Portable Thermal Massaging Pad

by

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Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
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CERTIFICATION OF APPROVAL

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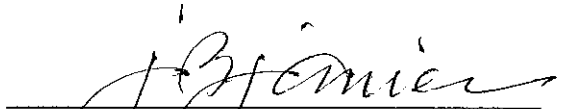
Approved by,



(Assoc.Prof.Dr JOSEFINA BARNACHEA JANIER)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

JUNE 2009

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MOHD KHAIRIL ANUAR BIN KAMARUDIN

ABSTRACT

Sitting can be rough on the body especially for long duration with wrong technique. Due to this situation, a person can experience stiffness, stress and soreness which will lead to loose of focus in their daily activities.

To remedy the situation, a project call Portable Massaging Pad is developed as to alleviate the body aches. The massager is attached with a thermal conductor and be placed on the cushion seat.

The innovation on the seat is expected that the Portable Massaging Pad can de-stress the user and can give comfort while traveling.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Sitting is one of the normal human daily activities. It is also a natural when people feel tired and need some rest where they will sit for a while. But sitting for a long period with minimum body activities can also harm the human body. It can affect the back, shoulder and lower body part. By this problem, people will feel pain at those parts and can effect their daily activities. People can also lose their focus from what they are doing and sometimes it can be dangerous especially for those who are driving for a long distance journey. Wrong sitting technique and ergonomic failure can also lead to this problem.

An innovation will be developed in response to help people to alleviate body aches and cramps because of long sitting period and less body activities. It will also help people to improve their daily activities. To remedy the problem, an innovation named "Portable Thermal Massaging Pad" is constructed.

1.2 Problem Statement

Below are some typical problems one would feel from exposure to the ergonomics risk factors of sitting, especially after a long period of time. Some of the typical problems from frequent sitting are:

1. Neck, back and shoulder pain.
2. Cramps, pressure points and poor circulation in the legs especially lower part and buttocks.
3. Cold, tension and spasms.
4. An increased chance of lower back injury.
5. Long term potential for degeneration of spinal discs

All of these happen because lack of body activity during sitting and keeping it in the same position for an extended period of time Only massaging and relaxing the muscles will help the blood circulation to flow properly as to reduce the pain.[1][7] Besides that for those who are quite rich can buy the car massaging seat which is in the market but the installation work is quite hard and it can't be remove easily even if we want to clean it. The massager that are in the market also do not provide the thermal conductor which is one of the basic element in massaging

1.3 Objectives & Scope Of Study

The main objective of this project is to construct a Portable Thermal Massaging Pad. It is limited to the mechanical components which the roller and motor especially for the massager part. The second part is the thermal conductor which will be use as to produce heat and the final part is the electronic components like relay, transistor, switches and several type of other component. Massager can be brought and can be used anywhere as long as there is a power source.

CHAPTER 2

LITERATURE REVIEW

2.1 Ergonomic Problems

A research was done regarding the problem that people usually faced while sitting. According to the research, most of people say that they feel pains on their neck and back while sitting for a long period especially for those who are working in front of the computer. This problem occurs because of the amount of stress and the unbalance body temperature beside the less body activity.[2][7] For those people who are using computer for a long period might feel tired faster compared to others because of the radiation caused by the screen. Besides that the seat also contribute to the problem, this is because seating is a styling element, so a good design may be sacrificed as to freshen up the look of a seat and make it more marketable.[3]

For the drivers, whole body vibration is also one of the problem according to Health Safety and Environment which lead to the muscle cramp and back pain.[3] Hazardous exposure to whole-body vibration can be found in various forms including driving off-road too fast or over a rough route, and driving on badly-paved highways in vehicles with poor suspension. While a vehicle is in motion, the body is subject to different forces which to accelerations and decelerations, to lateral swaying from side to side, and to whole-body up and down vibrations.[4]

Human figure actually need wide space to fit in and suppose to move freely most of the time. While driving, the activity of the body is very limited to the usage of the foot where one on the gas pedal and the other on the break pedal. But the upper part of the body just stay at the same place most of the time especially during long distance journey. Less activity of the body could cause a problem to the blood flow and muscle cramp. Because of the limited space in the vehicle, driver can not do so many things as to relieve their body. So they need a gadget that can massage their body as to reduce the pain and can be installed easily with existing power source.

2.2 Massage

Massage is a healing practice that has been performed for thousands of years in many cultures. Touching is a natural human reaction to pain and stress, and for conveying compassion and support. As to relieve the pain and all the cramps while driving is by massaging the affected area. Massage is the activity of applying certain amount of pressure on the body as to relieve the affected area and reduce pain. By massaging our body at certain place, it can cure the pain and prevent the area from major injury or be affected by our daily activities.

Massage or massage therapy maybe accomplished manually by using the movement, superficial heat or cold, electric or mechanical device, water, lubricant or salt.[1]

Pressure that can be applied during the massaging treatment according to Pressure law states that pressure applied is equal to force applied on the massaging area divided by area of the surface.[10]

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} \qquad \text{Force} = \text{Mass} \times \text{Gravity}$$

The force applied during the massaging treatment is according to the Newton Second Law of motion and the gravity, pressure applied is related to the weight of the masseur.

There are many health benefits that people can get from massaging rather than cure the pain like it can relieve stress, encourages relaxation, improves blood circulation and posture. In addition good massaging treatment also can help to reduce blood pressure, improves flexibility, breathing, and relieves tension. [1]

From the internet to see whether there is any new massaging equipment in the market are found to be expensive and just emphasize on the pleasure massaging rather than to treat the muscles pain. According to the research most of the equipment just applies a certain rate of pressure to the user so as to relieve their body without thermal treatment.

If we consider the cool climate country, a simple massage application does not look very effective to the user in order to de-stress their body.

2.3 Thermal Application

Thermal is one of the basic elements which is so important during massaging. It is an ancient technique and always been used as to stimulate the healing process, balance the body's energies, and induce deep relaxation. By combining the thermal with massaging, it will enhance blood circulation, and can be used to benefit injury healing, pain management, and relaxation in specific muscles.[1] Because of that the traditional Malay masseur always put some oil on people body while massaging and sometimes use the hot stone as to supply heat to the body.

Basically there are many ways to produce heat for example by the chemical reaction from the usage of the massage oil, but if we are going to use a device or substance as to supply heat to the body, we must follow the heat transfer law because the heat energy source can not directly been contact to human body because it might harm the human epidermis. So the only way is to use something which can keep the heat energy first then supply it to the body for example the heating stone.

According to the heat transfer law, the amount of heat energy transfer depends on the type of the material, the surface area, conduction temperature and the thickness of the material.

$$q = \frac{-kA}{dx} (T2-T1)$$

where:

q= Amount of heat
k=Constant of the material
A=Area of the surface
x= Thickness of the material
T= Temperature

2.4 Existing Massager

There are a lot of massager in the market nowadays so as to treat muscle cramp and body aches. Some of them work by using battery, electric application and also been made in the rigid form like bid matt. But according to the research that had been made, most of it does not give such a good result and not so effective.

Bead mat is one of the famous massager device which has been used especially in the car. It is usually been placed on the upper side of the seat. From the medical point of view, the bead mat work by using the acupuncture theory. The beads on the mat will press our back when we lied on it but not all of the bead will act on our body. This application seems not so effective for those who are suffering of major back aches where the bead did not reach the lower back part.

The other type of massager which is famous among the rich people in the market nowadays is the massaging chair and in this case we just want to focus on the portable massaging chair which can be used in the car. The Massaging chair is quite expensive but the result meet the satisfaction. The massaging scope cover all area near the back bone and the amount of pressure been applied is also depend on the user weight. This type of chair use the motor with roller ball which will move up and down in its path gear and will press our body while it moves.[5]

Figure 1 Massaging Chair

This application is very nice and can satisfy all users but it is very expensive. Besides that this chair seems not so effective when it been used in the cold climate country because the temperature of the body must be about 38C then only the massaging result can take place.[6] It is because the flow of the blood need to be considered while massaging, that's why people usually use massaging oil while massaging.[6]

The main cause of muscle cramp while driving is because the blood flow system in the body is not stable and always stuck because some parts of the body stay at the same place and not be move.[6] So the way to treat this kind of problem is by first improving the blood flow by increasing the temperature on the affected area then only massaging treatment can take place. This sequence can give more effective result on the user. As to do that we need to combine the massaging treatment together with the thermal application on the massaging chair. But the amount of temperature also need to be controlled so that it might not harm the human epidermis.

2.5 Muscle Cramp

There are a lots of factors that lead to the muscle cramp like the affected area stay at the same place for a long time or extra pressure been applied to it constantly in long duration.[8] Basically people take this problem for granted but when we get older then only the problem easily effect our body.[6]

The problem actually happens because there is an obstacle that disturbs the blood flow. Blood is a fluid which flows in the nerve and carries oxygen together with it.[1] When the blood flow has been disturb, the affected area didn't receive enough amount of oxygen and it will affect the whole area. The first thing that might happen is we will feel numb for a minute then it will get better after the pressure has been removed. But this phenomena is not the same to the senior people. This is because their blood circulation and flow is not so good and sometimes its getting slower.

Our body part needs oxygen same as when we need to take a breath. There is a case where there is a person whose hand had been tied at the back for about 2 days then his hand can't be used anymore. This is because his hand is dead already where the blood and oxygen can't go through it anymore. The cell in his hand is dead because the amount of oxygen received is not enough and it's getting worst hours by hours.

CHAPTER 3

METHODOLOGY

3.1 Procedure and Identification

The work flow is as below:

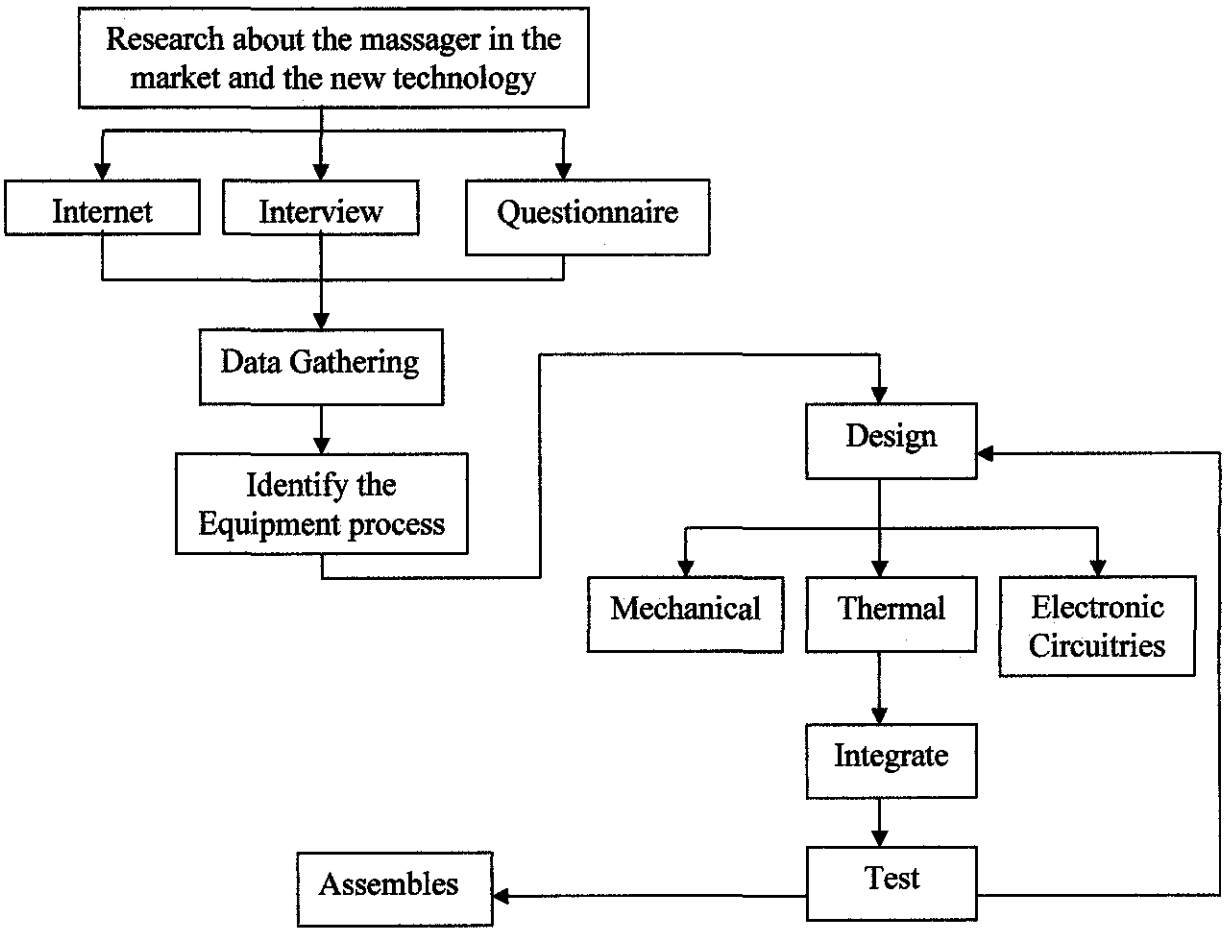


Figure 2 Flow Chart

Figure 2 shows the work flow for the project. During the process, research on the suitable component will be conducted to choose the best device for the prototype.

3.2 Hardware/ Tools and Software

Choosing the suitable hardware and efficient software is very essential in creating a project. The software has been downloaded in the computer. To bring up the quality of the project, the hardware ware carefully chosen, more research on the massager and the heating element had been done

Below are the lists of software and hardware used for this project:

Table 1 List of software that been used

Software	Function / Use
PSPICE	Design schematic diagram
Borland C++	Program the PIC chip
Microsoft Office	Write reports & data documentation
Proteus	Circuit Design
Microsoft Visio	Hardware Drawing

Table 2 List of hardware needed

Electronic Motor	Crystal Oscillator	Rubber Ball
Heating Element	Capacitor	Vibrator
Cushion	Resistor	Gears
Multi-core Wire	Voltage Regulator	Wires
PIC 16F84A	BJT	Diodes
Relay	Switch	Perspex

CHAPTER 4

RESULT AND DISCUSSION

4.1 Result

4.1.1 *The Pressure*

Massage is the activity of applying certain amount of pressure on the body so as to relieve the affected area and reduce pain. By massaging our body at certain place, it can cure the pain and prevent the area from major injury. The amount of the pressure applied during massaging need to be considered because it might harm the body part if the excess pressure applied.

