MENG411 CAPSTONE TEAM PROJECT

Eastern Mediterranean University
Faculty of Engineering
Department of Mechanical Engineering

Designing and Fabrication of Digital Monitoring System to Check Engine Operations

Course Coordinator:

Assist. Prof. Dr. Mostafa Ranjbar

Project Supervisor:

Assoc. Prof. Dr. Hasan Hacışevki

Team Members:

Anıl Berk ERÜN 110800
Mustafa ALSADI 139697
Volkan AKTAY 112610

Group Name: Engines Doctors

CAPSTONE TEAM PROJECT FALL 2015-2016

JURY MEMBERS;

Name of the Jury Member	Signature
Assoc. Prof. Dr. Hasan Hacışevki	
Assist. Prof. Dr. Mostafa Ranjbar	
Assoc. Prof. Dr. Qasim Zeeshan	

ACKNOWLEDGMENTS

Firstly we would like to thank almighty God on his graces…

Secondly, we would like to thank our parents and families for supporting and encouraging us continuously.

As well as, we would like to thank our professors who gave us the necessary theoretical information at Eastern Mediterranean University.

We also take this opportunity to express a profound sense of gratitude to our advisor Assoc. Prof. Dr. Hasan Hacışevki for his valuable assistance, monitoring, and warm support during the period of this project work.

Moreover, every person gave us piece of information.

ABSTRACT

The main purpose of this report is to investigate and explain the concepts of monitoring system that maximize engine operation and minimize emission and fuel consumption. First, the report examines engine constructions, and the wide range of internal combustion engine classifications. It then focuses on ignition system types and how do they function. It shows also the applied fundamental concepts of sensors such as Throttle Body Sensor, Manifold Absolute Pressure (MAP) Sensor, Camshaft Position Sensor, and Crankshaft Position Sensor. After that it illustrates in details how to set up an Engine Control Unit (ECU) linked to the sensors outputs. Finally at the end of the report diagrams and calculations are explained to crystallize the team work has been done in this report.

Key words: Monitoring System, Electric Control Module, Temperature Sensor, Engine Operation.

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LIST OF ACRONYMS

MAP	Manifold Absolute Pressure
TPS	Throttle Position Sensor
ECU	Electric Control Unit
ECM	Engine Control Module
LPG	Liquid Petroleum Gas
SI	Spark Ignition
CI	Compression Ignition
CD	Capacitor Discharge
OTS	Oil Temperature Sensor
RPS	Rotations per Seconds
ROM	Read Only Memory
RAM	Random Access Memory
CTS	Coolant Temperature Sensor
RPM	Revolution per Minute

CHAPTER 1

INTRODUCTION

The automobiles have become a trusted and servant of the human being. Engineers' designs and manufactures skills have made engines nowadays simple to operate service and maintain. To achieve the maximum of simplicity of operation, and consequently ensure greatest utility, engineers have discovered many improvements designs and have added new devices from time to time. Electronic ignition system, for example, was added to reduce the amount of maintenance, cars have electronic ignition system lasts for 60,000 km with no service for the ignition system, and more over about 90% to 95% of air-fuel mixture is burned in electronic ignition system inside the combustion chamber, thus more fuel efficiency and less emissions. Electronic control unit (ECU) is another great example for the new devices. ECU is a control unit programmed and designed for engines to operate and function between automobile systems, and it receives the inputs and outputs through sensors and actuators. These sensors and actuators send signals through a harness connected to the ECU which in its job will operate and organize the operations between engine systems.

Engine monitoring system is our project topic, its purpose to have the highest efficiency and lowest fuel consumption and emissions. The report will clarify sensors operation, how it work and how to install them, lastly connect the sensors to an ECU and program it to reach the project main purpose.

This project will be a good reference for mechanical and mechatronic departments because it will show the combination between the mechanical and mechatronic work during the engine operation.

1.1 Construction of the automobile

Over 15,000 separate parts are assembled together to manufacture an automobile. These parts are categorized into different systems. Each system is fabricated of more than two parts that work together to perform a certain job. Such as steering and braking systems.

Automotive vehicles are produced in a huge diversity of shapes and sizes (Fig1). All have the same basic systems and parts. Today many of these systems are controlled electronically by one or more Engine Control Modules (ECM). They call the ECM sometimes a computer. The basic parts and systems in an automotive are major components.

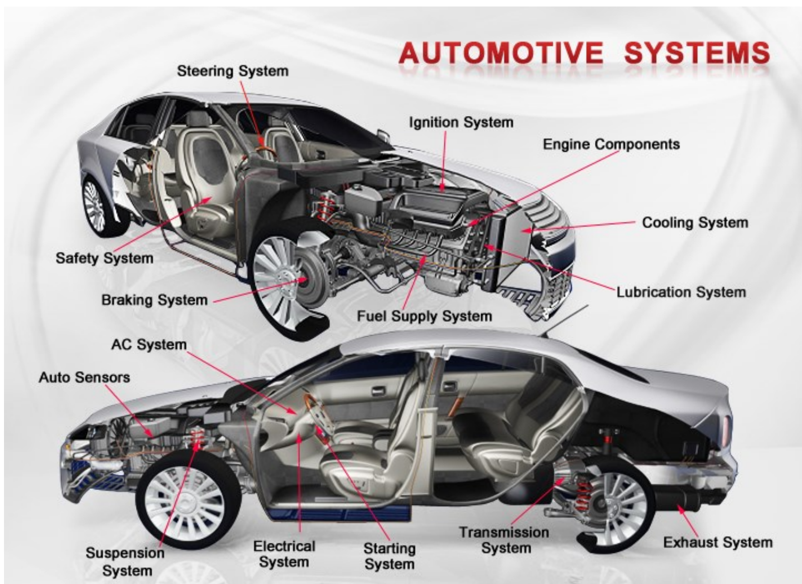


Figure 1 The major components of an automobile [1].

- Engine, or power plant, that produces energy to move the car.
- Power train (Transmission), to carry the energy from the engine to the driving wheels.
- Suspension system, this system absorbs the shocks of the tires and wheels when meeting holes and bumps in the road.
- A braking system, so the driver can stop or slow down the car.
- Electrical system, to provide the electricity for cranking the engine, recharging the battery, and powering the lights and other electrical devices.
- Body, that provides enclosures or compartments for the engine, passengers and luggage. [1]

1.2 Engine Construction

Spark ignition and diesel engines has similar type of engine construction. They consists same components like; cylinder blocks, cylinder head, crankshafts, pistons, bearings, connecting rods and valves. The biggest difference between SI and CI engine is compression ignition (CI) engine is heavier than spark ignition (SI) engine.

1.2.1 Cylinder Block

The main structural member of all automotive engines is a cylinder block that usually extends upward from the center line of the main support for the crankshaft to the junction with the cylinder head. The block serves as the structural framework of the engine and carries the mounting pad by which the engine is supported in the chassis. Large, stationary power-plant engines and marine engines are built up from a foundation, or bedplate, and have upper and lower crankcases that are separate from the cylinder assemblies. The cylinder block of an automobile engine is a casting with appropriate machined surfaces and threaded holes for attaching the cylinder head, main bearings, oil pan, and other units. The crankcase is formed by the portion of the cylinder block below the cylinder bores and the stamped or cast metal oil pan that forms the lower enclosure of the engine and also serves as a lubricating oil reservoir, or sump. [2]. Also, cylinder block contains valve and valve mechanism on the top.

1.2.2 Cylinder Head

The cylinder head is assembled on top of cylinder block which closes cylinder to form combustion chamber. It has a smooth surface which is sealed by head gasket. Also, cylinder head has one more duty that provides spaces that air and fuel pass through in cylinder and allow exhaust gas to escape.

1.2.3 Crankshaft

It is a mechanical part that located in the bottom of engine and it converts reciprocating motion of pistons to rotational motion. It is connecting with flywheel so it transmits power to flywheel, clutch, transmission and the differential.

1.2.4 Camshaft

Where the camshaft is mounted in the engine block, small metal cylinders tappets sit in channels above each cam, and from the tappets metal pushrod extend up into the cylinder head. The top of each pushrod meets a rocker arm which bears against the stem of a valve, which is held in a raised (closed) position by a strong coiled spring the valve spring. As the pushrod rises on the cam it pivots the rocker arm, which pushes the valve down (open) against the pressure of its spring. [3]

1.2.5 Pistons

The piston moves due to pressure of combustion and transmits this pressure to connecting rod and crankshaft. Also piston rings and piston pin are located on the piston so another job of the piston is hold them while operating in the cylinder. Pistons are made from cast or forged aluminum alloy. Forged pistons are commonly used in Today's cars.

1.2.6 Bearings

Bearings are needed where rotational motion occurs between engine parts. Generally these bearings are sleeve bearings that fit like sleeves around the rotating shafts. Journal is a part that rotates in the bearing.

1.2.7 Connecting Rods

Connecting rods are used for connection between crankshaft and pistons. One side of connecting rod connects with crankpin and the other connects with piston pin. They must be strong enough to withstand of pistons moving. So, designs of connecting rods are form of the I-beam to give highest strength and lowest weight.

1.2.8 Valves

Generally there are two valves operates in the engine, one of them is intake valve, and other one is exhaust valve. These valves must operate at different times so each valve has own mechanism. Valve motions are driven by camshaft. Camshaft lobes push rocker arm to open valves. Then, heavy springs held valves to close them immediately.

1.3 Classification of Internal Combustion Engines

Classification of Internal Combustion Engines can be divided into: Application, Engine Design, Operating Cycle, Working Strokes, Valve design and location, Type of Fuel, Mixture Preparation, Ignition, Charge Stratification, Combustion Chamber Design, and Cooling. The importance classifications will be mention below;

1.3.1 Engine Design

a) **Reciprocating Engines** divides into two group; Single Cylinder, Multi Cylinder (In line, V, Radial, Boxer etc.).

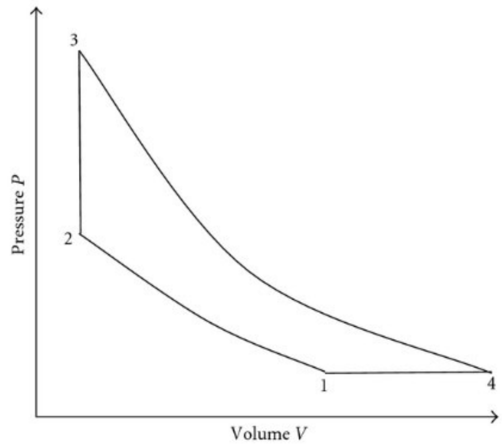
b) **Rotary** divides into two group; Single and Multi Rotor.

1.3.2 Operation Cycle

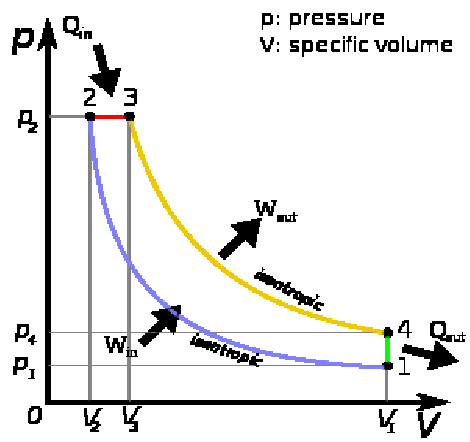
- Otto Cycle: it is used for conventional Spark Ignition Engines.
- Atkinson Cycle: it is designed for supply efficiency at the expense of shorter intake stroke.
- Miller Cycle: it is designed for closing time of inlet valve type Spark Ignition Engines.
- Diesel Cycle: Cycle of ideal diesel engine.
- Dual Cycle: Cycle of actual diesel engine.

Figure 2 shows the each cycle (1 Atkinson, 2 Diesel, 3 Dual, 4 Miller and 5 Otto

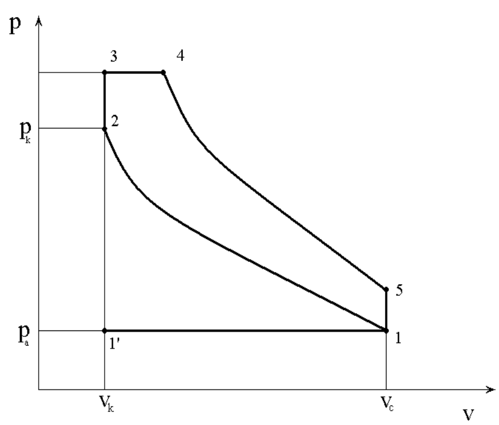
Atkinson Cycle



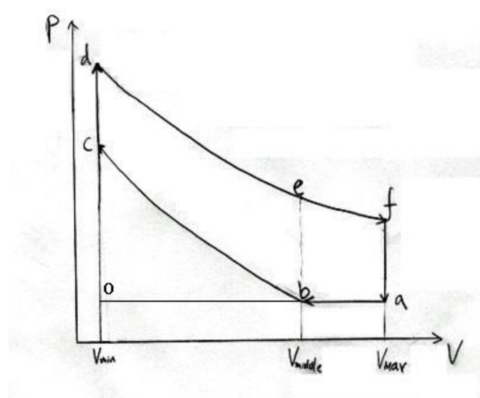
Diesel Cycle



Dual Cycle



Miller Cycle



Otto Cycle

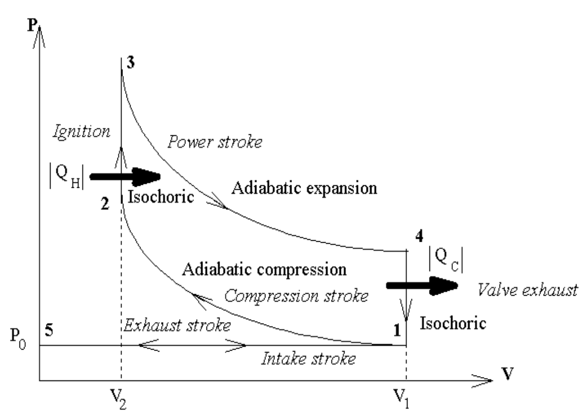


Figure 2 Atkinson, Diesel, Dual, Miller and Otto Cycles [3]

1.3.3 Working Strokes

a) Four Stroke Engine: it is type of internal combustion engine that operates two crankshaft revolutions to complete one cycle.

b) Two Stroke Engine: it operates one crankshaft revolution to complete one cycle.

