DEVELOPMENT OF AUTOGREASE ELECTRIC MOTOR'S BEARING SYSTEM

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"I hereby acknowledge that the scope and quality of this thesis is qualify for the award of the Bachelor Degree of Electrical Engineering (Power Systems)"

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Dedicated to my beloved wife, parents, supervisor, lecturers, siblings and friends
for giving a constant source of support and encouragement.

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ABSTRACT

Even with an advancement of technologies, most of industries are still using manual greasing method in maintaining the electric motor’s performance. Even though it has helped to maintain the motors performance, yet it presents associated problems such that difficulties in maintaining the regreasing time interval and regreasing volume as well as reaching motor in an inaccess area. These motivating factors lead this project to develop automatic grease system in order to extend bearing lifetime without danger the maintenance technician; it also will increase electric motor performance. This project focuses on developing a system that capable to automate greasing an electrical motor according to required specification or preventive and maintenance plan.

ABSTRAK

Di era teknologi yang berkembang dengan pesat ini, kebanyakkan industri masih menggunakan teknik gris secara manual ketika melakukan kerja-kerja penyelenggaraan pada motor elektrik. Teknik ini memberi kesan yang baik terhadap prestasi motor tersebut namun, ia mengundang beberapa permasalahan seperti permasalahan mengenalpasti sela masa untuk melakukan penyelanggaraan, permasalahan mengenalpasti isipadu gris yang optimum dan permasalahan untuk melakukan penyelenggaraan di tempat yang sukar dan merbahaya. Faktor-faktor ini mendorong kepada projek membina sistem yang mampu untuk melakukan kerja-kerja penyelanggaraan gris pada motor elektrik tanpa membahayakan penyelenggara dan juga mampu meningkatkan prestasi motor elektrik tersebut. Projek ini akan tertumpu kepada pembinaan system gris secara automatik berdasarkan spesifikasi yang telah ditetapkan.

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CHAPTER 1

INTRODUCTION

1.1. Overview

Electric motor was used widely in industry[1]. Some of them were running 24 hours for many days. Therefore, the performance of the electric motor is very important to ensure the production target achieved. Furthermore, the top performance of the electric motor will save the money from expend it to the utility bill for running more hours. One of the important components inside the electric motor is the bearing. It can be said that the performance of the electric motor also depend on the condition of their bearings [2,3].

The bearing is normally installed to ensure the shaft rotate smoothly without any obstacle [4]. Also, the bearing will avoid the shaft and the other related component from breaking. One of the factors that really related to the bearing performance is the greasing of the bearing. Greasing is the liquid that applied in the bearing surface which touch with the end bell (end shield). This greasing will protect the bearing from overheating which can affect the bearing damage [5,6,7].

Currently, the method of bearing greasing is done in many ways. Either using really manual which need to open the end bell and applied the grease by hand to the bearing or using grease gun which the grease will inject to the bearing via grease nipple. However, it has several problems associated to this current method of greasing.

Through this project, it will help the technician who did the greasing job. The goal of this project is to develop a system which can make the greasing job done automatically without danger to the technician and also to ensure the bearing is always in good condition.

1.2. Problem Statements

Most industry even in advance electronic gadget days, yet still use manual lubrication to relubricate industrial electric motors operating in plants. This method is applied because of cheap in operation which only need to buy grease gun. Furthermore, auto grease application is still new and not very well-known in our country especially. The usage of manual regreasing method has been foreseen as significant drawback which can affect bearing damage and will influence reducing overall electric motor performance. There are few reported associated problems regarding to this method which are; regrease interval, amount of grease and safety.

Regrease interval is one of most important thing that maintenance person need to stress[3]. If the interval is too long then the bearing will wear and damage but if the interval is too short, it will make waste of grease because the grease applied still can be used. In manual greasing, the maintenance person will determine regrease interval either by waiting for a weird sound or by referring to data given by supplier[8]. However, the data given is by referring to high efficiency motor or a new motor and this is not practical for an old motor that have been used for many years and do not gain high efficiency.

Amount of grease applied to the bearing can be divided to three conditions; overgrease, optimum and less grease. In manual lubrication, maintenance person usually will apply the grease as much as he can to the bearing and it will cause overgrease. Overgrease will affect the pressure and temperature inside the bearing increase [9]. But, if too small amount of grease applied, less grease will happen which will make friction increase, temperature of the bearing increase, noise and bearing wear [3]. The optimum amount of grease is the best volume that will maintain the top performance of bearing.

Not all electric motor was placed at accessible place. In some cases, electric motor was placed at inaccessible place such as at the higher place or also in hazardous place. This will danger to the maintenance person [10].

1.3. Objectives

The aim of this project is to develop automatic greasing system for electric motor’s bearing. The objectives of the project are:

I. Identify the problems in current greasing method.
II. To investigate the best method of regreasing.
III. To develop an automatic greasing system for electric motor’s bearing.

1.4. Scope of Project

The scopes of this project are:

1. Identifying the current method of electric motor bearing greasing and its associated problems.
2. Hardware development
    a. To develop greasing method which operate automatically.
    b. To install autogreasing system to three phase induction motor.
3. Software development
    a. To make a controller circuit by using temperature sensor.
    b. To create the feedback for the current bearing condition.
4. Integration stage
    a. To integrate hardware and software to be one complete system.

1.5. Chapter Outline

This thesis consists of five chapters. The content of each chapter can be outlined as follows:

Chapter 1 presents the aim, objective of the project, problem statements and scope of the project. This chapter shows the problem associated with the current greasing method which becomes a motivating factor to do this project.

Chapter 2 provides a literature review, previous research done by other researchers in the related area and relevant issues related to bearing greasing. These include a review on the importance of electric motor's bearing greasing job. There are also discussed about the associated problem regarding current greasing method which will cover one of the project objectives.

Chapter 3 describes a broad description of the methodology in this project. These chapters begin with discussing about bearing temperature as a feedback for this system, the advantages of using LM35. Also discussed in this chapter is the grease tank design. Grease tank is one of major parts in this project and need to design properly. Therefore, this subchapter will briefly discuss about several design to be considered as final design for this system. Furthermore, this chapter describes the methodology on software development. It is discussed about circuit design as well as programming for this system. At the end of this chapter shows the integration stage of this project which integrates software and hardware part.

Chapter 4 presents the analysis from the experiment done. The experiment has been done is about LM35 accuracy, bearing temperature increase, reliability of the system and amount of grease. This analysis of the experiment has been noted in this chapter and it is important to justify this system is reliable or not.

Chapter 5 provides a general conclusion for this thesis. Also added in this chapter is future recommendation to improve this system, the cost of this project and the potential for commercialization.

1.6. Summary

This section introduces the overall project and explains the objectives and also the scope of the project in order to give general overview of the project. In the next chapter will review on previous research that is related to the current work which concern to current greasing method and its associated problem.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter will review on previous research which concern to the importance of electric motor bearing greasing job, current method of the greasing and its associated problem. There are several factors which can stress about the important of doing greasing job properly.

2.2 Electric Motor Losses

Electrical motor was used widely in industries including Malaysia. In most application especially in heavy industries, the motor was running for many hours. For example, in steel mills industries, the motor was used widely and was never stop until the production target achieve. These cases need the motor to be in good condition without any breakdown. Also need to consider when motor was running for many hours is their efficiency. To gain full efficiency of motor, motor losses must be avoid. The five components of motor losses are [9]:

1. Primary I^2r
2. Iron
3. Secondary I^2r
4. Friction and windage
5. Stray load

The friction and windage losses are those associated with rotation and subtract from the net power delivered to the load. Additional windage loss is created by the rotor fan blades which circulate air within the motor and of course there is some friction loss in bearings [9]. Figure 1 shows the motor percentage failure distribution according to [10]. The biggest percentage of failure is related to bearings damage [11].

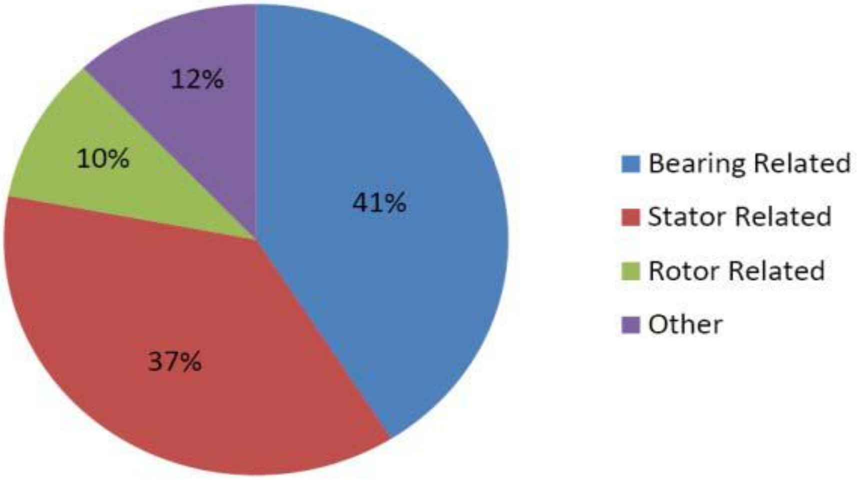

Figure 2.1 Motor percentage failure by component[11]

Reducing friction in bearings is often important for efficiency, to reduce wear and to facilitate extended use at high speeds and to avoid overheating and premature failure of the bearing. Essentially, a bearing can reduce friction by virtue of its shape, by its material, by introducing and containing fluid between surfaces or by separating the surfaces with an electromagnetic field [9].

2.3 The Needs for Bearing Greasing

This method was known as lubricant or greasing. However, greasing is not as simple way to reduce friction. The volume of grease applied to the bearing should be optimum and not more than specified volume. Over grease will happen if the greasing process use too lot of grease. The problem of overgrease electric motor was first identified in the nuclear power industry in 1988. Several motor and bearing failures occurred at various nuclear power plants due to excessive grease addition [10].

In some cases, over greasing may causing grease to pass through the rolling elements and between the air gap between the inner bearing cap and the shaft into the winding. This led to windings and insulation becoming covered with grease, which led to motor failure or degraded operations [11].

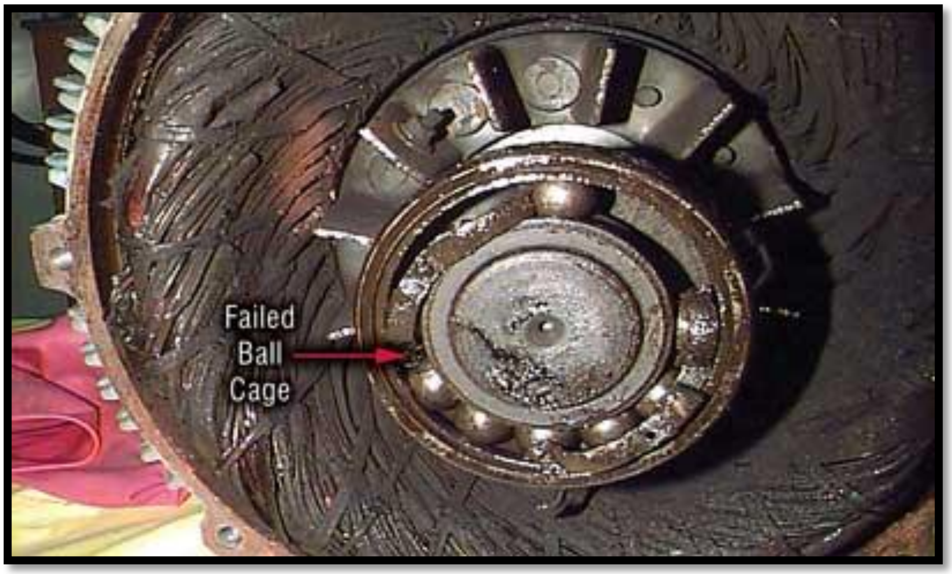

Figure 2.2 Example of a bearing failure[9]

Figure 2.3 A ball cage failures due to the bearing shield[9]

Figure 2.3 shows the bearing experienced a ball cage failure due to the bearing shield being pushed down on the ball cage due to over pressurization of the grease cavity. Regreasing can be done when the factors that may need regreasing occur. Some factor that influences regrease frequency including:

1. Temperature
2. Continuity of service
3. Quantity of grease in housing
4. Size and speed of bearing
5. Vibration
6. Exposure to contaminants
7. Effectiveness of seals
8. Suitable grease for the particular service

High temperatures increase the rate of bleeding and evaporation of the oil. Grease tends to soften as temperature increase and may become fluid enough to leak the housing. Operating at high temperatures will require more frequent regreasing. Running motor for many hours per day will need replacement or regreasing too. More frequent relubrication usually will be required if the grease is marginal in any major characteristic such as oxidation, bleeding, pump ability, antiwear and antirust properties or mechanical stability. However, it is not simple to decide when and how frequent need to regrease. This decision usually need an experience and the machine builder's and grease supplier's recommendations. It is very important to regrease on an appropriate schedule so that the old grease remains soft enough for purging [9].

Another scenario which happens in real industry world is the electric motor was placed at the inaccess area. For example, the location of the electric motor is at the high place or in a danger area. This may danger the person who did the greasing job. Instead of transfer the electric motor to another place which maybe can interrupt the operation, it is better to create a system which is the greasing job is done not by a man.

2.4 Bearing Temperature

The bearing temperature may detect the bearing failure if it is designed properly[8]. To measure the bearing temperature, there will be several method may use. According to Bharat Maru and Peter A. Zotos in their report title “Anti friction bearing temperature rise for NEMA frame motors”, the temperature sensor may be used to measure the bearing temperature[13]. However, it must be placed very closely to the bearing housing or else, the temperature reading might be the motor temperature itself.

