DECLARATION OF ORIGINALITY

FACULTY/ SCHOOL/ INSTITUTE: Engineering
DEPARTMENT: Electrical and Information Engineering
COURSE NAME: Bachelor of Science in Electrical & Electronic Engineering
TITLE OF NAME OF STUDENT: KITUyi KENNEDY NAMARU
REGISTRATION NUMBER: F17/29215/2009
COLLEGE: Architecture and Engineering
WORK: NON-CONTACT ROTATIONAL SPEED MEASUREMENT

1) I understand what plagiarism is and I am aware of the university policy in this regard.
2) I declare that this final year project report is my original work and has not been submitted elsewhere for examination, award of a degree or publication. Where other people’s work or my own work has been used, this has properly been acknowledged and referenced in accordance with the University of Nairobi’s requirements.
3) I have not sought or used the services of any professional agencies to produce this work.
4) I have not allowed, and shall not allow anyone to copy my work with the intention of passing it off as his/her own work.
5) I understand that any false claim in respect of this work shall result in disciplinary action, in accordance with University anti-plagiarism policy.

Signature: …………………………………………………………………………………………………………………

Date: …………………………………………………………………………………………………………………
DEDICATION.
This project is dedicated to my mother who has sacrificed too much to see me get to this point in my life.
ACKNOWLEDGEMENT

I would like to take this opportunity to express gratitude to everyone who has provided me with invaluable help over the course of this project. I would like to acknowledge the immense contribution of my supervisor Prof. Elijah Mwangi, for giving me the freedom to think through this project without restrictions.

I also acknowledge our machines and electronics laboratory technicians who provided both advice and equipment.
ABSTRACT

Rotational speed measurement is important in all areas of engineering. Rotating machines are everywhere from airplane engines, disc readers in computers, cassette players to large scale motors and generators in industries. For proper and efficient operation, speeds of these machines need to be accurately measured. Rotational speed measurement has been one of the many beneficiaries of advancements in microprocessor and semiconductor technology.

This report details stages involved in designing and implementing a cheap non-contact microprocessor based speed measurement system based on the PIC 16F690 from Microchip. Readings of rotations per minute were displayed on a 16x2 LCD based on Hitachi’s HD 44780 LCD Controller/Driver.

Computer simulation experiments performed on Proteus software version 7.8 from Labcenter have been used to demonstrate the accuracy and stability of the designed device based on the proposed algorithm. The device was then implemented and its performance compared against the DT-2234A+ ,an industrial standard tachometer.
LIST OF FIGURES

FIGURE 2.1: PHOTODIODE ........................................................................................................... 6
FIGURE 2.2: THROUGH BEAM TYPE OPTICAL SENSOR ......................................................... 7
FIGURE 2.3: RETROREFLECTIVE TYPE OPTICAL SENSOR ..................................................... 8
FIGURE 2.4: MAGNETIC SENSING TECHNIQUE ....................................................................... 9

FIGURE 3.1: DESIGN CIRCUIT .................................................................................................. 10
FIGURE 3.2: POWER SUPPLY ................................................................................................... 11
FIGURE 3.3: IR TRANSMITTER RECEIVER UNIT ................................................................. 11
FIGURE 3.4: COMPARATOR INPUT AND OUTPUT ............................................................... 13
FIGURE 3.5: PIC 16F690 PIN DIAGRAM ............................................................................... 14
FIGURE 3.6: LM 016L LCD ...................................................................................................... 15
FIGURE 3.7: ALGORITHM ......................................................................................................... 16
FIGURE 3.8: T1CON REGISTER .............................................................................................. 17
FIGURE 3.9: VIRTUAL 24-BIT REGISTER .............................................................................. 19

FIGURE 4.1: SIMULATION CIRCUIT ...................................................................................... 22
FIGURE 4.2: PLOT OF AVERAGE RPM VALUES OBTAINED BY DESIGNED DEVICE
AND STANDARD TACHOMETER FOR VARIOUS READINGS. RESULTS ARE
FROM MACHINE I ................................................................................................................... 25
FIGURE 4.3: PLOT OF AVERAGE RPM VALUES OBTAINED BY DESIGNED DEVICE
AND STANDARD TACHOMETER FOR VARIOUS READINGS. RESULTS ARE
FROM MACHINE II ............................................................................................................... 26
FIGURE 4.4: DISPLAY OF 2400 RPM ON LCD DISPLAY .................................................... 27
LIST OF TABLES

TABLE 3.1: PIN DESCRIPTION OF THE LM 016L LCD DISPLAY ............................................. 14
TABLE 3.2: TIME CONTRIBUTIONS ....................................................................................... 19

TABLE 4.1: RESULTS FROM SIMULATION .............................................................................. 23
TABLE 4.2: TEST MACHINE DETAILS ..................................................................................... 24
TABLE 4.3: TACHOMETER DETAILS ....................................................................................... 24
TABLE 4.4: RESULTS FROM MACHINE I AND TACHOMETER ............................................... 24
TABLE 4.5: RESULTS FROM MACHINE II AND TACHOMETER ............................................ 25

TABLE 5.1: DEVICE SPECIFICATIONS .................................................................................... 28
ACRONYMS AND ABBREVIATIONS

RPM  Rotations per minute.
PIC  Programmable Intelligent Controller.
LCD  Liquid crystal Display.
PPR  Pulses per revolution.
IR  Infrared.
DC  Direct current.
GND  Ground.
TX  Transmitter.
RX  Receiver.
SRAM  Static Random Access Memory.
EEPROM  Electrically Erasable.
TMRI  Timer1.
T1CO  TIMER1 CONTROL REGISTER.
TOIF  Timer0 Interrupt flag.
BCD  Binary Coded Decimal.
Contents
DECLARATION OF ORIGINALITY .................................................................i
DEDICATION....................................................................................................ii
ACKNOWLEDGEMENT ....................................................................................iii
ABSTRACT.........................................................................................................iv
LIST OF FIGURES............................................................................................v
LIST OF TABLES...............................................................................................vi
ACRONYMS AND ABBREVIATIONS .................................................................vii
1.0 INTRODUCTION:........................................................................................1
1.1 PROBLEM STATEMENT:.............................................................................2
1.2 PROJECT OBJECTIVE................................................................................2
CHAPTER 2: LITERATURE REVIEW .................................................................3
  2.1 FREQUENCY MEASUREMENT METHOD..............................................3
  2.2 PERIOD MEASUREMENT METHOD.....................................................4
  2.3 SENSING MECHANISM.........................................................................5
    2.2.1 OPTICAL SENSING......................................................................6
  2.4 MAGNETIC SENSING............................................................................8
3.0 DESIGN.......................................................................................................10
  3.1 Hardware design....................................................................................10
    3.1.1 Power Supply.................................................................................11
    3.1.2 Detector Unit.................................................................................11
    3.1.3 Square Wave Generator..............................................................12
    3.1.4 Microcontroller.............................................................................14
    3.1.5 Display Unit..................................................................................14
  3.2 Software design.....................................................................................16
CHAPTER 4: RESULTS AND DISCUSSION.......................................................22
  4.1 SIMULATION RESULTS.........................................................................22
  4.2 PRACTICAL RESULTS...........................................................................23
CHAPTER 5 CONCLUSION AND RECOMMENDATIONS................................28
  5.1 CONCLUSION........................................................................................28
  5.2 RECOMMENDATIONS............................................................................28
CHAPTER 1: 

1.0 INTRODUCTION:

RPM or rotations per minute are a measure of the frequency of rotation of an object. It is an indication of how many full rotations are made in the space of a minute around a fixed axis [1]. RPM measurement is important when control and measurement of speed is important e.g. in monitoring motors, conveyors and turbines. DC tachometers are a common sight anywhere where knowledge of rotational speeds is needed e.g. in industrial drives. This is mainly due to them being inexpensive and also having good dynamic performance.

