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Design, Construction and Testing of a Port Fuel Injection (PFI) System for a Four Cylinder SI Engine

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Abstract

The Port Fuel Injection system have the advantages over throttle body manifold fuel injection system for providing uniform fuel air mixture in each cylinder and it can control fuel injection quantity more precisely. Thus it can provide fuel economy and minimize environmental pollution. The present research work can help the automotive engineers to understand the design and operation principle of Port Fuel Injection technologies in operation , maintenance and research fields.

Keywords: *Port fuel injection, Fuel economy, Pollution control*

1. Introduction

The construction of the carburetor is relatively simple and it has been used almost exclusively on gasoline engines in the past. However, in response to recent demands for cleaner exhaust emissions, more economical fuel consumption, and improved drivability, the carburetor now must be equipped with various compensating devices and it makes carburetor more complex. In place of carburetor, therefore, Electronic Fuel Injection (EFI) System got advantages, which can assures the proper air-fuel ratio to the cylinder by controlling electronic devices in accordance with various driving conditions. In the port fuel injection system, the fuel is supplied directly into the intake port in suction stroke where the injection period varies with speed and load [1]. In the port fuel injection system fuel is injected in the intake port which provides desired homogeneous mixture in each cylinder (1-5] which can reduce emissions and increased engine efficiency.

Engines generate their worst emissions-just after cold-start. During warm-up of an engine, a small shot of fuel is injected just before the exhaust valve opens. There is still enough heat and oxygen in the chamber for this charge to ignite, and the heat from t Unlike throttle body fuel injection (TBI), hat after burn gets the catalyst warm-up to operating temperature just seconds after cold-start. In port fuel injection system, injectors are either open or closed and pulsed unlike throttle body fuel injection (TBI) system.

2. Layout and Components of Port Fuel Injection System

The fuel delivery system incorporates the following components:

(i) Fuel tank, (ii) Fuel pump (iii) Fuel pipe and filter in line (iv) Fuel delivery pipe (rail) (v) Pulsation damper (in many engines) (vi) Fuel injectors (vii) Cold start injectors (most engines) (viii) Fuel pressure regulator and (ix) Fuel return pipe

There are two types of electric fuel pump used in the EFI systems. The early conventional EFI system used an externally mounted in-line pump. These roller cells pumps incorporate an integral pressure pulse damper or silencer designed to smooth out pressure pulses and provide quiet operation

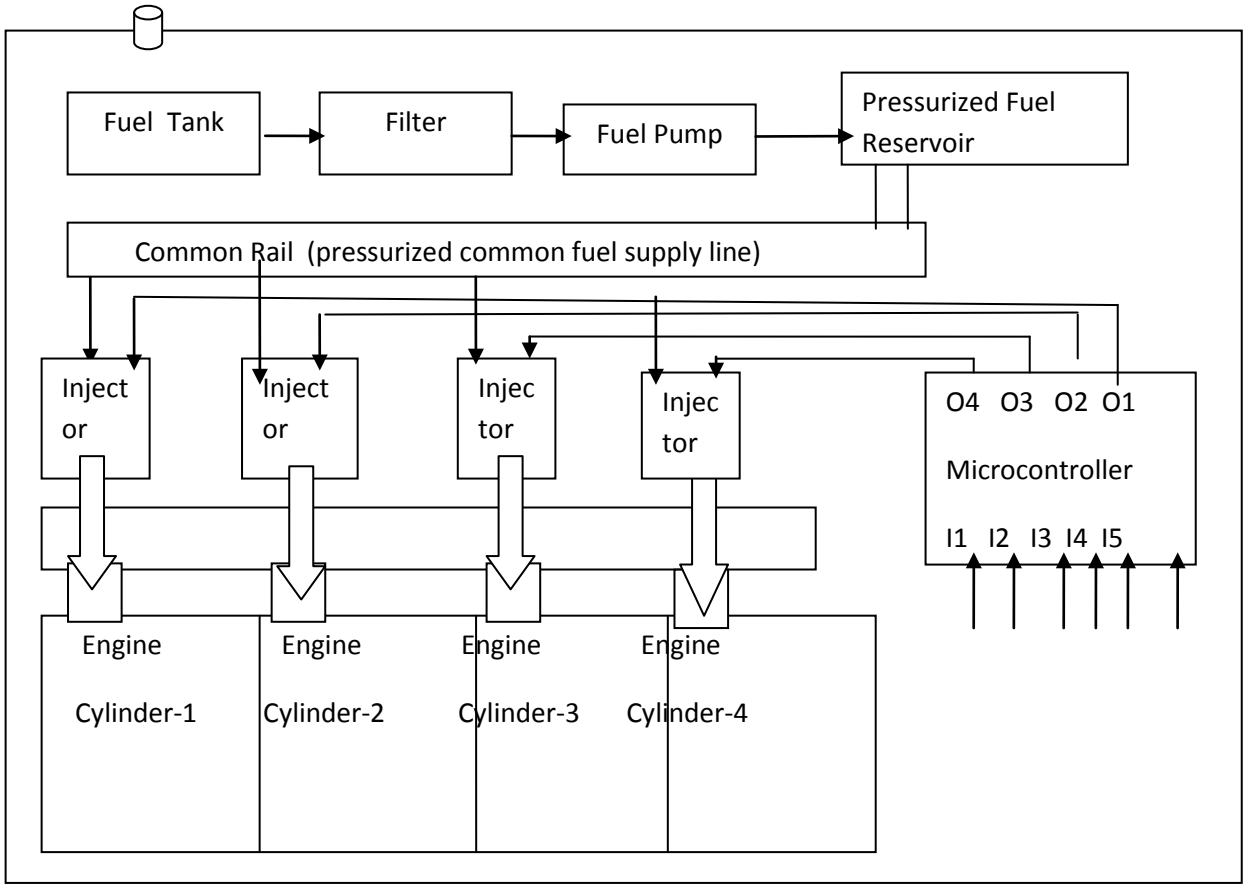
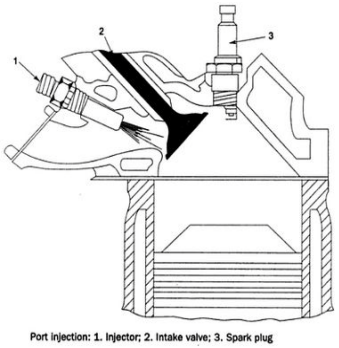


