the task to detect the angle of pedal and then the system will ready to notify the driver when they getting sleepy or fatigue based on the hand grip.

When the driver looses or tighten grip on the steering wheel (out of the calibration value) due to sleepiness or fatigue the resistance will be decrease or increase respectively, therefore triggering the seat vibration and sound warning. For the most cases, driver will lose the hand grip while fatigue or sleepiness [8]. This will allow the LCD panel displaying "vibration is switch ON" and the bright LED will turn on. The LED used to interrupt the driver vision by dazzle their eyes. The overall systems only function when the car is moving and the potentiometer detect resistance exceed 20 % from the full scale value, 20 kΩ. This is important especially when the car is stagnant due to warming up of engine or stops at traffic lights, and we don't want the seat vibration and also sound warning activate during both situations.

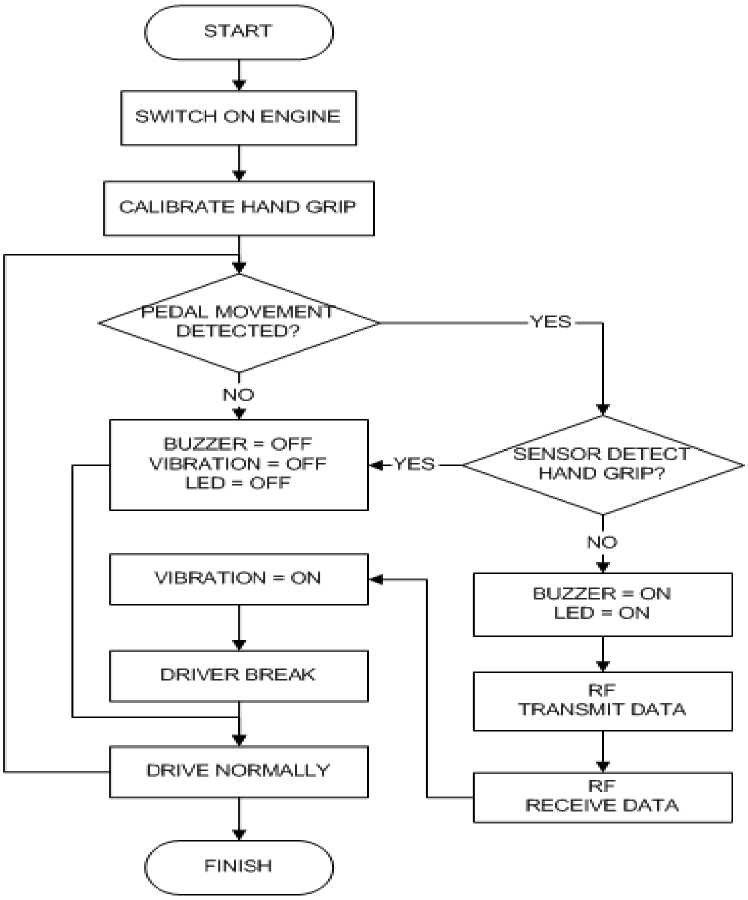

Fig. 14. System flow chart.

5. Results Analysis

5.1. Grasp Hand Data

After the car engine get started the system will synchronously activated and the LCD will display as shown in Fig. 15. At this time, all the value of fuel pedal, right hand grip and left hand grip will display zero means no movement of car and hand force act on the steering. Therefore, the systems not trigger the vibration and sound system. Notice that the system only triggers the warning system when there are no hand forces acts on the steering wheels while driving.

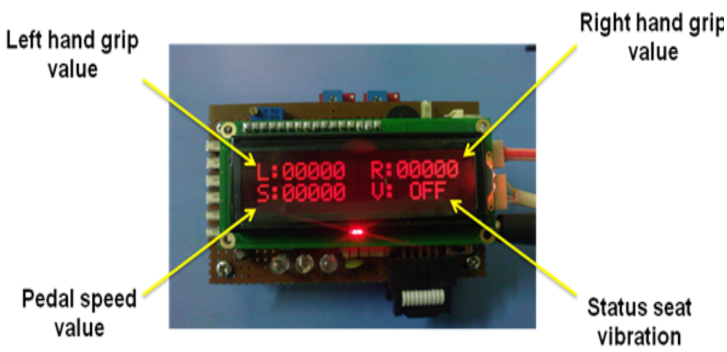

Fig. 15. The display of LCD panel when the car gets started.

