DIGITAL DISTANCE METER USING MICROCONTROLLER

Estd-1984

Submitted by

D.S.ARAVIND KUMAR	(99MCE 02)
S.MADHAN MOHAN RAJ	(99MCE 12)
M.PRABAHARAN	(99MCE 15)
V.SRINIVASAN	(99MCE 24)

Project Report
2002-2003

Under the guidance of

Mr. G. Mohan Kumar, M.E., M.B.A., MISTE.,

In partial fulfillment of the requirements for the award of

BACHELOR OF ENGINEERING in MECHATRONICS ENGINEERING

BRANCH OF BHARATHIAR UNIVERSITY

Department of Mechatronics Engineering

Kumaraguru College of Technology

Coimbatore-641006.

Certificates

DEPARTMENT OF MECHATRONICS ENGINEERING
KUMARAGURU COLLEGE OF TECHNOLOGY
COIMBATORE - 641006.

PROJECT REPORT 2002-2003
CERTIFICATE

This is to certify that the report entitled
DIGITAL DISTANCE METER USING MICROCONTROLLER
has been submitted by

D.S.ARAVIND KUMAR (99MCE02)
S.MADHAN MOHAN RAJ (99MCE12)
M.PRABAHARAN (99MCE15)
V.SRINIVASAN (99MCE24)

In partial fulfillment of the requirements for the award of the Degree of **BACHELOR OF ENGINEERING** in Mechatronics Engineering branch of Bharathiar University, Coimbatore.

17/3/03

Guide   Head of Department

The certificate was examined by us in the project work viva-voce examination held on __________ and his university register number is __________.

Internal Examiner   External Examiner

CERTIFICATE

This is to certify that this project work entitled **DIGITAL DISTANCE METER USING MICROCONTROLLER** carried out in **PDE (Instruments) department of PRICOL, Coimbatore** by **D.S.ARAVIND KUMAR (99MCE02), S.MADHAN MOHAN RAJ (99MCE12), M.PRABAHARAN (99MCE15)** and **V.SRINIVASAN (99MCE24)** for the award of the degree of Bachelor of Engineering in **MECHATRONICS ENGINEERING**, is a bonafide work carried out under my guidance. The results embedded in this report has not been submitted for the award of any other degree/fellowship etc of any other University or institute.

Mr. G. Mohan Kumar,
Senior Lecturer,
Dept. of Mechatronics Engineering,
Kumaraguru college of Technology,
Coimbatore – 6.

PREMIER INSTRUMENTS & CONTROLS LIMITED

pricol
PLANT I

PERIANAICKENPALAYAM
COIMBATORE - 641 020. INDIA
PHONE : ++91 - 422 - 2692901
FAX : ++91 - 422 - 2692028
e-mail : factory@pricol.co.in

HRD/PROJ/2003
12-March-2003

TO WHOMSOEVER IT MAY CONCERN

This is to certify that **Mr. D.S. ARAVIND KUMAR,** final year B.E. (Mechatronics) student of Kumaraguru College of Technology – Coimbatore. has undergone project work in our organisation.

The details are:

- Project Title : DIGITAL DISTANCE METER
- Period of project : November 2002 to March 2003
- Department : Product Development Engineering (Instruments)

During this period his performance, attendance and conduct were **Good.**

We wish him the very best for a bright future.

ANTHONY THIAGARAJAN
DY. MANAGER – HUMAN RESOURCES

REGD OFFICE : 1087A, AVANASHI ROAD, COIMBATORE - 641 037. INDIA
PHONE : ++91 - 422 - 2211520 FAX : ++91 - 422 - 2210028
e-mail : city@pricol.co.in

PREMIER INSTRUMENTS & CONTROLS LIMITED

pricol
PLANT I

PERIANAICKENPALAYAM
COIMBATORE - 641 020. INDIA
PHONE : ++91 - 422 - 2692901
FAX : ++91 - 422 - 2692028
e-mail : factory@pricol.co.in

HRD/PROJ/2003
12-March-2003

TO WHOMSOEVER IT MAY CONCERN

This is to certify that **Mr. S. MADHAN MOHAN RAJ,** final year B.E. (Mechatronics) student of Kumaraguru College of Technology – Coimbatore, has undergone project work in our organisation.

The details are:

- Project Title : DIGITAL DISTANCE METER
- Period of project : November 2002 to March 2003
- Department : Product Development Engineering (Instruments)

During this period his performance, attendance and conduct were **Good.**

We wish him the very best for a bright future.

ANTHONY THIAGARAJAN
DY. MANAGER – HUMAN RESOURCES

REGD OFFICE : 1087A, AVANASHI ROAD, COIMBATORE - 641 037. INDIA
PHONE : ++91 - 422 - 2211520 FAX : ++91 - 422 - 2210028
e-mail : city@pricol.co.in

ᐩREMIER INSTRUMENTS & CONTROLS LIMITED

pricol

PLANT I

PERIANAICKENPALAYAM
COIMBATORE - 641 020. INDIA
PHONE : ++91 - 422 - 2692901
FAX : ++91 - 422 - 2692028
e-mail : factory@pricol.co.in

HRD/PROJ/2003
12-March-2003

TO WHOMSOEVER IT MAY CONCERN

This is to certify that **Mr. M. PRABAHARAN,** final year B.E. (Mechatronics) student of Kumaraguru College of Technology – Coimbatore, has uncergone project work in our organisation.

The details are:

- Project Title : DIGITAL DISTANCE METER
- Period of project : November 2002 to March 2003
- Department : Product Development Engineering (Instruments)

During this period his performance, attendance and conduct were **Good.**

We wish him the very best for a bright future.

ANTHONY THIAGARAJAN
DY. MANAGER – HUMAN RESOURCES

:GD OFFICE : 1087A, AVANASHI ROAD, COIMBATORE - 641 037. INDIA
PHONE : ++91 - 422 - 2211520 FAX : ++91 - 422 - 2210028
e-mail : city@pricol.co.in

PREMIER INSTRUMENTS & CONTROLS LIMITED

pricol
PLANT I

PERIANAICKENPALAYAM
COIMBATORE - 641 020. INDIA
PHONE : ++91 - 422 - 2692901
FAX ++91 - 422 - 2692028
e-mail : factory@pricol.co.in

HRD/PROJ/2003
12-March-2003

TO WHOMSOEVER IT MAY CONCERN

This is to certify that **Mr. V. SRINIVASAN,** final year B.E. (Mechatronics) student of Kumaraguru College of Technology – Coimbatore, has undergone project work in our organisation.

The details are:

- Project Title : DIGITAL DISTANCE METER
- Period of project : November 2002 to March 2003
- Department : Product Development Engineering (Instruments)

During this period his performance, attendance and conduct were **Good.**

We wish him the very best for a bright future.

ANTHONY THIAGARAJAN
DY. MANAGER – HUMAN RESOURCES

REGD OFFICE 1087A AVANASHI ROAD, COIMBATORE - 641 037. INDIA
PHONE : ++91 - 422 - 2211520 FAX : ++91 - 422 - 2210028
e-mail : city@pricol.co.in

Declaration

DECLARATION

We hereby declare that the project work entitled **DIGITAL DISTANCE METER USING MICROCONTROLLER** submitted to the **BHARATHIAR UNIVERSITY**, Coimbatore in partial fulfillment of the requirements for the award of Bachelor of Engineering in **MECHATRONICS ENGINEERING** is a record of the original project work, done in the department of **PDE (Instruments) of PRICOL**, Periyanaickenpalayam at Coimbatore by us during our period of study (1999 – 2003) in **Kumaraguru college of Technology**, Coimbatore -6 , under the guidance of **Mr. G. Mohan Kumar M.E., M.B.A., MISTE**. It has not been submitted for the award of any degree/fellowship etc of any other University or institute.

PLACE: Coimbatore

DATE :

D.S.ARAVIND KUMAR

S.MADHAN MOHAN RAJ

M.PRABAHARAN

V.SRINIVASAN

Dedicated To

My Beloved Parents

Acknowledgement

ACKNOWLEDGEMENT

We are highly indebted to our Principal, **Dr. K.K.Padmanabhan** and our beloved HOD, **Dr. V.Gunaraj** for providing us with excellent facilities to carry out this project.

We express our gratitude to our guide, **Mr. G. Mohan kumar** , Senior Lecturer, Department of Mechatronics Engineering who stood with us and helped us in solving the problems that we faced in this project.

We are very much thankful to **Mr. S.DhinakaraRajan**, General Manager, PDE(Instruments), PRICOL for granting us the project. We are grateful to **Mr.D.Roy Justin**, **Mr.M.Siva Kumar** & **Mr.V.Prabhu Shankar**, PDE(Instruments), PRICOL for understanding and providing us with valuable suggestions to make this project a success.

We owe our sincere gratitude and heart felt thanks to our parents, our friends and all the staff members of Mechatronics Department for their encouraging support for finishing this project successfully in time.

Synopsis

SYNOPSIS

The major drawback in any of the two wheelers is that, one could not know how many kilometers the vehicle could run for the fuel present in the tank. If any specific meter fulfills this disadvantage, it would be a boon to the drivers. Our project "Digital Distance Meter using Micro controller" is developed to fulfill the above said drawback.

In our project, the fuel level is sensed using the fuel sender unit. The corresponding voltage level from the fuel gauge is given to the PIC micro controller. The micro controller displays the distance range on a display thus helping the driver to know the distance range that could be covered for the fuel present in the tank.

The usage of electronic components in this project offers many advantages such as low cost, high reliability, increase in quality and reduction in usage area. Furthermore, the concept explained in this project remains same for all the two-wheelers in calculating the distance.

Contents

CONTENTS

Introduction

1.INTRODUCTION

1.1 ABOUT THE COMPANY

Established in 1974, **PREMIER INSTRUMENTS AND CONTROLS LIMITED (PRICOL)** has emerged a pioneer in multi- engineering products like Automobile instruments, Electronic counters and controllers, Defense instrumentation and Industrial pressure gauges. It has its manufacturing bases at **Coimbatore** and **Gurgaon –Haryana** and its corporate offices at various parts in India.

In 1993, it has been awarded the prestigious **ISO 9001** certificate. **Recently** it has been awarded the **QS 9001** certificate. As a matter of fact, it is the **first company in the Indian Automobile Instrumentation Industry to get ISO 9001** certificate. This is a clear proof of its stride towards keeping pace with global advances in technology. Its products stand testimony to quality and customer satisfaction.

Even with liberalization of Indian Economy and inflow of foreign products, PRICOL has maintained its standard as a pioneer in the automobile instruments industry by maintaining International standard and Quality.

The company manufactures products that are applicable in wide ranges of fields. Some of the products are mechanical pressure gauge, temperature gauges, ammeter, battery, condition indicators, vacuum gauges, voltmeter, tank units, speedometer, odometer, check valve and emission valve, assembly pumps etc.

PRICOL products are approved and used by most of the **Original Equipment Manufacturers (OEMs)** in India and also exported for OEMs and market needs of many foreign countries. The company has full-fledged infrastructure facilities to manufacture and test components to International standards.

There are four plants in PRICOL

PLANT I (PERIYANAICKENPALAYAM, TAMIL NADU)

1. Auto Product Group

Design/development, manufacture and servicing of dashboard instruments, windshield washers, cables, switches, gauges, sensors and accessories for on and off road vehicles.

2. Pump Division

Design/development, manufacture and servicing of oil pumps for two wheelers and stationary engines, speed drive components for two wheelers valve and gears.

3. Electronic Product Group

Design/development/manufacture and servicing of electronic counters, controllers for textile machinery and provides support for auto product group for manufacturing of electronic based instruments.

4. Defense Product Group

Design/development, manufacturing and servicing of pressure gauges of various types for process industries, hospital and other special applications.

5. Manufacturing Engineering

Design/development, manufacturing and servicing of pressure gauges, coil winding machines, screen printing machines, foil stamping machines, metal cutting and assembly SPMs to meet the internal manufacturing and market needs.

PLANT II (GURGAON, HARYANA)

Manufacturing and servicing of dashboard instruments for automotive vehicles, predominantly for servicing OEM customers, in and around New Delhi area.

PLANT III (CHINNAMADDAMPALAYAM, TAMIL NADU)

1. Pumps Product Group

Design/development, manufacturing and servicing of oil pumps for two wheelers and stationary engines, speed drive components for two wheelers valves and gears.

PLANT IV (KAARAMADAI, TAMIL NADU)

An expert oriented unit, setup for manufacture of all types of lubricating oil pumps and valves for two wheelers, stationary engines and machined components.

AWARDS AND ACCOMPLISHMENTS

1. Auxiliary development award by CODISSIA, Coimbatore in **1982**.
2. In–hour R&D recognition by DGID (Department of Science and Technology, Government of India) in **1986 (continuously extended up to date)**.
3. ACMA Technology award in **1988-1989**.
4. Outstanding quality performance award by HERO HONDA MOTORS in **1990**.
5. Best vendor award by KINETIC HONDA MOTORS in **1991**.
6. Outstanding performance award by HONDA SIEL CARS INDIA in **2000**.

COMPANY'S MEMBERSHIP WITH PROFESSIONAL ASSOCIATIONS.

International:

- Metal Power Industries Federation (MPIF), USA.

- Society of Automotive Engineers (SAE), USA.
- Screen Graphic International Association (SGIA), USA
- Society of Manufacturing Engineers, (SIME), USA.

National:

- Automotive Research Association of India, Pune
- Indian Value Engineering Society
- Member of TPM Club India. (Confederation of Indian Industry-in Association with Japan Institute of Plant Maintenance, Tokyo).

FOREIGN COLLABORATIONS

- M/s. DENSO Corporation ,Japan
- M/s. Nippon Seiki Company Limited, Japan
- M/s. N.S International Limited, USA
- M/s. Kojima Press Industrial Company Limited, Japan
- M/s. Toyoda Gosei Company Limited, Japan
- M/s. Deok Chang Machinery Company Limited, Korea

1.2 ABOUT THE DEPARTMENT

PRODUCT DEVELOPMENT ENGINEERING (INSTRUMENTS)

The Product Development and Engineering (Instruments) department provides a strong support towards new product development, improvement in the existing products, quality enhancement and technology up-gradation to suit the products to changing needs and preferences of customers.

Cross-functional team is formed to induct quality into the product. A full- fledged sample making cell for fabricating the parts, tools and prototype samples to lessen the design-to-development cycle time.

The designs are verified and validated by intensive application of various techniques like **FMEA, GD&T, DFA, DFM, DOE** etc.

The products are tested to **customer-specific standards, PRICOL standards, Indian standards and International standards like SAE, DIN and JIS.**

Continuous cost-effective programs are carried out through value Analysis and Value Engineering techniques. Sustained and continuous efforts are on for increasing productivity.

1.3 ABOUT THE PROJECT

Microcontrollers play a vital role in our day-to-day applications. Our project **"Digital Distance Meter using Microcontroller"** is one of those applications.

The project provides the user to know the distance range that could be covered for the fuel present in the tank & provides the digital output of the distance in Kms.

The hardware unit of the project deals with the sensor unit, signal conditioning unit to give the microcontroller acceptable voltage level input, the microcontroller and the display unit.

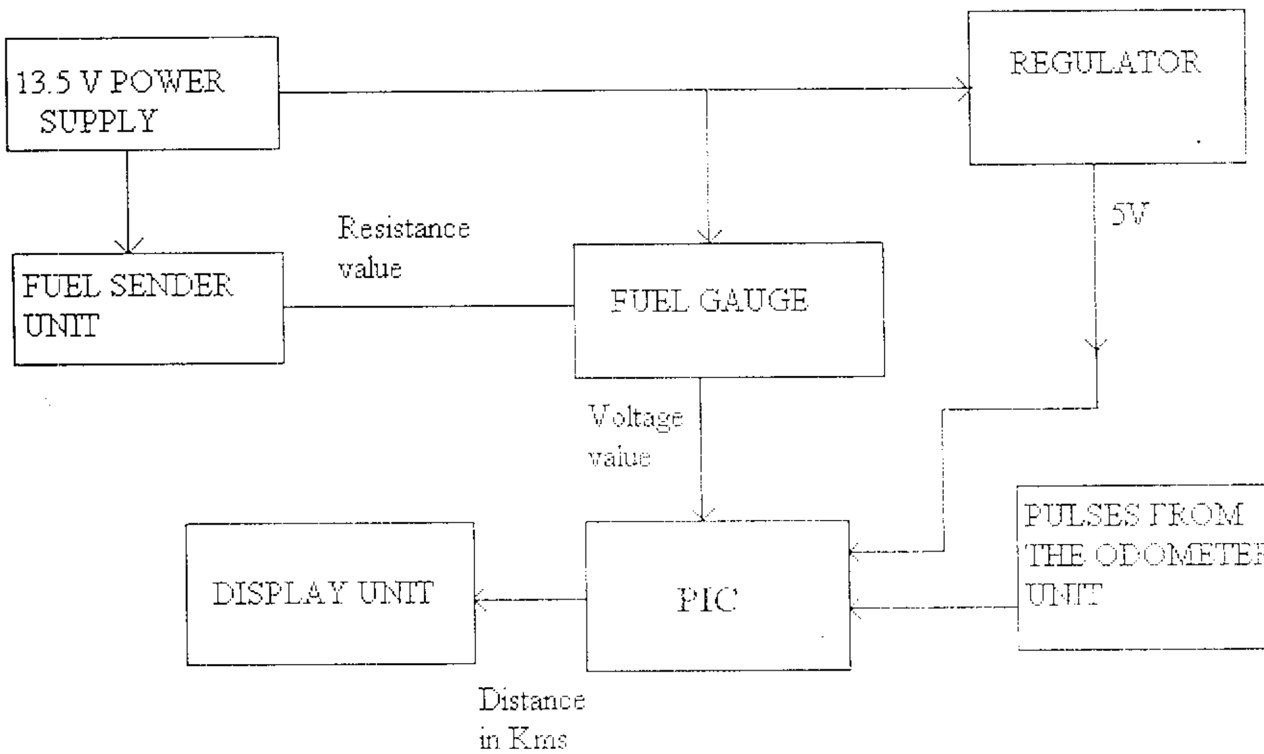
The software part consists of programming the microcontroller for getting input through its analog input channels and displaying the output data accordingly.

The microcontroller used is PIC 16F73. The software part uses MPLAB software from Microchip Corporation for programming PIC microcontrollers.

The project has been applied and tested in a two-wheeler having a reed switch in its odometer unit, which simplified the indication of the completion of one kilometer from the pulses obtained from it.

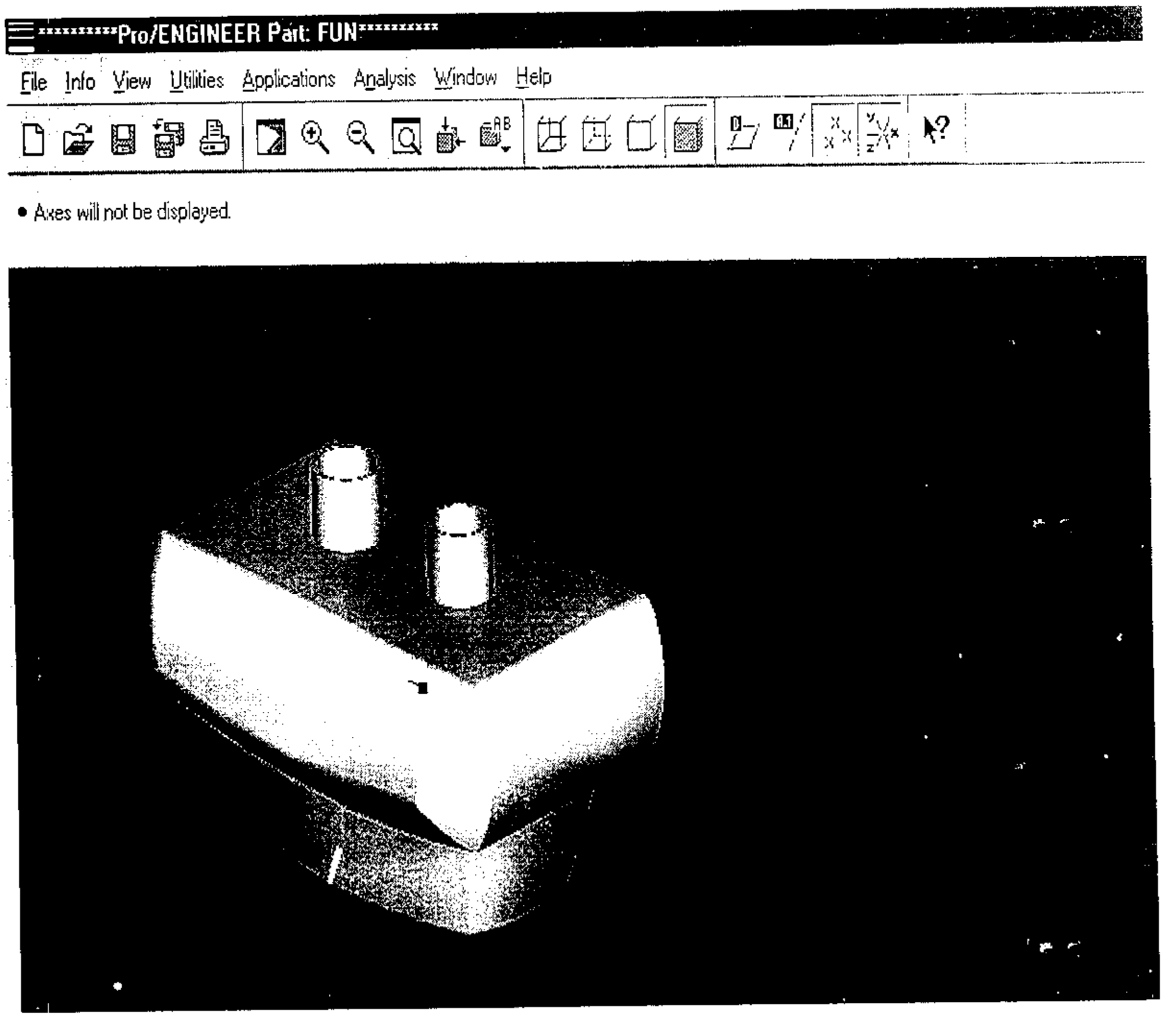
Block Diagram

2. BLOCK DIAGRAM OF THE SYSTEM



Tank Unit

3. TANK UNIT



TANK CAPACITY: 5.5 litres

MATERIAL: Plastic

HEIGHT: 16.1 cms

WIDTH: Upper part: 21.0 cms Lower part:17.5 cms

Fuel Sender Unit

4.FUEL SENDER UNIT

4.1 INTRODUCTION

A fuel sender is an important part of the fuel tank which indicates the amount of fuel in the tank and gives the output to the fuel gauge. It works on the principle of rheostat.