According to the pressure law, pressure applies equal to the force divided with the area[10].

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} \qquad \text{Force} = \text{Mass} \times \text{Gravity}$$

In this case, if the area of the equipment which will be contact to the body is too small so it might also harm the human body and the user might feel uncomfortable. Referring to the pressure law again, we know that the amount of force to be applied must be taken into consideration.

There area several types of massager that can be used, but each of it need to be consider because different type of massager produce different amount of pressure for example if we are using a roller ball base massager, the amount of pressure is not so high compared to the narrow shape metal.

By examining the massager, the amount of Force applied actually follow the Newton 3rd Law that:

> If two objects interact, the force F_{12} exerted by object 1 on object 2 is equal in magnitude but opposite in direction for force F_{21} [10]

Calculation:

Below is the calculation to find the amount of net force acting on the user body which has been reflected by the massager. In the calculation, the amount of upper part of the body has been consider as 50% of the total body weight and it's been divided into 2 parts the left and the right each about 25%.

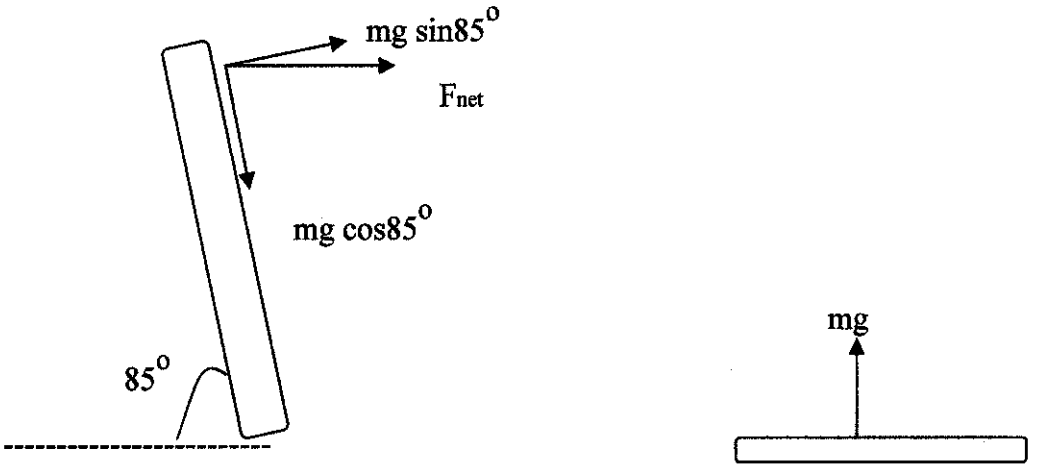
The calculation had been made for a person from 50kg to 100kg and the results and shown in Table 3.

The Force

Weight: 50kg

Degree of the Back seat= 85^{o}

Gravity= 9.81 ms^{-1}



Back Seat Bottom Seat

Figure 3 Seat Force Illustrations

Net Force Acting for Back Seat part:

$F_{net} = ((mg \cos 85^{o})^2 + (mg \sin 85^{o})^2)^{1/2}$

Net Force Acting for Bottom Seat part:

$F_{net} = mg$

The Pressure applied

The amount of pressure applied during massaging depends on the force and the area of the massager. For this project, the massager is in a round shape with a radius of 4cm.

Area of the Massaging part = $\prod$ x r^2

Where: Radius r = 0.04m

So Area= 3.1415 x $(0.04)^2$

= 5.026×10^{-3} m^2

Pressure = Force / Area

The Result for the Seat at 85^0

Table 3 Pressure Result Table for Seat at 85^0

Weight(kg)	25% of weight (kg)	mg sin85	mg cos85	Fnet (N)	Pressure(Nm-2)
50	12.50	122.16	10.69	122.63	0.616
55	13.75	134.37	11.76	134.88	0.678
60	15.00	146.59	12.82	147.15	0.740
65	16.25	158.81	13.89	159.42	0.801
70	17.50	171.02	14.96	171.67	0.863
75	18.75	183.24	16.03	183.94	0.924
80	20.00	195.45	17.10	196.20	0.986
85	21.25	207.67	18.17	208.46	1.048
90	22.50	219.89	19.24	220.73	1.109
95	23.75	232.10	20.31	232.99	1.171
100	25.00	244.32	21.37	245.25	1.233

From the result it shows that when the amount of weight of the user is increased, the amount of pressure applied to the massaging part is also increased.

4.1.2 *Heat Transfer*

Normally human body temperature can range from 36.1°C to 37.8 °C.[9] For the application of heat transfer using the thermal massaging pad, the temperature range is between 40^0 C to 60^0 C .[6]

The amount of heat will increase continuously when the current flow through the conductor. It is hard to control the heat by using the sensor, so the only practical way to control it is by setting the duration of the current flow during the conduction. The relay will act as the switch where when the control system been programmed to let the relay make a contact with the terminal for 5 seconds it will make a contact with the terminal then after 5 seconds the connection will end and the cycle will restart back after some delay.

It is intended to keep the driver's body temperature to increase about from 2°C to 5°C. This is due to the fact that to achieve therapeutic effect, the body tissue must be at least 38°C to 42°C.[6] Only then will the blood flow increase to the heated area.

$$Q = mc\,dT$$

Where

Q = Amount of heat been transfer

m = Mass of the heating element

c = Heat Capacity per mole

dT = Different of Temperature between applied area

Table 4 Material Comparison

Materials	Zinc	Nickel-Cadmium	Copper
Density, $g \cdot cm^{-3}$	7.14	1.49	8.96
Melting Point	692.68K, 419.53 °C	845.32 K, 572.17 °C	1357.77 K, 1084.62 °C
Heat Capacity, $J \cdot mol^{-1} \cdot K^{-1}$	23.390	24.310	24.440
Thermal Conductivity, $W \cdot m^{-1} \cdot K^{-1}$	116	313	401
Cost (USD) / pound	1.3830	1.2010	3.3090

In the final stages, **Nickel-Cadmium** was chosen as the heating element.

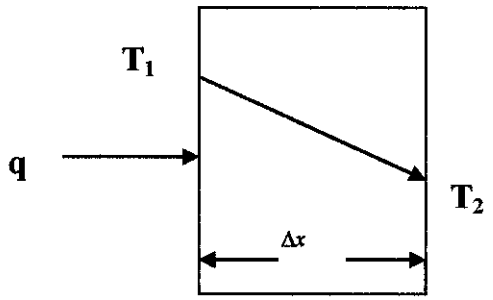
Reasons:

- Since the project is based on the characteristics of cost-saving, nickel-cadmium is the most inexpensive metal that can be used, but still provides the same efficiency as the other metals.
- It has a moderate thermal conductivity, which enables it to conduct heat effectively.
- It has a moderate heat capacity, which means that it needs only a small amount of energy to increase its temperature per mole.
- It is the lightest metal amongst the three (3) based on the density property, thus enabling the massaging pad to be mobile.

It has a moderate melting point, which prevents it from melting when a significant amount of heat is passed through it.

The equation that is used in determining the heat transfer from the solenoid through the seat coat and on to the user's back.

Basically, assuming an amount of heat q is transferred through a plane wall with thickness x, with T_1 and T_2 for the high and low temperatures respectively, as shown below,



The heat transfer rate through this wall is given by equation below As stated before, the k value will depend on the type of materials being used. The equation can also be written as,

$$q = -\frac{kA}{\Delta x}(T_2 - T_1)$$

- The negative sign shows that the heat flows from the higher to the lower point.
- By substituting the values of k, A, T_1, T_2 and Δx, the value of q can be calculated. The term of (Δx/kA) is also known as thermal resistance.

However, since the thermal resistance, (Δx/kA) is unknown, we used a simpler method which is just to measure the temperature of the solenoid (T_1) and the temperature of the outer surface of the seat coat (T_2) which comes into contact with the user's back. This is how we determine the suitable setting for the temperature controller.

The temperature settings are:

1. Low = 40°C (T_1), ±42 °C (T_2).
2. Medium = 50°C (T_1), ±52 °C (T_2).
3. High = 60°C (T_1), ±62 °C (T_2).

4.1.3 *Design*

4.1.3.1 *The Circuit*

Below are the initial circuit which has been designed. The circuit has been designed for the usage of 12V DC power supply in the car.

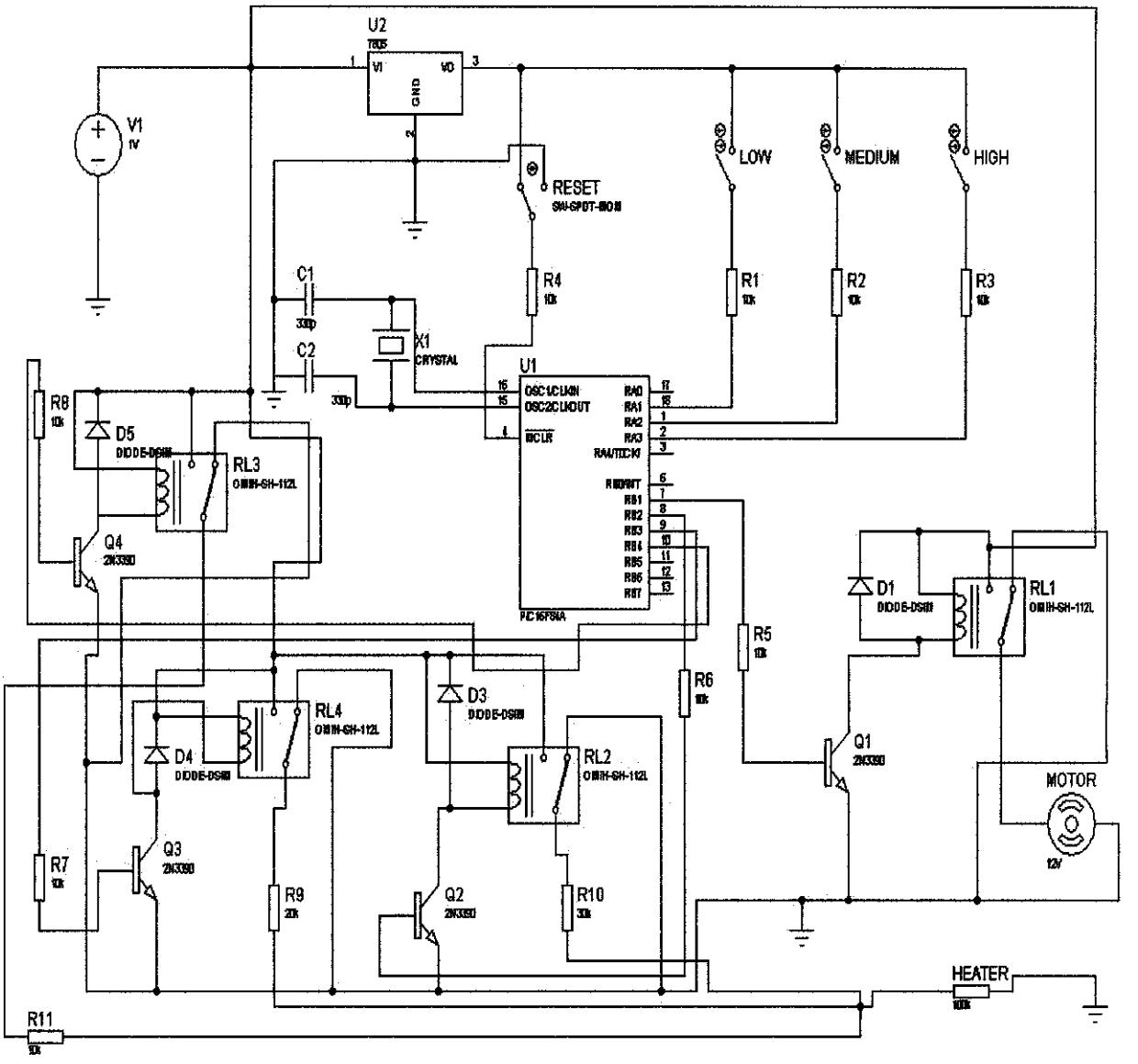


Figure 4 Circuit Design

4.1.3.1.1 *Circuit Mechanism*

Input Part

1. To activate the PIC 16F84A chip, we need to apply 5V but now we have the 12V voltage input so we need the Voltage Regulator to change from 12 to 5V.
2. Now we use the PIC chip as the controller of the relay especially for the heater part. So the purpose of the Crystal Oscillator is to form a set of timer during the process.
3. There are 3 modes of switches provided which are Low, Medium and High. Each switch will perform the same process but in the different duration of time.
4. When the switch has been ON, the 5V of voltage will be detected by the respective port at the PIC and the signal will be processed according to the program.

Output Part

1. After the PIC read the command it will send a signal to the BJT in sense of bits which will allowed the amount of current to go through it and activate the relay.
2. The switch inside the relay will move from its common point to the active point where the 12V of voltage will go through it and flow into the Heater. After the setting duration, the switch will return back to the common point for a short period and will keep rotating.
3. For the motor part, there are 3 relays which will perform the same process but in this situation the relay will continue moving until the RESET button been press.
4. The speed for the motor depend on the resistance attach to its connection. The resistive will reduce the speed of the motor.
5. When the RESET button had been activated all process will be terminated at the instant.

4.1.3.2 *Seat Design*

Below is the design of the seat when the outer layer of it had been removed. The illustration shows the combination of the gear together with the rotation equipment and the placement of all massager components.