In industry, the bearing which most commonly used in AC motor is single row, deep grove (Conrad) type bearings. This bearing can operate until 121˚C and sometimes can be up to 176˚C [13]. It means that, if the bearing temperature is more than 121 ˚C, the bearing may damage. The factor may lead to this problem are:

1. Winding temperature rise
2. Motor operating speed
3. Temperature distribution within the motor
4. Oil viscosity of the grease
5. Amount of grease in the bearing cavity

In other literature review indicates that, bearing temperature is increased due generation of heat during bearing rotation[14]. This project will highlight the point where the amount of grease in the bearing can influence the bearing temperature. This also will influence the bearing condition. In other words, amount of grease may affect to the bearing condition. The less grease in the bearing could lead to the bearing damage.

2.5 Bearing Grease

Grease lubrication should be used when the bearing operates under normal speeds and temperatures. Grease has several advantages over oil, including simpler and less expensive application procedures, better adhesion and improved protection against moisture and contaminants [15].

Grease selection varies with the application. Factors to consider include hardness (consistency), stability (ability to retain consistency) and water resistance (emulsification). However, grease is oil suspended in a base or carrier, and when these bases are exposed to moisture or heat, they can turn into soap or carbon ash. Therefore, it may be necessary to use synthetic additives to prevent deterioration of the base. Overfilling may cause a rapid rise in temperature, particularly at high speeds because the rolling elements have to push the grease out of the way. This leads to churning in the grease, which produces heat. Adding more grease only worsens the problem, adding the risk of blowing out a seal. Bearings operating at slow speeds, and those requiring corrosion protections, can have their housing completely full of grease. The length of time that a grease-lubricated bearing will operate satisfactorily without relubrication depends on bearing size, type, speed, operating temperature and the grease used.

2.6 Amount of Grease

One of the more important and frequently botched components of the greasing strategy is amount of grease applied to the bearing. Usually, in conventional method, they will apply as much as he can to the bearing. This is obviously not a precise method. There are many acceptable methods for estimating the appropriate relubrication volume. One of method can be used is using mathematical equation below [16].

$$G_p = 0.005 \times D \times B$$

Where,

G_p = grease replenishment amount (gm)

D = bearing outside diameter (mm)

B = total bearing width (mm)

This method generally provides positive results, but does not always take every factor into consideration. For example, it does not account for differences in bearing housings and application points. Instead, it assumes the grease is added at the optimum location. Also, it is not always possible to know the amount and condition of old grease in the housing at the time of reapplication. For these reasons, it may be advantageous to modify the calculated values with a condition-based approach. The most advanced condition-based technique is ultrasonic instrumentation, which optimizes the relubrication volume. By establishing a baseline value and determining a statistically appropriate limit, the volume of grease added can be optimized. It is the opinion of the author that this hybrid approach is the best method for arriving at the optimum relubrication volume rather than relying on calculated values or instrument feedback.

2.7 Summary

Literature review has been presented in terms of different aspect. The important point in this chapter is the stress about the important of greasing job. Furthermore, this chapter has covered one of the objectives for this project which is to identify the current greasing method and its associated problem.

CHAPTER 3

METHODOLOGY

3.1 Overview

The scope of this chapter is to provide further details of methodology and approach in completing this project. This chapter will discuss in detail about how the project is done. For this project, the three phase induction motor was used to install the autogreasing system. This is because according to M. J. Devaney and L. Eren in their journal title Detecting Motor Bearing Fault, more than 90% of all motor used in industry in the world is AC induction motor [17]. This project consists of four main parts which is background study, software development, hardware development and lastly integration of software and hardware. All the studies will benefit to compare manual greasing and autogrease. Software development will cover programming of regrease interval.

3.2 Bearing Temperature As a Feedback

To determine when the regreasing needs to be done, feedback need to use here. There are several method can be used such as by monitoring noise, number of revolution, vibrate analysis, pressure and temperature [18]. Most application was use number of revolution and pressure as their feedback. By using number of revolution, the greasing will start grease when bearing rotation was equal to the number that has been set. The set number is according to the data from supplier that only practical to the new motor. This method was really not practical to use for old motor. Pressure feedback commonly use for mechanical autogrease. The grease inside bearing has specific pressure and when the pressure inside bearing was decrease then it indicates that the bearing should regrease. For this project, temperature will be use as a feedback. According to Exxonmobil, monitoring increasing temperature is the best way to indicate when regreasing need to be done. However, the increasing of temperature is not only because of grease problem but it also because of poor motor ventilating, excessive loading on the device the motor drives, broken motor rotor bar, single phasing on three phase induction motor, loose bearing fit on the motor shaft, bearing failing, poor coupling condition, poor shaft alignment between the motor and the driven unit and poor motor mounting[19,20]. The specific temperature will just determine after selecting electric motor that will be used in this project.

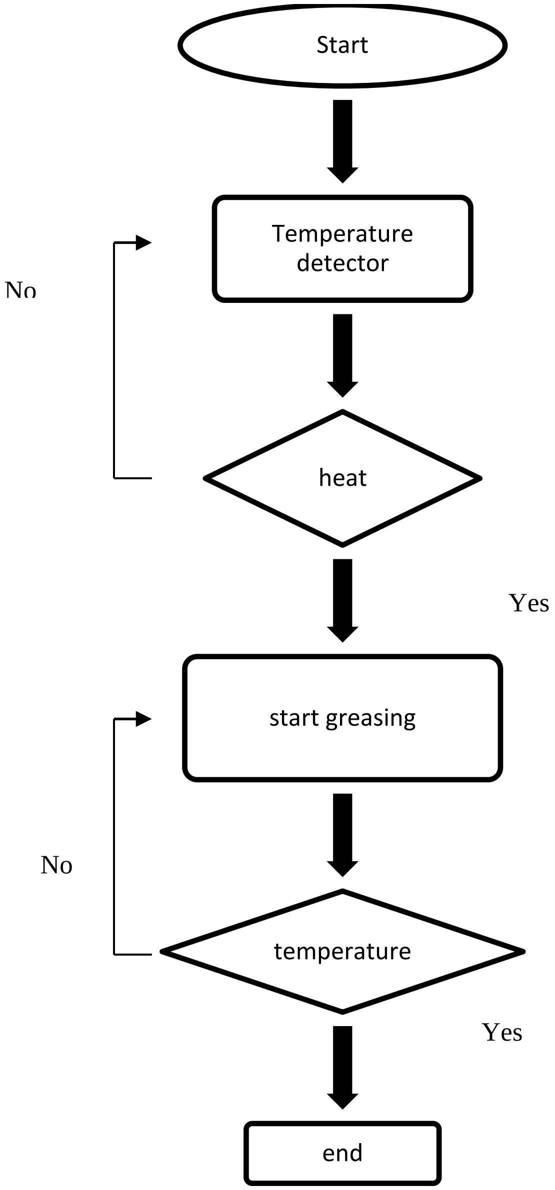

Figure 3.1 The system flowchart

3.3 Hardware Design

For hardware development, it is focusing on how the grease will transfer to the bearing. To do a further action, the design for the whole hardware system is designed. When design the hardware part, it is important to consider is how to store the grease effectively and how the grease will flow when greasing is needed. There are three designs for grease tank that has been considered for the first time.

3.3.1 Design 1

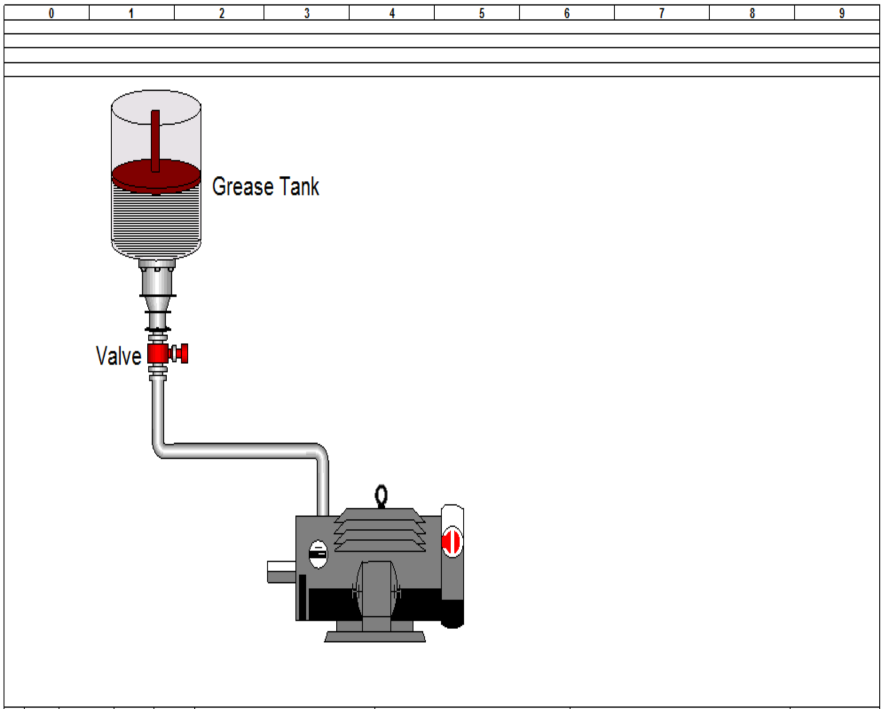

Figure 3.2 Hardware Design 1

For this design, the grease tank was control by using pipe head as shown in figure below.

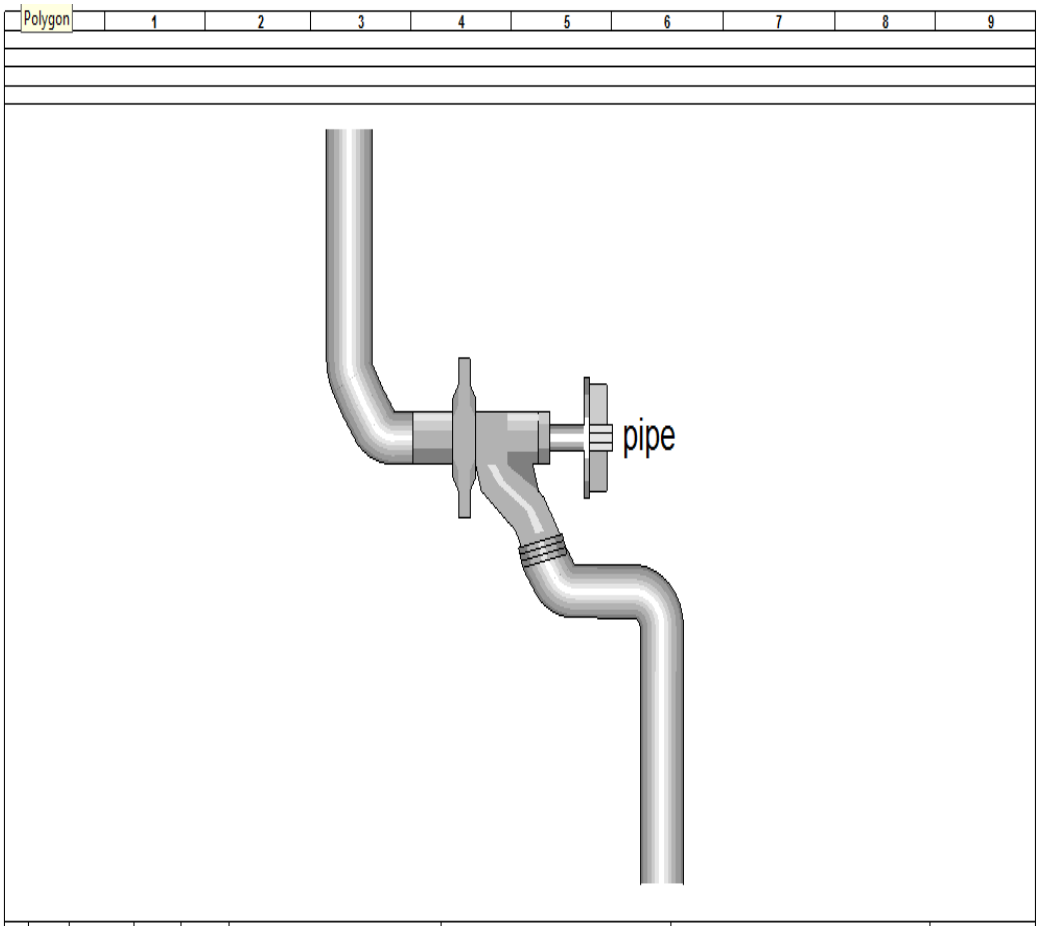

Figure 3.3 Valve Design for Hardware Design 1

The head pipe which can get from normal hardware shop, with a little bit modification may use to be a valve for this system. The valve for this design will act as controller for greasing. It means, when the greasing are needed, and then the pipe will open. For automated opening valve, small DC motor may attach to the head pipe so that when the greasing is needed, the DC motor will switch on to open the valve. Same procedure may use for closing the valve.

The advantage for this design is, easy to find the head pipe as well as tube use. But, the weakness for this design is the grease will not flowing just like water through the valve. The grease thickness is high, so the system needs to have something to push the grease to flow. This point was really important in order to transfer the grease to the bearing.