4.2 CHARACTERISTICS OF FUEL SENDER UNIT

- **TYPE**: Wire wound
- **MOUNTING**: Top of fuel tank with no mounting holes
- **CONNECTION**: With wiring harness (two pin)
- **PLATING & PASSIVATION**: Zinc plating and Yellow passivation
- **LEVER FLOAT**: Spring steel, diameter = 2.0 mm
- **FLOAT**: Cylindrical – hard rubber sponge
- **LEVER FLOAT SWING**: 50 degrees

4.3 DESCRIPTION OF PARTS, MATERIAL USED AND THEIR FUNCTIONS

Sl.No	PART	MATERIAL	FUNCTION
1.	Flange	Steel	To mount the housing on the mating part.
2.	Housing	Mild Steel	To accommodate sub-assembly.
3.	Lever float	Spring Steel	To move the spring contact as it moves on [illegible] surface of the fuel.
4.	Float	Hard rubber sponge	To float on the surface of the fuel.
5.	Spring contact	Phosphor bronze	To move over the wire and vary resistance
6.	Rivet bearing	Brass	For connecting the lever float and the spring contact.
7.	Holder	Steel	To hold the lever float and move along with it as it floats on the surface of the fuel.
8.	Spring compression	Phosphor bronze	To give the right contact pressure to the spring contact.
9.	Bobbin	Nylon	To accommodate wire windings.
10.	Terminal	Brass with tin coating	For electrical connection.
11.	Bush	Nitrite rubber	To prevent leakage of fuel.
12.	Wire	Nichrome	For electrical contact and to vary resistance.

4.4 CONSTRUCTION

The wire is wound on the bobbin which is held straight and the spring contact moves along the edge of the bobbin which forms the means of measuring the resistance. The spring compression gives the right contact pressure to the spring contact. The fuel sender unit is mounted on the top of the fuel tank and is held in position by means of a threaded cap since no mounting holes are provided on the top of the flange for holding the unit in position. All the steel parts are zinc plated and yellow passivated in order to prevent corrosion. Wiring harness in which the output is taken to the fuel gauge is provided. The float is made of rubber and is arrested i.e. it cannot rotate about its axis. The housing is used to hold the sub-assembly parts and it determines the mounting of the bobbin. The bobbin and the spring contact are closed by a cover that is attached to the housing. A holder is used to hold the lever float and it moves along with the lever float as it floats on the surface of the fuel. The lever float and the spring contact are connected by means of a rivet bearing. A bush and gasket to prevent the leakage of the fuel is also provided.

4.5 PRINCIPLE OF OPERATION

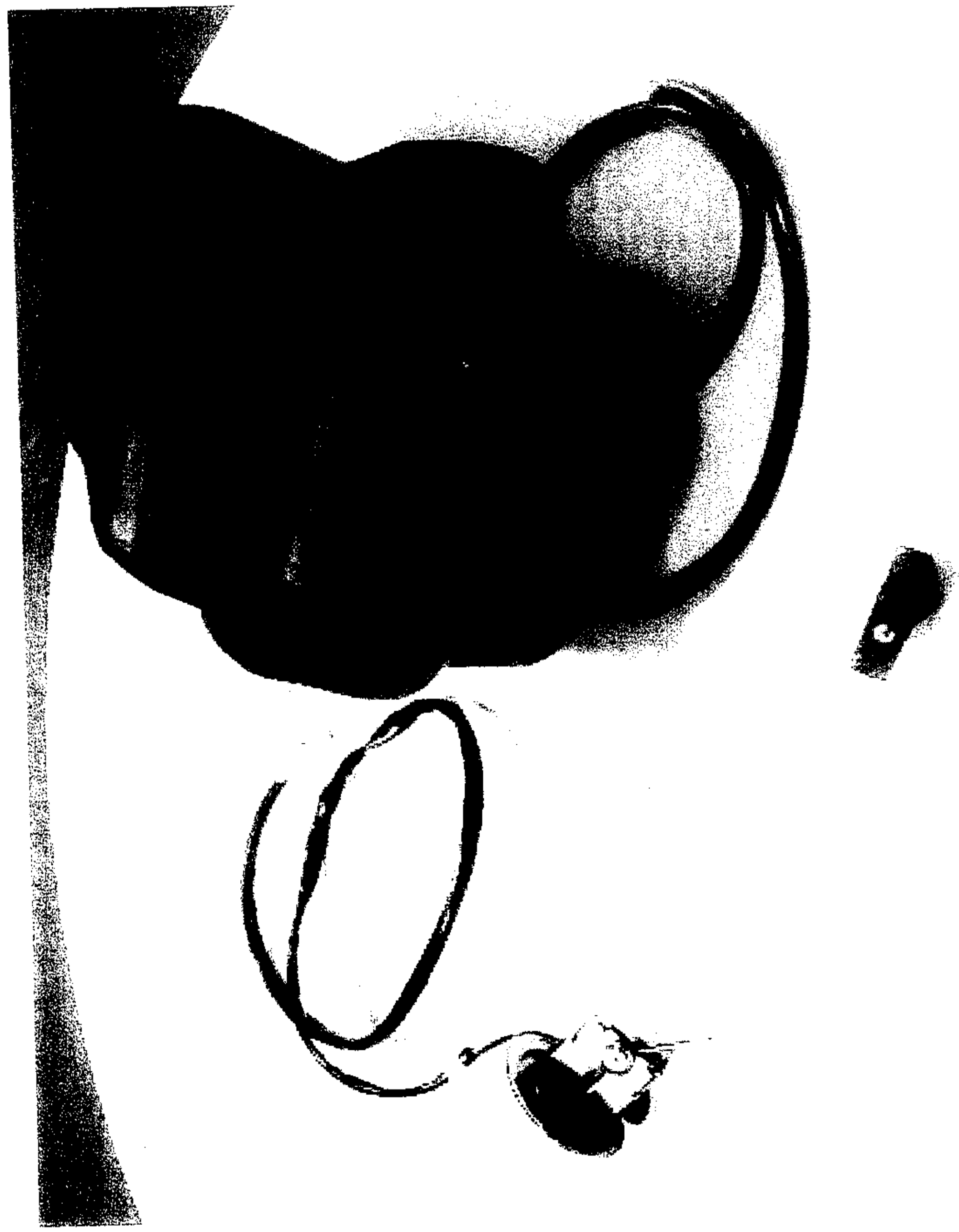
The float along with the lever float, floats on the surface of the fuel. The lever float is attached to the spring contact on the other side. As the lever float moves, the spring contact also moves on the bobbin containing the wire windings. The value of resistance varies as the spring contact moves over the wire. The terminal is used to connect the output to the indication unit. The change in resistance causes deflection of the pointer in the indication unit which indicates the level of fuel in the tank.

4.6 VALUES OF RESISTANCE TAKEN CORRESPONDING TO DIFFERENT FUEL LEVELS

Total capacity of fuel tank = 5500 ml

Sl. No	FUEL LEVEL(ml)	RESISTANCE (ohms)
1.	500	90.4
2.	600	87.4
3.	700	82.7
4.	800	82.6
5.	900	82.5
6.	1000	80.4
7.	1100	78.1
8.	1200	76.0
9.	1300	76.0
10.	1400	65.0
11.	1500	63.0
12.	1600	62.9
13.	1700	62.8
14.	1800	60.6
15.	1900	58.5
16.	2000	54.4
17.	2100	51.7
18.	2200	49.5
19.	2300	47.8
20.	2400	45.1
21.	2500	42.9
22.	2600	42.9
23.	2700	40.7
24.	2800	38.4

25.	2900	38.4
26.	3000	36.2
27.	3100	34.3
28.	3200	34.2
29.	3300	32.0
30.	3400	30.0
31.	3500	30.0
32.	3600	28.4
33.	3700	27.5
34.	3800	25.3
35.	3900	25.3
36.	4000	23.2
37.	4100	21.5
38.	4200	21.3
39.	4300	19.0
40.	4400	18.9
41.	4500	16.7
42.	4600	14.7
43.	4700	14.4
44.	4800	12.0
45.	4900	11.1
46.	5000	10.6
47.	5100	8.0
48.	5200	8.0
49.	5300	8.0

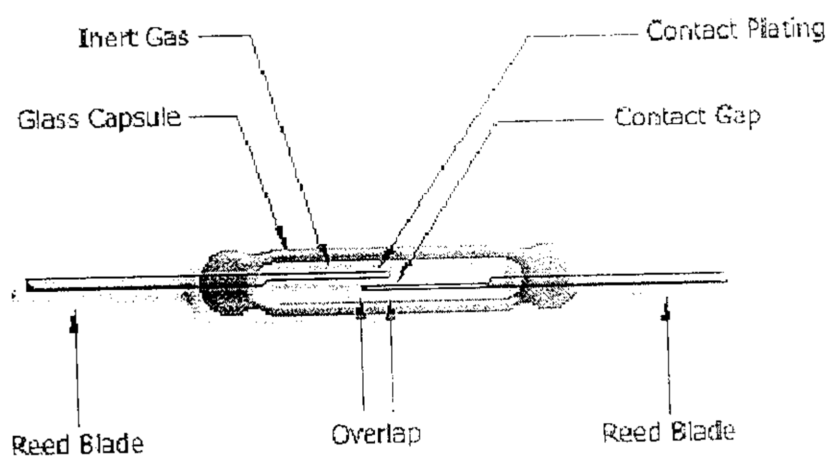


Reed Switch

5. REED SWITCH

5.1 INTRODUCTION

A reed switch assembly contains ferromagnetic contact blades, hermetically sealed in a glass envelope which is filled with an inert gas. The switch is operated by an externally generated magnetic field, either from a coil or permanent magnet.



5.2 TYPE USED

ORD2212

5.3 GENERAL DESCRIPTION

The ORD2212 is a single-contact reed switch designed for the purpose of low operating noise and closed differential motion. The contacts are sealed within the glass tube with inert gas to maintain contact reliability.

5.4 FEATURES

- Reed contacts are hermetically sealed within a glass tube with inert gas and do not receive any influence from the external atmospheric environment.
- Quick response
- The structure comprises an operating system and electrical circuits coaxially. Reed switches are suited to applications in radio frequency.
- Reed switches are compact and light weight.
- Superior corrosion resistance and wear resistance of the contacts assures stable switching operation and long life.
- With a permanent magnet installed, reed switches economically and easily become proximity switches.

5.5 CONSTRUCTION

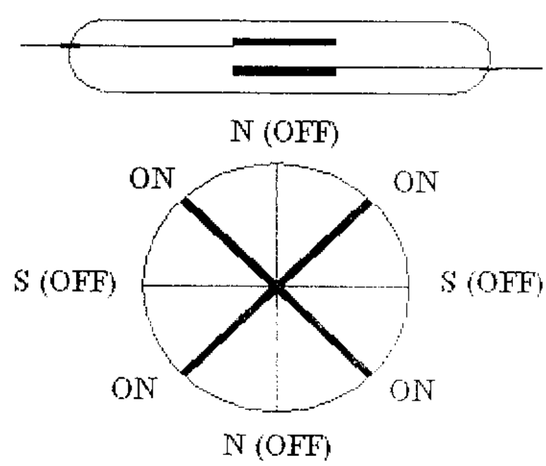
A basic magnetic reed switch consists of a pair of low resistance, ferromagnetic, slender flattened reeds, hermetically sealed into a glass tube with a controlled atmosphere in cantilever fashion so that the ends align and overlap - but with a small air gap. Since the reeds are ferromagnetic, the extreme ends will assume opposite magnetic polarity when brought into the influence of a magnetic field. When the magnetic flux density is sufficient, the attraction forces of the opposing magnetic poles overcome the reed stiffness causing them to flex toward each other and make contact.

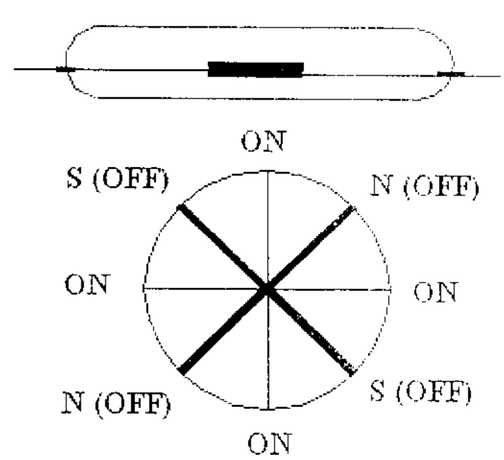
5.6 PRINCIPLE OF OPERATION

Magnetic reed switches are actuated by the presence of a magnetic field with sufficient flux. This is accomplished by bringing a permanent magnet close to the reed switch.

The reed switch of type ORD2212 is a normally closed contact switch. Whenever a pole of the permanent magnet comes close to the reed switch, due to the magnetic force of attraction, the contact lips tend to move towards the pole. Since the bottom lip has more flexibility than the top lip, the contact between the two lips become open and hence the reed contact can be closed and opened based on the proximity of the pole of the permanent magnet. This operation can be repeated millions of times at extremely high speeds.

REED SWITCH ON AND OFF POSITIONS





5.7 CALCULATION PART

The reed switch and the permanent magnet arrangement is used to indicate the completion of one kilometer. The steps involved in the calculation denoting the completion of one kilometer are listed below.

STEP 1: Calculation of number of revolutions of the wheel for covering one Kilometer

The number of revolutions of the wheel is calculated based on wheel diameter.

The wheel diameter = 31.75 cms

The circumference is given by **$2*\Pi*r$ = 99.745 cms**

approximately **100cms**

Thus, one revolution of the wheel corresponds to **1 metre**

Therefore for covering 1 km, we need **1000 revolutions.**

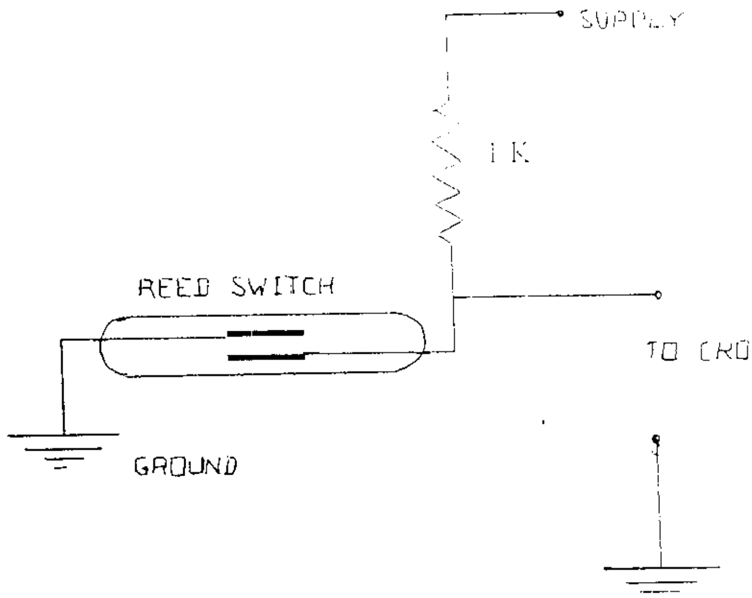
STEP 2: Calculation of number of rotations of the four pole ring magnet

The wheel is directly connected to the four-pole ring magnet in the odometer unit. Therefore, the number of revolutions of the wheel and the number of rotations of the four-pole ring magnet are the same. From the above step, the number of revolutions of the wheel for covering one kilometer = **1000** = the number of rotations of the four pole magnet.

STEP 3: Calculation of number of pulses to indicate the completion of one kilometer

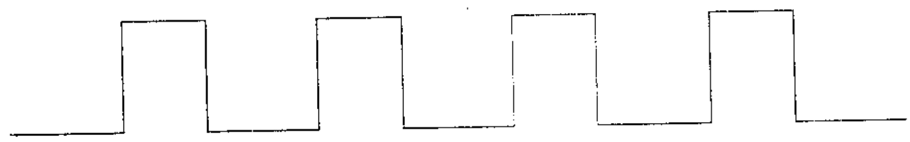
One complete rotation of the four-pole ring magnet causes the reed contact to open and close for four times.

The arrangement for measuring the pulses in CRO is shown below.



The pulse is measured by connecting a load (resistor of value 1k) to one end of the reed switch (the other end is ground) and the other end of the load is connected to the supply. The CRO is connected between one end of the resistor and the ground. A supply of 5 volts is given to the circuit.

When the reed contact is opened, the 5 volts will appear across the load and when the reed contact is closed, the current will take the least resistance path offered by the ground and hence negligible voltage will appear across the load. Thus, pulses are obtained in the CRO.



Observation

ON time = **4 ms**

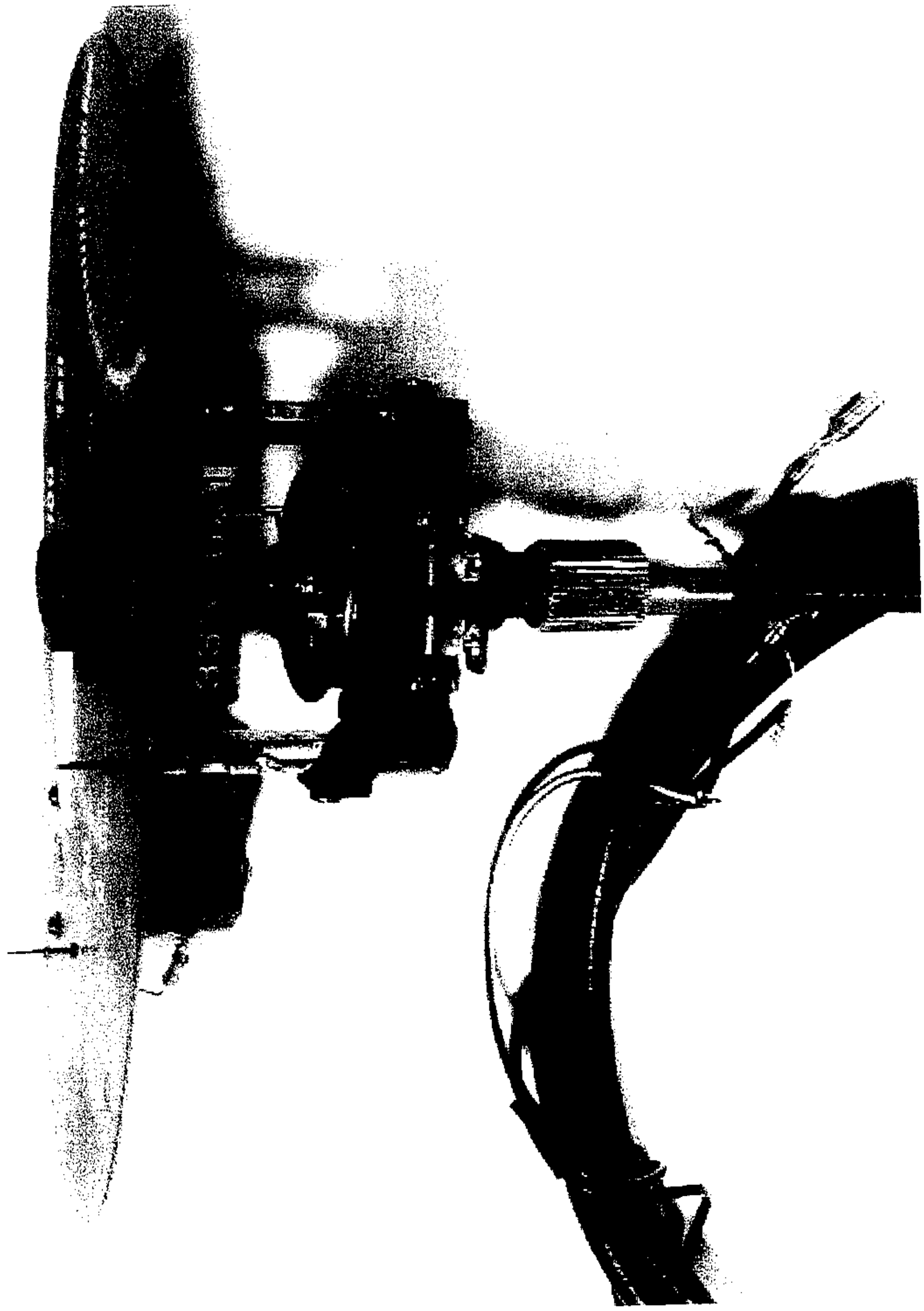
OFF time = **5ms**

DUTY CYCLE = ON time/ (ON time+ OFF time)

= **44%**

Thus, for one rotation of four-pole magnet, we get **four pulses.**

Therefore for 1000 rotations of the four pole ring magnet (for one kilometer), we get 4000 pulses.



Fuel Gauge

6. FUEL GAUGE

6.1 INTRODUCTION

The fuel gauge is a part of the indication system and is used to indicate the amount of fuel in the tank based on the resistance value obtained from the fuel sender unit.

6.2 CONSTRUCTIONAL DETAILS

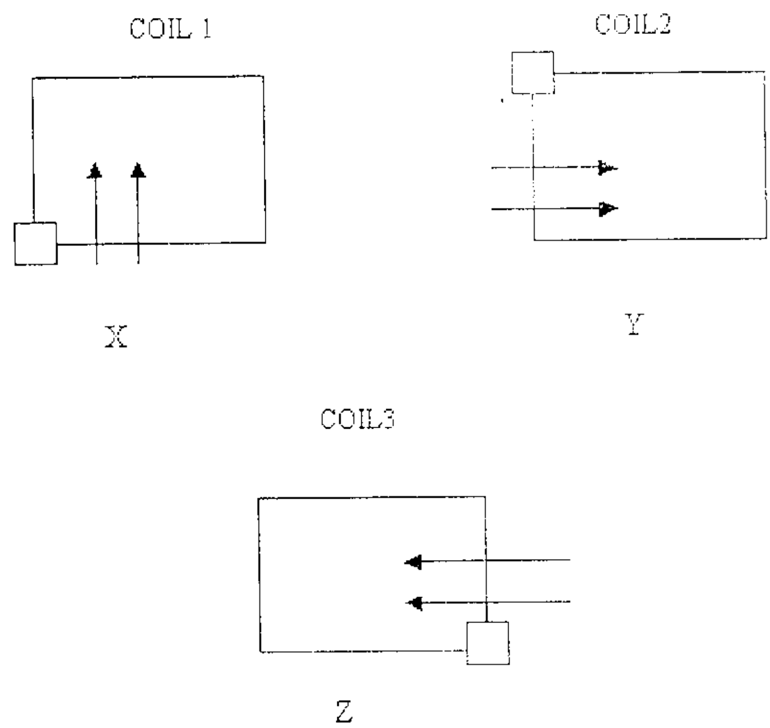
The fuel gauge has four terminals namely

- Positive terminal
- Negative terminal
- Signal terminal
- Dummy terminal, the usage of which may be extended when needed.

A supply of 13.5 volts is given between the positive and the negative terminal. The resistance value corresponding to the fuel level from the fuel sender unit is given to the signal terminal. Based on the resistance value, the pointer deflects in the indication system.

The fuel gauge also incorporates a disc magnet, which is responsible for the deflection of the pointer indicating the fuel level and a return magnet, which returns the pointer to the low fuel indication level when the ignition is off.

Coils (**0.12 mm thick**) are wound in the fuel gauge in three different directions. The number of turns as specified by the manufacturer and the direction of winding is shown below.

