COOLING STORAGE FOR VEHICLES USING THERMOELECTRIC COOLER

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ELECTRICAL & ELECTRONICS ENGINEERING
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Dissertation submitted in partial fulfilment of
the requirements for the
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CERTIFICATION OF APPROVAL

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

June 2010

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.

MARLIYANA BINTI ABDUL WAHAB

ABSTRACT

There is a need to develop energy efficient cooling system as compared to the conventional electro-mechanical refrigerant liquid/gas evaporation system. Thermoelectric devices have been in use but at a very high cost and could not get market acceptance. This project addresses the above situation and as a further development of the solid state system, it is intended to build a cooler box for use in vehicles. The thermoelectric cooler device used is peltier which follow Peltier Effect Theory that produces heat difference from electrical voltage. The product promises a big market by looking at the growth of automotive market over the years. It can become a convenience consumer durable of choice. Implementing the project involve detailed research in identifying components, material and its availability besides the pricing. Constructing a thermal insulated box could not be under-estimated. It was observed that there is tremendous ground for further development of energy efficient thermo-electronics in a total scenario of a mobile fridge. At this stage the project have created deeper understanding of scientific and engineering properties of material as well as exposure on techniques of information sourcing, besides the challenge in making the electronics work to expectation. It is meant to benefit the general public with a convenient coolbox within reach in their automobiles.

ACKNOWLEDGEMENT

With my sincere appreciation, I would like to express my utmost gratitude to my supervisor, Mrs. Salina binti Mohmad for her continuous help, support, motivation and guidance throughout this project.

My greatest gratitude and appreciation is extended to Dr. Mohd Zuki bin Yusoff especially for the entire efforts and contribution of his ideas in this project, and also for the guidance in CCS-C programming.

I also would like to express my special million of thanks to beloved my parents and sisters who always giving me confidence and continuous support all the way.

Last but not least, thank you to all lecturers and colleagues who had directly and indirectly contributed to this project.

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CHAPTER 1
INTRODUCTION

1.1 Background Of Study

The whole project would start with knowledge gathering and theoretical studies. The project is intended as a further development from past student's project on the same subject and it is intended to achieve freezing temperature of water (0°C) using thermoelectric device.

The first step taken for the project is research on thermal insulation and to identify and select the most ideal material. Base on information gathered, there are few types of insulation material available and will be discussed in forth coming chapter. To achieve the desired result it is necessary to identify materials with better thermal insulation properties.

Revision on the basic heat transfer theory (Thermodynamics) is needed in order to pick the best method and theory. Meanwhile, further research and development would continue to ensure satisfactory results are achieved.

1.2 Problem Statement

Traditional coolers filled with ice will keep your food cool and fresh for a while, but will end up with a sopping wet messy food. With the Cooling Storage Device, it will keep food fresh even on long distance journey.

This device is design based on the space constraints in vehicles. It comes in a small size and is portable.

This device can also store fresh marinated meat (barbeque) beside fruits, drinks and snacks. This is because; the interior temperature will go down to 0°C. This Cooling Storage Device may also keep ice cream solid with ease.

1.3 Objective and Scope of Study

1. To study and understand:
   - Heat transfer theory,
   - Thermoelectric freezer including Peltier effect and Seebeck effect,
   - and Bismuth telluride semiconductor
2. To do research on thermal insulation materials that is good as heat insulator.
3. To implement the theories into practice and build a working prototype
4. To explore possibilities for product design that will have market acceptance.

1.4 Organization of Report

This report is divided into five chapters. This introductory chapter explains about the background of the project, the problem statement, objectives and scope of study.

Chapter 2 is about the literature review. This chapter describes about the types of mini fridge available in the market, types of heat insulator and explanations on the peltier.

Chapter 3 is the methodology. This chapter discuss about the methods used while working on the project. It includes circuit designs, box designs, experimental work and programming.

Chapter 4 represents the result and discussion for the experiments held in order to achieve the desired result

The last chapter concludes on the overall aspect of the project. Some recommendations are stated for improvement in the future.

CHAPTER 2
LITERATURE REVIEW

2.1 Fridge

Fridge is one of the very basic equipment needed for every family and it is for storing fresh food as well as drinks, snacks and fruits. People who travel frequently and on long distance journeys may need a mini fridge in their vehicles to store food. However the types of fridge needed may vary. The manufacturers have come up with various designs to fulfill the demand of the buyers but they are yet to come up with the best solution.

2.2 Types of Portable Thermoelectric Mini Fridge Available in Market

A study is done on products that are already available in the market. It is found that most of the manufactures have come up with 'cold/warm' function. They provide both cooling and can easily be switched over to the heating function. The size is no doubt suitable for vehicles.

Some examples of portable thermoelectric mini fridge are discussed below.

2.2.1 Waeco tropicool bord

This mini fridge is suitable for those who have space constrain in a vehicle because the device comes in a mini size that can be put on the car floor. It uses peltier system. The device has cool and warm mode. It can go up to 20°C below the ambient temperature. The light-weight box (5.2 kg) features a polyurethane foam core.

Figure 1 Waeco Tropicool Bord [1]

2.2.2 Digital mini fridge

The mini fridge as shown in Figure 2 has the temperature display. The temperature can be raised and lowered by the user. It also has interior light using white LED and has adjustable shelf to configure available space.

Figure 2: Digital mini fridge [2]

2.3 Types of Heat Insulator

2.3.1 Polyethylene (PE) foam

PE foam is mainly produced through extrusion technologies. The foams are created by first dissolving and mixing a gas in the molten PE, secondly expanding the gas into a lot of small bubbles or cells and finally cooling the expanded PE and thereby creating the final foam [3].

As a result of the excellent heat insulation, PE foams are used for the insulation of central heating pipes. For the same reason and also for the sound absorption it is used on concrete floors under tiles or parquet floors. Again for it's sound absorption and heat insulation PE foam sheets are used in buildings as roof insulation.

PE foam is extremely water resistant. It also has very low moisture absorption coefficient because it contains only hydrogen and carbon [3].

Figure 3: Polyethylene Foam [3]

2.3.2 Polyurethane foam (PU)

Polyurethane (PU) foam is an important thermal insulating material in which gas with low thermal conductivity is encapsulated. PU foam is endowed with low density, low thermal conductivity, low cost and high strength to weight ratio, all of which make it a useful insulating material in refrigerated vehicles, vessels for refrigerated cargo, pipelines, and cryogenic wind tunnels [4].

A refrigerator cabinet typically comprises, as illustrated in Figure 4 of the drawing, an outer shell (1) and a liner (2) which are spaced from one another, the space between these two components being filled with foamed polyurethane insulation. (3) shows the inner part and (4) shows the space for the peltier [4].

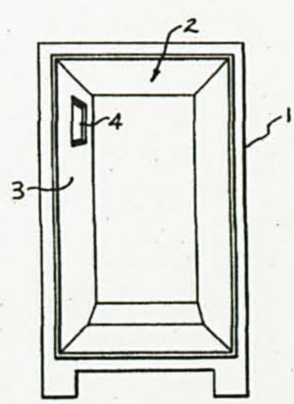

Figure 4: fridge cabinet with polyurethane insulation [5]

2.3.3 *Expanded polystyrene (EPS) foam*

Expanded Polystyrene has many useful properties. It has low thermal conductivity, and therefore can be used as an insulator against heat and cold. It is widely used to package fresh fish and produce, as it is able to help keep food fresh through the distribution chain. It is also used within the pharmaceutical industry to package items that are temperature sensitive, and need to be transported throughout the world [6].

With its high compressive strength, it is excellent at absorbing shocks, and protecting delicate items. As there is no loss of strength in damp conditions, it is ideal for cool-chain products. Being moisture resistant, EPS easily exceeds the most stringent of hygiene requirements [6].

Figure 5: Expanded Polystyrene [6]

2.4 Peltier

2.4.1 Introduction to peltier

A single-stage thermoelectric module or device is typically composed of thermoelectric elements (n- and p- types) that are connected electrically in series and thermally in parallel and sandwiched between two ceramic plates, as shown in Figure 6. The thermoelectric elements are interconnected with electric conductors [7].

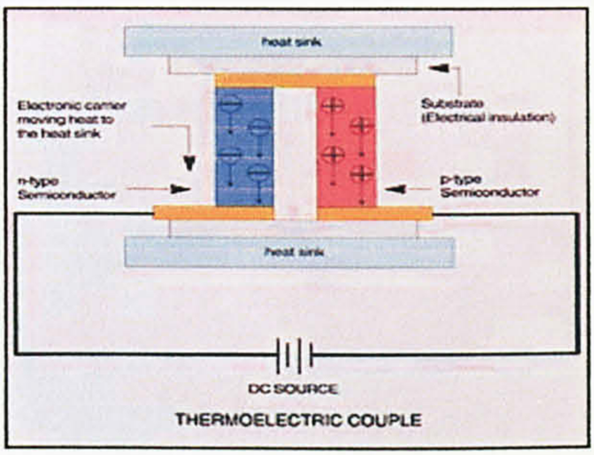

Figure 6: Peltier Effect Process [7]

Approximate Figure-Of-Merit (Z) for Various Te Materials

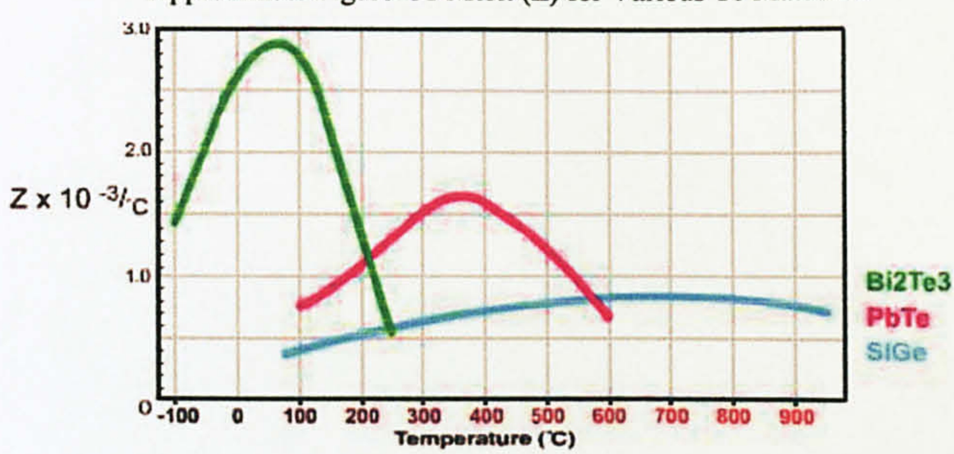

Figure 7: Performance of Thermoelectric Materials at Various Temperatures [8]

It can be seen from the graph in Figure 7 that the performance of Bismuth Telluride (Bi_2Te_3) peaks within a temperature range that is best suited for most cooling applications [8].

Bismuth Telluride and its alloys are the most-common thermoelectric materials used in refrigeration. The ceramic plates form the cold and hot surfaces of the module, providing mechanical integrity and both electrical insulation and thermal conduction to the heat sink and the object to be cooled. The plates are made from alumina but when large lateral heat transfer is required, higher thermal conductivity plates are desired [9].

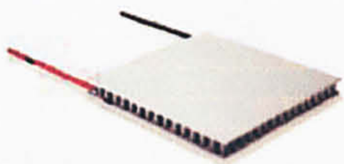

Figure 8: Single stage peltier [10]

When an electric current passed a circuit consisting of dissimilar conductors, the temperature in the vicinity of the junctions changed, that is, the current drove a heat flux from one junction to the other, as shown in Figure 9. This effect is known as "Peltier effect", which is characterized by the peltier coefficient, Π. The Peltier effect representing how much heat current is carried per unit charge current through a given material. Since charge current must be continuous across a junction, the associated heat flow will develop a discontinuity if Π_X and Π_Y are different. The peltier effect is the principle at work behind thermoelectric coolers or refrigerators which are used for transferring heat from one side of the device to the other. Thermoelectric coolers are also called peltier coolers [11].

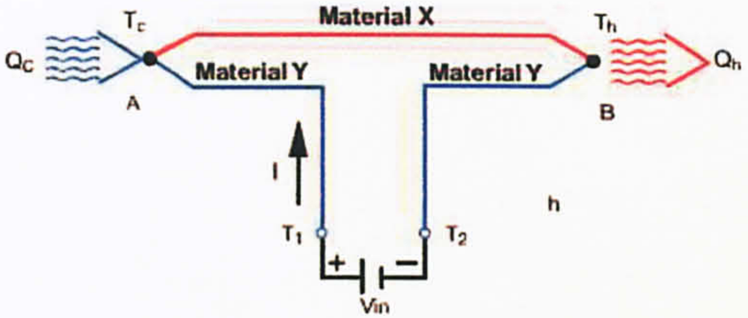

Figure 9 Peltier effect process [11]

2.4.2 Advantages of peltier

Thermoelectric cooling provides many substantial advantages over other cooling technologies, as stated below:

The peltier has no moving parts. It works electrically without any moving parts and virtually maintenance free. Next, it comes in small size and weight compared to other mechanical system. In addition, they come in variety of standard, sizes and configurations available to meet the application requirements. Peltier has the ability to heat and cool with the same module depending on the polarity applied to the DC power. Thus, this component eliminates the necessity of providing separate heating and cooling functions within a given system. Other than that, this feature has precise temperature control which can control temperatures to +/- 0.1°C. Besides that, this thermoelectric module has a very high reliability due to the solid state construction. The life of typical thermoelectric coolers is greater than 200,000 hours. Unlike a mechanical refrigeration system, thermoelectric modules generate virtually no electrical noise and also acoustically silent. Many conventional refrigeration equipment use chlorofluorocarbon gases as refrigerant that may be harmful to the environment. Thermoelectric devices do not use or generate gases of any kind [12].

