DESIGN OF ELECTRICAL CIRCUIT OF ELECTRONIC FUEL INJECTOR TESTER FOR EDUCATION PURPOSE

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A report submitted in partial fulfillment of the requirement for the degree of Bachelor of Mechanical Engineering Technology (Automotive Technology) with Hons.

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DECEMBER 2017

"I hereby declare that I have read through this report entitle *"Design of Electrical Circuit of Electronic Fuel Injector Tester for Education Purpose"* and found that it has complied the partial fulfillment for awarding the degree of Bachelor of Mechanical Engineering Technology (Automotive Technology)."

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Supervisor"s Name	: Mr. Ahmad Zainal Taufik bin Zainal Arifin
Date	: …….

"I declare that this report "*Design of Electrical Circuit of Electronic Fuel Injector Tester for Education Purpose"* is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree."

Signature : …….

Name : Amirul Dzakiyy Bin Rozman

Date : …….

DEDICATION

To my beloved mother and father

ACKNOWLEDGEMENT

Alhamdulillah, I would like to express my fully gratitude to Allah S.W.T. with His grace that I have completed this Final Year Project also known as „Projek Sarjana Muda" with great success within the whole two semester of having this subject as part of my learning course here. During this period it would not have been possible to achieve completion upon this project without help from other people around me, therefore, I felt grateful for being given an opportunity to be a part of this working process.

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ABSTRACT

Electronic Fuel Injection (EFI) system are part of engine fuel system and it is controlled by the engine Electronic Control Unit (ECU) management component that is found on the vast majority of road transportation either it is passenger or commercial vehicles. The fuel injectors act as the nozzles that spray the fuel into the engine in specific patterns and at specific timed intervals that will optimize engine performance. The electronic fuel injector specific timed intervals operations are controlled by the engine ECU. As a part of the fuel system, any problems with these components can cause all sorts of engine performance issues and may lead to engine terminal failure if the problems lead to become more worsen and neglected by vehicle owner. In local automotive service industry and learning institute nowadays, automotive service technician usually taking conventional troubleshoot approach when dealing with faulty electronic fuel injector. The technician usually take a conventional approach where they use screwdriver method to diagnose whether the electronic fuel injector is produce pulsating reaction at it nozzle when spraying fuel inside the combustion chamber or not. This conventional method is done by place the tip of the screwdriver on the fuel injector body while hearing by using their ear at the other end of the screwdriver. This conventional method however are no giving accurate results as other external interference such as from engine vibration may cause an interference in this procedure. Besides, the electronic fuel injector spray pattern from it nozzle may not be able to be analyse as the fuel injector is not being taking out from the fuel rail. Therefore, the purpose of this research is to design and analyze electrical circuit of electronic fuel injector tester for education purpose that would simulate the electronic fuel injector system operation such as open and close it plunger valve in specific timed intervals. The design and analysis will be done by using National Instrument (NI) circuit design suite Multisim and Ultiboard software version 12.0. The simulation is analyzed based on the voltage reading, current output besides signal's voltage over time graph that can be acquired by using a virtual oscilloscope that were provided in the NI Multisim software analysis tool application before being transfer to NI Ultiboard for Printed Circuit Board (PCB) layout.