The measurement of RPM can be divided into three methods:

- **Mechanical**- The revolutions in a mechanical sensor are analyzed electronically in the instrument (tachometer). Mechanical RPM meters utilize physical contact for purposes of measurement. They work on the concept that the centrifugal force on a rotating object is dependent on the speed of rotation.

  Centrifugal force is given by $F = m\omega^2 r$, where $m$ is the mass of the rotating shaft, $\omega$ is the angular velocity and $r$ is the radius of the shaft. Given that $\omega = 2\pi f$, $F = m (2\pi f)^2 r$.

  \[
  \text{Frequency} = \frac{\sqrt{F/m}}{2\pi} \quad (1.1)
  \]

  Given that mass and radius are constant, the frequency (rotations per second) is therefore dependent only on the centrifugal force $F$. The speed of the is given by:

  \[
  \text{Frequency} = \frac{N \text{ (number of rotations)}}{T \text{ (time in seconds)}} \quad (1.2)
  \]

  Numbers of rotations made in a minute (RPM) is therefore given by frequency x 60.

- **Optical**- In this method rotations are transmitted to the measuring device by an infrared beam originating from the instrument which is reflected by a reflective tape on the rotating shaft. The rotating shaft will have one reflective spot and the rate at which the IR beam is reflected back is used to determine the rotations per minute of the shaft.

- **Stroboscopic**- In the stroboscopic effect, objects are viewed as stationary by the observer if the frequency of the pulses from the instrument are synchronized with the RPM of the shaft. This method has clear advantages over the other two given that the mechanical method is limited to speeds in the range of 0-30,000 rpm. The optical method although superior, it is not always possible to have reflective tapes on a rotating object. With the stroboscopic method however, it is always possible the rotational speed of even very small objects.
1.1 PROBLEM STATEMENT:
Non-contact means for determining rotational speeds have several advantages over the contact methods namely:

- No frictional losses involved.
- Significant reduction in bulkiness
- Low power consumption.
- Devices are usually portable.
- Rapid response to changes in speed
- Increased accuracy
- Increased safety for the user.

A digital output from the instrument also offers direct readability of the speed compared to an analog output where the user’s ability to accurately read a needle’s location on a scale becomes a factor. It is therefore clearly necessary to device means by which rotational speeds can be read via non-contact means.

1.2 PROJECT OBJECTIVE
The objectives of this project are to design and construct a system based on a PIC microcontroller that will:

i) Measure the rotational speed of a rotating disc via non-contact means.
ii) Display this speed in RPM on an LCD screen.
iii) Compare the accuracy of the designed system against commercially available instruments.
CHAPTER 2: LITERATURE REVIEW

A revolutions counter is a device that measures and indicates the speed (usually in rotations per minute-RPM) at which a shaft is rotating. These devices find extensive use in areas such as:

i) Trains and light rail vehicles where they are used to determine how fast the train is moving. In this case Hall Effect sensors are used together with a rotating target attached to the wheel to measure speed. A probe is mounted with its head at a precise distance from the rotating wheel. As the target passes in front of the probe, the magnetic flux inside the sensor changes. This is due to the reduction in distance between the probe and the target. The changing magnetic flux density induces a voltage in the sensor (which is an analog transducer). The resulting current is the measured by the Hall sensor which is usually combined with external circuitry to act in a digital on/off mode. This allows for the speed of the wheel to be measured using computers and displayed.

ii) Audio recorders/players where the speed of the tape as it passes across the head needs to be known. This is essential in making sure that the speed at which the tape is played is the right one.

iii) Aircraft and automobile to measure the speed of the rotating crankshaft. In automobiles, knowledge of the speed of the crankshaft is important in determining what gear to operate at particular driving conditions.

To accurately measure the rotational speed of an object in RPM, the number of full cycles completed in a given period must be known. Continuous evolution in microprocessor technology has led to their wide use in areas such as speed measurement. Two commonly used methods in digital speed measurement exist. Both are based on a pulse train originating from a shaft encoder. The first method counts the number of pulses arriving from the encoder in a fixed time period (Frequency measurement method) while the second measures the time that elapses between the arrival of successive pulses from the encoder (Period measurement method). Both methods however have their short fallings with the frequency measurement method having low accuracy for low speeds. It is however suitable for fastrotating devices like motors and turbines who’s RPMs are in the thousands per minute range. The period measurement method offers low accuracy for high speeds and is suitable for devices rotating at low speeds.

2.1 FREQUENCY MEASUREMENT METHOD

In the frequency measurement method, the key point is the number of pulses per revolution (PPR) arriving from the encoder. This is suitable for high PPR sensors but offers low accuracy with low PPR sensors. With a 600 PPR sensor, the rotations per minute are calculated as:
\[ \text{RPM} = \frac{\text{PULSE FREQUENCY} \times 60}{600} \] (2.1)

i) For a pulse of 1 Hz, the rotational speed of the shaft is 0.1 RPM.
ii) At 2 Hz, the speed is 0.2 RPM.
iii) At 3 Hz, the speed is 0.3 RPM.

This clearly indicates that for an increase of 1 Hz in pulse frequency, the RPM changes by 0.1 Hz. The resolution of 0.1 Hz is appropriate for most applications. Using a 60 PPR sensor:

\[ \text{RPM} = \frac{\text{PULSE FREQUENCY} \times 60}{60} \] (2.2)

i) For a pulse frequency of 1 Hz, the rotational speed of the shaft is 1 RPM.
ii) At 2 Hz, the speed is 2 RPM.
iii) At 3 Hz, the speed is 3 RPM.

Thus for an increase of 1 Hz in pulse frequency, the RPM changes by 1 Hz. This indicates a reduced resolution compared to when a 600 PPR sensor is used. For most applications, this resolution of 1 Hz is the minimum acceptable resolution.

Using a 1 Hz PPR sensor, the rotations per minute are calculated as:

\[ \text{RPM} = \frac{\text{PULSE FREQUENCY} \times 60}{1} \] (2.3)

i) At a pulse frequency of 1 Hz, the rotational speed of the shaft is 60 RPM.
ii) At 2 Hz, the speed is 120 RPM.
iii) At 3 Hz, the speed is 180 RPM.

This indicates that for a 1 Hz frequency change, the RPM changes by 60 RPM. This resolution of 60 RPM is unacceptable for any application. For low PPR sensors, the preferred solution is to measure the pulse period.

With the frequency measurement method, the following points are noted:

i) The resolution depends on the speed of rotation.
ii) The time taken to take a reading is independent of the speed of rotation.
iii) Accuracy of measurement improves with increase in speed of rotation.