1.3.4 Type of Fuel

1) **Conventional Type:** i) Petrol, Diesel Type of Engines.

   ii) Other sources like Coal, Wood to burn.

2) **Alternative:** i) Liquid Petroleum Gas (LPG): Uses some gases like propane and butane to burn.

   ii) Compressed Natural Gas (CNG): It compressed natural gas (which is mainly methane) to burn it.

1.3.5 Mixture Preparation Types

1) **Carburetor Type:** It is a mechanical part that is used to mix vaporized fuel and air for the combustion.
2) **Fuel injection Type:** It is a system that uses nozzle to inject high pressure fuel in to combustion chamber. It is divided into Diesel injection, Gasoline injection.

1.3.6 Ignition Type

1) **Spark Ignition:** It is type of ignition that is used in Gasoline Engines. Spark plugs are used in this type of ignition systems to ignite air fuel mixture.
2) **Compression Ignition:** This method is used in Diesel Engines that air is compressed in compression stroke and fuel is injected on to compressed air to start the combustion.

1.4 Brief Information about the Engine:

The Engine which is located in the work shop has a serial number 12H702E-H3511. Picture of our engine is provided in Figure 3.

- 12 mean 1275cc.
- H means transverse.
- 702 is the tricky part, it seems to be from the Austin 1300 of 1967-1973. So 702 means: "mechanical fuel pump, alternator, negative ground, standard ratio rod change gearbox with inboard CV ("pot") joints."
- E means carb/crankcase ventilation.

Figure 3 View of used engine

The suspected car that carried that engine. It is Mark II (1967-71) Austin 1300 is provided in Figure 4 below.

Figure 4 Picture of Mark II (1967-71) Austin 1300 [3]

1.5 Objective of the Project

- **Re-run the engine again**

  The engine needs a full maintenance since the engine is not running for more than a decade and especially the cooling system, fuel system, electrical system and should be diagnosed and monitored after the maintenance to make sure that the engine is reliable for the upcoming upgrades.

- **Install a monitoring system**

  A full monitoring system will be installed using sensors and actuators (will be mentioned and explained in details through the report) and the operation of these sensors and actuators will be combined with a programmed ECU.

- **Programming**

  The ECU will be programmed, tested and diagnosed to change the operation settings of the engine to get the highest efficiency, lowest fuel consumption and lowest emissions

1.6 Report Organization

The whole report will summarize the engine construction, classification of internal combustion engines, ignition systems, sensors, ECU and how to connect the ECU with the sensors then monitor engine through programmed software. And will let the reader to be familiar with these words in his/her carrier as a mechanical/mechatronic engineer.

CHAPTER 2

Literature Review

2.1 History of the Automobile:

Figure 5 An early Ford car built in 1896. [4]

The automobile has been around for more than 115 years. The first automobiles were basically horse-drawn buggies and carriages powered by gasoline-fueled engines instead of horses. They were called gas buggies and horse less carriages. The early engines had one cylinder that could produce only one or two horse power. A horse power is roughly the power of one horse. [4]

The first automobile was a gas buggy built by Karl Benz in Germany in 1885 and 1886. It had three wheels, one in the front and two in the rear. That year another German, Gottlieb Daimler, mounted an engine in a wooden bicycle. The next year he also built a four-wheel gas buggy. [4]

Two brothers, Charles and Frank Duryea, built the first automobile in the United States in 1893. By 1895 Henry Ford, Ransom Olds, and others were building cars in this country. Fig (5) shows a car built by Ford in 1896. The early cars were crude compared to today's cars. But they ran most of the time. [4]

By 1900, several factories in Detroit and elsewhere were making automobiles. Most manufactures were building cars that kept getting bigger and more expensive. Ford wanted to make cars as cheaply as possible so more people could buy them. By 1908, he had the car in production that put America on wheels. This was the Model T Ford, manufactured on the first modern assembly line. During the next 20 years, 15 million T Fords were sold. [4]

Today, the automotive industry is one of the biggest in the world. In the United States, about 12 million people works in the automotive industry and its related businesses. This is one out of every seven workers. The job of about a million of these men and women is to serve automotive vehicles and keep them running. [4]

Previous mechanical engineer students have done modifications on the same engine since 2002, they have rebuilt the engine and replaced the ignition system, and from that point we will clarify the ignition system in details.

2.2 Purpose of ignition system

The purpose of ignition system is to ignite the compressed air-fuel mixture in the engine combustion chamber. This should occur at the proper time for combustion to begin. To start combustion, the ignition system delivers an electric spark that jumps a gap at the combustion chamber ends of the spark-plugs. The heat from this arc ignites the compressed air-fuel mixture. The mixture burns, creating pressure that pushes the pistons so the engine runs. [4]

The ignition system may be either a contact-point ignition system or an electronic ignition system.

2.3 Contact-point ignition system

2.3.1 Components in contact-point ignition system

The ignition system Fig (6) includes the battery, ignition switch, ignition coil, ignition distributor (with contact points and condenser), secondary wiring, and spark plugs. Note that the original ignition system was contact-point ignition system.

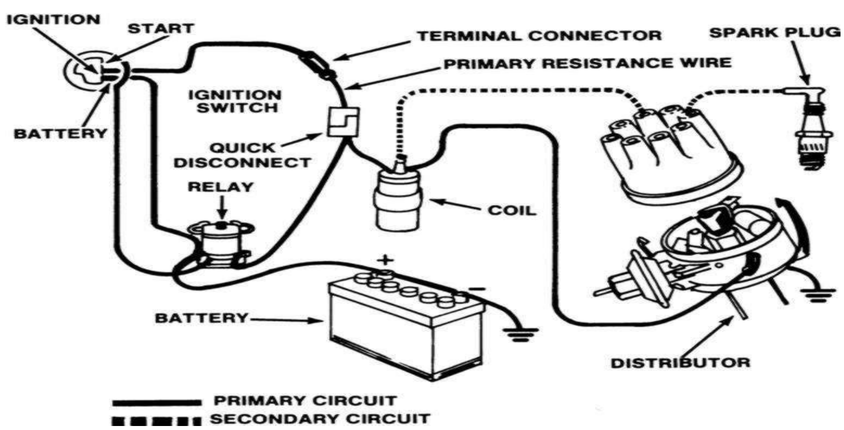


Figure 6 Components in the contact-point ignition system [4]

2.3.2 Ignition switch

The ignition switch connects the ignition coil to the battery when the ignition key is ON. When the key is turned to START, the starting motor cranks the engine for starting.

2.3.3 Ignition coil

The ignition coil is a step-up transformer that raises the battery voltage to a high voltage may go up to 25.000 Volts. The high voltage causes sparks to jump the gap at the spark plugs.

2.3.4 Ignition distributor

The ignition distributor does two jobs. First, it has a set of contact points or breaker points that work as a fast-acting switch. When the points close, current flow stops and the coil produce a high-voltage surge. A condenser connects across the points. It aids in the collapse of the magnetic field and helps reduce arcing that burns away the points.

Second, the distributor distributes the high-voltage surges to the spark plugs in the correct firing order. A coil wire delivers the high voltage from the coil to the center terminal of the distributor cap. Inside the cap, a rotor is on top of the distributor shaft is driven from the engine camshaft by a pair of spiral gears. The rotor has a metal blade. One end of the blade contacts the center terminal of the distributor cap.

When the rotor turns, the other end passes close to the outer terminals in the distributor cap. These are connected by spark-plug wires to the spark plugs. The high-voltage surge jumps the small gap from the rotor blade to the terminal. The spark-plug wires carry the high voltage surge to the spark plug in the cylinder that is ready to fire.

2.3.5 Secondary ignition cables

The secondary cables or wiring include the coil wire and the spark-plug wire Fig (6). These cables connect between the center of the ignition coil and the distributor cap, and between the distributor cap and the spark plugs. The construction of an older spark-plug wire with the resistance cable now used on all cars. Secondary cables for contact-point ignition systems have a 7mm diameter.

2.3.6 Spark plugs

The spark plug Fig (6) has two solid-metal conductors called electrodes positioned to form a gap. The gap is between the insulated center electrode and the ground electrode. The spark jumps the gap to ignite the compresses air-fuel mixture in the engine cylinders.

2.4 Electronic Ignition System

By the early 1970s, most automotive engines using a contact-point distributor could not meet exhaust-emission standards. Federal regulations required the ignition system to operate for [~80.465 km] with little or no maintenance. Contact points cannot do this. They burn and wear during normal operation. This changes the point gap, which changes ignition timing and reduces spark energy. Misfiring and increased exhaust emission result. [4]

Most 1975 and later automotive engines have an electronic ignition system Fig (7). It does not use contact points. Instead, transistors and other semiconductor devices act as an electronic switch that turns the coil primary current on and off. [4]

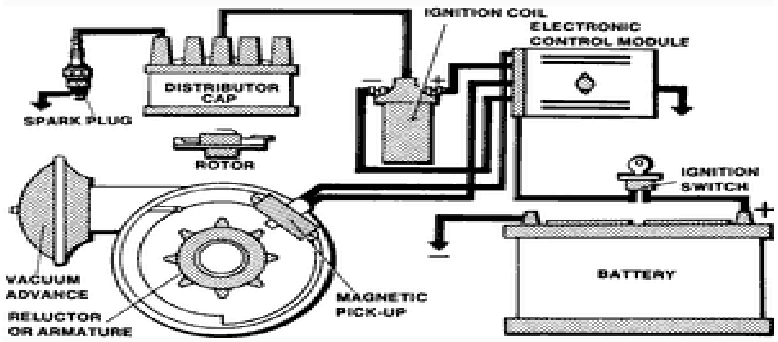


Figure 7 Electronic ignition system [4]

There are four basic types of electronic ignition systems:

1. Distributor type with mechanical centrifugal and vacuum advanced. (The modified one from previous students).
2. Distributor type with electronic spark advance.
3. Distributorless type with multiple ignition coils.
4. Distributorless type with direct capacitor-discharge (CD) ignition for each spark Plugs. [4]

In our report we will explain in details the first type due to modifications that have been done on the engine.

Distributor with mechanical spark advance

Contact-point and electronic ignition systems are similar in operation and also often in construction. Both distributors Fig (8) may have centrifugal and vacuum advance mechanisms. The major difference is the use of and electronic switch instead of mechanical switch (contact points) to control the primary current.

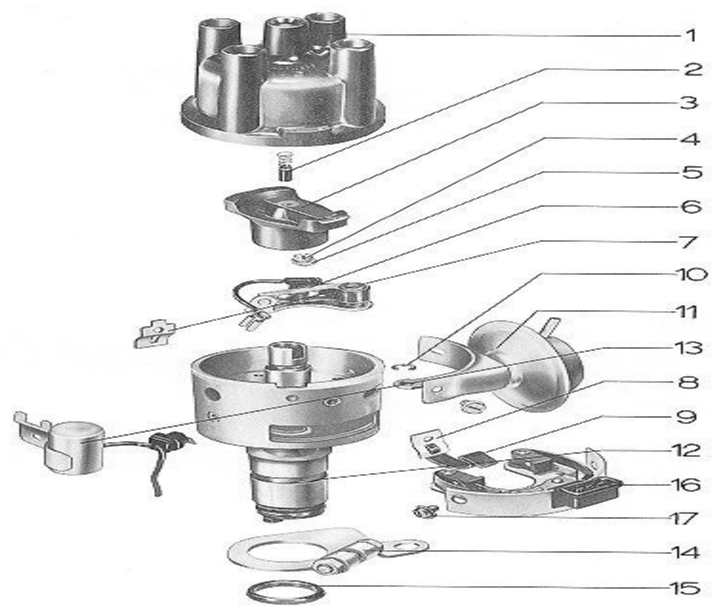


Figure 8 Disassembled electronic-ignition distributor. [4]

Fig (9) compares the primary circuits of a basic electronic-ignition system and the contact-point ignition system. The electronic distributor has an armature or reluctor and magnetic sensor to instead of a breaker cam and contact points. Like the breaker cam, the reluctor has the same number of teeth or tips as there are cylinders in the engine. When the reluctor rotates, each tooth creates a voltage pulse in the pickup coil. This signals the ignition module to open the primary circuit.

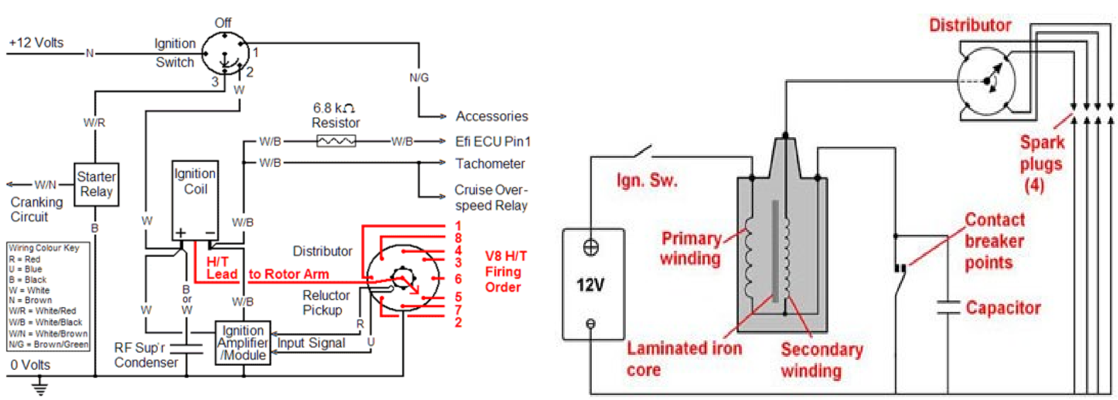


Figure 9 Comparison between contact-point & electronic ignition systems. [4]

The ignition module may be separate unit or mounted on or in the distributor. Engines with and electronic-ignition-control system may not have a separate ignition module. The engine controller or Electronic Control Module (ECM) completely controls the ignition system. [4]

2.5 Sensors

Today's cars are covered with various sensors to provide critical data for safety, performance, comfort and convenience functions. Fuelling control systems and measuring inlet manifold absolute pressure were the most successful applications of sensors and they are becoming more important day by day. Also, there are other sensors that increase the powertrain performance. These are including engine speed, throttle position, intake air flow, atmospheric and air temperature, coolant temperature and oxygen sensors. Nowadays, modern cars use electronically controlled electrically actuated systems and due to these trends new opportunities have created for sensor developers.