ABSTRAK

Sistem suntikan bahan api elektronik (EFI) adalah sebahagian daripada sistem bahan api enjin dan ia dikawal oleh komponen pengurusan enjin Unit kawalan elektronik (ECU) yang terdapat di sebahagian besar pengangkutan jalan raya sama ada ia adalah penumpang atau kenderaan perdagangan. Penyuntik bahan api bertindak sebagai muncung yang menyembur bahan api ke dalam enjin dalam corak tertentu dan pada jangka masa yang ditetapkan masa tertentu yang akan mengoptimumkan prestasi enjin. Operasi penyuntik bahan api elektronik tetapan masa tertentu selang dikawal oleh ECU. Sebagai sebahagian daripada sistem bahan api, sebarang masalah dengan komponen ini boleh menyebabkan pelbagai isu-isu prestasi enjin dan boleh membawa kepada kegagalan enjin jika masalah ini menjadi lebih teruk dan diabaikan oleh pemilik kenderaan. Dalam industri perkhidmatan dan pembelajaran automotif institut tempatan pada masa kini, juruteknik automotif biasanya mengambil pendekatan penyelesaian masalah konvensional apabila berurusan dengan penyuntik bahan api elektronik yang rosak. Juruteknik biasanya mengambil pendekatan konvensional di mana mereka menggunakan kaedah pemutar skru untuk mendiagnosis sama ada penyuntik bahan api elektronik itu menghasilkan tindak balas denyut pada muncung apabila menyembur bahan api dalam kebuk pembakaran atau tidak. Kaedah konvensional dilakukan oleh dengan menempatkan hujung pemutar skru pada badan penyuntik bahan api ketika mendengar dengan menggunakan telinga mereka di hujung pemutar skru. Kaedah konvensional bagaimanapun tidak memberikan keputusan yang tepat akibat factor campur tangan luar yang lain seperti dari getaran enjin boleh menyebabkan gangguan di dalam prosedur ini. Selain itu, corak semburan penyuntik bahan api elektronik daripadanya muncung mungkin tidak dapat dianalisis kerana penyuntik bahan api tidak diambil keluar dari rel bahan api. Oleh itu, tujuan kajian ini adalah untuk mereka bentuk dan menganalisis litar elektrik ujian penyuntik bahan api elektronik untuk tujuan pendidikan yang akan mensimulasikan operasi sistem penyuntik bahan api elektronik seperti injap terbuka dan tertutup dalam jangka masa tertentu yang ditetapkan. Reka bentuk dan analisis akan dilakukan dengan menggunakan National Instrument (NI) reka bentuk litar suit Multisim dan Ultiboard perisian versi 12.0. Simulasi dianalisis berdasarkan bacaan keluaran arus voltan selain voltan isyarat dari masa ke masa graf yang boleh diperolehi dengan menggunakan osiloskop maya yang telah disediakan dalam analisis perisian aplikasi alat NI Multisim sebelum dihantar ke NI Ultiboard untuk proses susun atur Papan Litar Bercetak (PCB).

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LIST OF ABBREVIATION

ECU - Electronic Control Unit
EFI - Electronic Fuel Injection
MAF - Mass Air Flow
MAP - Mass Absolute Pressure
PCB - Printed Circuit Board
AC - Alternate Current
DC - Direct Current
PSU - Power Supply Unit
PCM - Powertrain Control Module
IC - Integrated Circuit
Vs - Supply Voltage
SR - Set Reset
+Ve - Positive
-Ve - Negative
LED - Light Emitting Diode
NI - National Instruments
SPICE - Simulation Program with Integrated Circuit Emphasis
PWM - Pulse Width Modulation
SPST - Single Pole Single Throw
SPDT - Single Pole Double Throw

CHAPTER 1

INTRODUCTION

1.0 Introduction

This chapter will tell about the introduction of the study and problem statement. The problem of method testing electronic fuel injector is briefly described. Besides that, the objective and scope of the study also explained in this chapter. The purpose of this project is to analyze and design electrical circuit of electronic fuel injector tester for education purpose. This project will be conducted by using National Instrument (NI) circuit design suite Multisim and Ultiboard software version 12.0. This software is the most suitable software application that can be used for designing electrical circuit and simulating the design as in electrical system to get various results.

Electronic Fuel Injection (EFI) system are part of engine fuel system and it is controlled by the engine Electronic Control Unit (ECU) management component that is found on the vast majority of road transportation either it is passenger or commercial vehicles. The fuel injectors act as the nozzles that spray the fuel into the engine in specific patterns and at specific timed intervals that will optimize engine performance. The electronic fuel injector specific timed intervals operations are controlled by the engine ECU. In EFI operating system at first, the ECU obtains information about the engine conditions and requirements using different internal sensors such as Mass Air Flow (MAF) or Mass Absolute Pressure (MAP) sensors. Once the state and requirements of the engine have been determined, the fuel is drawn from the fuel tank and transported through the fuel lines before being pressurized with fuel pumps. A suitable pressure is checked by a fuel pressure regulator into certain value. Then the fuel is divided by using a fuel rail that will supply the fuel into different cylinders of the engine respectively. Finally, the injectors are ordered to inject the necessary fuel for the combustion.

The electronic fuel injector in an electronic system is held closed by a spring, but is opened by an electromagnet built into the injector body. As the injector electromagnet is

energized by supplied current, it moves a plunger that opens the valve that will allow the pressurized fuel to squirt out through a fine nozzle that is designed to atomize the fuel. The ECU then determines how long the injector stays open depending on the engine current demand.