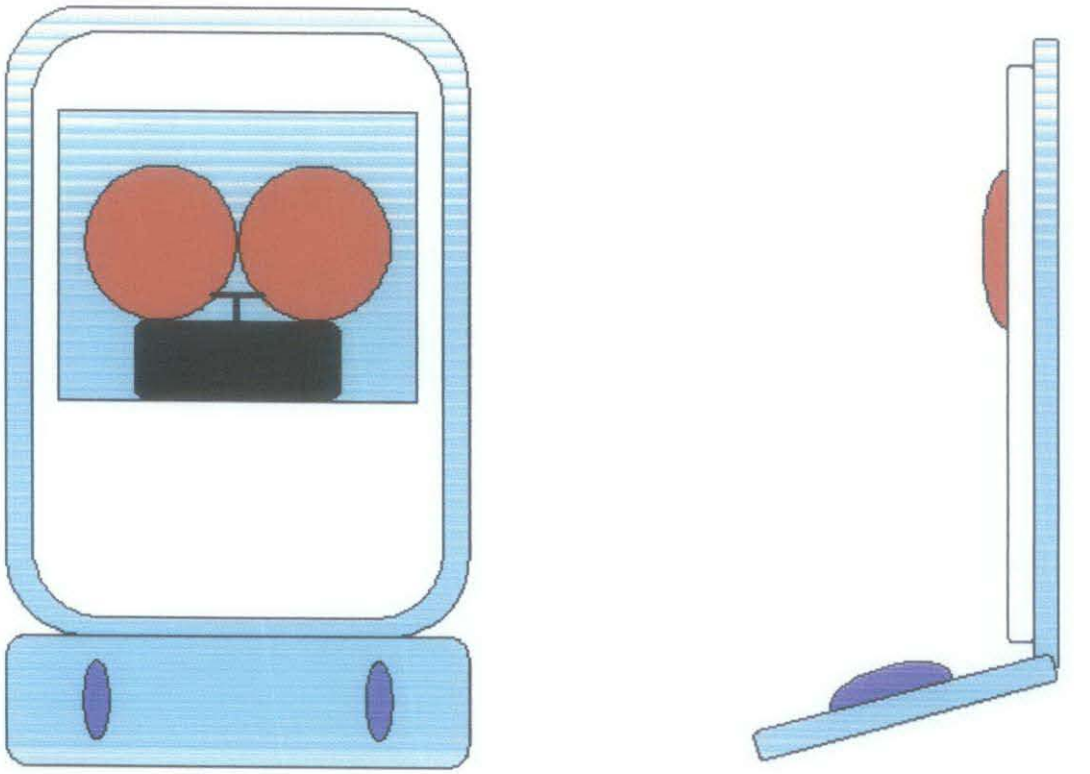


Figure 5 Seat Design

4.1.3.3 *The Massager Design*

This is the design of the massager. It consists of a thermal conductor in the middle of the massager and 4 rubber ball rollers. The rubber balls will move in a circular motion when the gear is moving. It will rub the user body a long the back bone area. The amount of pressure to be applied on the user body depends on the pressure applied on the car seat by the human weight. This is because this massager is a rigid object which does not changes and can reflect.

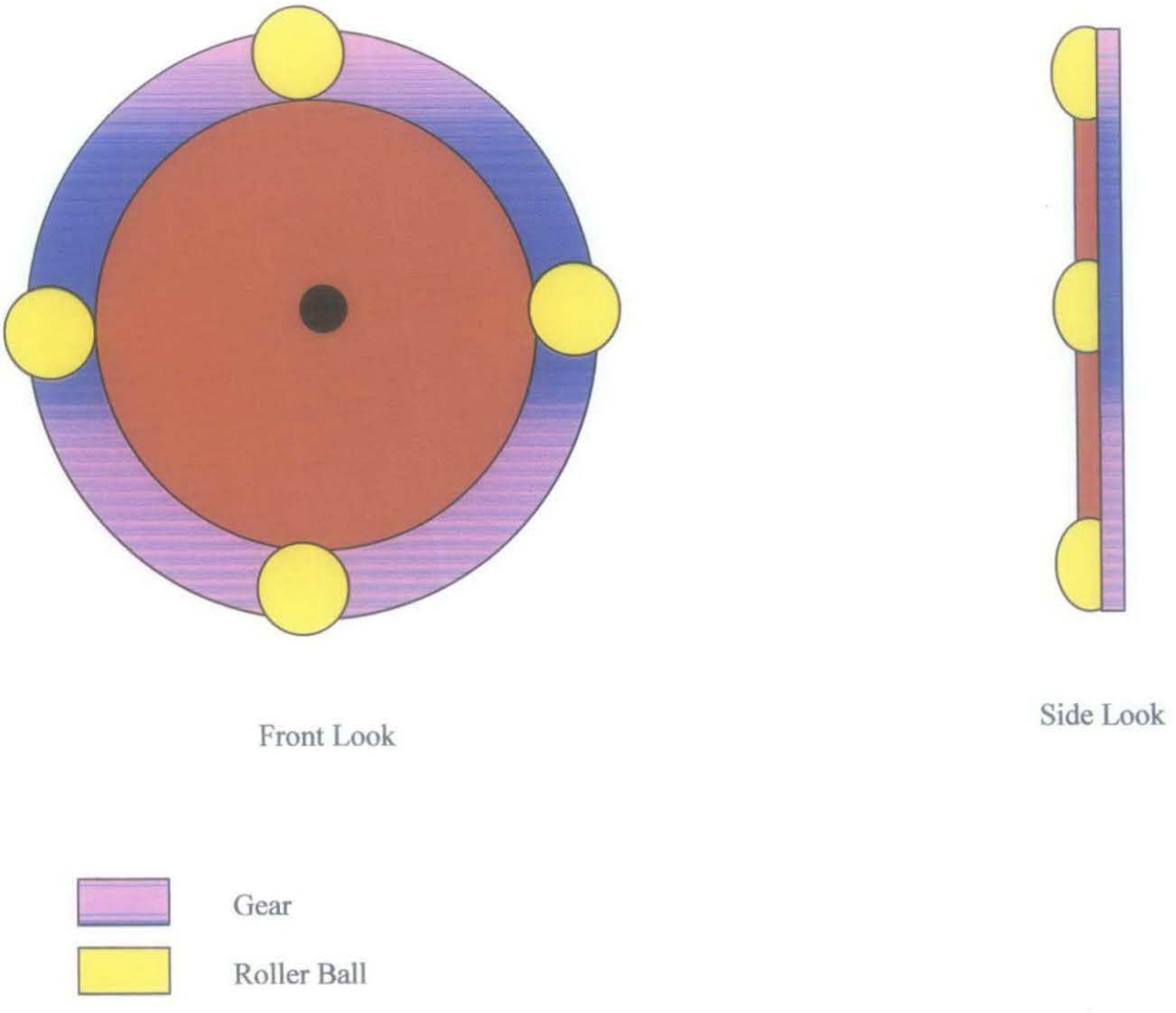
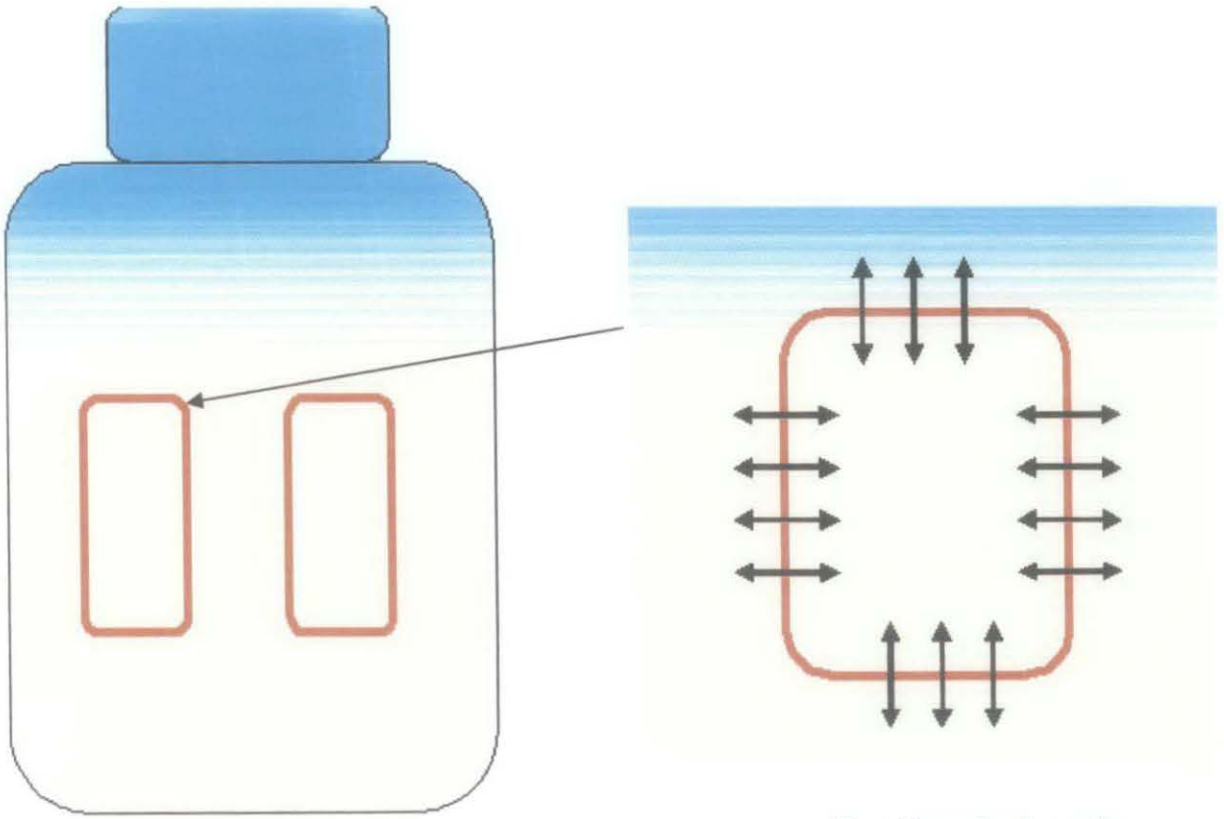


Figure 6 Massager Design

4.1.3.4 *The attachment of the Heating Element*

The heating element is one of the most important thing in this project. It will produce the heat while massaging treatment takes place. For this project, the Nickel Chrome wire had been selected as the heating element because of the amount of heat that can be produce, the behavior of the element that can stand in high temperature and can produce and release heat in short period.

The best place to put the element is under the front outer layer, because the amount of heat can easily transfers to the user. The placement of the heater need to be strategically place at both sides beside the back bone because that is the place that pain always occurs.



Heat Transfer from the element

Figure 7 Heating Element implementation

4.1.3.5 *Full Set Installation Design*

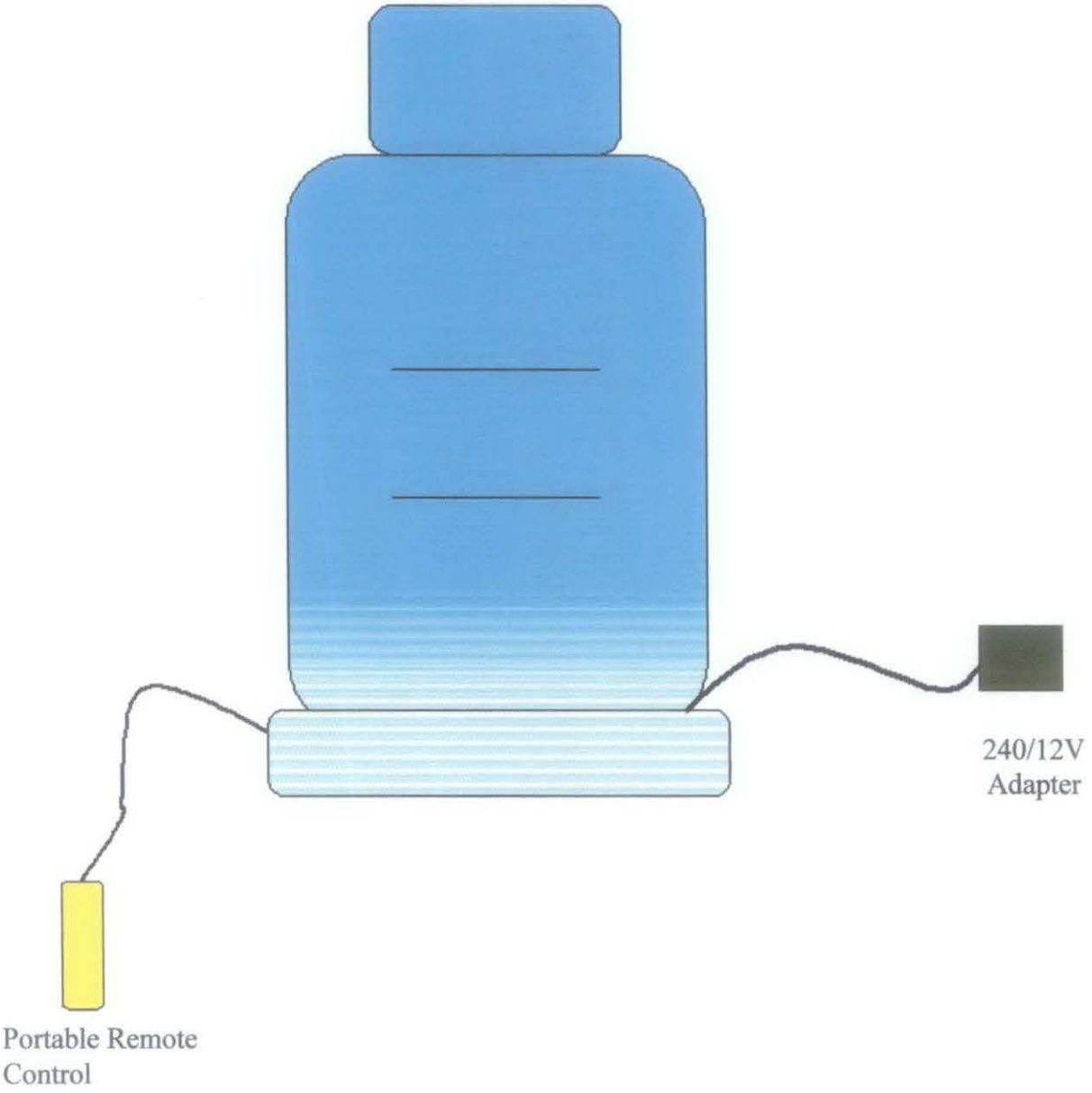


Figure 8 Full Set Installation Design

4.1.4 Cost Estimation

Table 5 The Cost Estimation of Entire Items

Item	Quantity	Price RM(each)	Total RM
Electronic Motor	1	60.00	60.00
Heating Element	3	11.50	34.50
Cushion	1	21.70	21.70
Multi-core Wire	3	1.00	3.00
PIC 16F84A	1	3.00	3.00
Relay	4	0.80	3.20
Crystal Oscillator	1	0.50	0.50
Capacitor	2	0.60	1.20
Resistor	14	0.30	4.20
Voltage Regulator	1	1.20	1.20
BJT	4	1.80	7.20
Switch	3	1.30	3.90
Rubber Ball	6	1.50	9.00
Vibrator	2	9.00	18.00
Gears	2	4.00	8.00
Diodes	4	0.40	1.60
Perspex	1	25.00	25.00
		Total RM	205.20

4.2 Discussion

The amount of pressure that is going to effect the human body depends on their own body weight, because the massager that going to be created is basically moving in the circulation flat movement. So it is not pressing the human body but the human body that lies on it will act as an obstacle for it to move.