2.5.1 Throttle-Position Sensor

Throttle Position Sensor (TPS) is a sensor that contains the throttle valve. Usually it is mounted on the intake manifold. Accelerator pedal is connected with throttle valve by a linkage, so depressing the pedal opens throttle valve. When the throttle valve opens, more air enters the engine. ECU must arrange proper air-fuel mixture to feed the engine and it depends on the position of the throttle valve. ECU must always be informed position of throttle valve. So, duty of Throttle Position Sensor (TPS) is continuously report the position of throttle valve to the ECU.

Moreover, throttle valve position is important for idle speed and in the shift patterns of automatic transmissions and transaxles. On some engines, while car speed is decreasing, throttle valve close, ECU shuts off fuel flow so it prevents over-rich mixture. Figure (10) illustrates mounting place of throttle body sensor

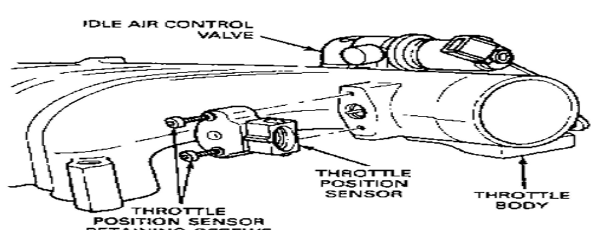


Figure 10 Mounting place of throttle position sensor [4]

The wiper blade has a contact that rides on the coil and connects to the throttle-valve shaft. As the throttle-valve position changes, the wiper blade moves along the coil. When the throttle valve is closed, the blade is at the grounded end of the coil. Only a small voltage signal is sent to the ECM. As the throttle valve moves toward the open position, the wiper blade swings toward the 5-Volt end of the coil. This sends an increasing voltage signal to the ECM. The voltage tells the ECM the exact position of the throttle valve. [4]

2.5.2 Measuring Intake Air Flow

The ECU must have information about the amount of air flowing into the intake manifold. According to measured air flow, ECU calculates the amount of fuel to inject in cylinders. Air flow can be measured:

- By using throttle position , intake-manifold vacuum and crankshaft position
- By using vane, air-flow sensor plate, hot-wire induction and heated film

2.5.3 Measuring Intake-Manifold Absolute Pressure (MAP)

There are two ways to measure intake-manifold vacuum; first is by using vacuum gauge and second is by using Manifold Absolute-Pressure (MAP) gauge.

These two gauges are similar to each other. Flexible diaphragm that both of them contain separate two chambers in the gauge. The difference is intake-manifold vacuum against atmospheric pressure is measured by vacuum gauge and intake manifold vacuum against a sealed-in a vacuum is measured by MAP gauge. Accuracy of MAP gauge is better because vacuum gauges measures vary data.

2.5.4 Coolant Temperature Sensor

Coolant Temperature Sensor is a sensor that has to report engine coolant temperature to the ECU. ECU gives order to fuel-metering system to supply fuel according to coolant temperature. Also ECU can arrange ignition timing to suit engine temperature. Some engines use electric fan to control the engine temperature. ECU makes a decision to shut down or turn on the fan depends upon the engine getting hot or cold.

2.5.5 Engine-Speed Sensor

Engine-speed sensor monitors the crankshaft position to tell the ECU turning speed of crankshaft. According those values, ECU controls ignition spark advance, fuel metering and electronic automatic transmission shifts. ECU counts number of RPS (Rotations per Seconds) to detect the crankshaft speed. Figure (11) provides diagram of engine speed sensor

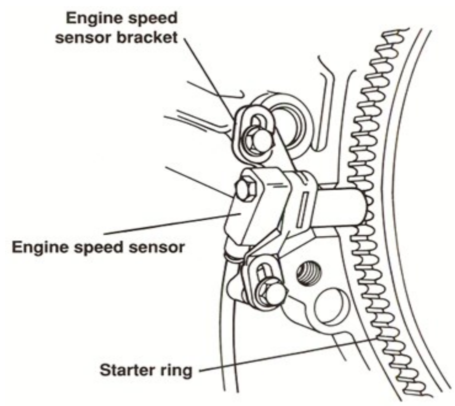


Figure 11 Location of Engine Speed Sensor. [5]

2.5.6 Camshaft-Position Sensor

The camshaft position sensor uses voltage pulses to determine the number 1 piston position. Camshaft position sensor also called cam-sensor sends signals and ignition module understands that signals as the beginning of each ignition cycle. So, all spark plugs fired during the two crankshaft revolutions. During the one complete cycle, crankshaft position sensor creates pulses that equal the number of cylinder but only one pulse is created by camshaft sensor. It determines which coil to be fired according to ignition sequence.

2.5.7 Oil Temperature Sensor (OTS)

Oil Temperature Sensor (OTS) is used to achieve temperature of oil in the engine. Purpose of this sensor is measuring the temperature of oil that cycles in the engine during operation and inform the obtained data to ECU. The important point of using oil temperature sensor is, if the oil temperature is too high, the engine will face a danger. When oil temperature sensor detects excess oil temperature, it signals the gauge to show operator about excess temperature. So operator can switch of the engine to prevent from over-heating.

2.6 Electronic Control Module (ECM)

Electronic Control Module (ECM) is also called Electronic Control Unit (ECU) controls all electronic systems in cars. ECM is a brain of the car and makes decision to run the automobile. It contains two main parts; microprocessor and memory. Figure 12 provides view of Electronic control unit.

Figure 12 View of Electronic Control Unit (ECU) [5]

2.6.1 Microprocessor

Microprocessor is a device that serves to control information flow. It is designed with many programs that help to solve problems. By using program, it is able to do calculations and that calculations are used to create ways to solve the problem. Although the problem may contain many parts, microprocessor can solve the problem quickly (around thousands of second).

The microprocessor chip is placed into carrier. Pins has a duty to connect circuits to input and output devices. Their signals transmitted to ECM with connections.

2.6.2 Memory

As we mentioned before, microprocessor needs information to solve problems and it cannot store this information itself. So, the microprocessor needs an electronic storage that allows to access to get information which contains formulas and some specifications. This electronic storage is called memory.

There are two types of memory that is used for microprocessor and computer. First one is Read Only Memory (ROM) and second is Random Access Memory (RAM). The difference between ROM and RAM is, ROM contains permanent information that microprocessor cannot write or change it. It has only permission to read information inside the ROM, but on the other hand RAM information can be changed or rewritten by microprocessor.

CHAPTER 3

Design Analysis and Calculation

3.1 Preliminary Design:

The engine has not been working since 2002 so a full diagnosing should be done. The diagnosing procedure will be discussed below in phases:

3.1.1 Compression test:

Is a maintenance test is applied on an engine to contend the ability of the cylinders to hold the high air pressure inside the combustion chamber during the engine operation. If a cylinder fails in a compression test the engine need to be disassembled and check where the leaking coming from.

Fortunately we did the compression test to our engine in the workshop with our supervisor as an advisor for our group members and we got great results. Table 1 shows the results that we obtained.

Table 1 Compression Test of Cylinders

PISTON NO	PRESSURE
1	9.5kg/cm²=135 psi
2	7.5 kg/cm²==106 psi
3	9 kg/cm²==128 psi
4	7 kg/cm²==99 psi

3.1.2 Cooling System:

Water pump: It is an impeller pump that located on the front of the engine. Water pump attached with crankshaft by belt. When crankshaft rotates, it transmits the rotation to the water pump impeller by teeth belt. During impeller rotation, curved blade sucks coolant from the radiator and pushes it strongly to the water jackets inside the engine. Prevention of impeller shaft is done by seals. These seals prevent leakage from bearings. So, lubrication is not required for the impeller shaft.

Thermostat: is a valve that located on the front of radiator. It regulates coolant flow depend on temperature of engine. When the engine is cold, thermostat closes so coolant cannot reach the radiator. While engine getting warmer, thermostat allow hot coolant to pass and radiator cools down the coolant again. Thermostat is very useful part that allows the engine operation more efficiently. When thermostat is closed, engine reaches its operating temperature quickly. So, this makes better fuel consumption, exhaust emission and reducing friction of the rotating parts.

Core plugs: cores are applied to shape the internal cavities when the engine block is casting, these cavities are commonly the cooling passages, and these punctures are premeditated to support internal sand form.

The thing that attracts us is an excessive corrosion in the cooling system, so a new water pump has been bought, new thermostat housing, new engine block water plugs and for sure new hoses for the cooling system. Figure 13 and Figure 14 shows pictures of old rusty cooling system components compared with new purchased parts.

After this maintenance for the cooling system the water can flow easily with, and engine now is cooled well to operate and perform perfect.

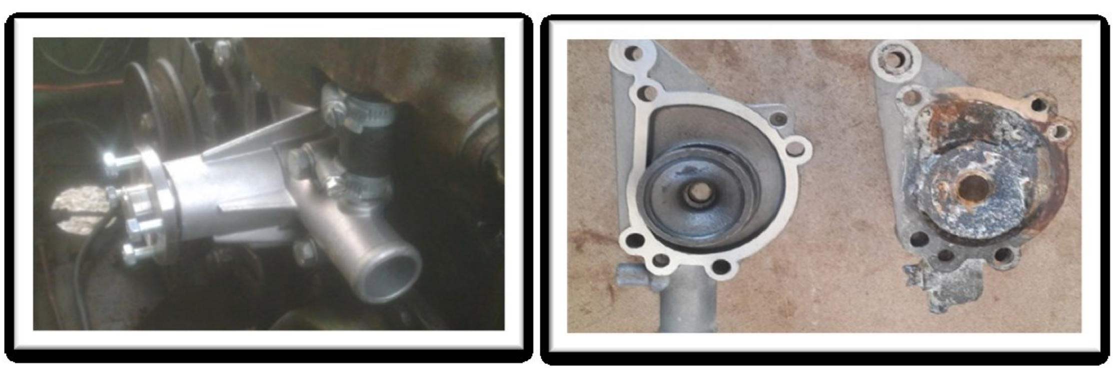


Figure 13 Rusted water pump compared with new one.

Figure 14 Rusted cooling system components compared with new parts

3.1.3 Fuel System:

Fuel Pump: The fuel pumps sends fuel from the fuel tank to the carburetor or fuel injectors. There are two types of automotive fuel pumps: mechanical and electrical. Most carbureted fuel systems use a mechanical fuel pump. It usually mounts on the side of the cylinder block (as in our engine). An eccentric on the camshaft operates the pump. The rotating eccentric rocks the rocker arm up and down. This flexes a diaphragm to produce the pumping action. Some overhead-camshaft engines have the mechanical fuel pump mounted on the side of the cylinder head. An eccentric on the overhead camshaft operates the fuel-pump rocker arm. [4]

Unfortunately the old fuel pump is leaking fuel from the gasket so there was not enough pressure to pump fuel into the carburetor, thus a new fuel pump is required, we searched a lot for a new one locally but we couldn’t find, at the end we managed to get a used good condition one Figure 15 from the Greek side. The figure below shows the used purchased fuel pump installed on the side of the cylinder block.

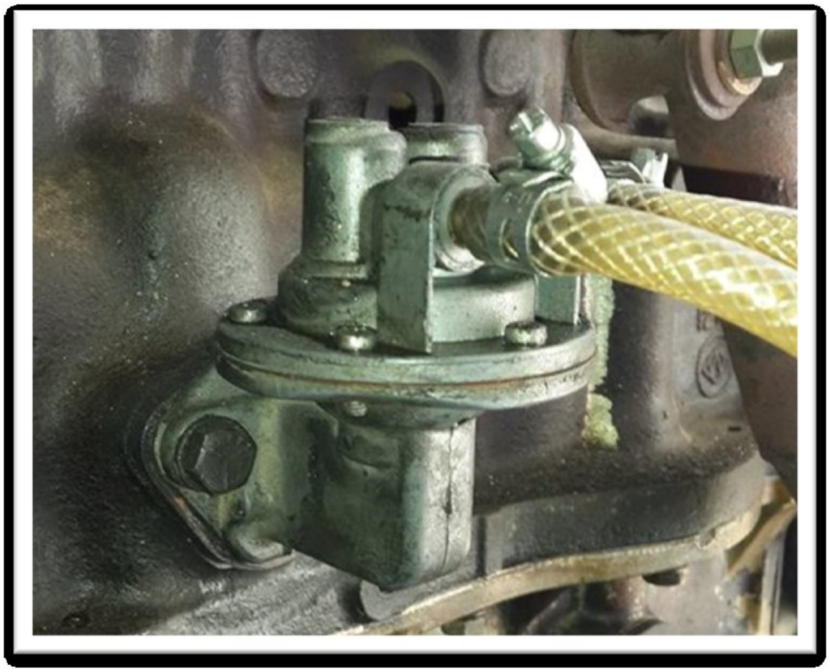


Figure 15 the second hand (new) fuel pump installed on the side of the cylinder block.

Choke Unloader: When the engine does not start quickly, there is a part that called choke can be used for better engine operation. Accumulation of gasoline in the intake manifold makes engine harder to start because of poor air flow. This problem can be eliminated by using pedal that controls opening and closing the choke. Pedal is linked with the choke so if pedal is pushed to the floor, choke valve opens and air flow freely to the carburetor. Regrettably the engine has not got any chock on it so a new chock is wanted. The Figure 16 below shows the new chock installed on the engine.

Figure 16 Installed choke and control unit display.

Fuel lines: one of the main properties of fuel lines that they can maintain the fuel pressure flowing inside them, unluckily the old fuel lines were solid and not flexible at all so we got a new fuel lines and installed them. Figure 17 shows the replaced fuel lines.