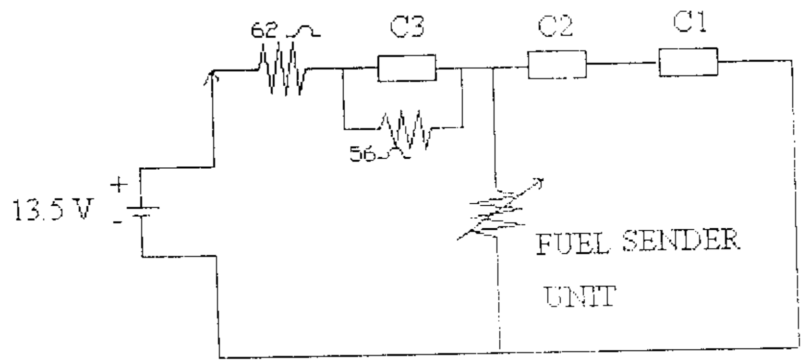


- X, Y and Z indicate the number of turns of the coils C1, C2 and C3 respectively and
- The arrows indicate the direction of winding.

One end of the coil is fixed to the terminal (any one among the three) and wound in CCW (forward) direction for the specified number of turns, corresponding to the terminal. This procedure is repeated for all the three terminals.

6.3 PRINCIPLE OF OPERATION

A supply of 13.5 volts is given to the circuit. The resistor 56 ohms acts as the current limiting resistor. The resistance offered by the coil C3 is reduced by connecting a resistor of value 62 ohms parallel to it. Based on the output resistance reading from the fuel sender unit, the current in the path of the variable resistance and the path of C2 and C1 is decided.



The magneto motive force is given by,

MMF = 2NI

where,

N = number of turns of the coil

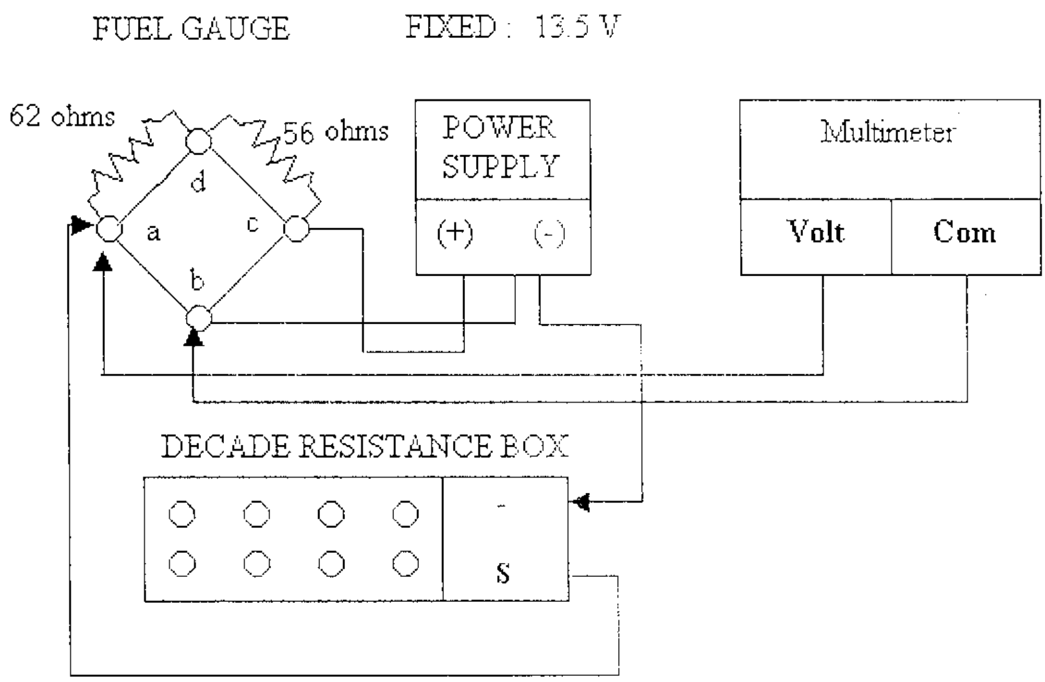
I = current through the coil.

Since the number of turns is fixed, the resultant magneto motive force depends on the current through the coils and the resistance value from the fuel sender unit. Based on the resultant MMF, the pointer is made to deflect in the fuel range of the indication system.

When the power supply is cut-off the pointer is attracted by the return magnet to the low fuel indication level.

6.4 MEASUREMENT OF VOLTAGE CORRESPONDING TO THE RESISTANCE VALUES

The circuit connection for measuring the voltage corresponding to the resistance values is shown below.



REPRESENTATION

a - signal

b - battery negative

c - battery positive

d - dummy

The resistance value indicating the fuel level cannot be directly fed as an input to the microcontroller unit. Hence the voltage level corresponding to the resistance value is measured and fed to the micro controller.

In the diagram, the resistance value (already taken from the fuel sender unit for different fuel levels) is fixed by using the decade resistance box and the corresponding voltage level is observed from the ohmmeter.

6.5 OBSERVATION

The voltage reading for different resistance values, as observed from the voltmeter and ohmmeter are listed below.

Sl. No	FUEL LEVEL(ml)	RESISTANCE (ohms)	VOLTAGE (volts)
1.	500	90.4	4.702
2.	600	87.4	4.652
3.	700	82.7	4.558
4.	800	82.6	4.556
5.	900	82.5	4.554
6.	1000	80.4	4.510
7.	1100	78.1	4.461
8.	1200	76.0	4.415
9.	1300	76.0	4.415
10.	1400	65.0	4.143
11.	1500	63.0	4.084
12.	1600	62.9	4.082
13.	1700	62.8	4.079
14.	1800	60.6	4.015
15.	1900	58.5	3.953
16.	2000	54.4	3.823

17.	2100	51.7	3.732
18.	2200	49.5	3.653
19.	2300	47.8	3.590
20.	2400	45.1	3.486
21.	2500	42.9	3.395
22.	2600	42.9	3.395
23.	2700	40.7	3.300
24.	2800	38.4	3.197
25.	2900	38.4	3.197
26.	3000	36.2	3.094
27.	3100	34.3	2.998
28.	3200	34.2	2.993
29.	3300	32.0	2.879
30.	3400	30.0	2.769
31.	3500	30.0	2.769
32.	3600	28.4	2.766
33.	3700	27.5	2.622
34.	3800	25.3	2.487
35.	3900	25.3	2.487
36.	4000	23.2	2.349
37.	4100	21.5	2.230
38.	4200	21.3	2.216
39.	4300	19.0	2.049
40.	4400	18.9	2.042
41.	4500	16.7	1.866
42.	4600	14.7	1.697
43.	4700	14.4	1.671
44.	4800	12.0	1.455
45.	4900	11.1	1.355
46.	5000	10.6	1.309
47.	5100	8.0	1.2
48.	5200	8.0	1.2
49.	5300	8.0	1.2

Hardware

7. HARDWARE DESCRIPTION

7.1 POWER SUPPLY SECTION

Since all electronic circuits work only with low D.C. voltage, we need a power supply unit to provide the appropriate voltage supply. This section consists of the IC voltage Regulator 7805 which is responsible for giving a proper DC output voltage of +5V to the system for its proper operation.12 to 15 V supply is given to the fuel gauge and the fuel sender unit.

7.2 SUPERVISORY CIRCUIT

The Microchip Technology Inc. MCP 130 is a voltage supervisory device designed to keep a micro controller in reset until the system voltage has reached the proper level and stabilized. It also operates as protection from brown-out conditions when the supply voltage drops below a safe operating level. The device is available with a choice of seven different trip voltages and has open drain output. The MCP130 has an internal 5k pull up resistor. The device has a active low RESET pin. The MCP 130 will assert the RESET signal whenever the voltage on the VDD pin is below the trip-point voltage.

7.2.1 NEED FOR A SUPERVISORY CIRCUIT

For many of today's micro controller applications, care must be taken to prevent low power conditions that can cause many different system problems. The most common causes are brown-out conditions where the system supply drops below the operating level momentarily, and the second, is when a slowly decaying power supply causes the micro controller to begin executing instructions without enough voltage to sustain SRAM and producing indeterminate results.

7.3 OSCILLATOR CIRCUITRY

The PIC16F73can be operated in four different oscillator modes. The user can program two configuration bits (FOSC1 and FOSC0) to select one of these four modes:

a) LP Low Power Crystal

b) XT Crystal/Resonator

c) HS High Speed Crystal/Resonator

d) RC Resistor/Capacitor

7.3.1 CRYSTAL OSCILLATOR

In XT, LP or HS modes, a crystal is connected to the OSC1/CLKIN and OSC2/CLKOUT pins to establish oscillation. The PIC16F73 oscillator design requires the use of a parallel cut crystal. Use of a series cut crystal may give a frequency out of the crystal manufacturer's specifications. When in HS mode, the device can accept an external clock source to drive the OSC1/CLKIN pin.

7.4 FUEL LEVEL INPUT SECTION

The resistance value from the fuel sender unit is converted in to corresponding voltage levels. This input signal is controlled since any high value may damage the I.C. This is done by using the voltage divider network and the Zener diode. The signal is filtered using capacitors.

7.5 REED SWITCH PULSE SECTION

The incoming voltage signal is controlled by using a voltage divider network and is filtered by a capacitor. When the reed switch is open, then current enters in the circuit and the transistor (npn configuration) conducts which causes the current to drain through the least resistance path offered by the ground and hence no output goes to pin 13 and when the reed switch is closed, the transistor does not conduct since current drain through the least resistance path offered by the ground before the transistor and hence the applied voltage goes to pin 13.

7.6 MICROCONTROLLER UNIT

The Micro controller that we have used for the project is **PIC16F73**, which is a 28 pin CMOS FLASH micro controller. The special features of this Micro controller are:

7.6.1 High Performance RISC CPU

- Only 35 single word instructions to learn
- All single cycle instructions except for program branches, which are two-cycle.
- Operating speed: DC - 20 MHz clock input
DC - 200 ns instruction cycle
- Up to 8K x 14 words of FLASH Program Memory, Up to 368 x 8 bytes of Data Memory (RAM)
- Pin-out compatible to the PIC16C73B/74B/76/77
- Pin-out compatible to the PIC16F873/874/876/877
- Interrupt capability (up to 12 sources)
- Eight level deep hardware stack
- Direct, Indirect and Relative Addressing modes
- Processor read access to program memory

7.6.2 Special Micro controller Features

- Power-on Reset (POR)
- Power-up Timer (PWRT) and
- Oscillator Start-up Timer (OST)

- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving SLEEP mode
- Selectable oscillator options
- In-Circuit Serial Programming(ICSP) via two pins

7.6.3 Peripheral Features

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during SLEEP via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. resolution is 12.5 ns
  - Compare is 16-bit, max. resolution is 200 ns
  - PWM max. resolution is 10-bit
- 8-bit, up to 8-channel Analog-to-Digital converter
- Synchronous Serial Port (SSP) with SPI (Master mode) and I 2 C (Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI)
- Parallel Slave Port (PSP), 8-bits wide with external RD, WR and CS controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

7.6.4 CMOS Technology

- Low power, high speed CMOS FLASH technology
- Fully static design

- Wide operating voltage range: 2.0V to 5.5V
- High Sink/Source Current: 25mA
- Industrial temperature range
- Low power consumption:
  - < 2 mA typical @ 5V, 4 MHz
  - 20 μA typical @ 3V, 32 kHz
  - < 1 μA typical standby current

7.7 DISPLAY SECTION

7.7.1 Interfacing Micro controller with 7-segment display

In our project, we have multiplexed 7- segment display hence we have connected a transistor to the Vcc input of the display, so that they may be enabled one at a time to accept the incoming data from the portB. Furthermore, we have connected a latch (IC 74 HC 244) at the output of portB pins. The output of the latch is connected to 270 ohms resistor and then to display unit so that required driving current of 20mA for each segment of 7-segment LED is obtained.

7.7.2 Nature of 7-segment LED used

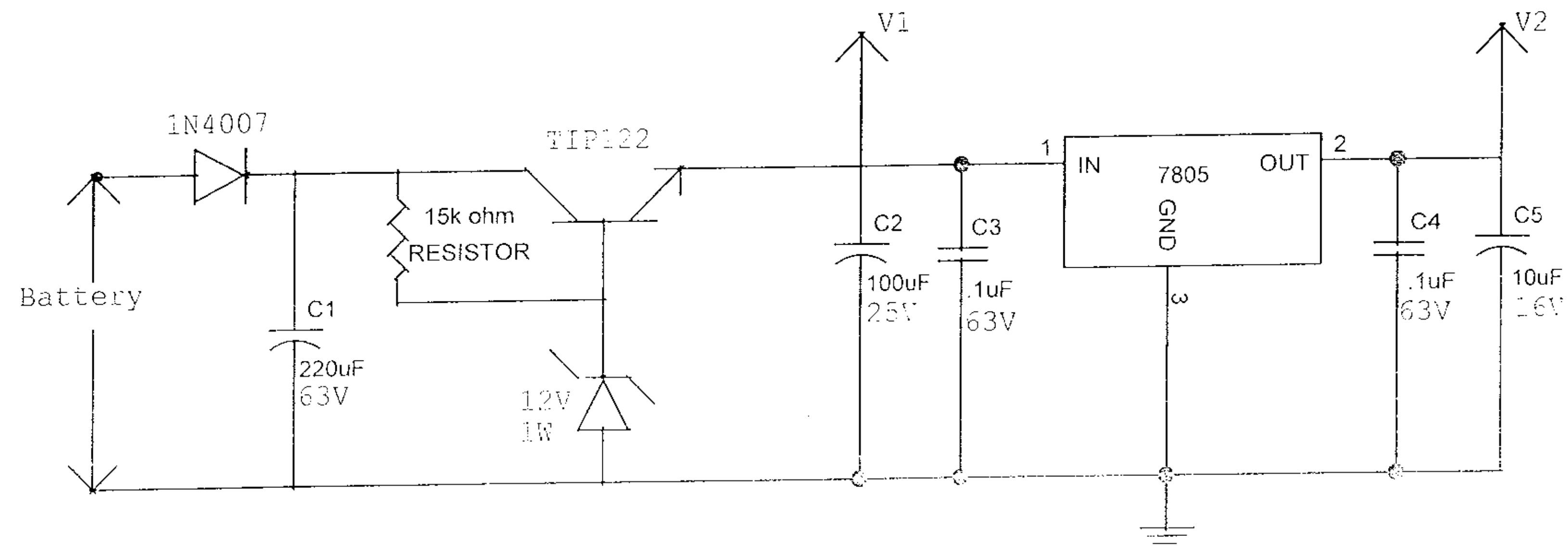
The 7-segment LED that we have used in our project is of common cathode type. Hence only when logic 1 input is given to a segment, it glows. Each segment would derive approximately 20mA of current hence a resistor is to be included to obtain the required driving current and the transistor used to enable the display is of type BC547A.

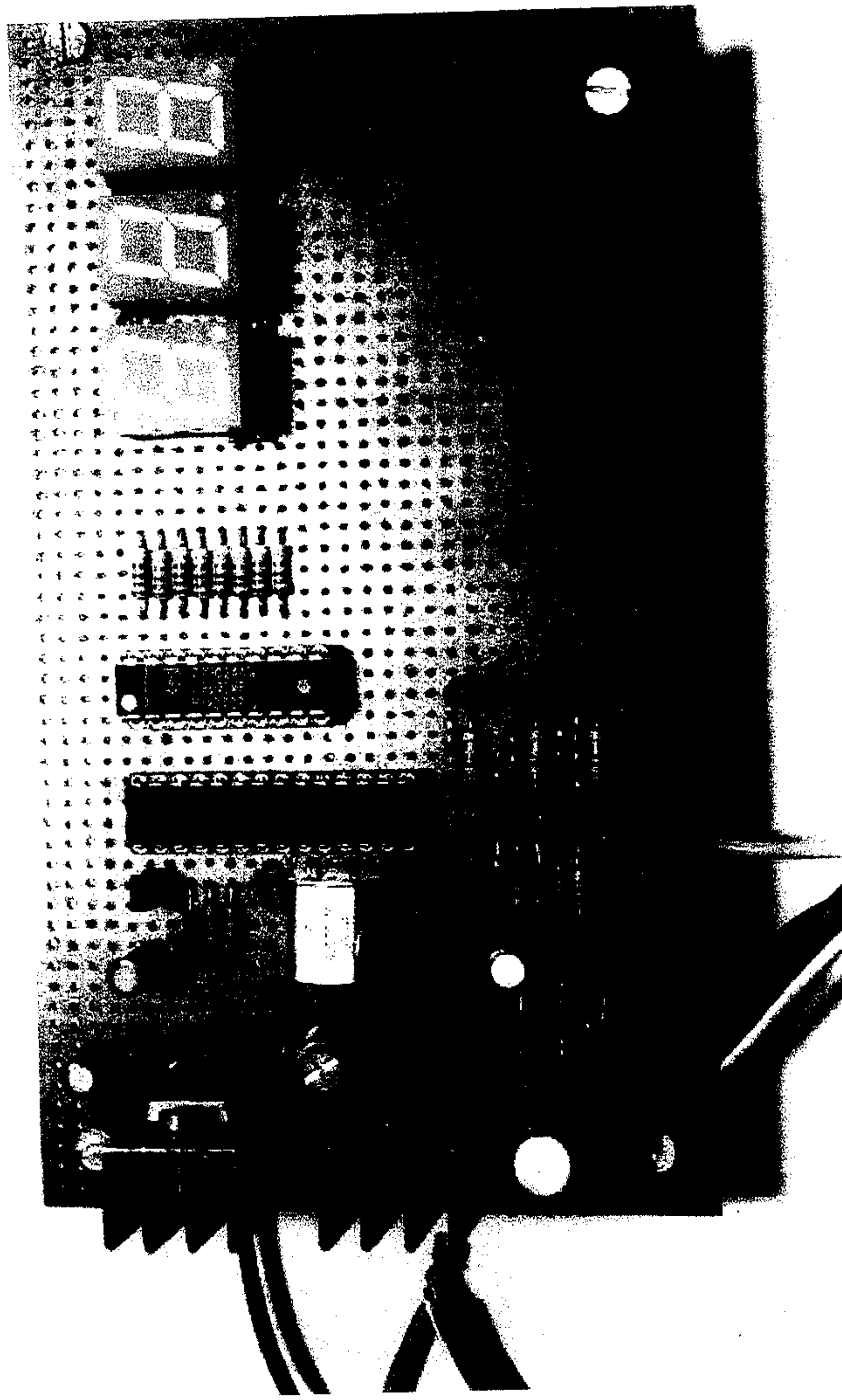
7.7.3 Connections

PortB pins	Latch(IC 74 HC 244) pins
21	2
22	4
23	6
24	8
25	11
26	13
27	15
28	17

- The latch pins 18, 16, 14, 12, 9, 7, 5, 3 are connected to the segments a, b, c, d, e, f, g and dp respectively.

- The portC pins (RC3, RC4, RC5) are connected through 1.2k to the BC547A transistors to enable the displays when needed.

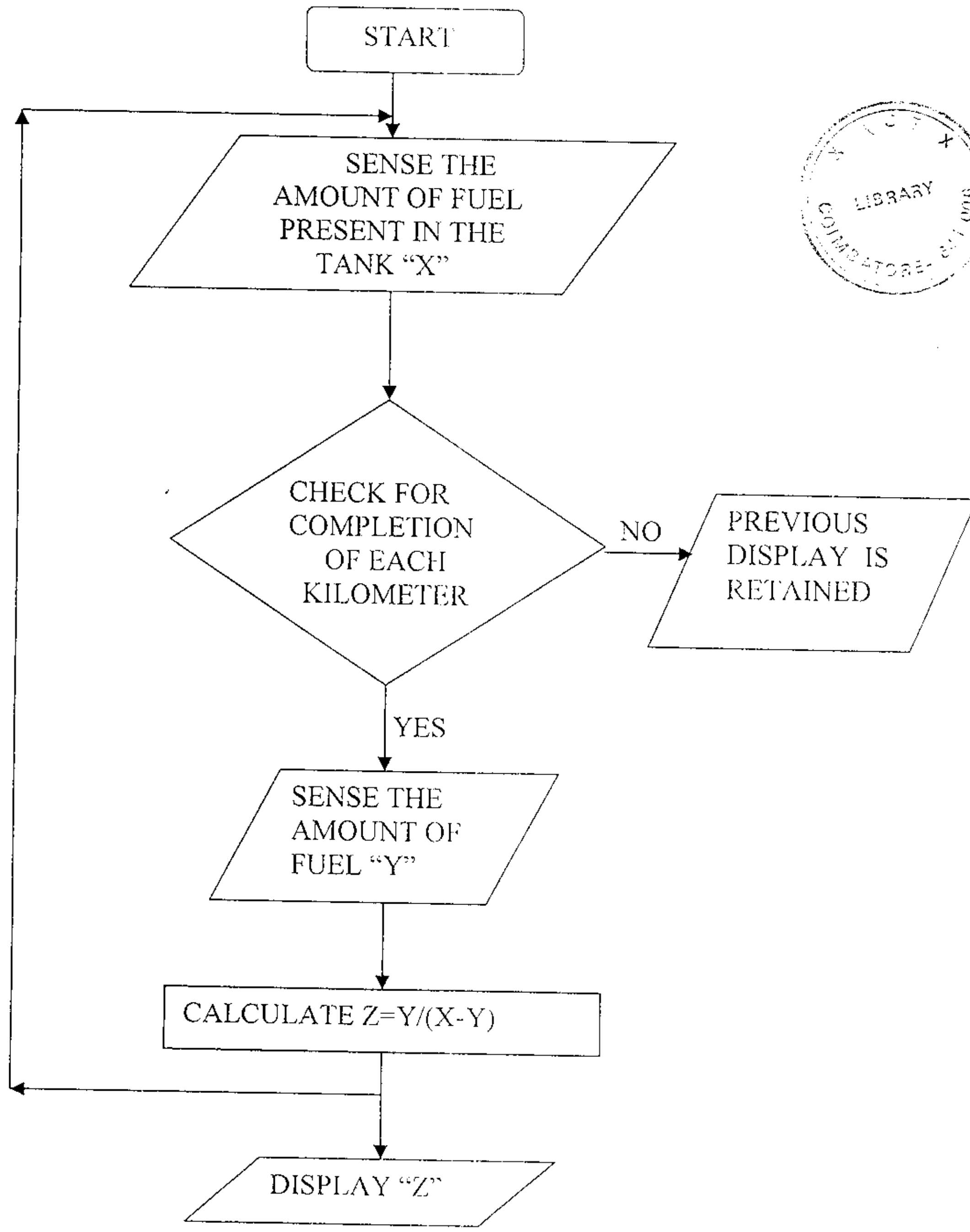

1N4007
Battery
C1
220uF
63V
15k ohm
RESISTOR
TIP122
12V
1W
V1
C2
100uF
25V
C3
.1uF
63V
1
IN
7805
GND
OUT
2
3
V2
C4
.1uF
63V
C5
10uF
16V



Concept

8. CONCEPT

8.1 FLOWCHART



8.2 PROCESSING STEPS

STEP 1: CALCULATION OF ADC VALUE FOR CORRESPONDING VOLTAGE READING

The voltage reading (obtained from fuel gauge) corresponding to the resistance value (obtained from the fuel sender unit) is converted into ADC value. This value is converted in to a digital code by the Micro controller for processing. This value is used to determine the amount of fuel present in the tank.