More over, The Portable Thermal Massaging Pad will be created to function by using 12V DC power supply. The cigarette choke in the car will be used as to supply the power and can supply up to 12V. It can also operate by using the 12V battery but the rechargeable is recommended especially for outdoor and house hold usage.

As to make it portable, the design of the pad will be small, thin and easy to install. The material that can easily transfer the heat are going to be used as the cover layer for the pad which are 60 cm long, 25cm width and 3cm thick.

The massaging pad can also operate under the AC supply conduction (240V), this is because the port for the external power adapter has also been implemented in this design and the user just need to attach the adapter to it and adjust the voltage. Portable Massaging Pad is designed in accordance to the ergonomic of the driver as to give comfort to them.

4.2.1 Expected Voltage

Below are the expected voltage that will activate the output which are the Heater and the Motor. All of the expected output will be produced based on the program that will be executed.

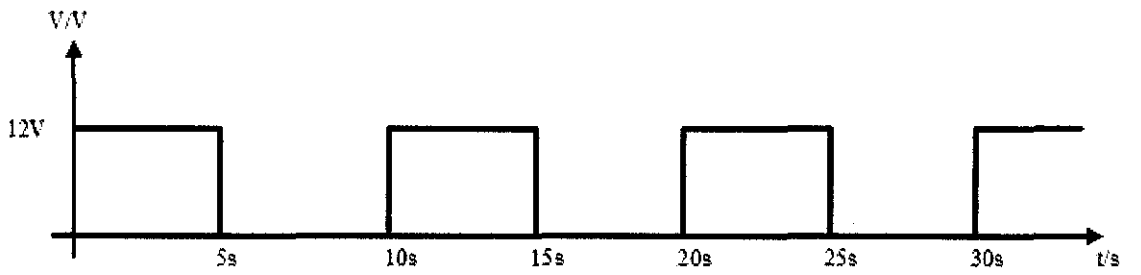


Figure 9 Voltage for Heater at Low mode

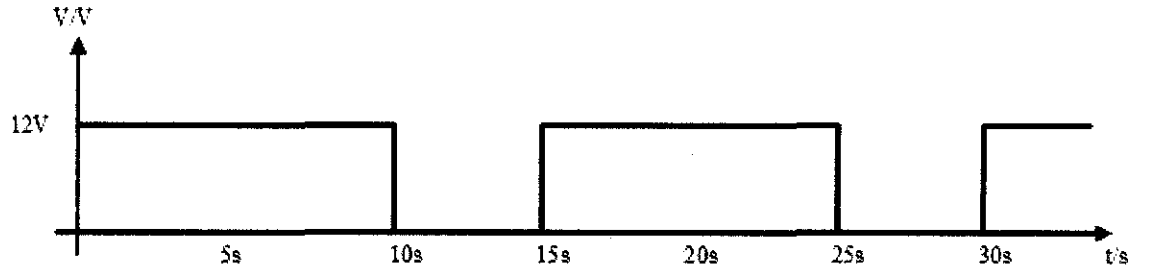


Figure 10 Voltage for Heater at Medium mode

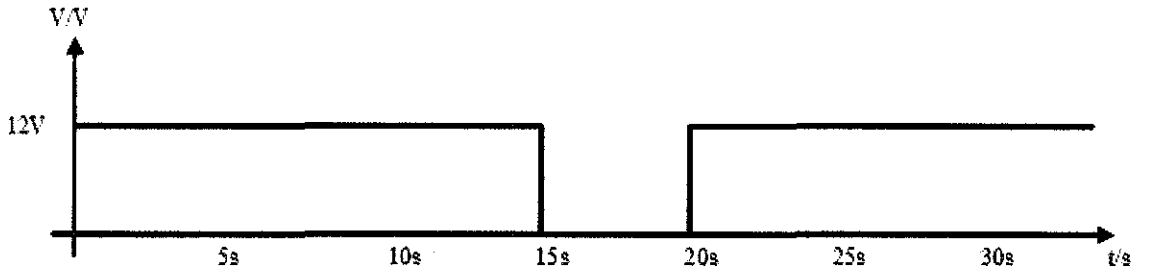


Figure 11 Voltage for Heater at High mode

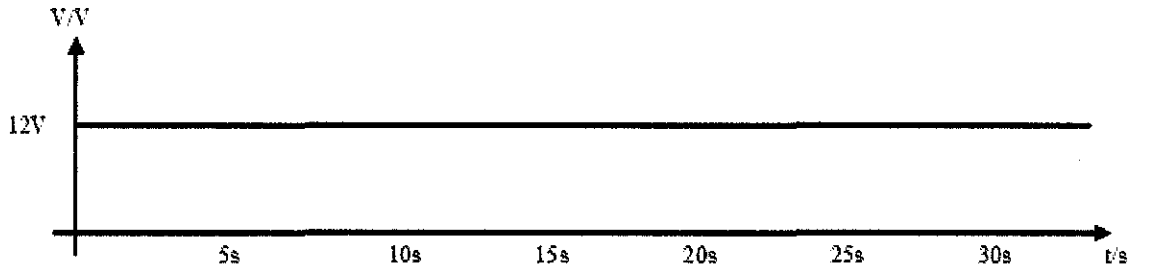


Figure 12 Voltage for Motor at Low, Medium & High

Explanations:

The voltages for Heater for Low, Medium and High mode are not be applied continuously constant because of the heater behavior itself. This is because if the heater is heating continuously for a period of time, the temperature will rise rapidly and it will be dangerous to the user.

The Heater is actually a high resistance resistor where when current try to flow through it, the resistance will act like an obstacle and it will produce heat. So if the heater keep producing heat without any observation it can damage the users epidermis.

The amount of voltage needed for Motor is actually constant because the Motor needs 12V to work. To control the speed of the motor, attach the resistor to it so that the current can be reduced.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

A project call Portable Thermal Massaging Pad for Automobile User is constructed as to treat muscle cramp, coldness and stress that drivers experience especially during long distance traveling.

The combination of massaging treatment together with the thermal conduction using the modern technology is more practical compared to the old version of massager because it emphases on the blood circulation improvement while massaging like the traditional massaging style.

This new innovation is a combination of massaging treatment together with the thermal conduction as to help release the driver's pain while driving and those who are seating for long duration. The design of this prototype is portable, quite compact, ergonomic and easy to be use. It is also recommended for the outdoor and house hold usage because it can also be attached to the AC power supply in the house as long as they have the adapter together.

Recommendation

For further improvement, an adapter will be implemented inside the cushion and the user don't need to buy the external adapter. The control system can be improved so that it can use the wireless remote control.

This innovation also recommended for those traveler who always carried a heavy bag where the massager can be place at the back of the bag as to remedy the back pain that they feel.

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Appendix 1-1

Gantt Chart for Final Year Project 2

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project Work Continue	■	■	■											
2	Submission of Progress Report 1				■										
3	Project Work Continue				■	■	■	■							
4	Submission of Progress Report 2								■						
5	Seminar (compulsory)									■	■	■			
6	Project work continue								■	■	■	■			
7	Poster Exhibition										■				
8	Submission of Dissertation (soft bound)												■		
9	Oral Presentation													■	
10	Submission of Project Dissertation (Hard Bound)														■

■ Process

Computer Programs / Source Codes

This is the all the Programming for those 3 Modes:

```
#include <16F84A.h>
#fuses XT,NOWDT,NOPROTECT,NOPUT
#use delay (clock=4000000)

Void main ()
{
        while(1)
        {
                output_high(PIN_B4);

                if(input(PIN_A1)==1&& input(PIN_A2)==0&& input(PIN_A3)==0)
                        {
                                output_high(PIN_B1);
                        delay_ms(5000);
                                output_low(PIN_B1);
                        delay_ms(5000);

                        }
                elseif(input(PIN_A2)==1&& input(PIN_A1)==0&& input(PIN_A3)==0)
                        {
                                output_high(PIN_B2);
                        delay_ms(10000);
                                output_low(PIN_B2);
                        delay_ms(5000);

                        }

                elseif(input(PIN_A3)==1&& input(PIN_A1)==0&& input(PIN_A2)==0)
                        {
                                output_high(PIN_B3);
                        delay_ms(15000);
                                output_low(PIN_B3);
                        delay_ms(5000);

                        }
                else
                        output_low(PIN_B5);
        }
  }
```

Appendix 3-1

Devices Specifications

Power Window Specification

- Model: ZD-01B
- Working voltage: 12V
- No-load current: Less than 5A
- No-load speed: 80 to 95rpm
- Current (3Nm): Less than 8.2
- Speed (3Nm): Greater than 50rpm
- Maximum torque: Greater than 11Nm
- Block current: Less than 30A
- Standard: ISO9001

Nichrome 80 Wire Specifications:

- Density (weight per cubic inch:) 0.2979 lbs.
- Specific gravity @ 68°F (20°C): 8.247
- Magnetic Attraction: Para
- Thermal conductivity watts/cm/°C @ 100°C (212°F): 0.132
- Approximate melting point: 2462°F (1350°C)
- Maximum operating temp: 1652°F (900°C)

PIC 16F84A Microcontroller Manual

MICROCHIP

PIC16F84A

18-pin *Enhanced* Flash/EEPROM 8-Bit Microcontroller

Devices Included in this Data Sheet:

- PIC16F84A
- Extended voltage range device available (PIC16LF84A)

High Performance RISC CPU Features:

- Only 35 single word instructions to learn
- All instructions single cycle except for program branches which are two-cycle
- Operating speed: DC - 20 MHz clock input
  DC - 200 ns instruction cycle
- 1024 words of program memory
- 68 bytes of data RAM
- 64 bytes of data EEPROM
- 14-bit wide instruction words
- 8-bit wide data bytes
- 15 special function hardware registers
- Eight-level deep hardware stack
- Direct, indirect and relative addressing modes
- Four interrupt sources:
  - External RB0/INT pin
  - TMR0 timer overflow
  - PORTB<7:4> interrupt on change
  - Data EEPROM write complete

Peripheral Features:

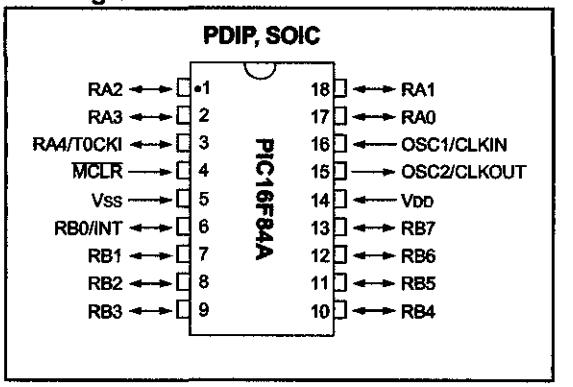
- 13 I/O pins with individual direction control
- High current sink/source for direct LED drive
  - 25 mA sink max. per pin
  - 25 mA source max. per pin
- TMR0: 8-bit timer/counter with 8-bit programmable prescaler

Special Microcontroller Features:

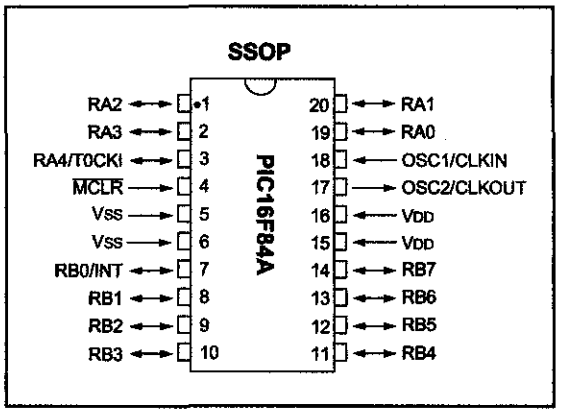
- 1000 erase/write cycles *Enhanced* Flash program memory
- 1,000,000 typical erase/write cycles EEPROM data memory
- EEPROM Data Retention > 40 years
- In-Circuit Serial Programming (ICSP™) - via two pins
- Power-on Reset (POR), Power-up Timer (PWRT), Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Code-protection
- Power saving SLEEP mode
- Selectable oscillator options

Pin Diagrams

PDIP, SOIC



SSOP



CMOS *Enhanced* Flash/EERPOM Technology:

- Low-power, high-speed technology
- Fully static design
- Wide operating voltage range:
  - Commercial: 2.0V to 5.5V
  - Industrial: 2.0V to 5.5V
- Low power consumption:
  - < 2 mA typical @ 5V, 4 MHz
  - 15 µA typical @ 2V, 32 kHz
  - < 0.5 µA typical standby current @ 2V

Table of Contents

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1.0 DEVICE OVERVIEW

This document contains device-specific information for the operation of the PIC16F84A device. Additional information may be found in the PICmicro™ Mid-Range Reference Manual, (DS33023), which may be downloaded from the Microchip website. The Reference Manual should be considered a complementary document to this data sheet, and is highly recommended reading for a better understanding of the device architecture and operation of the peripheral modules.

The PIC16F84A belongs to the mid-range family of the PICmicro™ microcontroller devices. A block diagram of the device is shown in Figure 1-1.

The program memory contains 1K words, which translates to 1024 instructions, since each 14-bit program memory word is the same width as each device instruction. The data memory (RAM) contains 68 bytes. Data EEPROM is 64 bytes.

There are also 13 I/O pins that are user-configured on a pin-to-pin basis. Some pins are multiplexed with other device functions. These functions include:

- External interrupt
- Change on PORTB interrupt
- Timer0 clock input

Table 1-1 details the pinout of the device with descriptions and details for each pin.