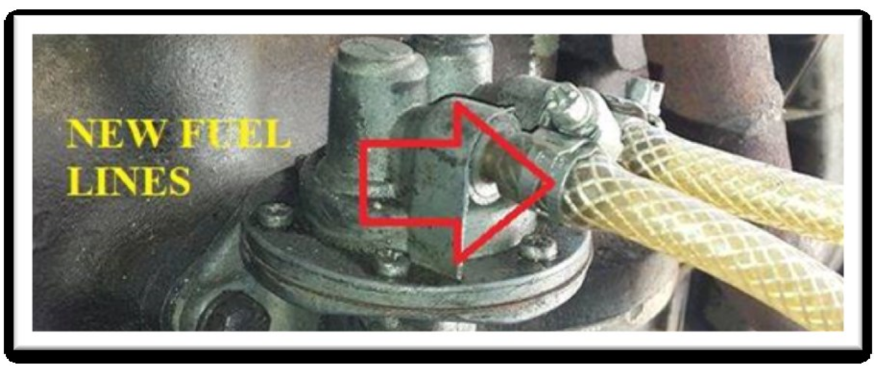


Figure 17 Installed new fuel lines.

Eventually the fuel system is now sustainable and maintained very well so fuel delivery can reach the carburetor with no leak.

3.1.4 Ignition System:

After the full service for cooling system and fuel system. A new coolant was added to the engine, oil filter was replaced and engine oil was topped up, after that the engine should work, however the engine did not crank from the switch but it was cranking if we shortcut the starting solenoid, thus the engine starter solenoid has been changed but still the engine is not cranking. The wiring has been checked through a test lamp, and we figured out that the toggle switch is not working neither, consequently we have replaced the switch with a new one and we re-did all the ignition wiring according to the diagram below Figure 18.

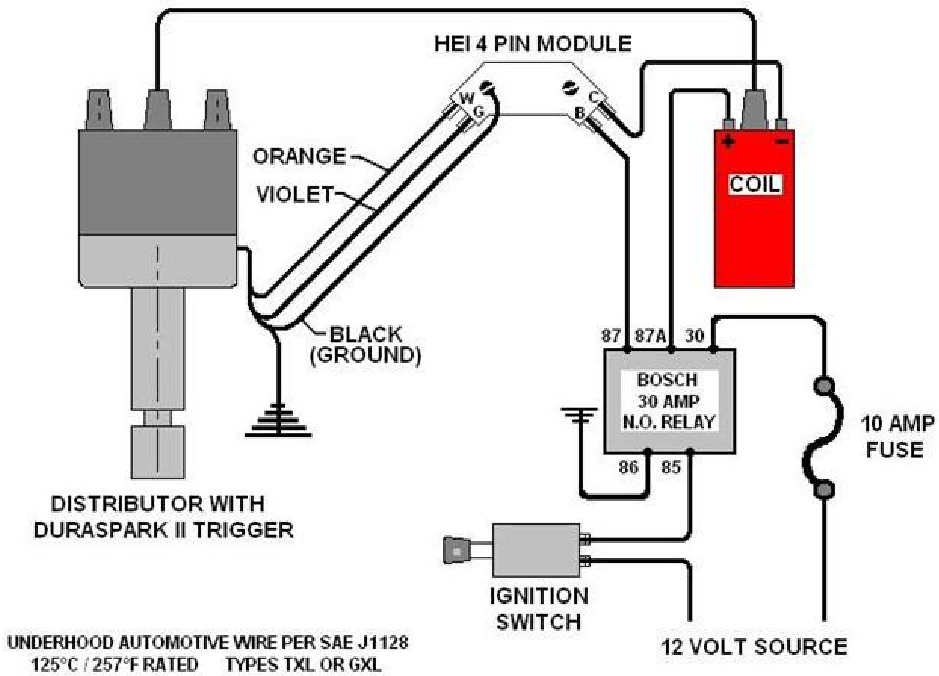


Figure 18 Ignition System Wiring Diagram. [5]

After the previous phase, all the probabilities show that the engine should run and it really runs after a couple of tries, but it was vibrating too much (misfiring) so HEI wires have been replaced to guarantee a full mixture burn with no misfiring and smooth idling.

Finally, engine now is maintained, monitored and sustainable enough for the upcoming modification (Monitoring System).

3.2 Detailed Design:

3.2.1 Design Selection

We had selected our design according to Pugh's matrix; these are the three concepts which we had considered in our design selection period.

- Concept A is Microquirt ECU with 5 Sensors (Temperature and Pressure)
- Concept B is Ardunio with 3 Temperature Sensors
- Concept C Megasquirt ECU with electrical ignition system with 2 sensors

Table 2 Pugh's Matrix

Criteria	Importance(/9)	Concept(A)	Concept(B)	Concept(C)
Easy to Install	6	3	5	2
Design	8	7	7	7
Cost Effective	9	2	8	1
Safety	6	8	8	8
Reliablity	7	5	6	3
Weighted Total	36	25	**34**	21

According to Pugh's Matrix we selected concept B which is the most suitable for our project requirements.

3.2.2 Arduino:

Arduino is an open-source prototyping platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board. To do so you use the Arduino programming language (based on Wiring), and the Arduino Software (IDE), based on Processing. We have chosen The UNO type because it is the best board to get started with electronics and coding. If this is our first experience with electronics and coding, the UNO is the most robust board we can start playing with. The UNO is the most used and documented board of the whole Arduino & Genuino family. [5]. The Figure 19 below explains the Arduino UNO components in details.

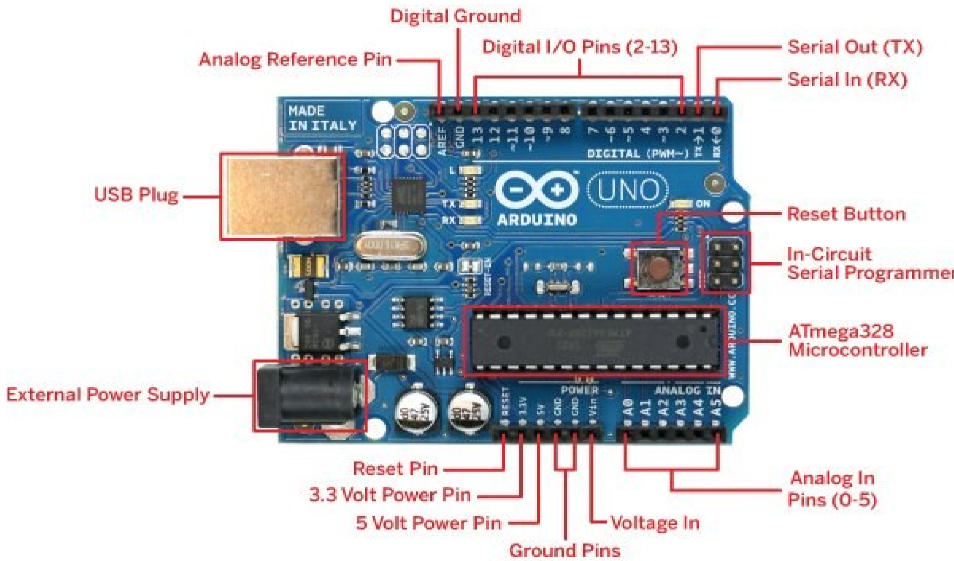


Figure 19 Arduino Components [5]

3.2.3 Chosen Sensors:

Three main types of sensors were chosen after the approval of the group advisor Dr.Hasan. All three sensors were selected for measuring various temperatures; two of them are gauging liquids temperatures and the last one for air temperatures.

- Coolant Temperature Sensor (CTS).
- Oil Temperature Sensor (OTS).
- Intake Air Temperature.

All three sensors were explained in Chapter 2.

3.3 COST ANALYSIS OF THE REPORT

Table 3 Cost Analysis of the Monitoring Engine System

ITEM	QUANTITY	SUPPLIER	COST(TL)
New Water Pump (OEM)	1	ZET	150
Fuel Pump	1	AUTOHOUSE	150
New Thermostat Housing	1	ZET	55
New Toothed Belt	1	ZET	45
New Radiator Upper Hose	1	ZET	40
New Radiator Lower Hose	1	ZET	40
Coolant Temperature Sensor (CTS)	1	SOLARBOTICS	240
Oil Temperature Sensor (OTS)	1	SOLARBOTICS	240
Intake Air Temperature	1	MEASUREMENTS SPECIALISTIES	240
ECU	1	POLOLU ROBOTICS&ELECTRONIC	1000
Shipping	-	-	280
Customs	-	-	250
Silicon	1	BOSCH SERVICE	25
Core Plugs	5	ZET	15
Engine Oil (20W50)	5 liters	BOSCH SERVICE	50
Fuel	6 Liters	ALPET	20
Fuel Line	2 meters	ZET	25
Solenoid	1	AUTOHOUSE	50
HEI wires	4	AUTOHOUSE	75
Choke	1	AUTOHOUSE	75
TOTAL COST			2710

3.4 Calculation of Actual Air Flow and Mechanical Efficiency

Brake Power (b_p) is the engine power that actually reaches the output shaft or flywheel of an engine. It is the power that is measured by a dynamometer.

The tested engine has a Torque (T) = 100 Nm at 2800 rpm, thus N=2800 RPM

So, brake power is calculating as follows;

$$b_p = \frac{2\pi TN}{1000} \text{ [6] } \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{ (1)}$$

- Torque (T) = 100 Nm.
- N=2800/60= 46.6 rev/s.

$$b_p = \frac{2x\pi x100(Nm)x46.6(\frac{rev}{s})}{1000} = 29,279\ KW$$

Indicated Power (ip) is the power that is developed inside the engine cylinders. It is determined by measuring the pressures inside the cylinders while the engine is on test.

$$ip= \frac{PlaN}{1000} \text{ KW [6] } \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{ (2)}$$

The experimented engine has 4 cylinders thus, 4 stroke engine develops and indicated mean effective pressure of P= 8 bar =8 x10^5 N/m^2, at 2800 rpm, L is length of stroke in meters $l = \frac{81.28\ mm}{1000} = 0.08$m, bore diameter is 112.83 mm, so the cross sectional area for the cylinder bore is 0.01m^2.

- N is the number of power strokes per second.
- P is indicated mean effective pressure.
- L is length of Stroke.
- a is the cross sectional.

$$N = \frac{\text{number of cylinders}}{2} x \frac{\text{rev/min}}{60}$$ [6]............................... (3)

$$N = \frac{4 \text{ cylinders}}{2} x \frac{2800 \text{ rpm}}{60} = 93.3 \text{ power stroke per second}$$

$$ip = \frac{800000 \left(\frac{N}{m^2}\right) x0.08(m) x0.01(m^2) x93.3(\text{power stroke per second})}{1000} = 59.712 \text{ kW}$$

The mechanical efficiency of an engine is defined as a brake power/indicated power

$$\text{Mechanical efficiency} = \frac{\text{Brake Power}}{\text{indicated power}}$$ [6]............................... (4)

$$\text{Mechanical efficiency} = \frac{29,279}{59,712} x100\% = 49.03\%$$

$$\text{Volumetric Efficiency} = \frac{\text{actual air flow}}{\text{theoretical air flow}}$$ [6]............................... (5)

$$\text{Theoretical air flow} = \text{swept volume of one cylinder x no of cylinders x} \frac{\text{rev/min}}{2}$$

$$\text{Swept volume of one cylinder} = \frac{\pi d^2 l}{4}$$ [6]............................... (6)

$$\text{Swept volume of one cylinder} = \frac{\pi \text{ x } 0.11x0.11x0.08}{4} = 7.6x10^{-4} m^3$$

$$\text{Theoretical volume of air} = 7.6x10^{-4}(m^3)x4x\frac{2800 \text{ rpm}}{2} = 4.256 \text{ m}^3/\text{min}$$

$$\text{Volumetric efficiency} = 70\%$$

$$\text{so, the actual air flow} = \text{volumetric efficiency x theoretical air flow}$$

$$\text{actual air flow} = 0.70x4.256 = 2.9792 \text{ m}^3/\text{min}$$

Intake air flow housing is manufactured in consideration of the actual air flow.

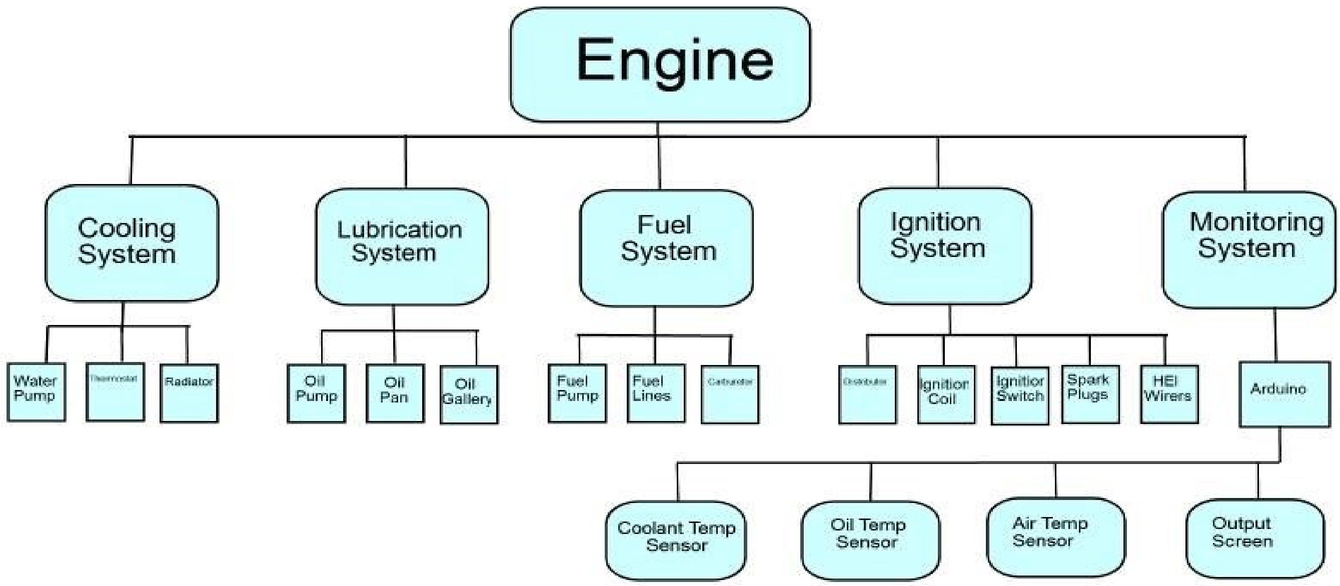


Figure 20 Engine Break Down Structure

The Figure above illustrate in details the whole engine systems with the new installed system (Monitoring System).