The formula for converting voltage level into corresponding ADC is given by,

$$\textbf{Value in ADC} = \frac{\textbf{voltage reading} * 255}{\textbf{Full scale voltage value}}$$

The full scale voltage value is **5 V** and

255 refers to the range from **00 to FF**, since 8 bit ADC is used.

READINGS:

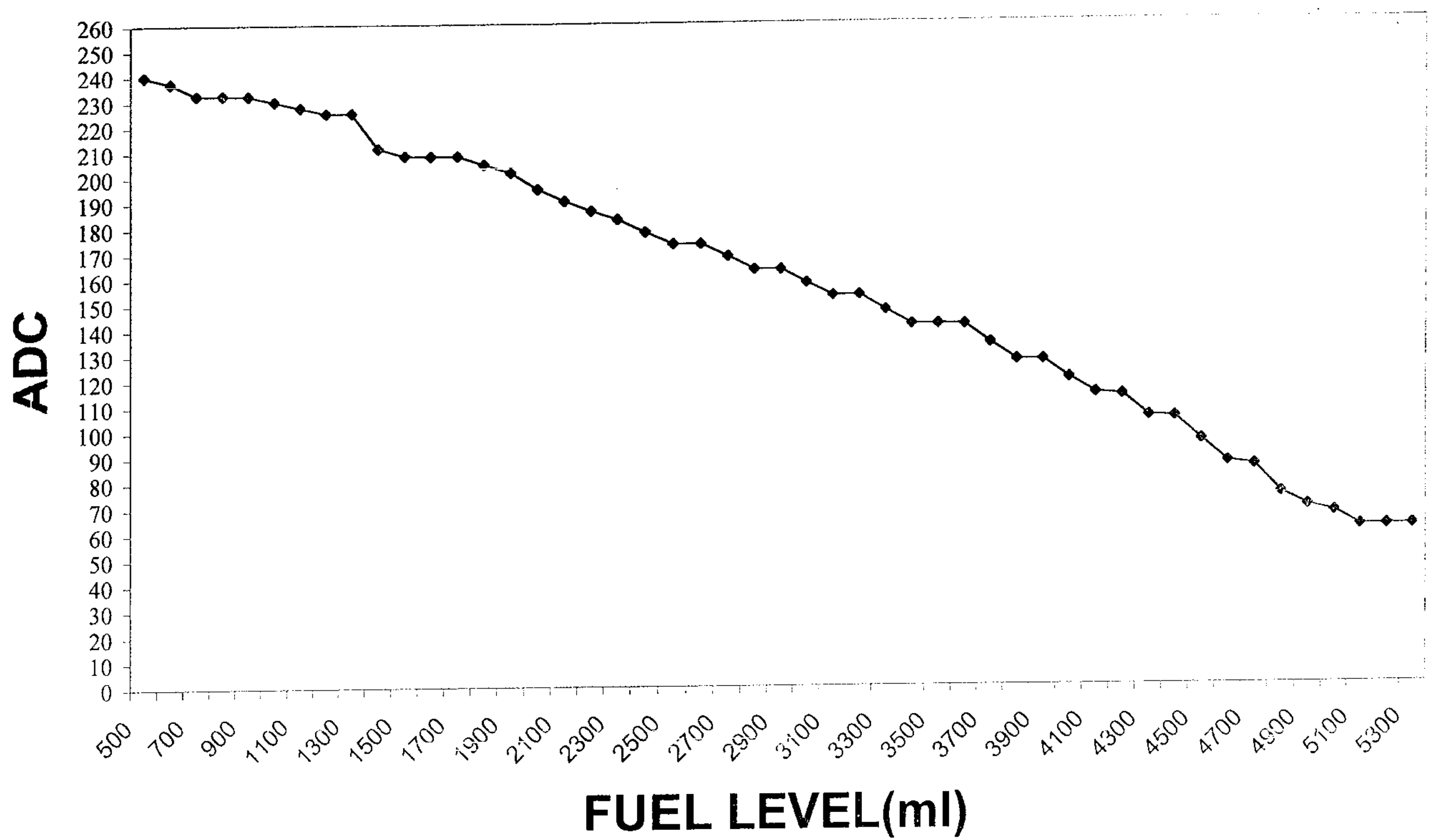
Sl. No	**FUEL LEVEL (ml)**	**RESISTANCE (ohms)**	**VOLTAGE (volts)**	**ADC value**
1.	500	90.4	4.702	239.802
2.	600	87.4	4.652	237.252
3.	700	82.7	4.558	232.458
4.	800	82.6	4.556	232.356
5.	900	82.5	4.554	232.254
6.	1000	80.4	4.510	230.010
7.	1100	78.1	4.461	227.511

8.	1200	76.0	4.415	225.165
9.	1300	76.0	4.415	225.165
10.	1400	65.0	4.143	211.293
11.	1500	63.0	4.084	208.284
12.	1600	62.9	4.082	208.182
13.	1700	62.8	4.079	208.029
14.	1800	60.6	4.015	204.765
15.	1900	58.5	3.953	201.603
16.	2000	54.4	3.823	194.973
17.	2100	51.7	3.732	190.332
18.	2200	49.5	3.653	186.303
19.	2300	47.8	3.590	183.090
20.	2400	45.1	3.486	177.786
21.	2500	42.9	3.395	173.146
22.	2600	42.9	3.395	173.146
23.	2700	40.7	3.300	168.300
24.	2800	38.4	3.197	163.047
25.	2900	38.4	3.197	163.047
26.	3000	36.2	3.094	157.794
27.	3100	34.3	2.998	152.898
28.	3200	34.2	2.993	152.643
29.	3300	32.0	2.879	146.829
30.	3400	30.0	2.769	141.219
31.	3500	30.0	2.769	141.219

32.	3600	28.4	2.766	141.066
33.	3700	27.5	2.622	133.722
34.	3800	25.3	2.487	126.837
35.	3900	25.3	2.487	126.837
36.	4000	23.2	2.349	119.799
37.	4100	21.5	2.230	113.730
38.	4200	21.3	2.216	113.016
39.	4300	19.0	2.049	104.499
40.	4400	18.9	2.042	104.142
41.	4500	16.7	1.866	095.166
42.	4600	14.7	1.697	086.547
43.	4700	14.4	1.671	085.221
44.	4800	12.0	1.455	074.205
45.	4900	11.1	1.355	069.105
46.	5000	10.6	1.309	066.759
47.	5100	8.0	1.2	061.200
48.	5200	8.0	1.2	061.200
49.	5300	8.0	1.2	061.200

STEP 2: PLOTTING A GRAPH BETWEEN FUEL LEVEL AND ADC VALUE

A graph is plotted between fuel level(ml) along X-axis and the ADC value along Y-axis.


ADC
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
500
700
900
1100
1300
1500
1700
1900
2100
2300
2500
2700
2900
3100
3300
3500
3700
3900
4100
4300
4500
4700
4900
5100
5300
FUEL LEVEL(ml)

STEP3: SPLITTING THE GRAPH PLOTTED ACCORDING TO THE LINEARITY AND FINDING THE CO-ORDINATES AND SLOPE OF EACH LINE.

The graph plotted between the **fuel level (ml) along X-axis** and **ADC value along Y-axis** is split up in to **three lines** according to the linearity.

LINE 1

x1 = 1350
y1 = 225
x2 = 550
y2 = 240

LINE 2

x1 = 4450
y1 = 105
x2 = 1350
y2 = 225

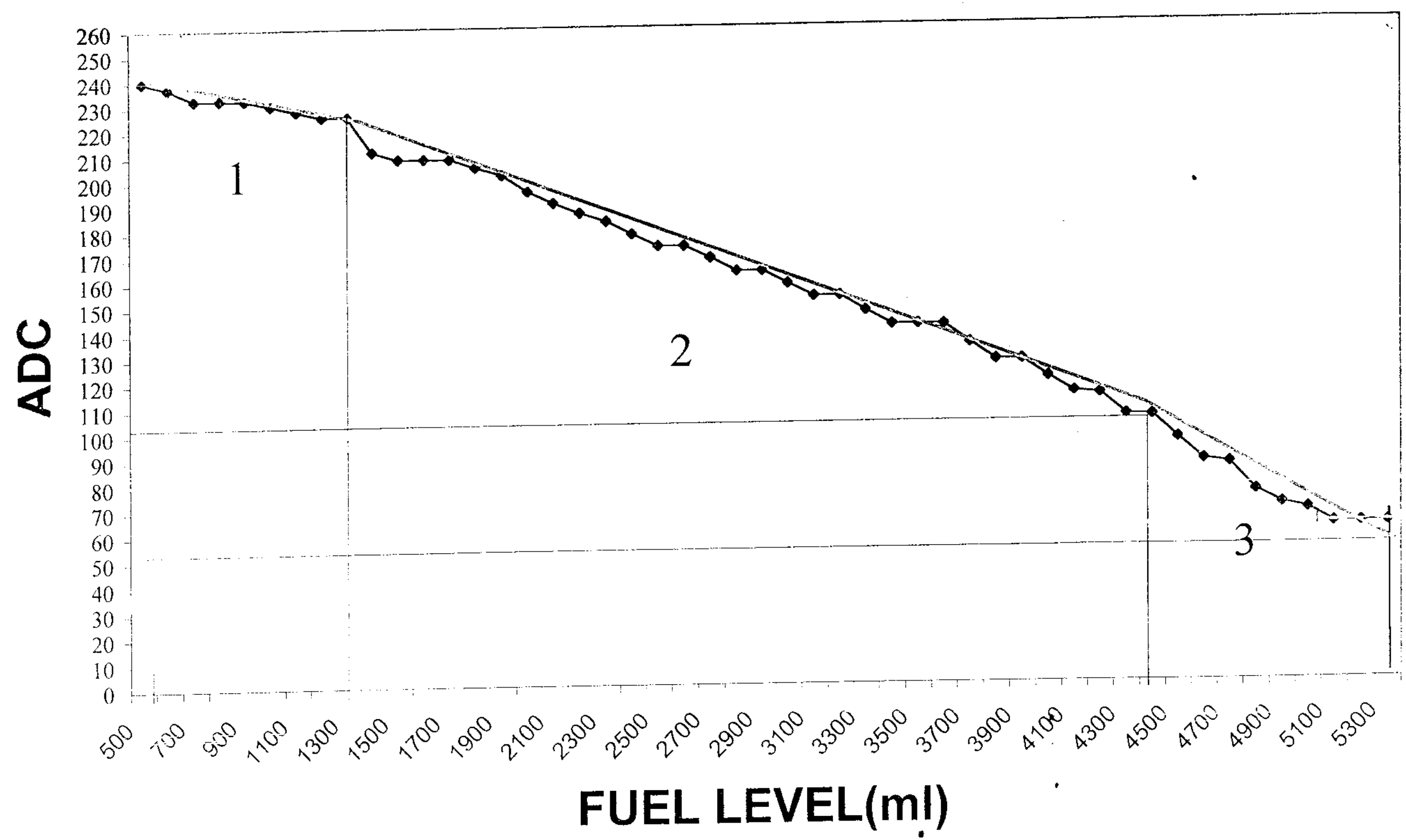
LINE 3

x1 = 5350
y1 = 50
x2 = 4450
y2 = 105

The slope of the line (m) is calculated using the formula,

$$\mathbf{m = \frac{y2-y1}{x2-x1}}$$

LINE 1: m = -0.0188
LINE 2: m = -0.0387
LINE 3: m = -0.0611



ADC
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
500
700
900
1100
1300
1500
1700
1900
2100
2300
2500
2700
2900
3100
3300
3500
3700
3900
4100
4300
4500
4700
4900
5100
5300
1
2
3
FUEL LEVEL(ml)

STEP 4: CALCULATION OF THE FUEL LEVEL

We know that for a line,

$$y-y1 = m\ (x-x1).$$

The above line equation is used to calculate the amount of fuel level according to the ADC value received.

i.e., $x = ((y-y1)/m) + x1$

where,

x = amount of fuel present according to the ADC value received

y = ADC value received

y1 = the minimum ADC value of the line to which the received ADC value belongs to.

m = slope of that line

x1 = the maximum fuel level of the line to which the received ADC value belongs to.

STEP 5: CALCULATING THE DISTANCE RANGE

From the above steps, the fuel level based on the ADC value received can be calculated. The distance range is calculated after the completion of each kilometer.

Consider

X to be the amount of fuel that is present in the tank initially

Y to be the amount of fuel that is present after traveling 1km

and

$$Z = X - Y$$

Then,

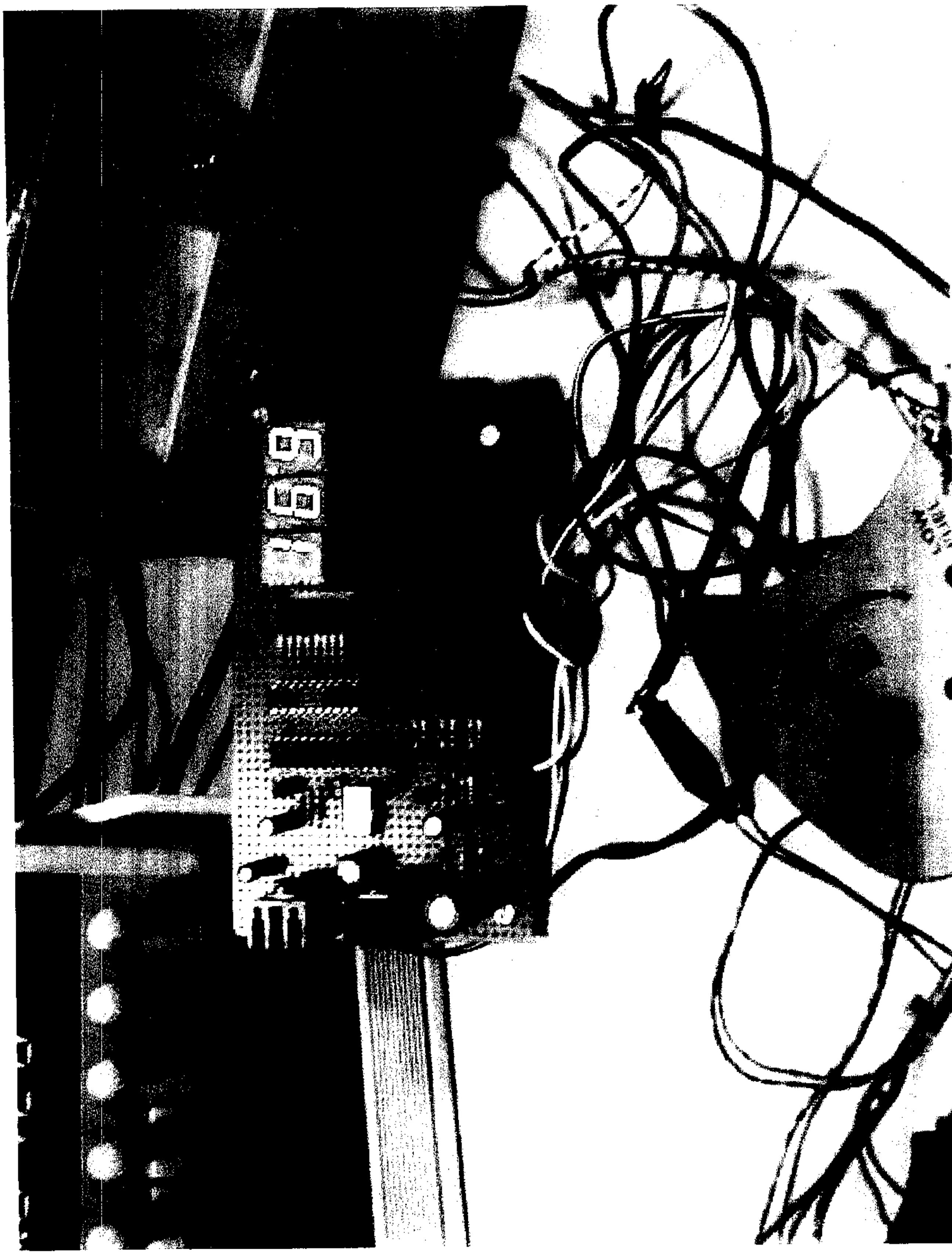
Y/Z gives the distance in kms that could be traveled for the remaining fuel.

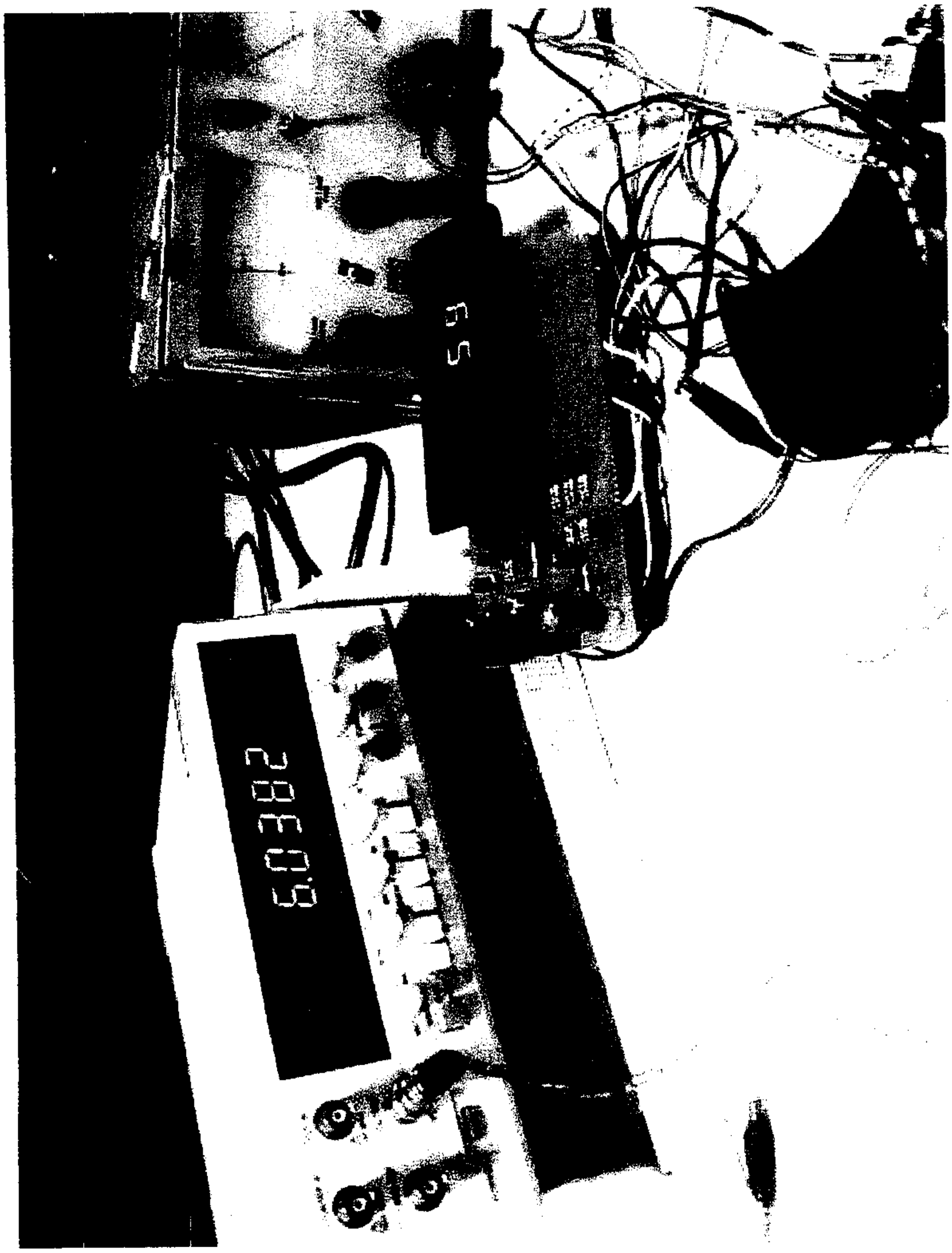
In general, previous fuel level will be stored in X and the current fuel level will be stored in Y.

Results

9. RESULTS OBTAINED

S.No	RESISTANCE VALUE (ohms)	FUEL LEVEL (ml)	DISTANCE RANGE (Kms)
1.	21.3	4200	147
2.	32.0	3300	89
3.	34.2	3100	81
4.	36.2	3000	80
5.	38.4	2900	79
6.	62.8	1700	67
7.	65.0	1400	62
8.	82.5	900	55





Bill of Materials

10. COST DETAILS (BILL OF MATERIALS)

S. No	COMPONENT	TYPE/RANGE	QUANTITY	COST PER ITEM (Rs)
1.	Diode	IN4007	2	0.26
2.	Zener diode	12 V/1 W	1	1.10
		5.1 V/0.5 W	1	0.58
3.	LED display module	HDSP 5503	3	14.00
4.	Resistors	15 kΩ	1	0.08
		100 kΩ	1	0.08
		1 kΩ	3	0.08
		10 kΩ	4	0.08
		470 kΩ	1	0.08
		1.2 kΩ	3	0.08
		270 Ω	8	0.08
5.	Capacitors	220μF/63 V	1	5.90
		0.1μF/63 V	2	0.85
		100μF/25 V	1	2.40
		10μF/16 V	2	0.80
		33pF	1	0.58
		3pF	1	0.58
		0.01μF/63 V	1	0.58
		10μF/16 V (non-polar)	1	1.22

6.	General purpose board	152*85 sq.mm	1	38.60
7.	Transistors	TIP 122	1	8.88
		BC 547	4	0.73
8.	Quartz crystal	8 MHz	1	9.27
9.	External reset	MCP 130	1	28.77
10.	Regulator	7805	1	4.93
11.	Heat sink	PI 49 (25 mm length)	2	4.12
12.	IC	74 HC 244	1	7.78
		PIC 16F73	1	142.63
13.	IC base	74 HC 244 (20 pin DIP)	1	8,95
		PIC 16F73 (28 pin DIP)	1	9.54
		40 pin HDSP 5503	1	36.67
			TOTAL	**347.62**

System Features

11. SYSTEM FEATURES

Our project **DIGITAL DISTANCE METER USING MICRO CONTROLLER** has the following advantages:

- When the driver has to travel in National Highways, knowing the distance range that could be covered for the remaining fuel, he can fill his tank in the near-by Petrol Bunk if needed, so that he could avoid the situation of being tied up in the middle of the travel due to unavailability of petrol and the unavailability of Petrol Bunk near-by.
- The concept used in this project could be applied to all the vehicles.
- The cost involved in development of this meter is very less, since many features are already existing, only an extra electronic circuitry is needed.
- It is very compactable.

Conclusion

12. CONCLUSION

Our project "**Digital Distance Meter using Micro controller**" is applied and tested in a two-wheeler but the concept behind the project could be applied to all vehicles. The device is suitable for Indian conditions and other countries. The device is designed in such a way that facilities available at present can be made use of.