2.4.3 Disadvantages of the peltier

Beside the advantages of the peltier, this device has low efficiency rating of 6 times worse than the compressor system. The high electricity consumption creates more heat as energy loss than it transports from the cold junction. Heat dissipation and the coolbox insulation become very stringent in the selection and design. Furthermore, the two heat exchangers are close to one another and condensation will lead to short circuit [13].

CHAPTER 3
METHODOLOGY

3.1 Procedure Identification

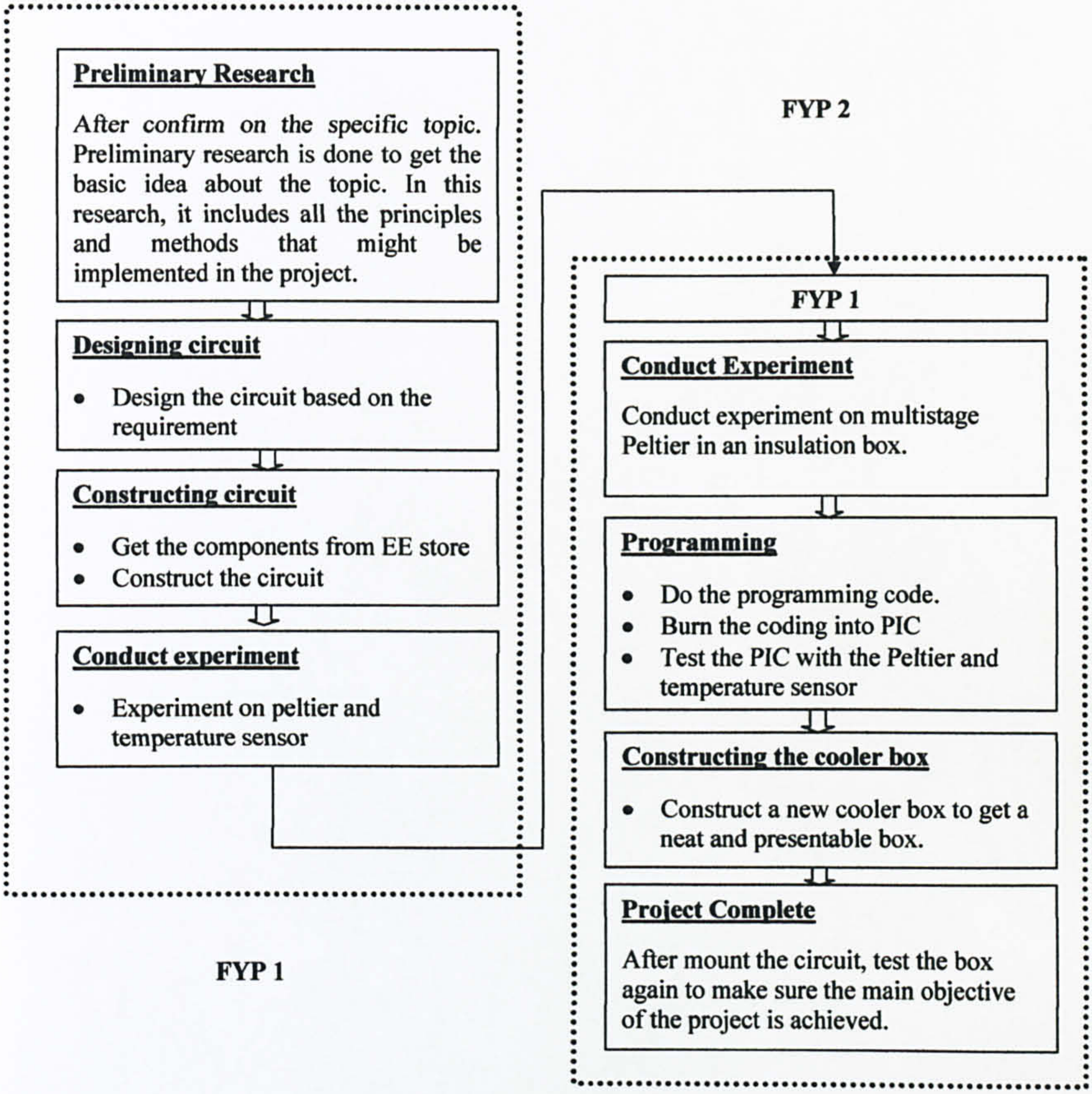

Figure 10: Flow Procedure

3.2 List of Components

Below is the list of components used in this project

Table 1: List of Components

	COMPONENTS	MODEL	QUANTITY
1	5 Volt Voltage Regulator	LM7805	1
2	8 Volt Voltage Regulator	LM7808	1
3	10 Volt Voltage Regulator	LM7810	2
4	Temperature sensor	LM35DZ	1
5	Microcontroller	PIC16F877	1
6	12 Volt Fan	D08T-12PH S	2
7	Peltier	CP1.0-127-05L-RTV	3
8	Resistor	-1k ohm	4
	Resistor	-330 ohm	2
	Resistor	-33k ohm	1
9	LED	-	3
10	Capacitor	-	12
11	LCD Screen	HD47780U	1
12	4MHz Crystal Oscillator	-	1
13	Push Button	-	3
14	Transistor	-	2
	Relay	-	2

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8	Resistor	-1k ohm	4
	Resistor	-330 ohm	2
	Resistor	-33k ohm	1
9	LED	-	3
10	Capacitor	-	12
11	LCD Screen	HD47780U	1
12	4MHz Crystal Oscillator	-	1
13	Push Button	-	3
14	Transistor	-	2
	Relay	-	2

3.3 The Specification of the Peltier

To buy the peltier, some specifications are to be considered:

- I_{max} (A): the DC current that yields the maximum junction temperature difference
- ΔT_{max} when the heat load is zero.
- ΔT_{max} (^oC): the maximum junction temperature difference across the module at I_{max} without heat load.
- $Q_{c\text{-}max}$ (W): the cooling power when the module operates at $\Delta T=0$ and $I= I_{max}$.
- V_{max} (V): the terminal voltage for I_{max} without heat load.

There are two types of peltier used in this project.

i) Single-stage peltier

Table 2: Specification of Peltier CP1.0-127-05L-RTV

Maximum Current (A)	Maximum Voltage (V)	ΔT(max) (°C)	Max Temp (°C)	Max Power (W)	Dimension (LxWxH)mm
3.9	15.4	64	85	33.4	30x30x3.2

Figure 11: Single-stage peltier CP1.0-127-05L-RTV

ii) Multi-stage peltier

Table 3: Specification of multi-stage Peltier PE-192-1420-1118

Maximum Current(A)	Maximum Voltage(V)	ΔT Max (°C)	Maximum Temp (°C)	Maximum Power (W)	Dimensions L x W x H (mm)
6.4	17.2	87	80	39.7	40 x 40 x 8.1

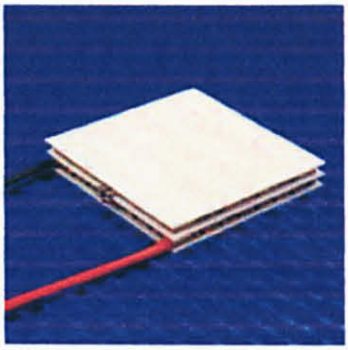

Figure 12: Multi-stage peltier PE-192-1420-1118

3.4 Hardware Tools/ Software

Table 4 and Table 5 show the list of software and hardware that are used in the project

Table 4: List of Software

	Software	Alternative	Justification
1	PSPICE	-Electronic Work Bench(EWB) -Multisim	To design the circuit, easy to get the software
2	CCS Compiler – Microchip PIC C Programming Software	MATLAB	Programming is needed to control the system according to the specification.

Table 5: List of Hardware

	Hardware	Alternative	Justification
1	Peltier		Easy to handle, it is the main component for the cooling system
2	Microcontroller	Controller	Microcontroller is used to control the peltier that works in two modes and also to minimize space used on the board.
3	Printed Circuit Board	Vero board	PCB is small and the component will be mounted, but vero board is much complicated. The copper must be scraped between 2 legs to get 2 nodes.
4	Temperature Sensor (LM35DZ)		To sense if the temperature is out of range. Microcontroller will then control the system to maintain the temperature.

3.5 Box Designs

3.5.1 Cooler box design 1

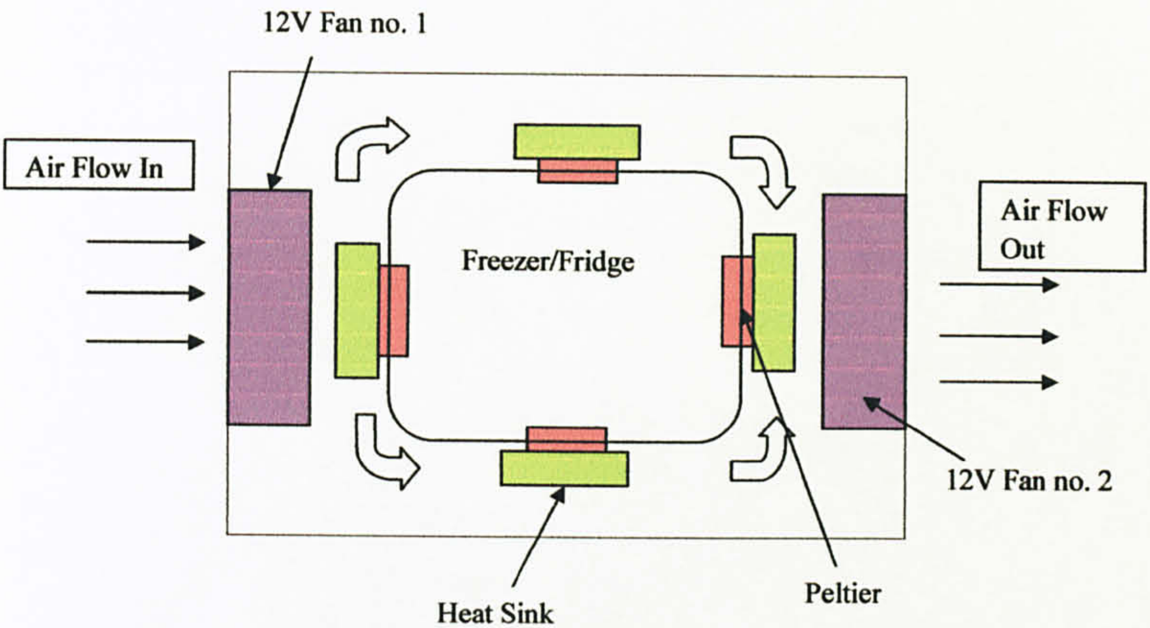

Figure 13: Cooler box design I

The box is redesign to be more effective. The real plan is to use 4 peltiers in this box and two 12 V fans. Fan no. 1 is to blow the air into the box. The second fan is to expel the air out of the box. The heat sink must be placed at the hot side of the peltier so that it can maximize heat dissipation according to the air flow.

The basic principle of Peltier effect is to convert ambient air in the box to cold air. The heat air is then transferred at the other side of the peltier. The air flow is important to dissipate the heat on the hot side. The function of fans is to blow in and extract out the air. At the same time, the temperature in the box will reduce. This will help to achieve the minimum temperature expected. However, after some research, this design consumes larger space.

3.5.2 Cooler box design II

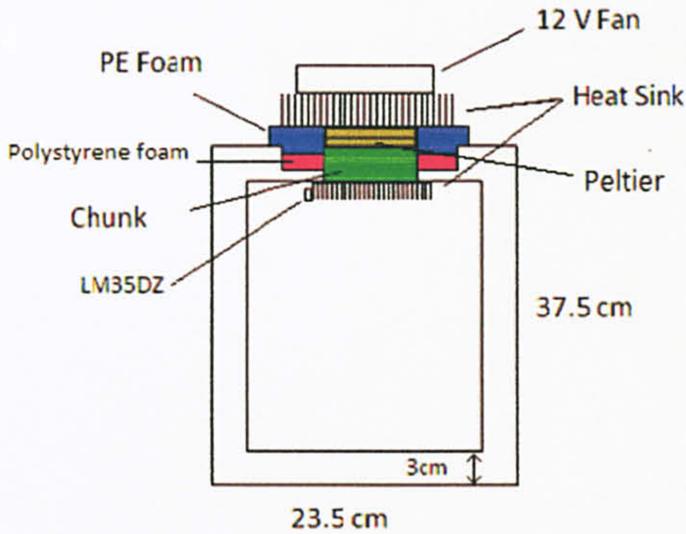

Figure 14: Cooler box design II

The earlier box design as shown in Figure 13 was to be fitted with four single-stage peltier. However, after some research and observation, the design was changed to as shown in Figure 14. This design uses multi-stage peltier which is having a higher temperature difference between the hot side and the cool side compared to the single-stage type. Furthermore, the heat sink is positioned to allow natural convection as well as forced convection whereas, the earlier design is for forced convection only. The use of a multi-stage peltier saves space and is in line with the objective of making a mini fridge.

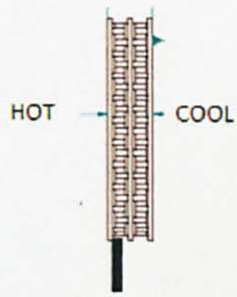

Figure 15 : Multi-stage peltier [14]

Thus, bigger size of heatsink is sticked to the hot side using thermal paste. This is because as the temperature difference lerger, the temperature at the hot side will get higher and need to release heat faster.