The analysis has been made for the hand forces that act on the steering wheel. Fig. 16 shows the value that display by the LCD when the left hand of driver grips the steering wheel either softly or hardly. The PIC18F452 microcontroller will convert analogue value from the amplifier to digital value for analysis purpose. Then the value of hand forces will display on the LCD panel. The same situations occur for the right hand forces as shown in Fig. 17.

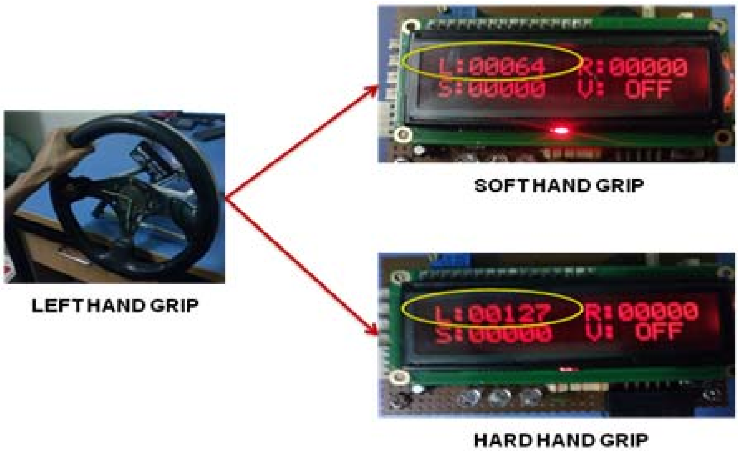

Fig. 16. The left hand force act on the steering.

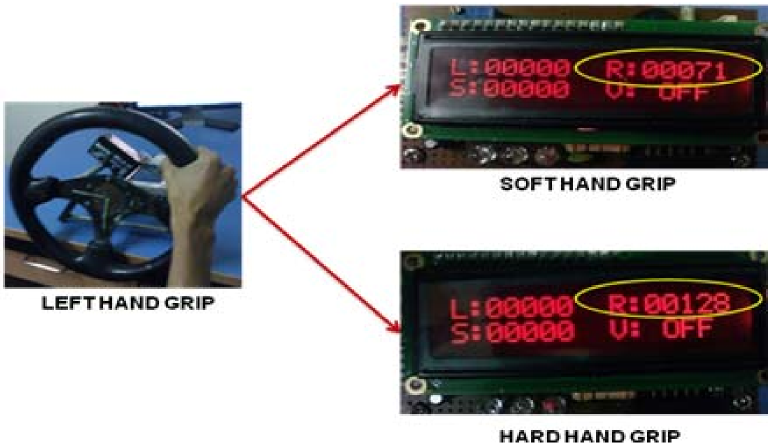

Fig. 17. The right hand force act on the steering.

5.2. Data Analysis

To make this system achieve the objectives, some of the cases should be test to the system. The system must continuously vibrate and triggering the sound system when the car is stagnant but the engine is still keeps running. The results that can be expect is the system only triggering the seat vibration and sound system while the car get moving and the driver loose or tighten their grip on to the steering wheel. The warning system not trigger while the driver use their single hand to drive the car.

Based on Fig. 18, illustrated that there are four possibilities that we should be test to the system that we design and the results should meet the objectives for this project. The possibilities list as below:

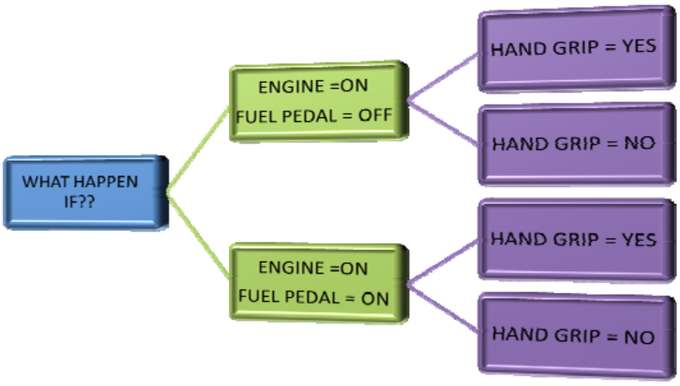

Fig. 18. The block diagram for system analysis.