3.3.2 Design 2

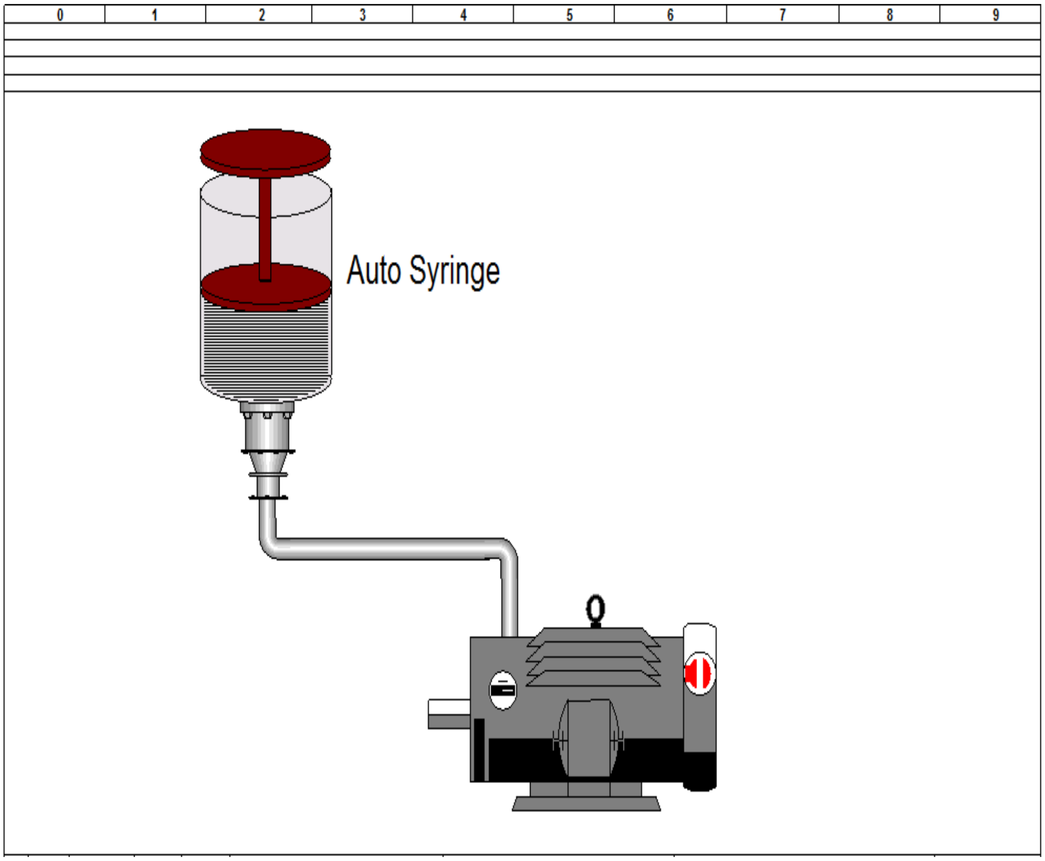

Figure 3.4 Hardware Design 2

Design 2 is the improvement from the design 1. In the design 1, it was used valve as a controller to allow the grease flowing to the bearing. However, the grease will not flowing just like that due to the higher thickness of the grease. Therefore, the design 2 was design to counter this problem.

For this design, it is use auto syringe to force the grease down. In other words, the auto syringe will act as a controller to allow grease flow. In this case, there doesn't need valve anymore. This is because the higher thickness of grease which will hold the grease from flowing. Therefore, the valve was removed from the design.

The operation of this system is auto syringe will turn on when the grease is needed. It will force the grease to flow through tube and next will transfer to the bearing. This system is considered as a better from design 1 but, it is difficult to get the auto syringe. Furthermore, the auto syringe which normally used in medical industry is too expensive to buy. In this case, design 2 also not really ideal for this system.

3.3.3 Design 3

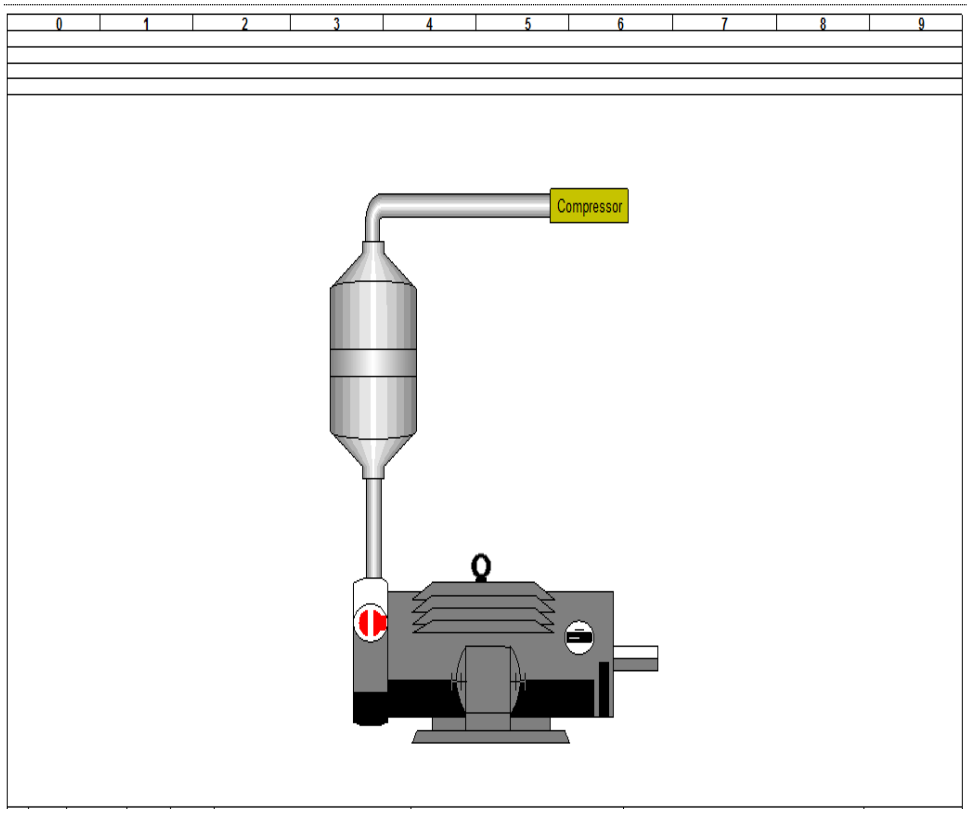

Figure 3.5 Hardware Design 3

Third design is a last option to develop the hardware part as well as control part. In this design, it will replace the auto syringe with compressor. This compressor was design to force the grease to flow to the bearing via tube.

The compressor may be used in this design is the 12Vdc compressor. The compressor will compress the air with high pressure and when the grease is needed, it will force the grease to flow. The controller circuit that may be used here is PIC circuit. The PIC circuit will attached to this design to complete the system.

This design is the best design to be used in this project due to the cost of compressor and easy to get the compressor. Therefore, this design; **DESIGN 3** will be used in this system.

3.4 Hardware Development

As shown in previous subtopic, the third design has been chosen to be the final design of the hardware part. Hardware development is consists of three main parts which are:

a. Grease Tank
b. Motor Casing (End Bell)
c. Air Compressor

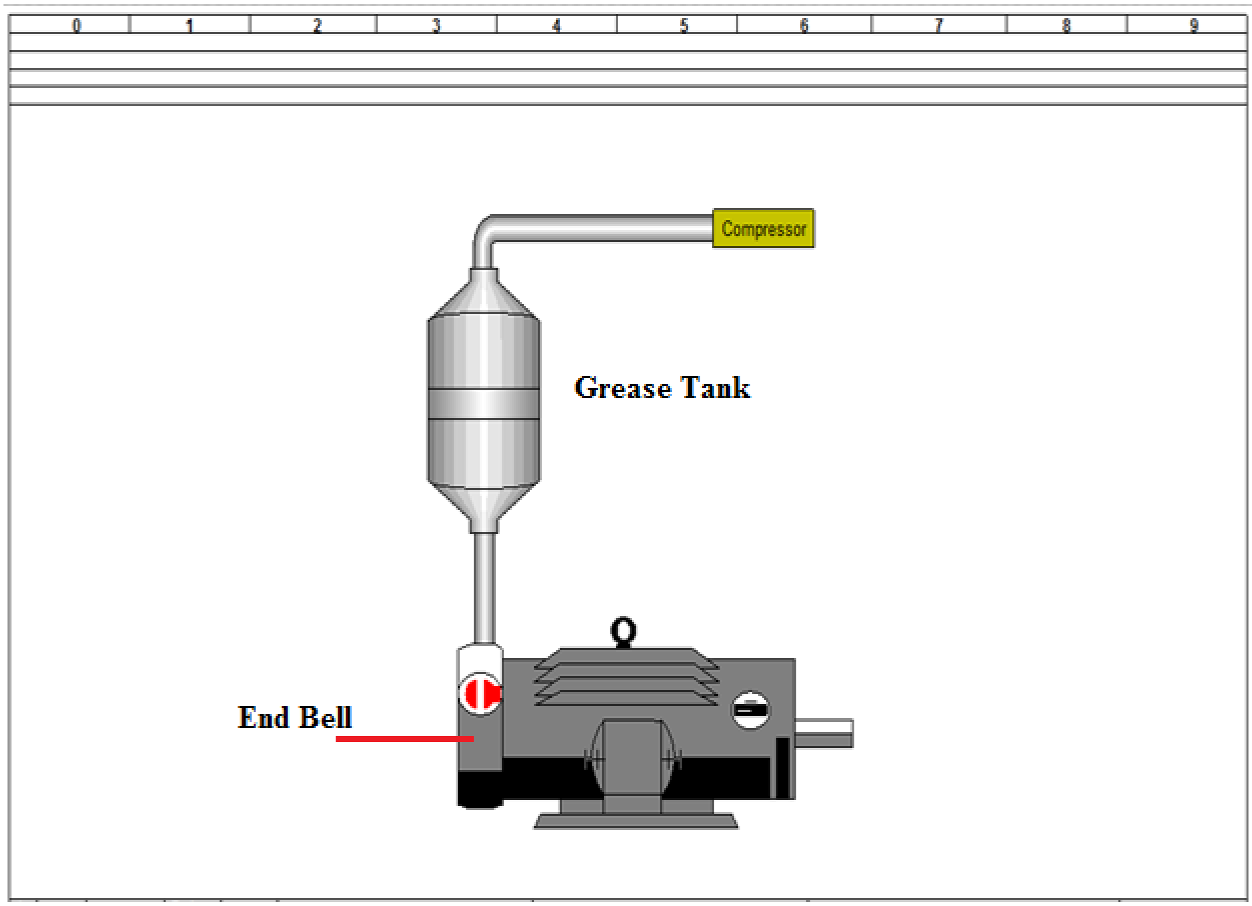

Figure 3.6 Final Design for Hardware Development

3.4.1 Grease Tank

Grease tank is actually will act as a place where the grease will store while waiting the signal to transfer the grease to bearing. Grease tank will build by using Polyvinyl chloride (PVC) pipe. The selection of using PVC pipe is because of the cost and also the PVC pipe is high resistance. This system was design to use air compressor, therefore the grease tank need to have higher resistance to avoid pipe from breaking. As shown in third design figure, the grease tank will combine several types of PVC pipe.