Fig. 1: Schematic Diagram of Fuel Supply System

Later model engines utilize an in-tank pump integrated with the fuel sender unit. These turbine pumps operate with less discharge pulsation and run quieter than the in-line variety [2-5] . In-tank pumps can be serviced by removing the fuel sender unit from the tank. Make sure that the pump coupling hose is in good condition prior to replacing the pump.In a port fuel injection engine, the fuel must be injected in a short period of time and with maximum injector pressures of 35 psig [2-5]. The electric fuel pump supplies the fuel to the injectors under pressure. As soon as the injector opens, fuel sprays out. An electric solenoid in the injector opens and closes the valve. The solenoid has a small coil that becomes magnetized when a voltage is supplied.



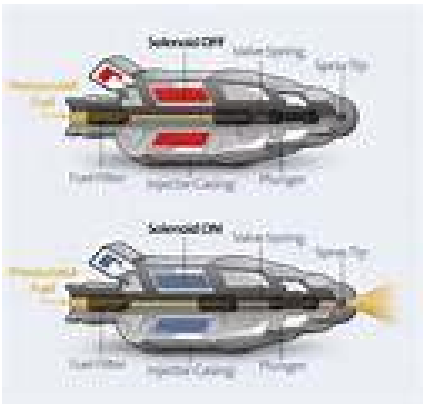


Fig. 2(a) Fuel injection in the intake port **Fig. 2(a) Fuel injector Cross- section**