### 2.2 PERIOD MEASUREMENT METHOD

Here a low PPR is considered to be any value less than 60 PPR. Pulse period can be measured at a higher resolution (about 0.1 ms). Due to the high resolution, this method is appropriate when using low PPR sensors such as proximity sensors and photoelectric sensors. The period is the time interval between the start of one pulse to the start of the next pulse. When using the Pulse Measurement Method, the RPM is calculated from:
RPM = \frac{60}{\text{PULSE PERIOD x PPR}} \quad (2.4)

For a pulse frequency of 1Hz and a PPR of 1,

\[
\text{RPM} = \frac{60}{1 \times 1} = 60
\]

For a pulse frequency of 6 Hz and a PPR of 1,

\[
\text{RPM} = \frac{60}{\frac{1}{6} \times 1} = 360
\]

If the PPR is greater than 1 however, and the pulses are not symmetrical e.g. when the shaft rotates at a constant speed but the reflector strips on a rotating disc are not evenly spaced (in the case where they reflect IR beams from an IR transmitter back to a receiver in a proximity sensor), the periods will be different and thus result is the RPM reading becomes erratic.

With the time measurement method, the following points are noted:

i) Resolution is independent of the speed of measurement.

ii) The time taken to take a reading depends on the speed of rotation and it increases with the decrease in speed.

iii) Its accuracy is greatest at low speeds.

The frequency measurement method allows for easy detection of zero speed. This is simply by detecting that the frequency of the incoming pulse is zero. With the period measurement method, complexity arises when trying to determine how much time has elapsed before deciding that the shaft has come to a halt and thus zero speed.

2.3 SENSING MECHANISM

RPM sensors are transducers which convert the mechanical motion of a rotating object into electrical pulses using either contact or non-contact means. The output signal can then be fed to a digital counter or any other monitoring device. Typical devices used for sensing purposes are shaft (rotary) encoders, magnetic (proximity type) sensors and photoelectric (optical) sensors. Shaft sensors offer the highest resolution among the sensors of about 1-5000 PPR with clearly defined and symmetrical pulses. Proximity sensors come second to shaft sensors in terms of resolution, providing medium to low resolution where as seen earlier using the period measurement method, this resolution is dependent on the number of pulses per revolution. Photo electric sensors use a reflective surface fixed on a rotating shaft to determine the rotations per minute.

Two sensing techniques are used for the non-contact means to measure the rotational speed of an object:
2.2.1 OPTICAL SENSING

The principle behind optical measuring techniques is that the light beam changes by the phenomena being measured [2]. The property of light that changes might be intensity, phase, polarization, wavelength or spectral distribution. The optical sensing technique converts a change in light intensity into an electrical signal that can then be read by the instrument. Different types of optical sensors exist e.g. photo-detectors, fiber optics and proximity sensors.

Photo detectors use the principle of photoelectric emission. When electromagnetic radiation is incident on a metal surface, electrons gain enough energy from the incident radiation to escape from the metal’s surface. The energy of the radiation depends solely on the frequency and is given by \( E = h \nu \) where \( h \) is the Planck constant and \( \nu \) is the frequency. A common photo detector is the photodiode. The photodiode is based on a junction composed of oppositely doped regions that form a pn junction. The result is a region depleted of charge carriers that has very high impedance. The high impedance of the depleted region is what allows for the construction of detectors using silicon and germanium. The photodiode functions by using an illumination window as shown in figure 2.1. That allows for the use of light as an external input. When light or more precisely a photon whose energy is sufficient strikes the photodiode, an electron-hole pair is generated. If the absorption of the photon is in the transition region i.e. the charge depleted region, the electric charge between the two oppositely charged regions sweep the charge carriers (electron moves towards the cathode and the hole moves towards the anode) away from it. The resulting current due to charge motion is referred to as a photocurrent. Since light is used as an input, the diode is operated under reverse bias conditions. Under the reverse bias condition, the current through the pn junction is approximately zero when there is no light falling on the photodiode. This allows the diode to be used as a switch or relay when sufficient light is present. In truth though there is a current that flows whether there is light or not. This is referred to as the dark current. The total current in the photodiode is the sum of the dark current and the photocurrent. The amount of dark current influences the sensitivity of the photodiode therefore to have a highly sensitive device, this current must be minimal. Photodiodes are able to function with high sensitivity at low temperatures.

![Illumination window](image)

**Figure 2.1**: Photodiode
Photodiodes are used in many applications such as flame detectors, smoke detectors, modern oil burning furnaces as a safety feature and in the switching on of relays in street lights.

**Proximity Sensors**- Optical proximity sensors or light beam sensors are composed of a light source and a detector unit that detects light. To minimize the effects of interference from other light sources, the light source emits light at a frequency least likely to be generated by the other light sources. Infra-red light is the most common in optical proximity sensors. The infra-red beam emitted by the source is also made to pulse at a particular frequency such that light from any other source that does not pulse at that particular frequency is rejected. This makes sure the sensor unit only responds to the infra-red light from the source of the device [10] [11].

The sensor is usually composed of a semiconductor device whose electrical properties vary with the changing intensity of the incoming IR beam. This can be a photodiode, a phototransistor or a photo-darlington.

![Diagram](image-url)

*Figure 2.2: Through beam type optical sensor*
Figures 2.2 and 2.3 illustrate through beam type and retroflective type optical sensors respectively. Through beam type sensors are designed to sense the presence of an object by detecting a break in the path of light by an opaque object. An example is in detecting whether or not a bottle has been filled by the amount of light that reaches the sensor through the bottle. In Retroflective sensors, the transmitter and receiver are both in the same package. A target is detected by the reflection of the IR beam from the transmitter. Retroflective type sensors that can sense a target only within a small distance are useful in non-contact rotational speed measurement. The choice of sensor to use depends on the desired range [10]. The light from the transmitter in the retroflective sensor travels the path to the target and back meaning it covers twice the distance of separation between the target and the sensor. Since light from the transmitter is emitted in a cone shape, the cross-section of the cone increases with increase in the distance of the target. A larger reflector target is therefore required at longer distances than at shorter distances. External control circuitry is needed for these sensors to work properly [11] [3].

2.4 MAGNETIC SENSING
Conventional sensors most of time directly measure the desired parameter. Magnetic sensors rarely ever measure the desired parameter directly [11]. They work by measuring the distortion on a magnetic field and thus offer accurate measurements of both direction and speed. The output of the sensor therefore often requires post signal processing. Figure 2.4 shows a Hall-effect Speed and Direction sensor. The first output of the sensor is a square wave which is an indication of how fast the gear is rotating. The second output is an indication of the direction of rotation of the gear. When the gear rotates in the clockwise direction, the output is logic HIGH and when rotating in the anti-clockwise direction, the output is a logic LOW. As the slots on the gear cut the magnetic field around the sensor they modulate the magnetic field around the sensor. This induces a voltage in the sensor which is converted to a square wave by a comparator and
then amplified. The frequency of the square wave is proportional to the rotational speed of the gear (for the case of only 1 slot on the gear, the speed of rotation is the same as the frequency of the induced voltage).

The digital square waves from the sensor can be fed to a microcontroller which can be used to determine the speed of the gear. For the sensor to function, the target device has to be made of ferrous material. This limits the areas of application since the rotational speed of non-ferrous material cannot be measured. The Hall-effect is greatly affected by temperature which in turn affects the maximum gap between the sensor and the target device.

