Design and Development of Centralized Tyre Pressure System

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Abstract –*Our study shows that a drop in tyre pressure by just a few PSI can result in the reduction of fuel mileage, tyre life, safety, and vehicle performance. We have developed an automatic, self-inflating and deflecting tyre system that ensures that tyres are properly inflated at all times. Our design proposes and successfully implements the use of a centralized compressor that will supply air to all four tyres via hoses and a rotary joint fixed on the wheel rim at each wheel. The rotary joints effectively allow air to be channeled to the tyres without the tangling of hoses. With the recent oil price hikes and growing concern of environmental issues, this system addresses a potential improvement in fuel mileage; tyre wear reduction; and an increase in handling and tyre performance in diverse conditions.*

Key Words: Tyre, Inflation, Deflation, Pneumatic, etc.

1. INTRODUCTION

Improperly inflated tyres are fairly common problems on passenger vehicles. In fact, 80% of passenger vehicles on the road have at least one under-inflated tyre and 30% of passenger cars have at least one tyre that is 20% or more under-inflated. Often pressure loss in tyres is a result of natural permeation of the gas through the elastic rubber, road conditions, and seasonal changes in temperature, for every drop of 10ºC, tyre pressure drops by 1 psi. Most vehicle owners are unaware of the fact that their tyres are not at the correct pressures because it is difficult to determine the tyre pressure visually; a tyre that is properly inflated to the correct pressure looks very similar to one that is either over-inflated or under- inflated. Thus, from the viewpoint of passenger vehicle owners, they are losing Money due to increased tyre wear and decreased fuel efficiency, and a solution needs to be found to correct this issue. From the viewpoint of the designers, however, the root cause of improperly- inflated tyres is due to vehicle owners not knowing proper tyre pressures for certain conditions, difficulty finding an air pump, lack of pressure measuring device, and a general lack of concern. Thus, the combination of the user and expert viewpoints will be used to make decisions in our design process of this product.

1.1 Benefits

The main beneficiaries of this advancement in technology that will allow for tyre pressure to be adjusted for driving conditions will be the vehicle owners. Despite an initial investment in the technology, they will experience a reduction in tyre wear and an increase in fuel economy; both of which will result in saving money in the long run.
It is plausible to say that society as a whole will benefit from the resulting design. The reduction in tyre disposal in landfills and decrease the rate of consumption of natural resources will truly benefit society. Also, the improvement in vehicle safety will benefit all people who drive a vehicle on the roadways.

2. DESIGN OBJECTIVES

The overall goal of our design project is to develop a product that will decrease tyre wear while improving fuel economy, performance and safety of a passenger vehicle through dynamically- adjustable tyre pressures. However, there are several key objectives that the team has targeted our design to meet, and these objectives include both design characteristics and business objectives.

2.1 Ability to Provide Proper Tyre Pressure

The ideal functional objective of our design is its capability to adjust the pressures in all four tyres of a passenger vehicle to obtain the proper pressure for varying road/driving conditions. Based on more detailed research on the components necessary for the system, it was discovered that a specialized rotary joint must be required to support this process. Objectives are,

1. Tyre pressure is maintained by ensuring that the rotary joint-shaft system does not fail structurally

2. Tyre pressure is maintained by ensuring that the rotary-joint shaft system does not leak excessively

3. Tyre pressure is maintained by ensuring that the entyre system can provided sufficient flow rate.

2.2 Minimize Negative Visual Aesthetics

Another design objective is to ensure that the product will not have a negative effect on current vehicle aesthetics.

All components should be located as inconspicuously as possible and should only be seen when servicing the unit. However, in the case of the rotary joints, which may still be visible through the wheel rims, an attempt must be made to minimize its visibility around the brake disks.

2.3 Ability to Provide Automatic System

A third objective is to provide all of the said benefits to the user through an automatic system, thus minimizing user intervention. Specifically, it is desired that the system automatically increase or decrease the tyre pressures for the given road conditions. However, since this objective is closely linked with the ideal objectives in maintaining the proper tyre pressure.