As a part of the fuel system, any problems with these components can cause all sorts of engine performance issues. Usually a bad or failing fuel injector will produce a few symptoms towards the engine performance or behaviour that can alert the driver of a potential issue that need to be fixed immediately.

1.1 Problem Statement

Fuel injector is a component that will inject fuel into the internal combustion engine. It is the component which plays an important role in the burning of the fuel system as it will inject fuel into the cylinder by a predetermined amount of fuel and specific time value. Bursts of fuel injector fuel can be continuously or intermittently such as pulse injection.

Among the common problems that fuel injector having after long time of operating in harsh condition is blockages. The problem starts with working on testing the electronic fuel injector first capability to open and closed it plunger valves by supplying current to energize it electromagnet. We need to ensure the electronic fuel injector is able to operate in normal circumstances. A few problems that were often faces when testing the fuel injector as follows: -

i. Any problem upon the fuel injector is advised to be sent to the authorised service panel to be tested as self-work is not recommended due to absent of special equipment.

ii. Testing the fuel injector always imposed high risk because of chemical involvement in working operation.

iii. Testing the fuel injector always consuming a lot of time and meticulous work by using conventional method and not delivered best results.

1.2 Objectives

The project aims to help solve the problem often encountered in the workplace or learning institute particularly where they are usually lack of this equipment to test or service cleaning the fuel injector. Among the objectives are as follows: -

i. To study electrical circuit for electronic fuel injector tester

ii. Design and developing electronic fuel injector tester prototype equipment with a minimum cost and user friendly which is available for lightweight vehicle only.

iii. Design a proper electrical circuit program for electronic fuel injector tester prototype that able to simulate fuel injector operation as for this particular project objective.

1.3 Scope of Works

Based on the study of the electronic fuel injector tester the scope will focus on the design of electrical circuit program for electronic fuel injector tester prototype equipment only. The scopes of work are as follows:-

i. The scope will focus on the design of electrical circuit program for electronic fuel injector tester prototype equipment, which will be design, simulate, and analyze by using NI Multisim software version 12.0 application to create prototype product. The Printed Circuit Board (PCB) layout will be utilized by the circuit designs at the end of the process by using NI Ultiboard software version 12.0 application.

ii. In addition, the electronic fuel injector tester prototype equipment is only designed for electronic fuel injector from petrol engine and light weight vehicle with engine displacement range from 600cc - 2000cc only.

1.4 Expected Project Outcome

By using the aided software which is National Instrument (NI) circuit design suite Multisim and Ultiboard software version 12.0, I would able to analyse the circuit diagram first before construct the electronic circuit, this will ensure a smooth and organise work progress all through the time period for the project development. The expected product will meet target design requirement without any system faulty or interruption when operating in future. The expected projected outcomes are as follows:-

i. To obtain a better understanding about electronic fuel injector operating system.

ii. To obtain and analyze the electronic fuel injector system requirement on different type of electronic fuel injector.

iii. Able to construct a proper and safe electronic fuel injector tester electrical circuit program that will work to simulate the electronic fuel injector operating system.

CHAPTER 2

LITERATURE REVIEW

2.0 Overview

This chapter will be analyzed further on the design of electrical circuit of electronic fuel injector tester for education purpose. This electrical circuit will consists many of electrical component that will create a program that will simulate the electronic fuel injector operation. The basic operation is such as opening and closing plunger valve besides having capabilities to operate in specific timed intervals operations depending on user setup, by designing this electrical circuit, I would able to simulate the design as in actual electrical system to get various parameter results.

2.1 Alternate Current (AC) To Direct Current (DC) Power Supply

Power supplies or also known as power supply units (PSU), is an essential part of electronics equipment. AC to DC Power supplies always involve power conversion which converting the available power takes in AC power from the mains supply and delivers a DC voltage to the item requiring power of electronics equipment[1]. In conversion of the AC or DC input voltage to the required AC or DC output voltage, it usually involves considering factors such as power efficiency and how well regulated the output voltage must be as some systems are more sensitive to fluctuations in power, therefore it may require a more regulated supply of voltage[2]. Figure 2.1 below shows the operating principle of the power supply in block diagram of electrical circuit[3].