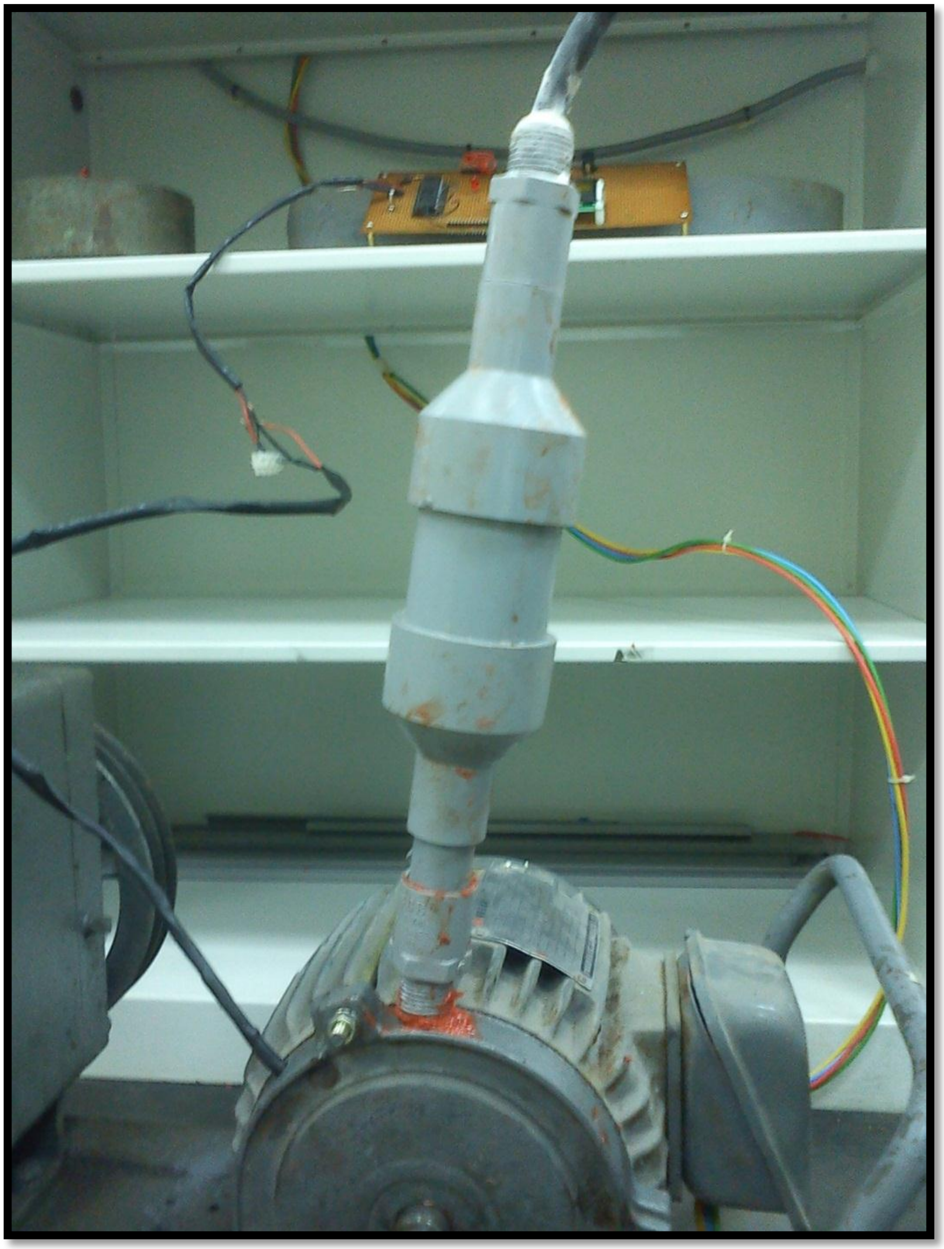

Figure 3.7 Grease Tank

3.4.2 End Bell

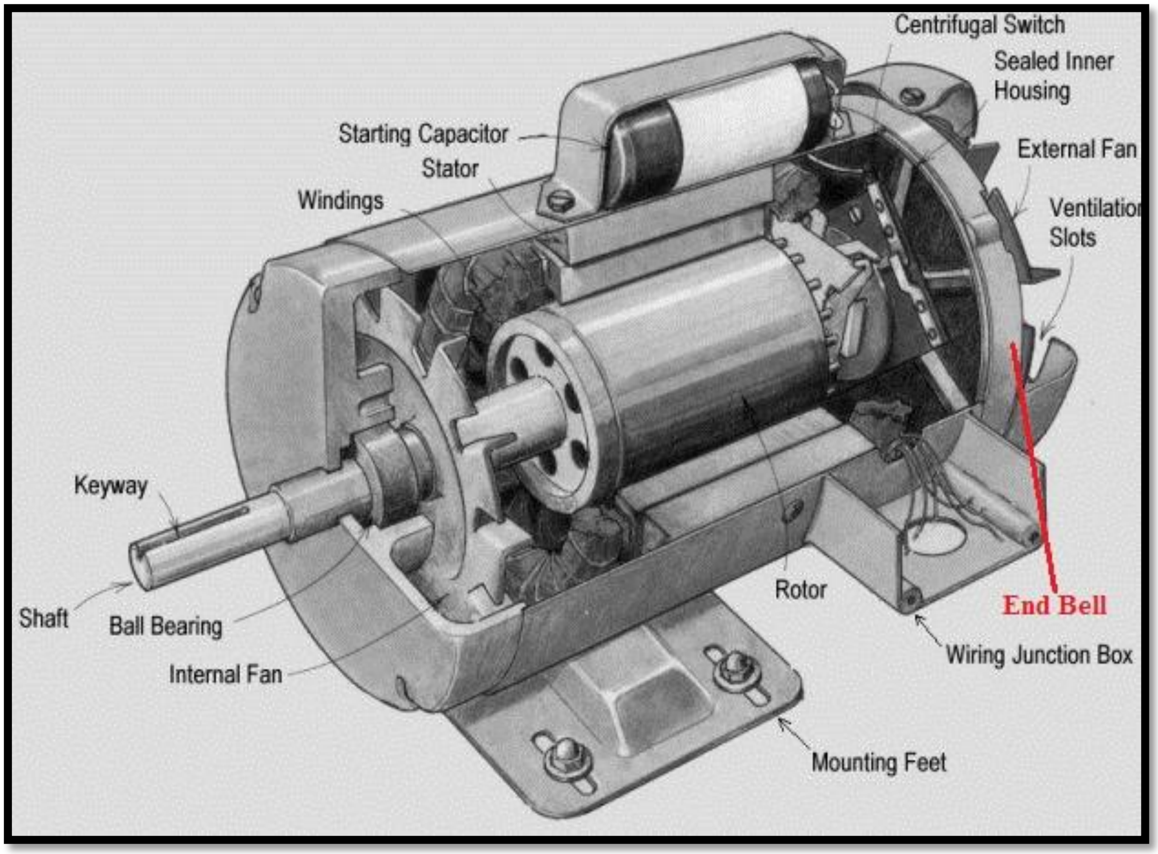

Figure 3.8 Electrical Motor Components

Motor casing or also known as “End Bell” is another part that important in doing this system. End bell need to consider as a main part because in this project, it is need to build new grease nipple. Normally, in industry, most of the electric motors already have their own grease nipple.

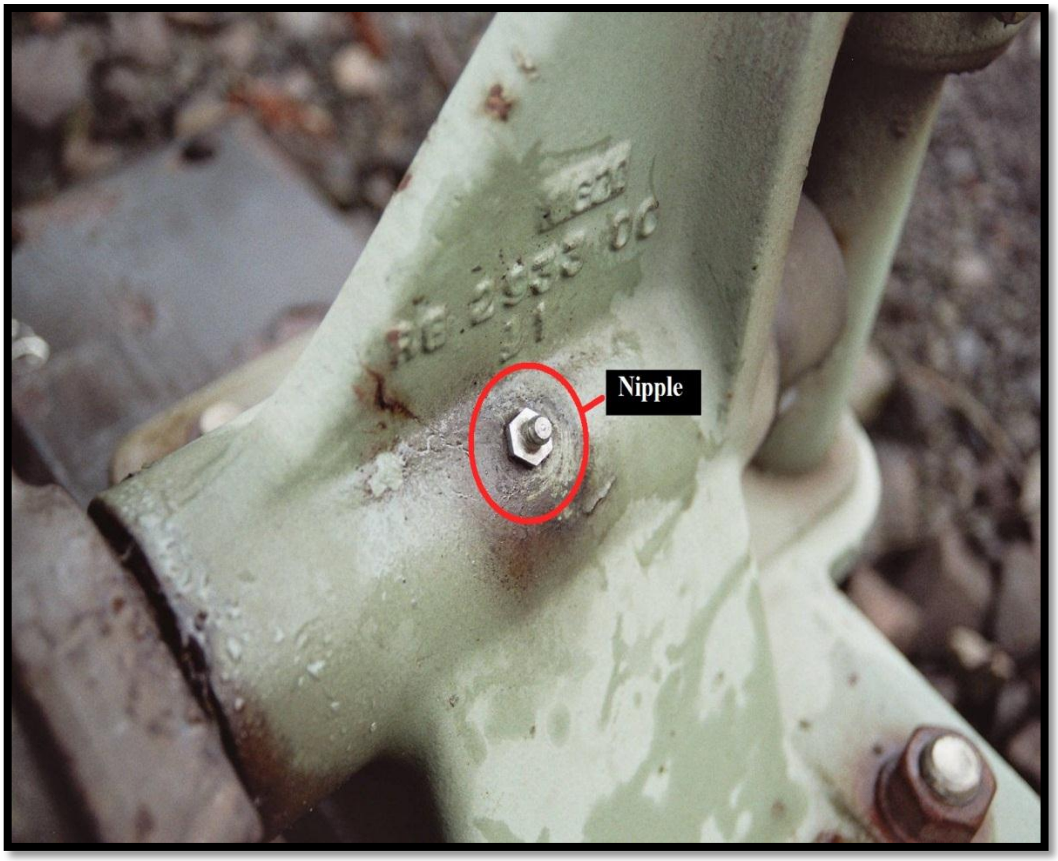

Figure 3.9 Greasing Nipple

This grease nipple is actually will act as a hole for grease. By using conventional method of bearing greasing, the technician will use grease gun and grease the bearing via this nipple. However, the induction motor used in this project has no grease nipple. Therefore, the grease nipple needs to develop first.

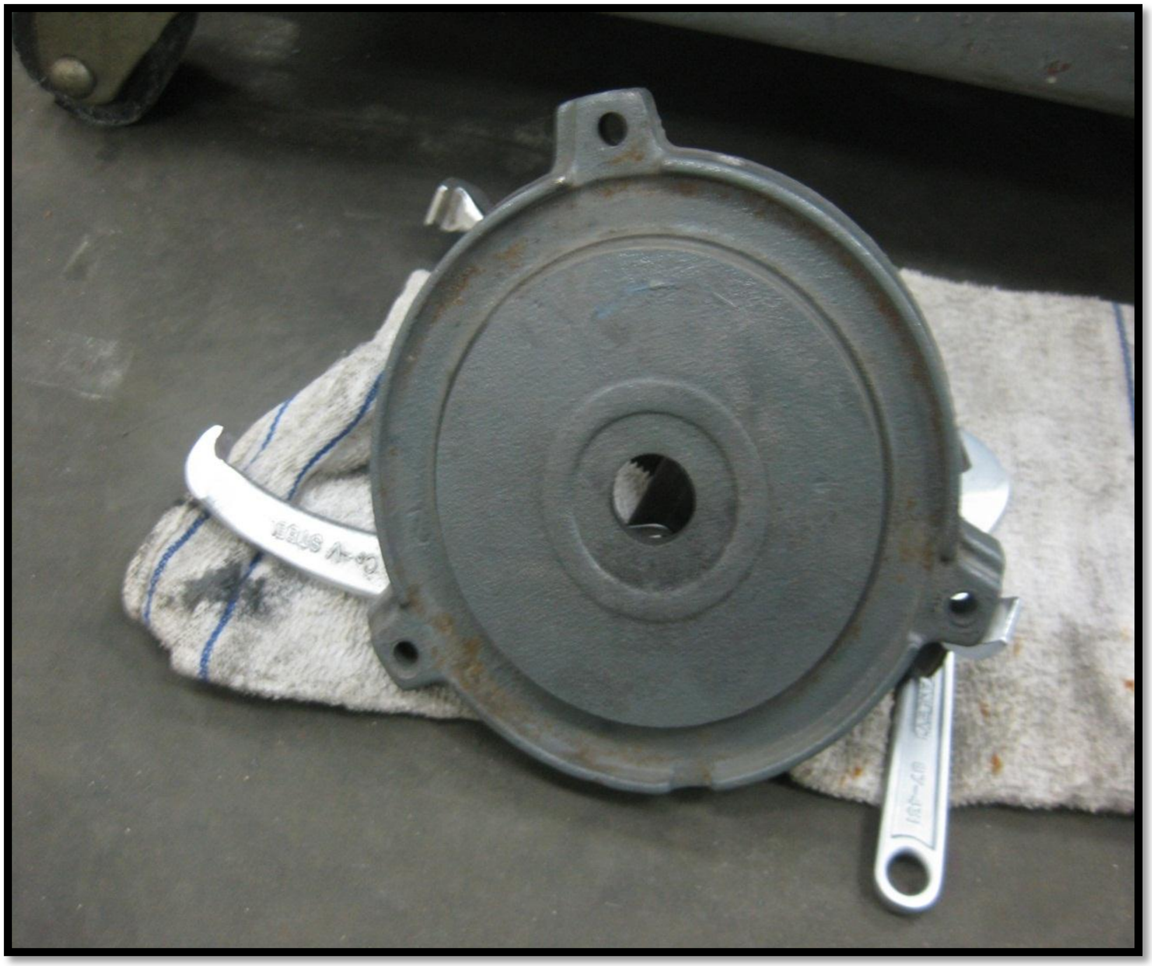

Figure 3.10 Original End Bell

Figure 3.10 shows the original end bell of the induction motor used in this project. This end bell will drill to build two new holes. These two new holes will be used to develop grease nipple and for temperature detector usage.

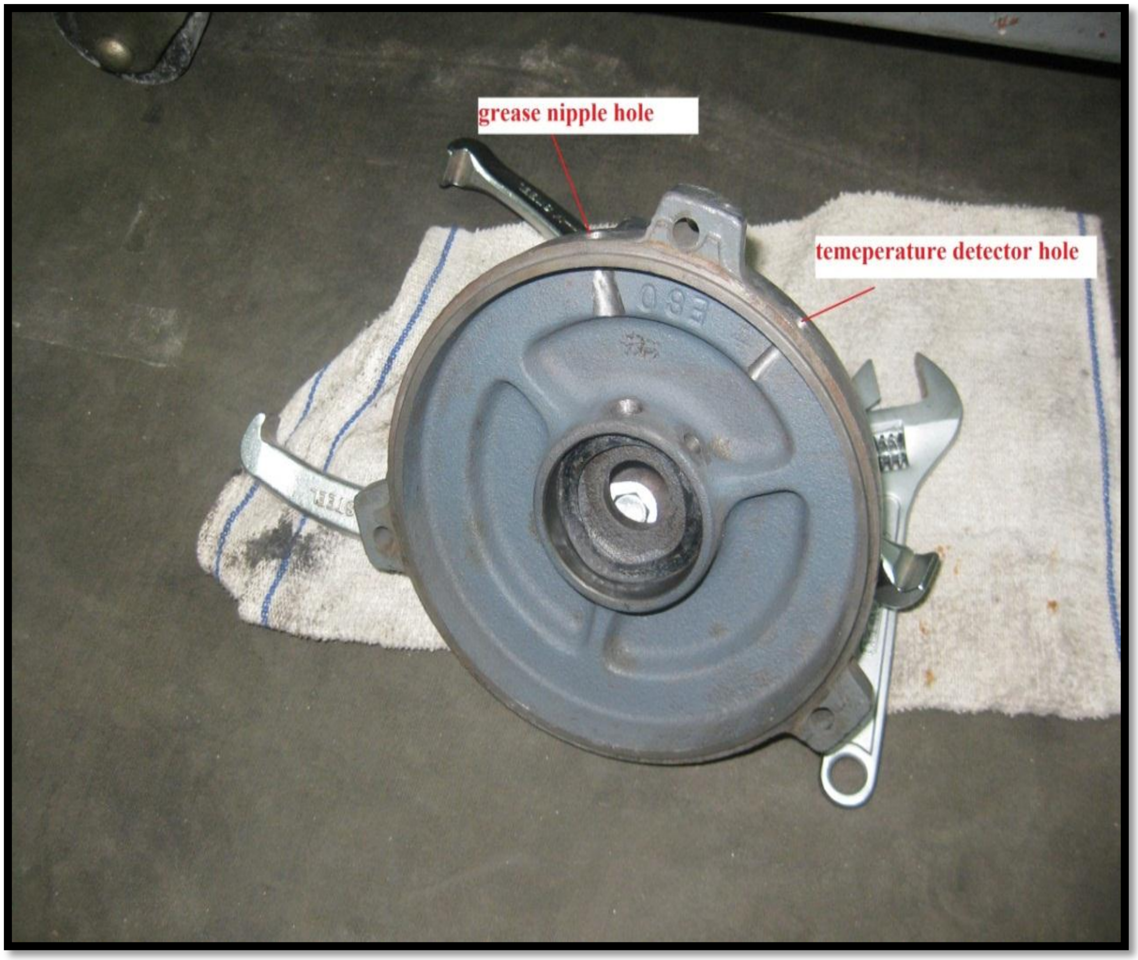

Figure 3.11 End Bell after Modification

3.4.3 Air Compressor

Figure 3.12 Air Compressor

Air compressor is another part of hardware development. This air compressor will act as an actuator to force the grease to flow from grease tank. It will compress the air into the grease tank and when the pressure is enough, the grease will be flowing through the tube. For this project, air compressor that will be used is a mini air compressor brand Klein-Kompressor. It is 12Vdc operated with 300PSI/ 20.7 Bar/ 2069KPa. The higher pressure of air compressor is better for this system. However, due to limitation of budget, this air compressor is enough to operate the system.