2.4 Low Cost Device

For both the customer (OEM) and end user (vehicle owner), it is imperative to keep the price of the device as low as possible. Considering the potential benefits and cost savings that this design has to offer and the prices of optional equipment for passenger vehicles with similar complexity, the target price range for this device has been identified as ⍰10,000 to ⍰15,000. This price range should be able to support the costs of components of the system, manufacturing, and any necessary installation

3. PRODUCT DEVELOPMENT

We will develop a system that is capable of automatically maintaining tyre pressure in a passenger vehicle. This will be achieving through use of a centralized air compressor that is placed in the engine compartment of a vehicle. This compressor is attached to a distribution block which houses solenoid valves used to control which tyres receive inflation pressure. From this distribution block, the air travels via ¼ dia. hoses to a rotary joint located at each wheel. This rotary joint allows our system to pass air from the vehicle chassis to the rotating tyre. The system that we have developed is to be integrated with the tyre pressure monitoring systems currently found on vehicles to provide our microprocessor with tyre pressure data. To reduce tyre pressures, our system also incorporates solenoid valves at each tyre valve which plan to be operated either through electrical contacts.

3.1 Problem Description

In day to day life improperly inflated tyre is most common problem. Most vehicle owners are unaware of the fact that their tyres are not at the correct pressures because it is difficult to determine the tyre pressure visually; a tyre that is properly inflated to the correct pressure looks very similar to one that is either over-inflated or under- inflated Most of people are unsure of how to check their tyre pressures. Thus, from the viewpoint of passenger vehicle owners, they are losing money due to increased tyre wear and decreased fuel efficiency, and a solution needs to be found to correct this issue.

3.2 Survey

We managed 14 questions survey to potential users for this Centralized Tyre Pressure System to gain an understanding of their knowledge regarding the topic as well as to observe their preferences for certain aspects that we can incorporate with our system. Based upon this survey we obtained results then we analysed results and made design objectives for product.

3.3 Design Process

The design process for this model has been developed based on observations made on the basis of survey conducted as well as knowledge of the team members. Therefore, the team's design process is an amalgamation of these ideas into the current best process for the product. It should be noted that only the process involving the refinement of the centralised air supply routing design included in this section.

3.4 Develop Design Prototype

This initial phase of concept refinement would involve the creation of virtual prototype model of centralised air supply system. The virtual prototype model primarily focuses on parts required and their position in system. This model is used to solve general concepts only i.e. no formal experimentation with real numbers. The virtual model would consist of a CAD drawing of system. This information would then be used to analyze the overall system design in a rigorous manner.

3.5 Develop Engineering Model

The virtual model from the prior phase would then be used to analyse and test the functionality of the product. In preparing for this stage of development, quantifiable design characteristics based on the design objectives have been generated. Each characteristic has been related with several design variables and parameters. The characteristics that we selected to examine are critical speed of Shaft–Rotary joint system, deflection amplitude of shaft rotary joint system, air valve sizing and overall mass flow rate of system.

Using these relations and making certain assumptions about the system, governing engineering equations describing the system can be developed. This would be then used to analyze the design concept in terms of vibration analysis and fluid analysis. The result from these analyses would then used for the next stage in design process.

3.6 Optimize Engineering Model

This phase would involve further refinement of the concept through prioritizing customer needs. Since some of the engineering objectives consists of conflicting engineering parameters, such as minimizing vibrations and stress on the rotary joint and maximizing air flow to the tyre. It should be observed that the purpose in performing this would be to obtain the best possible model based on predetermined vital product attributes.

3.7 Purchasing

This phase would involve preparing of part list. Part list majorly consisting tyre with rim shaft bearings frame materials compressor 3/2 DCV solenoid valve hoses battery and fasteners. Then we bought parts from nearby market in affordable price.

3.8 Fabrication

To demonstrate our concept and how we expect things to work, we created a rough design. The main focus of frame is that to give rigid support to shaft-tyre assembly. We would cut the L-shaped channel into various sections according to dimensions provided in design. After that we would perform operations like drilling and bending. Finally we would weld the sections and form rigid structure. Welding operation would consisting spot welding, butt welding and lap welding.

3.9 Electronic Control Program Description

The logic that our OOPic needs to control is quite basic. Circuit components are interfacing with: air compressor, tyre pressure sensors, block solenoid valves.

Figure shows a flowchart of the logic steps that we will be taking in our program. When the program starts up, the first thing that it does is check all of the tyre pressures. If at least one of the tyre pressures is low, it will turn on the compressor. For the given low pressure tyre, the corresponding distribution block solenoid valve will open allowing the tyre to inflate. This inflation process will continue until the pressure sensor detects that the tyre has reached the optimal pressure; the solenoid valve will then close. However, if a tyre pressure is too high, the pressure release valve at the appropriate tyre will open and stay open until optimum tyre pressure is achieved.