CHAPTER 4

Installation & Manufacturing

4.1 Pre-Installation Period:

4.1.1 ECU and Sensors:

- **Programming**

  First of all we downloaded the Arduino Software to program UNO Arduino board. Then we had to understand the principles of Arduino, Arduino programs, which are divided into three main parts: Structure, Values, and Functions. After studying and understanding Arduino principles, with the help of mechatronic engineer students. ”because our group doesn’t contain a mechatronic engineer student” we managed to program the system. The codes that we wrote in Arduino Software is provided in the Appendix F. Later we connect the Arduino to the Computer and upload the codes on the memory. From this point the Arduino is ready to wire with the sensors and outputs screen.

- **Wiring, Packing**

  According to the following diagram which is shown in Figure 21, the wiring has been done carefully because any wrong shortcut will burn the board or outputs screen or both, again we did a double check and test the system individually waiting for the sensors to be installed; meanwhile the sensors are prepared well and protected with pure copper covers which isolate the sensors from any contact with liquid and in the same time it is a thermal conductivity to obtain accurate Figure 25 reading results on the output screen. Wiring the sensors required two positive lines to receive and send signals but in our project one wire method is the rule that we follow, in this way the positive line (Voltage) is sending and receiving input and output signals. Figure 23 explains the one wire method in details.

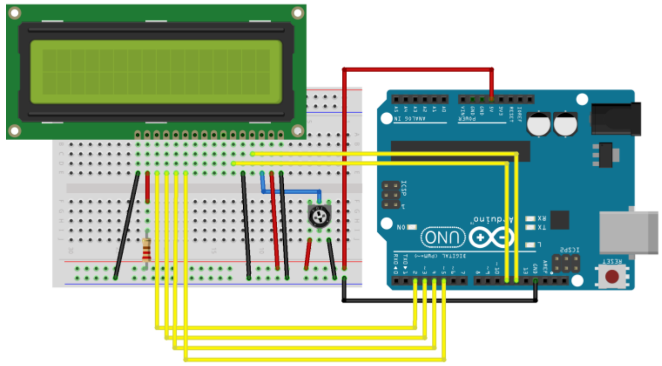


Figure 21 Arduino and Output Screen Wiring. [5]

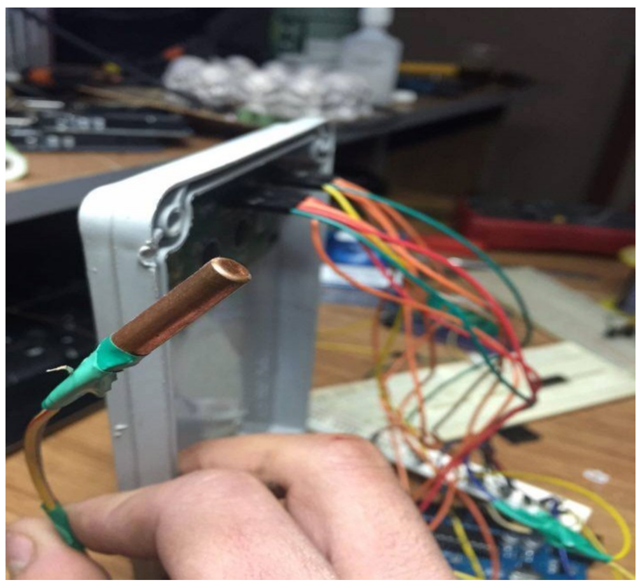


Figure 22 Copper Covers for sensors.

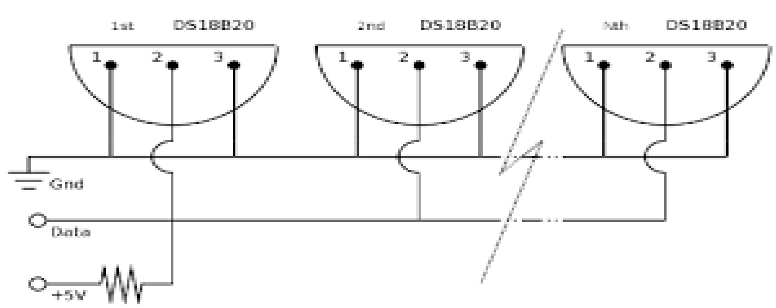


Figure 23 One Wire Method to connect three sensors. [5]

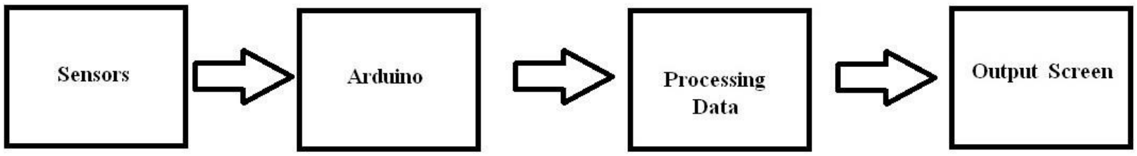


Figure 24 Schematic diagram for the procedure

Figure 25 Showing Random Results while testing it.

Eventually the wiring is completely done, and then the whole system which contains (Arduino-Screen-Circuit) is packed and fixed in a Plastic Box (to avoid Vibration or any possible wear) as shown in the following Figure 26.

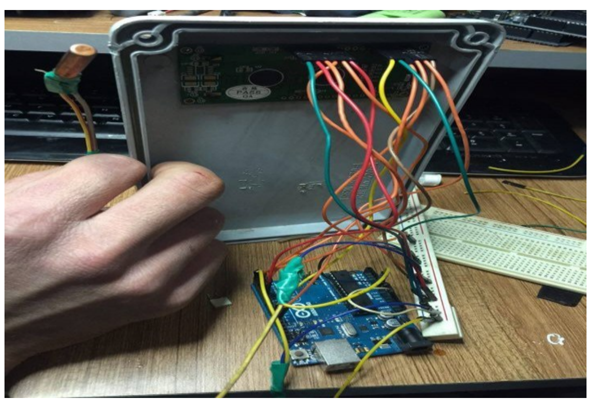


Figure 26 Preparing the System to be packed as a Final Wiring.

Finally, the System is packed and tested with the aid of our supervisor, and then we got a confirmation that the system is ready to be installed on the engine.

4.1 Installation Period:

To install the monitoring system, the engine should be suitable and compatible with it, so a bit of modification will be explained in details below.

4.1.1 Engine Modification:

- Cooling System

To obtain accurate readings, we decided to place the coolant temperature sensor in the middle of the outer radiator hose, so a machined stainless steel pipe is designed and manufactured in the mechanical engineering work shop, later a small guide is manufactured and assembled inside the machined pipe. This small guide has to be thermal conductivity thus we have chosen brass raw material to maintain accurate reading. Moreover, this small guide has an inner diameter match the outer diameter of the sensor housing which is (6mm). Following figure 27 shows the coolant temperature mount drawn by the use of Solid Work.

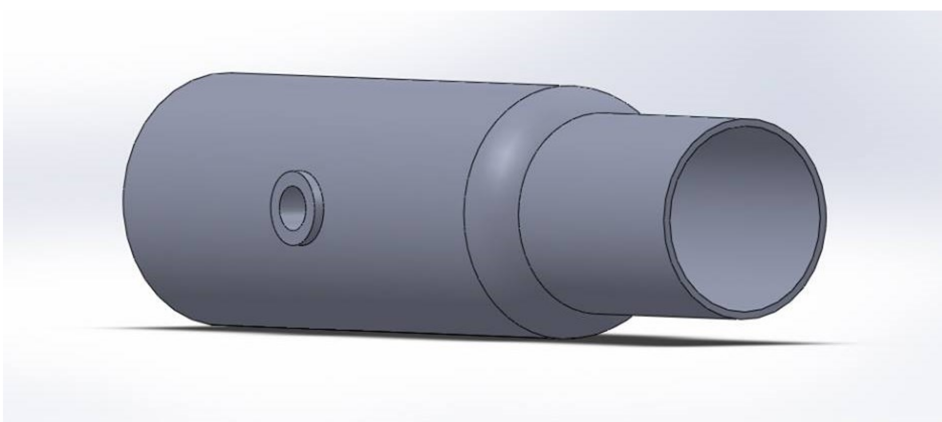


Figure 27 Coolant Temp Sensor Mount.

- Old Oil Temp Sensor.

  We decided after the suggestion of our supervisor to use the old oil pressure sensor housing to fit the new temperature oil sensor, but we had to do a bit of modification on it so it can be reliable for the new oil temperature sensor. Figure 28 illustrates the old oil pressure sensor mount and the new oil temperature sensor mount.

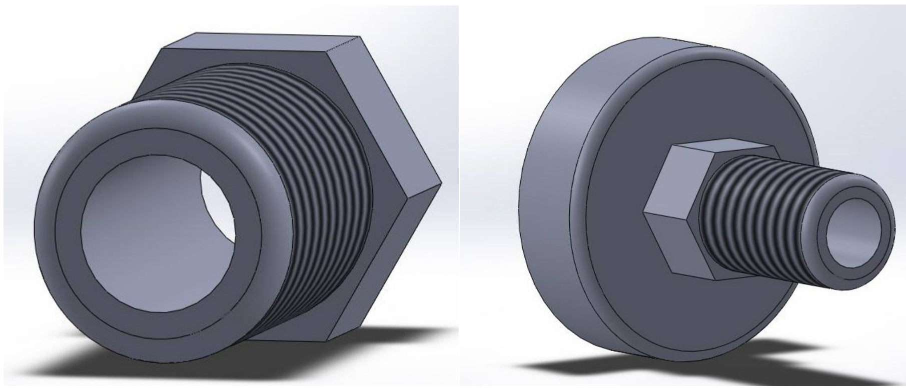


Figure 28 The modified oil temperature adapter (left) compared with the old one (right)

- Plastic Housing.

  The intake air that needed to be measured is going through the carburetor, but there is no mount for the air temperature sensor, so we modify a plastic housing for the intake temperature sensor after the approval of our supervisor to make sure that the used plastic will not leak air and to get the most accurate result. Figures 29 showing the air temperature housing adapter.

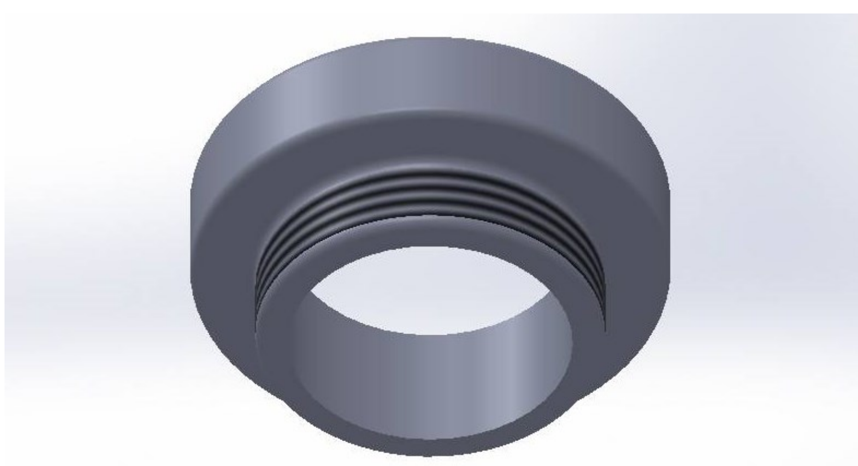


Figure 29 Air Temp Housing Adapter.

CHAPTER 5

Result and Discussion

Eventually, we can now take the most accurate outputs from the sensors through our programmed monitoring system, and analyze the engine condition according to the results. Table 4 and Graph 1 illustrating our monitor sensors output according to Revolution per Minute (RPM)

Table 4 Output Sensors Results

RPM	Air Temp Sensor (C^0)	Coolant Temp Sensor (C^0)	Oil Temp Sensor (C^0)
700	72	81	61
800	75	92	83
900	77	99	105
1000	78	108	123
1100	79	118	145
1200	79	128	167
1300	79	138	193

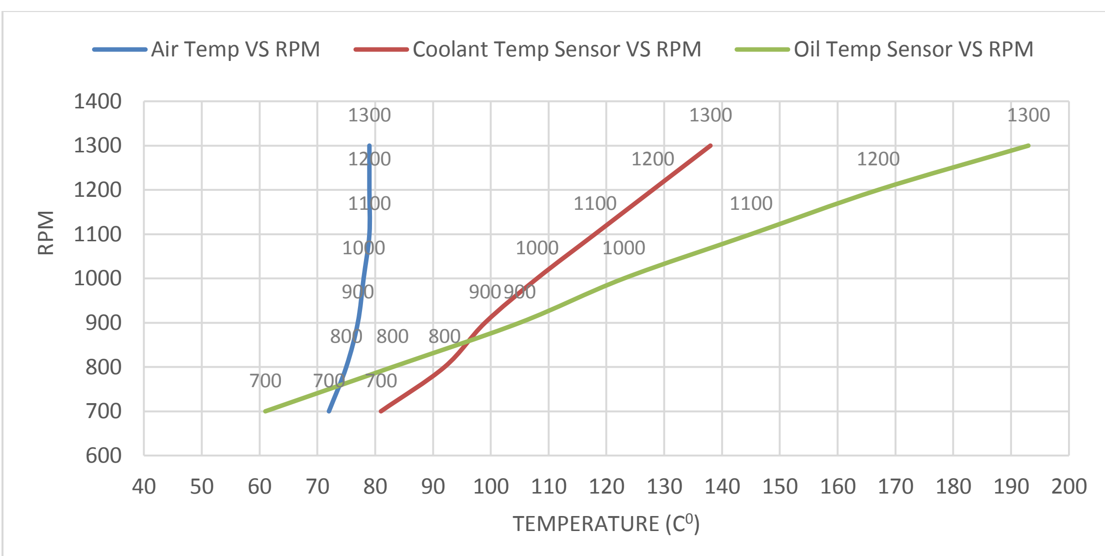


Figure 30 Output of each sensor's temperature according to RPM

CHAPTER 6

Conclusion and Future Work

Our monitor system results show that the engine is running smooth and idle. Furthermore, the three main systems in the engine (Cooling, Lubrication, and Ignition) are running into their limits and they are not exceeding any dangerous temperature, so now the engine can run and get more modification by time.