Klein-Kompressor mini air compressor is normally used for inflates tires on motorcycle. This compressor requires high current for optimum operation. Therefore, 12Vdc 45AH FujiMatic battery will be used as power supply for this air compressor.

Figure 3.13 12Vdc Fuji Matic Battery

3.5 Software Development (Controller Development)

In almost project, controller will be the heart of the systems. Controller will distinguish certain system with another system. For example, the difference from this greasing system with conventional greasing system is at controller part. For conventional greasing system, they don’t have any feedback to show the bearing condition but in autogreasing system, it has feedbacks which build-in inside controller.

In this system, the controller used is a Peripheral Interface Controller (PIC). The PIC is an advancement of microcontroller. The PIC was chosen due to several advantage of using PIC. The advantages are:

I. Low cost
II. Wide availability
III. Large user base
IV. Extensive collection of application notes
V. Availability of low cost or free development tools
VI. Serial programming capability

There are many types of PIC and for this system; the PIC will used is Microchip PIC18F4525. As a feedback for this system, the temperature sensor LM35 will be used.

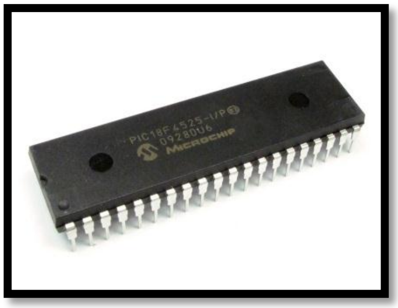

Figure 3.14 PIC18F4525

3.5.1 Temperature Sensor LM35

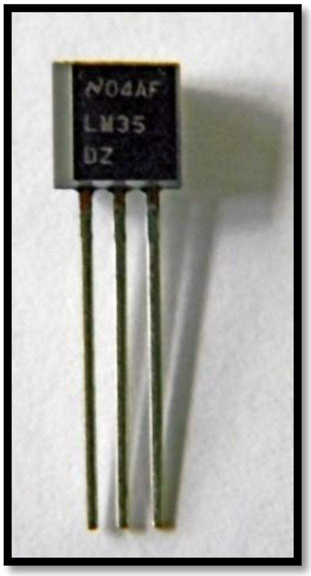

Figure 3.15 Temperature Sensor LM35

Temperature sensor LM35 in this system will act as an analog input for the PIC as well as feedback component for the system. The selection of using LM35 is due to several advantages which are:

I. Calibrated directly in ° Celsius (Centigrade)
II. Linear + 10.0 mV/°C scale factor

III. 0.5°C accuracy guaranteeable (at +25°C)
IV. Rated for full −55°C to +150°C range
V. Suitable for remote applications
VI. Low cost due to wafer-level trimming
VII. Operates from 4 to 30 volts
VIII. Less than 60 µA current drain
IX. Low self-heating, 0.08°C in still air
X. Nonlinearity only ±1⁄4°C typical

According to the datasheet of LM35, it seems suitable for this system. The rated temperature range is in between -55°C to +150°C is really suit for the bearing used inside the induction motor. Furthermore, LM35 is very affordable and it makes LM35 are really suitable for this system.

3.5.2 Schematic Diagram

For designing the controller, firstly need to design is the circuit. For this system, it will use Proteus ISIS 7.8 software for developing the circuit.

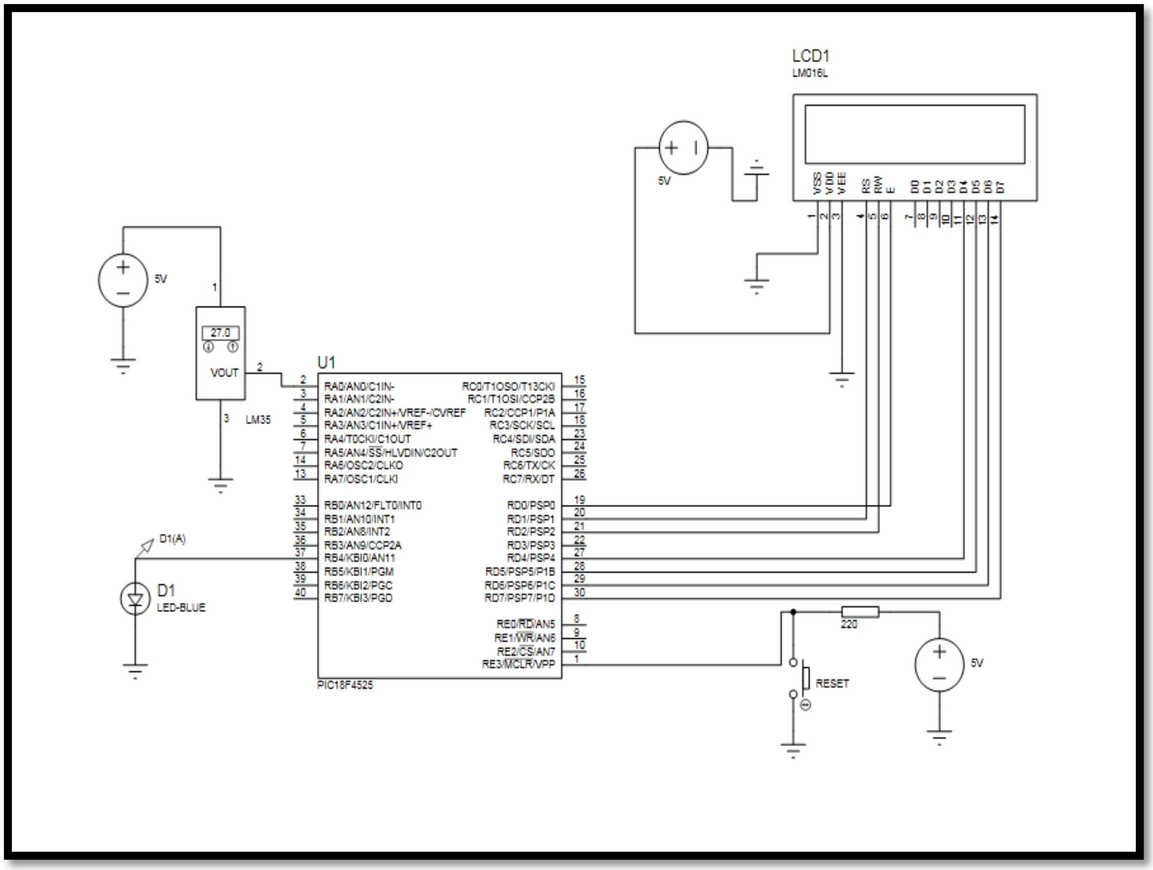

Figure 3.16 Autogrese System Schematic Diagram

This wholly original schematic diagram was developing by using 1 analog input which connected to the pin number 2 in PIC18F4525. The analog input for this system is the temperature sensor LM35. There are 2 output for this system which is output for LCD screen display and the output for energize air compressor. The LED D1 is an indicator for energizing air compressor. When the output is high for air compressor, the LED will turn on.

3.5.3 Source Code

Source code is a programming software where the programming will be written and compile to use in PIC18F4525. The program coding can refer to appendix C.This source code next will test with schematic design using Protues software. After test the source code, the hex file of the source code will burn into the real PIC18F4525. Also, the wiring for the circuit needs to be done by following the schematic diagram.

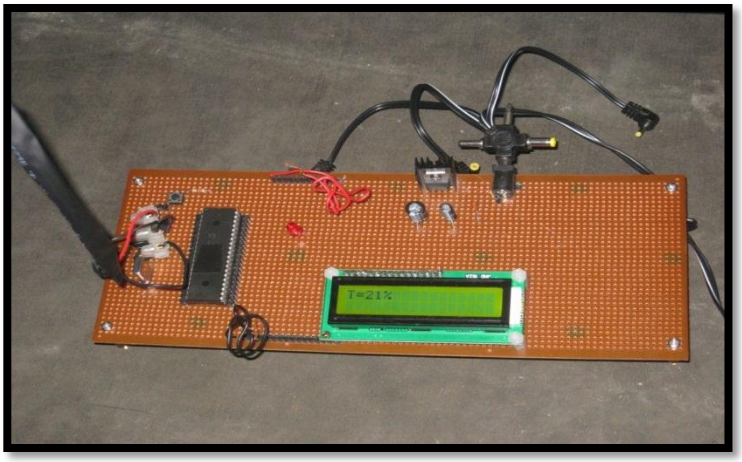

Figure 3.17 Software Development Circuit

3.6 Integration Stage

Integration stage is almost like finishing for this project. After done the controller development as well as hardware development, it is the time to integrate it to be one brilliant system. For integration part, it has decided to integrate it at FKEE Laboratory. Firstly, the three phase induction motor was set up with Direct On-line (DOL) wiring connection. It is not necessary to DOL as a connection for the motor and it is also can use star-delta connection. However, DOL was used because it is simple compare to other connection. Furthermore, the connection of the motor is not including in the scope of project, so the simplest connection has been choose. The DOL connection connected 3 phase (Red, Yellow and Blue) to the motor. The motor will run when push button "START" was pushed and the Green Lamp turn on. To stop the motor, the push button "STOP" need to push and the Green Lamp will turn off and Red Lamp will turn on. After done with wiring session, the end bell will install into the induction motor. Next, the hardware and controller circuit will integrate together to be complete system.

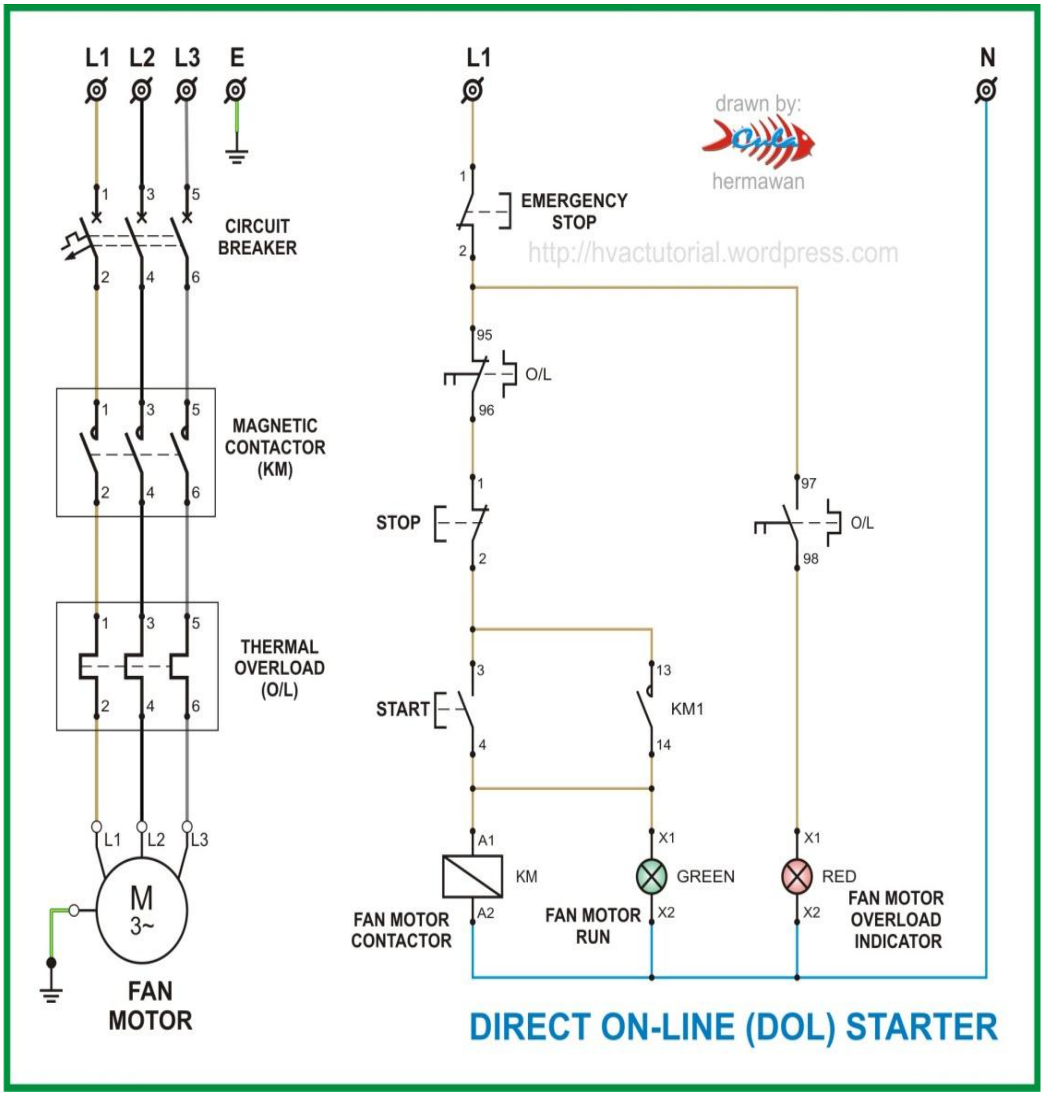

Figure 3.18 Electric Motor Power and Control Circuit For Direct On-Line

Figure 3.19 Complete System After Integrate Software and Hardware Parts

Figure 3.19 shows the whole system after completing integration stage. These figures also show how the motor look like and the purpose of two new holes; one use for greasing and one use for temperature sensor.