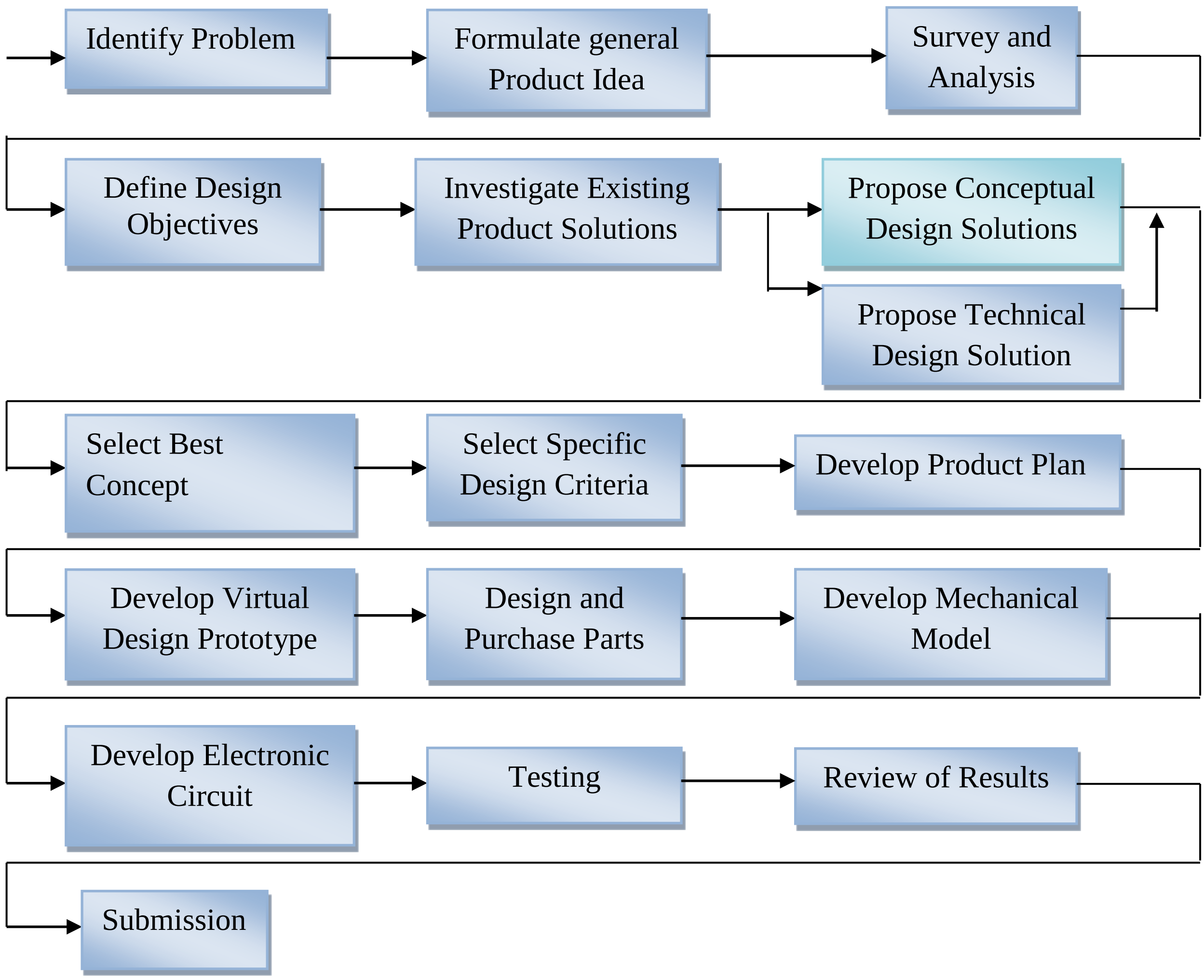


Chart: Product Development Steps

4. PRODUCT DESCRIPTION

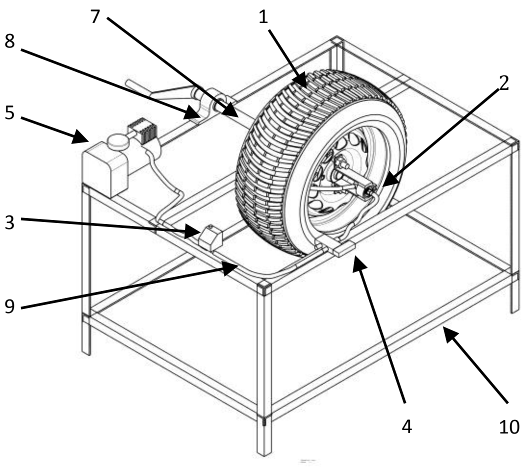


Fig: Product Assembly

1.	Tyre Assembly	2.	Rotary Joint
3.	Pressure Sensor.	4.	Solenoid Valve
5.	Air Compressor	6.	Battery
7.	Shaft	8.	Bearing
9.	Pipes	10.	Frame

4.1 TYRE ASSEMBLY

To demonstrate project we decided to make a model of one automobile tyre. For that purpose we choose a CEAT tyre which was used in Indica car.