For the future work, as we discussed with our supervisor, this project is going to be an open source, ready for customization for next generation of mechanical and mechatronic students, the ECU can handle more sensors and more systems such as a fully distributorless electronic ignition system, and fuel electronic systems (injectors, electronic fuel pump). But due to our budget, we were limited with our choices.

This experience taught a lot especially our group doesn't contain a mechatronic student, but we were handling it in a good way, and it make our eyes clearer than before about how mechanical engineer act in the real field, how to diagnose problems, how to modify parts …etc.

We were really blessed working with Assoc. Prof. Dr.Hasan as an advisor for us, he was very helpful and he gave us a lot from his experience especially when we were stuck in our diagnoses, he consumed many hours helping us in the workshop, Thanks A lot Assoc. Prof. Dr. Hasan Hacışevki

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[2] Gasoline engine. (2013). Dated On (21 October 2015). In Encyclopædia Britannica. Retrieved from http://www.britannica.com/technology/gasoline-engine/Cylinder-block

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[4] Crouse,W. & Anglin,D. (1993).Automotive Mechanics(tenth edition) (p. 3)

[5] What is Arduino? (nd). Dated On (3 January 2016) Retrieved from https://www.arduino.cc/en/Guide/Introduction

[6] Pulkrabek, Williard W. Prentice Hall 1997, 1st edition. “Engineering Fundamentals of Internal Combustion Engine”.

APPENDICES

Appendix A – Log Book.

Appendix B – Gantt Chart.

Appendix C – Drawings.

Appendix D – Engineering Standards

Appendix E – Poster and CD.

Appendix F – Arduino Codes.

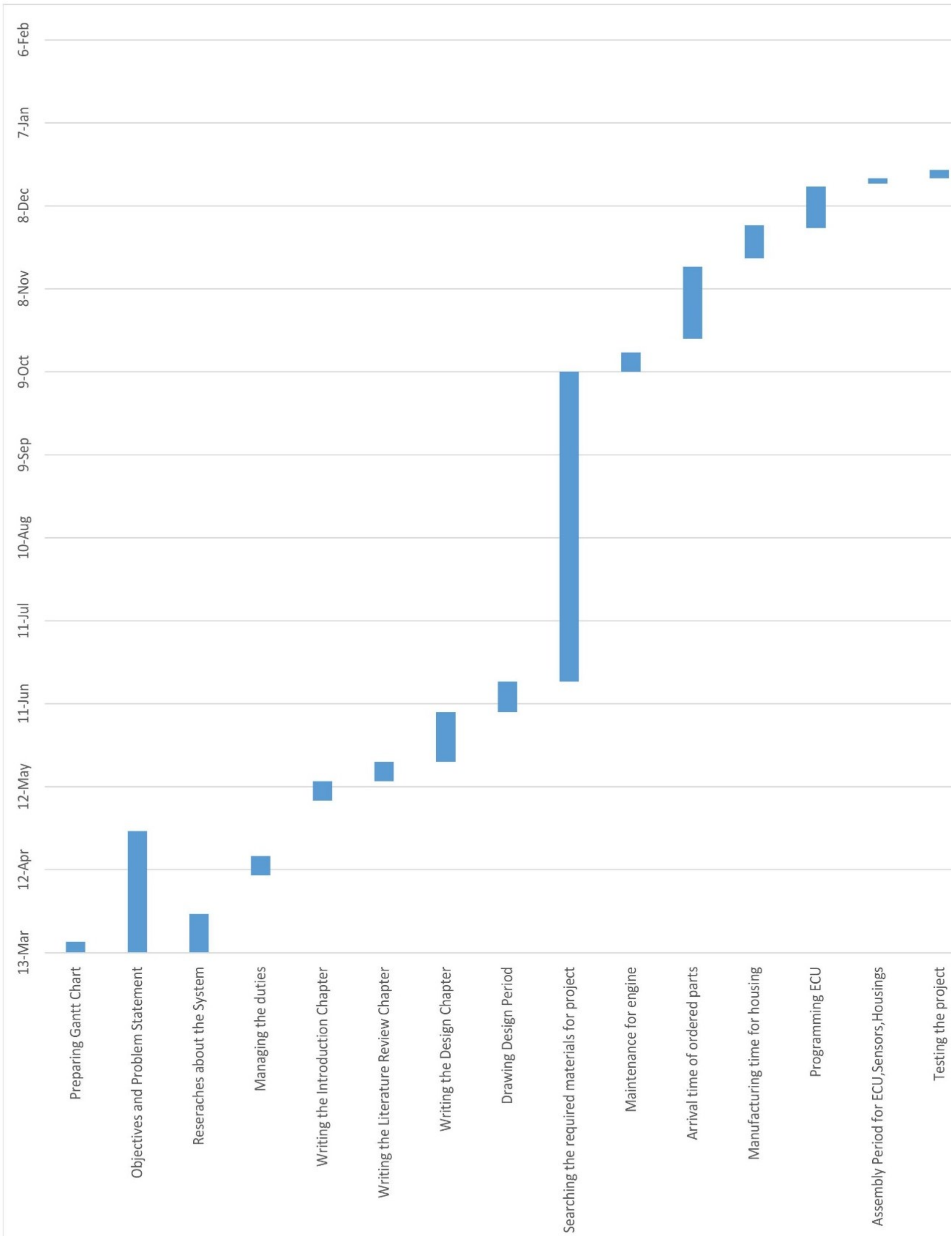
Appendix G –.Quotations.

APPENDIX A-LOGBOOK

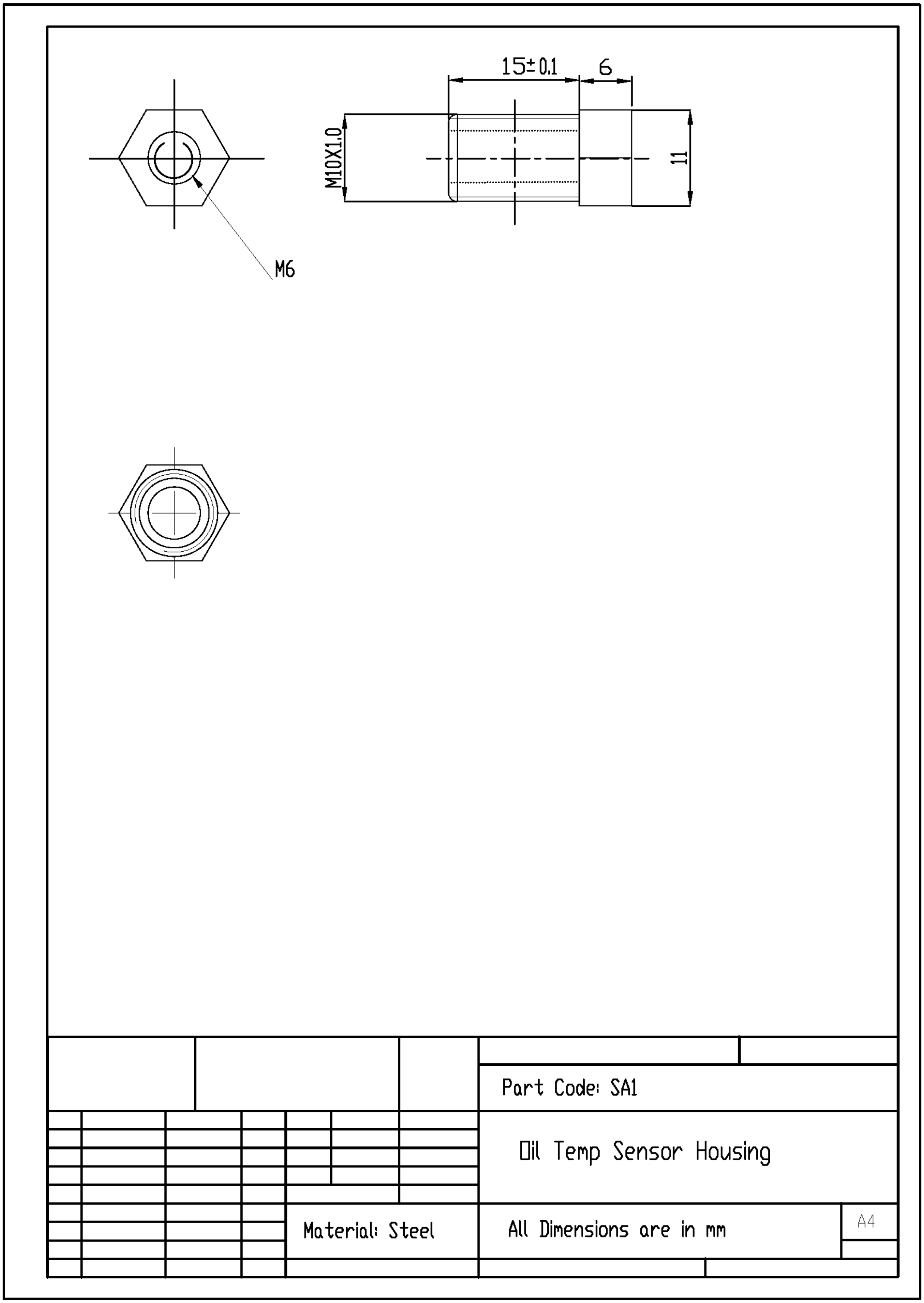
Dates	Details
13/03/2015	First of all, we choose the topic to be about ‘engine monitoring system. We took the approval from our advisor Assoc.Prof.Dr Hasan Hacışevki. He explained briefly about the project.
27/03/15	Started seeking about the project from previous published papers and gathering the necessary information for our project.
10/04/2015	Distribution to loads for each group member. Anıl Berk ERÜN was responsible for introduction, literature review, design and calculations. Mustafa ALSADİ was responsible for manufacturing, result and conclusion. Volkan AKTAY was responsible for engineering drawings, appendix, poster and website designing.
17/04/15	Our engine was carried to workshop to work on it easily.
22/04/15	Compression test was done for the cylinders as a team with help of Assoc.Prof.Dr Hasan Hacışevki.
27/04/15	All information was gathered from each group members.
30/04/15	We have visited Assoc.Prof.Dr Hasan Hacışevki for asking him about structure of report.
07/05/15	Started writing and preparing the report
21/05/15	Started doing the required calculations for the project.
29/05/15	We have visited Assoc.Prof.Dr Hasan Hacışevki to let him check the capstone report structure.
08/06/15	After the approval of Assoc.Prof.Dr Hasan Hacışevki, our report was finalized

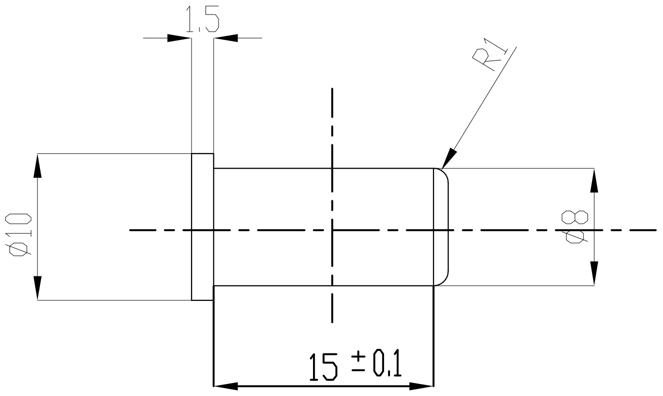
19/06/15	Submission date of our capstone report to Assist. Prof. Dr. Neriman Özada.
09/10/2015	Parts were bought locally for the maintenance of our engine
16/10/2015	New parts were assembled as a group to run the engine
21/10/2015	engine monitoring system parts were ordered such as ECU and Sensors
17/11/2015	The parts were arrived in Cyprus
18/11/2015	Testing the parts were working properly without mounting
19/11/2015	water temperature sensor housing was manufactured
23/11/2015	oil temperature sensor fitting was manufactured
27/11/2015	air intake temperature sensor housing was manufactured
30/11/2015	ECU was started to program as a group and sensors were wired to ECU
14/12/2015	ECU and sensors were ready to mount on engine.
16/12/2015	All housings, ECU, sensors were mounted on engine.
18/12/2015	Project was tested as a group
21/12/2015	We started to write Capstone 2 project
31/12/2015	We have visited Assoc.Prof.Dr Hasan Hacışevki to let him check the capstone 2 report structure.
04/01/2016	After the approval from Assoc.Prof.Dr Hasan Hacışevki, we finalized our report
08/01/2016	Submission date of Capstone 2 project