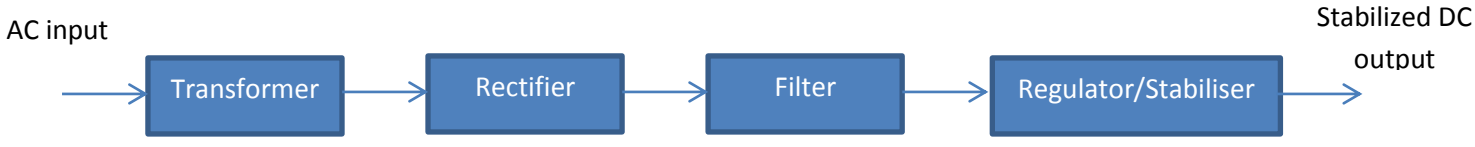

Figure 2.1: Power supply operation block diagram.

i. The input transformer is used to transform the incoming line voltage down to the required level for the power supply. Usually the input transformer provides a step down function and also isolates the output circuit from the line supply.

ii. The rectifier converts the incoming signal from an AC format into raw DC. Either half wave or more commonly full wave rectifiers may be used as they make use of both half of the incoming AC signal.

iii. In filtering, as the raw DC from the rectifier is far from constant falling to zero when the AC waveform crossed the zero axis, and then rising to its peak. The addition of a reservoir capacitor here fills in the troughs in the waveform, enabling the next stage of the power supply to operate. It is usually necessary to also include a low pass filter or a regulator stage after the reservoir capacitor to remove any remaining AC ripple and improve the stabilisation of the DC output voltage under variable load conditions.

iv. In regulator stage, the power supply takes the filtered voltage and uses a regulator circuit to provide a constant output virtually regardless of the output current and any minor fluctuations in the input level.

For this particular project the voltage target output that the AC to DC power supply need to achieve is 12.0 volts. This is because the automotive components that were used in this equipment required 12.0 volts DC power supply to operate as in actuals on the road light passenger vehicle.

2.2 12 Volts Automotive Lead-Acid Battery Power Supply

An automotive lead-acid battery is a rechargeable battery that supplies DC electrical energy to a motor vehicle. Batteries use a chemical reaction to do work on charge and produce a voltage between their output terminals. As for this particular project, the 12.0 volts lead-acid battery is utilized as power supply[4]. This is because the automotive component such as fuel pump and electronic fuel injector that were used in the electronic fuel injector tester equipment required 12.0 DC volts power supply to operate.

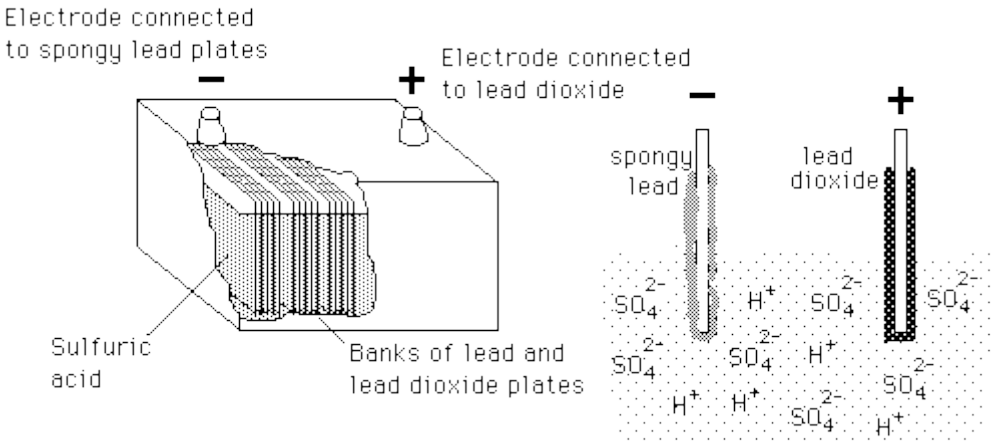

Figure 2.2: Lead-acid battery diagram.