3.8 Summary

This chapter has been describing briefly about the methodology on how this project has been done. All three main parts of this project; hardware developing, software developing and integrations has been discussed in detail.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Overview

This chapter will show the result from the experiment done towards the three phase induction motor. The experiment is to detect the bearing temperature increasing when the electric motor is running.

4.2 LM35 Accuracy

This experiment is purposely to justify the accuracy of LM35 as well as reliability of this system. To check the accuracy of LM35, the temperature reading from LM35 will compare to the temperature reading of digital thermometer Omron MC-245 and the temperature reading of Samsung air conditioner. The experiment has been done at the room which already installed the Samsung air conditioner. The comparison with digital thermometer Omron MC-245 is because of digital thermometer Omron MC-245 has 99% accuracy.

Table 4.1 Temperature Reading Comparison

Air Conditioner Temperature	LM35	Omron MC-245
21°C	21°C	21°C

Accuracy:

(LM35/Omron MC-245) x 100 = (21/21) x 100

= 100% accuracy

Even though LM35 is accurate compare to digital thermometer Omron MC-245, the LM35 still have their weaknesses. This LM35 is a sensitive device where if the pins have little scratch, the LM35 will fluctuate too much. However, at this stage where new LM35 was used, the fluctuate is not too much and the temperature reading is consistent. Therefore, this temperature sensor LM35 is 100% accurate compare to digital thermometer Omron MC-245 and it is proved that this system is reliable.

4.3 Bearing Temperature Increasing

For analyzing data, the data taken is the bearing temperature increasing when induction motor in running and it’s time to achieve that temperature. The experiment was done in FKEE laboratory at 2.00pm. The temperature was taken by using the LM35 which has been installed in the controller circuit.

Ambient Temperature: 21°C

Table 4.2 Bearing Temperature Increasing With Time

Bearing Temperature (°C)	Time (seconds)
22	55
23	115
24	180
25	240
26	345
27	390
28	454
29	520
30	593

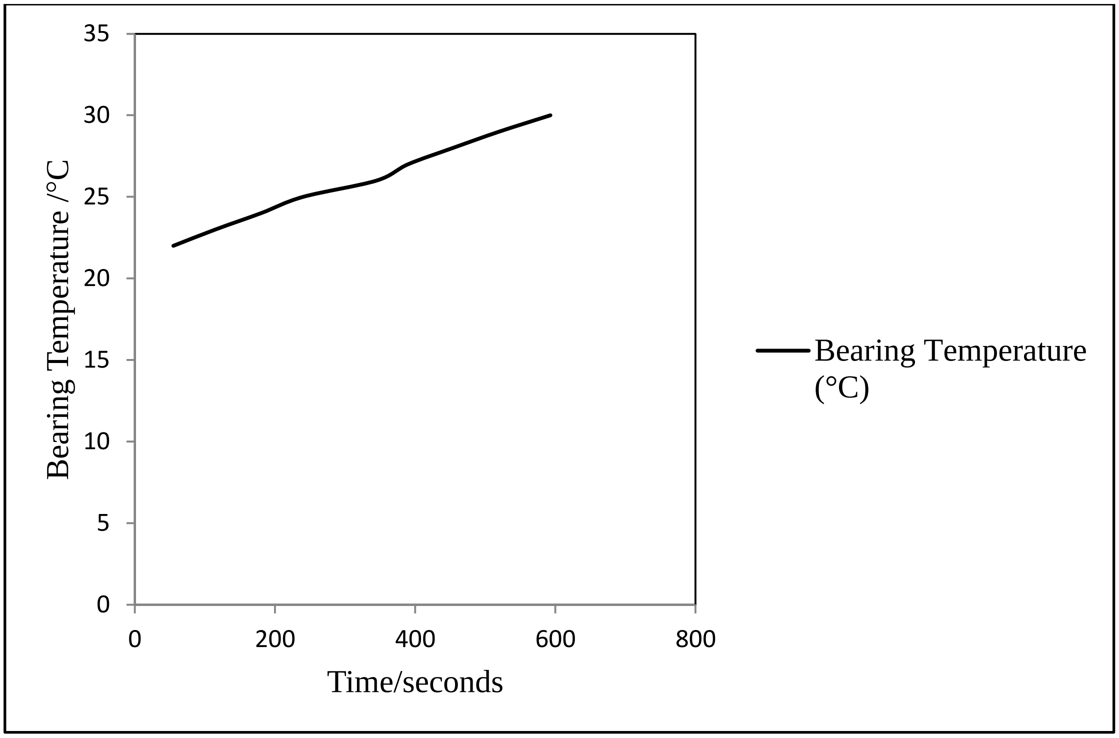

Figure 4.1 Graph for Bearing Temperature vs Time

According to the data in table 4.2, the bearing temperature is increasing slowly. It takes 593 seconds equivalent to 9.53 minutes to gain 30°C. However, the temperature is increasing faster when the reaching 27°C. Before 27°C, the time to increase 1°C is around 120 seconds but starting from 27°C, the time to increase 1°C is just around 60 to 70 seconds. This is due to friction between bearing and the shaft. This is the important of using greasing which may help the reducing bearing temperature so that the bearing lifetime may be longer.

4.4 Reliability of the System

This experiment is to determine the reliability of this system by monitoring the bearing temperature. This system will consider as reliable if the bearing temperature which already increase will decrease to the safe temperature for the baring after injecting the grease. For this experiment, the safe temperature has been set to 25°C while the critical temperature has been set to 30°C and above.

Amount of grease: 3.20 gram

Ambient temperature: 21°C

Table 4.3 Bearing Temperature Decreasing

Bearing Temperature (°C)	Time (seconds)
35	30
30	57
25	65

According to the data, the time taken to bearing temperature decrease from 35°C to 25°C is 65 seconds. The amount of grease use is 3.20 gram. Since the temperature of bearing is decrease, this system can be considered as reliable system.

4.5 Amount of Grease

For analysis, the data taken is the amount of grease supplied by the system by using measurement cylinder (in milliliter). The system was supplied the grease after the bearing temperature reached the set temperature. The experiment was done at FKEE laboratory. In this autogrease system, it use mini air compressor 300PSI. The objective of this experiment is to identify the ability of this grease system. In deep, this experiment will show how many gram of grease can be supply by this system. For this motor, it is used the bearing type 6204ZZ (radial Ball Bearing). The specification of this bearing is noted below.

Type: Conrad/Deep groove ball bearing

Dimension:

Bore	: 0.7874 inch
Outside Diameter	: 47 mm
Overall Width	: 14 mm

Amount of grease: 24 ml

In doing greasing job, it is very important to make sure the amount of grease applied to the bearing is not exceeding the correct amount of grease. To determine the optimum amount of grease it's needed to use formula below.

$$GP = 0.005 \times D \times B$$

Where,

GP: Amount of grease (gram)

D : Bearing outside diameter (mm)

B : Total bearing width (mm)

Therefore, the optimum amount of grease for this bearing is:

$GP = 0.005 \times D \times B$

= 0.005 x 47 x 14

= 3.29 gram

It is justified that the bearing for this motor, 6204ZZ need 3.29gram of grease to operate effectively. Since the amount of grease supplied by this system was measured by using measurement cylinder (in milliliter), the formula below was used to determine the amount of grease (in gram).

Amount of grease = Density/Mililiter

The milliliter of grease supplied by the system is 24ml while the density for the grease is 880g/ml.

Therefore, the amount of grease in gram is:

Amount of grease = (880 g/ml)/(24 g)

= 36 gram

At the end of this experiment, it was shown that this autogrease system can supplied 36 gram of grease.

4.6 Summary

This chapter has shown all the data related to the experiment which to identifying the accuracy of LM35, bearing temperature increasing when the electric motor running, reliability of the system and amount of grease. All the data, graphical analysis also include in this chapter.

CHAPTER 5

CONCLUSION AND FUTURE RECOMMENDATION

5.1 Conclusion

At the end of this project, it has found that current method of greasing has a number of associated problems. Therefore, the autogreasing system for electric motor's bearing is one of the best methods to make the greasing job easily without danger to anybody and also to maintain the performance of the electric motor. The temperature of the bearing has been proved to be a feedback on bearing condition. Finally, the three main objectives of this project have been successfully achieved.

5.2 Cost and Potential for Commercialization

5.2.1 Cost

In doing any project, the cost is a thing that must be considered. The costs to develop this automatic greasing system are shown in the table 5.1.

Table 5.1 Cost for develop prototype of the system

Items	Quantity	Price (RM)	Total Price (RM)
1x40 Pin Header	5	0.45	2.25
2x16 LCD Screen	1	19.00	19.00
Jumper cable	10 meter	0.30	3.00
PIC 18F4525	1	29.00	29.00
Switch	1	0.80	0.80
Relay	1	2.00	2.00
LED (Red, Yellow and Blue)	3	1.00	3.00
100nF Capacitor	2	0.30	0.60
10uF Capacitor	1	0.25	0.25
Heat Sink	1	0.80	0.80
LM7805	1	1.00	1.00
Donut Board	1	2.00	2.00
Mini Air Compressor	1	60.00	60.00
Rubber Silicon Glue	1	10.00	10.00
12Vdc 45AH Battery	1	125.00	125.00
PVC Pipe	1	2.00	2.00
TOTAL			250.70

5.2.2 Potential for Commercialization

The needs of greasing are important to maintain the electric motor performance as well as to reduce down time cost. Therefore, this prototype has a bright potential for commercialization to the industry. The industry that might be interested this prototype are steel mill industry, manufacturing industry and many else. These industries have a lot of down time because of electric motor failure and its give the financial effect of the company. However, to use in industry, some modification need to be done to this prototype which noted at future recommendations part.

5.2 Future Recommendation

After finishing this project, it shows something that can be improved for further action.

I. The air compressor used must be in high pressure. In this project just used 300PSI and it is quite slow for grease flowing. If the system use high pressure pump, the system will response faster compare to this system.
II. The usage of this system is advice not for one motor only. This is due to cost of installation the system and the air compressor can be used for many points.
III. Use more reliable temperature sensor such as PT100 or thermocouple. If the system use more reliable temperature sensor, the system will have real temperature reading without fluctuation.

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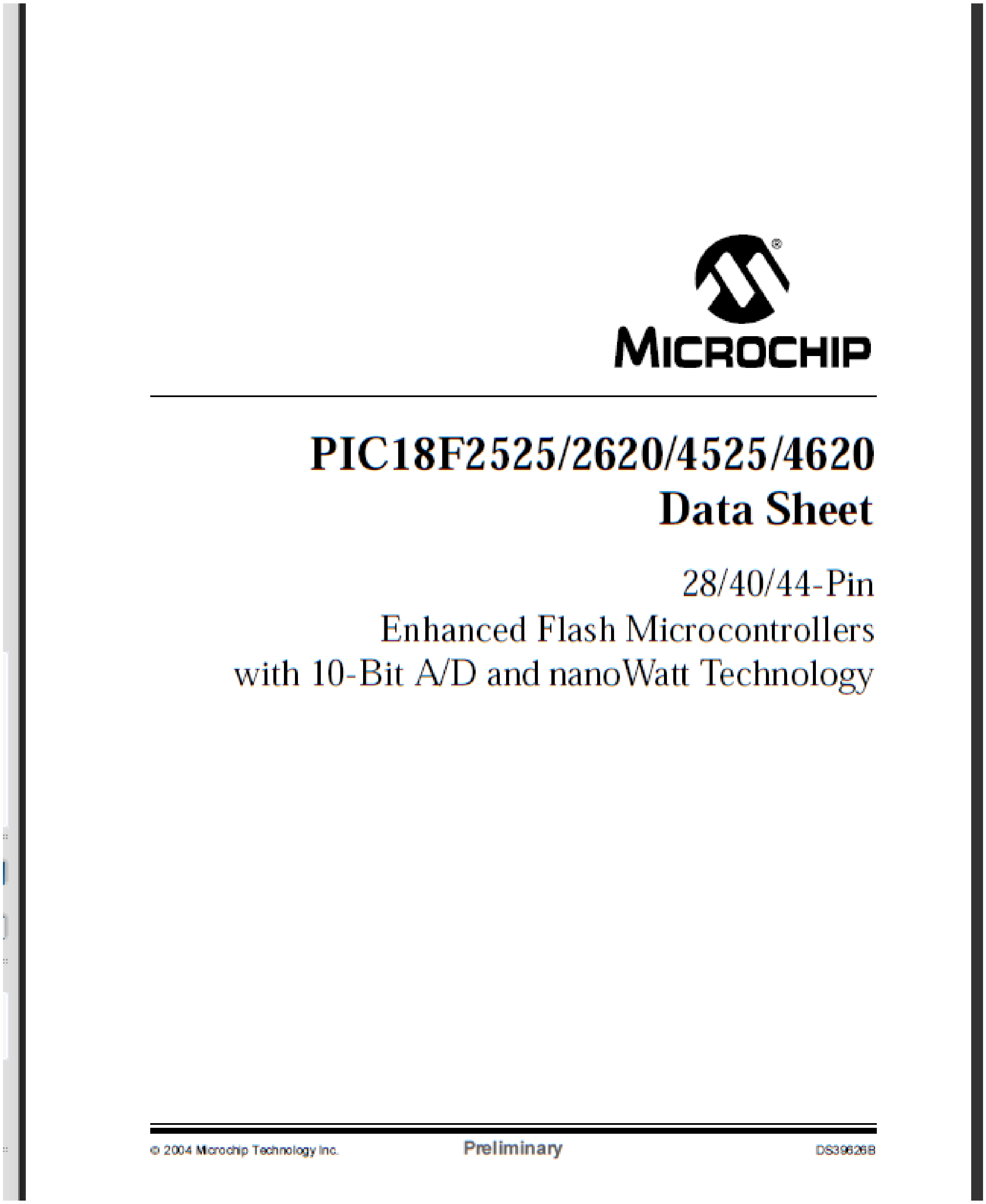
APPENDIX A