Figure 2.4: Magnetic sensing technique.
CHAPTER 3

3.0 DESIGN

The non-contact measuring system was based on the PIC 16F690. The design process consists of:

i) Hardware design
ii) Software design

3.1 Hardware design.

Figure 3.1 shows the design of the circuit for the device.

![Design Circuit Diagram]

Figure 3.1: Design circuit.

The five volt supply needed to power the above circuit is provided by the set-up in figure 3.2.
3.1.1 Power Supply
The LM 7805 voltage regulator outputs a constant +5V dc voltage which is used to power the device. For proper operation, the LM 7805 needs to be fed an input dc voltage that is as smooth as possible (this results in the best regulated output). Capacitor C1 filters out any noise originating from the battery. This ensures that the dc signal fed to the regulator is “clean”. A “clean” dc input to the regulator ensures most efficient operation of the regulator. Any a.c component riding on the dc voltage from the battery is shorted to ground by C1 thus allowing only dc portion to the regulator. C2 just like C1 is a by-pass capacitor. It filters out noise and any other high frequency components of the voltage on the output pin.

3.1.2 Detector Unit

Figure 3.3: IR transmitter receiver unit.
The sensor/detector unit comprises of an IR transmitter-receiver unit made from easily available infrared transmitter and receiver diodes. TX is the IR-transmitter and RX is the receiver diode. Diode TX connected in forward biased mode conducts continuously thus emitting a constant beam which bounces off a reflector strip on the rotating disc. The receiver diode RX connected in reverse biased mode together with R4 form a voltage divider unit. When no IR beams (from the reflector) fall on RX, its impedance is in the order of mega ohms. The voltage at node Q is given by:

\[ V_Q = \frac{5R_4}{R_4 + R_{RX}} \]  

(3.1)

With \( R_{RX} \) much greater than \( R_4 \) the ratio of \( 5R_4/(R_4+R_{RX}) \) can properly be approximated to be equal to \( 5R_4/R_{RX} \) which yields a value of \( V_Q \) very nearly equal to zero. Once IR light falls on RX, its impedance is in the tens of ohms range. For this case, \( R_4 \) is now much greater than \( R_{RX} \) giving a value of \( V_Q \) approximately equal to \( 5R_4/R_4 \). The voltage at Q is therefore very nearly equal to 5V. \( V_Q \) changes from nearly 0V to nearly 5V at the rate at which the reflector strip passes in front of the receiver diode RX which is basically the speed of rotation of the disc.

3.1.3 Square Wave Generator

Voltage \( V_Q \) is fed to the non-inverting input of the op-amp LM 324 set to operate as a non-inverting comparator. Voltages \( V_Q \) and \( V_P \) are compared by the op-amp whose output depends on the difference between the two voltage. Voltage \( V_P \) is given by:

\[ V_P = \frac{R_1}{R_1 + R_2} = \frac{5(4.7)}{3.3+4.7} = \text{2.9375 Volts.} \]

For the case where \( V_Q \) is greater than 2.9375V, the output of the op-amp is ideally supposed to be +5V dc but practically, it was found to be 4.51V dc. When \( V_Q \) is less than 2.9375V the output is ideally supposed to be 0V but was found to be 0.2V. The output of the op-amp alternates between 4.91V and 0.2V at a frequency equal to the rotations per second of the rotating disc. The choice of the voltage level at P is based on the working distance of the device from the rotating disc. The IR beam starts its journey from diode TX travelling to the disc where it bounces off the reflective strip and then travels to diode RX. The impedance of RX depends on the beam intensity falling on it. This means that the greater the beam intensity, the smaller the impedance of the diode and vice-versa. As the distance from the detector to the disc increases, the intensity of the beam arriving at RX reduces. The impedance of RX which should ideally fall to zero when IR beams fall on it is still of considerable value if the beams intensity is too low. From equation 3.1 voltage at Q is closest to +5V when \( R_4 \) is much greater than \( R_{RX} \). For practical working distances, the choice of \( V_P \) to be at 2.9375 allows for a working distance of up to 10cm. This means that within the range of 0cm-10cm, the voltage at Q is still greater than 2.9375V when IR beams fall on RX. The comparator therefore outputs a logic high which from measurements is 4.51V. Figure 3.3 shows the input and output wave forms of the op-amp from simulation on Proteus VSM software of a disc rotating at 720 RPM. The op-amp outputs a pulse train which is fed to the microcontroller at pin 2 which is set to operate as an input pin to the TIMER1 module.
Figure 3.4: Comparator input and output.
3.1.4 Microcontroller
The PIC 16F690 is a 20-pin 8-bit microcontroller from Microchip based on the Harvard architecture. Some of its main features are;

i) Operating frequency range of 8 MHz to 32 MHz
ii) Operating voltage range of 2.0V dc to 5.5V dc.
iii) A 10-bit resolution analog to digital converter.
iv) 256 bytes of both SRAM (static RAM) memory and EEPROM (electrically erasable read only memory).
v) 14-bit wide program bus.
vi) 8-bit wide data bus.

![PIC 16F690 Pin diagram](image)

Figure 3.5: PIC 16F690 Pin diagram.

3.1.5 Display Unit.
The LM 016L display unit is based on the HD44780 controller/driver from Hitachi. It has 2 rows for display with 20 characters per row with a character dot matrix of 5x8.

Table 3.1: Pin description of the LM 016L LCD display.

<table>
<thead>
<tr>
<th>Pin Number</th>
<th>Symbol</th>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VSS</td>
<td>0V</td>
<td>Ground</td>
</tr>
<tr>
<td>2</td>
<td>VDD</td>
<td>5V</td>
<td>Supply voltage for logic</td>
</tr>
<tr>
<td>3</td>
<td>V&lt;sub&gt;O&lt;/sub&gt;</td>
<td>---</td>
<td>Input voltage for LCD</td>
</tr>
<tr>
<td>4</td>
<td>RS</td>
<td>H/L</td>
<td>H : Data, L : Instruction code</td>
</tr>
<tr>
<td>5</td>
<td>R/W</td>
<td>H/L</td>
<td>H : Read mode, L : Write mode</td>
</tr>
<tr>
<td>6</td>
<td>E</td>
<td>H, L</td>
<td>Chip Enable signal</td>
</tr>
<tr>
<td>7</td>
<td>D0</td>
<td>H/L</td>
<td>Data Pin 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>-----------</td>
</tr>
<tr>
<td>8</td>
<td>D1</td>
<td>H/L</td>
<td>Data Pin 1</td>
</tr>
<tr>
<td>9</td>
<td>D2</td>
<td>H/L</td>
<td>Data Pin 2</td>
</tr>
<tr>
<td>10</td>
<td>D3</td>
<td>H/L</td>
<td>Data Pin 3</td>
</tr>
<tr>
<td>11</td>
<td>D4</td>
<td>H/L</td>
<td>Data Pin 4</td>
</tr>
<tr>
<td>12</td>
<td>D5</td>
<td>H/L</td>
<td>Data Pin 5</td>
</tr>
<tr>
<td>13</td>
<td>D6</td>
<td>H/L</td>
<td>Data Pin 6</td>
</tr>
<tr>
<td>14</td>
<td>D7</td>
<td>H/L</td>
<td>Data Pin 7</td>
</tr>
<tr>
<td>15</td>
<td>A</td>
<td>---</td>
<td>LCD Backlight (Anode)</td>
</tr>
<tr>
<td>16</td>
<td>K</td>
<td>---</td>
<td>LCD Backlight (Cathode)</td>
</tr>
</tbody>
</table>

Pins 15 and 16 although not shown are the backlight anode and cathode pins.