Due to the thick polystyrene foam, an aluminium chunk is used as a medium to transfer heat from the cool side to the heat sink. The chunk and heat sink are mounted to a piece of plywood. The plywood also becomes the base for the peltier. On top of the peltier is the big heat sink for the hot side. To prevent heat loss to environment, polystyrene foam is used as an insulator. It is the standard type of polystyrene and it is easy to find at the shop. It is placed tightly around the peltier. The actual plan is to use PE foam which the insulation is more reliable.

There are two sizes of heat sinks used, the big heat sink and the small heat sink. The function of heat sink is basically to increase the surface area of the heat transfer medium. It also helps to improve the drawing off heat from compartment. The big heat sink is used at the hot side of the peltier to help release heat faster because if the heat at hot side is high, it might burn the peltier. The small peltier is used at the cool side.

After a few experiments, it was observed that peltier will be needed to achieve a much lower temperature

3.5.3 Cooler box design III

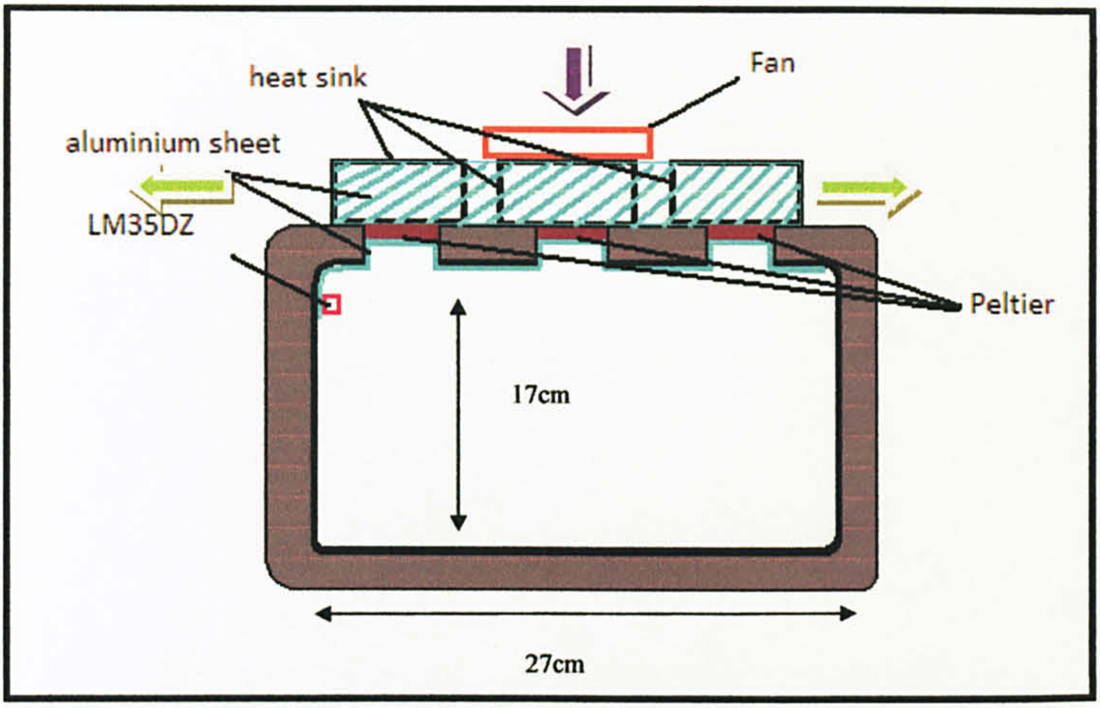

Figure 16: Cooler box design III

This is the latest design for the cooler box. The area of the box is much smaller than previous box and this will help the inner temperature to get cold faster. This design is the improvement from previous design. There are few changes made in order to achieve the expected temperature.

Three peltiers are connected to the box in series and electrically in parallel. Three peltiers are used so that the temperature in the inner box will get cooler. Heat sink is attached to the hot side of each peltier using thermal paste that allows heat to be transferred successfully.

Only one 12 V fan used to blow out the heat from the heatsinks. Two aluminum sheets are used to cover the gap between heatsinks so that the air blow out from the fan goes through the heatsinks. The air flow is as shown in Figure 16. The air blow in (purple arrow) and release at both end (green arrow).

Small aluminum sheet act as heat conductor is attached to the cold side of each peltier using thermal paste. This is to maximize the surface so that maximum heat can be transferred to the hot side and reduce the time for the box to get cold. The temperature sensor is stick to the aluminum sheet that act as heat conductor so it can sense the actual inner temperature.

3.6 Circuit Design

Below are the functions of the components used in the project. This device will be using the car battery (12 V). Figure 17 and Figure 18 show the circuit diagrams of the cooling storage.

i. 5 V voltage regulator (LM7805)
   LM7805 is used to drop down the voltage from 12 V to 5 V. The regulator is needed because the maximum voltage for the microcontroller is 5 V. Because of the load current allowed to go through the regulator is high; a heat sink is required as the protection

ii. 8 V voltage regulator (LM7808)
   LM7808 is used to drop down the voltage from 12 V to 8 V. One of the peltier uses 8V. This is to prevent the components from being damage by high current. The cost and budget are one of the factors to test the peltier carefully.

iii. 10 V voltage regulator (LM7810)

LM7810 is used to drop down the voltage from 12 V to 10 V. The other peltiers use 10V. This is to prevent the components from being damage by high current.

iv. Temperature sensor (LM35DZ)

This temperature sensor is used to get the temperature of the inner box. The temperature is obtained by the voltage of the sensor. The voltage is measured by the voltage drop between the base and emitter (V_{be}) of a transistor. The middle pin of the sensor will have an analog voltage that is directly proportional to the temperature.

v. Single-stage and multi-stage peltier

The thermoelectric cooler (peltier) is the main cooling system. Peltier is the best thermoelectric device as in cooling performance. Heat sinks and fans are required in order to maintain the temperature at the inner box.

vi. Microcontroller (PIC16F877)

Programming is used to read the temperature and to make sure the temperature does not exceed the cooling range programmed. It is programmed using C language. A 4 MHz crystal oscillator is connected for the clocking of the microcontroller.

vii. 12 Volt fan

The fans are used as the air cooling. One fan is use to absorb air and another fan is used to extract the air out. This forced air will make the air circulation flowing smoother. It also reduces the pressure at the hot side and proportionally reduces the temperature at the cold side.

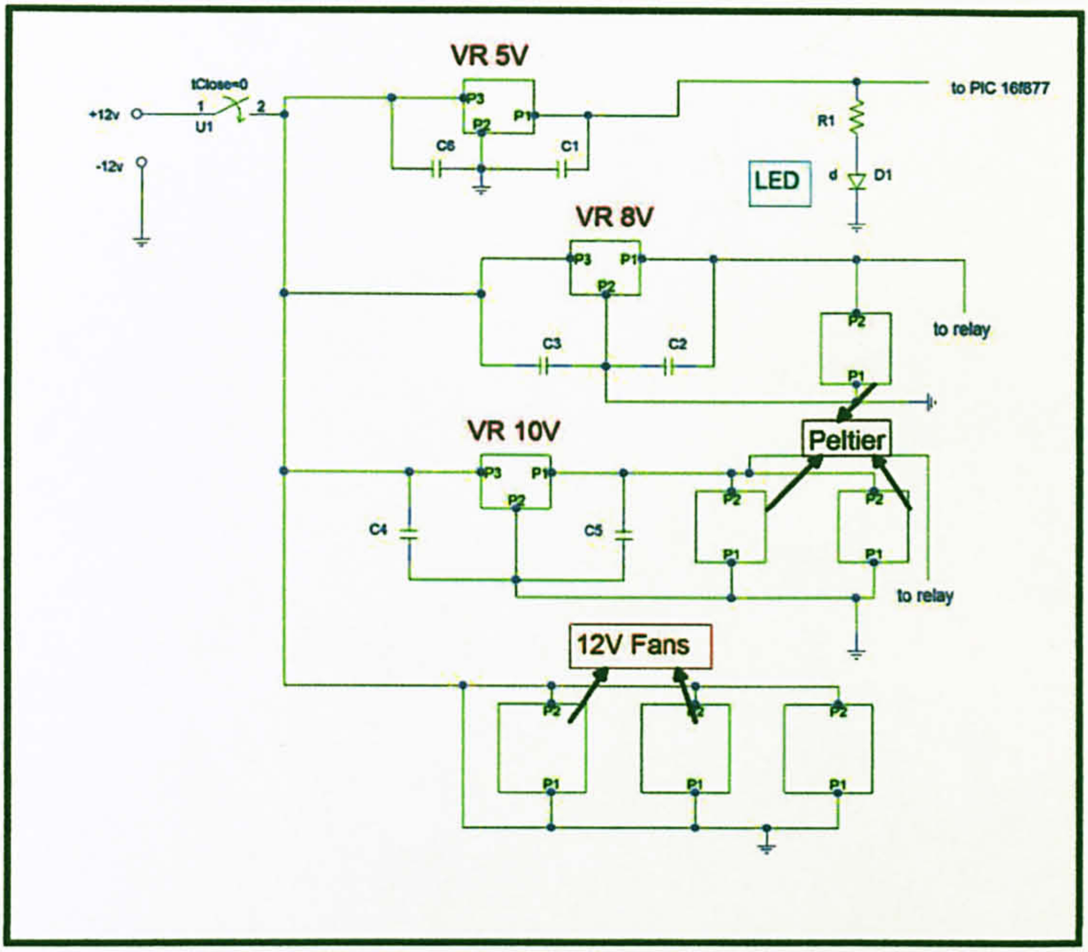

Figure 17: The peltier circuit design

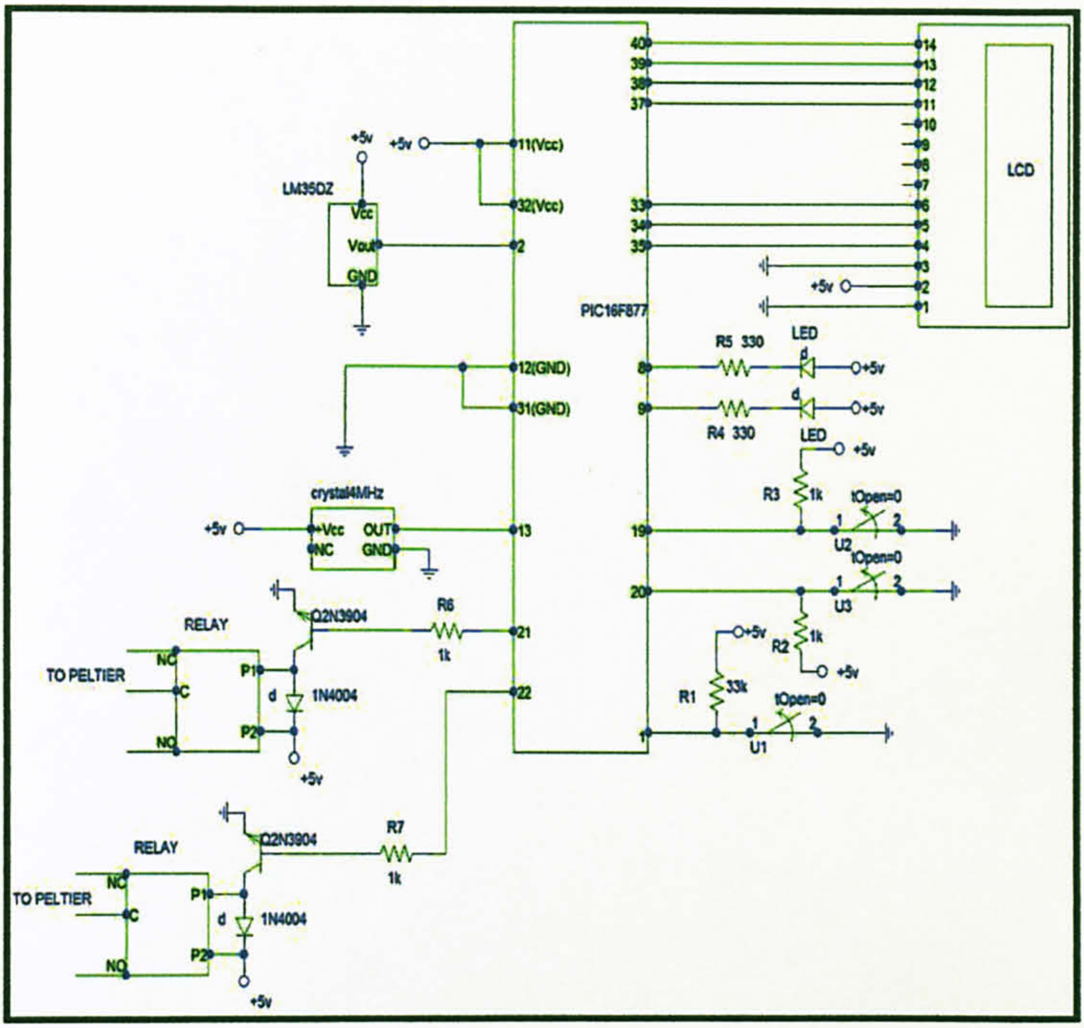

Figure 18: PIC 16F877 circuit design

3.7 Experimental work

There are some failure happens during the experiment and below are the lesson learnt:

1. The voltage regulator is a small component. The distance between each leg is small that makes multimeter probes easier to touch other legs and caused sparks. Few regulators burned because of the sparks. The solution was to use insulation tape to prevent spark.