FIGURE 1-1: PIC16F84A BLOCK DIAGRAM

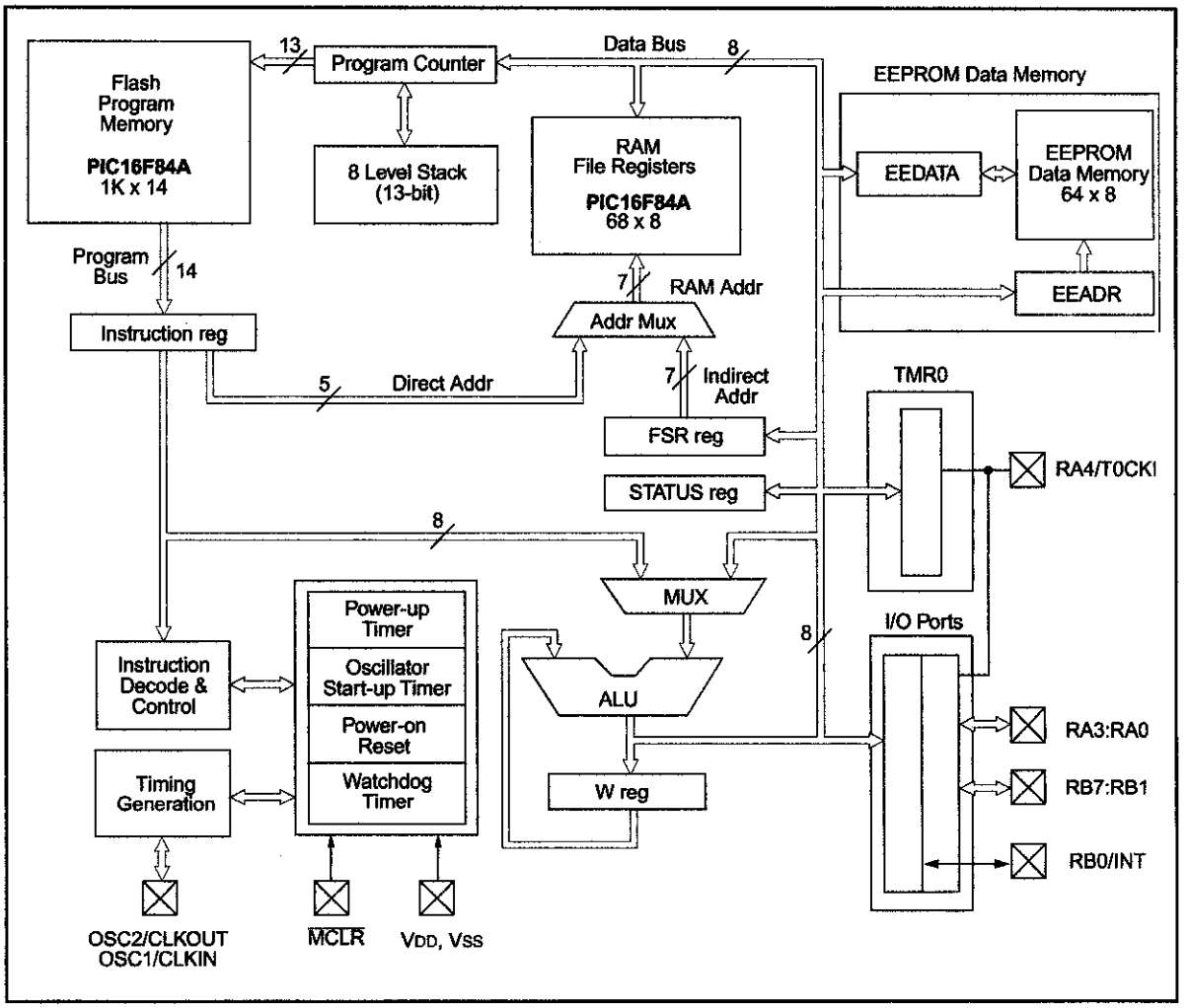


TABLE 1-1 PIC16F84A PINOUT DESCRIPTION

Pin Name	DIP No.	SOIC No.	SSOP No.	I/O/P Type	Buffer Type	Description
OSC1/CLKIN	16	16	18	I	ST/CMOS (3)	Oscillator crystal input/external clock source input.
OSC2/CLKOUT	15	15	19	O	—	Oscillator crystal output. Connects to crystal or resonator in crystal oscillator mode. In RC mode, OSC2 pin outputs CLKOUT which has 1/4 the frequency of OSC1, and denotes the instruction cycle rate.
$\overline{MCLR}$	4	4	4	I/P	ST	Master clear (reset) input/programming voltage input. This pin is an active low reset to the device.
						PORTA is a bi-directional I/O port.
RA0	17	17	19	I/O	TTL	
RA1	18	18	20	I/O	TTL	
RA2	1	1	1	I/O	TTL	
RA3	2	2	2	I/O	TTL	
RA4/T0CKI	3	3	3	I/O	ST	Can also be selected to be the clock input to the TMR0 timer/counter. Output is open drain type.
						PORTB is a bi-directional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs.
RB0/INT	6	6	7	I/O	TTL/ST (1)	RB0/INT can also be selected as an external interrupt pin.
RB1	7	7	8	I/O	TTL	
RB2	8	8	9	I/O	TTL	
RB3	9	9	10	I/O	TTL	
RB4	10	10	11	I/O	TTL	Interrupt on change pin.
RB5	11	11	12	I/O	TTL	Interrupt on change pin.
RB6	12	12	13	I/O	TTL/ST (2)	Interrupt on change pin. Serial programming clock.
RB7	13	13	14	I/O	TTL/ST (2)	Interrupt on change pin. Serial programming data.
VSS	5	5	5,6	P	—	Ground reference for logic and I/O pins.
VDD	14	14	15,16	P	—	Positive supply for logic and I/O pins.

Legend: I= input O = output I/O = Input/Output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.
2: This buffer is a Schmitt Trigger input when used in serial programming mode.
3: This buffer is a Schmitt Trigger input when configured in RC oscillator mode and a CMOS input otherwise.

2.0 MEMORY ORGANIZATION

There are two memory blocks in the PIC16F84A. These are the program memory and the data memory. Each block has its own bus, so that access to each block can occur during the same oscillator cycle.

The data memory can further be broken down into the general purpose RAM and the Special Function Registers (SFRs). The operation of the SFRs that control the "core" are described here. The SFRs used to control the peripheral modules are described in the section discussing each individual peripheral module.

The data memory area also contains the data EEPROM memory. This memory is not directly mapped into the data memory, but is indirectly mapped. That is, an indirect address pointer specifies the address of the data EEPROM memory to read/write. The 64 bytes of data EEPROM memory have the address range 0h-3Fh. More details on the EEPROM memory can be found in Section 5.0.

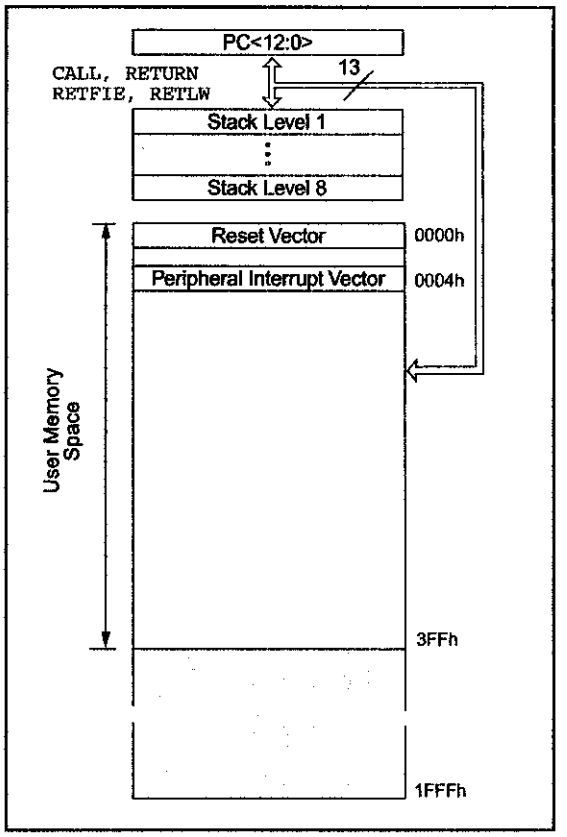
Additional information on device memory may be found in the PICmicro™ Mid-Range Reference Manual, (DS33023).

2.1 Program Memory Organization

The PIC16FXX has a 13-bit program counter capable of addressing an 8K x 14 program memory space. For the PIC16F84A, the first 1K x 14 (0000h-03FFh) are physically implemented (Figure 2-1). Accessing a location above the physically implemented address will cause a wraparound. For example, for locations 20h, 420h, 820h, C20h, 1020h, 1420h, 1820h, and 1C20h will be the same instruction.

The reset vector is at 0000h and the interrupt vector is at 0004h.

FIGURE 2-1: PROGRAM MEMORY MAP AND STACK - PIC16F84A



2.2 Data Memory Organization

The data memory is partitioned into two areas. The first is the Special Function Registers (SFR) area, while the second is the General Purpose Registers (GPR) area. The SFRs control the operation of the device.

Portions of data memory are banked. This is for both the SFR area and the GPR area. The GPR area is banked to allow greater than 116 bytes of general purpose RAM. The banked areas of the SFR are for the registers that control the peripheral functions. Banking requires the use of control bits for bank selection. These control bits are located in the STATUS Register. Figure 2-1 shows the data memory map organization.

Instructions MOVWF and MOVF can move values from the W register to any location in the register file ("F"), and vice-versa.

The entire data memory can be accessed either directly using the absolute address of each register file or indirectly through the File Select Register (FSR) (Section 2.4). Indirect addressing uses the present value of the RP0 bit for access into the banked areas of data memory.

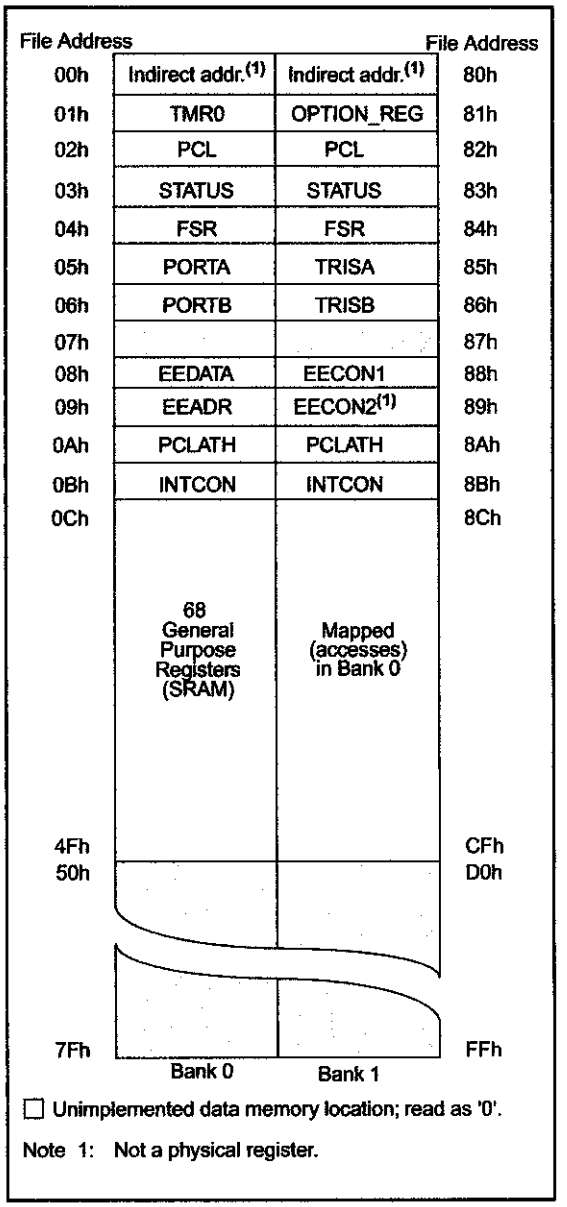
Data memory is partitioned into two banks which contain the general purpose registers and the special function registers. Bank 0 is selected by clearing the RP0 bit (STATUS<5>). Setting the RP0 bit selects Bank 1. Each Bank extends up to 7Fh (128 bytes). The first twelve locations of each Bank are reserved for the Special Function Registers. The remainder are General Purpose Registers implemented as static RAM.

2.2.1 GENERAL PURPOSE REGISTER FILE

Each General Purpose Register (GPR) is 8 bits wide and is accessed either directly or indirectly through the FSR (Section 2.4).

The GPR addresses in bank 1 are mapped to addresses in bank 0. As an example, addressing location 0Ch or 8Ch will access the same GPR.

FIGURE 2-1: REGISTER FILE MAP - PIC16F84A



2.2.2 SPECIAL FUNCTION REGISTERS

The Special Function Registers (Figure 2-1 and Table 2-1) are used by the CPU and Peripheral functions to control the device operation. These registers are static RAM.

The special function registers can be classified into two sets, core and peripheral. Those associated with the core functions are described in this section. Those related to the operation of the peripheral features are described in the section for that specific feature.

TABLE 2-1 REGISTER FILE SUMMARY

Addr	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on Power-on Reset	Value on all other resets (Note3)
Bank 0											
00h	INDF	Uses contents of FSR to address data memory (not a physical register)								---- ----	---- ----
01h	TMR0	8-bit real-time clock/counter								xxxx xxxx	uuuu uuuu
02h	PCL	Low order 8 bits of the Program Counter (PC)								0000 0000	0000 0000
03h	STATUS (2)	IRP	RP1	RP0	$\overline{TO}$	$\overline{PD}$	Z	DC	C	0001 1xxx	000q quuu
04h	FSR	Indirect data memory address pointer 0								xxxx xxxx	uuuu uuuu
05h	PORTA (4)	—	—	—	RA4/T0CKI	RA3	RA2	RA1	RA0	---x xxxx	---u uuuu
06h	PORTB (5)	RB7	RB6	RB5	RB4	RB3	RB2	RB1	RB0/INT	xxxx xxxx	uuuu uuuu
07h		Unimplemented location, read as '0'								---- ----	---- ----
08h	EEDATA	EEPROM data register								xxxx xxxx	uuuu uuuu
09h	EEADR	EEPROM address register								xxxx xxxx	uuuu uuuu
0Ah	PCLATH	—	—	—	Write buffer for upper 5 bits of the PC (1)					---0 0000	---0 0000
0Bh	INTCON	GIE	EEIE	T0IE	INTE	RBIE	T0IF	INTF	RBIF	0000 000x	0000 000u
Bank 1											
80h	INDF	Uses contents of FSR to address data memory (not a physical register)								---- ----	---- ----
81h	OPTION_REG	$\overline{RBPU}$	INTEDG	T0CS	T0SE	PSA	PS2	PS1	PS0	1111 1111	1111 1111
82h	PCL	Low order 8 bits of Program Counter (PC)								0000 0000	0000 0000
83h	STATUS (2)	IRP	RP1	RP0	$\overline{TO}$	$\overline{PD}$	Z	DC	C	0001 1xxx	000q quuu
84h	FSR	Indirect data memory address pointer 0								xxxx xxxx	uuuu uuuu
85h	TRISA	—	—	—	PORTA data direction register					---1 1111	---1 1111
86h	TRISB	PORTB data direction register								1111 1111	1111 1111
87h		Unimplemented location, read as '0'								---- ----	---- ----
88h	EECON1	—	—	—	EEIF	WRERR	WREN	WR	RD	---0 x000	---0 q000
89h	EECON2	EEPROM control register 2 (not a physical register)								---- ----	---- ----
0Ah	PCLATH	—	—	—	Write buffer for upper 5 bits of the PC (1)					---0 0000	---0 0000
0Bh	INTCON	GIE	EEIE	T0IE	INTE	RBIE	T0IF	INTF	RBIF	0000 000x	0000 000u

Legend: x = unknown, u = unchanged, - = unimplemented read as '0', q = value depends on condition.