Figure 3.6: LM 016L LCD.
3.2 Software design

Figure 3.7: Algorithm.
The flow chart in figure 3.7 was used to implement the program for the non-contact rotational speed measurement.

To be able to receive the square wave from the comparator circuit, pin 5 of the microcontroller was configured as an input pin. This pin also serves as:

i) Timer1 clock input.
ii) External clock input/RC oscillator connection.
iii) Crystal/Resonator input.
iv) General purpose input/output pin on PORTA.

To configure pin 5 for input, the binary sequence ‘00000000’ was saved in the 8-bit TRISA (address 85h) register. A zero indicates that the pin corresponding to the position of the zero in the binary sequence is set to receive inputs. Pin 2 was used to input the pulses arriving from the comparator to the 16-bit Timer1. The Timer1 module consists of two 8-bit registers, TMR1L (address 0Eh) and TMR1H (address 0Fh) which together form the 16-bit register [14].

The TMR1 register increments from 0000h to FFFFh and on overflow, rolls back to 0000h[3][14]. Overflow is indicated by TMR1F which changes from logic 0 to logic 1 on overflow. This register has three modes of operation:

i) Synchronous timer mode.
ii) Synchronous counter mode.
iii) Asynchronous counter mode.

For this particular case, Timer1 was to be used as an asynchronous counter to increment on the rising edge of every arriving pulse on pin 5. It was configured for the above function using the T1CON register (address 10h). Figure 3.1 shows the T1CON register. The binary sequence ‘00000111’ was saved in the T1CON register.

\[
\begin{array}{cccccccc}
\text{U-O,} & \text{U-O} & \text{T1CKPS1} & \text{T1CKPS0} & \text{T1OSCEN} & \text{T1SYNC} & \text{TMR1CS} & \text{TMR1ON} \\
\hline
\text{R/W-O} & \text{R/W-O} & \text{R/W-O} & \text{R/W-O} & \text{R/W-O} & \text{R/W-O} & \text{R/W-O} \\
\end{array}
\]

Figure 3.8: T1CON register.

i) Bit 0 of the T1CON register turns on the Timer1 register when set and turns it off when cleared. Setting this bit in software therefore turned the Timer on.

ii) Bit 1 allows for the selection of a clock source between the internal clock (done by clearing this bit) and an external clock (done by setting this bit).
iii) Bit 2 allows for the timer to run in synchronous mode (done by clearing this bit) or in asynchronous mode (done by setting this bit). Since Timer1 was to run in asynchronous mode, this bit was set.
iv) Bit 3 was used to turn off the oscillator since there was no external oscillator used. This was done by clearing this bit.
v) Bits 4 and 5 were both cleared. This allowed for the prescale ratio of 1:1 to be used. This allowed for the Timer1 register to increment on every arriving pulse. Available prescale ratios are 1:1, 1:2, 1:4, and 1:8.
vi) Bits 6 and 7 were unimplemented and were all cleared.

To measure the number of pulses arriving at pin 5 every one second, a precise 1 second window was created. This was done by using the Timer0 (address 01h and 101h) register. The Timer0 register is an 8-bit register that has the following properties:

i) Can operate as a counter or a timer.
ii) Is both readable and writable.
iii) It overflows on the 256th bit and this sets the TOIF (Timer0 Interrupt flag).
iv) Has an 8-bit software programmable prescaler.
v) Internal or external clock select.
vi) Edge select for external clock.

With the knowledge that Timer0 overflows on the 256th instruction count, an interrupt driven 1 second timer was created using this concept. For a given clock frequency in MHz, it takes 4 clock cycles to execute an instruction for the PIC 16F690 microcontroller meaning that an instruction cycle takes:

\[
\text{instruction execution time} = \frac{1}{\frac{1}{4} \times \text{clock frequency}} \quad (3.1)
\]

The microcontroller was chosen with the internal clock running at 4MHz. This means that from expression 3.1, the instruction execution time is \(1/(0.25\times4\times10^6) = 1\times10^{-6}\) seconds. To achieve a 1 second delay within which the number of pulses arriving at pin 2 would be saved in the Timer1 register, a countdown needs to be implemented. A 1 second delay requires a million instruction cycles to achieve. The countdown would therefore be from one million to zero. The countdown was implemented as follows.

i. The hexadecimal equivalent of 1 million (0F4240h) was stored in three 8-bit general purpose registers COUNT_H, COUNT_M and COUNT_L. Register COUNT_H stored 0Fh (decimal 15) which represents the most significant byte in the binary sequence equivalent of 1 million. COUNT_M stored 42h (decimal 66) which represents the second most significant byte in the binary sequence equivalent of 1
million. COUNT_L stored 40h (decimal 64). The three general purpose registers form a virtual 24-bit register as shown if fig 3.3.

<table>
<thead>
<tr>
<th>COUNT_H</th>
<th>COUNT_M</th>
<th>COUNT_L</th>
</tr>
</thead>
<tbody>
<tr>
<td>00001111</td>
<td>01000010</td>
<td>01000000</td>
</tr>
</tbody>
</table>

![Virtual 24-bit register](image)

Figure 3.9: Virtual 24-bit register.

ii. Since Timer0 counts upwards, the value in register COUNT_L is subtracted from 256 and the result (C0h) is stored in Timer0. This means that on every increment of the Timer0 register (which occurs on every instruction cycle) a countdown from 40h will be running. On Timer0 overflow which occurs on the 256th instruction count, the first part of the countdown would have been completed.

iii. On every Timer0 overflow, the TOIF bit in the INTCON register is set. Implementation of the remaining part of the countdown is reliant on this concept. An interrupt service routine (ISR) is serviced on every TIMER0 overflow. This consists of decrementing the mid-byte register COUNT_M on every TIMER0 overflow. When the contents of COUNT_M reach zero, contents of register COUNT_H are decremented on every TIMER0 overflow. Once the contents of COUNT_H are also zero, the countdown is complete and the contents of the TIMER1 register can be read.

A bit in the COUNT_M register is 256 times greater than a corresponding bit in the COUNT_L register. A decrement of the contents of COUNT_M therefore represents 256 clock cycles or 256x10^-6 seconds. A bit in the COUNT_H register is 256 times greater than a corresponding bit in the COUNT_M register and also 65536 (256x256) times greater than a corresponding bit in the COUNT_L register. A decrement of the COUNT_H represents 65536 clock cycles or 65.536 milliseconds. Time contributions from the decrements of the contents of COUNT_H, COUNT_M and COUNT_L can be summarised as shown in figure 3.2.

Table 3.2: Time contributions.