12.0 volts batteries are typically made of six galvanic cells in a series circuit[5]. Each cell provides 2.1 volts for a total of 12.6 volts at full charge. Each cell of a lead storage battery consists of alternate plates of lead that act as cathode and lead coated with lead dioxide that act as anode immersed in an electrolyte of sulfuric acid solution. The actual standard cell potential is obtained from the standard reduction potentials as follows:-

E = E (cathode) - E (anode)
E = (+1.685 V) - (-0.356 V)
E = + 2.041 V
6 cells x 2.041 V/cell = 12.246 V

This causes a chemical reaction that releases electrons, allowing them to flow through conductors to produce electricity. The reaction of lead and lead oxide with the

sulfuric acid electrolyte produces a voltage. The supplying of energy to and external resistance discharges the battery. The discharge reaction can be reversed by applying a voltage from a charging source[6]. In the electronic fuel injector tester equipment, the battery will only optimize discharge capability because there is no charging components were installed.

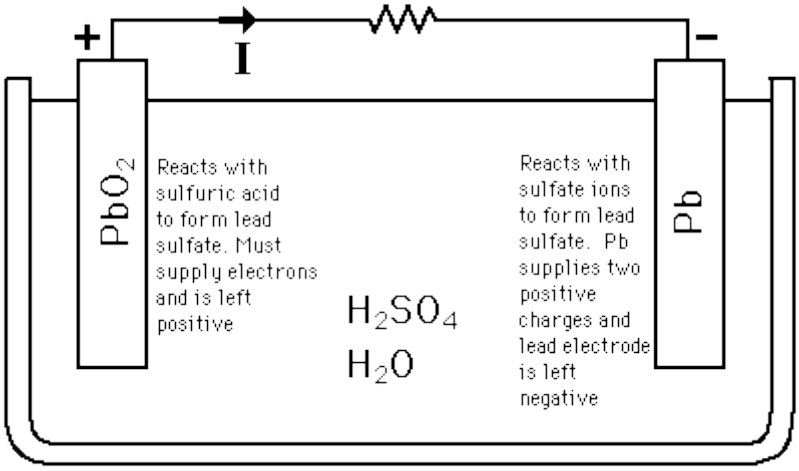

Figure 2.3: Discharging the lead-acid battery diagram.

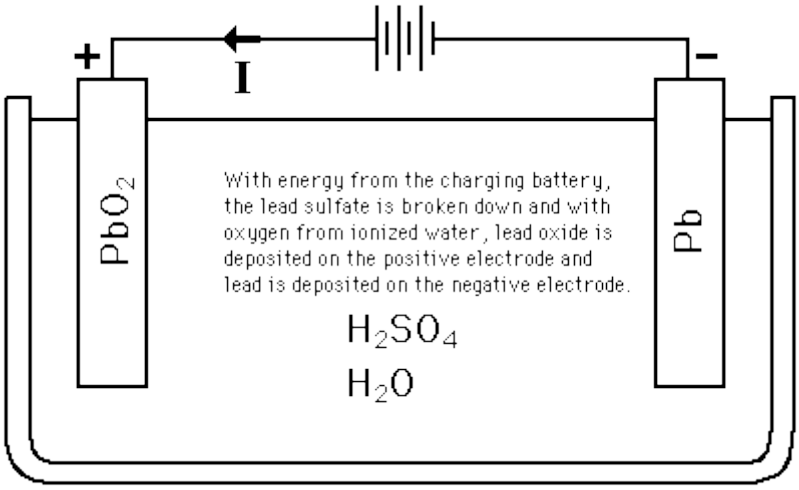

Figure 2.4: Charging the lead-acid battery diagram.

2.3 Electronic Fuel Injector

In modern petrol injection systems nowadays, most of the system optimized indirect injection system where fuel pump deliver the fuel under pressure from the fuel tank to the fuel rail before being distributed individually to each electronic fuel injector then went to each cylinder[7]. Electronic fuel injectors are electronically controlled mechanical devices that are responsible for delivering the right amount of fuel into the engine to give a suitable air/fuel mixture into the engine combustion system. The electronic fuel injectors must be able to deliver the precise amount of fuel and disperse the fuel at the right angle, pressure and spray pattern to create an optimal combustion in combustion chamber[8].