Improvement that can be made for future use:
The LED display can be replaced by LCD display.

Bibliography

BIBLIOGRAPHY

1. Design with PIC Micro controllers, John. B. Peatman, Microchip Corporation
2. PIC MICRO™ MID RANGE MCU Family reference manual
3. Programming and customizing the PIC Microcontrollers, Myke Predko
4. OKI sensor manual
5. Microchip Corporations MPLAB IDE Manual

WEBSITES REFERRED

1. www.microchip.com
2. www.honeywell.com
3. www.reed-sensor.com
4. www.crydom.com
5. www.bajajauto.com

Appendices

APPENDICES

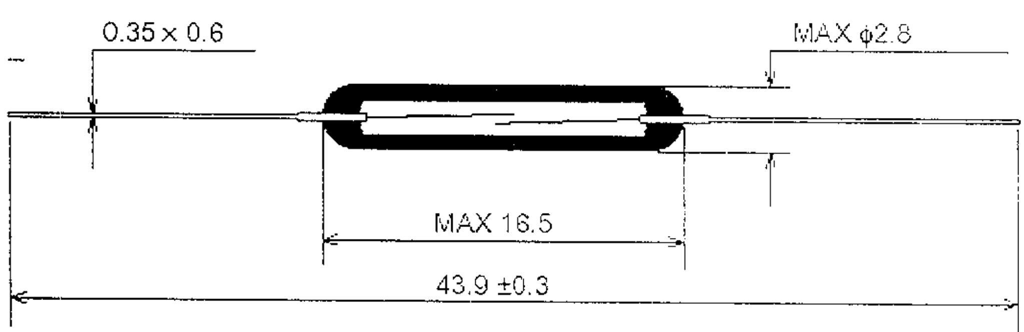
APPENDIX A

REED SWITCH

TYPE: ORD2212

EXTERNAL DIMENSIONS

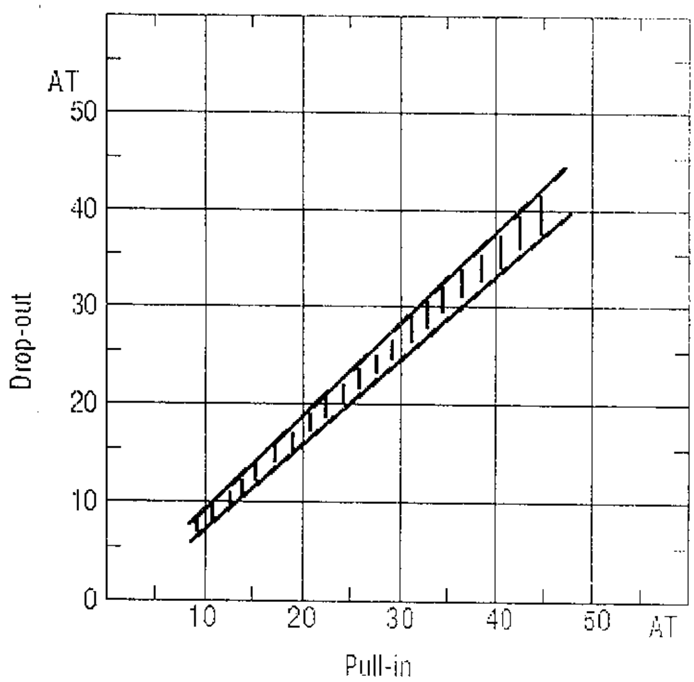
(UNIT: mm)



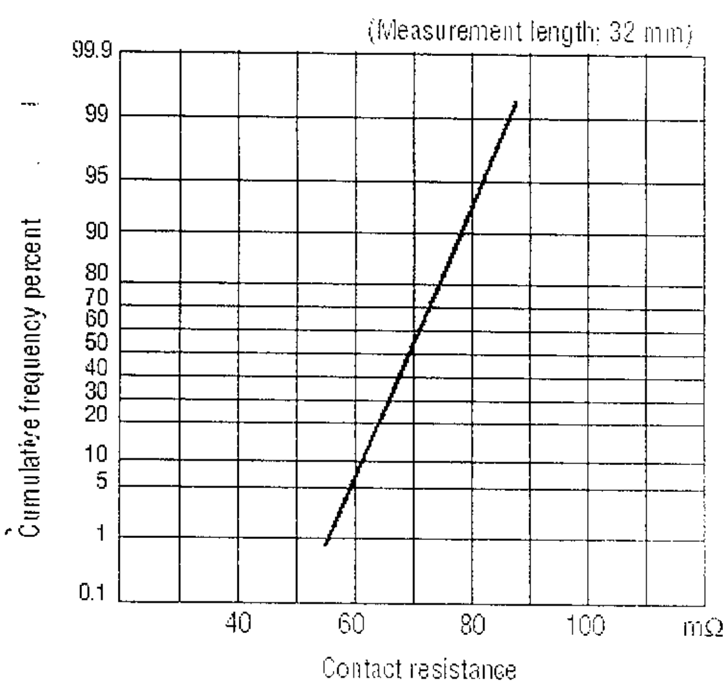
ELECTRICAL CHARACTERISTICS

PARAMETER	SYMBOL	CONDITION	RATED VALUE (MINIMUM)	RATED VALUE (TYPICAL)	RATED VALUE (MAXIMUM)	UNI
Pull-in value	PI	-------	15	-------	35	AT
Drop-out value	DO	PI>20	-------	DO/PI>=0.8	-------	----
Drop-out value	DO	PI<20	-------	DO/PI>=0.7	-------	----
Contact resistance	CR	-------	-------	-------	100	mΩ
Breakdown voltage	-------	-------	150	-------	-------	VD
Insulation resistance	-------	-------	10^9	-------	-------	Ω
Electrostatic capacitance	-------	-------	-------	-------	0.5	Pic fara
Contact rating	-------	-------	-------	-------	10	VA
Maximum switching voltage	-------	-------	-------	-------	100 DC AC	V
Maximum switching current	-------	-------	-------	-------	0.2	A
Maximum carry current	-------	-------	-------	-------	0.5	A

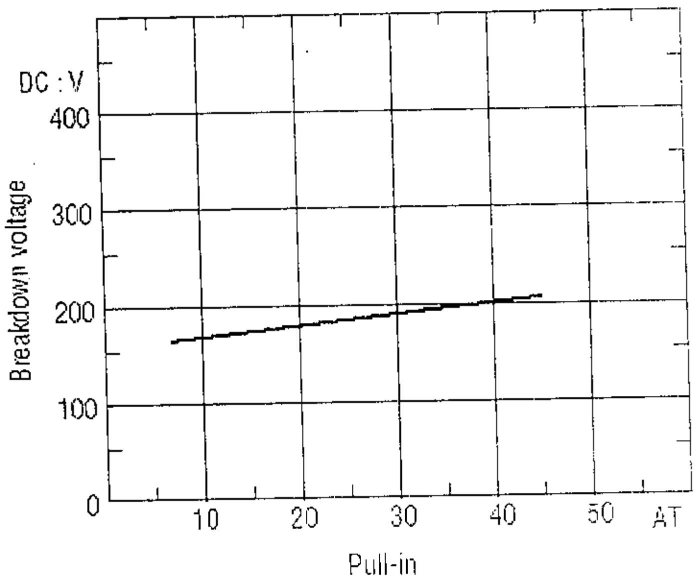
1. Drop-out Vs Pull-in



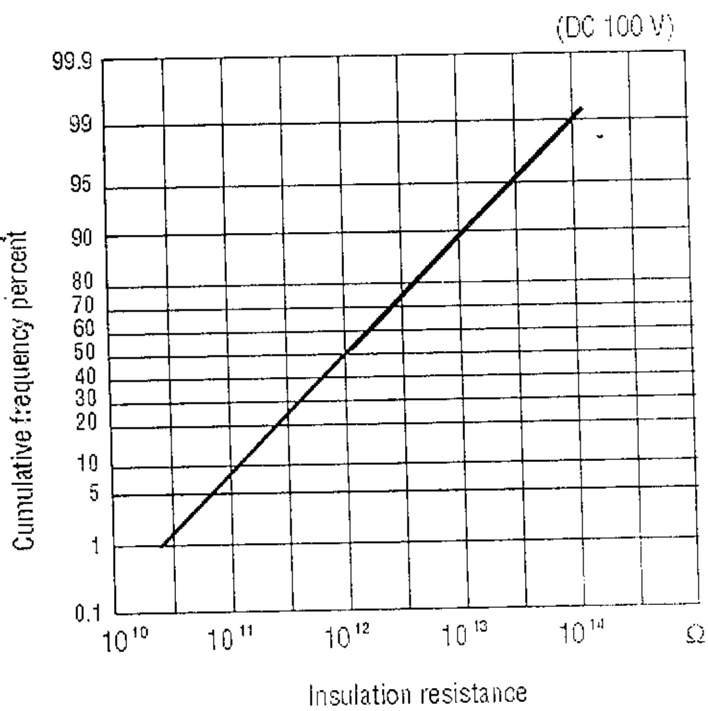
2. Contact resistance



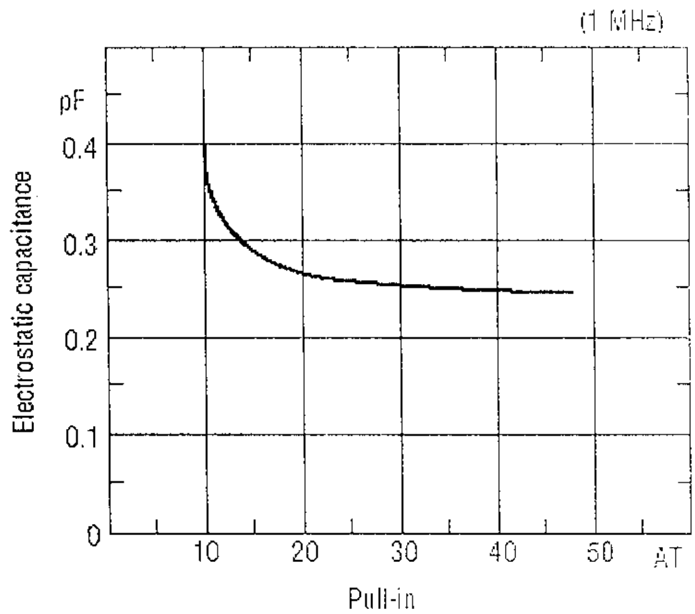
3. Breakdown voltage



4. Insulation resistance



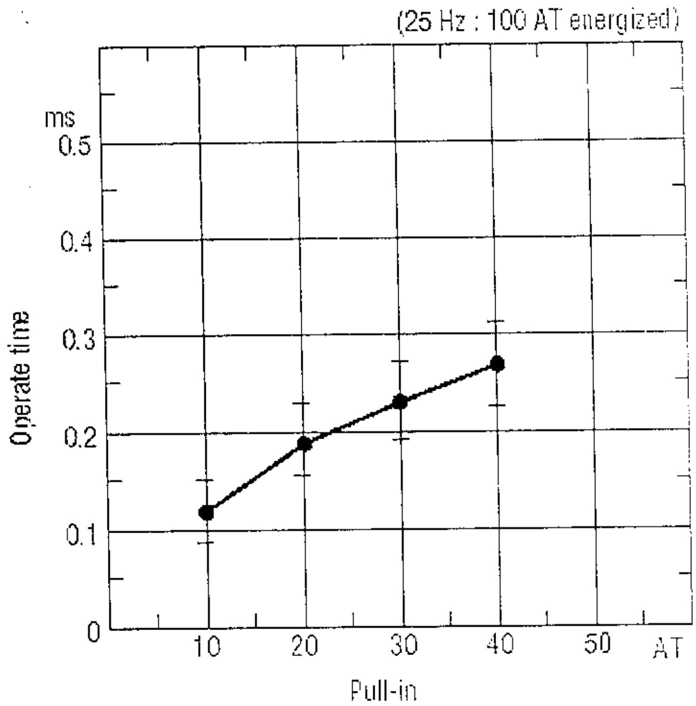
5. Electrostatic capacitance



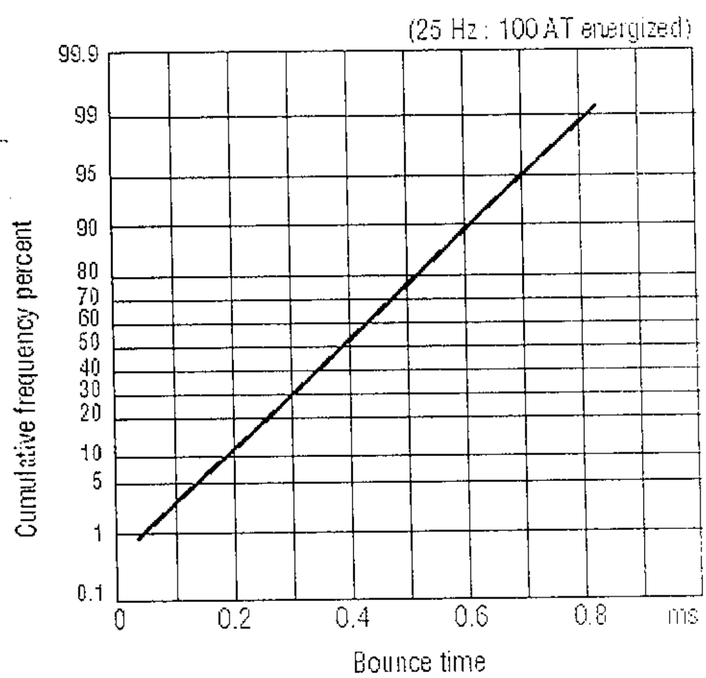
OPERATING CHARACTERISTICS

PARAMETER	RATED VALUE (MINIMUM)	RATED VALUE (TYPICAL)	RATED VALUE (MAXIMUM)	UNIT
Operate time	-------	-------	0.4	ms
Bounce time	-------	-------	1.0	ms
Release time	-------	-------	0.05	ms
Resonant frequency	3400	3900	4400	Hz
Maximum operating frequency	-------	-------	500	Hz