<table>
<thead>
<tr>
<th>Register</th>
<th>Time contribution (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>COUNT_L</td>
<td>64x10^-6=0.000064</td>
</tr>
<tr>
<td>COUNT_M</td>
<td>66x256x10^-6=0.016896</td>
</tr>
<tr>
<td>COUNT_H</td>
<td>15x256x256x10^-6=0.98304</td>
</tr>
<tr>
<td></td>
<td>Total= 1 second.</td>
</tr>
</tbody>
</table>
The method applied above yields absolutely no error in the generation of a 1 second window as it gives a precise 1 second delay. The use of an interrupt driven delay also means that other procedures can run in the foreground while the countdown runs in the background.

Once the countdown expires, the contents of the 16-bit TIMER1 register are read and stored in memory. Special attention is needed in reading TMR1H and TMR1L when they are operating in asynchronous mode from an external clock. This is because as contents of TMR1L are read and stored in memory, the TIMER1 module is still incrementing on every arriving pulse. On coming back to read contents of TMR1H, TMR1L might have overflowed and therefore changed the contents of TMR1H. An overflow of TMR1L occurs on the 256th pulse count and this results in TMR1H incrementing by one. Storing this value of TMR1 does not represent the true count.

The method of dealing with this is given by Microchip where contents of TMR1L are read and stored. TMR1H is then read and stored before coming back and reading it again. The two values from the two reads are subtracted and if they are not the same, it indicates an overflow of TMR1L. If this is the case TMR1H and TMR1L are re-read and contents stored in memory. The code to implement this is shown below [1] [2] [14].

```
movf  TMR1L,w  ;read high and low bytes of TIMER1 register.
movwf TMR1_TEMP_L
movf  TMR1H,w
movwf TMR1_TEMP_H
movf  TMR1H,w
subwf    TMR1_
btfscSTATUS, Z
goto      SAVE; Contents of TMR1h and TMR1L are saved if result of subtraction is zero.
movf    TMR1H, w; Otherwise TMR1H and TMR1L are re-read
movwf   TMR1_TEMP
movf   TMR1L,
movwf TMR1_TEMP_L
```

The contents from reading of Timer1 represent the number of complete cycles made in 1 second or rotations per second. To convert this to RPM, the value is simply multiplied by 60. The RPM value is converted to BCD. The purpose of conversion to BCD is to characterize every number in the decimal equivalent of the RPM value by a four bit sequence before sending this data to the
display. For the RPM value to be displayed, its BCD equivalent is converted to ASCII before sending it to the LCD display.
CHAPTER 4: RESULTS AND DISCUSSION.

4.1 SIMULATION RESULTS

Figure 4.1: Simulation Circuit.
Fig 4.1 shows the simulation of a disc rotating at 31,800 RPM on Proteus VSM. The signal generator simulates the IR pulses arriving at the receiver diode RX.

Table 4.1: Results from simulation.

<table>
<thead>
<tr>
<th>PULSE FREQUENCY (Hz)</th>
<th>SPEED INDICATED ON DESIGN</th>
<th>IDEAL SPEED (RPM) Pulse frequency x 60</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>READ 1</td>
<td>READ 2</td>
</tr>
<tr>
<td>1</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>50</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>100</td>
<td>6000</td>
<td>6000</td>
</tr>
<tr>
<td>150</td>
<td>9000</td>
<td>9000</td>
</tr>
<tr>
<td>200</td>
<td>12000</td>
<td>12000</td>
</tr>
<tr>
<td>300</td>
<td>18000</td>
<td>18000</td>
</tr>
<tr>
<td>400</td>
<td>24000</td>
<td>24000</td>
</tr>
<tr>
<td>500</td>
<td>29440</td>
<td>30000</td>
</tr>
<tr>
<td>600</td>
<td>35940</td>
<td>36000</td>
</tr>
<tr>
<td>700</td>
<td>41940</td>
<td>42000</td>
</tr>
<tr>
<td>850</td>
<td>50940</td>
<td>51000</td>
</tr>
<tr>
<td>950</td>
<td>56940</td>
<td>56940</td>
</tr>
<tr>
<td>1000</td>
<td>59940</td>
<td>59940</td>
</tr>
<tr>
<td>1050</td>
<td>62940</td>
<td>62940</td>
</tr>
</tbody>
</table>

Simulated results indicate an introduction of an error in readings as the speed of the rotating device increases. This is first noted at a pulse frequency of 500 Hz or 30,000 rpm.

4.2 PRACTICAL RESULTS
Two computer fans of different ratings were chosen and their speeds at different input voltages compared against a standard issue tachometer kindly provided by the machines lab. Details of the two machines and the tachometer are:
Table 4.2: Test Machine details.

<table>
<thead>
<tr>
<th>Machine (Fans)</th>
<th>Manufacturer</th>
<th>Model</th>
<th>Rating dc</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>CHERRY KING</td>
<td>Model-YB8025SM</td>
<td>12V-0.14 Amps</td>
</tr>
<tr>
<td>II</td>
<td>SHENZHEN FU YU HONG SCIENCE TECHNOLOGY Co. LTD</td>
<td>---------------------</td>
<td>24V, 0.40Amps</td>
</tr>
</tbody>
</table>

Details of the tachometer are:

Table 4.3: Tachometer details.

<table>
<thead>
<tr>
<th>Model</th>
<th>Serial number</th>
<th>Range (RPM)</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>DT-2234A+</td>
<td>S908614</td>
<td>0.1-99,999</td>
<td>0.1 rpm for speeds in the range 0.1 rpm-999.9 rpm.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1rpm for the range of 1,000 rpm-99,999 rpm.</td>
</tr>
</tbody>
</table>

Table 4.4: Results from machine I and Tachometer.

<table>
<thead>
<tr>
<th>Designed device.</th>
<th>Laboratory Tachometer.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read1 (RPM)</td>
<td>Read2 (RPM)</td>
</tr>
<tr>
<td>960</td>
<td>960</td>
</tr>
<tr>
<td>1380</td>
<td>1440</td>
</tr>
<tr>
<td>1860</td>
<td>1860</td>
</tr>
<tr>
<td>2340</td>
<td>2340</td>
</tr>
<tr>
<td>2700</td>
<td>2700</td>
</tr>
<tr>
<td>3540</td>
<td>3540</td>
</tr>
</tbody>
</table>
Table 4.5: Results from machine II and Tachometer.

<table>
<thead>
<tr>
<th>Speed (RPM)</th>
<th>Designed Device</th>
<th>Laboratory Tachometer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read1 (RPM)</td>
<td>Read2 (RPM)</td>
<td>Average (RPM)</td>
</tr>
<tr>
<td>660</td>
<td>720</td>
<td><strong>690</strong></td>
</tr>
<tr>
<td>900</td>
<td>960</td>
<td><strong>930</strong></td>
</tr>
<tr>
<td>1200</td>
<td>1200</td>
<td><strong>1200</strong></td>
</tr>
<tr>
<td>1380</td>
<td>1440</td>
<td><strong>1410</strong></td>
</tr>
<tr>
<td>1920</td>
<td>1980</td>
<td><strong>1950</strong></td>
</tr>
</tbody>
</table>

SPEED (RPM)

![Figure 4.2: Plot of average RPM values obtained by designed device and standard tachometer for various readings. Results are from machine I.](image-url)

25
Figure 4.3: Plot of average RPM values obtained by designed device and standard tachometer for various readings. Results are from machine II.
Figure 4.4: Display of 2400 rpm on LCD display.
CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION
A microcontroller based disc rotational speed measurement system was successfully designed and implemented.