Inside diameter of wheel rim is 55 mm. It will not be feasible to have 55 mm shaft diameter. So bush is used to reduce shaft diameter. Outside diameter of bush is 55 mm and inside diameter will be equal to diameter of shaft with considering tolerances

4.2 ROTARY JOINT

The rotary joint, which is one of the key components of our design, consists of two cylindrical pieces with a hollow channel for air flow to the tyre. A rotary joint is a union that allows for rotation of united parts. It is a device that provides a seal between a stationary supply passage and a rotating part to permit the flow of fluid into and/or out of the rotating part. The fluid used in our system is compressed air. A rotary joint is also called as rotary union or rotary valve.

Specifications:

Model	ASRS
Size	1/4"
Body	S.S 304 (CF8)
Shaft	S.S 304 (CF8)
Pressure	8 Kg/cm^2
Temperature	50°C
RPM	1000
Media	Compressed Air

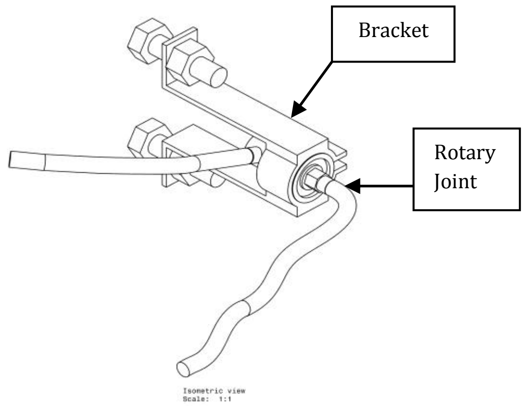


Fig: Rotary Joint Assembly

4.3 PNEUMATIC PRESSURE SENSOR

The pressure sensor we used in project is **PQ7834**. The PQ series pressure sensors are designed to monitor system pressure in pneumatic and compressed-air networks of machines and plants. The sensors can be used for both relative and differential pressure measurement. This makes them particularly suited for monitoring of filters for soiling or clogging. The measuring cell is insensitive to liquids or deposits that might occur in the system. It is overload protected and highly accurate.

A 4-digit LED display, which can be seen from a distance and easily read, and two pushbuttons allow easy set-up, maintenance and operation of the sensor. The display can be switched from the indication of "red" to an alternating indication of "red – green". So, switching states can be highlighted or an independent colour window can be created. Sensors with analogue output can also be configured via IO-Link, e.g. using a USB interface. The LINE RECORDER SENSOR software is used to visualise, transfer and archive parameter sets.

Applications:

1. Compressed air

Type of Pressure: Relative Pressure.

Table: Pressure Sensor Specifications

Order no.	Measuring Range		Permissible Overpressure		Bursting Pressure	
	bar	PSI	bar	PSI	bar	PSI
PQ7834	-1 to 10	-14.5 to 145	20	290	30	435

4.4 SOLENOID VALVE

3/2 solenoid valve is used to pass compressed air into tyre as well as into atmosphere form compressor unit. 3/2 Way Direct Acting solenoid valves utilises the armature movement as the direct means to the Open / Close the inlet or exhaust ports of the solenoid valve.

3/2 way normally open solenoid valve inlet port 1 is open to outlet port 2 with exhaust port 3 closed, when powered or energised inlet port 1 is closed and outlet port 2 is allowed to vent through exhaust port 3. However in some instances a 3/2 way normally open solenoid valve configuration will use port 3 as the inlet port and port 2 as outlet thus makes port 1 the exhaust port. This configuration is quite common and offers a reduced cost way of obtaining a 3/2 way normally open functions.

3/2 way universal solenoid valve has the added advantage of being able to accept inlet pressure at any port and control flow in any direction. The functionality of this valve works on the same principles as normally closed or open versions but does not have the limitations of flow directly associated with other designs. This is very beneficial as the inlet, outlet and exhaust ports can be piped up in any configuration to suit the application, so can be used as normally closed, open or as a diverting valve.

Symbol:

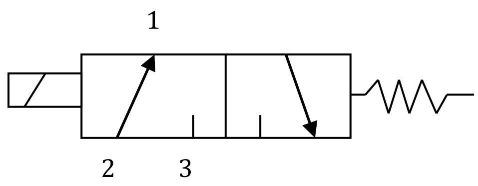


Fig: 3/2 DCV

4.5 AIR COMPRESSOR

12V DC Compressor is used to provide compressed air in system.