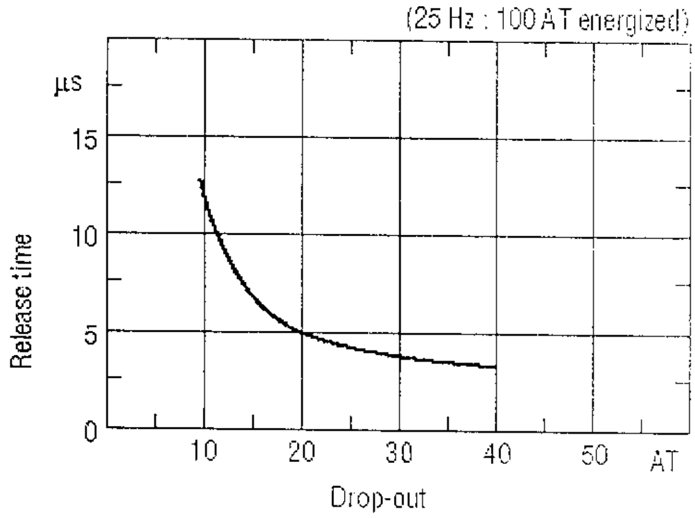
1. Operate time



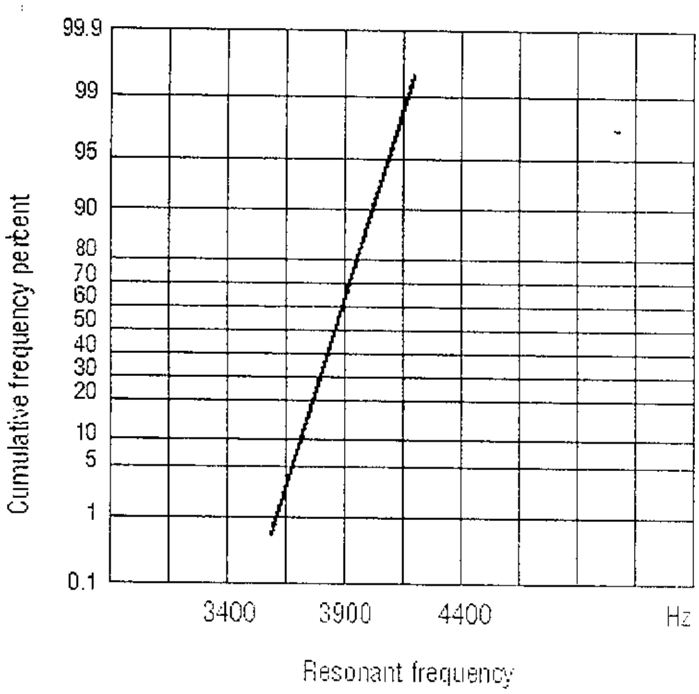
2. Bounce time



3. Release time

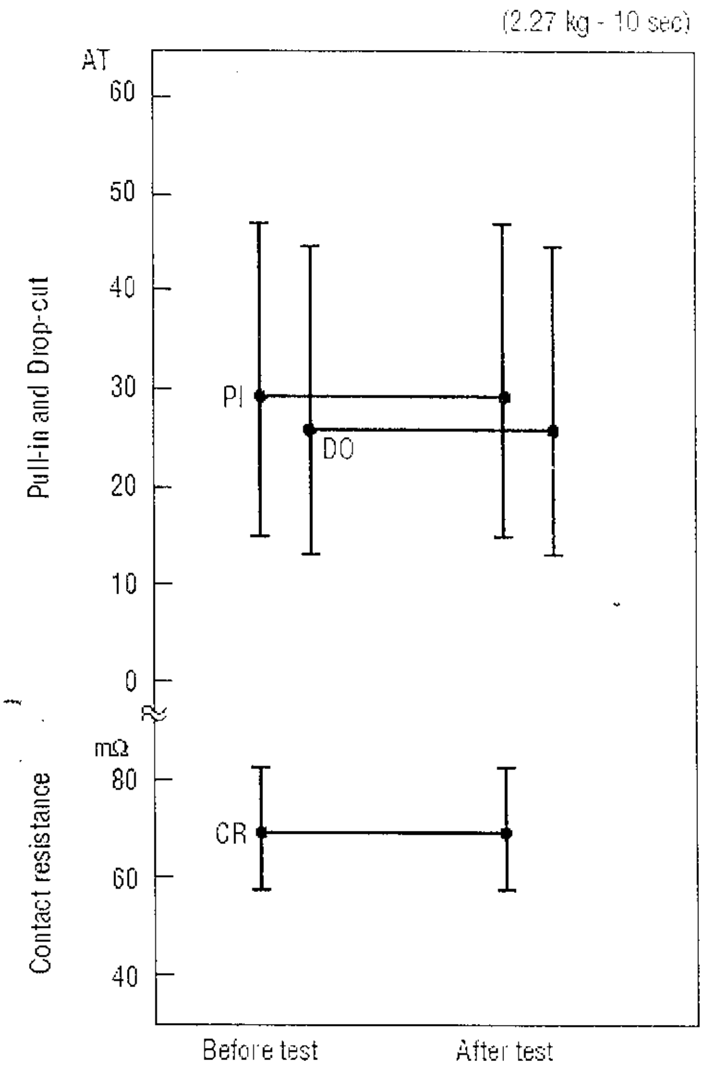


4. Resonant frequency

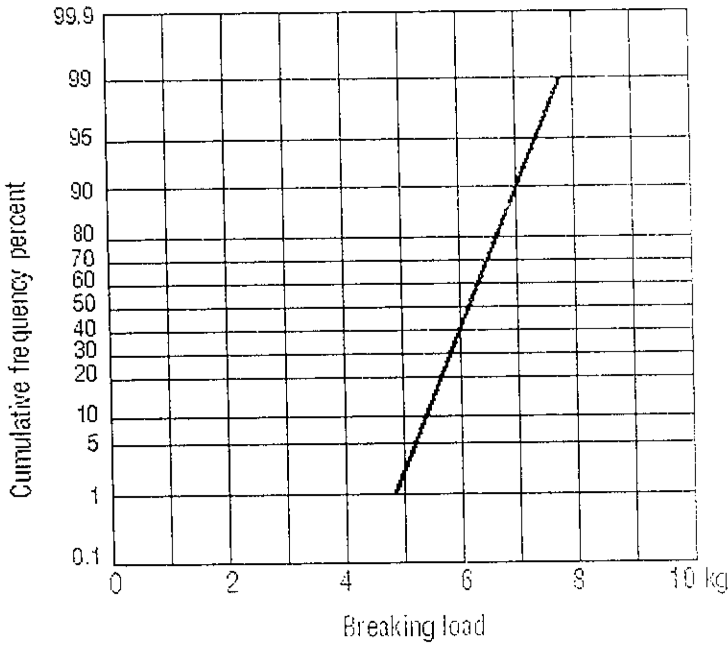


MECHANICAL CHARACTERISTICS

1. Lead tensile test (static load)

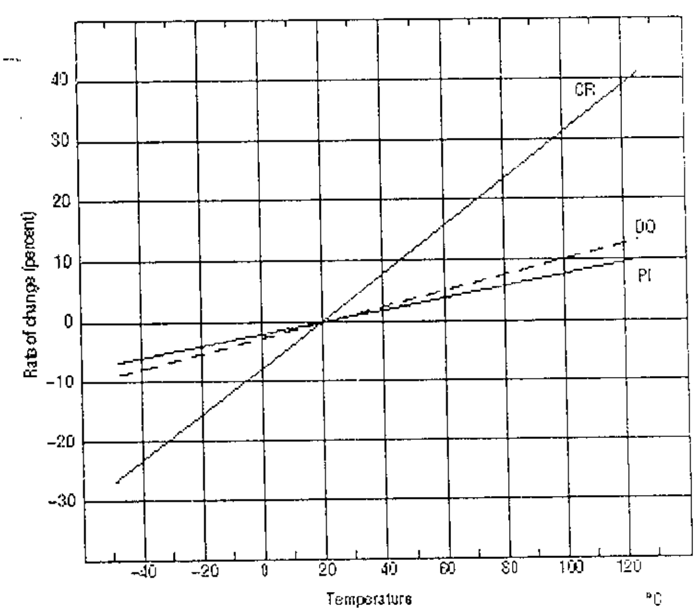


2. Lead tensile strength

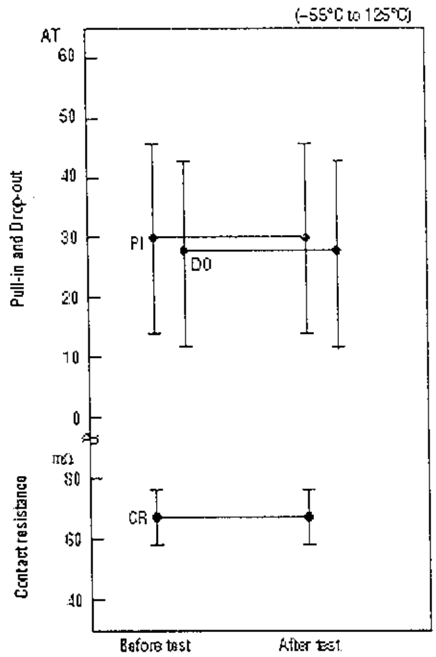


ENVIRONMENTAL CHARACTERISTICS

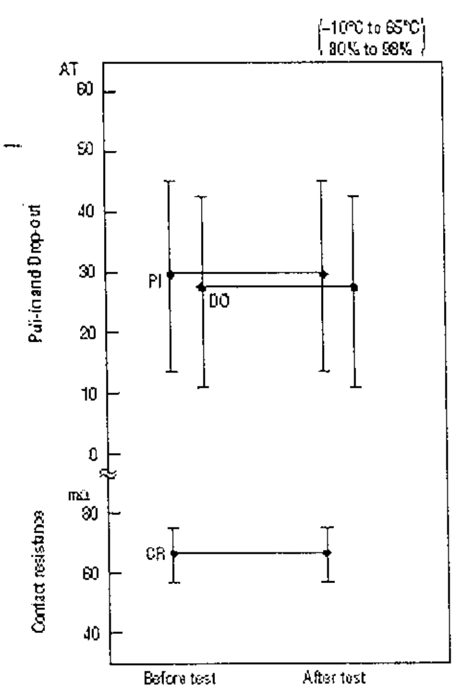
1. Temperature characteristics



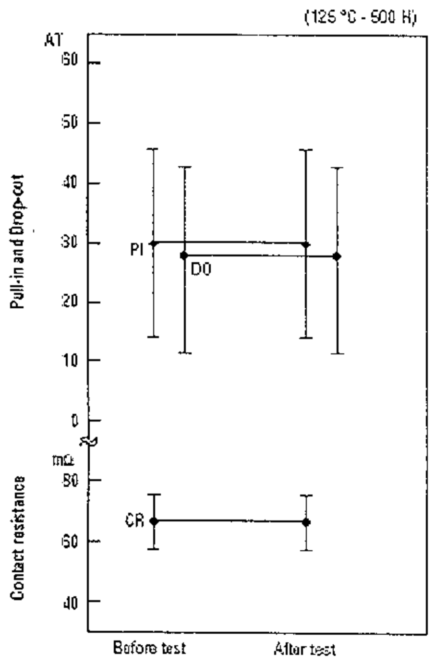
2. Temperature cycle



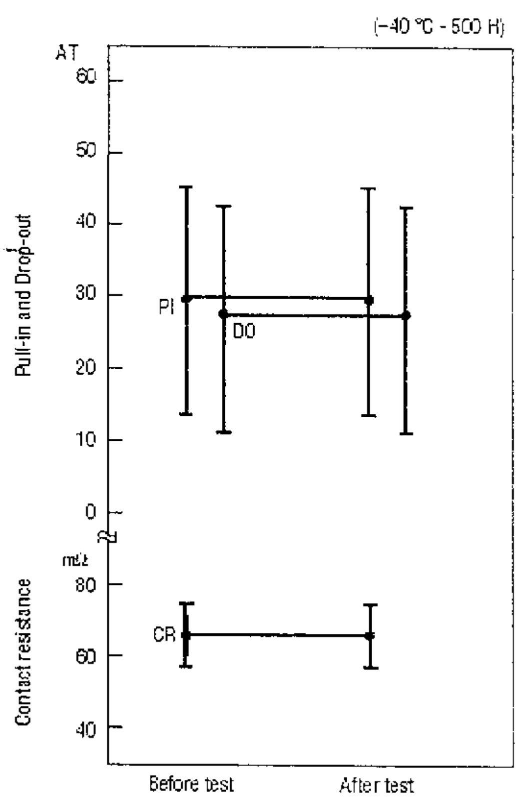
3. Temperature and humidity cycle



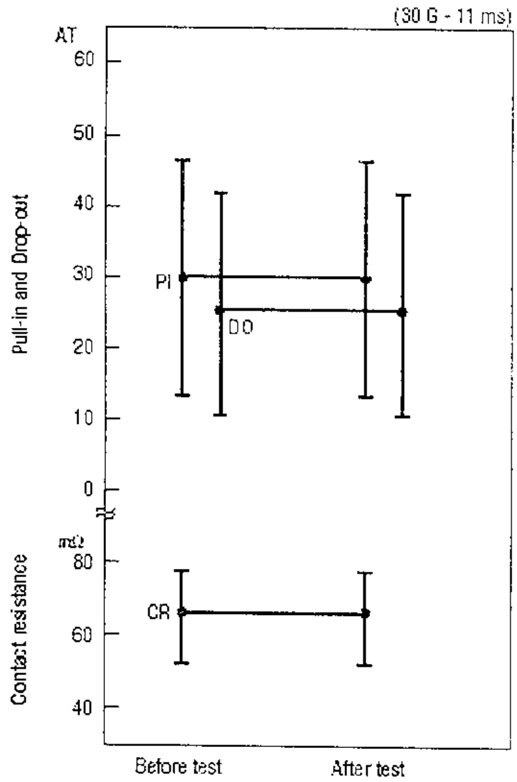
4. High temperature storage test



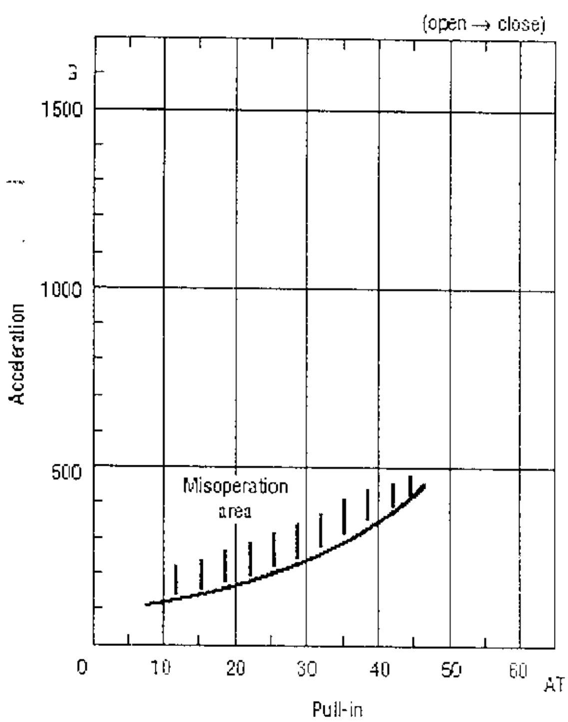
5. Low temperature storage test



6. Shock test

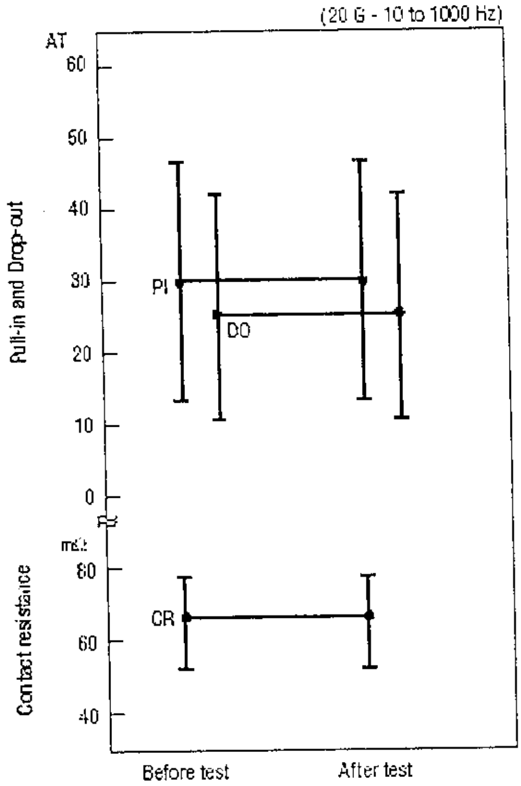


(30 G - 11 ms)
AT
60
50
40
30
20
10
0
Pull-in and Drop-out
PI
DO
mΩ
80
60
40
Contact resistance
CR
Before test
After test



(open → close)
G
1500
1000
500
Acceleration
Misoperation area
0
10
20
30
40
50
60
AT
Pull-in

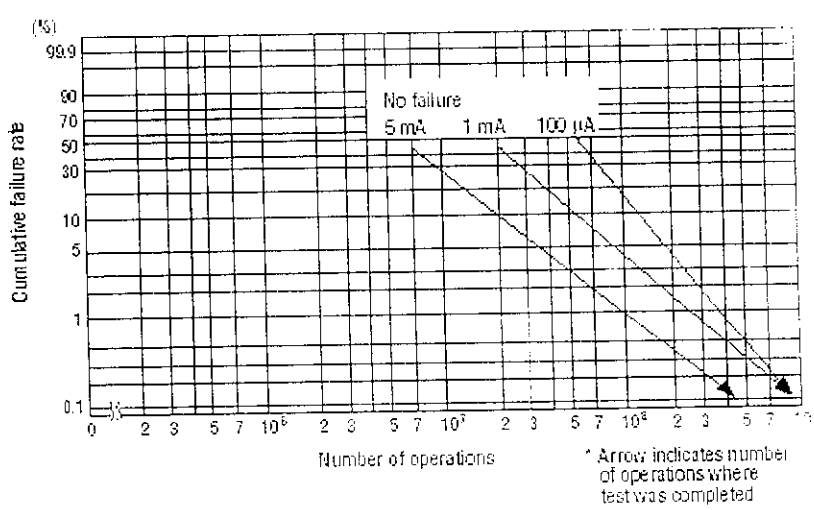
7. Vibration test



LIFE EXPECTANCY DATA

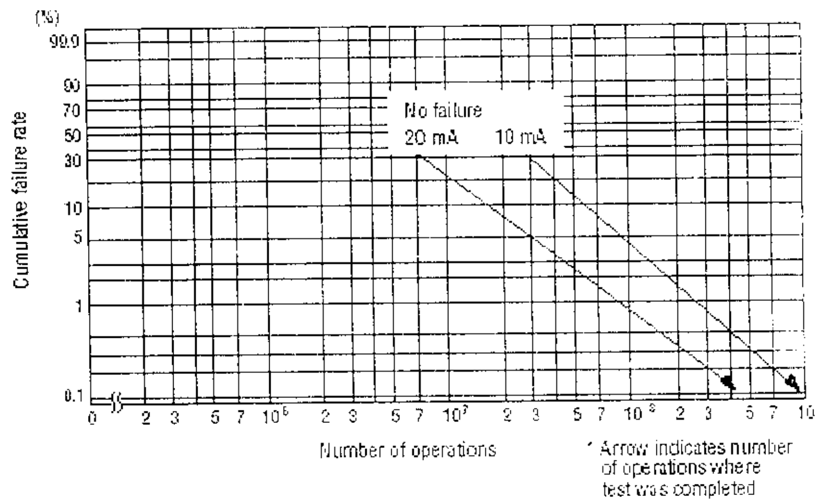
Load conditions

Voltage : 5 VDC
Current : 100 µA, 1 mA, 5 mA
Load : Resistive load



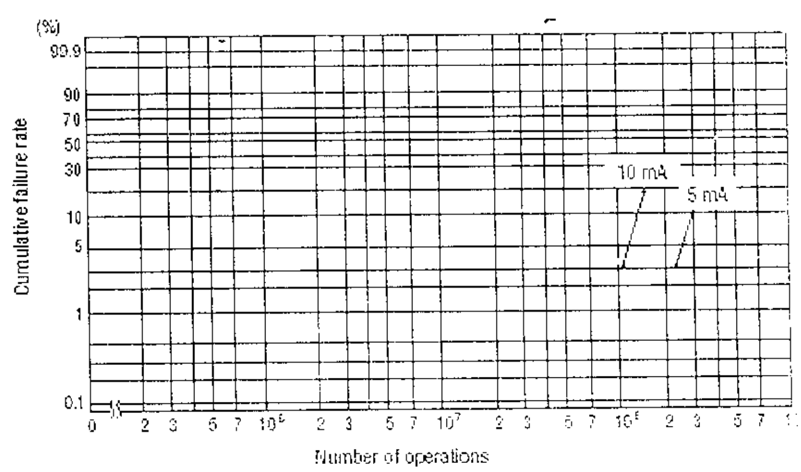
Load conditions

Voltage : 6 VDC
Current : 10 mA, 20 mA
Load : Resistive load



Load conditions

Voltage : 15 VDC
Current : 5 mA, 10 mA
Load : Resistive load



DEFINITION OF THE TERMS USED

1. **Ampere Turn (AT)**

   The product of the number of turns of wire in an electromagnetic coil winding and the current in amperes passing through the winding. This is a direct measure of a reed contacts sensitivity.

2. **Bounce**

   Intermittent opening of closed contacts or closing of opening contacts, usually implying the motion resulting from contact impact.

3. **Bounce Time (ms)**

   Time taken for bounce.

4. **Carry Current (amperes)**

   The maximum current that can be applied to an already closed contact.

5. **Contact**

   The current-carrying parts of a reed contact that engage or disengage to open or close electrical circuits.

6. **Contact Gap**

   The distance between mating reed contacts when the contacts are open.

7. **Contact Rating (Watts)**

   The maximum power, a reed contact can switch.

8. **Dynamic Contact Resistance (DCR)**

   The electrical resistance of closed contacts, when the contact is in continuous operation.

9. **Insulation Resistance**

   The electrical resistance measured between insulated terminals.

10. **Operating Temperature**

    The temperature range within which a reed contact will meet all specified operating parameters.

11. **Operate Time**

The time interval after actuation of a reed contact to the closing of the reed contact.

12. **Release Time**

The time interval from coil de-energisation to the opening of the reed contact.

13. **Resonant Frequency (Hz)**

The maximum operating frequency that a reed switch can withstand, after which it chatters, or starts sympathetic vibration.

14. **Breakdown Voltage**

The voltage which may be applied between insulated parts of a reed contact without damaging, arcing, causing breakdown or excessive leakage.

15. **Static Constant Resistance (CR)**

The electrical resistance of closed reed contacts, as measured terminal to terminal, at their associated terminals.

16. **Switching Frequency (Hz)**

The maximum frequency at which a reed contact can operate.

17. **Switching Voltage (volts)**

The maximum voltage a reed contact can switch.

18. **Switching Current (amperes)**

The maximum current a reed contact can switch.

19. **Variable Contact Resistance (VCR)**

The difference in lowest and highest static CR readings out of a set of test cycles.

20. **Drop-out**

The measured value, in AT, at which a reed contact opens.

21. **Pull-in**

The measured value, in AT, at which a reed contact closes.

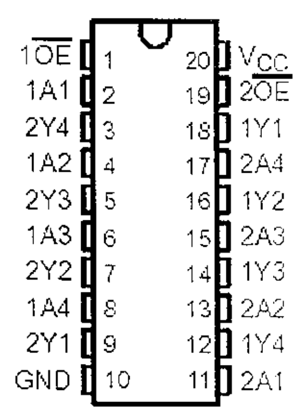
APPENDIX B

IC 74HC244

- 3-State Outputs Drive Bus Lines or Buffer Memory Address Registers
- High-Current Outputs Drive up to 15 LSTTL Loads
- Package Options Include Plastic Small-Outline (DW), Shrink Small-Outline(DB), Thin Shrink Small-Outline (PW), and Ceramic Flat (W) Packages, Ceramic Chip Carriers (FK), and Standard Plastic (N) and Ceramic (J) 300-mil DIPs

PIN CONFIGURATION

SN54HC244 . . . J OR W PACKAGE
SN74HC244 . . . DB, DW, N, OR PW PACKAGE
(TOP VIEW)



DESCRIPTION

These octal buffers and line drivers are designed specifically to improve both the performance and density of 3-state memory address drivers, clock drivers, and bus-oriented receivers and transmitters. The 'HC244 are organized as two 4-bit buffers/drivers with separate output-enable (OE) inputs. When OE is low, the device passes noninverted data from the A inputs to the Y outputs. When OE is high, the outputs are in the high-impedance state. The SN54HC244 is characterized for operation over the full military temperature range of –55°C to 125°C. The SN74HC244 is characterized for operation from –40°C to 85°C.

FUNCTION TABLE
(each buffer/driver)

INPUTS		OUTPUT
$\overline{OE}$	A	Y
L	H	H
L	L	L
H	X	Z

recommended operating conditions

			SN54HC244			SN74HC244			UNIT
			MIN	NOM	MAX	MIN	NOM	MAX	
V_{CC}	Supply voltage		2	5	6	2	5	6	V
V_{IH}	High-level input voltage	V_{CC} = 2 V	1.5			1.5			V
		V_{CC} = 4.5 V	3.15			3.15			
		V_{CC} = 6 V	4.2			4.2			
V_{IL}	Low-level input voltage	V_{CC} = 2 V	0		0.5	0		0.5	V
		V_{CC} = 4.5 V	0		1.35	0		1.35	
		V_{CC} = 6 V	0		1.8	0		1.8	
V_I	Input voltage		0		V_{CC}	0		V_{CC}	V
V_O	Output voltage		0		V_{CC}	0		V_{CC}	V
t_t	Input transition (rise and fall) time	V_{CC} = 2 V	0		1000	0		1000	ns
		V_{CC} = 4.5 V	0		500	0		500	
		V_{CC} = 6 V	0		400	0		400	
T_A	Operating free-air temperature		–55		125	–40		85	°C

electrical characteristics over recommended operating free-air temperature range (unless otherwise noted)

PARAMETER	TEST CONDITIONS		V_{CC}	T_A = 25°C			SN54HC244		SN74HC244		UNIT
				MIN	TYP	MAX	MIN	MAX	MIN	MAX	
V_{OH}	$V_I = V_{IH}$ or V_{IL}	I_{OH} = –20 µA	2 V	1.9	1.998		1.9		1.9		V
			4.5 V	4.4	4.499		4.4		4.4		
			6 V	5.9	5.999		5.9		5.9		
		I_{OH} = –6 mA	4.5 V	3.98	4.3		3.7		3.84		
		I_{OH} = –7.8 mA	6 V	5.48	5.8		5.2		5.34		
V_{OL}	$V_I = V_{IH}$ or V_{IL}	I_{OL} = 20 µA	2 V		0.002	0.1		0.1		0.1	V
			4.5 V		0.001	0.1		0.1		0.1	
			6 V		0.001	0.1		0.1		0.1	
		I_{OL} = 6 mA	4.5 V		0.17	0.26		0.4		0.33	
		I_{OL} = 7.8 mA	6 V		0.15	0.26		0.4		0.33	
I_I	$V_I = V_{CC}$ or 0		6 V		±0.1	±100		±1000		±1000	nA
I_{OZ}	$V_O = V_{CC}$ or 0,	$V_I = V_{IH}$ or V_{IL}	6 V		±0.01	±0.5		±10		±5	µA
I_{CC}	$V_I = V_{CC}$ or 0,	I_O = 0	6 V			8		160		80	µA
C_i			2 V to 6 V		3	10		10		10	pF

switching characteristics over recommended operating free-air temperature range, C_L = 50 pF (unless otherwise noted) (see Figure 1)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	V_{CC}	T_A = 25°C MIN	T_A = 25°C TYP	T_A = 25°C MAX	SN54HC244 MIN	SN54HC244 MAX	SN74HC244 MIN	SN74HC244 MAX	UNIT
t_{pd}	A	Y	2 V		40	115		170		145	ns
			4.5 V		13	23		34		29	
			6 V		11	20		29		25	
t_{en}	$\overline{OE}$	Y	2 V		75	150		225		190	ns
			4.5 V		15	30		45		38	
			6 V		13	26		38		32	
t_{dis}	$\overline{OE}$	Y	2 V		75	150		225		190	ns
			4.5 V		15	30		45		38	
			6 V		13	26		38		32	
t_t		Y	2 V		28	60		90		75	ns
			4.5 V		8	12		18		15	
			6 V		6	10		15		13	

switching characteristics over recommended operating free-air temperature range, C_L = 150 pF (unless otherwise noted) (see Figure 1)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	V_{CC}	T_A = 25°C MIN	T_A = 25°C TYP	T_A = 25°C MAX	SN54HC244 MIN	SN54HC244 MAX	SN74HC244 MIN	SN74HC244 MAX	UNIT
t_{pd}	A	Y	2 V		56	165		245		210	ns
			4.5 V		18	33		49		42	
			6 V		15	28		42		35	
t_{en}	$\overline{OE}$	Y	2 V		100	200		300		250	ns
			4.5 V		20	40		60		50	
			6 V		17	34		51		43	
t_t		Y	2 V		45	210		315		265	ns
			4.5 V		17	42		63		53	
			6 V		13	36		53		45	

operating characteristics, T_A = 25°C

PARAMETER		TEST CONDITIONS	TYP	UNIT
C_{pd}	Power dissipation capacitance per buffer/driver	No load	35	pF

APPENDIX C

SEVEN SEGMENT DISPLAYS
HDSP 5503

Features

- **Industry Standard Size**
- **Industry Standard Pinout**

  15.24 mm (0.6 in.) DIP Leads on 2.54 mm (0.1 in.) Centers
- **Choice of Colors**

  Red, AlGaAs Red, High Efficiency Red, Yellow, Green
- **Excellent Appearance**

  Evenly Lighted Segments

  Mitered Corners on Segments

  Gray Package Gives Optimum

  Contrast

  ± 50° Viewing Angle
- **Design Flexibility**

  Common Anode or Common Cathode

  Single and Dual Digits

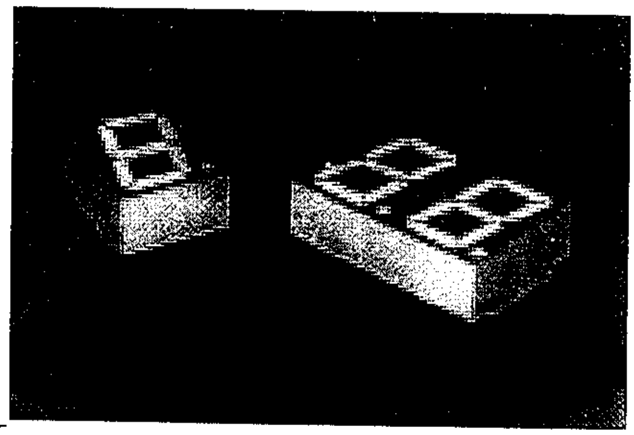
  Right Hand Decimal Point

  ± 1. Overflow Character
- **Categorized for Luminous Intensity**

  Yellow and Green Categorized for Color. Use of Like Categories Yields a Uniform Display
- **High Light Output**
- **High Peak Current**
- **Excellent for Long Digit String Multiplexing**
- **Intensity and Color Selection Option**

- **Sunlight Viewable AlGaAs Description**

The 14.2 mm (0.56 inch) LED seven segment displays are designed for viewing distances up to 7 metres (23 feet). These devices use an industry standard size package and pinout. Both the numeric and ± 1 overflow devices feature a right hand decimal point. All devices are available as either common anode or common cathode.