Table 5.1: Device specifications.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>0-65,535 rpm.</td>
</tr>
<tr>
<td>Working distance</td>
<td>5mm-100mm.</td>
</tr>
<tr>
<td>Resolution</td>
<td>60 rpm.</td>
</tr>
<tr>
<td>Detection technique</td>
<td>Reflective method.</td>
</tr>
</tbody>
</table>

5.2 RECOMMENDATIONS
i) The transmitter-receiver pair that comprised of IR diodes suffered from slight interference from direct and indirect ambient light sources and sunlight. To prevent this, the diodes were covered by a black surface. It is recommended however that sensors that suffer much less interference from sources of ambient lighting and sunlight be used.

ii) The design offered a resolution of 60 rpm. This resolution can easily be improved by attaching more than one reflector strip on the rotating surface. This increases the number of pulses generated per revolution where the resolution will be improved by a factor of 60/number of reflector strips. Where the number of reflector strips indicate the PPR.

iii) Memory can be added to the device. This would allow for a set or readings to be taken continuously to be recorded later simply by inspecting memory contents of the device.
APPENDIX

Appendix 1-code for microcontroller

radix hex
include "P16F690.INC"
__config _CP_OFF & _WDT_ON & _BOR_ON & _PWRT_ON
& _INTRC_OSC_NOCLKOUT & _MCLRE_ON
errorlevel-302;

; Code protection OFF.
; Watch-dog timer ON.
; Brown out detect ON.
; Power up timer ON.
; Internal oscillator selected.
; Master clear ON.

;==================================================================
;Variable stored in general purpose register starting from memory location 0x20
;==================================================================
COUNTH
    COUNTM
    COUNTL
    TEN_THOUSANDS
    THOUSANDS
    HUNDREDS
    TENS
    ONES
    BINARYH
    BINARYL
    COUNT1
    COUNT2
    TEMP
    COUNTER1
    TIMER1
OLD_WORKING_REG
    OLD_STATUS
    TMR1_TEMP_H
    TMR1_TEMP_L
    COUNT3
    COUNT_60
    TMR1_TEMP_BUFFER_H
    TMR1_TEMP_BUFFER_L

ENDC
STATUS equ 0x03
PORTA equ 0x05
PORTB equ 0x06
PORTC equ 0x07
TRISB equ 0x86
TRISC equ 0x87
RS equ 0x06
E equ 0x07
TOIF equ 0x02
GIE equ 0x07
RP0 equ 0x05
T1CON equ 0x10
INTCON equ 0x0B
OPTION_REG equ 0x81
TMR1H equ 0x0F
TMR1L equ 0x0E

org 0x0000 ; Program storage starting at address 0x0000 in program memory
goto MAIN

org 0x004

Interrupt_Service:
btfss INTCON,TOIF ; Test if interrupt is due to TMR0 overflow
goto NOT_TOIF ; NO

;=====================================================================================================
; TOIF bit of INTCON register cleared to allow for the next overflow of TMR0 to be detected.;
movwf OLD_WORKING_REG
swapf STATUS,w
movwf OLD_STATUS
;=====================================================================================================
; Contents of working and STATUS registers saved to be recovered once ISR is executed.

movlw 0x00
addwf COUNTM,F
btfss STATUS, Z
decf COUNTM,F
btfss STATUS, Z
goto EXIT_ISR
decfsz COUNT3,F
goto EXIT_ISR
decfsz COUNTTH,F

30
goto EXIT_ISR

crlfSTATUS ;Select bank0 to access TMR1H & TMR1L

movfTMR1L,w ;read high and low bytes of TIMER1 reg.
movwf TMR1_TEMP_L
movfTMR1H,w
movwf TMR1_TEMP_H

movfTMR1H,w
subwfTMR1_TEMP_H,w
btfscSTATUS,Z
gotoSAVE
movfTMR1H,w
movwf TMR1_TEMP_H
movfTMR1L,w
movwf TMR1_TEMP_L

;MULTIPLICATION
BY 60 FOR CONVERSION TO RPM

SAVE: movf TMR1_TEMP_H,w
movwf TMR1_TEMP_BUFFER_H
movfTMR1_TEMP_L,w
movwf TMR1_TEMP_BUFFER_L
MULTIPLY:
movfTMR1_TEMP_BUFFER_L,w
addwfTMR1_TEMP_L,F
btfscSTATUS,C
incfTMR1_TEMP_H,F
movfTMR1_TEMP_BUFFER_H,w
addwfTMR1_TEMP_H,F
decfszCOUNT_60,F
gotoMULTIPLY
movlw0x3B
movwfCOUNT_60

callONE_SEC_DELAY
movlw0xFF
movwfCOUNT3
crlfTMR1H
crlfTMR1H
crlfTMR1_TEMP_BUFFER_H
crlfTMR1_TEMP_BUFFER_L

EXIT_ISR:
swapf OLD_STATUS, w
movwf STATUS
swapf OLD_WORKING_REG, F
swapf OLD_WORKING_REG, w

NOT_TOIF:
retfie

; Program Counter is loaded with address 004 when an interrupt occurs and GIE bit of INTCON register is cleared to disable interrupts. It is automatically set by the RETFIE instruction so as to service pending interrupts.

MAIN:
clf STATUS ; Bank0 selected
clf TMR1L
clf TMR1H
clf PORTA
clf PORTB
clf PORTC
clf TEN_THOUSANDS
clf THOUSANDS
clf HUNDREDS
clf TENS
clf ONES
clf BINARYH
clf BINARYL
clf TMR1_TEMP_H
clf TMR1_TEMP_H
clf TEMP
clf TMR1_TEMP_BUFFER_H
clf TMR1_TEMP_BUFFER_L
clf STATUS
clf TMR0

movlw b'10100000'
movwf INTCON
movlw b'00000111' ; TMR1 set as asynchronous counter increment on every rising edge.
movwf T1CON
bsf STATUS, RP0 ; Move to bank1
movlw b'00100000'
movwf TRISA ; Pin5 of PORTA for input
movlw b'11001000'
movwf OPTION_REG
clr TRISB ; PORTB set for outputs
clr TRISC ; PORTC set for outputs
movlw0x08
    movwf COUNT1 ;counter will decrement from 8 to 0
movlw0x02
    movwf COUNT2 ;counter will decrement from 2 to 0
movlw0xFF     ;255
movwf COUNT3
movlw0x3B     ;59
movwf COUNT_60

;=======================================================
              ;L
CD SET_UP

;=======================================================
clrf STATUS;BANK0 selected
movlw 0X14
call Xms ;20ms time delay allows LCD to complete initialisation process.
movlw 0x01 ;Display clear command
call instw
movlw 0x38
call instw;LCD set for 8-bit, 2-Line,5x8 dot matrix display.
movlw 0x0c
call instw ;Display on,Cursor off, no Blinking.
movlw 0x04
call instw ;
            ;====================================================================
            ;DDRAM address incremented by 1, no Cursor shift, no display shift
            ;====================================================================
movlw 0x01
call instw;Display cleared,DDRAM address=0
movlw 0x80
call instw ;DDRAM address set to 0