Calculation of Ai Flow Rate

Assuming an adiabatic compressor, air as an ideal gas, stagnant inlet velocity of air, inlet air temperature and pressure at atmospheric conditions, negligible pressure losses through joints and tubing, and a rough estimate of outlet air temperature; the first law of thermodynamic is employed to determine outlet velocity of air. By rearranging parameters in the first law of thermodynamics, the outlet velocity (V_2) can be found by equation 1, where w represents the work done on the compressor, h_1 and h_2 represent inlet and outlet enthalpies respectively, T_1 and T_2 represent inlet and outlet temperatures respectively, and C_p represents constant heat capacity

$$V_2 = \sqrt{2w(h_2 - h_1)} \qquad \text{(Equation 1)}$$

$$h_2 - h_1 = C_p(T_2 - T_1) \qquad \text{(Equation 2)}$$

Using $\frac{1}{4}$ air hose the flow rate (Q) of the air is dictated by the cross-section area of air hose, and the velocity of the flow, as stated in below equation no.3

$$Q_2 = \pi \left[\frac{1}{8}\right]^2 V_2 \qquad \text{(Equation 3)}$$

4.6 ELECTRIC BATTERY

Electric battery is used to provide DC current supply to the system including compressor, solenoid valve and sensor.

Table: Battery Specifications

Manufacturer	AMCO Batteries Ltd.
Model	NS-40-1
Type	Lead-Acid Battery
Capacity	28 AH
Dimensions	197x129x227 mm
Weight	9.3 Kg
Voltage	12V DC
Current	2 Amp
Electrolyte Volume	2.6 litre

4.7 SHAFT

Shaft is rotating machine element usually circular in cross-section, which is used to transmit power from one end to another end. Tyre with rim is attached at one end and lever is on another end. Inside diameter of wheel rim is 55 mm. It will not be feasible to have 55 mm shaft diameter. So bush is used to reduce shaft diameter. Outside diameter of bush is 55 mm and inside diameter will be equal to diameter of shaft with considering tolerances.

Material: Plain Carbon steel

Grade: 30C8

Dimensions:

Outer Diameter = 33 mm

Inner Diameter = 27 mm

5. ELECTRONIC DESCRIPTION

Our final product possesses the ability to automatically maintain the tyre pressure in automobile tyre of the vehicle that it is installed on. The main functions of these electronics is to take the pressure sensor reading from each of the tyres, and then decide whether or not to inflate them or deflate them to ensure proper cold tyre pressure.

5.1 ARDUINO

The Arduino is the main component of our electronics system. This allows us to make virtual circuits in a small chip so we can link logic between our different objects like compressor, pressure sensor and voltage sensor, etc. Figure shows the different components of an Arduino board.

Fig: Arduino Board

5.1.1 Arduino Architecture:

Arduino's processor basically has separate memory for program code and program data. It consists of two memories- Program memory and the data memory. The code is stored in the flash program memory, whereas the data is stored in the data memory.

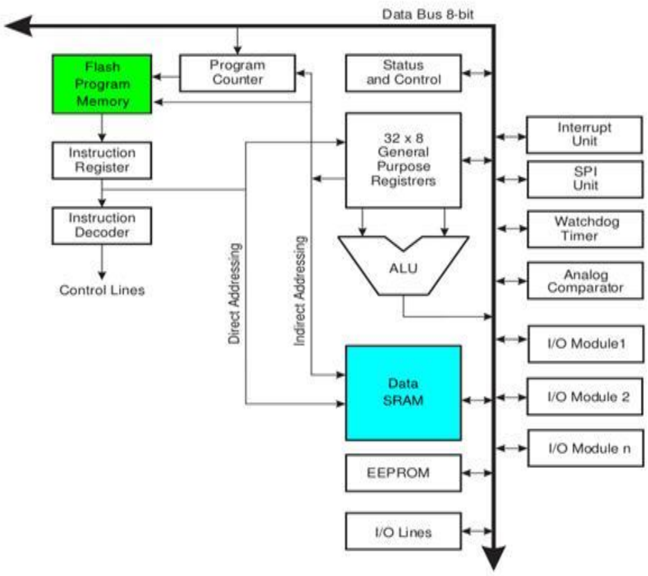


Fig: Arduino Architecture

5.1.2 Arduino Pin Diagram

Our centralized tyre pressure system consists of ATmega328 pin microcontroller. Figure shows pin diagram of Arduino.