- **Case 1:** The car engine is still keep running but the car is stagnant and there are no hand grips acts on the steering wheel. As the result we expect that the warning system not be trigger on this situation. This case happens when the car is stagnant due to warming up of engine.

- **Case 2:** The car engine is still keep running but the car is stagnant and there are hand grips acts on the steering wheel. As the result we expect that the warning system not be trigger on this situation. This case happens when the car is stagnant due to stops at traffic lights while the driver holds the steering wheel.

- **Case 3:** The car is moving and the driver holds the steering wheel in normal grips that in the range of calibration. As the result we expect that the warning system not be trigger on this situation. This case happens if the drivers drive the car normally.

- **Case 4:** The car is moving and the driver holds the steering wheel but the hand grip is out of the range of calibration. As the result we expect that the warning system will be trigger on this situation. This case happens if the drivers get sleepiness or fatigue while driving.

By applying these four possibilities to the system the results meet the objectives requirements. As the results, the warning system not been triggered for the case 1, 2 and 3. The only case 4 triggering all the warning system when the car get moving and the hand grip is out of the range. The all results explained as Figs. 19, 20, 21, and 22 respectively.

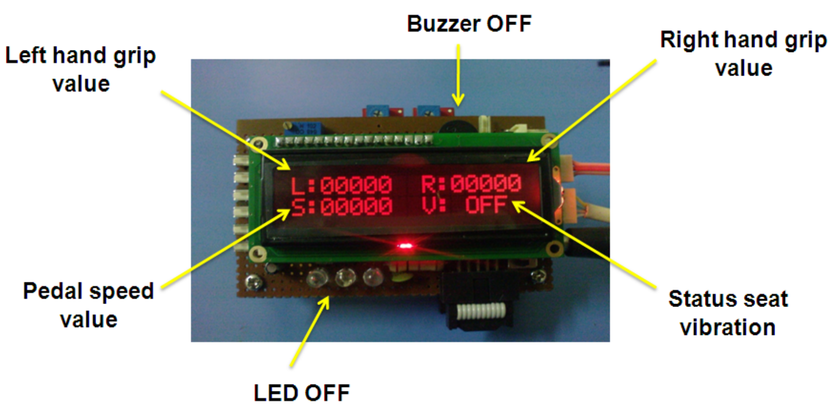

Fig. 19. Results for case 1 (seat vibration not triggered).

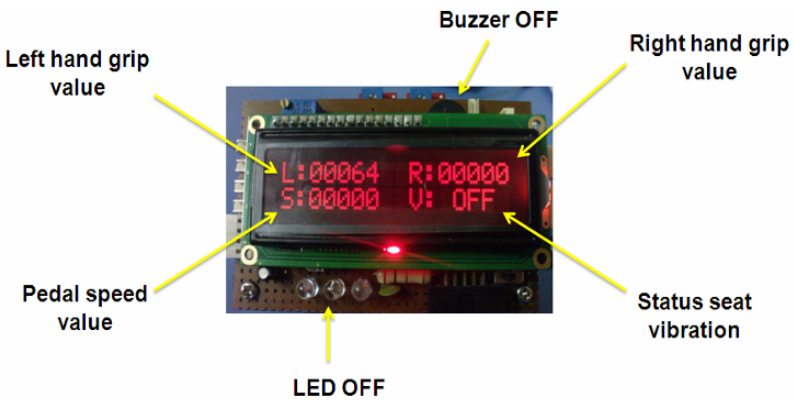

Fig. 20. Results for case 2 (seat vibration not triggered).

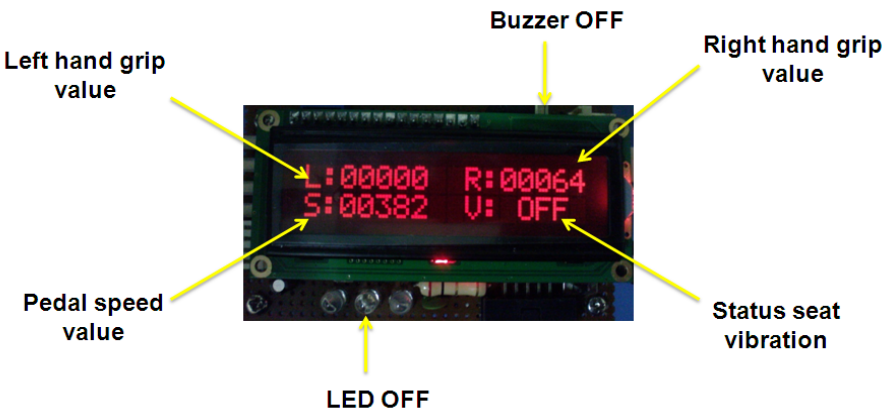

Fig. 21. Results for case 3 (seat vibration not triggered).