Note 1: The upper byte of the program counter is not directly accessible. PCLATH is a slave register for PC<12:8>. The contents of PCLATH can be transferred to the upper byte of the program counter, but the contents of PC<12:8> is never transferred to PCLATH.

2: The $\overline{TO}$ and $\overline{PD}$ status bits in the STATUS register are not affected by a $\overline{MCLR}$ reset.

3: Other (non power-up) resets include: external reset through $\overline{MCLR}$ and the Watchdog Timer Reset.

4: On any device reset, these pins are configured as inputs.

5: This is the value that will be in the port output latch.

2.2.2.1 STATUS REGISTER

The STATUS register contains the arithmetic status of the ALU, the RESET status and the bank select bit for data memory.

As with any register, the STATUS register can be the destination for any instruction. If the STATUS register is the destination for an instruction that affects the Z, DC or C bits, then the write to these three bits is disabled. These bits are set or cleared according to device logic. Furthermore, the $\overline{TO}$ and $\overline{PD}$ bits are not writable. Therefore, the result of an instruction with the STATUS register as destination may be different than intended.

For example, CLRF STATUS will clear the upper-three bits and set the Z bit. This leaves the STATUS register as 000u uluu (where u = unchanged).

Only the BCF, BSF, SWAPF and MOVWF instructions should be used to alter the STATUS register (Table 7-2) because these instructions do not affect any status bit.

Note 1: The IRP and RP1 bits (STATUS<7:6>) are not used by the PIC16F84A and should be programmed as cleared. Use of these bits as general purpose R/W bits is NOT recommended, since this may affect upward compatibility with future products.

Note 2: The C and DC bits operate as a $\overline{borrow}$ and digit borrow out bit, respectively, in subtraction. See the SUBLW and SUBWF instructions for examples.

Note 3: When the STATUS register is the destination for an instruction that affects the Z, DC or C bits, then the write to these three bits is disabled. The specified bit(s) will be updated according to device logic

FIGURE 2-1: STATUS REGISTER (ADDRESS 03h, 83h)

R/W-0	R/W-0	R/W-0	R-1	R-1	R/W-x	R/W-x	R/W-x
IRP	RP1	RP0	$\overline{TO}$	$\overline{PD}$	Z	DC	C
bit7							bit0

R = Readable bit
W = Writable bit
U = Unimplemented bit, read as '0'
- n = Value at POR reset

bit 7: **IRP**: Register Bank Select bit (used for indirect addressing)
The IRP bit is not used by the PIC16F84A. IRP should be maintained clear.

bit 6-5: **RP1:RP0**: Register Bank Select bits (used for direct addressing)
00 = Bank 0 (00h - 7Fh)
01 = Bank 1 (80h - FFh)
Each bank is 128 bytes. Only bit RP0 is used by the PIC16F84A. RP1 should be maintained clear.

bit 4: $\overline{TO}$: Time-out bit
1 = After power-up, CLRWDT instruction, or SLEEP instruction
0 = A WDT time-out occurred

bit 3: $\overline{PD}$: Power-down bit
1 = After power-up or by the CLRWDT instruction
0 = By execution of the SLEEP instruction

bit 2: **Z**: Zero bit
1 = The result of an arithmetic or logic operation is zero
0 = The result of an arithmetic or logic operation is not zero

bit 1: **DC**: Digit carry/$\overline{borrow}$ bit (for ADDWF and ADDLW instructions) (For $\overline{borrow}$ the polarity is reversed)
1 = A carry-out from the 4th low order bit of the result occurred
0 = No carry-out from the 4th low order bit of the result

bit 0: **C**: Carry/$\overline{borrow}$ bit (for ADDWF and ADDLW instructions)
1 = A carry-out from the most significant bit of the result occurred
0 = No carry-out from the most significant bit of the result occurred
Note: For $\overline{borrow}$ the polarity is reversed. A subtraction is executed by adding the two's complement of the second operand. For rotate (RRF, RLF) instructions, this bit is loaded with either the high or low order bit of the source register.

2.2.2.2 OPTION_REG REGISTER

The OPTION_REG register is a readable and writable register which contains various control bits to configure the TMR0/WDT prescaler, the external INT interrupt, TMR0, and the weak pull-ups on PORTB.

Note:	When the prescaler is assigned to the WDT (PSA = '1'), TMR0 has a 1:1 prescaler assignment.

FIGURE 2-1: OPTION_REG REGISTER (ADDRESS 81h)

R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1
$\overline{\text{RBPU}}$	INTEDG	T0CS	T0SE	PSA	PS2	PS1	PS0
bit7							bit0

R = Readable bit
W = Writable bit
U = Unimplemented bit, read as '0'
- n = Value at POR reset

bit 7: **$\overline{\text{RBPU}}$**: PORTB Pull-up Enable bit
1 = PORTB pull-ups are disabled
0 = PORTB pull-ups are enabled (by individual port latch values)

bit 6: **INTEDG**: Interrupt Edge Select bit
1 = Interrupt on rising edge of RB0/INT pin
0 = Interrupt on falling edge of RB0/INT pin

bit 5: **T0CS**: TMR0 Clock Source Select bit
1 = Transition on RA4/T0CKI pin
0 = Internal instruction cycle clock (CLKOUT)

bit 4: **T0SE**: TMR0 Source Edge Select bit
1 = Increment on high-to-low transition on RA4/T0CKI pin
0 = Increment on low-to-high transition on RA4/T0CKI pin

bit 3: **PSA**: Prescaler Assignment bit
1 = Prescaler assigned to the WDT
0 = Prescaler assigned to TMR0

bit 2-0: **PS2:PS0**: Prescaler Rate Select bits

Bit Value	TMR0 Rate	WDT Rate
000	1 : 2	1 : 1
001	1 : 4	1 : 2
010	1 : 8	1 : 4
011	1 : 16	1 : 8
100	1 : 32	1 : 16
101	1 : 64	1 : 32
110	1 : 128	1 : 64
111	1 : 256	1 : 128

2.2.2.3 INTCON REGISTER

The INTCON register is a readable and writable register which contains the various enable bits for all interrupt sources.

Note: Interrupt flag bits get set when an interrupt condition occurs regardless of the state of its corresponding enable bit or the global enable bit, GIE (INTCON<7>).

FIGURE 2-1: INTCON REGISTER (ADDRESS 0Bh, 8Bh)

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-x
GIE	EEIE	T0IE	INTE	RBIE	T0IF	INTF	RBIF
bit7							bit0

R = Readable bit
W = Writable bit
U = Unimplemented bit, read as '0'
- n = Value at POR reset

bit 7: **GIE:** Global Interrupt Enable bit
1 = Enables all un-masked interrupts
0 = Disables all interrupts

Note: For the operation of the interrupt structure, please refer to Section •.

bit 6: **EEIE:** EE Write Complete Interrupt Enable bit
1 = Enables the EE write complete interrupt
0 = Disables the EE write complete interrupt

bit 5: **T0IE:** TMR0 Overflow Interrupt Enable bit
1 = Enables the TMR0 interrupt
0 = Disables the TMR0 interrupt

bit 4: **INTE:** RB0/INT Interrupt Enable bit
1 = Enables the RB0/INT interrupt
0 = Disables the RB0/INT interrupt

bit 3: **RBIE:** RB Port Change Interrupt Enable bit
1 = Enables the RB port change interrupt
0 = Disables the RB port change interrupt

bit 2: **T0IF:** TMR0 Overflow Interrupt Flag bit
1 = TMR0 has overflowed (must be cleared in software)
0 = TMR0 did not overflow

bit 1: **INTF:** RB0/INT Interrupt Flag bit
1 = The RB0/INT interrupt occurred
0 = The RB0/INT interrupt did not occur

bit 0: **RBIF:** RB Port Change Interrupt Flag bit
1 = When at least one of the RB7:RB4 pins changed state (must be cleared in software)
0 = None of the RB7:RB4 pins have changed state

2.3 PCL and PCLATH

The program counter (PC) specifies the address of the instruction to fetch for execution. The PC is 13 bits wide. The low byte is called the PCL register. This register is readable and writable. The high byte is called the PCH register. This register contains the PC<12:8> bits and is not directly readable or writable. All updates to the PCH register go through the PCLATH register.

2.3.1 STACK

The stack allows a combination of up to 8 program calls and interrupts to occur. The stack contains the return address from this branch in program execution.

Midrange devices have an 8 level deep x 13-bit wide hardware stack. The stack space is not part of either program or data space and the stack pointer is not readable or writable. The PC is PUSHed onto the stack when a CALL instruction is executed or an interrupt causes a branch. The stack is POPed in the event of a RETURN, RETLW or a RETFIE instruction execution. PCLATH is not modified when the stack is PUSHed or POPed.

After the stack has been PUSHed eight times, the ninth push overwrites the value that was stored from the first push. The tenth push overwrites the second push (and so on).

2.4 Indirect Addressing; INDF and FSR Registers

The INDF register is not a physical register. Addressing INDF actually addresses the register whose address is contained in the FSR register (FSR is a *pointer*). This is indirect addressing.

EXAMPLE 2-1: INDIRECT ADDRESSING

- Register file 05 contains the value 10h
- Register file 06 contains the value 0Ah
- Load the value 05 into the FSR register
- A read of the INDF register will return the value of 10h
- Increment the value of the FSR register by one (FSR = 06)
- A read of the INDF register now will return the value of 0Ah.

Reading INDF itself indirectly (FSR = 0) will produce 00h. Writing to the INDF register indirectly results in a no-operation (although STATUS bits may be affected).

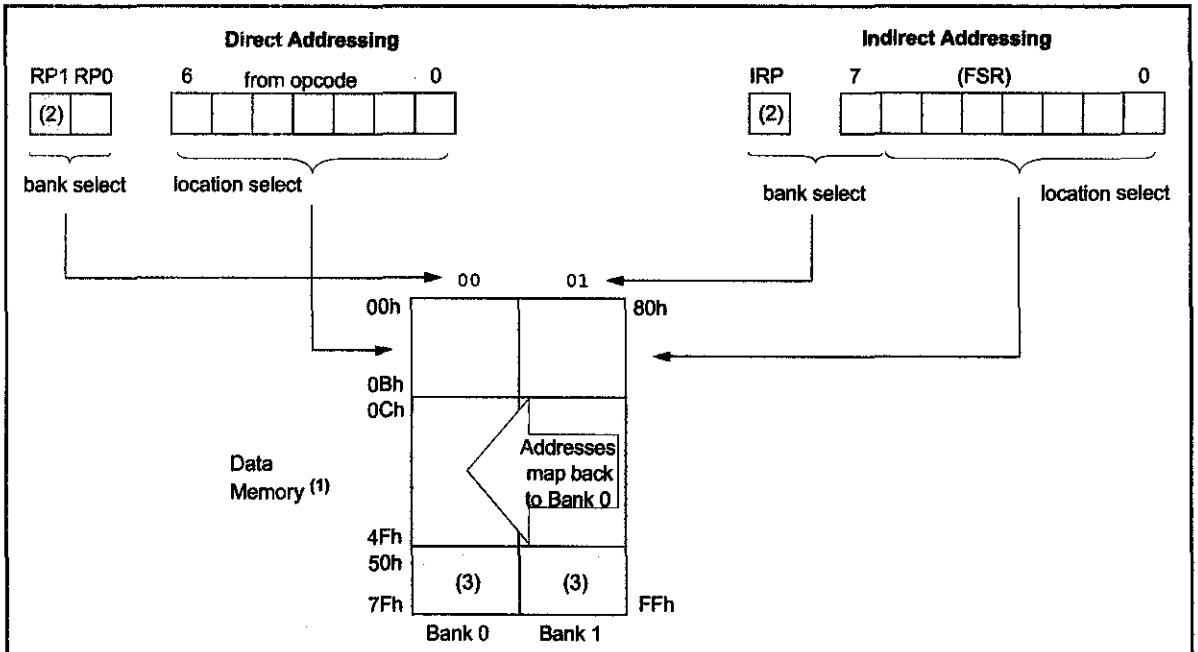
A simple program to clear RAM locations 20h-2Fh using indirect addressing is shown in Example 2-2.

EXAMPLE 2-2: HOW TO CLEAR RAM USING INDIRECT ADDRESSING

```
        movlw   0x20    ;initialize pointer
        movwf   FSR     ;  to RAM
NEXT    clrf    INDF    ;clear INDF register
        incf    FSR     ;inc pointer
        btfss   FSR,4   ;all done?
        goto    NEXT    ;NO, clear next
CONTINUE
        :               ;YES, continue
```

An effective 9-bit address is obtained by concatenating the 8-bit FSR register and the IRP bit (STATUS<7>), as shown in Figure 2-1. However, IRP is not used in the PIC16F84A.

FIGURE 2-1: DIRECT/INDIRECT ADDRESSING



Note 1: For memory map detail see Figure 2-1.
2: Maintain as clear for upward compatiblity with future products.
3: Not implemented.

3.0 I/O PORTS

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

Additional information on I/O ports may be found in the PICmicro™ Mid-Range Reference Manual, (DS33023).

3.1 PORTA and TRISA Registers

PORTA is a 5-bit wide bi-directional port. The corresponding data direction register is TRISA. Setting a TRISA bit (=1) will make the corresponding PORTA pin an input, i.e., put the corresponding output driver in a hi-impedance mode. Clearing a TRISA bit (=0) will make the corresponding PORTA pin an output, i.e., put the contents of the output latch on the selected pin.