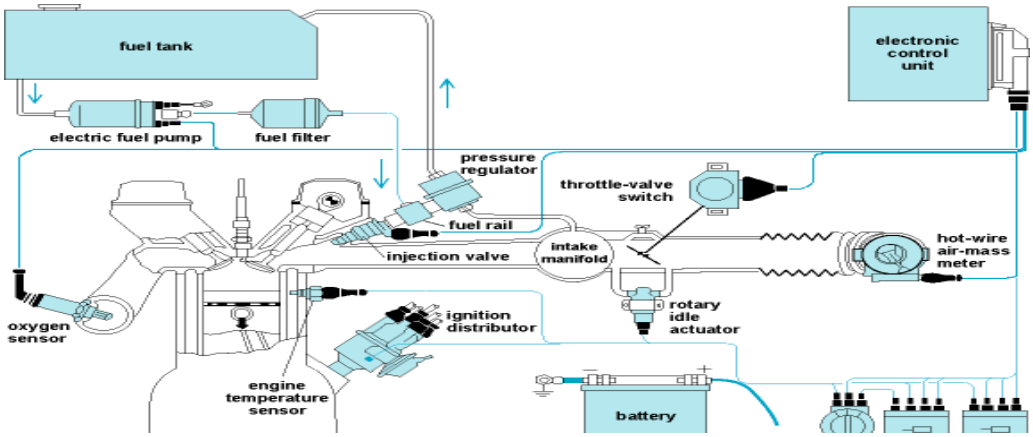


Fig. 2: Diagram of Fuel Injector and Fuel Injection System in US Vehicles

3. Design Consideration for the Program in Microcontroller

A microcontroller has following key features:

- Central Processing Unit –usually small and simple
- Output and input interface such as serial ports.
- RAM for data storage.
- Peripherals such as timers and watchdog circuits.
- ROM for program storage.
- Clock generator- an oscillator for a quartz timing crystal, resonator or RC circuit.

This integration minimizes the number of chips and the amount of wiring and PCB space that would be needed to produce equivalent systems using separate chips. Now a day's microcontroller is used in traffic signals, electrical devices, washing machines, microwave ovens, telephones, vehicles etc.

The engine management system usually continually chooses among three combustion modes: ultra lean burn, stoichiometric, and full power output. Each mode is characterized by the air-fuel ratio. The stoichiometric air-fuel ratio for petrol (gasoline) is 14.7 to 1 by weight, but ultra lean mode can involve ratios as high as 25:1. These leaner mixtures of PFI system is much leaner than in a conventional engine, reduce fuel consumption [6].

PFI system was designed for variable speed and variable load and other operating conditions of a real engine. In this design instead of three modes, six modes of engine operation like starting (choke circuit) idle circuit, slow speed circuit, medium speed circuit, high-speed circuit, acceleration circuit are considered. In each running condition there is provision of extra fuel supply for high load and low load operation so that wide varying of fuel air ratio can be supplied keeping in conformity of engine operation conditions.

Various types of sensors, ICs and transistors are used to sense the speed and suction pressure and engine operating conditions. An engine demand various quantity of air depending on load and speed. The intake air flow and air pressure represents the variation of load. The distributor of EFI, PFI and DGI systems have built in signaling system for engine rpm and crank angle postion. Ne – signal and Ge-signal give engine rpm and crank angle position. Oxygen signal fitted in catalytic converter give presence of excess or low oxygen in exhaust gas which in term give information to the engine that it is running with lean or rich or with optimum fuel air ratio.

