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An Intelligent Online Vehicle Tyre Pressure Monitoring System

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ABSTRACT

This paper aims at designing an intelligent online tyre pressure monitoring system (TPMS). The objective of this work is to display the tyre pressure of the tyre and also give the indication about the quality. The data corresponding to the tyre pressure is obtained with a high precision MEMS pressure sensor. The output of the MEMS pressure sensor is amplified and transmitted to the processing unit placed on the dash of the vehicle using wireless communication (RF). The processing is carried on using fuzzy logic algorithms on LabVIEW platform. The output pressure is displayed along with the indicator representing the quality. Indicator is green when the tyre pressure is in the desired range specified by the manufacturer. Yellow when the pressure has dropped and need to be inflated. Red indicates tyre pressure is below the safety driving conditions. After testing and validating the entire system using LabVIEW. The entire code is converted to verilog code and dumped on to FPGA chip (Spartan 3E) using FPGA module of LabVIEW with CompactRIO, for implementation of FPGA chip on real time system. The system after implementing on real time system measured actual pressure of tyre online.

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1. INTRODUCTION

The tyres are the only components that link the vehicle with the ground and facilitate the movement of the vehicle. Tyres need to be looked after as it plays a major role in safety of the passengers. Tyres are made of individual layers of fabric and steel encased in rubber. If a tyre is allowed to run low on pressure, the rubber is forced to stretch beyond the elastic limits of the fabric and steel reinforcing cords. When this happens, the bond between various materials can weaken and if the same continues, the tyres will eventually fail. Tyre pressure is an important thing and need to be maintained as specified by the tyre manufacturer. Maintaining the right pressure increases the safety while driving, tyre life and fuel efficiency. Moreover it increases the travelling comfort and improves the life of suspension assemblies. Studies in USA have shown that 26% of cars and 29% of trucks were operating with tyre pressure at least in one tyre 25% or more below the specification, which not only has negative impact on fuel economy and the tyre wear but poses a significant safety risk to the motorist. Tyre Pressure alters naturally with ambient air temperature. Pressure also increase when the vehicle is driven due to flexing of tyre's side walls and tread as a result of vehicle load and engine input as this generates heat. Risks of low tyre pressure are (i) weakens the tyre and changes driving behaviour of car, (ii) lowers the contact force between the tyre and road, (iii) heightens the rolling drag and consequently the fuel consumption, (iv) in the front tyres causes an indirect steering behaviour, (v) in the rear tyres increases the risk of over steering, (vi) 85% of punctures are related to tyres with a history of under-inflation, and (vii) leads to rising tyre temperature, high temperature amplifies the abrasion of tyre and in the end may cause sudden burst of the tyre. Similarly risk of high tyre pressure (i) lowers the contact force between tyre and road, (ii) in the front tyres increases the risk of under steering, (iii) in the rear tyres increases the risk of over steering and (iv) leads to irregular abrasion [1 - 4]. Drivers do not check the tyre pressure very often and this leads to a general under-inflation of tyres and therefore an increase in fuel consumption and Carbon-dioxide emissions are also increased. Tyre Gauges at Petrol stations are generally in-accurate and contributes to poor fuel consumption.

To overcome the above discussed problem this paper proposes an intelligent online tyre pressure monitor system which will indicate the driver the tyre pressure online using fuzzy logic algorithms. Benefits of having a tyre pressure monitoring system is (i) Increased fuel efficiency, (ii) longer tyre life, (iii) reduced tyre blow outs (less accidents), (iv) right vehicle handling (riding and travelling comfort), (v) longer suspension assembly life, (vi) if any puncture, the driver gets the alert so that he can react to the situation and (vii) indirectly reduction in pollution.

The proposed system is designed by having a high precision MEMS pressure sensor to sense the tyre pressure. The output of the sensor is fed to the signal conditioning circuitry consisting of an amplifier, RF transmitter-receiver. The data is acquired by a processor (PC or FPGA chip) to process using fuzzy logic algorithm to indicate the actual pressure and along with the indicator of the tyre health for driving condition.

The paper is organised as follows: After introduction in Section 1, a brief description on sensor is given in Section 2. A description on the data conversion unit is discussed in Section 3. Section 4 deals with the problem statement followed by proposed solution in Section 5. Finally, results and conclusion is given in Section 6.