Note:	On a Power-on Reset, these pins are configured as inputs and read as '0'.

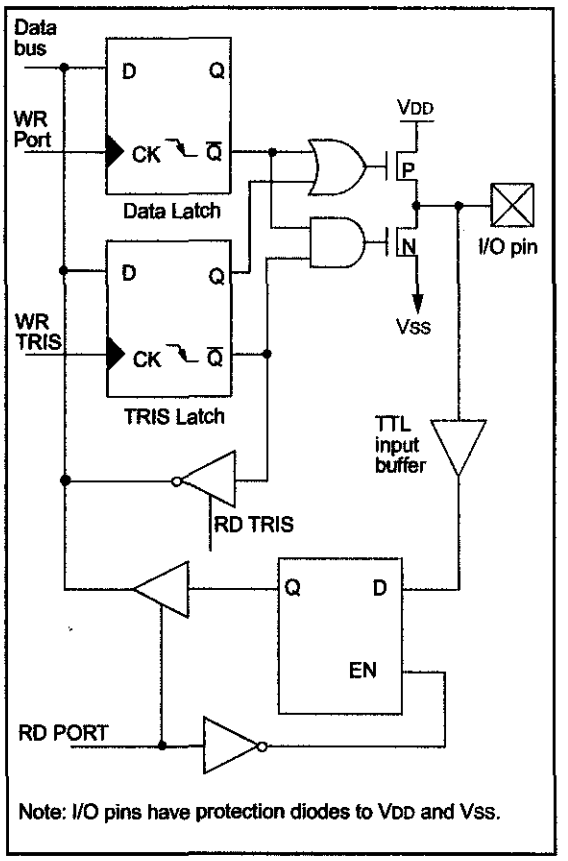
Reading the PORTA register reads the status of the pins whereas writing to it will write to the port latch. All write operations are read-modify-write operations. Therefore a write to a port implies that the port pins are read, this value is modified, and then written to the port data latch.

Pin RA4 is multiplexed with the Timer0 module clock input to become the RA4/T0CKI pin. The RA4/T0CKI pin is a Schmitt Trigger input and an open drain output. All other RA port pins have TTL input levels and full CMOS output drivers.

EXAMPLE 3-1: INITIALIZING PORTA

```
BCF     STATUS, RP0   ;
CLRF    PORTA         ; Initialize PORTA by
                      ; clearing output
                      ; data latches
BSF     STATUS, RP0   ; Select Bank 1
MOVLW   0x0F          ; Value used to
                      ; initialize data
                      ; direction
MOVWF   TRISA         ; Set RA<3:0> as inputs
                      ; RA4 as output
                      ; TRISA<7:5> are always
                      ; read as '0'.
```

FIGURE 3-1: BLOCK DIAGRAM OF PINS RA3:RA0



Note: I/O pins have protection diodes to VDD and VSS.

FIGURE 3-2: BLOCK DIAGRAM OF PIN RA4

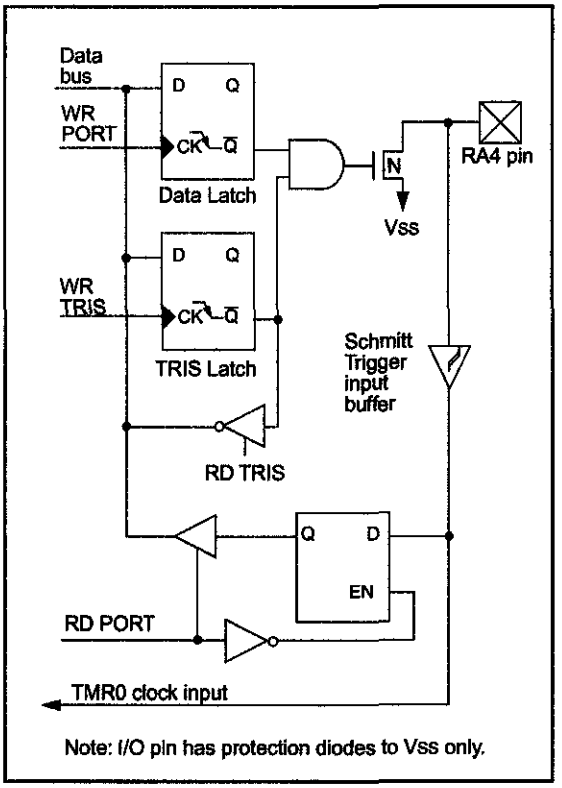


TABLE 3-1 PORTA FUNCTIONS

Name	Bit0	Buffer Type	Function
RA0	bit0	TTL	Input/output
RA1	bit1	TTL	Input/output
RA2	bit2	TTL	Input/output
RA3	bit3	TTL	Input/output
RA4/T0CKI	bit4	ST	Input/output or external clock input for TMR0. Output is open drain type.

Legend: TTL = TTL input, ST = Schmitt Trigger input

TABLE 3-2 SUMMARY OF REGISTERS ASSOCIATED WITH PORTA

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on Power-on Reset	Value on all other resets
05h	PORTA	—	—	—	RA4/T0CKI	RA3	RA2	RA1	RA0	---x xxxx	---u uuuu
85h	TRISA	—	—	—	TRISA4	TRISA3	TRISA2	TRISA1	TRISA0	---1 1111	---1 1111

Legend: x = unknown, u = unchanged, - = unimplemented read as '0'. Shaded cells are unimplemented, read as '0'

3.2 PORTB and TRISB Registers

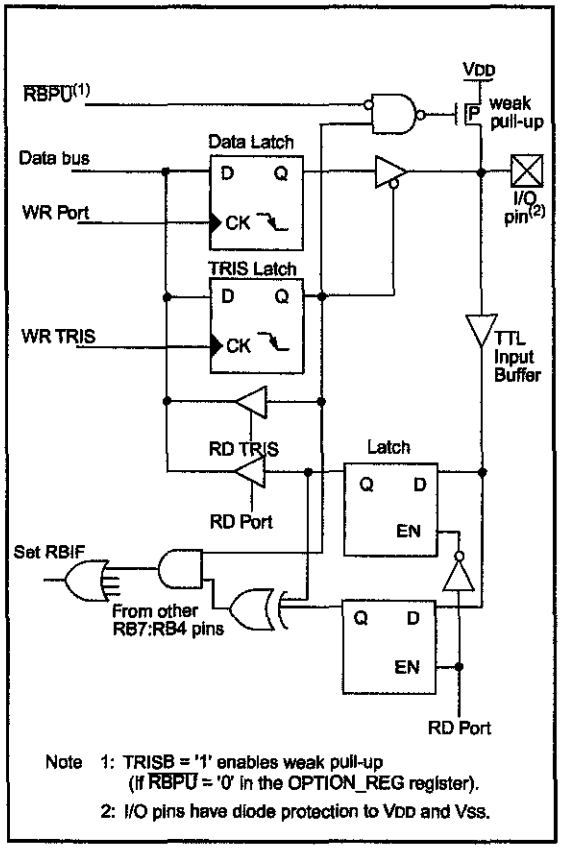
PORTB is an 8-bit wide bi-directional port. The corresponding data direction register is TRISB. Setting a TRISB bit (=1) will make the corresponding PORTB pin an input, i.e., put the corresponding output driver in a hi-impedance mode. Clearing a TRISB bit (=0) will make the corresponding PORTB pin an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

EXAMPLE 3-1: INITIALIZING PORTB

```
BCF     STATUS, RP0  ;
CLRF    PORTB        ; Initialize PORTB by
                     ; clearing output
                     ; data latches
BSF     STATUS, RP0  ; Select Bank 1
MOVLW   0xCF         ; Value used to
                     ; initialize data
                     ; direction
MOVWF   TRISB        ; Set RB<3:0> as inputs
                     ; RB<5:4> as outputs
                     ; RB<7:6> as inputs
```

Each of the PORTB pins has a weak internal pull-up. A single control bit can turn on all the pull-ups. This is performed by clearing bit $\overline{RBPU}$ (OPTION<7>). The weak pull-up is automatically turned off when the port pin is configured as an output. The pull-ups are disabled on a Power-on Reset.

FIGURE 3-3: BLOCK DIAGRAM OF PINS RB7:RB4



Note 1: TRISB = '1' enables weak pull-up (if $\overline{RBPU}$ = '0' in the OPTION_REG register).
2: I/O pins have diode protection to VDD and Vss.

Four of PORTB's pins, RB7:RB4, have an interrupt on change feature. Only pins configured as inputs can cause this interrupt to occur (i.e. any RB7:RB4 pin configured as an output is excluded from the interrupt on change comparison). The input pins (of RB7:RB4) are compared with the old value latched on the last read of PORTB. The "mismatch" outputs of RB7:RB4 are OR'ed together to generate the RB Port Change Interrupt with flag bit RBIF (INTCON<0>).

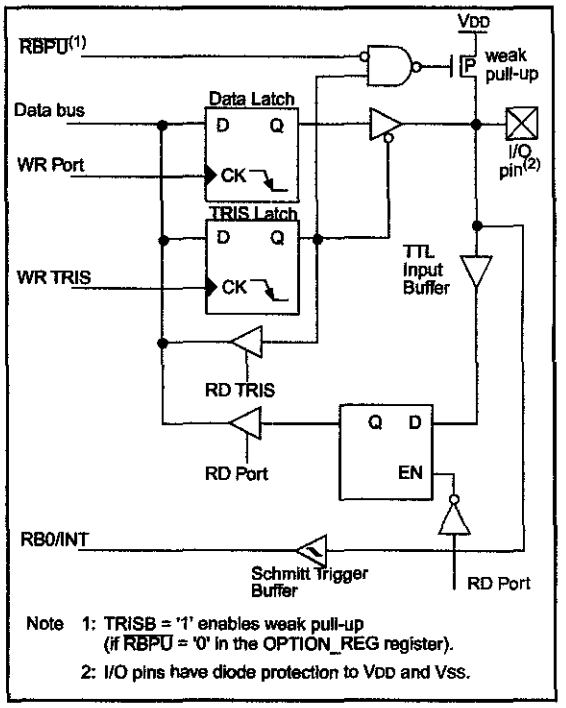
This interrupt can wake the device from SLEEP. The user, in the interrupt service routine, can clear the interrupt in the following manner:

a) Any read or write of PORTB. This will end the mismatch condition.
b) Clear flag bit RBIF.

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

The interrupt on change feature is recommended for wake-up on key depression operation and operations where PORTB is only used for the interrupt on change feature. Polling of PORTB is not recommended while using the interrupt on change feature.

FIGURE 3-4: BLOCK DIAGRAM OF PINS RB3:RB0



Note 1: TRISB = '1' enables weak pull-up (if $\overline{RBPU}$ = '0' in the OPTION_REG register).
2: I/O pins have diode protection to VDD and Vss.

TABLE 3-3 PORTB FUNCTIONS

Name	Bit	Buffer Type	I/O Consistency Function
RB0/INT	bit0	TTL/ST(1)	Input/output pin or external interrupt input. Internal software programmable weak pull-up.
RB1	bit1	TTL	Input/output pin. Internal software programmable weak pull-up.
RB2	bit2	TTL	Input/output pin. Internal software programmable weak pull-up.
RB3	bit3	TTL	Input/output pin. Internal software programmable weak pull-up.
RB4	bit4	TTL	Input/output pin (with interrupt on change). Internal software programmable weak pull-up.
RB5	bit5	TTL	Input/output pin (with interrupt on change). Internal software programmable weak pull-up.
RB6	bit6	TTL/ST(2)	Input/output pin (with interrupt on change). Internal software programmable weak pull-up. Serial programming clock.
RB7	bit7	TTL/ST(2)	Input/output pin (with interrupt on change). Internal software programmable weak pull-up. Serial programming data.

Legend: TTL = TTL input, ST = Schmitt Trigger.

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

2: This buffer is a Schmitt Trigger input when used in serial programming mode.

TABLE 3-4 SUMMARY OF REGISTERS ASSOCIATED WITH PORTB

Addr	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on Power-on Reset	Value on all other resets
06h	PORTB	RB7	RB6	RB5	RB4	RB3	RB2	RB1	RB0/INT	xxxx xxxx	uuuu uuuu
86h	TRISB	TRISB7	TRISB6	TRISB5	TRISB4	TRISB3	TRISB2	TRISB1	TRISB0	1111 1111	1111 1111
81h	OPTION_REG	$\overline{RBPU}$	INTEDG	T0CS	T0SE	PSA	PS2	PS1	PS0	1111 1111	1111 1111

Legend: x = unknown, u = unchanged. Shaded cells are not used by PORTB.

4.0 TIMER0 MODULE

The Timer0 module timer/counter has the following features:

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

Figure 4-1 is a simplified block diagram of the Timer0 module.

Additional information on timer modules is available in the PICmicro™ Mid-Range Reference Manual, (DS33023).

4.1 Timer0 Operation

Timer0 can operate as a timer or as a counter.

Timer mode is selected by clearing bit T0CS (OPTION_REG<5>). In timer mode, the Timer0 module will increment every instruction cycle (without prescaler). If the TMR0 register is written, the increment is inhibited for the following two instruction cycles. The user can work around this by writing an adjusted value to the TMR0 register.

Counter mode is selected by setting bit T0CS (OPTION_REG<5>). In counter mode, Timer0 will increment either on every rising or falling edge of pin RA4/T0CKI. The incrementing edge is determined by the Timer0 Source Edge Select bit T0SE (OPTION_REG<4>). Clearing bit T0SE selects the rising edge. Restrictions on the external clock input are discussed below.

When an external clock input is used for Timer0, it must meet certain requirements. The requirements ensure the external clock can be synchronized with the internal phase clock (Tosc). Also, there is a delay in the actual incrementing of Timer0 after synchronization.

Additional information on external clock requirements is available in the PICmicro™ Mid-Range Reference Manual, (DS33023).

4.2 Prescaler

An 8-bit counter is available as a prescaler for the Timer0 module, or as a postscaler for the Watchdog Timer, respectively (Figure 4-2). For simplicity, this counter is being referred to as "prescaler" throughout this data sheet. Note that there is only one prescaler available which is mutually exclusively shared between the Timer0 module and the Watchdog Timer. Thus, a prescaler assignment for the Timer0 module means that there is no prescaler for the Watchdog Timer, and vice-versa.

The prescaler is not readable or writable.