2. The peltier itself is fragile. One of the single stage peltier cracks during installation process. The crack is small but it affects the contact between semiconductors in the middle.

3. Next, problem occurs when the voltage and current drops abruptly after the power supply is turned on. The connection is as in Figure 19.

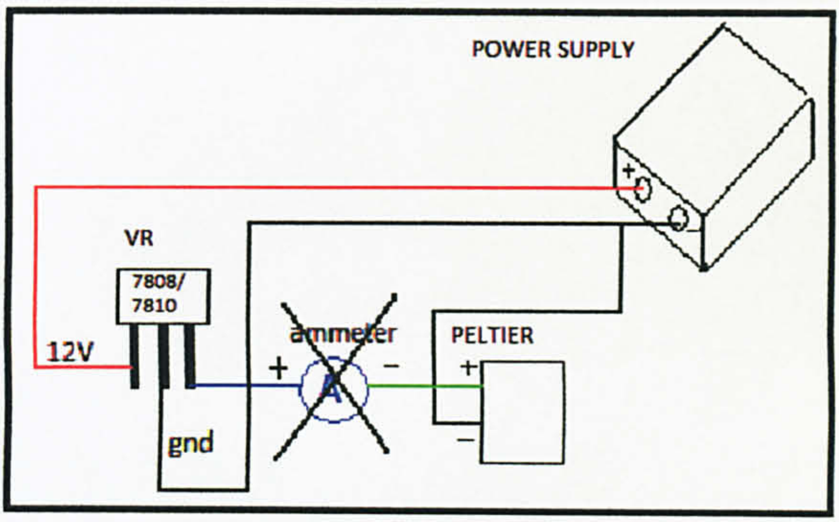

Figure 19: Circuit for peltier

After few experiments done, it is found that the ammeter should not be connected in series. It is supposed to connect the ammeter in series only when measuring.

4. There is an error occur while cutting the box to put the peltier. Even if there is tiny gap, still air can move in and out of the box. When this happen, the temperature of the inner box will not get cooler since the ambient temperature is higher. The air entering the box will cause the peltier and the aluminum sheet to get frost. The peltier cannot get cooler when it surface is full with frost. After removing the frost, the temperature decreases about 2°C. Silicon sealant is used to fill in the gap. It is easy to be used and easy to be removed.

5. The insulation box used might be too light and low density. It may not be the good insulator for this project. It releases heat to surrounding easier because the foam has big pores. It is planned to put another layer of insulator, (polystyrene or polyethylene). PE foam is much recommended but it is difficult to find, whereas polystyrene foam is moderate but easier to find.

6. The peltier used for this experiment is multi-stage peltier. This is because the power supply used cannot afford so many loads. But for car battery has high current capacity that can afford high load. Power supply with larger range will be used so that all three peltier can be used.

3.8 Programming

3.8.1 Process flow description

When the device is switched on, the user is required to choose between two modes and the LCD will display "CHOOSE FRIDGE OR FREEZER". When push button at port RD0 is pushed, the current mode now becomes a fridge mode. The LCD will display the current mode and also the inner temperature of the box. Two LEDs are used to indicate the mode chosen. The experiment for the peltiers are still in progress, therefore the temperature for testing the controller is assumed based on the previous temperature reading.

When the fridge mode is entered, the two normally open relay contacts which directly control the peltiers will become closed; therefore the peltiers are activated and the temperature will start to decrease. For the fridge mode, the temperature is supposed to be not less than 12°C but during initial testing the range produced is not less than 20°C. When temperature reaches 20°C, the controller will send a signal to the two relays. The relays that are previously closed will then become de-energize and become open circuit for 7 seconds. In the meantime, the peltiers will stop running and the temperature will started to increase. After 7 seconds, the relays will be energized (short circuited) again and peltiers will be turned ON. This loop is continuously repeated. As for the LCD, it will display "FRIDGE" and "TEMP:__°C".

For the freezer mode the temperature is supposed to be zero but it will be a tough job working with this device because it has a low efficiency. For this mode, the peltier will keep running all the time so that the minimum temperature can be achieved. The LCD will display "FREEZER" and "TEMP: _ _°C".

This description is represented in a state machine in Figure 20.

3.8.2 The state machine

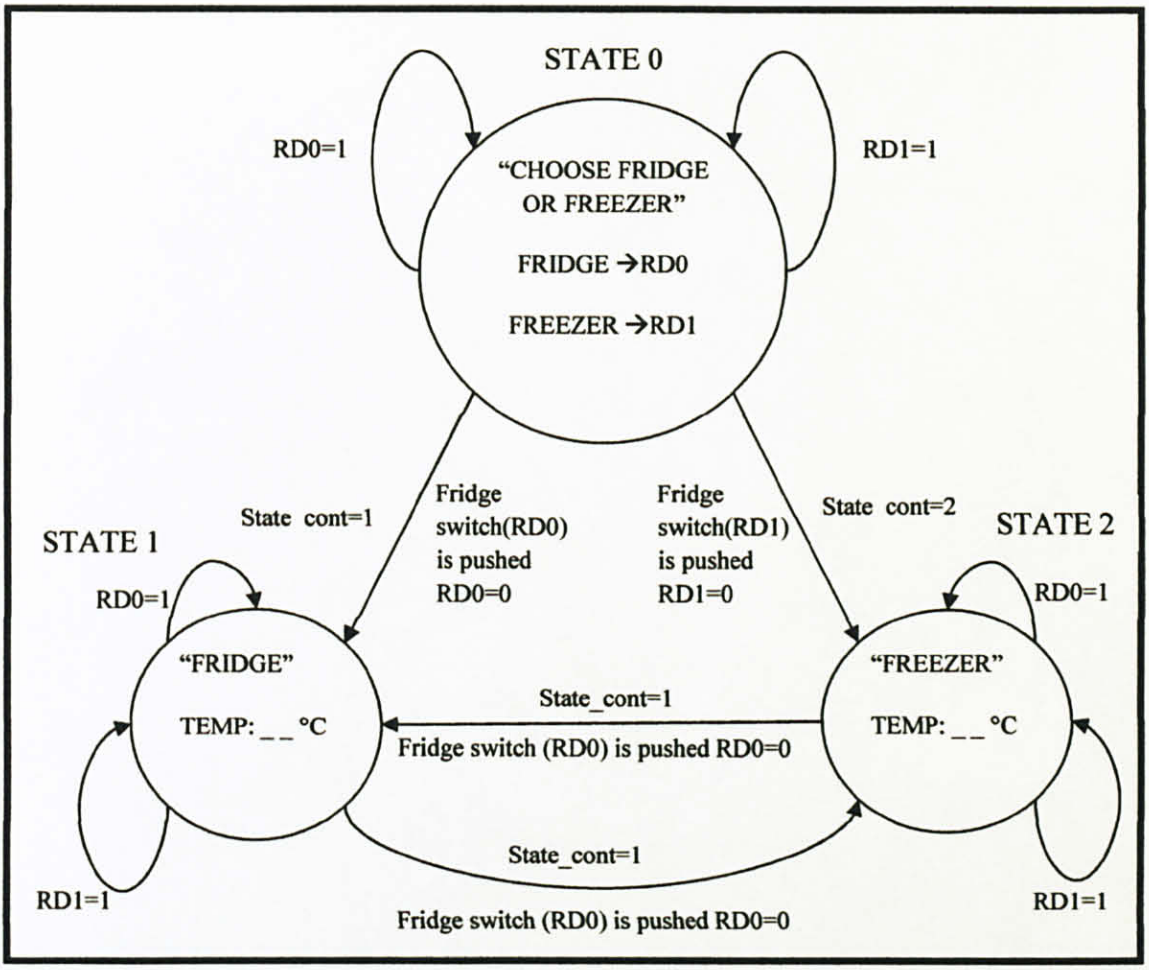

Figure 20: State machine

3.8.3 The inputs and outputs

Table 6: The table of inputs and outputs

Input	Port	Output	Port
LM35DZ	AN0	Relay	RD2/RD3
Push button fridge mode	RD0	LCD display	RB0/RB1/RB2/RB4/ RB5/RB6/RB7
Push button freezer mode	RD1	LED (fridge)	RE0
Reset button	MCLR*/VPP	LED (freezer)	RE1

CHAPTER 4:
RESULT AND DISCUSSIONS

4.1 Surface Temperature of Peltier

An experiment was conducted to obtain the inner temperature of the multi stage peltier. The voltage is varied from 8 V to 12 V. The result is as shown in Table 7 and Figure 21 shows the graph of surface temperature decreasing over voltage.

Table 7: Surface temperature of peltier with varied voltage.

Voltage(V)	Current(A)	Temperature(°C)
8.0	2.0	6.6
8.5	2.1	5.9
9.0	2.2	5.3
9.5	2.3	4.8
10.0	2.4	4.3
10.5	2.5	3.6
11.0	2.6	3.0
11.5	2.7	2.7
12.0	2.8	2.4

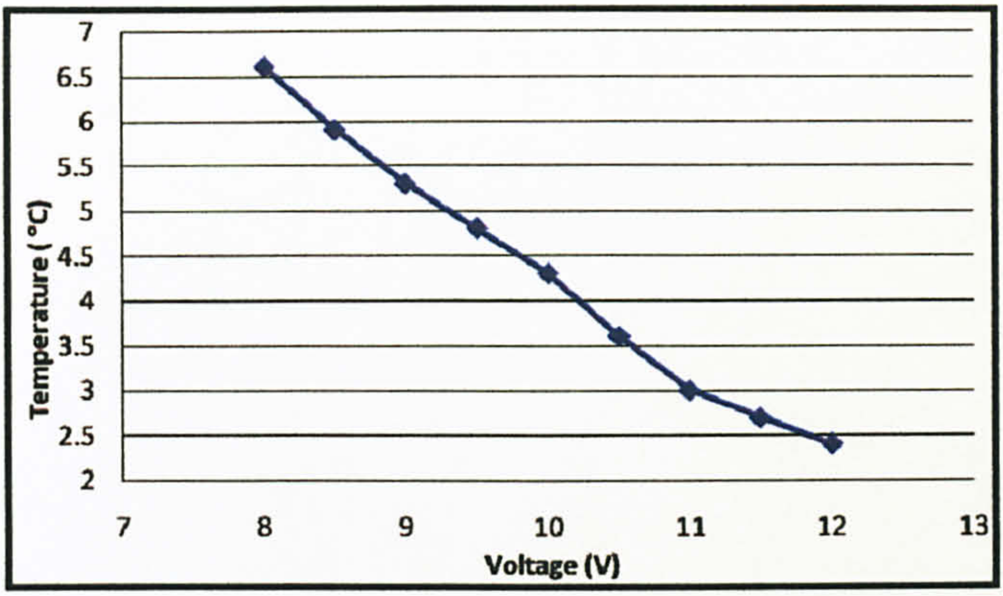

Figure 21 : Surface temperature of peltier versus voltage

Discussion

From the graph in Figure 21, the surface temperature decrease when the voltage is increase. The temperature sensor LM35DZ is stick to the heat sink surface. This is because heat sink is a heat conductor. The temperature on the peltier supposed to be the same as on the heat sink surface. But for this experiment the insulator used is standard polystyrene which is thin and not as good as PE foam. Besides that, the chunk used for the multi-stage peltier is on 2 cm x 2 cm but the multi-stage peltier is 4 cm x 4 cm. The chunk is designed based on the size of single-stage peltier. The chunk for the multi-stage peltier was still in progress during the experiment. These are the problems held during the implementation of the first experiment with the cooler box.

4.2 Temperature of Cooler Box

An experiment was conducted to obtain the inner temperature of the multi stage peltier. The voltage is varied from 0 V to 9 V. The time taken for each voltage to reduce the inner box temperature is 30 minutes. The results are as shown in Table 8 and the graph in Figure 22.

Table 8: Temperature of cooler box with varied voltage.