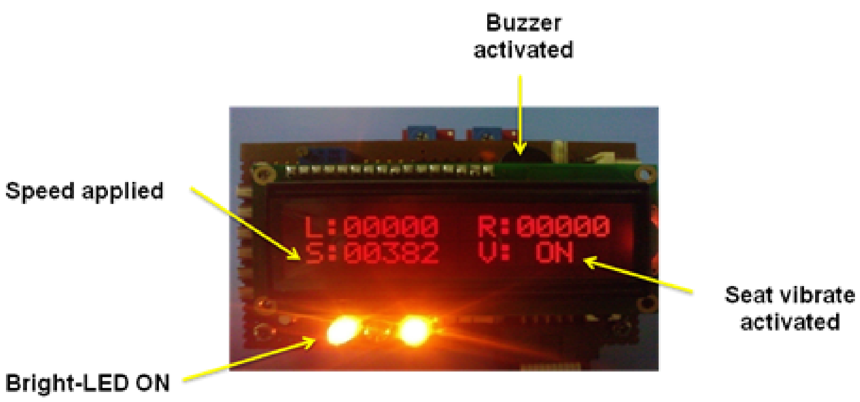

Fig. 22. Results for case 4 (seat vibration triggered).

6. Conclusion

The system had a value added in bringing the safety features especially to sleepy head and fatigue drivers. The system will ensure that all car drivers to give their full attentiveness while driving on the road and not to take safety for granted as it will not only caused their lives but others too. The system may be a reminder to all drivers that they should be in the best of alertness when they are behind the wheels or otherwise the system will automatically remind them.

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Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In additional, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc.

Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
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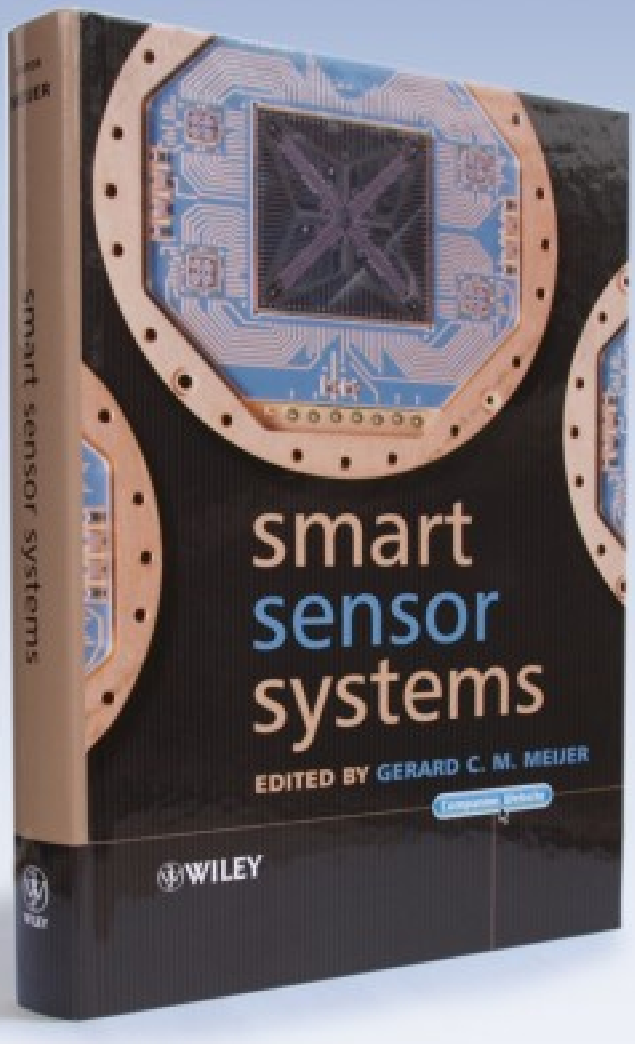
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