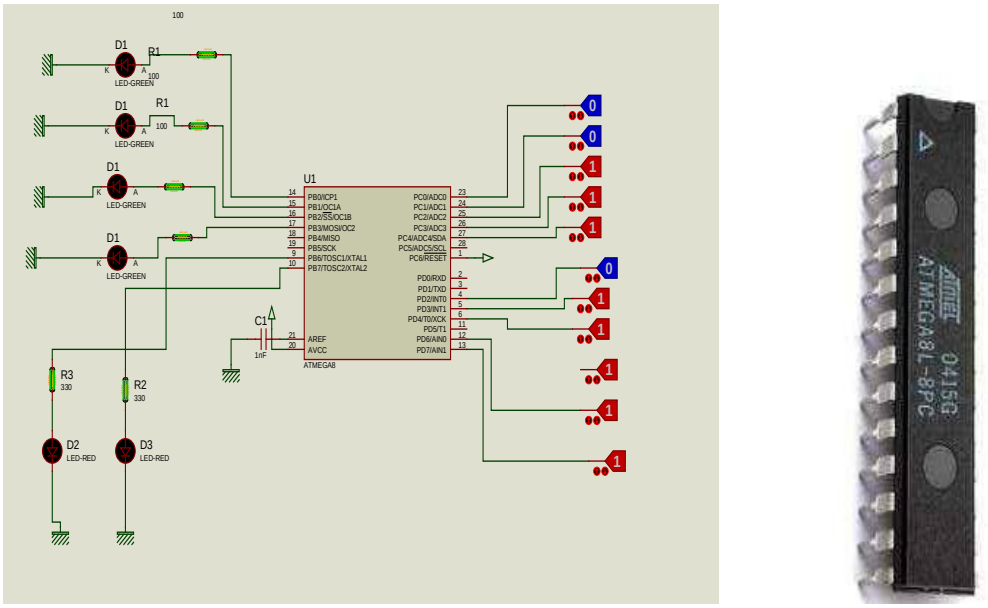


Fig. 3: Microcontroller Input Output diagram and IC

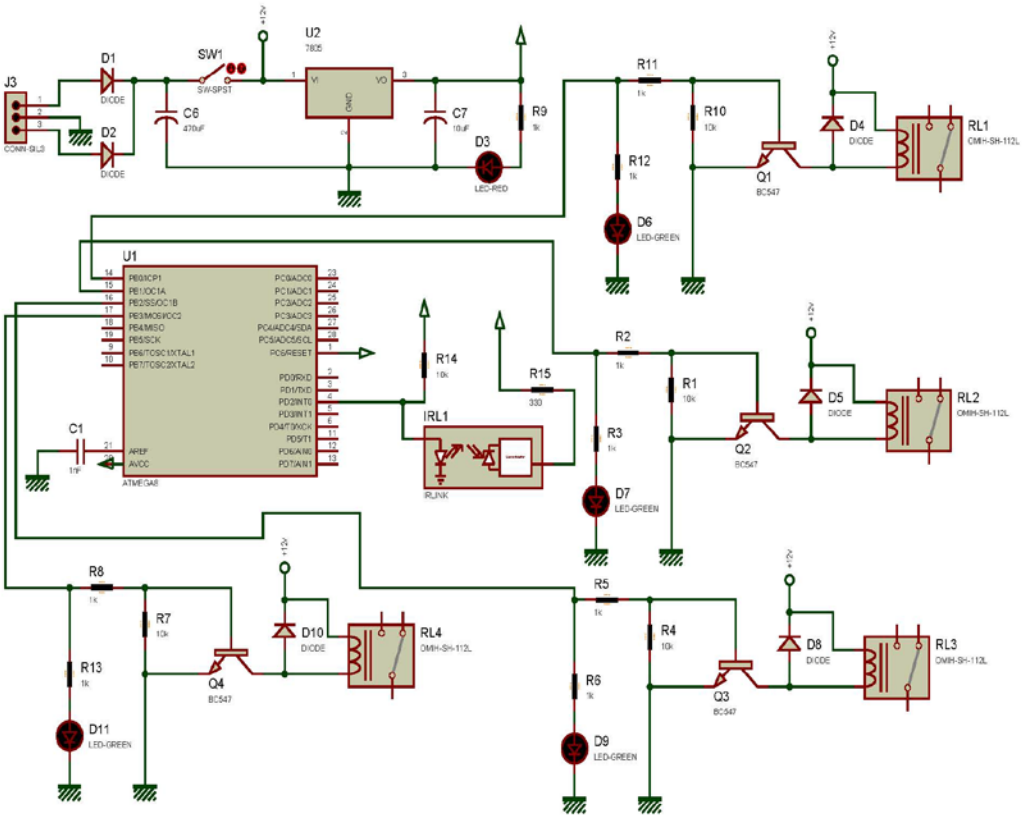


Fig. 4: Schematic Diagram of Main Circuit

The program was made on the logics required for operating conditions of the engine [7]. Input signals are taken for Starting position (I1), Idle Position (I2) Slow running position (I3), Medium Speed Position (I4)

High-speed (I5) and Acceleration (I6). The air velocity and pressure determine the loading position in each mode. The Oxygen sensor gives the level of fuel air ratio. All these parameter are set to the programe to get required output signal for Injector nozzle opening.

Before programming on a microcontroller based PFI system, the fuel air ratio required in all engine operating conditions like starting system (choke system), idle system, slow speed, medium speed, high speed system, acceleration system with variable engine load are considered and accordingly the required input are set to microcontroller. The output of microcontroller to injectors, controls injector valve opening times on which fuel injection quantity varies depending on engine operating conditions. The controlling parameters especially valve opening time can be changes during engine test on test bed or on road running conditions if desired. Thus engine can run with required fuel air ratio if designed parameters are changed and set to the required value in road test.

4. Experimental setup

A common fuel rail for fuel supply from fuel tank is constructed from local workshop. A fuel pump and four injectors are procured from local market and these are installed with fuel supply common rail in the experimental set up. An artificial fly wheel is coupled to a Dc motor having various to generate signal of engine rotation and sensing crank angle position. The module of fuel supply is replaced by the microcontroller .Necessary power supply for fuel pump, injectors and microcontroller board is completed.