Voltage(V)	Current(A)	Temperature(°C)
0	0	31.3
1	0.26	28.2
2	0.45	25.1
3	0.53	23.0
4	0.98	21.5
5	1.24	20.3
6	1.46	19.6
7	1.70	19.3
8	1.96	18.3
9	2.05	19.1

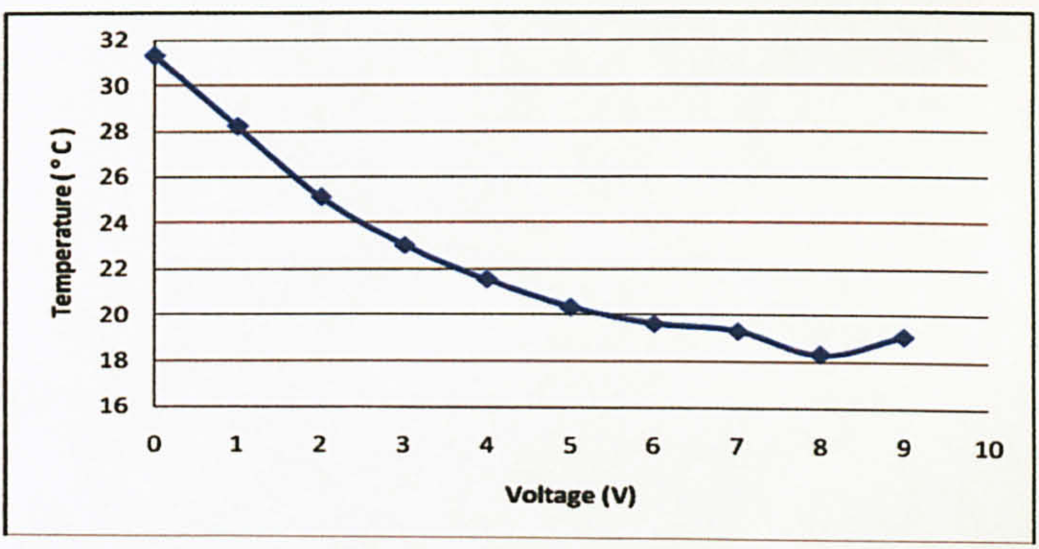

Figure 22: Temperature of inner box versus voltage

Discussion

From 1 V – 5 V, the temperature reduce as the voltage increase. At 6 V the box has already ON for three hours. With the absence of small and tiny gap on the box, frost started to occur. That is why from 6 V to 7 V, the temperature does not have much difference. After removes the frost, it is observed that the temperature increase to 18.3 °C. When it comes to 9 V the peltier is getting cooler, thus the frost re-appear faster. Other than that, during this experiment, only multi-stage peltier is used. This is because the power supply used cannot run three peltiers at a time. Car battery will be replaced with power supply because car battery has high current capacity. With that, all three peltiers can be running at the same time and the temperature will reduce more.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

As the conclusion, we learned that safety aspect is very important when dealing with electrical circuitry work. Next, is to be more careful when handling fragile material. We have a better understanding on the thermoelectric cooler concept such as peltier effect. Other than that, microcontroller is also important in this project because it act as 'middle man' between the input (LM35DZ) and the output (LCD display). From the observation, besides the size and the maximum voltage of peltier, the insulation material plays an important factor towards the cooling process. This is because the environmental heat gain and outside air entering the box causes frosting and will make the temperature reading to be unstable.

5.2 Recommendation

Some recommendations are provided for future improvement on this project. The peltier device that comes in light and small size, it is recommended to further develop on the power source for the mini fridge. Having rechargeable solar batteries may result in true portability. As for the thermoelectric cooler (TEC), work have to go on for the development of the TEC to use cheaper and abundant material as well as to obtain higher power efficiency. As it is now it uses high current.

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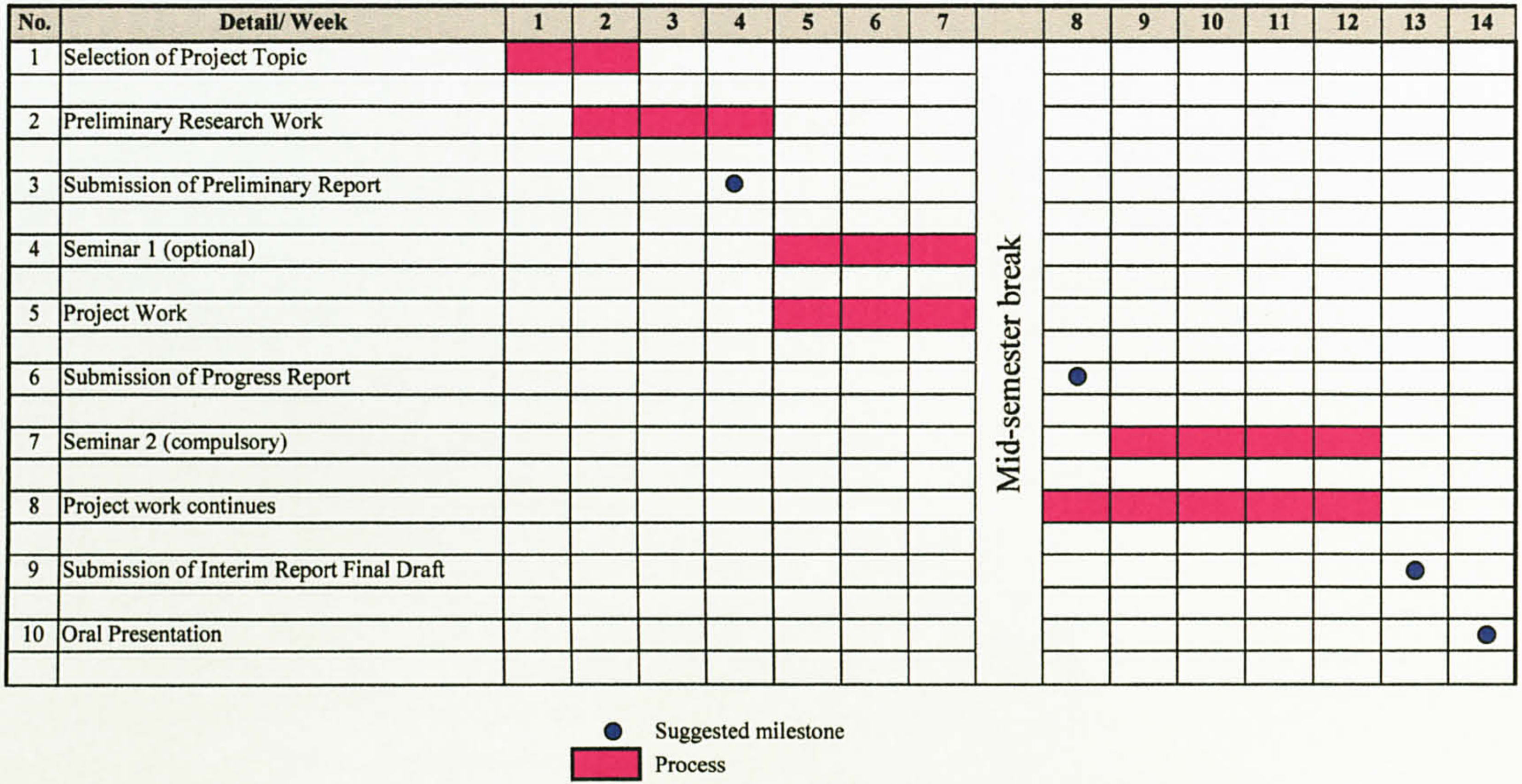
APPENDIX A

GANTT CHART FOR FINAL YEAR PROJECT I



GANTT CHART FOR FINAL YEAR PROJECT II

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

● Suggested milestone
■ Process

APPENDIX B

C PROGRAMMING

```
#include <16F877.h>

#device ADC=10


#fuses   XT,NOWDT,NOPROTECT, NOPUT, NOBROWNOUT, NOLVP
#use delay(clock = 4000000)

#include <LCD420.C>


unsigned int8 adcValue;
int16 suhu;




void main()
{
      static int8 state_cont = 0;
      lcd_init();     //lcd initialization

      setup_adc_ports( ALL_ANALOG );            //ADC initialization
      setup_adc(ADC_CLOCK_INTERNAL);           // Use internal ADC clock
      set_adc_channel(0);
      output_low(PIN_E0);                       // LED 0 = FRIDGE
      output_low(PIN_E1);                       // LED 1 = FREEZER

   while(true)
   {


     while (state_cont == 0)
     {
            delay_ms(100);
            lcd_gotoxy(1,1);
            lcd_putc('\f');
            lcd_putc("Choose FRIDGE");
            lcd_putc('\n');
            lcd_putc("or FREEZER");

            if (input(PIN_D0) == 0)
            {

               delay_ms(10);
               while(input(PIN_D0) == 0)
               {
               }
               state_cont = 1;
            }


            if (input(PIN_D1) == 0)
            {

               delay_ms(10);
               while(input(PIN_D1) == 0)
```

```
        {
        }
        state_cont = 2;
    }


 }



if (state_cont == 1)
{
    delay_us(50);  // Delay for sampling cap to charge
    adcValue = read_adc(); // Get ADC reading
    delay_us(50);  // Preset delay, repeat every 10ms

    suhu = (5.0 * adcValue * 100) / 1023;


    output_high(PIN_D2);  //peltier1 ON
    output_high(PIN_D3);  //peltier2 ON

    output_high(PIN_E0);  //LED0 ON :: fridge mode


    //if(temp >= 20 )
    if(suhu < 20)
    {
    output_low(PIN_D2);  //Peltier1 OFF
    output_low(PIN_D3);  //Peltier2 OFF


    }

    delay_ms(100);
    lcd_gotoxy(1,1);
    lcd_putc('\f');
    lcd_putc("FRIDGE");
    lcd_putc('\n');
    printf(lcd_putc,"\Temp(C):%ld", suhu);



    if (input(PIN_D1) == 0)   //If freezer switch is pushed
    {

        delay_ms(10);
        while(input(PIN_D1) == 0)  //Loop here as long as freezer switch is push
        {
        }
        state_cont = 2;  //as soon as freezer switch is released, goto state 2
        output_low(PIN_E0);   // LED0 OFF
    }
}
```

```
    else if (state_cont == 2)
    {

            delay_us(50);  // Delay for sampling cap to charge
            adcValue = read_adc(); // Get ADC reading
            delay_us(50);  // Preset delay, repeat every 10ms

            suhu = (5.0 * adcValue * 100) / 1023;


            output_high(PIN_D2);    // PELTIER ALWAYS ON
            output_high(PIN_D3);    // PELTIER ALWAYS ON


            output_high(PIN_E1); // LED1 ON:: freezer mode


            delay_ms(100);
            lcd_gotoxy(1,1);
            lcd_putc('\f');
            lcd_putc("FREEZER");
            lcd_putc('\n');
            printf(lcd_putc,"\Temp(C):%ld", suhu);



            if (input(PIN_D0) == 0)
            {

               delay_ms(10);
               while(input(PIN_D0) == 0)
               {
               }
               state_cont = 1;
               output_low(PIN_E1);  //LED1 OFF
            }
    }


  }

}
```

APPENDIX C

DATASHEET

National Semiconductor

November 2000

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

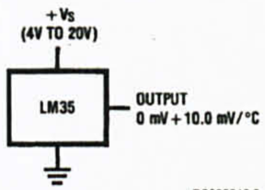
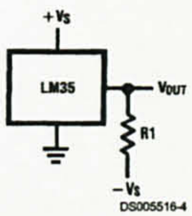


FIGURE 1. Basic Centigrade Temperature Sensor (+2˚C to +150˚C)



Choose $R_1 = -V_S/50\ \mu A$

V_{OUT}=+1,500 mV at +150˚C

= +250 mV at +25˚C

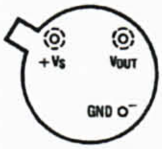
= −550 mV at −55˚C

FIGURE 2. Full-Range Centigrade Temperature Sensor

 DS005516

Connection Diagrams

TO-46
Metal Can Package*

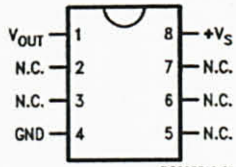


BOTTOM VIEW
DS005516-1

*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



DS005516-21

N.C. = No Connection

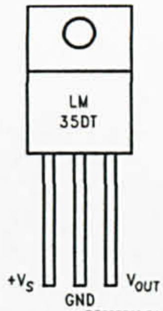
Top View
Order Number LM35DM
See NS Package Number M08A

TO-92
Plastic Package

BOTTOM VIEW
DS005516-2

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

TO-220
Plastic Package*



DS005516-24

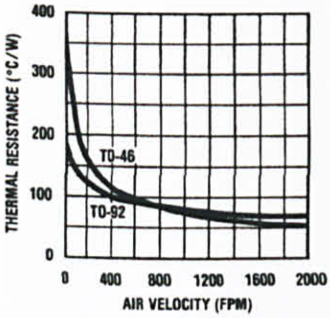
*Tab is connected to the negative pin (GND).

Note: The LM35DT pinout is different than the discontinued LM35DP.

Order Number LM35DT
See NS Package Number TA03F

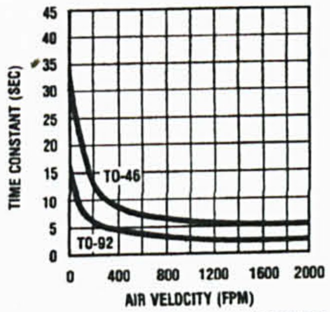
Typical Performance Characteristics

Thermal Resistance Junction to Air



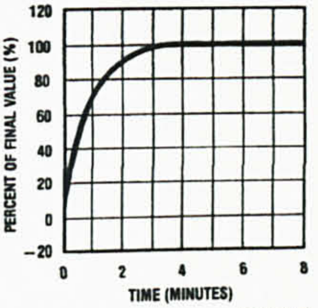
DS005516-25

Thermal Time Constant



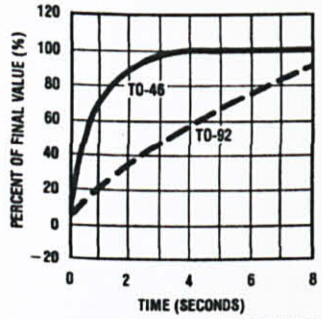
DS005516-26

Thermal Response in Still Air



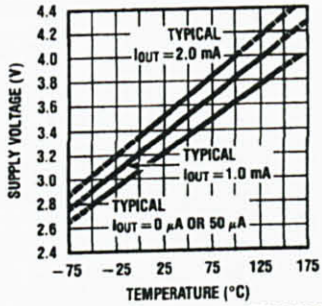
DS005516-27

Thermal Response in Stirred Oil Bath



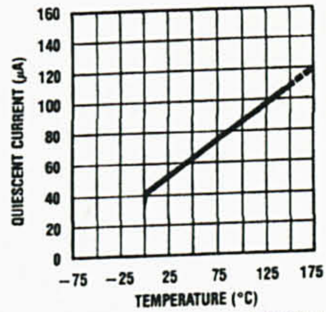
DS005516-28

Minimum Supply Voltage vs. Temperature



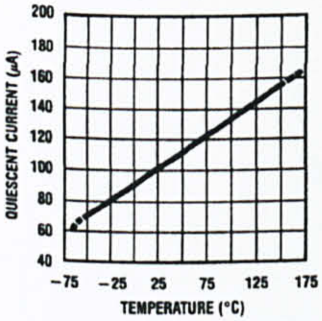
DS005516-29

Quiescent Current vs. Temperature (In Circuit of *Figure 1*.)