The PSA and PS2:PS0 bits (OPTION_REG<3:0>) determine the prescaler assignment and prescale ratio.

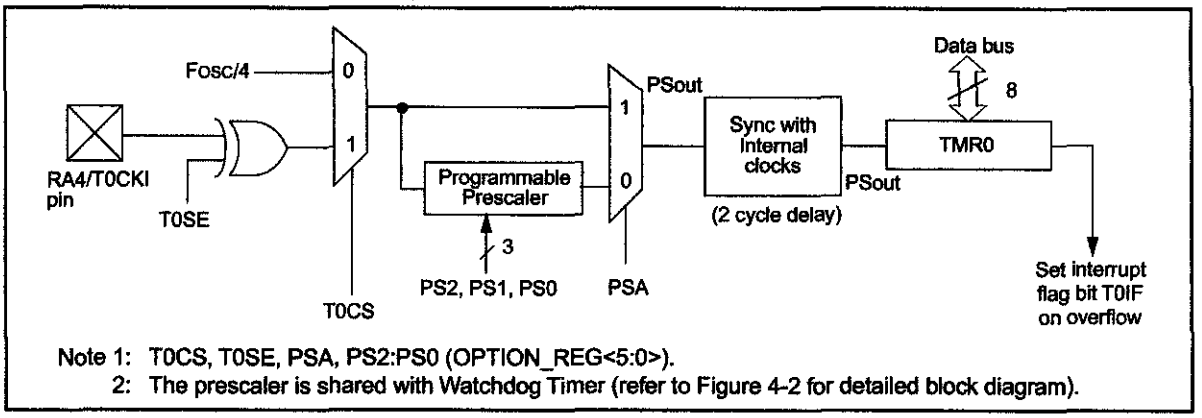
Clearing bit PSA will assign the prescaler to the Timer0 module. When the prescaler is assigned to the Timer0 module, prescale values of 1:2, 1:4, ..., 1:256 are selectable.

Setting bit PSA will assign the prescaler to the Watchdog Timer (WDT). When the prescaler is assigned to the WDT, prescale values of 1:1, 1:2, ..., 1:128 are selectable.

When assigned to the Timer0 module, all instructions writing to the TMR0 register (e.g. `CLRF 1`, `MOVWF 1`, `BSF 1,x`....etc.) will clear the prescaler. When assigned to WDT, a `CLRWDT` instruction will clear the prescaler along with the WDT.

Note:	Writing to TMR0 when the prescaler is assigned to Timer0 will clear the prescaler count, but will not change the prescaler assignment.

FIGURE 4-1: TIMER0 BLOCK DIAGRAM



Note 1: T0CS, T0SE, PSA, PS2:PS0 (OPTION_REG<5:0>).
2: The prescaler is shared with Watchdog Timer (refer to Figure 4-2 for detailed block diagram).

4.2.1 SWITCHING PRESCALER ASSIGNMENT

The prescaler assignment is fully under software control, i.e., it can be changed "on the fly" during program execution.

Note:	To avoid an unintended device RESET, a specific instruction sequence (shown in the PICmicro™ Mid-Range Reference Manual, DS3023) must be executed when changing the prescaler assignment from Timer0 to the WDT. This sequence must be followed even if the WDT is disabled.

4.3 Timer0 Interrupt

The TMR0 interrupt is generated when the TMR0 register overflows from FFh to 00h. This overflow sets bit T0IF (INTCON<2>). The interrupt can be masked by clearing bit T0IE (INTCON<5>). Bit T0IF must be cleared in software by the Timer0 module interrupt service routine before re-enabling this interrupt. The TMR0 interrupt cannot awaken the processor from SLEEP since the timer is shut off during SLEEP.

FIGURE 4-2: BLOCK DIAGRAM OF THE TIMER0/WDT PRESCALER

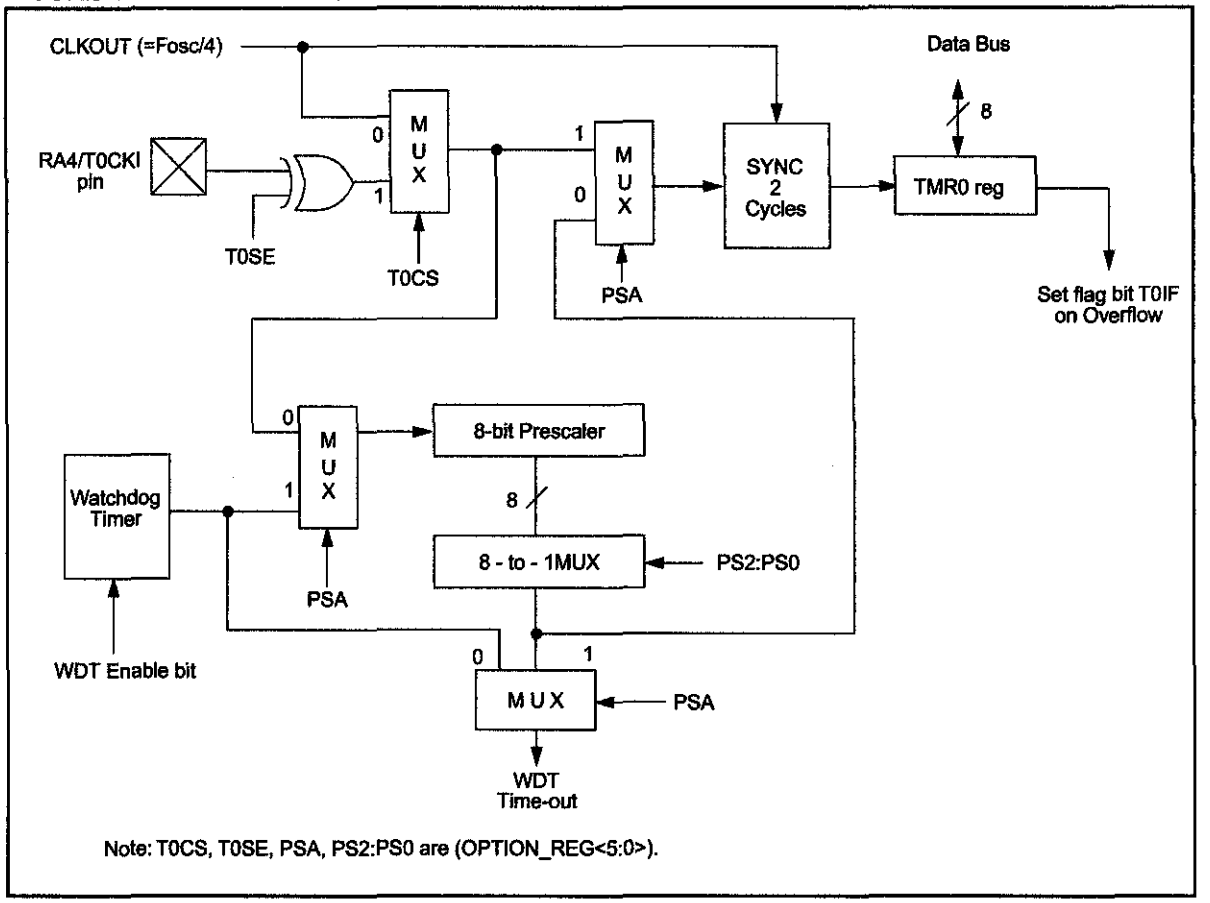


TABLE 4-1 REGISTERS ASSOCIATED WITH TIMER0

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on POR, BOR	Value on all other resets
01h	TMR0	Timer0 module's register								xxxx xxxx	uuuu uuuu
0Bh,8Bh	INTCON	GIE	PEIE	T0IE	INTE	RBIE	T0IF	INTF	RBIF	0000 000x	0000 000u
81h	OPTION_REG	RBPU	INTEDG	T0CS	T0SE	PSA	PS2	PS1	PS0	1111 1111	1111 1111
85h	TRISA	—	—	PORTA Data Direction Register						--11 1111	--11 1111

Legend: x = unknown, u = unchanged, - = unimplemented locations read as '0'. Shaded cells are not used by Timer0.

5.0 DATA EEPROM MEMORY

The EEPROM data memory is readable and writable during normal operation (full VDD range). This memory is not directly mapped in the register file space. Instead it is indirectly addressed through the Special Function Registers. There are four SFRs used to read and write this memory. These registers are:

- EECON1
- EECON2 (Not a physically implemented register)
- EEDATA
- EEADR

EEDATA holds the 8-bit data for read/write, and EEADR holds the address of the EEPROM location being accessed. PIC16F84A devices have 64 bytes of data EEPROM with an address range from 0h to 3Fh.

The EEPROM data memory allows byte read and write. A byte write automatically erases the location and writes the new data (erase before write). The EEPROM data memory is rated for high erase/write cycles. The write time is controlled by an on-chip timer. The write-time will vary with voltage and temperature as well as from chip to chip. Please refer to AC specifications for exact limits.

When the device is code protected, the CPU may continue to read and write the data EEPROM memory. The device programmer can no longer access this memory.

Additional information on the Data EEPROM is available in the PICmicro™ Mid-Range Reference Manual, (DS33023).

FIGURE 5-1: EECON1 REGISTER (ADDRESS 88h)

U	U	U	R/W-0	R/W-x	R/W-0	R/S-0	R/S-x
—	—	—	EEIF	WRERR	WREN	WR	RD
bit7							bit0

R = Readable bit
W = Writable bit
S = Settable bit
U = Unimplemented bit, read as '0'
- n = Value at POR reset

bit 7:5 **Unimplemented:** Read as '0'

bit 4 **EEIF**: EEPROM Write Operation Interrupt Flag bit
1 = The write operation completed (must be cleared in software)
0 = The write operation is not complete or has not been started

bit 3 **WRERR**: EEPROM Error Flag bit
1 = A write operation is prematurely terminated
(any $\overline{MCLR}$ reset or any WDT reset during normal operation)
0 = The write operation completed

bit 2 **WREN**: EEPROM Write Enable bit
1 = Allows write cycles
0 = Inhibits write to the data EEPROM

bit 1 **WR**: Write Control bit
1 = initiates a write cycle. (The bit is cleared by hardware once write is complete. The WR bit can only be set (not cleared) in software.
0 = Write cycle to the data EEPROM is complete

bit 0 **RD**: Read Control bit
1 = Initiates an EEPROM read (read takes one cycle. RD is cleared in hardware. The RD bit can only be set (not cleared) in software).
0 = Does not initiate an EEPROM read

5.1 Reading the EEPROM Data Memory

To read a data memory location, the user must write the address to the EEADR register and then set control bit RD (EECON1<0>). The data is available, in the very next cycle, in the EEDATA register; therefore it can be read in the next instruction. EEDATA will hold this value until another read or until it is written to by the user (during a write operation).

EXAMPLE 5-1: DATA EEPROM READ

```
BCF     STATUS, RP0  ; Bank 0
MOVLW   CONFIG_ADDR  ;
MOVWF   EEADR        ; Address to read
BSF     STATUS, RP0  ; Bank 1
BSF     EECON1, RD   ; EE Read
BCF     STATUS, RP0  ; Bank 0
MOVF    EEDATA, W    ; W = EEDATA
```

5.2 Writing to the EEPROM Data Memory

To write an EEPROM data location, the user must first write the address to the EEADR register and the data to the EEDATA register. Then the user must follow a specific sequence to initiate the write for each byte.

EXAMPLE 5-1: DATA EEPROM WRITE

```
        BSF     STATUS, RP0  ; Bank 1
        BCF     INTCON, GIE  ; Disable INTs.
        BSF     EECON1, WREN ; Enable Write
        MOVLW   55h          ;
Required
Sequence
        MOVWF   EECON2       ; Write 55h
        MOVLW   AAh          ;
        MOVWF   EECON2       ; Write AAh
        BSF     EECON1,WR    ; Set WR bit
                             ;   begin write
        BSF     INTCON, GIE  ; Enable INTs.
```

The write will not initiate if the above sequence is not exactly followed (write 55h to EECON2, write AAh to EECON2, then set WR bit) for each byte. We strongly recommend that interrupts be disabled during this code segment.

Additionally, the WREN bit in EECON1 must be set to enable write. This mechanism prevents accidental writes to data EEPROM due to errant (unexpected) code execution (i.e., lost programs). The user should keep the WREN bit clear at all times, except when updating EEPROM. The WREN bit is not cleared by hardware

After a write sequence has been initiated, clearing the WREN bit will not affect this write cycle. The WR bit will be inhibited from being set unless the WREN bit is set.

At the completion of the write cycle, the WR bit is cleared in hardware and the EE Write Complete Interrupt Flag bit (EEIF) is set. The user can either enable this interrupt or poll this bit. EEIF must be cleared by software.

5.3 Write Verify

Depending on the application, good programming practice may dictate that the value written to the Data EEPROM should be verified (Example 5-1) to the desired value to be written. This should be used in applications where an EEPROM bit will be stressed near the specification limit. The Total Endurance disk will help determine your comfort level.

Generally the EEPROM write failure will be a bit which was written as a '0', but reads back as a '1' (due to leakage off the bit).

EXAMPLE 5-1: WRITE VERIFY

```
    BCF   STATUS, RP0 ; Bank 0
    :                 ; Any code can go here
    :                 ;
    MOVF  EEDATA, W   ; Must be in Bank 0
    BSF   STATUS, RP0 ; Bank 1
READ
    BSF   EECON1, RD  ; YES, Read the
                      ;   value written
    BCF   STATUS, RP0 ; Bank 0
;
; Is the value written (in W reg) and
;   read (in EEDATA) the same?
;
    SUBWF EEDATA, W   ;
    BTFSS STATUS, Z   ; Is difference 0?
    GOTO  WRITE_ERR   ; NO, Write error
    :                 ; YES, Good write
    :                 ; Continue program
```

TABLE 5-1 REGISTERS/BITS ASSOCIATED WITH DATA EEPROM

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on Power-on Reset	Value on all other resets
08h	EEDATA	EEPROM data register								xxxx xxxx	uuuu uuuu
09h	EEADR	EEPROM address register								xxxx xxxx	uuuu uuuu
88h	EECON1	—	—	—	EEIF	WRERR	WREN	WR	RD	---0 x000	---0 q000
89h	EECON2	EEPROM control register 2								---- ----	---- ----

Legend: x = unknown, u = unchanged, - = unimplemented read as '0', q = value depends upon condition. Shaded cells are not used by data EEPROM.