2. SENSOR

The SX series of pressure sensors provides the most cost effective method of measuring pressures up to 150 psi. These sensors were specifically designed to be used with non-corrosive and non-ionic media, such as air and dry gases. Convenient pressure ranges are available to measure differential, gage and absolute pressures from 0 to 1 psi up to 0 to 150 psi. The absolute devices have an internal vacuum reference and an output voltage proportional to absolute pressure. The differential devices allow application of pressure to either side of the diaphragm and can be used for gage or differential pressure measurements. This product is packaged either in SenSym's standard low cost chip carrier "button" package, a plastic ported "N" package or a dual inline package (DIP). All packages are designed for applications where the sensing element is to be integral to the OEM equipment. Because of its high-impedance bridge, the SX series is ideal for portable and low power or battery operated systems. Due to its low noise, the SX is an excellent choice for medical and low pressure measurements. Here we are using SX 150 which is as absolute device. Fig 1(a) shows the picture of the sensor used for the proposed system. Fig 1(b) shows the placement of the sensor on the rim of the tyre whose pressure is to be measured [5], [6].

Figure 1 (a). MEMS Pressure sensor

Figure 1 (b). Placement of sensor and transmitter part on the rim of the tyre

3. DATA CONVERSION UNIT

The block diagram representation of the proposed instrument is given in Fig 2 and Fig 3. Fig 2 shows the transmitter module placed on the tyre of the vehicle, Fig 3 shows the Receiver and processor module which can be placed on the dash of the vehicle.

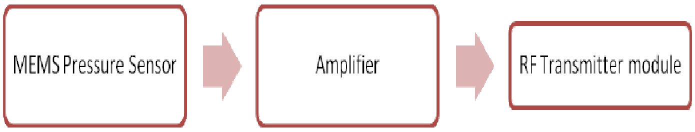

Figure 2. Block diagram of the transmitter block

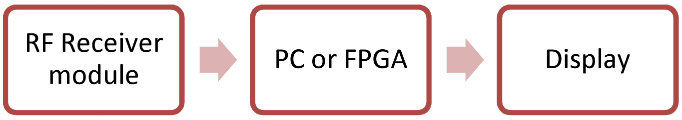

Figure 3. Block diagram of the receiver block

3.1. Amplifier

Since the voltage output of the MEMS sensor is in the order of a few milli volts, we require an amplifier to bring it in the order of volts. For the purpose here we use a non inverting amplifier designed using LM 324, operational amplifier. The gain of the amplifier can be controlled by varying the ratios of R_1 and R_2 as shown in Fig 4.

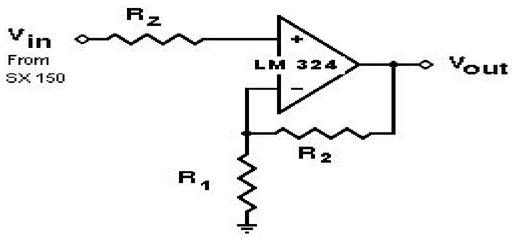

Figure 4. Amplifier using LM 324

3.2. Wireless communication (RF module)

For acquiring the signal corresponding to tyre pressure and monitoring, it is required that the data should be transmitted using wireless communications, since the wheel is in motion and it's not possible to have a wired communication. Here we are using the RF communication for the purpose of transferring signal from the transmitter module to the receiver module for processing. This RF module comprises of a RF Transmitter and a RF Receiver. The transmitter/receiver (Tx/Rx) pair operates at a frequency of 434 MHz An RF transmitter receives serial data and transmits it wirelessly through RF through its antenna connected at pin4 (HT640). The transmission occurs at the rate of 1Kbps - 10Kbps.The transmitted data is received by an RF receiver (HT648) operating at the same frequency as that of the transmitter. The RF module is used along with a pair of encoder/decoder. The encoder (HT12E) is used for encoding parallel data for transmission feed while reception is decoded by a decoder (HT12D).

4. PROBLEM STATEMENT

After the tyre pressure is acquired using a MEMS pressure sensor and transmitter/receiver through the RF communication. Now the signal should be processed. Here for processing we acquire the data on to the PC with the help of LabVIEW, by using the fuzzy logic algorithm the processing is done and tested with the real time data, once tested and validated the code is converted to verilog code to dump on to the FPGA Spartan 3E chip using FPGA module of LabVIEW with CompactRIO. Further on real time the FPGA chip does the processing job. The objectives of the processing unit is

(i) Display the actual tyre pressure online
(ii) Indicate green when the tyre pressure is within the specified range mentioned by manufacturer for driving conditions
(iii) Indicate yellow when the tyre pressure has dropped and needs to be checked.
(iv) Display red when the tyre pressure is not fit for driving condition.