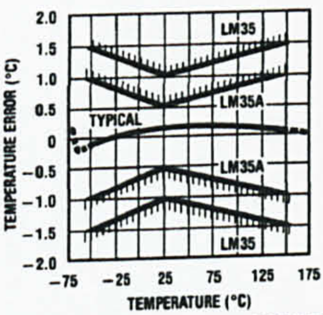
DS005516-30

Quiescent Current vs. Temperature (In Circuit of *Figure 2*.)



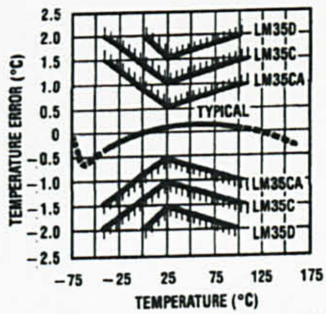
DS005516-31

Accuracy vs. Temperature (Guaranteed)



DS005516-32

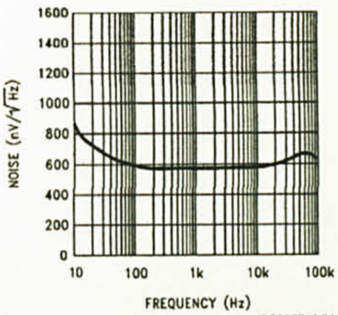
Accuracy vs. Temperature (Guaranteed)



DS005516-33

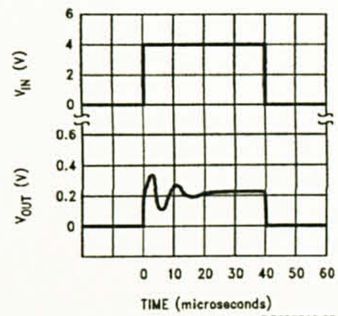
Typical Performance Characteristics (Continued)

Noise Voltage



DS005516-34

Start-Up Response



DS005516-35

Applications

The LM35 can be applied easily in the same way as other integrated-circuit temperature sensors. It can be glued or cemented to a surface and its temperature will be within about 0.01˚C of the surface temperature.

This presumes that the ambient air temperature is almost the same as the surface temperature; if the air temperature were much higher or lower than the surface temperature, the actual temperature of the LM35 die would be at an intermediate temperature between the surface temperature and the air temperature. This is expecially true for the TO-92 plastic package, where the copper leads are the principal thermal path to carry heat into the device, so its temperature might be closer to the air temperature than to the surface temperature.

To minimize this problem, be sure that the wiring to the LM35, as it leaves the device, is held at the same temperature as the surface of interest. The easiest way to do this is to cover up these wires with a bead of epoxy which will insure that the leads and wires are all at the same temperature as the surface, and that the LM35 die's temperature will not be affected by the air temperature.

The TO-46 metal package can also be soldered to a metal surface or pipe without damage. Of course, in that case the V− terminal of the circuit will be grounded to that metal. Alternatively, the LM35 can be mounted inside a sealed-end metal tube, and can then be dipped into a bath or screwed into a threaded hole in a tank. As with any IC, the LM35 and accompanying wiring and circuits must be kept insulated and dry, to avoid leakage and corrosion. This is especially true if the circuit may operate at cold temperatures where condensation can occur. Printed-circuit coatings and varnishes such as Humiseal and epoxy paints or dips are often used to insure that moisture cannot corrode the LM35 or its connections.

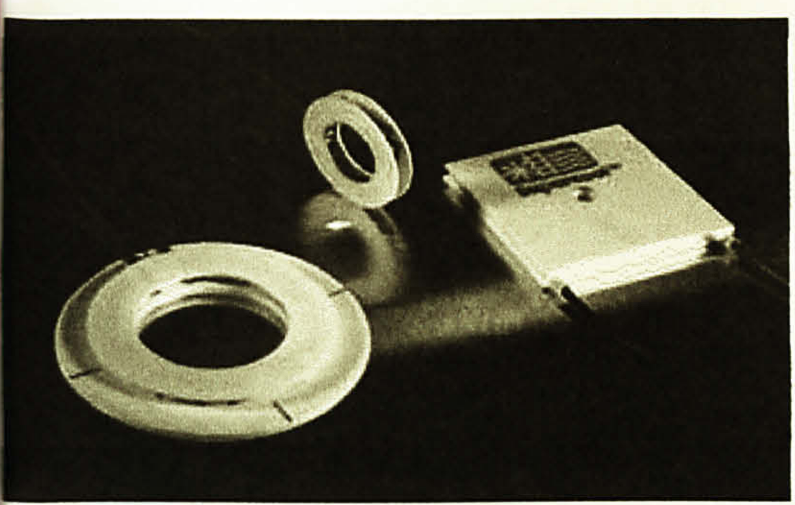
These devices are sometimes soldered to a small light-weight heat fin, to decrease the thermal time constant and speed up the response in slowly-moving air. On the other hand, a small thermal mass may be added to the sensor, to give the steadiest reading despite small deviations in the air temperature.

Temperature Rise of LM35 Due To Self-heating (Thermal Resistance, θ_{JA})

	TO-46, no heat sink	TO-46*, small heat fin	TO-92, no heat sink	TO-92**, small heat fin	SO-8 no heat sink	SO-8** small heat fin	TO-220 no heat sink
Still air	400˚C/W	100˚C/W	180˚C/W	140˚C/W	220˚C/W	110˚C/W	90˚C/W
Moving air	100˚C/W	40˚C/W	90˚C/W	70˚C/W	105˚C/W	90˚C/W	26˚C/W
Still oil	100˚C/W	40˚C/W	90˚C/W	70˚C/W			
Stirred oil	50˚C/W	30˚C/W	45˚C/W	40˚C/W			
(Clamped to metal, Infinite heat sink)		(24˚C/W)				(55˚C/W)	

*Wakefield type 201, or 1" disc of 0.020" sheet brass, soldered to case, or similar.

**TO-92 and SO-8 packages glued and leads soldered to 1" square of 1/16" printed circuit board with 2 oz. foil or similar.

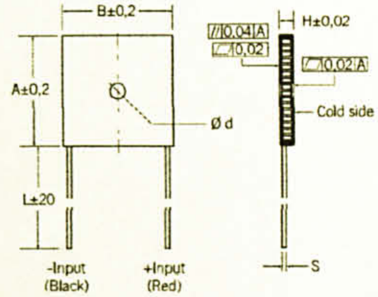


Center hole modules

Center hole modules are used when light, wires or other hardware need to be transferred through the module.

We only stock a limited number of modules of this type. Let us know about the challenges of your application, and we'll make sure you get just the right module. In principle, all modules can be supplied with a center hole.

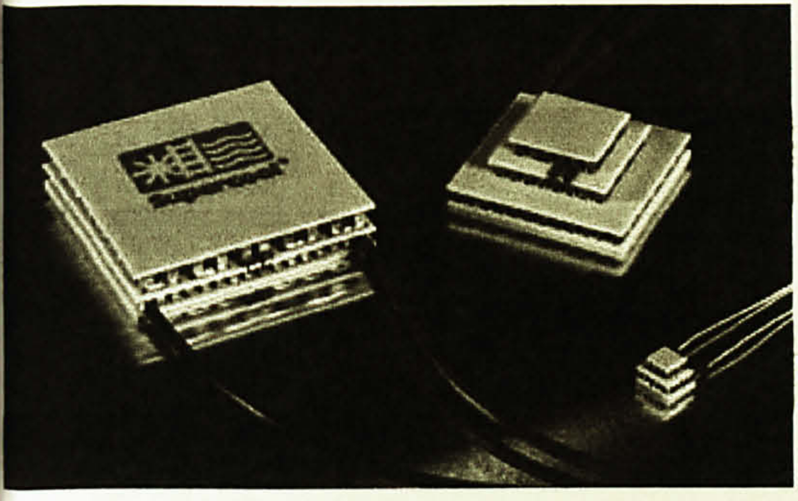
Operating temperature is max. 80°C.



- *Lead wires are approved acc. to UL 1569..*
- *R_{AC} tolerance = ±10%*
- *Tolerance of I_{max}, U_{max}, Q_{max} = ±5%*

Product No.	I_{max} (A)	U_{max} (V)	$P_{c\,max}$ (W)	ΔT_{max} (°C)	R_{AC} (ohm)	(mm) A, B, D	d	H	L	S AWG #
Center hole modules										
PE-119-10-13HS [1]	3.9	14.7	35.5	71	3.37	30	4.7	3.6	200	24
PE-125-14-11HS [1]	8.5	15.6	81.5	70	1.46	40	4.7	3.8	300	20
PE-125-14-15HS [1]	6	15.5	58.5	72	2.16	40	4.7	3.9	300	22
PE-014-14-25RH [2]	3.9	1.7	4.3	75	0.37	26	14	4.7	200	22
PE-032-14-15RH [2]	6	4.0	15	74	0.54	55[3]	27	3.9	200	22
PE-038-10-13RH [2]	3.9	4.7	11.4	74	1.05	24	10	3.6	200	24

1) S = Silicon sealed versions.
2) Round design. D = outer diameter and d = inner diameter.
3) Outer diameter on warm side = 55 mm. Outer diameter on cold side = 44 mm.



Multistage modules

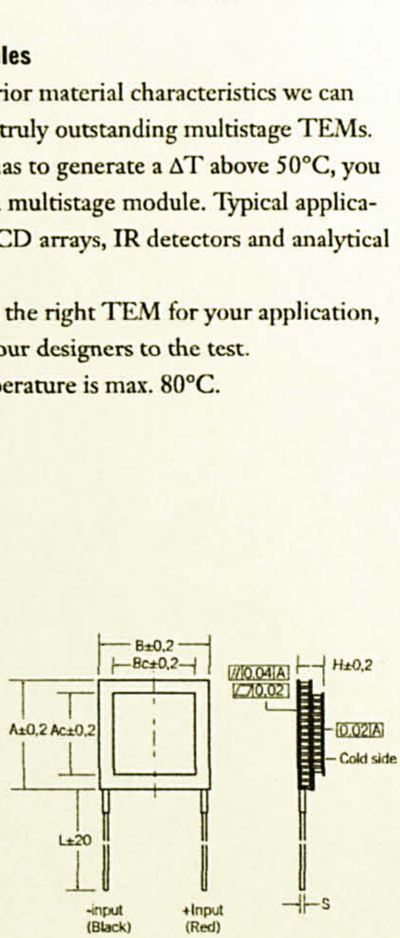
Thanks to superior material characteristics we can offer a range of truly outstanding multistage TEMs. If your system has to generate a ΔT above 50°C, you normally need a multistage module. Typical applications include CCD arrays, IR detectors and analytical instruments.

If you can't find the right TEM for your application, feel free to put our designers to the test.

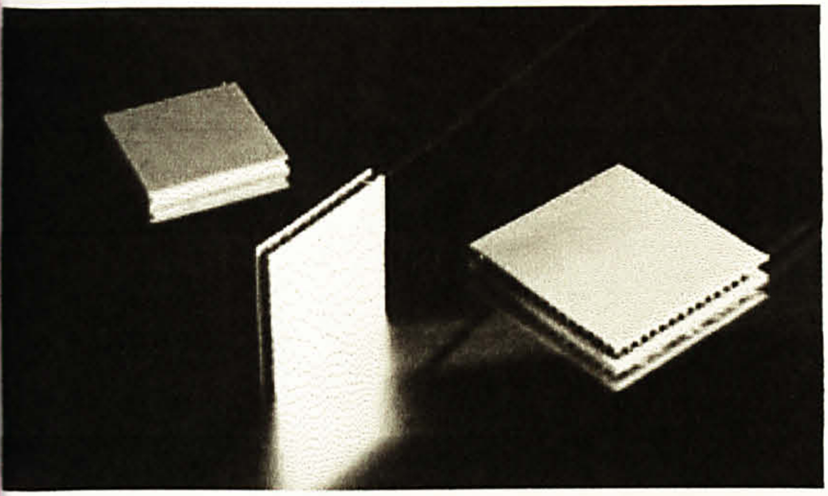
Operating temperature is max. 80°C.