PIC18F4525 DATASHEET

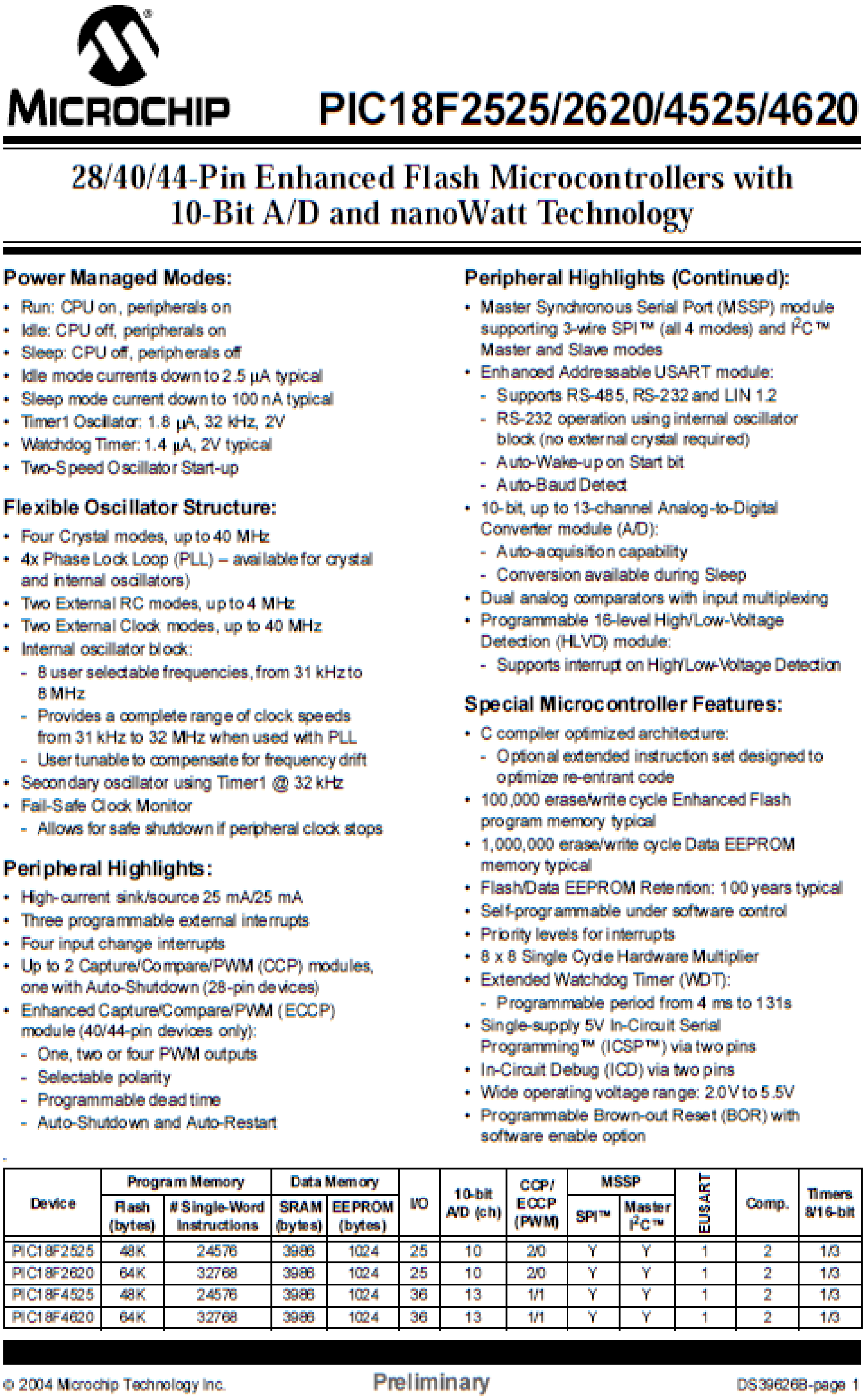


MICROCHIP

PIC18F2525/2620/4525/4620 Data Sheet

28/40/44-Pin
Enhanced Flash Microcontrollers
with 10-Bit A/D and nanoWatt Technology

© 2004 Microchip Technology Inc. Preliminary DS39626B



MICROCHIP

PIC18F2525/2620/4525/4620

28/40/44-Pin Enhanced Flash Microcontrollers with 10-Bit A/D and nanoWatt Technology

Power Managed Modes:

- Run: CPU on, peripherals on
- Idle: CPU off, peripherals on
- Sleep: CPU off, peripherals off
- Idle mode currents down to 2.5 µA typical
- Sleep mode current down to 100 nA typical
- Timer1 Oscillator: 1.8 µA, 32 kHz, 2V
- Watchdog Timer: 1.4 µA, 2V typical
- Two-Speed Oscillator Start-up

Flexible Oscillator Structure:

- Four Crystal modes, up to 40 MHz
- 4x Phase Lock Loop (PLL) – available for crystal and internal oscillators)
- Two External RC modes, up to 4 MHz
- Two External Clock modes, up to 40 MHz
- Internal oscillator block:
  - 8 user selectable frequencies, from 31 kHz to 8 MHz
  - Provides a complete range of clock speeds from 31 kHz to 32 MHz when used with PLL
  - User tunable to compensate for frequency drift
- Secondary oscillator using Timer1 @ 32 kHz
- Fail-Safe Clock Monitor
  - Allows for safe shutdown if peripheral clock stops

Peripheral Highlights:

- High-current sink/source 25 mA/25 mA
- Three programmable external interrupts
- Four input change interrupts
- Up to 2 Capture/Compare/PWM (CCP) modules, one with Auto-Shutdown (28-pin devices)
- Enhanced Capture/Compare/PWM (ECCP) module (40/44-pin devices only):
  - One, two or four PWM outputs
  - Selectable polarity
  - Programmable dead time
  - Auto-Shutdown and Auto-Restart

Peripheral Highlights (Continued):

- Master Synchronous Serial Port (MSSP) module supporting 3-wire SPI™ (all 4 modes) and I^{2}C™ Master and Slave modes
- Enhanced Addressable USART module:
  - Supports RS-485, RS-232 and LIN 1.2
  - RS-232 operation using internal oscillator block (no external crystal required)
  - Auto-Wake-up on Start bit
  - Auto-Baud Detect
- 10-bit, up to 13-channel Analog-to-Digital Converter module (A/D):
  - Auto-acquisition capability
  - Conversion available during Sleep
- Dual analog comparators with input multiplexing
- Programmable 16-level High/Low-Voltage Detection (HLVD) module:
  - Supports interrupt on High/Low-Voltage Detection

Special Microcontroller Features:

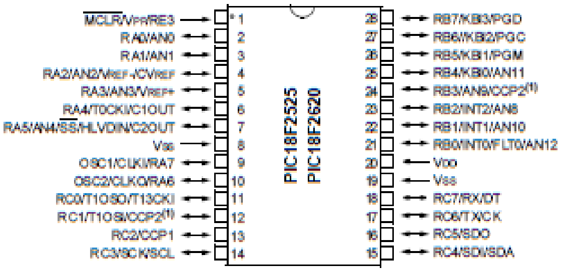
- C compiler optimized architecture:
  - Optional extended instruction set designed to optimize re-entrant code
- 100,000 erase/write cycle Enhanced Flash program memory typical
- 1,000,000 erase/write cycle Data EEPROM memory typical
- Flash/Data EEPROM Retention: 100 years typical
- Self-programmable under software control
- Priority levels for interrupts
- 8 x 8 Single Cycle Hardware Multiplier
- Extended Watchdog Timer (WDT):
  - Programmable period from 4 ms to 131s
- Single-supply 5V In-Circuit Serial Programming™ (ICSP™) via two pins
- In-Circuit Debug (ICD) via two pins
- Wide operating voltage range: 2.0V to 5.5V
- Programmable Brown-out Reset (BOR) with software enable option

Device	Program Memory		Data Memory		I/O	10-bit A/D (ch)	CCP/ ECCP (PWM)	MSSP		EUSART	Comp.	Timers 8/16-bit
	Flash (bytes)	# Single-Word Instructions	SRAM (bytes)	EEPROM (bytes)				SPI™	Master I^{2}C™			
PIC18F2525	48K	24576	3968	1024	25	10	2/0	Y	Y	1	2	1/3
PIC18F2620	64K	32768	3968	1024	25	10	2/0	Y	Y	1	2	1/3
PIC18F4525	48K	24576	3968	1024	36	13	1/1	Y	Y	1	2	1/3
PIC18F4620	64K	32768	3968	1024	36	13	1/1	Y	Y	1	2	1/3

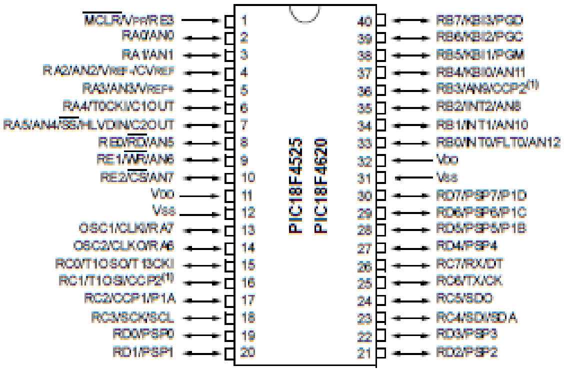
Preliminary DS39626B-page 1

Pin Diagrams

28-Pin SPDIP, SOIC



40-Pin PDIP

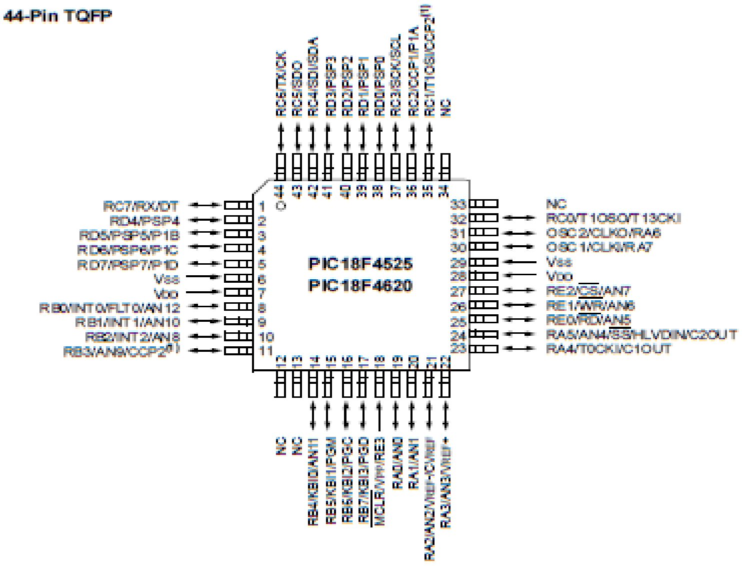


Note 1: RB3 is the alternate pin for CCP2 multiplexing.

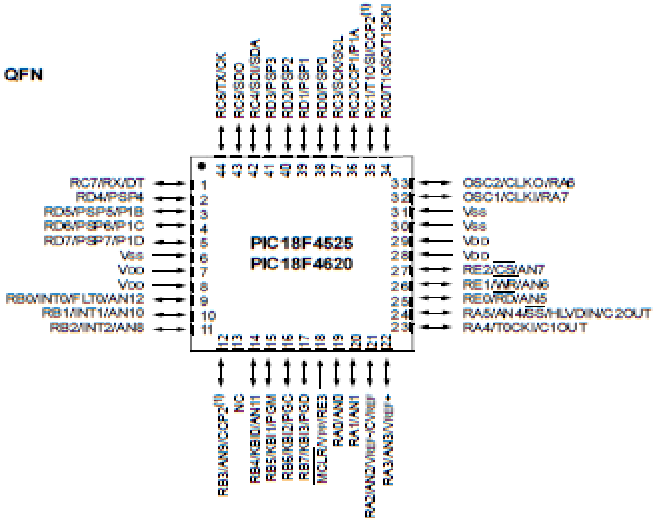
PIC18F2525/2620/4525/4620

Pin Diagrams (Cont.'d)