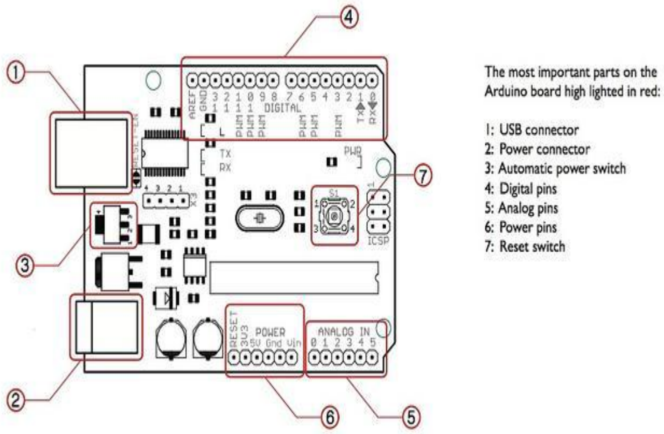


Fig: Arduino Pin Diagram

Arduino consists of 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button

Power Jack: Arduino can be power either from the pc through a USB or through external source like adaptor or a battery. It can operate on a external supply of 7 to 12V. Power can be applied externally through the pin Vin or by giving voltage reference through the IORef pin.

Digital Inputs: It consists of 14 digital inputs/output pins, each of which provide or take up 40mA current. Some of them have special functions like pins 0 and 1, which act as Rx and Tx respectively , for serial communication, pins 2 and 3-which are external interrupts, pins 3,5,6,9,11 which provides pwm output and pin 13 where LED is connected.

Analog inputs: It has 6 analog input/output pins, each providing a resolution of 10 bits.

ARef: It provides reference to the analog inputs

Reset: It resets the microcontroller when low.

5.2 MICROCONTROLLER – ATMEGA328P

The Atmel 8-bit AVR RISC-based microcontroller combines 32 kb flash memory with read-while-write capabilities, 1 kb EEPROM, 2 kb SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter. The device operates between 1.8-5.5 volts. The device achieves throughput approaching 1 MIPS per MHz

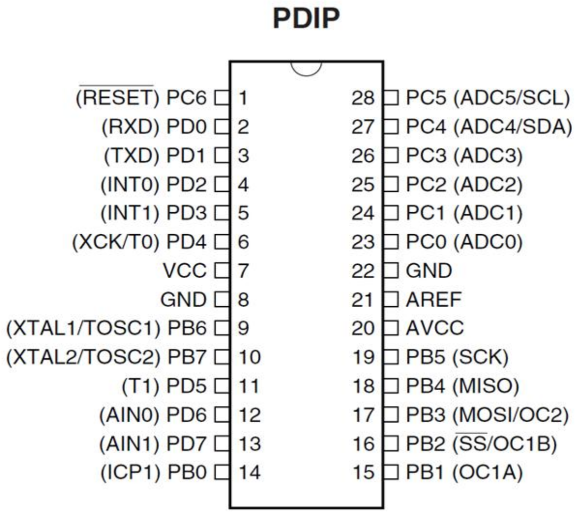


Fig: Pin Diagram

5.3 RELAY – JQF T91

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch. Relays are used where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal.

A simple electromagnetic relay consists of a coil of wire wrapped around a soft iron core, an iron yoke which provides a low reluctance path for magnetic flux, a movable iron armature, and one or more sets of contacts there are two contacts in the relay pictured. The armature is hinged to the yoke and mechanically linked to one or more sets of moving contacts. The armature is held in place by a spring so that when the relay is de-energized there is an air gap in the magnetic circuit. In this condition, one of the two sets of contacts in the relay pictured is closed, and the other set is open. Other relays may have more or fewer sets of contacts depending on their function. The relay in the picture also has a wire connecting the armature to the yoke. This ensures continuity of the circuit between the moving contacts on the armature, and the circuit track on the PCB via the yoke, which is soldered to the PCB.

When an electric current is passed through the coil it generates a magnetic field that activates the armature, and the consequent movement of the movable contact either makes or breaks a connection with a fixed contact. If the set of contacts was closed when the relay was de-energized, then the movement opens the contacts and breaks the connection, and vice versa if the contacts were open. When the current to the coil is switched off, the armature is returned by a force, approximately half as strong as the magnetic force, to its relaxed position. Usually this force is provided by a spring, when the coil is energized with direct current, a diode is often placed across the coil to dissipate the energy from the collapsing magnetic field at deactivation, which would otherwise generate a voltage spike dangerous to semiconductor circuit components.