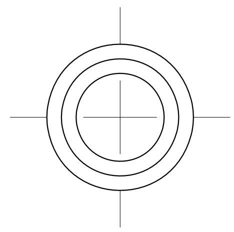
APPENDIX B-GANTT CHART



Appendix C – DRAWINGS







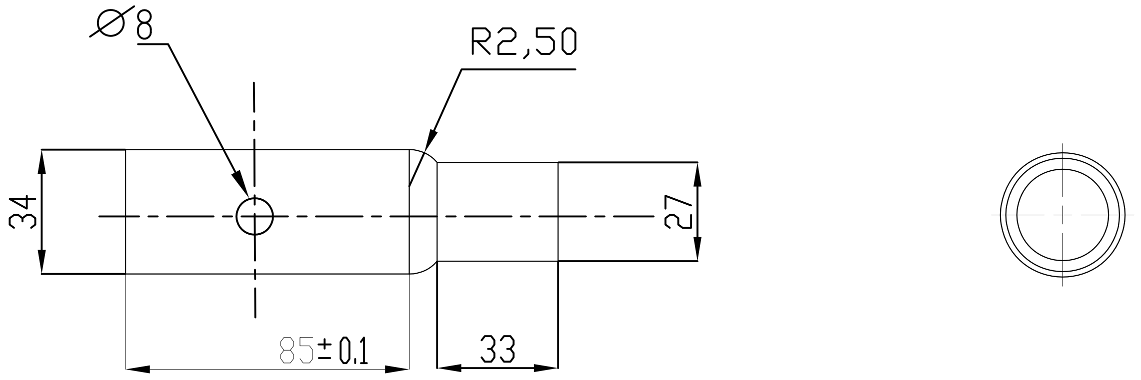
Part Code: SA2

Coolant Temp Sensor Fitting

Material: Copper

All Dimensions are in mm

A4



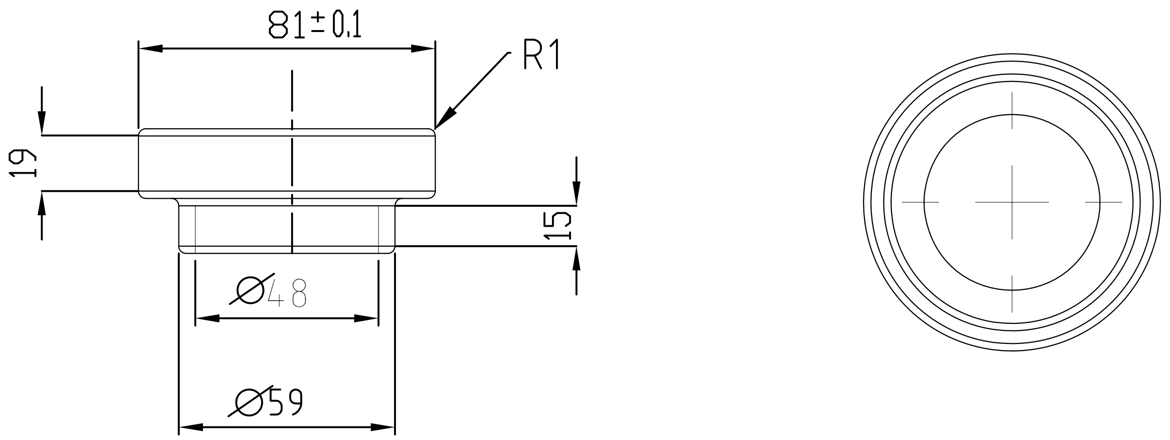
Part Code: SA3

Coolant Temp Sensor Housing

Material: Steel

All Dimensions are in mm

A4



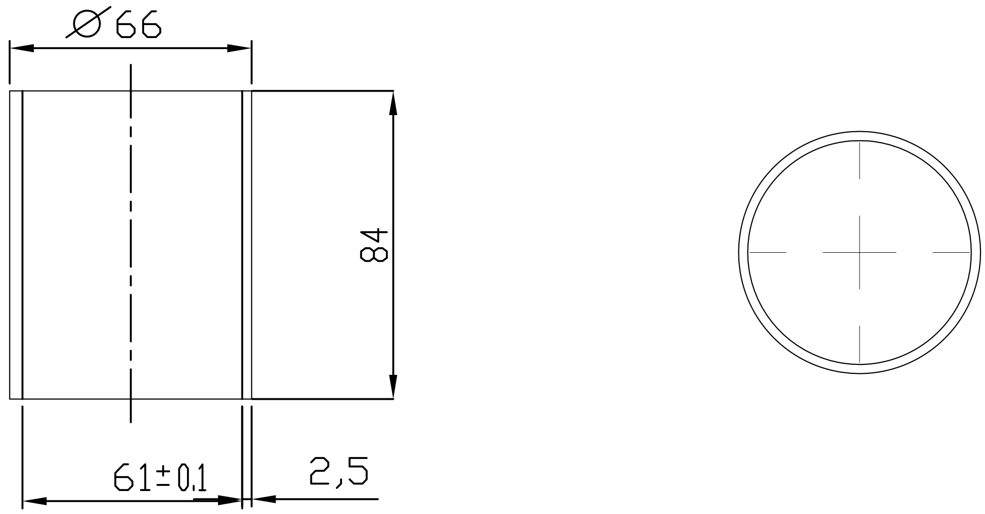
Part Code: SA4

Intake Temp Sensor Housing

Material:
Polycarbonate

All Dimensions are in mm

A4



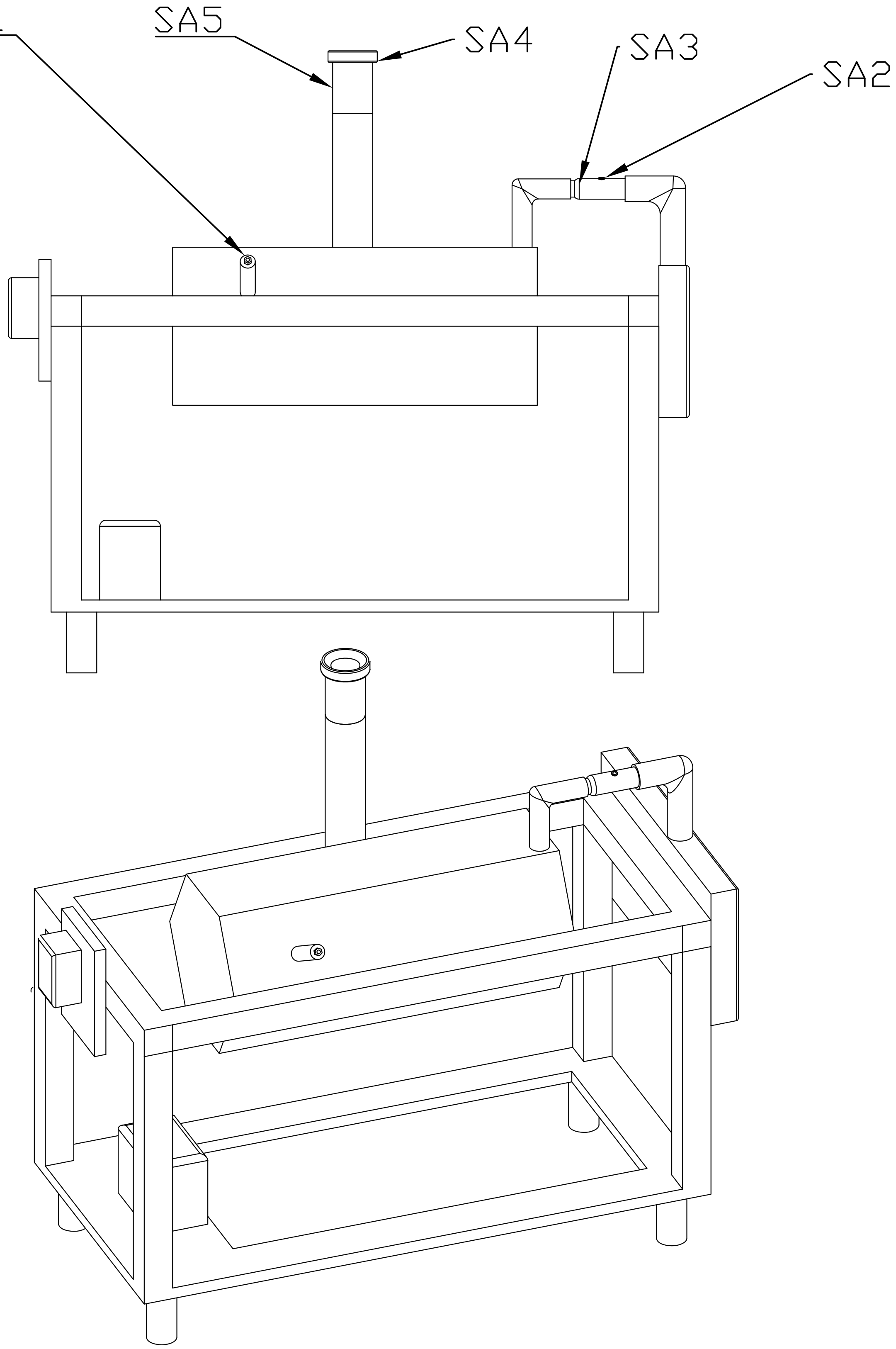
Part Code: SA5

Intake Temp Sensor Housing

Material:
Polycarbonate

All Dimensions are in mm

A4



Part Code: AA1

System Assembly

Part Code	PART NAME
SA1	Oil Temp Sensor Housing
SA2	Coolant Temp Sensor Fitting
SA3	Coolant Temp Sensor Housing
SA4	Intake Temp Sensor Housing
SA5	Intake Temp Sensor Housing

All Dimensions are in mm

A4

Appendix D- ENGINEERING STANDARDS

Typical properties of selected material used in Engineering (SI Units)

Appendix B. Typical Properties of Selected Materials Used in Engineering[1,5] (SI Units)

Material	Density kg/m³	Ultimate Strength: Tension, MPa	Ultimate Strength: Compression,[2] MPa	Ultimate Strength: Shear, MPa	Yield Strength[3]: Tension, MPa	Yield Strength[3]: Shear, MPa	Modulus of Elasticity, GPa	Modulus of Rigidity, GPa	Coefficient of Thermal Expansion, $10^{-6}/°C$	Ductility, Percent Elongation in 50 mm
Steel										
Structural (ASTM-A36)	7860	400			250	145	200	77.2	11.7	21
High-strength-low-alloy										
ASTM-A709 Grade 345	7860	450			345		200	77.2	11.7	21
ASTM-A913 Grade 450	7860	550			450		200	77.2	11.7	17
ASTM-A992 Grade 345	7860	450			345		200	77.2	11.7	21
Quenched & tempered										
ASTM-A709 Grade 690	7860	760			690		200	77.2	11.7	18
Stainless, AISI 302										
Cold-rolled	7920	860			520		190	75	17.3	12
Annealed	7920	655			260	150	190	75	17.3	50
Reinforcing Steel										
Medium strength	7860	480			275		200	77	11.7	
High strength	7860	620			415		200	77	11.7	
Cast Iron										
Gray Cast Iron										
4.5% C, ASTM A-48	7200	170	655	240			69	28	12.1	0.5
Malleable Cast Iron										
2% C, 1% Si,										
ASTM A-47	7300	345	620	330	230		165	65	12.1	10
Aluminum										
Alloy 1100-H14										
(99% Al)	2710	110		70	95	55	70	26	23.6	9
Alloy 2014-T6	2800	455		275	400	230	75	27	23.0	13
Alloy-2024-T4	2800	470		280	325		73		23.2	19
Alloy-5456-H116	2630	315		185	230	130	72		23.9	16
Alloy 6061-T6	2710	260		165	240	140	70	26	23.6	17
Alloy 7075-T6	2800	570		330	500		72	28	23.6	11
Copper										
Oxygen-free copper										
(99.9% Cu)										
Annealed	8910	220		150	70		120	44	16.9	45
Hard-drawn	8910	390		200	265		120	44	16.9	4
Yellow-Brass										
(65% Cu, 35% Zn)										
Cold-rolled	8470	510		300	410	250	105	39	20.9	8
Annealed	8470	320		220	100	60	105	39	20.9	65
Red Brass										
(85% Cu, 15% Zn)										
Cold-rolled	8740	585		320	435		120	44	18.7	3
Annealed	8740	270		210	70		120	44	18.7	48
Tin bronze (88 Cu, 8Sn, 4Zn)	8800	310			145		95		18.0	30
Manganese bronze (63 Cu, 25 Zn, 6 Al, 3 Mn, 3 Fe)	8360	655			330		105		21.6	20
Aluminum bronze (81 Cu, 4 Ni, 4 Fe, 11 Al)	8330	620	900		275		110	42	16.2	6

(*Table continued on page 747*)

ENGINEERING STANDARD

FOR

PROCESS DESIGN OF COOLING WATER CIRCUITS

ORIGINAL EDITION

JULY 1994

This standard specification is reviewed and updated by the relevant technical committee on Feb. 1999(1) and Oct. 2004(2). The approved modifications are included in the present issue of IPS.

PI = Pressure Indicator

PA = Pressure Alarm

PRC = Pressure Recorder Controller

PDI = Pressure Differential Indicator

PRV = Pressure Relieve Valve

TIC = Temperature Indicator Controller

THA = Temperature High Alarm

TI = Temperature Indicator

TCV = Temperature Control Valve

TSHA = Temperature Switch High Alarm

TT = Temperature Transmitter

V = Vent

5. UNITS

This Standard is based on International System of Units, (SI) except where otherwise specified.

6. DESIGN

6.1 Internal Combustion Engines, Cooling Systems

6.1.1 General

When the fuel is burnt in the cylinder, a part of the heat developed during combustion, flows to cylinder walls. If the temperature of cylinder walls is allowed to rise above a certain limit (about 150°C) then the oil lubricating the piston starts evaporating. This action damages both piston and cylinder. The high temperature developed may sometimes cause excess thermal stresses and hence cracking of the cylinder head and piston. The hot spots may also cause preignition in the combustion space. In order to avoid any damages, the heat flowing to the cylinder walls must be carried away.

6.1.2 Methods

All heat carried away from an engine shall finally be conveyed to atmosphere. However, the methods of cooling may be divided into two main groups of direct or air-cooling and indirect or liquid-cooling.

6.1.3 Heat transfer

In cooling of engine cylinders, all three means of heat transfer, i.e., conduction, convection and radiation will be utilized. But, conduction will play the most important part in carrying the heat through the thin layers of hot gases and water in contact with cylinder walls and will be sole object of process design in this Standard.

6.1.4 Heat lost to cylinder's inside surface

The quantity of heat lost per second to the heating surface i.e, inside surface of cylinder wall, head and exhaust valve cages by combustion gases shall be considered.

c) Forced liquid coolant system shall be provided, where cylinders will operate fully unloaded for extended period of time and either (1) the expected maximum discharge temperature is above 99°C or (2) the rise in adiabatic gas temperature is 66°C or greater (see Fig. B.1, (c) of Appendix "B").

6.2.2.3 Unless otherwise specified, forced closed cooling water system shall be used for taking away the heat traveled to cylinder wall. The water shall be pumped through the secondary cooler and then back to cylinder jacket for reuse.