;WELCOME message sent to screen
movlw 0x57 ;'W'
call dataw
movlw 0x45 ;'E'
call dataw
movlw 0x4C ;'L'
call dataw
movlw 0x43 ;
call dataw
movlw 0x4F ;'O'
call dataw
movlw 0x4D ;'M'
call dataw
movlw 0x45 ;'E'

33
calldata

calldelay ;Delay allows for message to be seen on screen
calldelay
call RPM_to_DISPLAY
callONE_SEC_DELAY

;====================================================================;
16-bit binary sequence held in TMR1 register is converted to binary coded decimal before
display to ;LCD
;====================================================================

START_CONVERSION:
movfTMR1_TEMP_H,w
movwf  BINARYH
movfTMR1_TEMP_L,w
movwfBINARYL

;==================================================================
;Test for whether 16-bit binary sequence is equal to zero
;

CONVERSION:
clr  STATUS
rlf  BINARYH,F ;Pass MSB ofBINARYH to ONES register
    rlf  ONES,F ;Carry bit acts as a carrier

;====================================================================
;Test of 5th bit of ONES Register to move overflow bit to TENS nibble
;====================================================================
    btfss  ONES,0x04
    goto   ZERO_TO_TENS
    bsf  STATUS,C
    rlf  TENS,F ;One is passed into LSB of TENS
    goto   ONES_CARRY_COMPLETE

;======================================
;=====================================;
;
ZERO_TO_TENS:
    bcf  STATUS,C
    rlf  TENS,F ;Zero is passed into LSB of TENS

ONES_CARRY_COMPLETE:
    bcf  ONES,0x04

;================================================================================

;Test bit 5 ofTENS register
;
    btfss  TENS,0x04
    goto   ZERO_TO_HUNDREDS

34
bsf STATUS,C
rlf HUNDREDS,F ;One is passed into LSB of HUNDREDS
goto TENS_CARRY_COMPLETE

ZERO_TO_HUNDREDS:
  bcf STATUS,C
  rlf HUNDREDS,F ;Zero is passed into LSB of HUNDREDS

TENS_CARRY_COMPLETE:
  bcf TENS,0x04
  btfss HUNDREDS,0x04
  goto ZERO_TO_THOUSANDS
  bsf STATUS,C
  rlf THOUSANDS,F ;One is passed into LSB of THOUSANDS
  goto HUNDREDS_CARRY_COMPLETE

ZERO_TO_THOUSANDS:
  bcf STATUS,C
  rlf THOUSANDS,F ;Zero is passed into LSB of THOUSANDS

HUNDREDS_CARRY_COMPLETE:
  bcf HUNDREDS,0x04
  btfss THOUSANDS,0x04
  goto ZERO_TO_TEN_THOUSANDS
  bsf STATUS,C
  rlf TEN_THOUSANDS,F ;One is passed into LSB of TEN_THOUSANDS
  goto THOUSANDS_CARRY_COMPLETE

ZERO_TO_TEN_THOUSANDS:
  bcf STATUS,C
  rlf TEN_THOUSANDS,F ;Zero is passed into LSB of TEN_THOUSANDS

THOUSANDS_CARRY_COMPLETE:
  bcf THOUSANDS,0x04
  btfss COUNT2,0 ;Test for completion of conversion from binary to bcd.
goto CONTINUE ;This prevents going through CONTINUE again which will
  movf COUNT1,w ;introduce an error to the final value
  sublw 0x01
  btfsc STATUS,Z
  goto AFTER_ADDITION_TO_THOUSANDS
CONTINUE:

; Check if ONES nibble is equal to or greater than 5
movf ONES, w
movwf TEMP
movlw 0x05
subwf TEMP, F
btfss STATUS, C
goto AFTER_ADDITION_TO_ONES
movf ONES, w
addlw 0x03
movwf ONES

; Check if Tens nibble is equal to or greater than 5
AFTER_ADDITION_TO_ONES:
movf TENS, w
movwf TEMP
movlw 0x05
subwf TEMP, F
btfss STATUS, C
goto AFTER_ADDITION_TO_TENS
movf TENS, w
addlw 0x03
movwf TENS

; Check if Hundreds nibble is greater than 5
AFTER_ADDITION_TO_TENS:
movf HUNDREDS, w
movwf TEMP
movlw 0x05
subwf TEMP, F
btfss STATUS, C
goto AFTER_ADDITION_TO_HUNDREDS
movf HUNDREDS, w
addlw 0x03
movwf HUNDREDS

; Check if Thousands nibble is greater than 5
AFTER_ADDITION_TO_HUNDREDS:
movf THOUSANDS, w
movwf TEMP
movlw 0x05
subwf TEMP,F
btfss STATUS,C
goto AFTER_ADDITION_TO_THOUSANDS
movf THOUSANDS,w
addlw 0x03
movwf THOUSANDS

AFTER_ADDITION_TO_THOUSANDS:
decfsz COUNT1,F
goto CONVERSION
decf COUNT2,F
btfsc STATUS,Z
goto END_CONVERSION
movlw 0x08
movwf COUNT1
movf BINARYL,w
movwf BINARYH

goto CONVERSION

;=====================================================================
;RPM value is sent to LCD after conversion is complete
;=====================================================================
RESULT_ZERO:
clrf TEN_THOUSANDS
clrf THOUSANDS
clrf HUNDREDS
clrf TENS
clrf ONES

END_CONVERSION:
movlw 0x30
addwf TEN_THOUSANDS,F
addwf THOUSANDS,F
addwf HUNDREDS,F
addwf TENS,F
addwf ONES,F
movlw 0x84 ;RPM written to LCD starting from address 0x04 in DDRAM
call instw

movf TEN_THOUSANDS,w
call dataw
movf THOUSANDS,w
call dataw
movf HUNDREDS,w
call dataw
movf TENS,w
call    dataw
movf  ONES,w
call    dataw

clrf    TEN_THOUSANDS
clrf    THOUSANDS
clrf    HUNDREDS
clrf    TENS
clrf    ONES

movlw   0x08
movwf   COUNT1
movlw   0x02
movwf   COUNT2

goto    START_CONVERSION

;========================================================
;SUBROUTINES
;========================================================

RPM_to_DISPLAY
movlw   0x01
call    instw ;Clear display and load DDRAM address counter with 0 for Home address

movlw   0x52  ;'R'
call    dataw
movlw   0x50  ;'P'
call    dataw
movlw   0x4D  ;'M'
call    dataw
movlw   0x3A  ;':'
call    dataw
return

ONE_SEC_DELAY:
    movlw   0x0F
    movwf   COUNTH
    movlw   0x42
    movwf   COUNTM
    clrf    STATUS
movlw   0xC0
movwf   TMR0
return

instw:
    movwf   PORTC
    bcf     PORTB,RS
    bsf     PORTB,E
bcf PORTB,E
    call delay10ms
    return

dataw:
    movwf PORTC
    bsf PORTB,RS
    bsf PORTB,E
    bcf PORTB,E
    call delay10ms
    return

One_ms:
    movlw 0XF9
    movwf TIMER1
    LOOP1:
        NOP
        decfsz TIMER1,F
        goto LOOP1
    return

Xms:
    movwf TIMERX
    LOOPX:
        call One_ms
        decfsz TIMERX,F
        goto LOOPX
    return

delay10ms:
    movlw 0X0A
    call Xms
    return

delay:
    movlw 0XFA
    call Xms
    return
END
REFERENCES