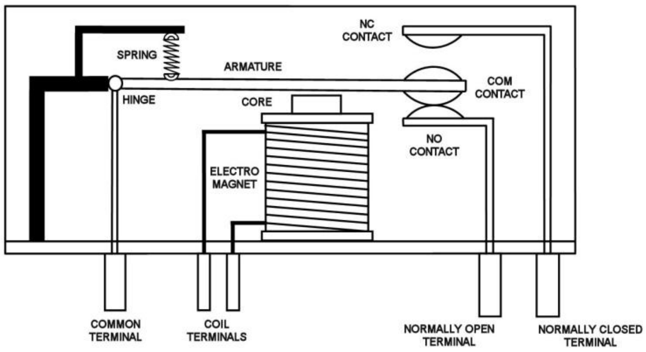


Fig: NO Type Relay

5.4 VOLTAGE SENSOR

A voltage sensor can in fact determine, monitor and can measure the supply of voltage. The input to the voltage sensor is the voltage output from pressure sensor. To convert the resistance of the sensing element to the voltage provide a voltage to the resistor divider circuit comprises of a sensor and a reference resistor which is represented below. The voltage that is developed across the reference resistor or sensor is buffered and then given to the Arduino

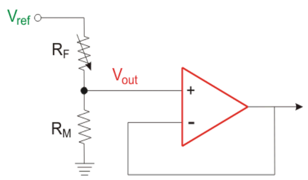


Fig: Circuit board.

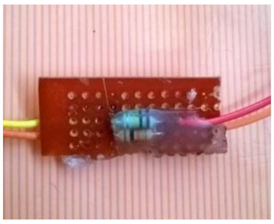


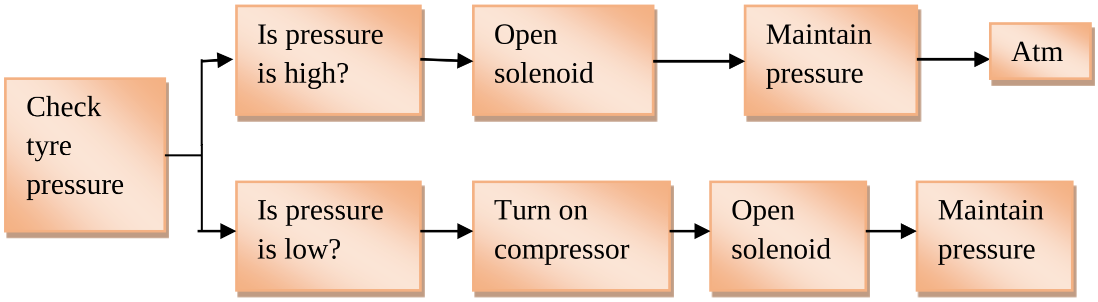
Fig: Voltage sensor

5.5 ELECTRONIC PROGRAM DESCRIPTION

The logic that electronic program needs to control is quite basic. System electronic program are interfacing with; the compressor, air pressure sensor and solenoid valve.

Figure shows flowchart of the logic steps that will be taking in electronic program. When the program starts up, the first thing that it does is check the tyre pressure. If the tyre pressure is low then sensor will the tyre pressure, it will compare with the set value of pressure. Then sensor will send signal to microcontroller. Microcontroller will send signal to relay to turn on compressor. Solenoid valve allow compressed air into tyre to inflate. This inflation process will continue until the pressure sensor detects that the tyre has reached the optimal pressure, and then sensor will send signal to microcontroller. Microcontroller will allow relay to turn off the compressor.

However in deflation process, compressor will turn off manually, and then air from tyre will release into atmosphere by operating switch. The air will release into atmosphere as per requirement. The sensor will show tyre pressure during process.