Product No.	I_{max} (A)	U_{max} (V)	$P_{c\,max}$ (W)	ΔT_{max} (°C)	R_{AC} (ohm)	(mm) Ac	Bc	A	B	H	L	S AWG #
Multistage modules												
PE-010-0606-1111	1.1	0.9	0.35	92	0.64	3.2	3.2	3.9	3.9	4.2	50	0.07[1]
PE-024-0606-1111	1.1	2.2	0.81	92	1.47	4.1	4.1	6.1	6.1	4.6	50	0.07[1]
PE-049-1010-1515	2.1	3.8	3.4	87	1.53	11.5	11.5	15	15	6.6	200	24
PE-049-1414-1515	4	3.8	3.7	87	0.83	15	15	20	20	7.2	200	22
PE-107-1010-1212	3	9.2	9.2	89	2.72	22.6	22.6	22.6	22.6	6.25	200	24
PE-190-1010-1212	2.8	15.7	16.4	87	4.78	30	30	30	30	6.5	200	24
PE-192-1420-1118	6.7	15.6	39.9	87	2.15	40	40	40	40	8.1	300	20
PE-192-1420-1525	4.4	16.0	27.3	88	3.03	40	40	40	40	8.1	300	22
PE3-070-20-25	6.5	6.5	3.0	118	0.93	14	8	36	36	16	200	22
PE3-119-14-15	3.9	8.0	7.5	100	2.09	15	15	30	30	10.4	200	22
PE3-119-20-15	8	8.2	14.9	100	0.97	22	22	44	44	12.9	200	20
PE3-231-10-15	1.9	15.5	6.9	104	7.22	15	15	30	30	9.5	200	24
PE4-115-14-15	3.5	7.6	2.6	122	1.95	14.5	4.5	33	24	13.8	200	22
PE4-129-10-15	1.8	8.2	1.9	115	3.83	8	8	23	23	12.5	200	24
PE5-257-10-15	1.5	14.5	2.0	123	7.9	8	8	30	30	15.4	200	24

1) Teflon insulated wire. Cross section in mm^2



- *Lead wires are approved acc. to UL 1569.*
- *R_{AC} tolerance = ±10%*
- *Tolerance of I_{max}, U_{max}, Q_{max} = ± 5%*



Medium performance modules

Kristall, our new range of medium performance thermoelectric modules, is specially designed for high volume applications. A novel manufacturing technique allows us to offer dependable performance – at an attractive price. Max. ΔT of up to 72°C at T_h = 25 °C.

The Kristall range is based on a patented method for growing thermoelectric material that delivers not only competitive cooling properties but also cost-effective production. Thanks to an advanced nickel diffusion barrier process, these modules can be used long-term at temperatures up to 90°C. Options are silicon or epoxy sealing and lapping.

Typical application areas include commercial refrigeration, electronics, industrial automation and automotive.

We stock a limited range of standard products. However, most specifications can be met for high volumes.

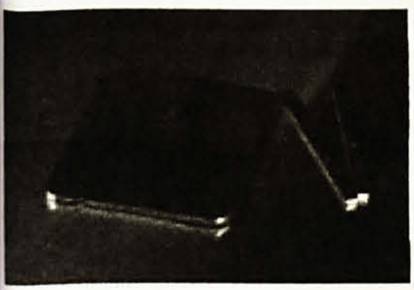
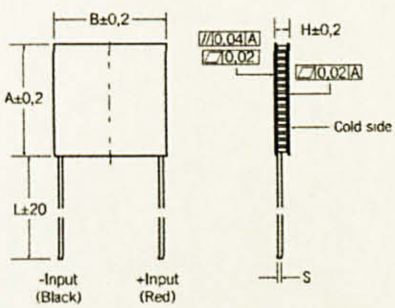


Plate and bar ingots – special materials technology

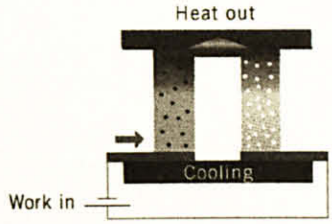


- *Lead wires are PVC insulated. Max temperature = 105°C*
- *R_{AC} tolerance = ±10%*
- *Tolerance of I_{max}, U_{max}, Q_{max} = ±5%*

Product No.	I_{max} (A)	U_{max} (V)	$P_{c\,max}$ (W)	ΔT_{max} (°C)	R_{AC} (ohm)	(mm) A	B	H	L	S AWG #
Medium performance modules										
PM-071-10-13	3.9	8.8	18.2	71	2.0	20	20	3.6	200	24
PM-071-14-15	6.0	8.6	29	71	1.30	30	30	3.9	200	22
PM-127-10-13	3.9	15.4	32.5	71	3.50	30	30	3.6	200	24
PM-127-14-11	8.5	15.4	73	69	1.50	40	40	3.8	200	20
PM-127-14-15	6.0	15.4	51.6	71	2.20	40	40	3.9	200	22
PM-127-14-25	3.9	15.4	32.5	72	3.4	40	40	4.8	200	22

Silicon sealed and Epoxy sealed version are available. Note ! Max ΔT is reduced by 2-3°C for S-type and 1-2°C for E-type

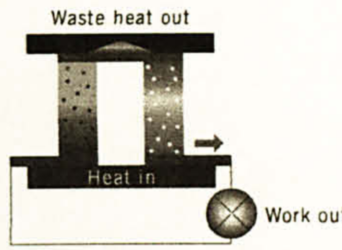
Thermoelectrics and how it works



Heat Pump (Refrigerator) Peltier (1834)

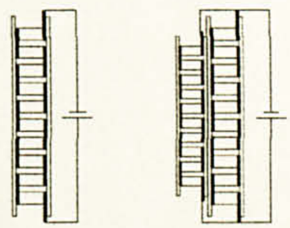
The Thermoelectric Peltier effect is the most direct way to utilize electricity to pump heat. Electrical current (work input) forces the matter to approach a higher energy state (black dots) and heat is absorbed (cooling).

The energy is released (heating) as the matter approaches a lower energy state (white dots). The net cooling or heating effect is proportional to the electric current and Peltier coefficient.



Power Generator Seebeck (1822)

Thermoelectric material can also be used for electric power generation. Some of the heat input is converted to electric current (work), as the higher energy matter (black dots) releases energy and cools to a lower energy state (white dots). The net work is proportional to the temperature difference and Seebeck coefficient.



Single stage Multistage

Thermoelectric modules

The material used at working temperatures up to 150°C is normally bismuth telluride, doped to obtain p (positive) and n (negative) semi-conducting properties.

A number of pn-couples, thermally parallel and electrically in series, are sandwiched between ceramic plates.

The maximum temperature differential (ΔT_{max}) between the cold and the warm side of a Supercool single stage module is up to 75°C at warm side temperatures of 25°C or ΔT = 85°C at a warm side temperature of 50°C. By increasing the number of stages in a multistage arrangement, you also increase maximum ΔT.

Installation

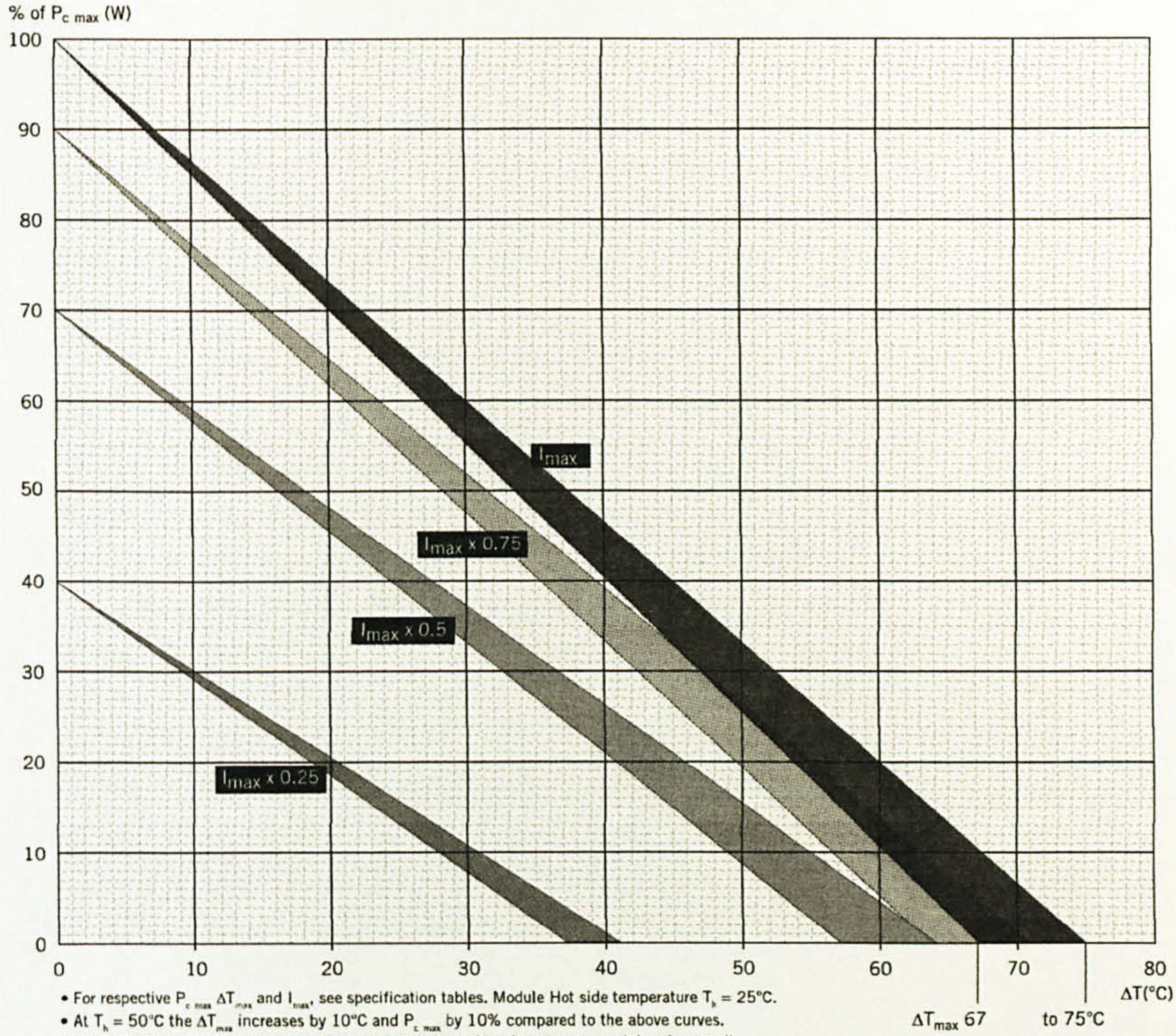
- Recommended mounting methods are clamping using thermal grease, bonding with thermal epoxy, or soldering with metallized ceramics (option).
- TE modules should not be subjected to significant shear forces.
- Surface flatness of heat sinks should be 0.05 mm/100 mm or better.
- Soldering is not recommended for TE modules whose size is 18 x 18 mm or larger.
- Maximum clamping pressure is 1000 kPa for miniatures and 1500 kPa for other modules.

Operation

- Storage and operation in a condensing environment is only recommended if you use sealed modules.
- Generally TE modules are operated at 40-80% of U_{max}.
- Be sure to handle TE modules carefully during transportation and in production.
- When regulating in ON/OFF mode, make sure cycle time is 60 sec. or more.
- If you use your own PWM-controller, make sure switching frequency is 5 kHz or more.

For more information, please contact Supercool.

Cooling power (P_c) versus Temperature difference (ΔT) for single stage modules.



- For respective $P_{c\ max}$ ΔT_{max} and I_{max}, see specification tables. Module Hot side temperature $T_h = 25°C$.
- At $T_h = 50°C$ the ΔT_{max} increases by 10°C and $P_{c\ max}$ by 10% compared to the above curves.
- For multistage modules, as well as for more detailed specifications for any module, please call for individual performance graphs.
- U_{max} and I_{max} are specified at $\Delta T = \Delta T_{max}$
- ΔT = Hot side temperature (T_h) less Cold side temperature (T_c).

MICROCHIP

PIC16F87X

28/40-pin 8-Bit CMOS FLASH Microcontrollers

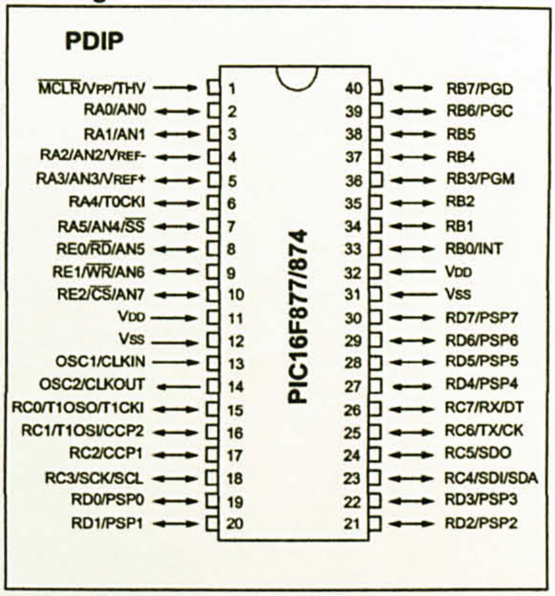
Devices Included in this Data Sheet:

- PIC16F873
- PIC16F874
- PIC16F876
- PIC16F877

Microcontroller Core Features:

- High-performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches which are two cycle
- Operating speed: DC - 20 MHz clock input
  DC - 200 ns instruction cycle
- Up to 8K x 14 words of FLASH Program Memory,
  Up to 368 x 8 bytes of Data Memory (RAM)
  Up to 256 x 8 bytes of EEPROM data memory
- Pinout compatible to the PIC16C73B/74B/76/77
- Interrupt capability (up to 14 sources)
- Eight level deep hardware stack
- Direct, indirect and relative addressing modes
- Power-on Reset (POR)
- Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code-protection
- Power saving SLEEP mode
- Selectable oscillator options
- Low-power, high-speed CMOS FLASH/EEPROM technology
- Fully static design
- In-Circuit Serial Programming™ (ICSP) via two pins
- Single 5V In-Circuit Serial Programming capability
- In-Circuit Debugging via two pins
- Processor read/write access to program memory
- Wide operating voltage range: 2.0V to 5.5V
- High Sink/Source Current: 25 mA
- Commercial and Industrial temperature ranges
- Low-power consumption:
  - < 2 mA typical @ 5V, 4 MHz
  - 20 µA typical @ 3V, 32 kHz
  - < 1 µA typical standby current