The electronic fuel injector has a 12 volt supply from the vehicle"s electrical system, which is usually a permanent supply via a relay whilst the ignition is switched on as the engine is running. The earth circuit for the injector passes through the ECU, which acts as the control switch. The electronic fuel injector must open and close it plunger valve very rapidly at high frequency as current were supplied to energized it electromagnet through the solenoid winding. The opening and closing time can often occur in around 3 milliseconds, and injectors might open and close more than 7 000 times a minute[9]. There are two basic types of fuel injectors such as low impedance injectors with a resistance of around 1.5 – 4.0 ohms that produce higher current amps value, and high impedance injectors of around 8.0 – 16.0 ohms that produce lower current amps value. This resistance value can be measured by using multimeter instrument across the two electrical terminals to obtain the value[10].

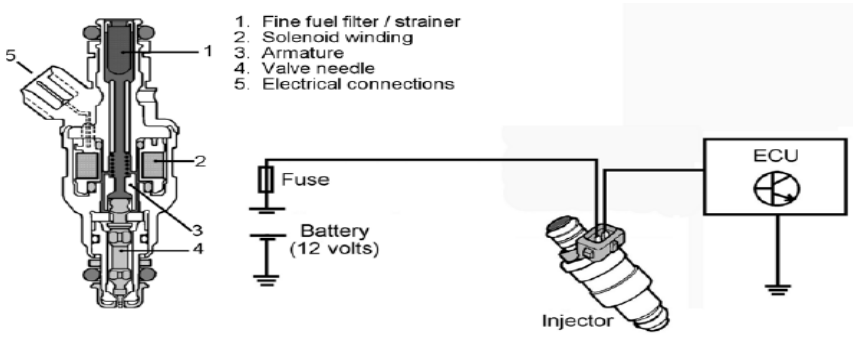

Figure 2.5: Solenoid type of electronic fuel injector and it wiring diagram in fuel injection system.

2.4 In Tank Diaphragm Electric Fuel Pump

An electric fuel pump is a component used to provide fuel through the use of electronic means as part of vehicle‟s fuel system. As in tank electric fuel pump name suggest, it means the electric fuel pump is located inside the fuel tank[11].

The diaphragm electric fuel pump type consists of 12 volts that utilise diaphragm mechanism where it is worked by a rod that is drawn into a solenoid switch which an electromagnetic switch until it opens a set of contacts to turn off the current[12]. This will provides the push on the diaphragm at the end of its travel the iron rod as the diaphragm return spring raises the diaphragm it stop the petrol from drawing into the chamber. Fuel is drawn into the pump through an inlet valve and mesh filter sock which helps keep any dirt out of the pump, then the fuel then exits the pump through a one way check valve[13]. The fuel then flows to the fuel rail and is routed to the fuel injectors, a fuel pressure regulator on the fuel rail maintains fuel pressure, and routes excess fuel back to the tank.

The diaphragm electric fuel pump type is commonly used on engines with fuel injection to pump fuel from the fuel tank to the fuel injectors. When the ignition is on, the powertrain control module (PCM) will supplies current to the fuel system circuit that will energizes a relay that supplies voltage to the fuel pump. The pump may run at a constant speed, or it may operate at a variable speed depending on engine load and speed, all of this operation is mainly controlled by the PCM[14].

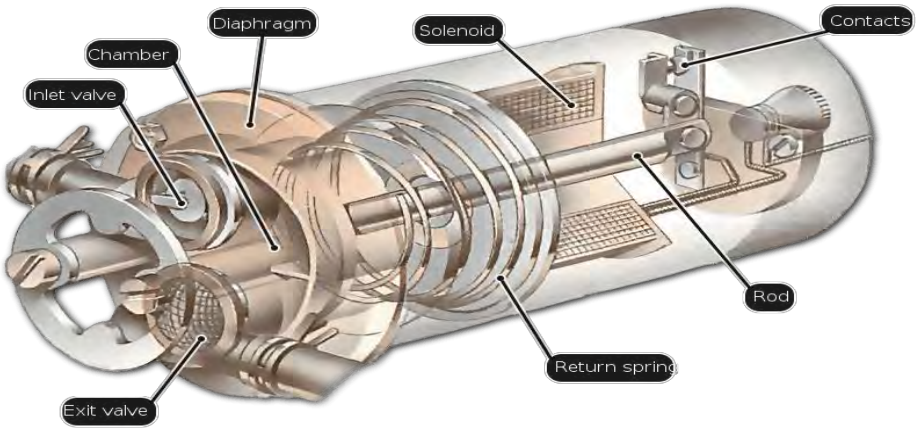

Figure 2.6: Diaphragm electric fuel pump type diagram in fuel injection system.