Electronic Program Flow Chart

5.6 ELECTRONIC HARDWARE INTERFACE

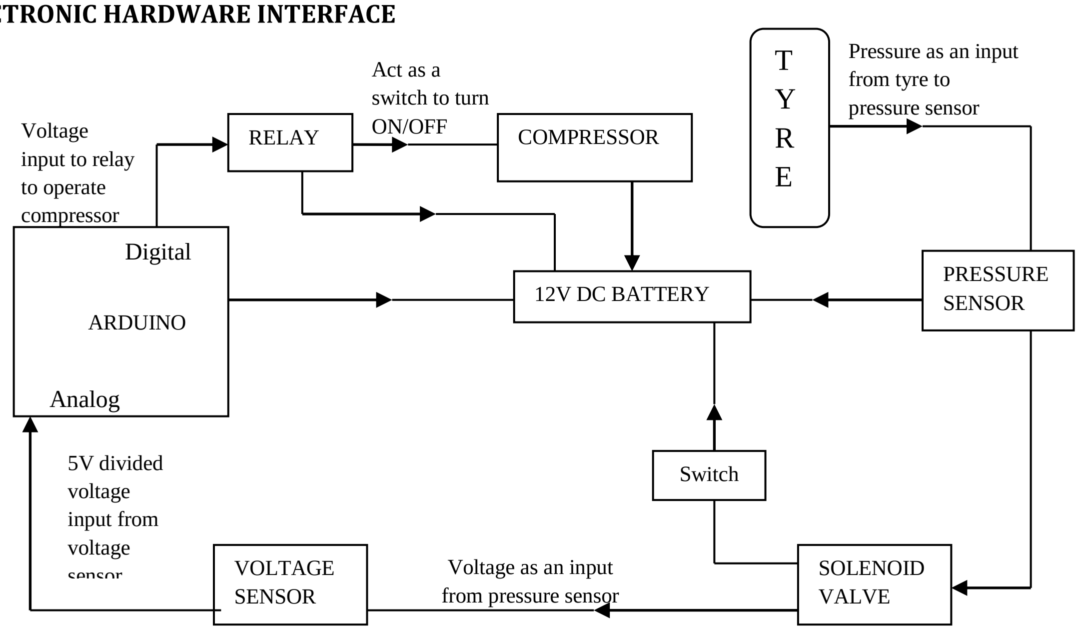


Fig: Electronic Hardware Interface

We cannot control the air compressor directly through the microcontroller. For that purpose relay is provided along with microcontroller. When tyre pressure falls below set value (31 PSI) the pressure sensor will sense the pressure as an input from tyre. Then sensor will send signals to microcontroller in the form of voltage. The voltage capacity of microcontroller is 5V and sensor has output 11.01V so we have to divide the output voltage so that we can send voltage signal to microcontroller. So we provided a voltage sensor to sense the voltage, divide it and send to microcontroller. Voltage sensor is made by two resistors having capacity 100K & 10K. The voltage sensor will send signals to microcontroller in analog form. Now consider a case,

If tyre pressure falls below set value then pressure sensor will send low voltage to microcontroller. Then microprocessor will send the 'Low' signal to relay by transistor and relay with actuates. Working of relay is explained earlier. Relay makes NO contact and compressor will start. This process will continue until tyre pressure reaches to its set value i.e. 31 PSI.

After reaching to its set value pressure sensor send high voltage i.e. 11.01V to microcontroller. Microcontroller will send 'High' signal to relay and relay will break the NO contact. Then relay will turn off power supply of compressor and system will be stop.

In Deflection process, only we have to break the contact of solenoid valve. Solenoid valve is operated on 12V DC supply. This is connected to battery as shown in figure. To break the contact a toggle switch is provided between the supplies. In normally open position of solenoid valve air directly passes from compressor to tyre. So in deflection process air passes from tyre to atmosphere by solenoid valve. To allow air pass into atmosphere we have to change the position of solenoid valve. It is done by toggle switch. We have to allow air from tyre into atmosphere manually by toggle switch as per requirement. The pressure sensor will show the pressure in the tyre during the process.

6. CONCLUSIONS

The **Centralized Tyre Pressure System** would be capable of succeeding as a new product in the automotive supplier industry. It specifically addresses the needs of the vehicle owner by maintaining appropriate tyre pressure conditions for:

- Reduced tyre wear
- Increased fuel economy
- Increased overall vehicle safety

This product currently does not exist in the majority of passenger vehicles and defense vehicles in India. Despite an initial investment in the technology, they will experience a reduction in tyre wear and an increase in fuel economy; both of which will result in saving money in the long run. We decided four design objectives for this project and we fulfilled all the four objectives.

It is plausible to say that society as a whole will benefit from the resulting design. The reduction in tyre disposal in landfills and decrease the rate of consumption of natural resources will truly benefit society. Also, the improvement in vehicle safety will benefit all people who drive a vehicle on the roadways.

Through extensive engineering design, it has also been determined that the self-inflating tyre system would actually function as desired. In particular, the product would capable of providing sufficient airflow to the tyre with minimal leakage.

For further development of this product, we recommend increasing the capability of the system by adding the following features:

- Pressure adjustment based on increasing vehicle speed.
- Pressure adjustment based on increasing vehicle load.
- Implementation of interactive display
- Creation of universal design for aftermarket use.

ACKNOWLEDGEMENT

It gives us immense pleasure to present our Report in **"Centralized Tyre Pressure System".** The able guidance of all working staff of our department made the study possible. They have been constant source of encouragement, knowledge and information throughout the completion of this project.

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