5. PROBLEM SOLUTION

From the discussions earlier the objective of the work to be carried is very clear. We have chosen LabVIEW platform to carry out the project initially for testing, once tested and validated the entire code is converted to logic code and dumped on to FPGA chip (Xilinx Spartan 3E) with the help of LabVIEW FPGA module with CompactRIO. The serial signal from RF module is connected to the RS232 port of the PC. LabVIEW is programmed to accept the inputs from the RS232 port and these inputs are fed as the input for the fuzzy logic palate the fuzzy algorithm [8], [9] is decided with the member function given in Fig. 5(a) for input normalized to 0 to 1. While taking the membership function the data sheet of the tyre manufacturer is considered. The membership function is programmed specifically for a particular tyre. It is different for different types of tyre like motor cycle, car, truck etc. So the specifications of the entire range of tyre are considered while programming and user is given the choice to choose the type of tyre so that the particular membership function is selected. Here for the sake of experimentation we have considered six different variety of tyre. Fig 5(b) shows the output membership function. Fig 6 shows the surface graph obtained from the input and output membership functions. Table 1 gives the brief summary of fuzzy rule bases setting for the proposed work. The Fig.7 shows the front panel of the LabVIEW code, while Fig.8 shows the block diagram [7], [12].

Table 1. Summarises the fuzzy rule bases

Normalisation range	0-1
And method	Prod
OR method	Max
Implication	Min
Aggregation	Sum
Defuzzification	Centroid

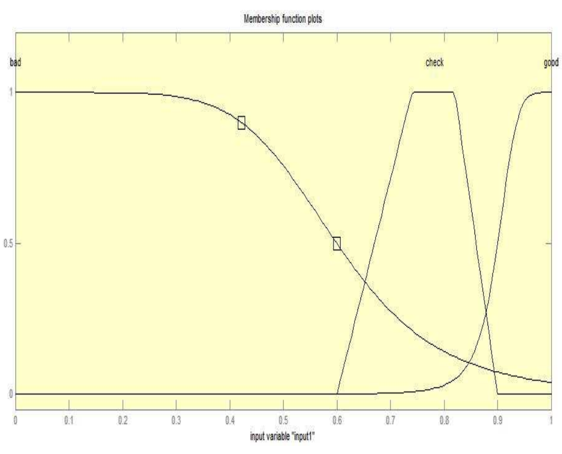

Figure 5(a). Input membership function

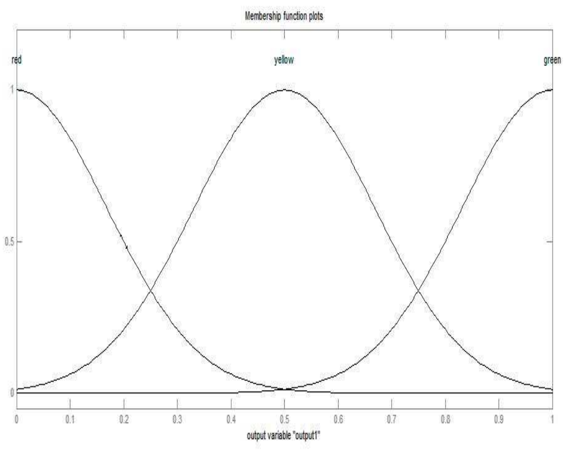

Figure 5(b). Output membership function

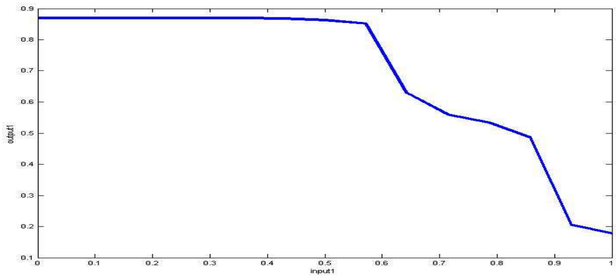

Figure 6. Surface graph

Fig 7. shows the front panel view of LabVIEW software designed for the proposed system. It consists of a control button where the user can choose the type of tyre for which the proposed instrument is used, this is very vital because this decides the membership function of fuzzy logic algorithm. Display indicating the actual tyre pressure. Three buttons to indicate the quality of tyre, if the tyre pressure is comfortable for driving conditions green button will glow the remaining is off, if tyre pressure has dropped less than the desired range and need to be inflated yellow will glow other remain off. Similarly when the tyre pressure is unfit for driving conditions red will glow.