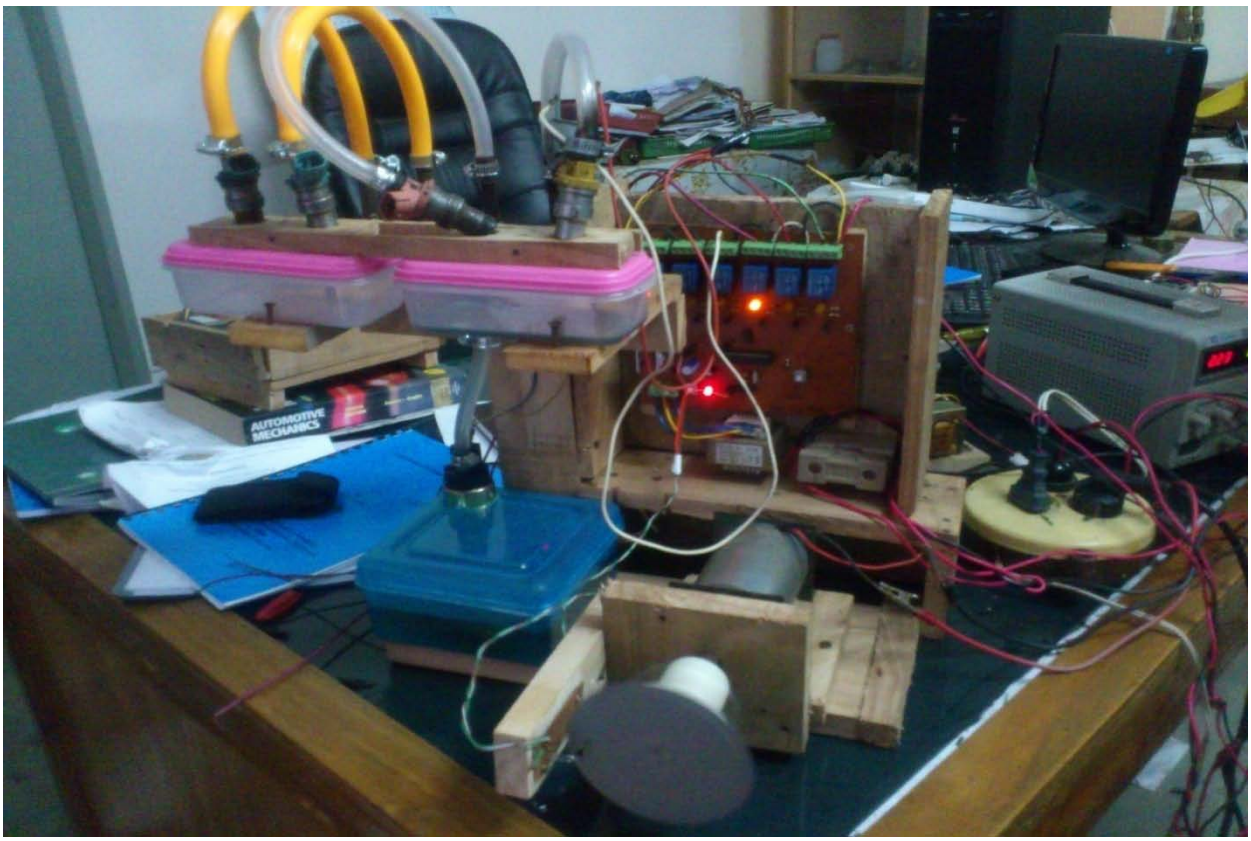


Fig. 5 Experimental Setup for the Model of a PFI

5. Results and Discussion

After completion of the experimental set-up the performance of the fuel supply module was tested this showed that fuel injection quantity can be varied to any required value.

This module can be set Port Fuel Injection system vehicle without or with small modification. Carburetor mounted vehicle with electronic distributor has the facility to give engine speed (rpm) and crank angle sensing device and oxygen sensor. In other word it can be used to controls the amount of fuel to be supplied from injector to engine cylinder in all engine operation modes.

6. Conclusion

At the end**,** it may be concluded that-

(i) The program for controlling the Port fuel injection is found to work properly.
(ii) The model test result showed variable fuel injection quantity at different speed and load can be maintained.
(iii) The emission reduction potential is very high as fuel injection can be controlled depending upon Engine running condition.
(iv) Fuel delivery module cost 1500-2000 USD in US market but locally made module costs nearly 20-25 USD or BD TK 1500- 2000 .

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