6.2.2.4 The Vendor is required to evaluate the Company's proposed standard coolant system as specified under Clause 6.2.2.3 above against his own standard coolant system or any other standard coolant system and shall recommend the use of the most efficient, effective and techno-commercially feasible other coolant system together with strong convincing proves. However the employment of any other coolant system will solely be upon the Company's written approval.

6.2.3 Calculation of heat rejected to circulating cooling water

The Vendor/Manufacturer will furnish complete design data on quantity of compression heat to be removed from cylinder jacket and the head in J/BkW. h.

6.2.3.1 The Vendor/Manufacturer if deemed necessary may furnish an integral closed cooling water system for compressor cylinder jackets, engine cylinder jackets, lubricating oil circuit and compressor packing boxes, he should provide separate design data on the quantity of heat rejected to cooling system from each section separately and as a whole along with quantity of water circulating and pressure drops.

6.2.4 Requirements

6.2.4.1 General

A closed cooling water system for packaged reciprocating compressor shall be furnished either in separate for cylinder jacket cooling or integral with engine cylinder, lubricating oil and cooling of compressor packing boxes, within the temperature limit recommended by the manufacturer for the specified compression services.

6.2.4.2 Cylinder jackets cooling

6.2.4.2.1 Unless otherwise specified, the following requirements shall be considered when the closed cooling water system is used only for cylinder jacket cooling:

a) The cylinder jackets when designed, all protective measures must be taken to prevent the process gas flow into the cooling water circuit.

b) A liberal supply of cooling water for cylinder jacket and cylinder head must be maintained.

c) The cylinder cooling system provided shall be designed to prevent gas condensation in the cylinder, that may dilute or remove lubricant or may cause knocking.

d) The use of untreated or scale depositing water that will cause fouling and plugging of the water passage, reducing cooling efficiency should strongly be avoided.

6.2.4.3 Integral cooling system

6.2.4.3.1 Not withstanding the requirements set-forth under clause or 6.2.4.2 unless otherwise specified, the following requirement, shall be considered when the closed cooling water system is

Appendix E- POSTER & CD

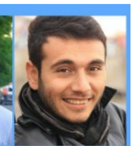
Eastern Mediterranean University

DEPARTMENT OF MECHANICAL ENGINEERING

Engine Monitoring System

Mustafa Alsadi
139697

Anıl Berk Erün
110800



Volkan Aktay
112610

Course Coordinator
Assist.Prof.Dr. Mostafa Ranjbar

Project Supervisor
Assoc.Prof.Dr. Hasan Hacışevki

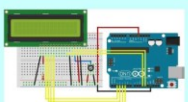
Fall 2015-2016

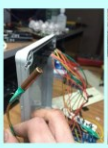
Group Name: Engine Doctors

INTRODUCTION

Engine monitoring system is our project topic, its purpose to have the highest efficiency and lowest fuel consumption and emissions. The report will clarify sensors operation, how it work and how to install them, lastly connect the sensors to an ECU and program it to reach the project main purpose.

This project will be a good reference for mechanical and mechatronic departments because it will show the combination between the mechanical and mechatronic work during the engine operation.





Programing

We connect the Arduino to the Computer and upload the codes on the memory. From this point the Arduino is ready to wire with the sensors and outputs screen.

Eventually the wiring is completely done, and then the whole system which contains (Arduino-Screen -Circuit) is packed and fixed in a Plastic Box

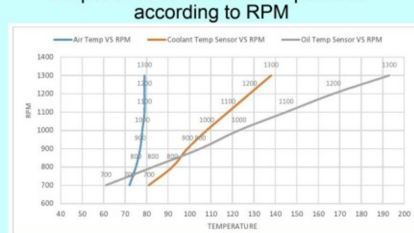
Result and Discussion

Eventually, we can now take the most accurate outputs from the sensors through our programmed monitoring system, and analyze the engine condition according to the results. Table and Graph illustrating our monitors sensors output according to revolution per minute (RPM)

Output Sensors Results

RPM	Air Temp Sensor (C^0)	Coolant Temp Sensor (C^0)	Oil Temp Sensor (C^0)
700	72	81	61
800	75	92	83
900	77	99	105
1000	78	108	123
1100	79	118	145
1200	79	128	167
1300	79	138	193

Output of each sensor's temperature according to RPM



Brief Information about the Engine:

The Engine which is located in the work shop has a serial number 12H702E-H3511.

•12 mean 1275cc.
•H means transverse.
•702 is the tricky part, it seems to be from the Austin 1300 of 1967-1973. So 702 means: "mechanical fuel pump, alternator, negative ground, standard ratio rod change gearbox with inboard CV ("pot") joints."
•E means carb/crankcase ventilation.

Measuring Intake Air Flow

The ECU must have information about the amount of air flowing into the intake manifold. According to measured air flow, ECU calculates the amount of fuel to inject in cylinders.
Air flow can be measured:
•By using throttle position , intake-manifold vacuum and crankshaft position
•By using vane, air-flow sensor plate, hot-wire induction and heated film

Discussions and Conclusion

Our monitor system results show that the engine is running smooth and idle. Furthermore, the three main systems in the engine (Cooling, Lubrication, and Ignition) are running into their limits and they are not exceeding any dangerous temperature, so now the engine can run and get more modification by time.

For the future work, as we discussed with Dr.Hasan, this project is going to be an open source, ready for customization for next generation of mechanical and mechatronic students, the ECU can handle more sensors and more systems such as a fully distributorless electronic ignition system, and fuel electronic systems (injectors, electronic fuel pump). But due to our budget, we were limited with our choices.

This experience taught a lot especially our group doesn't contain a mechatronic student, but we were handling it in a good way, and it make our eyes clearer than before about how mechanical engineer act in the real field, how to diagnose problems, how to modify parts …etc.
We were really blessed working with Dr.Hasan as an advisor for us, he was very helpful and he gave us a lot from his experience especially when we were stuck in our diagnoses, he consumed many hours helping us in the workshop, Thanks A lot Dr.Hasan.

Appendix F – ARDUINO CODES

```
/*-----( Import needed libraries )-----*/

#include <OneWire.h>

#include <DallasTemperature.h>

#include <LiquidCrystal.h>

LiquidCrystal lcd(12,11,5,4,3,2);

/*-----( Declare Constants )-----*/

#define ONE_WIRE_BUS 0

/*-----( Declare objects )-----*/

/* Set up a oneWire instance to communicate with any OneWire device*/

OneWire ourWire(ONE_WIRE_BUS);

/* Tell Dallas Temperature Library to use oneWire Library */

DallasTemperature sensors(&ourWire);

/*-----( Declare Variables )-----*/

int thermistorPin = A0; //analog pin 0

void setup() /*----( SETUP: RUNS ONCE )----*/

{

/*-(start serial port to see results )-*/

delay(1000);

lcd.begin(16,2);

lcd.print("Car Temp Control");

delay(400);

lcd.clear();

/*-( Start up the DallasTemperature library )-*/

sensors.begin();
```

```
}/*--(end setup )---*/

void loop() /*----( LOOP: RUNS CONSTANTLY )----*/

{

sensors.requestTemperatures();

lcd.setCursor(1,0);

lcd.print("oil");

lcd.setCursor(7,0);

lcd.print("int");

lcd.setCursor(12,0);

lcd.print("wtr");

lcd.setCursor(0,1);

lcd.print(sensors.getTempCByIndex(0));

lcd.setCursor(11,1);

lcd.print(sensors.getTempCByIndex(1));

 double thermistorReading = analogRead(thermistorPin);

  double x;

x = thermistorReading/24;

lcd.setCursor(6,1);

 lcd.print(x);

  delay(100); //just here to slow down the output for easier reading

}/* --(end main loop )-- */

/* ( THE END ) */
```

Appendix G – QUOTATIONS

Technical specs

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
Length	68.6 mm
Width	53.4 mm
Weight	25 g

Product Description

package content :

1 x Digital Laser Photo Tachometer
1 x 9V Battery
1 x sheet full instruction manual

Features:

Display:Large 5 digit, 18mm LCD
Test select: Automatic
Range:2.5 to 99,999 RPM
Resolution:0.1RPM(from 2.5 to 999.9 RPM)1RPM(over1,000RPM)
Accuracy:+/-(0.05% +1 digit)
Time base:Quartz crystal
Distance:50 to 500mm/ 2 to 20 inch
Memory:Last Value. Max Value. Min RPM
Battery: 6F22 9V (Included)
Size: 15x9.5x4cm
Weight: 7.40oz

Temperature Sensor - 44900 Series GSFC Space Qualified Thermistor

Overview | Literature | Quality & Compliance | Related Products | Additional Information | How To Buy

Applications: Extended Space Applications, Low and Mid Range Temperature Applications, Tight Tolerance Instrumentation, Applications Requiring Sensing Small Changes in Temperature, Applications With Outgassing Requirements

Industries: Aerospace and Military

Replaces:

Datasheet: 44900 Series

Description: NASA Qualified epoxy encapsulated precision interchangeable NTC thermistors for use in extended space flight applications. All parts are fully flight tested and characterized. Line re-qualified yearly per MIL-PRF-23648 requirements as specified in S311-P18 document. All S311-P18 lead options wire options available.

Features:

- Flight Qualified
- 2252 Ohm to 30K Ohm Resistance @ 25°C
- Interchangeability to ± 0.1°C
- High Sensitivity
- Thermally Conductive Epoxy Coating Exhibits <0.66% TML, <0.01% CVCM, 0.10% WVR when tested per ASTM E-

Refer to the Literature tab for more information on this series of products.

larger image

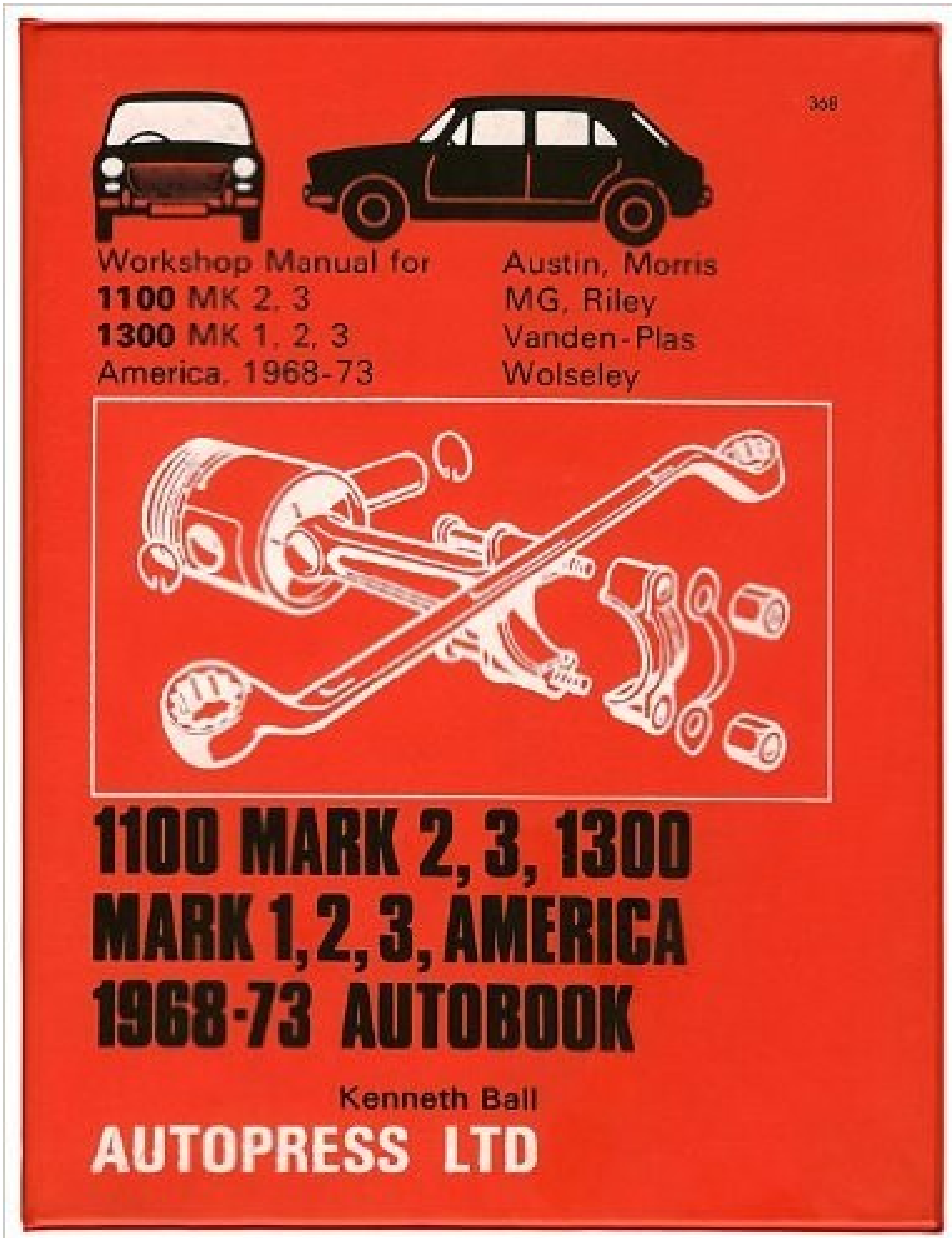
TMP36 - Temperature Sensor

£1.50 Ex VAT
£1.80 Inc VAT

This is the same temperature sensor that is included in our SparkFun Inventor's Kit. The TMP36 is a low voltage, precision centigrade temperature sensor. It provides a voltage output that is linearly proportional to the Celsius temperature. It also doesn't require any external calibration to provide typical accuracies of ±1°C at +25°C and ±2°C over the −40°C to +125°C temperature range. We like it because it's so easy to use: Just give the device a ground and 2.7 to 5.5 VDC and read the voltage on the Vout pin. The output voltage can be converted to temperature easily using the scale factor of 10 mV/°C.

Features

- Voltage Input: 2.7 V to 5.5 VDC
- 10 mV/°C scale factor
- ±2°C accuracy over temperature
- ±0.5°C linearity
- Operating Range: −40°C to +125°C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MG, Riley
Vanden-Plas
Wolseley
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