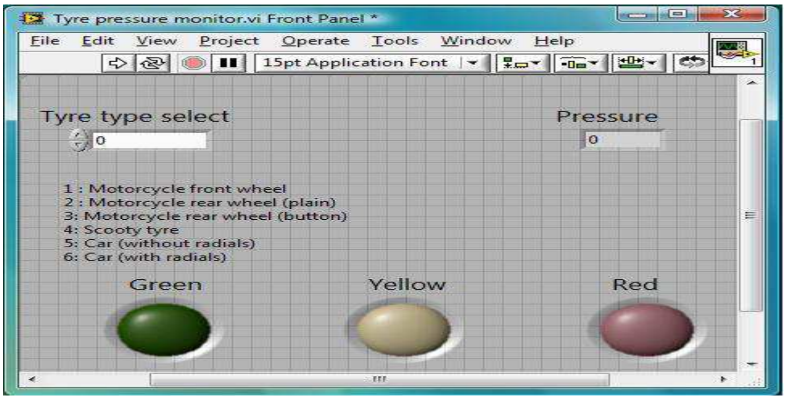

Figure 7. Front panel of LabVIEW

Fig 8 shows the block diagram view of LabVIEW programmed for designing the proposed system. It consists of palates first which will accept the serial data from RS232 and convert it to parallel data this data is fed as the input to the fuzzy palate using load fuzzy palate and control is done by control fuzzy palate the rule base to the fuzzy using control fuzzy palate. The member ship function corresponding to six different type of tyre which we had considered is given with the help of membership function palate as shown. Then output of the fuzzy is indicate with help of three indicators and defuzzified output is displayed as the actual pressure.

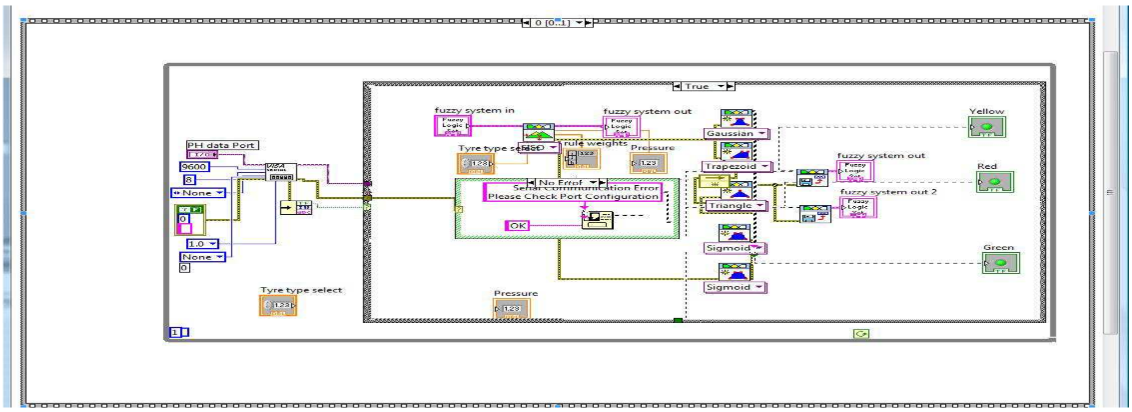

Figure 8. Block diagram of LabVIEW

The LabVIEW program is executed by the sensor inputs and commands given by user. Fig 9 shows the output of the fuzzy when tyre is not fit for driving condition. Fig 10 shows the output of the fuzzy when tyre pressure is dropped and need to be inflated. Fig 11 shows the output of the fuzzy when tyre pressure is comfortable for driving conditions.