High Efficiency Red

Device Series HDSP-	Parameter	Symbol	Min.	Typ.	Max.	Units	Test Conditions
55XX	Luminous Intensity/Segment[1,2,6] (Digit Average)	I_V	900	2800		μcd	I_F = 10 mA
				3700			I_F = 60 mA Peak: 1 of 6 df
	Forward Voltage/Segment or DP	V_F		2.1	2.5	V	I_F = 20 mA
	Peak Wavelength	λ_{PEAK}		635		nm	
	Dominant Wavelength[3]	λ_d		626		nm	
	Reverse Voltage/Segment or DP[4]	V_R	3.0	30		V	I_R = 100 μA
	Temperature Coefficient of V_F/Segment or DP	$\Delta V_F/°C$		-2		mV/°C	
	Thermal Resistance LED Junction-to-Pin	$R\theta_{J-Pin}$		345		°C/W/Seg	

APPENDIX D

MCP 130

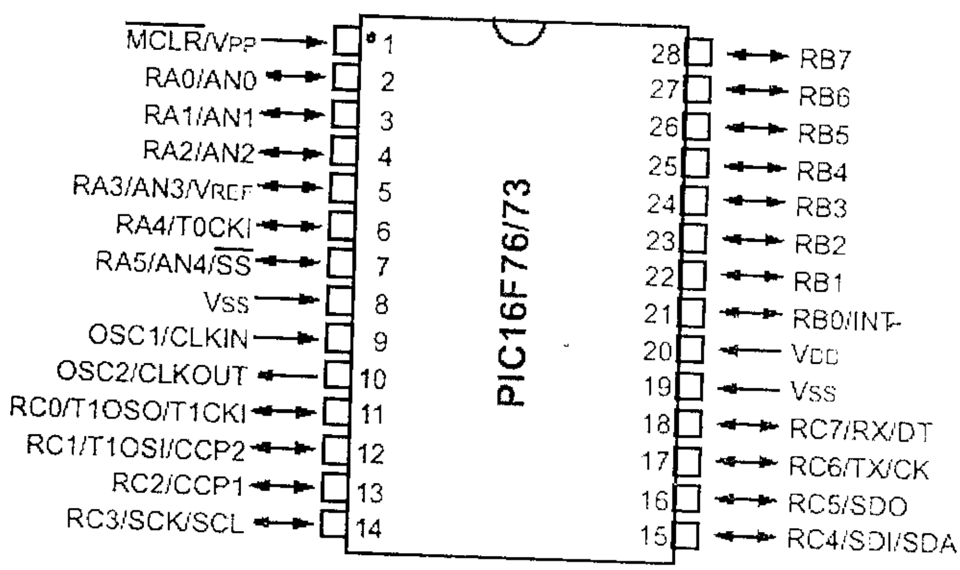
- Open drain + pull-up resistor

ANALOG PRODUCTS - Precision System Supervisor Products

Product	Vcc Range	Reset	Output	Typical Trpu	Typical Idd	Temperature	Packages	TO-92 Bond options
MCP 100	1.0V-5.5V	Active Low	CMOS Push-Pull	350ms	32uA	-40¡É to +85¡É	TO-92 SOT-23-3	D,H
MCP 101	1.0V-5.5V	Active High	CMOS Push-Pull	350ms	32uA	-40¡É to +85¡É	TO-92 SOT-23-3	D,H
MCP 120	1.0V-5.5V	Active Low	Open Drain	350ms	32uA	-40¡É to +85¡É	TO-92 SOT-23-3 8SN	D,G,H
MCP 130	1.0V-5.5V	Active Low	Open Drain W/5k ohm Pull-up	350ms	32uA	-40¡É to +85¡É	TO-92 SOT-23-3 8SN	D,F,H
MCP 809	1.0V-5.5V	Active Low	CMOS Push-Pull	350ms	32uA	-40¡É to +85¡É	SOT-23-3	¡
MCP 810	1.0V-5.5V	Active High	CMOS Push-Pull	350ms	32uA	-40¡É to +85¡É	SOT-23-3	¡

APPENDIX E
PIC 16F73
PIN DIAGRAM

DIP, SOIC, SSOP



PINOUT DESCRIPTION:

Pin Name	DIP Pin#	SSOP SOIC Pin#	I/O/P Type	BUFFER TYPE	DESCRIPTION
OSC1/CLKIN	9	9	I	ST/CMOS (3)	Oscillator crystal input/external clock source input.
OSC2/CLKOUT	10	10	O	—	Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode. In RC mode, the OSC2 pin outputs CLKOUT which has 1/4 the frequency of OSC1, and denotes the instruction cycle rate.
$\overline{\text{MCLR}}$/VPP	1	1	I/P	ST	Master clear (RESET) input or programming voltage input or High Voltage Test mode control. This pin is an active low RESET to the device.
					PORTA is a bi-directional I/O port.
RA0/AN0	2	2	I/O	TTL	RA0 can also be analog input0
RA1/AN1	3	3	I/O	TTL	RA1 can also be analog input1.
RA2/AN2	4	4	I/O	TTL	RA2 can also be analog input2.
RA3/AN3/VREF	5	5	I/O	TTL	RA3 can also be analog input3 or analog reference voltage.
RA4/T0CKI	6	6	I/O	ST	RA4 can also be the clock input to the Timer0 module. Output is open drain type.
RA5/$\overline{\text{SS}}$/AN4	7	7	I/O	TTL	RA5 can also be analog input4 or the slave select for the synchronous serial port.
					PORTB is a bi-directional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs.
RB0/INT	21	21	I/O	TTL/ST (1)	RB0 can also be the external interrupt pin.
RB1	22	22	I/O	TTL	
RB2	23	23	I/O	TTL	
RB3	24	24	I/O	TTL	

RB4	25	25	I/O	TTL	Interrupt-on-change pin.
RB5	26	26	I/O	TTL	Interrupt-on-change pin.
RB6	27	27	I/O	TTL/ST (2)	Interrupt-on-change pin or Serial programming clock.
RB7	28	28	I/O	TTL/ST (2)	Interrupt-on-change pin or Serial programming data.
					PORTC is a bi-directional I/O port.
RC0/T1OSO/T1CKI	11	11	I/O	ST	RC0 can also be the Timer1 oscillator output or Timer1 clock input.
RC1/T1OSI/CCP2	12	12	I/O	ST	RC1 can also be the Timer1 oscillator input or Capture2 input/ Compare2 output/PWM2 output.
RC2/CCP1	13	13	I/O	ST	RC2 can also be the Capture1 input/Compare1 output/PWM1 output.
RC3/SCK/SCL	14	14	I/O	ST	RC3 can also be the synchronous serial clock input/output for both SPI and I ^2 C modes.
RC4/SDI/SDA	15	15	I/O	ST	RC4 can also be the SPI Data In (SPI mode) or Data I/O (I ^2 C mode).
RC5/SDO	16	16	I/O	ST	RC5 can also be the SPI Data Out (SPI mode).
RC6/TX/CK	17	17	I/O	ST	RC6 can also be the USART Asynchronous Transmit or Synchronous Clock.
RC7/RX/DT	18	18	I/O	ST	RC7 can also be the USART Asynchronous Receive or Synchronous Data.
VSS	8,19	8,19	P	-	Ground reference for logic and I/O pins.
VDD	20	20	P	-	Positive supply for logic and I/O pins.

Legend: I = input O = output I/O = input/output P = power

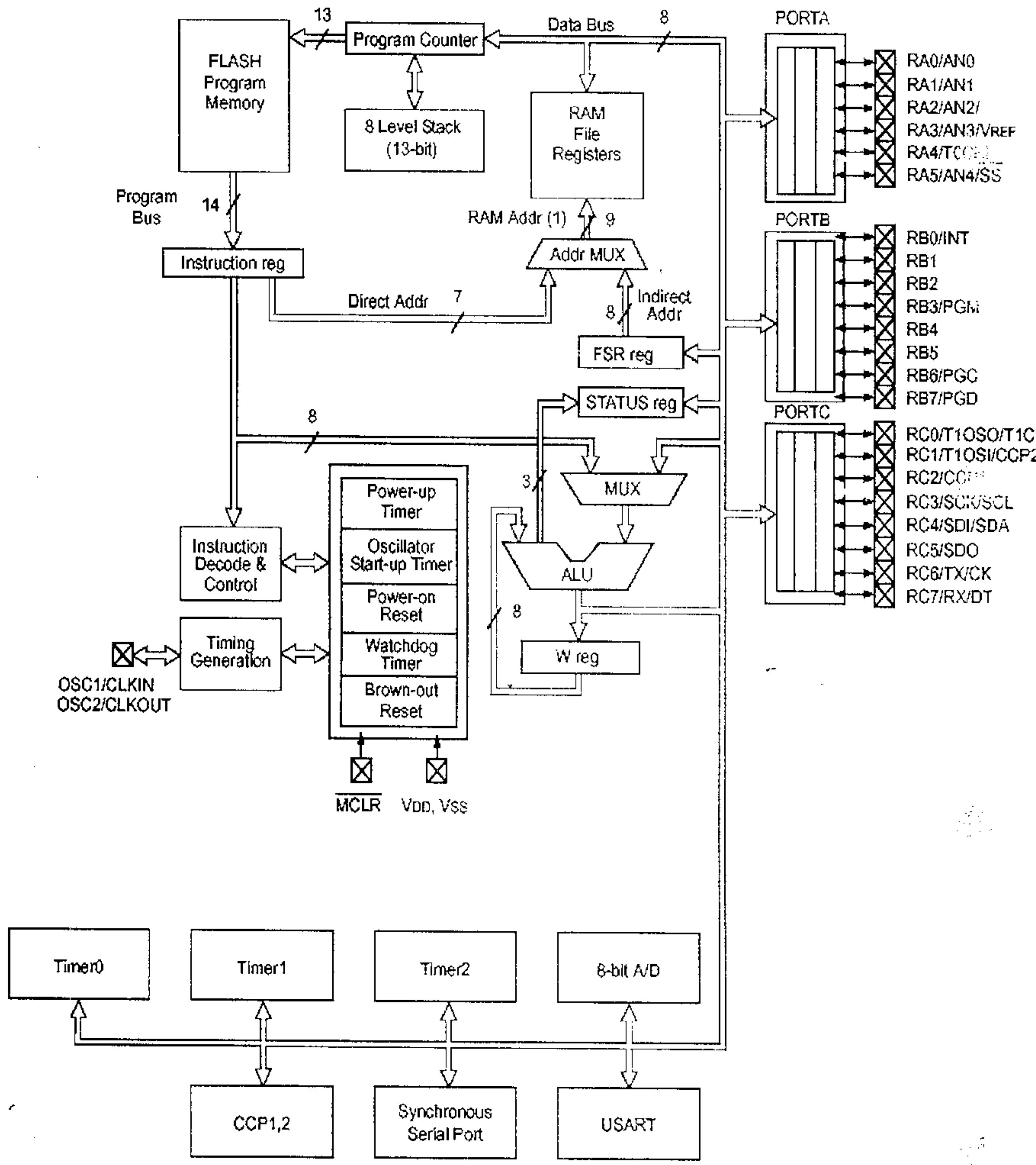
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.

2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.

3: This buffer is a Schmitt Trigger input when configured in RC Oscillator mode and a CMOS input otherwise.

BLOCK DIAGRAM



Note 1: Higher order bits are from the STATUS register.

DESCRIPTION OF THE BLOCK DIAGRAM

The various blocks in PIC 16F73 is highlighted here:

TIMER 0 MODULE

The Timer0 module timer/counter has the following features:

- 8-bit timer/counter
- Readable and writable
- 8-bit software programmable prescaler
- Internal or external clock select
- Interrupt on overflow from FFh to 00h
- Edge select for external clock

In Timer mode, the Timer0 module will increment every instruction cycle (without prescaler). If the TMR0 register is written, the increment is inhibited for the following two instruction cycles.

TIMER1 MODULE

The Timer1 module is a 16-bit timer/counter consisting of two 8-bit registers (TMR1H and TMR1L), which are readable and writable. The TMR1 Register pair (TMR1H:TMR1L) increments from 0000h to FFFFh and rolls over to 0000h. The TMR1 Interrupt, if enabled, is generated on overflow, which is latched in interrupt flag bit TMR1IF (PIR1<0>). This interrupt can be enabled/disabled by setting/clearing TMR1 interrupt enable bit TMR1IE (PIE1<0>).

Timer1 can operate in one of two modes:

- As a timer
- As a counter

In Timer mode, Timer1 increments every instruction cycle.

In Counter mode, it increments on every rising edge of the external clock input.

TIMER 2 MODULE

Timer2 is an 8-bit timer with a prescaler and postscaler. It can be used as the PWM time base for PWM mode of the CCP module(s). The TMR2 register is readable and writable, and is cleared on any device RESET.Timer2 can be shut off by clearing control bit TMR2ON (T2CON<2>) to minimize power consumption.

Timer2 Prescaler and Postscaler:

The prescaler and postscaler counters are cleared when any of the following occurs:

- a write to the TMR2 register
- a write to the T2CON register
- any device RESET (POR, MCLR Reset, WDT Reset or BOR)
- TMR2 is not cleared when T2CON is written.

ANALOG-TO-DIGITAL CONVERTER (A/D) MODULE

The 8-bit analog-to-digital (A/D) converter module has five inputs for the PIC16F73/76 and eight for the PIC16F74/77. The A/D allows conversion of an analog input signal to a corresponding 8-bit digital number. The output of the sample and hold is the input into the converter, which generates the result via successive approximation. The analog reference voltage is software selectable to either the device's positive supply voltage (VDD), or the voltage level on the RA3/AN3/VREF pin.

SYNCHRONOUS SERIAL PORT (SSP) MODULE

The Synchronous Serial Port (SSP) module is a serial interface useful for communicating with other peripheral or microcontroller devices. These peripheral devices may be Serial EEPROMs, shift registers, display drivers, A/D converters, etc. The SSP module can operate in one of two modes:

- Serial Peripheral Interface (SPI)
- Inter-Integrated Circuit (I^ 2C)

CCP1 MODULE

Capture/Compare/PWM Register1 (CCPR1) is comprised of two 8-bit registers:

a) CCPR1L (low byte) and

b) CCPR1H (high byte).

The CCP1CON register controls the operation of CCP1. The special event trigger is generated by a compare match and will reset Timer1.

CCP2 Module

Capture/Compare/PWM Register2 (CCPR2) is comprised of two 8-bit registers:

a) CCPR2L (low byte) and

b) CCPR2H (high byte).

The CCP2CON register controls the operation of CCP2. The special event trigger is generated by a compare match and will reset Timer1 and start an A/D conversion (if the A/D module is enabled).

UNIVERSAL SYNCHRONOUS ASYNCHRONOUS RECEIVER TRANSMITTER (USART)

The Universal Synchronous Asynchronous Receiver Transmitter (USART) module is one of the two serial I/O modules. (USART is also known as a Serial Communications Interface or SCI.) The USART can be configured as a full duplex asynchronous system that can communicate with peripheral devices, such as CRT terminals and personal computers, or it can be configured as a half duplex synchronous system that can communicate with peripheral devices, such as A/D or D/A integrated circuits, serial EEPROMs, etc.

I/O PORTS

Some pins for these I/O ports are multiplexed with an alternate function for the peripheral features on the device. In general, when a peripheral is enabled, that pin may not be used as a general purpose I/O pin.

PORTA AND THE TRISA REGISTER

PORTA is a 6-bit wide, bi-directional port. The corresponding data direction register is TRISA. Setting a TRISA bit (=1) will make the corresponding PORTA pin an input (i.e., put the corresponding output driver in a high impedance mode). Clearing a TRISA bit (=0) will make the corresponding PORTA pin an output (i.e., put the contents of the output latch on the selected pin).

PORTB and the TRISB Register

PORTB is an 8-bit wide, bi-directional port. The corresponding data direction register is TRISB. Setting a TRISB bit (=1) will make the corresponding PORTB pin an input (i.e., put the corresponding output driver in a high-impedance mode). Clearing a TRISB bit (=0) will make the corresponding PORTB pin an output (i.e., put the contents of the output latch on the selected pin).

PORTC and the TRISC Register

PORTC is an 8-bit wide, bi-directional port. The corresponding data direction register is TRISC. Setting a TRISC bit (=1) will make the corresponding PORTC pin an input (i.e., put the corresponding output driver in a hi-impedance mode). Clearing a TRISC bit (=0) will make the corresponding PORTC pin an output (i.e., put the contents of the output latch on the selected pin).

SPECIAL FEATURES OF THE CPU

These devices have a host of features intended to maximize system reliability, minimize cost through elimination of external components, provide power saving operating modes and offer code protection. These are:

- Oscillator Selection
- RESET
  - Power-on Reset (POR)
  - Power-up Timer (PWRT)
  - Oscillator Start-up Timer (OST)
  - Brown-out Reset (BOR)
- Interrupts
- Watchdog Timer (WDT)
- SLEEP
- Code Protection
- ID Locations
- In-Circuit Serial Programming

These devices have a Watchdog Timer, which can be shut off only through configuration bits. It runs off its own RC oscillator for added reliability.

READING PROGRAM MEMORY

The FLASH Program Memory is readable during normal operation over the entire VDD range. It is indirectly addressed through Special Function Registers (SFR). Up to 14-bit numbers can be stored in memory for use as calibration parameters, serial numbers, packed 7-bit ASCII, etc. Executing a program memory location containing data that forms an invalid instruction results in a NOP.

There are five SFRs used to read the program and memory. These registers are:

a) PMCON1

b) PMDATA

c) PMDATH

d) PMADR

e) PMADRH

MEMORY ORGANIZATION

There are two memory blocks.

- The Program Memory and
- Data Memory

Both the memories have separate buses so that concurrent access can occur. The Program Memory can be read internally by user code.

Program Memory Organization

The PIC16F7X devices have a 13-bit program counter capable of addressing an 8K x 14 program memory space. Accessing a location above the physically implemented address will cause a wrap-around. The RESET Vector is at 0000h and the Interrupt Vector is at 0004h.

PIC16F7X	Characteristic
28/40	Pins
3	Timers
11 or 12	Interrupts
PSP, USART, SSP (SPI, I^2C Slave)	Communication
20 MHz	Frequency
8-bit	A/D
2	CCP
4K, 8K FLASH (100 E/W cycles)	Program Memory
192, 368 bytes	RAM
None	EEPROM Data
—	Other

OSCILLATOR CONFIGURATIONS

OSCILLATOR TYPES

The PIC16F7X can be operated in four different oscillator modes. The user can program two configuration bits (FOSC1 and FOSC0) to select one of these four modes:

- LP Low Power Crystal
- XT Crystal/Resonator
- HS High Speed Crystal/Resonator
- RC Resistor/Capacitor

CRYSTAL OSCILLATOR/CERAMIC RESONATORS

In XT, LP or HS modes, a crystal or ceramic resonator is connected to the OSC1/CLKIN and OSC2/CLKOUT pins to establish oscillation. The PIC16F7X oscillator design requires the use of a parallel cut crystal. Use of a series cut crystal may give a frequency out of the crystal manufacturers specifications. When in XT, LP or HS modes, the device can have an external clock source to drive the OSC1/CLKIN pin.

RC OSCILLATOR

For timing insensitive applications, the "RC" device option offers additional cost savings. The RC oscillator frequency is a function of the supply voltage, the resistor (REXT) and capacitor (CEXT) values, and the operating temperature. In addition to this, the oscillator frequency will vary from unit to unit due to normal process parameter variation.

RESET

The PIC16F7X differentiates between various kinds of RESET:

- Power-on Reset (POR)
- MCLR Reset during normal operation
- MCLR Reset during SLEEP
- WDT Reset (during normal operation)
- WDT Wake-up (during SLEEP)
- Brown-out Reset (BOR)

Some registers are not affected in any RESET condition. Their status is unknown on POR and unchanged in any other RESET. Most other registers are reset to a "RESET state" on Power-on Reset (POR), on the MCLR and WDT Reset, on MCLR Reset during SLEEP, and Brown-out Reset (BOR). They are not affected by a WDT Wake-up, which is viewed as the resumption of normal operation.

Power-up Timer (PWRT)

The Power-up Timer provides a fixed 72 ms nominal timeout on power-up only from the POR. The Power-up Timer operates on an internal RC oscillator. The chip is kept in RESET as long as the PWRT is active. The PWRT's time delay allows VDD to rise to an acceptable level. A configuration bit is provided to enable/disable the PWRT. The power-up time delay will vary from chip to chip due to VDD, temperature and process variation.

Oscillator Start-up Timer (OST)

The Oscillator Start-up Timer (OST) provides 1024 oscillator cycles (from OSC1 input) delay after the PWRT delay is over (if enabled). This helps to ensure that the crystal oscillator or resonator has started and stabilized. The OST time-out is invoked only for XT, LP and HS modes and only on Power-on Reset or wake-up from SLEEP.

Brown-out Reset (BOR)

The configuration bit, BODEN, can enable or disable the Brown-out Reset circuit. If VDD falls below VBOR (parameter D005, about 4V) for longer than TBOR (parameter #35, about 100S), the brown-out situation will reset the device. If VDD falls below VBOR for less than TBOR, a RESET may not occur. Once the brown-out occurs, the device will remain in Brown-out Reset until VDD rises above VBOR. The Power-up Timer then keeps the device in RESET for TPWRT (parameter #33, about 72mS). If VDD should fall below VBOR during TPWRT, the Brown-out Reset process will restart when VDD rises above VBOR, with the Power-up Timer Reset. The Power-up Timer is always enabled when the Brown-out Reset circuit is enabled, regardless of the state of the PWRT configuration bit.

Watchdog Timer (WDT)

The Watchdog Timer is as a free running on-chip RC oscillator which does not require any external components. This RC oscillator is separate from the RC oscillator of the OSC1/CLKIN pin. That means that the WDT will run, even if the clock on the OSC1/CLKIN and OSC2/CLKOUT pins of the device has been stopped, for example, by execution of a SLEEP instruction. During normal operation, a WDT time-out generates a device RESET (Watchdog Timer Reset). If the device is in SLEEP mode, a WDT time-out causes the device to wake-up and continue with normal operation (Watchdog Timer Wake-up). The TO bit in the STATUS register will be cleared upon a Watchdog Timer time-out.