44-Pin TQFP



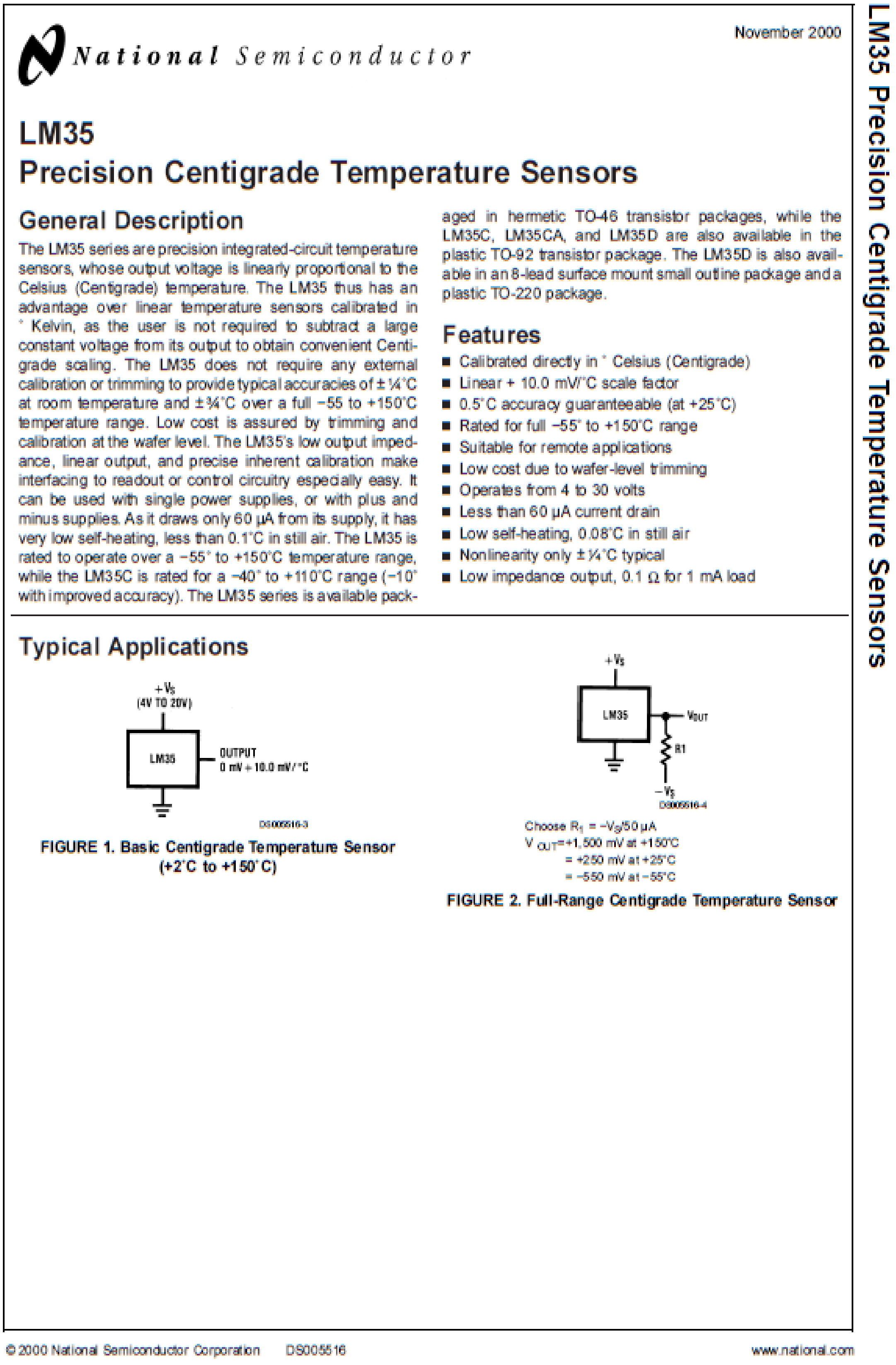
44-Pin QFN



Note 1: RB3 is the alternate pin for CCP2 multiplexing.

APPENDIX B

LM35 DATASHEET



National Semiconductor

November 2000

LM35 Precision Centigrade Temperature Sensors

LM35
Precision Centigrade Temperature Sensors

General Description

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55 to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 µA from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35 is rated to operate over a −55° to +150°C temperature range, while the LM35C is rated for a −40° to +110°C range (−10° with improved accuracy). The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-220 package.

Features

- Calibrated directly in ° Celsius (Centigrade)
- Linear + 10.0 mV/°C scale factor
- 0.5°C accuracy guaranteeable (at +25°C)
- Rated for full −55° to +150°C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60 µA current drain
- Low self-heating, 0.08°C in still air
- Nonlinearity only ±¼°C typical
- Low impedance output, 0.1 Ω for 1 mA load

Typical Applications

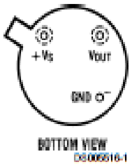
FIGURE 1. Basic Centigrade Temperature Sensor (+2°C to +150°C)

Choose $R_1 = -V_S/50\ \mu A$
V_{OUT}=+1,500 mV at +150°C
= +250 mV at +25°C
= −550 mV at −55°C

FIGURE 2. Full-Range Centigrade Temperature Sensor

Connection Diagrams

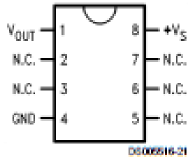
TO-46
Metal Can Package*



*Case is connected to negative pin (GND)

Order Number LM35H, LM35AH, LM35CH, LM35CAH or LM35DH
See NS Package Number H03H

SO-8
Small Outline Molded Package



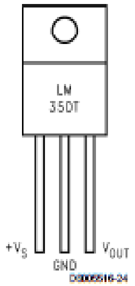
N.C. = No Connection

Top View
Order Number LM35DM
See NS Package Number M08A

TO-92
Plastic Package

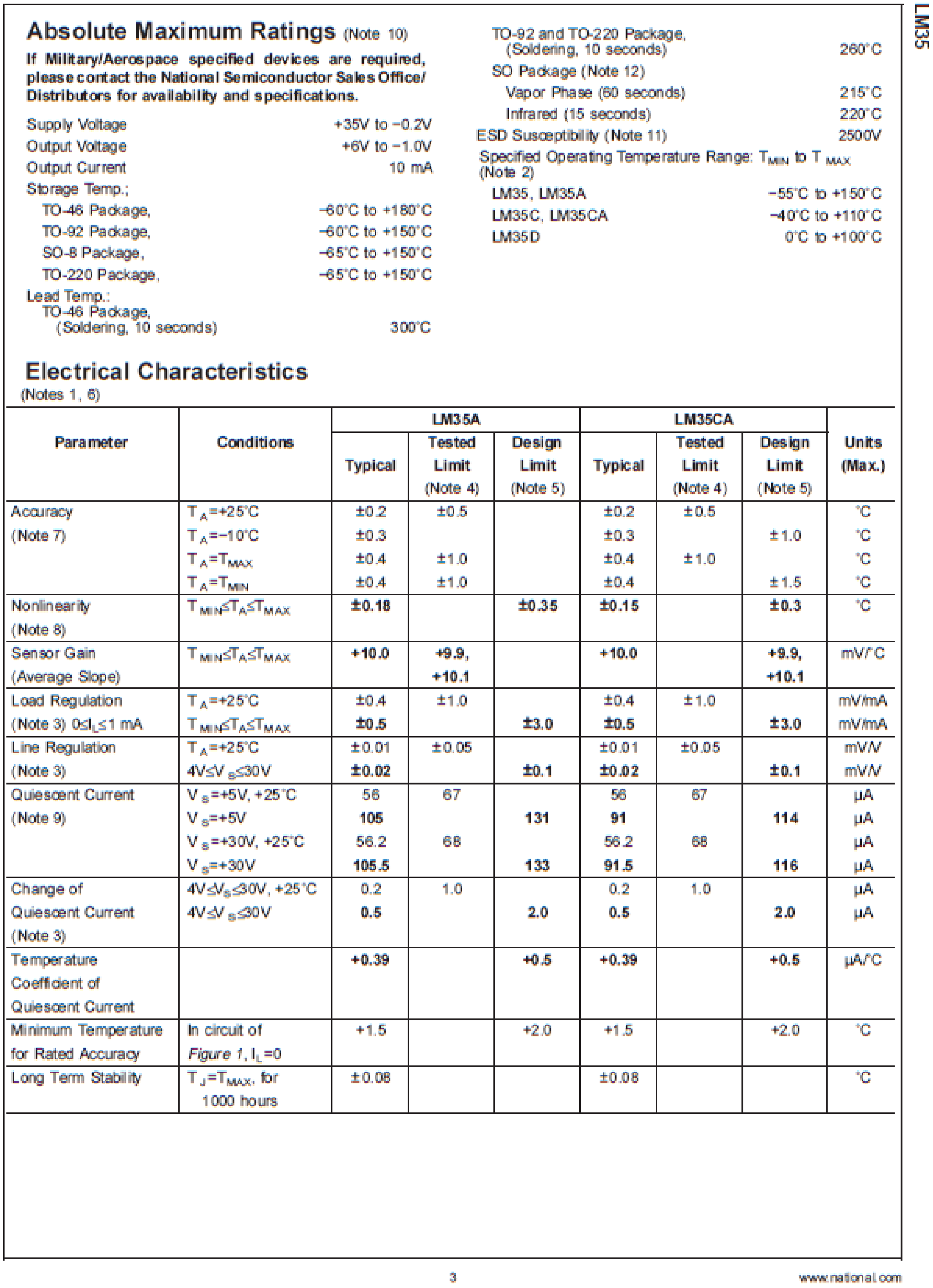
Order Number LM35CZ, LM35CAZ or LM35DZ
See NS Package Number Z03A

TO-220
Plastic Package*



*Tab is connected to the negative pin (GND).
Note: The LM35DT pinout is different than the discontinued LM35DP.

Order Number LM35DT
See NS Package Number TA03F



LM35

Absolute Maximum Ratings (Note 10)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Supply Voltage	+35V to −0.2V
Output Voltage	+6V to −1.0V
Output Current	10 mA
Storage Temp.;	
TO-46 Package,	−60°C to +180°C
TO-92 Package,	−60°C to +150°C
SO-8 Package,	−65°C to +150°C
TO-220 Package,	−65°C to +150°C
Lead Temp.:	
TO-46 Package, (Soldering, 10 seconds)	300°C
TO-92 and TO-220 Package, (Soldering, 10 seconds)	260°C
SO Package (Note 12)	
Vapor Phase (60 seconds)	215°C
Infrared (15 seconds)	220°C
ESD Susceptibility (Note 11)	2500V
Specified Operating Temperature Range: T_{MIN} to T_{MAX} (Note 2)	
LM35, LM35A	−55°C to +150°C
LM35C, LM35CA	−40°C to +110°C
LM35D	0°C to +100°C

Electrical Characteristics

(Notes 1, 6)

Parameter	Conditions	LM35A			LM35CA			Units (Max.)
		Typical	Tested Limit (Note 4)	Design Limit (Note 5)	Typical	Tested Limit (Note 4)	Design Limit (Note 5)	
Accuracy (Note 7)	T_A=+25°C	±0.2	±0.5		±0.2	±0.5		°C
	T_A=−10°C	±0.3			±0.3		±1.0	°C
	T_A=T_{MAX}	±0.4	±1.0		±0.4	±1.0		°C
	T_A=T_{MIN}	±0.4	±1.0		±0.4		±1.5	°C
Nonlinearity (Note 8)	T_{MIN}≤T_A≤T_{MAX}	**±0.18**		**±0.35**	**±0.15**		**±0.3**	°C
Sensor Gain (Average Slope)	T_{MIN}≤T_A≤T_{MAX}	**+10.0**	**+9.9,** **+10.1**		**+10.0**		**+9.9,** **+10.1**	mV/°C
Load Regulation (Note 3) 0≤I_L≤1 mA	T_A=+25°C	±0.4	±1.0		±0.4	±1.0		mV/mA
	T_{MIN}≤T_A≤T_{MAX}	**±0.5**		**±3.0**	**±0.5**		**±3.0**	mV/mA
Line Regulation (Note 3)	T_A=+25°C	±0.01	±0.05		±0.01	±0.05		mV/V
	4V≤V_S≤30V	**±0.02**		**±0.1**	**±0.02**		**±0.1**	mV/V
Quiescent Current (Note 9)	V_S=+5V, +25°C	56	67		56	67		μA
	V_S=+5V	**105**		**131**	**91**		**114**	μA
	V_S=+30V, +25°C	56.2	68		56.2	68		μA
	V_S=+30V	**105.5**		**133**	**91.5**		**116**	μA
Change of Quiescent Current (Note 3)	4V≤V_S≤30V, +25°C	0.2	1.0		0.2	1.0		μA
	4V≤V_S≤30V	**0.5**		**2.0**	**0.5**		**2.0**	μA
Temperature Coefficient of Quiescent Current		**+0.39**		**+0.5**	**+0.39**		**+0.5**	μA/°C
Minimum Temperature for Rated Accuracy	In circuit of *Figure 1*, I_L=0	+1.5		+2.0	+1.5		+2.0	°C
Long Term Stability	T_J=T_{MAX}, for 1000 hours	±0.08			±0.08			°C

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APPENDIX C

SOURCE CODE

```
#include <18F4525.h>

#fuses XT,NOWDT,NOLVP,NOPROTECT

#device adc=10

#use delay (clock=4M)

#include <lcd.c>

#define LED1   PIN_B4

#define TEMP_AI2  PIN_A0

#define LCD_E   PIN_D0

#define LCD_RS  PIN_D1

#define LCD_RW  PIN_D2

#define LCD_D4  PIN_D4

#define LCD_D5  PIN_D5

#define LCD_D6  PIN_D6

#define LCD_D7  PIN_D7

void main ()

{

  int32 AI2;

   int32 TEMP;

   setup_adc(ADC_CLOCK_INTERNAL);
```

```
setup_adc_ports(AN0_TO_AN1);
 set_tris_b(0x00);
output_b (0x00);
lcd_init();
 while (TRUE)
{
    delay_ms(200);
   set_adc_channel(0);
   delay_us(100);
   AI2=read_adc();
   TEMP=5*AI2*100/(1024-1);
  printf(lcd_putc,"\fBEARING TEMP\n\%u deg Celcius", (int) TEMP);
  delay_ms(200);
  if (TEMP>25)
   {
      output_high (LED1);
      printf(lcd_putc,"\fBEARING TEMP\n\%u deg Celcius", (int) TEMP);
      delay_ms(200);
    }
     else if (TEMP<25)
   {
```

```
         output_low (LED1);

         printf(lcd_putc,"\fBEARING TEMP\n\%u deg Celcius", (int) TEMP);

         delay_ms(200);

        }

      }

}
```