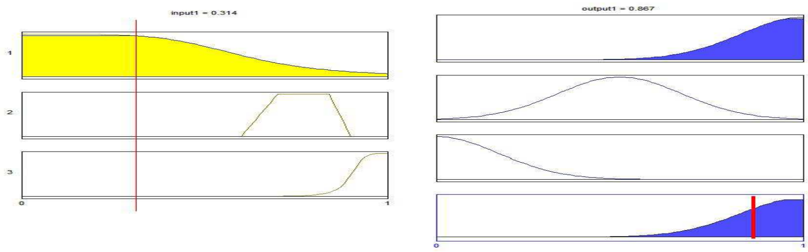

Figure 9. Fuzzy output for normalisation input value of 0.314

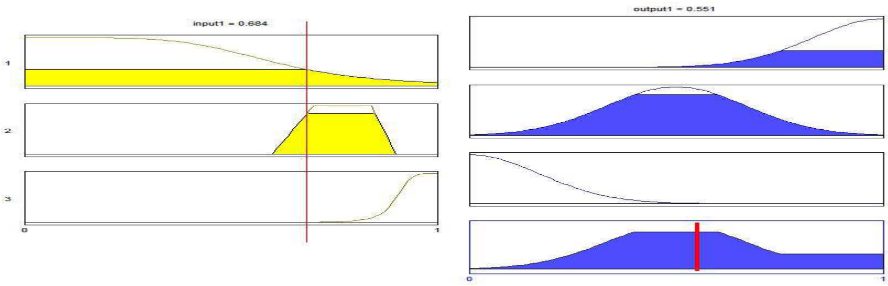

Figure 10. Fuzzy output for normalisation input value of 0.684

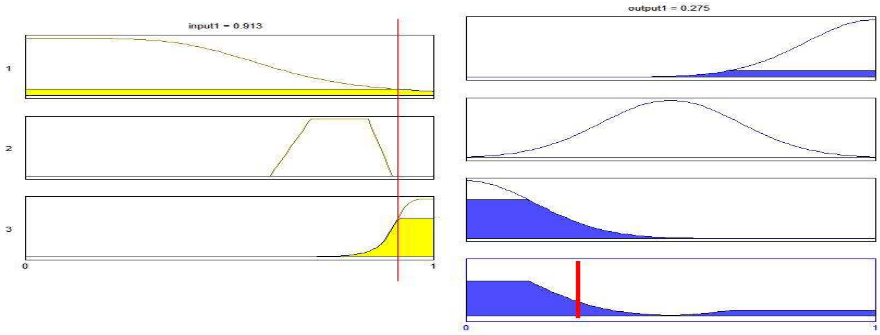

Figure 11. Fuzzy output for normalisation input value of 0.913

Now the code which is tested and validated on LabVIEW platform is converted to a verilog code by using the FPGA module of LabVIEW [10]-[12], then the whole code is dumped on to FPGA chip Spartan 3E with the help of CompactRIO.

6. RESULT AND CONCLUSION

The proposed system was first tested on LabVIEW platform. To test we used two tyres one from motor cycle and other from a LMV. The results are tabulated in Table 2.

Table 2. Summarises the results on LabVIEW platform

Tyre	Actual pressure	Output display	Fuzzy output display
Motor cycle (Front tyre)	22 psi	22 psi	Green
	18 psi	18 psi	Yellow
	26 psi	26psi	Red
	20psi	20psi	Green
	16psi	16psi	Red
	19psi	19psi	Yellow
	13 psi	13 psi	Red
LMV	33 psi	33 psi	Green
	28 psi	28 psi	Yellow
	36psi	36psi	Red
	18psi	18psi	Red
	31psi	31psi	Green
	27psi	27psi	yellow
	15 psi	15 psi	Red

Then the code which was tested on LabVIEW was dumped on the FPGA chip and was tested on a real time system. The results are tabulated in Table 3.

Table 3. Summarises the results using FPGA chip

Tyre	Output display	Fuzzy output display
Motor cycle (Front tyre)	22 psi	Green
	18 psi	Yellow
	26psi	Red
	20psi	Green
	16psi	Red
	19psi	Yellow
	13 psi	Red
LMV	33 psi	Green
	28 psi	Yellow
	36psi	Red
	18psi	Red
	31psi	Green
	27psi	yellow
	15 psi	Red

The above tables clearly indicate the functionality of the proposed system. The system can be implemented on the commercial usage so that the driver is getting the indication about quality of the tyre and necessary action can be taken.

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