REGISTER FILE MAPPING

Bank 0	File Address	Bank 1	File Address	Bank 2	File Address	Bank 3	File Address
Indirect addr.(*)	00h	Indirect addr.(*)	80h	Indirect addr.(*)	100h	Indirect addr.(*)	180h
TMR0	01h	OPTION_REG	81h	TMR0	101h	OPTION_REG	181h
PCL	02h	PCL	82h	PCL	102h	PCL	182h
STATUS	03h	STATUS	83h	STATUS	103h	STATUS	183h
FSR	04h	FSR	84h	FSR	104h	FSR	184h
PORTA	05h	TRISA	85h		105h		185h
PORTB	06h	TRISB	86h	PORTB	106h	TRISB	186h
PORTC	07h	TRISC	87h		107h		187h
PORTD(1)	08h	TRISD(1)	88h		108h		188h
PORTE(1)	09h	TRISE(1)	89h		109h		189h
PCLATH	0Ah	PCLATH	8Ah	PCLATH	10Ah	PCLATH	18Ah
INTCON	0Bh	INTCON	8Bh	INTCON	10Bh	INTCON	18Bh
PIR1	0Ch	PIE1	8Ch	PMDATA	10Ch	PMCON1	18Ch
PIR2	0Dh	PIE2	8Dh	PMADR	10Dh		18Dh
TMR1L	0Eh	PCON	8Eh	PMDATH	10Eh		18Eh
TMR1H	0Fh		8Fh	PMADRH	10Fh		18Fh
T1CON	10h		90h		110h		190h
TMR2	11h		91h				
T2CON	12h	PR2	92h				
SSPBUF	13h	SSPADD	93h				
SSPCON	14h	SSPSTAT	94h				
CCPR1L	15h		95h				
CCPR1H	16h		96h				
CCP1CON	17h		97h				
RCSTA	18h	TXSTA	98h				
TXREG	19h	SPBRG	99h				
RCREG	1Ah		9Ah				
CCPR2L	1Bh		9Bh				
CCPR2H	1Ch		9Ch				
CCP2CON	1Dh		9Dh				
ADRES	1Eh		9Eh				
ADCON0	1Fh	ADCON1	9Fh				
General Purpose Register 96 Bytes	20h	General Purpose Register 96 Bytes	A0h	accesses 20h-7Fh	120h	accesses A0h - FFh	1A0h
					16Fh		1EFh
					170h		1F0h
	7Fh		FFh		17Fh		1FFh

☐ Unimplemented data memory locations, read as '0'.

* Not a physical register.

Note 1: These registers are not implemented on 28-pin devices.

SPECIAL FUNCTION REGISTERS USED IN THE PROGRAM

INTCON Register

The INTCON register is a readable and writable register, which contains various enable and flag bits for the TMR0 register overflow, RB Port change and External RB0/INT pin interrupts.

Note:

Interrupt flag bits are set when an interrupt condition occurs, regardless of the state of its corresponding enable bit or the global enable bit, GIE (INTCON<7>). User software should ensure the appropriate interrupt flag bits are clear prior to enabling an interrupt.

INTCON REGISTER (ADDRESS 0Bh, 8Bh, 10Bh, 18Bh)

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-x
GIE	PEIE	T0IE	INTE	RBIE	T0IF	INTF	RBIF
bit 7							bit 0

bit 7 **GIE:** Global Interrupt Enable bit

1 = Enables all un-masked interrupts

0 = Disables all interrupts

bit 6 **PEIE:** Peripheral Interrupt Enable bit

1 = Enables all un-masked peripheral interrupts

0 = Disables all peripheral interrupts

bit 5 **T0IE:** TMR0 Overflow Interrupt Enable bit

1 = Enables the TMR0 interrupt

0 = Disables the TMR0 interrupt

bit 4 **INTE:** RB0/INT External Interrupt Enable bit

1 = Enables the RB0/INT external interrupt

0 = Disables the RB0/INT external interrupt

bit 3 **RBIE:** RB Port Change Interrupt Enable bit

1 = Enables the RB port change interrupt

0 = Disables the RB port change interrupt

bit 2 **T0IF**: TMR0 Overflow Interrupt Flag bit

1 = TMR0 register has overflowed (must be cleared in software)

0 = TMR0 register did not overflow

bit 1 **INTF**: RB0/INT External Interrupt Flag bit

1 = The RB0/INT external interrupt occurred (must be cleared in software)

0 = The RB0/INT external interrupt did not occur

bit 0 **RBIF**: RB Port Change Interrupt Flag bit

A mismatch condition will continue to set flag bit RBIF. Reading PORTB will end the mismatch condition and allow flag bit RBIF to be cleared.

1 = At least one of the RB7:RB4 pins changed state (must be cleared in software)

0 None of the RB7:RB4 pins have changed state

PIE1 Register

The PIE1 register contains the individual enable bits for the peripheral interrupts.

Note: Bit PEIE (INTCON<6>) must be set to enable any peripheral interrupt.

PIE1 REGISTER (ADDRESS 8Ch)

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
PSPIE[(1)]	ADIE	RCIE	TXIE	SSPIE	CCP1IE	TMR2IE	TMR1IE
bit 7							bit 0

bit 7 **PSPIE (1)** : Parallel Slave Port Read/Write Interrupt Enable bit

1 = Enables the PSP read/write interrupt

0 = Disables the PSP read/write interrupt

bit 6 **ADIE**: A/D Converter Interrupt Enable bit

1 = Enables the A/D converter interrupt

0 = Disables the A/D converter interrupt

bit 5 **RCIE**: USART Receive Interrupt Enable bit

1 = Enables the USART receive interrupt

0 = Disables the USART receive interrupt

bit 4 **TXIE**: USART Transmit Interrupt Enable bit

1 = Enables the USART transmit interrupt

0 = Disables the USART transmit interrupt

bit 3 **SSPIE**: Synchronous Serial Port Interrupt Enable bit

1 = Enables the SSP interrupt

0 = Disables the SSP interrupt

bit 2 **CCP1IE**: CCP1 Interrupt Enable bit

1 = Enables the CCP1 interrupt

0 = Disables the CCP1 interrupt

bit 1 **TMR2IE**: TMR2 to PR2 Match Interrupt Enable bit

1 = Enables the TMR2 to PR2 match interrupt

0 = Disables the TMR2 to PR2 match interrupt

bit 0 **TMR1IE**: TMR1 Overflow Interrupt Enable bit

1 = Enables the TMR1 overflow interrupt

0 = Disables the TMR1 overflow interrupt

Note 1: PSPIE is reserved on 28-pin devices; always maintain this bit clear.

- **PORT C FUNCTIONS:**

Name	Bit#	Buffer type	Function
RC0/T1OSO/T1CKI	bit0	ST	Input/output port pin or oscillator output/Timer1 clock input.
RC1/T1OSI/CCP2	bit1	ST	Input/output port pin or oscillator input or Capture2 input/Compare2 output/PWM2 output
RC2/CCP1	bit2	ST	Input/output port pin or Capture1 input/Compare1 output/PWM1 output.
RC3/SCK/SCL	bit3	ST	RC3can also be synchronous serial clock for both SPI and I^2 modes.
RC4/SDI/SDA	bit4	ST	RC4 can also be the SPI Data in (SPI mode) or Data I/O (I^2C mode).
RC5/SDO	bit5	ST	Input/output port pin or Synchronous Serial Port data output.
RC6/TX/CK	bit6	ST	Input/output port pin or USART Asynchronous Transmit or Synchronous Clock.
RC7/RX/DT	bit7	ST	Input/output port pin or USART Asynchronous Receive or Synchronous data.

Legend: ST =Schmitt Trigger input

T1CON: TIMER1 CONTROL REGISTER (ADDRESS 10h)

U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	—	T1CKPS1	T1CKPS0	T1OSCEN	$\overline{\text{T1SYNC}}$	TMR1CS	TMR1ON
bit 7							bit 0

bit 7-6 **Unimplemented:** Read as '0'

bit 5-4 **T1CKPS1:T1CKPS0**: Timer1 Input Clock Prescale Select bits

11 = 1:8 Prescale value

10 = 1:4 Prescale value

01 = 1:2 Prescale value

00 = 1:1 Prescale value

bit 3 **T1OSCEN**: Timer1 Oscillator Enable Control bit

1 = Oscillator is enabled

0 = Oscillator is shut off (The oscillator inverter is turned off to eliminate power drain)

bit 2 **T1SYNC:** Timer1 External Clock Input Synchronization Control bit

TMR1CS = 1 bit 7 **GIE:** Global Interrupt Enable bit

1 = Enables all un-masked interrupts

0 = Disables all interrupts

bit 1 **TMR1CS**: Timer1 Clock Source Select bit

1 = External clock from pin RC0/T1OSO/T1CKI (on the rising edge)

0 = Internal clock (FOSC/4)

bit 0 **TMR1ON**: Timer1 On bit

1 = Enables Timer1

0 = Stops Timer1

PIR1 Register

The PIR1 register contains the individual flag bits for the peripheral interrupts.

Note:

Interrupt flag bits are set when an interrupt condition occurs, regardless of the state of its corresponding enable bit or the global enable bit, GIE (INTCON<7>). User software should ensure the appropriate interrupt bits are clear prior to enabling an interrupt.

PIR1 REGISTER (ADDRESS 0Ch)

R/W-0	R/W-0	R-0	R-0	R/W-0	R/W-0	R/W-0	R/W-0
PSPIF(1)	ADIF	RCIF	TXIF	SSPIF	CCP1IF	TMR2IF	TMR1IF
bit 7							bit 0

bit 7 **PSPIF (1)** : Parallel Slave Port Read/Write Interrupt Flag bit

1 = A read or a write operation has taken place (must be cleared in software)

0 = No read or write has occurred

bit 6 **ADIF**: A/D Converter Interrupt Flag bit

1 = An A/D conversion completed

0 = The A/D conversion is not complete

bit 5 **RCIF**: USART Receive Interrupt Flag bit

1 = The USART receive buffer is full

0 = The USART receive buffer is empty

bit 4 **TXIF**: USART Transmit Interrupt Flag bit

1 = The USART transmit buffer is empty

0 = The USART transmit buffer is full

bit 3 **SSPIF**: Synchronous Serial Port (SSP) Interrupt Flag

1 = The SSP interrupt condition has occurred, and must be cleared in software before returning from the interrupt Service Routine. The conditions that will set this bit are:

SPI - A transmission/reception has taken place.

I 2 C Slave - A transmission/reception has taken place.

I 2 C Master - A transmission/reception has taken place.

The initiated START condition was completed by the SSP module.

The initiated STOP condition was completed by the SSP module.

The initiated Restart condition was completed by the SSP module.

The initiated Acknowledge condition was completed by the SSP module.

A START condition occurred while the SSP module was idle (Multi-master system).

A STOP condition occurred while the SSP module was idle (Multi-master system).

0 = No SSP interrupt condition has occurred.

bit 2 **CCP1IF**: CCP1 Interrupt Flag bit

Capture Mode:

1 = A TMR1 register capture occurred (must be cleared in software)

0 = No TMR1 register capture occurred

Compare Mode:

1 = A TMR1 register compare match occurred (must be cleared in software)

0 = No TMR1 register compare match occurred

PWM Mode:

Unused in this mode

bit 1 **TMR2IF**: TMR2 to PR2 Match Interrupt Flag bit

1 = TMR2 to PR2 match occurred (must be cleared in software)

0 = No TMR2 to PR2 match occurred

bit 0 **TMR1IF**: TMR1 Overflow Interrupt Flag bit

1 = TMR1 register overflowed (must be cleared in software)

0 = TMR1 register did not overflow

CCP1CON REGISTER/CCP2CON REGISTER (ADDRESS: 17h/1Dh)

U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	—	CCPxX	CCPxY	CCPxM3	CCPxM2	CCPxM1	CCPxM0
bit 7							bit 0

bit 7-6 **Unimplemented:** Read as '0'

bit 5-4 **CCPxX:CCPxY**: PWM Least Significant bits

Capture Mode: Unused

Compare Mode: Unused

PWM Mode: These bits are the two LSbs of the PWM duty cycle. The eight MSbs are found in CCPRxL.

bit 3-0 **CCPxM3:CCPxM0**: CCPx Mode Select bits

0000 = Capture/Compare/PWM disabled (resets CCPx module)

0100 = Capture mode, every falling edge

0101 = Capture mode, every rising edge

0110 = Capture mode, every 4th rising edge

0111 = Capture mode, every 16th rising edge

1000 = Compare mode, set output on match (CCPxIF bit is set)

1001 = Compare mode, clear output on match (CCPxIF bit is set)

1010 = Compare mode,generate software interrupt on match (CCPxIF bit is set, CCPx pin is unaffected)

1011 = Compare mode, trigger special event (CCPxIF bit is set, CCPx pin is unaffected); CCP1 resets TMR1; CCP2 resets TMR1 and starts an A/D conversion (if A/D module is enabled)

11xx = PWM mode

ANALOG-TO-DIGITAL CONVERTER (A/D) MODULE

The 8-bit analog-to-digital (A/D) converter module has five inputs for the PIC16F73/76 and eight for the PIC16F74/77. The A/D allows conversion of an analog input signal to a corresponding 8-bit digital number. The output of the sample and hold is the input into the converter, which generates the result via successive approximation. The analog reference voltage is software selectable to either the device's positive supply voltage (VDD), or the voltage level on the RA3/AN3/VREF pin. The A/D converter has a unique feature of being able to operate while the device is in SLEEP mode. To operate in SLEEP, the A/D conversion clock must be derived from the A/D's internal RC oscillator.

The A/D module has three registers. These registers are:

- A/D Result Register (ADRES)
- A/D Control Register 0 (ADCON0)
- A/D Control Register 1 (ADCON1)

The ADCON0 register controls the operation of the A/D module.

The ADCON1 register configures the functions of the port pins. The port pins can be configured as analog inputs (RA3 can also be a voltage reference), or as digital I/O.

ADCON0 REGISTER (ADDRESS 1Fh)

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	U-0	R/W-0
ADCS1	ADCS0	CHS2	CHS1	CHS0	GO/$\overline{DONE}$	—	ADON
bit 7							bit 0

bit 7-6 **ADCS1:ADCS0:** A/D Conversion Clock Select bits

00 = FOSC/2

01 = FOSC/8

10 = FOSC/32

11 = FRC (clock derived from the internal A/D module RC oscillator)

bit 5-3 **CHS2:CHS0**: Analog Channel Select bits

000 = channel 0, (RA0/AN0)

001 = channel 1, (RA1/AN1)

010 = channel 2, (RA2/AN2)

011 = channel 3, (RA3/AN3)

100 = channel 4, (RA5/AN4)

101 = channel 5, (RE0/AN5) (1)

110 = channel 6, (RE1/AN6) (1)

111 = channel 7, (RE2/AN7) (1)

bit 2 **GO/DONE:** A/D Conversion Status bit

If ADON = 1:

1 = A/D conversion in progress (setting this bit starts the A/D conversion)

0 = A/D conversion not in progress (This bit is automatically cleared by hardware when the A/D conversion is complete)

bit 1 **Unimplemented**: Read as '0'

bit 0 **ADON**: A/D On bit

1 = A/D converter module is operating

0 = A/D converter module is shutoff and consumes no operating current

Note 1: A/D channels 5, 6 and 7 are implemented on the PIC16F74/77 only.

ADCON1 REGISTER (ADDRESS 9Fh)

U-0	U-0	U-0	U-0	U-0	R/W-0	R/W-0	R/W-0
—	—	—	—	—	PCFG2	PCFG1	PCFG0
bit 7							bit 0

bit 7-3 **Unimplemented**: Read as '0'

bit 2-0 **PCFG2:PCFG0**: A/D Port Configuration Control bits

PCFG2:PCFG0	RA0	RA1	RA2	RA3	RA5	RE0(1)	RE1(1)	RE2)	VREF
000	A	A	A	A	A	A	A	A	VDD
001	A	A	A	VREF	A	A	A	A	RA3
010	A	A	A	A	A	D	D	D	VDD
011	A	A	A	VREF	A	D	D	D	RA3
100	A	A	D	A	D	D	D	D	VDD
101	A	A	D	VREF	D	D	D	D	RA3
11x	D	D	D	D	D	D	D	D	VDD

A = Analog input
D = Digital I/O

Note 1 : RE0,RE1and RE2 are implemented on the PIC16F74/77 only

Legend:

R = Readable bit **W** = Writable bit **U** = Unimplemented bit, read as '0'

'1'= Bit is set **'0'** = Bit is reset **- n** = Value at POR reset

x = Bit is unknown

APPENDIX F

CODING

```
#include(pic.h>

typedef unsigned char    U1;
typedef unsigned int     U2;
typedef unsigned long    U4;

#define nop asm("nop");

U1      u1_AdcFuelInit, u1_AdcFuelFinal, u1_OneDigit, u1_TenthDigit;
U1      u1_AdcFuel, u1_HundredthDigit, u1_Count, u1_DelayCounter;

U2      u2_2msCount, u2_DelayCounter, u2_FuelLevel1;
U2      u2_DelayCounter, u2_SpeedPulse:

bank1 U4
u4_FuelLevel2, u4_FuelLevel1, u4_FuelLevel3, u4_FuelLevel, u4_FuelInitValue,
u4_FuelFinalValue;
U4      u4_KmAvailable, u4_Fuel1Km, u4_Display, u4_DisplayTemp;

U1      bFuelEnable, bFuelCalcOver, bInitialValue, bFinalValue;
U1      bRefreshValue, bSensorFault, bDelayOver, bNextOperation;

Const  U1    WriteDisplay[]={0x3f, 0x06, 0x5b, 0x4f, 0x66, 0x6d, 0x7d, 0x07,
                             0x7f, 0x6f};
```

```
/* FUNCTION DECLARATIONS */

void Init_Port(void);
void Init_Timer0(void);
void Init_Adc(void);
void Init_Capture(void);
void Fuel_Level(void);
void delay(U2);
void FuelCalc(U1,U1,U2,U4);
void delay1(void);
//void Distance_Calc(void);

/* MAIN FUNCTION */

void main(void)
{
   Init_Port( );
   Init_Timer0( );
   Init_Adc( );
   Init_Capture( );

   While(1)
   {
      Fuel_Level( );
 //   Distance_Calc( );
   }
}
```

```
void Init_Port( )
{
   TRISA0=TRISA1=1;
   TRISB=0;
   TRISC=0X04;
   bInitialValue=0;
   bFinalValue=0;
}

void Init_Timer0( )
{
   TMR0=0X00;
   INTCON=0X00;
   OPTION=0XC4;
   T0IE=1;
   GIE=1;
   TMR0=0X82;          /*   for 2ms interrupt   */
}

void Init_Adc( )
{
   ADCON1=0X02;
   ADIE=0;
}

void Init_Capture( )
{
   CCP1CON=0X00;
```

```
    TMR1H=0X00;
    TMR1L=0X00;
    PIE1=0X00;
    PIR1=0;
    TMR1IF=0;
    CCP1IF=0;

    CCP1CON=0X06;
    T1CON=0X01;

//  TMR1IE=1;
    CCP1IE=1;

    GIE=1;
    PEIE=1;
}

void Fuel_Level( )
{
    if(bFuelEnable)
    {
      bFuelEnable=0;

      ADCON0=0X89;          // CHANNEL 1
      Delay1( );
     ADGO=1;
     while(ADGO);
     u1_AdcFuel=ADRES;
     nop;
```

```
if(u1_AdcFuel>250)
{
   bSensorFault=1;
//  switch on red LED
}
else if(u1_AdcFuel>224)
{
    bSensorFault=0;
    FuelCalc(u1_AdcFuel,225,188,1350);
}
else if(u1_AdcFuel>104)
{
    bSensorFault=0;
    FuelCalc(u1_AdcFuel,105,387,4450);
}
else if(u1_AdcFuel>49)
{
    bSensorFault=0;
    FuelCalc(u1_AdcFuel,50,611,5350);
}
if(bInitialValue)
{
    bInitialValue=0;
    u4_FuelInitValue=u4_FuelLevel;
}
if(bFinalValue)
{
    bFinalValue=0;
```

```
        u4_FuelFinalValue=u4_FuelLevel;
//      bFuelCalcOver=1;
        u4_Fuel1Km = (u4_FuelInitValue-u4_FuelFinalValue);
        u4_KmAvailable = (u4_FuelFinalValue/u4_Fuel1Km);
        u2_SpeedPulse=0;
        bNextOperation=0;
        PEIE = 1;
        CCP1IE = 1;
      }
  }
}

/* void Distance_Calc( )
{
    if(bFuelCalcOver)
    {
        bFuelCalcOver=0;
        u4_Fuel1Km = (u4_FuelInitValue-u4_FuelFinalValue);
        u4_KmAvailable = (u4_FuelFinalValue/u4_Fuel1Km);
        PEIE=1;
        CCP1IE=1;
        u2_SpeedPulse=0;
        bNextOperation=0;
    }
}       */

/* void delay(U2 u2_Msec)
{
   //U2 u2_DelayCounter;
```

```
    u2_DelayCounter = (u2_2msCount+u2_Msec);
    if(u2_DelayCounter>500)
    {
        u2_DelayCounter=(u2_DelayCounter-500);
    }
    while(!bDelayOver);
    bDelayOver=0;
    nop;
}       */

void delay1(void)
{
    u1_DelayCounter=0xFF;
    while(--u1_DelayCounter);
}

void FuelCalc(U1 u1_AdcFuel,U1  u1_Y1,U2  u2_slope,U4 u4_X1)
{
    u4_FuelLevel1 = ((u1_AdcFuel-u1_Y1)*100);
    u4_FuelLevel2=u4_FuelLevel1*100;
    u4_FuelLevel3 = (u4_FuelLevel2/u2_slope);
    u4_FuelLevel=u4_X1-u4_FuelLevel3;
    nop;
}

/* ISR function */

interrupt void isr(void)
{
```

```
if(T0IF)            /* for 2 ms */
{
    if(++u2_2msCount>500)
    {
        u2_2msCount=0;
        bRefreshValue=1;
    }
    if(bRefreshValue)
    {
        bRefreshValue=0;
        u4_Display=u4_KmAvailable;
    }
    if(++u1_Count<4)
    {
        if(u1_Count= = 1)
        {
            u1_OneDigit=(u4_DisplayTemp%10);
            RC5=RC4=0;RC3=1;

            PORTB=WriteDisplay[u1_OneDigit];
            u4_DisplyTemp=(u4_DisplayTemp/10);
            if(!u4_DisplayTemp)
            u1_Count=0;
        }
        else if(u1_Count= =2)
        {
            u1_TenthDigit=(u4_DisplayTemp%10);
            RC3=RC5=0;RC4=1;
```

```
        PORTB=WriteDisplay[u1_TenthDigit];
        u4_DisplayTemp=(u4_DisplayTemp/10);
        if(!u4_DisplayTemp)
        u1_Count=0;
    }
    else if(u1_Count= = 3)
    {
         u1_HundredthDigit=(u4_DisplayTemp%10);
         RC3=RC4=0;RC5=1;

         PORTB=WriteDisplay[u1_HundredthDigit];
         u4_DisplyTemp=(u4_DisplayTemp/10);
         if(!u4_DisplayTemp)
         u1_Count=0;
     }
}
else
{
    u1_Count=0;
}
if(!u1_Count)
  u4_DisplayTemp = u4_Display;

if(u2_DelayCounter= = u2_2msCount)
   bDelayOver=1;
    T0IF=0; TMR0=0XCF;
INTF=0;
nop;
}
```

```
if(CCP1IF)
{
    CCP1IF=0;
    if(!bNextOperation)
      ++u2_SpeedPulse;
    if(u2_SpeedPulse= =1)
    {
        bfuelEnable=1;
        bInitialValue=1;
        bFinalValue=0;
    }
    if(u2_SpeedPulse>4000)
    {
        if(!bNextOperation)
        {
          PEIE=0;
          CCP1IE=0;
          bFuelEnable=1;
          bInitialValue=0;
          bFinalValue=1;
          bNextOperation=1;
        }
    }
   nop;
  }
}
```