Pin Diagram

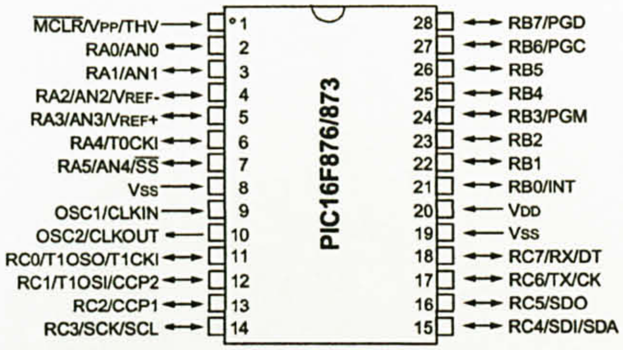


Peripheral Features:

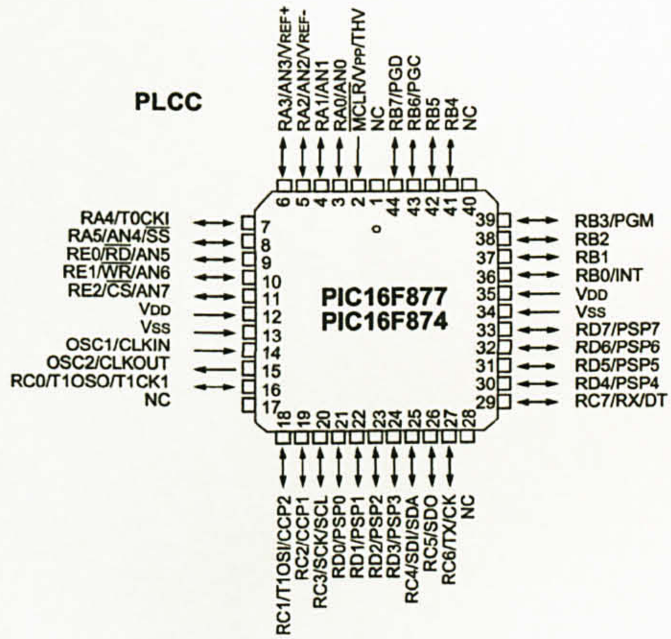
- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during sleep via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. resolution is 12.5 ns
  - Compare is 16-bit, max. resolution is 200 ns
  - PWM max. resolution is 10-bit
- 10-bit multi-channel Analog-to-Digital converter
- Synchronous Serial Port (SSP) with SPI™ (Master Mode) and I²C™ (Master/Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection
- Parallel Slave Port (PSP) 8-bits wide, with external $\overline{RD}$, $\overline{WR}$ and $\overline{CS}$ controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

Pin Diagrams

DIP, SOIC



PLCC



QFP

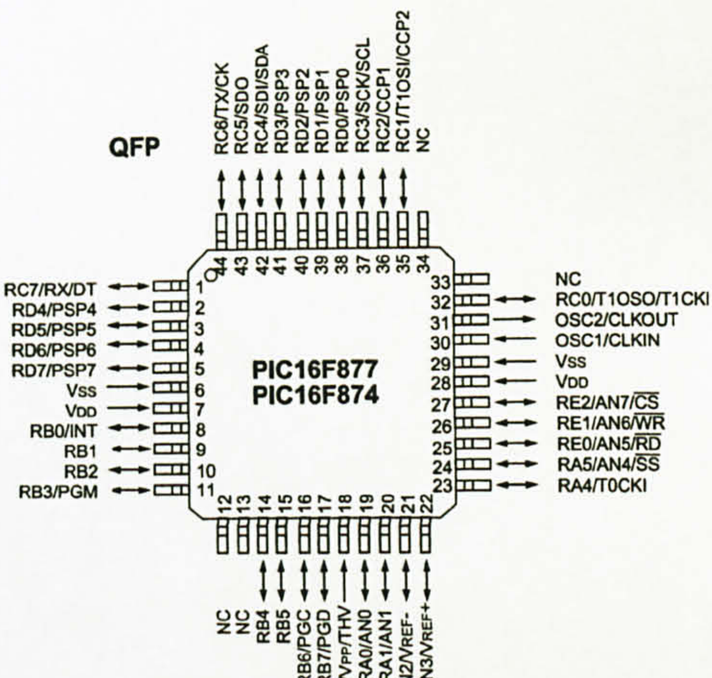


TABLE 1-1: PIC16F873 AND PIC16F876 PINOUT DESCRIPTION

Pin Name	DIP Pin#	SOIC Pin#	I/O/P Type	Buffer Type	Description
OSC1/CLKIN	9	9	I	ST/CMOS(3)	Oscillator crystal input/external clock source input.
OSC2/CLKOUT	10	10	O	—	Oscillator crystal output. Connects to crystal or resonator in crystal oscillator mode. In RC mode, the OSC2 pin outputs CLKOUT which has 1/4 the frequency of OSC1, and denotes the instruction cycle rate.
$\overline{MCLR}$/VPP/THV	1	1	I/P	ST	Master clear (reset) input or programming voltage input or high voltage test mode control. This pin is an active low reset to the device.
					PORTA is a bi-directional I/O port.
RA0/AN0	2	2	I/O	TTL	RA0 can also be analog input0
RA1/AN1	3	3	I/O	TTL	RA1 can also be analog input1
RA2/AN2/VREF-	4	4	I/O	TTL	RA2 can also be analog input2 or negative analog reference voltage
RA3/AN3/VREF+	5	5	I/O	TTL	RA3 can also be analog input3 or positive analog reference voltage
RA4/T0CKI	6	6	I/O	ST	RA4 can also be the clock input to the Timer0 module. Output is open drain type.
RA5/$\overline{SS}$/AN4	7	7	I/O	TTL	RA5 can also be analog input4 or the slave select for the synchronous serial port.
					PORTB is a bi-directional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs.
RB0/INT	21	21	I/O	TTL/ST(1)	RB0 can also be the external interrupt pin.
RB1	22	22	I/O	TTL	
RB2	23	23	I/O	TTL	
RB3/PGM	24	24	I/O	TTL	RB3 can also be the low voltage programming input
RB4	25	25	I/O	TTL	Interrupt on change pin.
RB5	26	26	I/O	TTL	Interrupt on change pin.
RB6/PGC	27	27	I/O	TTL/ST(2)	Interrupt on change pin or In-Circuit Debugger pin. Serial programming clock.
RB7/PGD	28	28	I/O	TTL/ST(2)	Interrupt on change pin or In-Circuit Debugger pin. Serial programming data.
					PORTC is a bi-directional I/O port.
RC0/T1OSO/T1CKI	11	11	I/O	ST	RC0 can also be the Timer1 oscillator output or Timer1 clock input.
RC1/T1OSI/CCP2	12	12	I/O	ST	RC1 can also be the Timer1 oscillator input or Capture2 input/Compare2 output/PWM2 output.
RC2/CCP1	13	13	I/O	ST	RC2 can also be the Capture1 input/Compare1 output/PWM1 output.
RC3/SCK/SCL	14	14	I/O	ST	RC3 can also be the synchronous serial clock input/output for both SPI and I^{2}C modes.
RC4/SDI/SDA	15	15	I/O	ST	RC4 can also be the SPI Data In (SPI mode) or data I/O (I^{2}C mode).
RC5/SDO	16	16	I/O	ST	RC5 can also be the SPI Data Out (SPI mode).
RC6/TX/CK	17	17	I/O	ST	RC6 can also be the USART Asynchronous Transmit or Synchronous Clock.
RC7/RX/DT	18	18	I/O	ST	RC7 can also be the USART Asynchronous Receive or Synchronous Data.
VSS	8, 19	8, 19	P	—	Ground reference for logic and I/O pins.
VDD	20	20	P	—	Positive supply for logic and I/O pins.

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

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

TABLE 1-2: PIC16F874 AND PIC16F877 PINOUT DESCRIPTION

Pin Name	DIP Pin#	PLCC Pin#	QFP Pin#	I/O/P Type	Buffer Type	Description
OSC1/CLKIN	13	14	30	I	ST/CMOS(4)	Oscillator crystal input/external clock source input.
OSC2/CLKOUT	14	15	31	O	—	Oscillator crystal output. Connects to crystal or resonator in crystal oscillator mode. In RC mode, OSC2 pin outputs CLK-OUT which has 1/4 the frequency of OSC1, and denotes the instruction cycle rate.
$\overline{MCLR}$/VPP/THV	1	2	18	I/P	ST	Master clear (reset) input or programming voltage input or high voltage test mode control. This pin is an active low reset to the device.
						PORTA is a bi-directional I/O port.
RA0/AN0	2	3	19	I/O	TTL	RA0 can also be analog input0
RA1/AN1	3	4	20	I/O	TTL	RA1 can also be analog input1
RA2/AN2/VREF-	4	5	21	I/O	TTL	RA2 can also be analog input2 or negative analog reference voltage
RA3/AN3/VREF+	5	6	22	I/O	TTL	RA3 can also be analog input3 or positive analog reference voltage
RA4/T0CKI	6	7	23	I/O	ST	RA4 can also be the clock input to the Timer0 timer/counter. Output is open drain type.
RA5/$\overline{SS}$/AN4	7	8	24	I/O	TTL	RA5 can also be analog input4 or the slave select for the synchronous serial port.
						PORTB is a bi-directional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs.
RB0/INT	33	36	8	I/O	TTL/ST(1)	RB0 can also be the external interrupt pin.
RB1	34	37	9	I/O	TTL	
RB2	35	38	10	I/O	TTL	
RB3/PGM	36	39	11	I/O	TTL	RB3 can also be the low voltage programming input
RB4	37	41	14	I/O	TTL	Interrupt on change pin.
RB5	38	42	15	I/O	TTL	Interrupt on change pin.
RB6/PGC	39	43	16	I/O	TTL/ST(2)	Interrupt on change pin or In-Circuit Debugger pin. Serial programming clock.
RB7/PGD	40	44	17	I/O	TTL/ST(2)	Interrupt on change pin or In-Circuit Debugger pin. Serial programming data.
						PORTC is a bi-directional I/O port.
RC0/T1OSO/T1CKI	15	16	32	I/O	ST	RC0 can also be the Timer1 oscillator output or a Timer1 clock input.
RC1/T1OSI/CCP2	16	18	35	I/O	ST	RC1 can also be the Timer1 oscillator input or Capture2 input/Compare2 output/PWM2 output.
RC2/CCP1	17	19	36	I/O	ST	RC2 can also be the Capture1 input/Compare1 output/PWM1 output.
RC3/SCK/SCL	18	20	37	I/O	ST	RC3 can also be the synchronous serial clock input/output for both SPI and I^2C modes.
RC4/SDI/SDA	23	25	42	I/O	ST	RC4 can also be the SPI Data In (SPI mode) or data I/O (I^2C mode).
RC5/SDO	24	26	43	I/O	ST	RC5 can also be the SPI Data Out (SPI mode).
RC6/TX/CK	25	27	44	I/O	ST	RC6 can also be the USART Asynchronous Transmit or Synchronous Clock.
RC7/RX/DT	26	29	1	I/O	ST	RC7 can also be the USART Asynchronous Receive or Synchronous Data.

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 an 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 as general purpose I/O and a TTL input when used in the Parallel Slave Port mode (for interfacing to a microprocessor bus).
4: This buffer is a Schmitt Trigger input when configured in RC oscillator mode and a CMOS input otherwise.

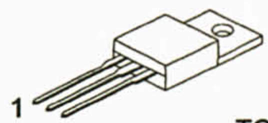
TABLE 1-2: PIC16F874 AND PIC16F877 PINOUT DESCRIPTION (CONTINUED)

Pin Name	DIP Pin#	PLCC Pin#	QFP Pin#	I/O/P Type	Buffer Type	Description
						PORTD is a bi-directional I/O port or parallel slave port when interfacing to a microprocessor bus.
RD0/PSP0	19	21	38	I/O	ST/TTL(3)	
RD1/PSP1	20	22	39	I/O	ST/TTL(3)	
RD2/PSP2	21	23	40	I/O	ST/TTL(3)	
RD3/PSP3	22	24	41	I/O	ST/TTL(3)	
RD4/PSP4	27	30	2	I/O	ST/TTL(3)	
RD5/PSP5	28	31	3	I/O	ST/TTL(3)	
RD6/PSP6	29	32	4	I/O	ST/TTL(3)	
RD7/PSP7	30	33	5	I/O	ST/TTL(3)	
						PORTE is a bi-directional I/O port.
RE0/$\overline{RD}$/AN5	8	9	25	I/O	ST/TTL(3)	RE0 can also be read control for the parallel slave port, or analog input5.
RE1/$\overline{WR}$/AN6	9	10	26	I/O	ST/TTL(3)	RE1 can also be write control for the parallel slave port, or analog input6.
RE2/$\overline{CS}$/AN7	10	11	27	I/O	ST/TTL(3)	RE2 can also be select control for the parallel slave port, or analog input7.
V_{SS}	12,31	13,34	6,29	P	—	Ground reference for logic and I/O pins.
V_{DD}	11,32	12,35	7,28	P	—	Positive supply for logic and I/O pins.
NC	—	1,17,28, 40	12,13, 33,34		—	These pins are not internally connected. These pins should be left unconnected.

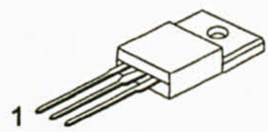
Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as an 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 as general purpose I/O and a TTL input when used in the Parallel Slave Port mode (for interfacing to a microprocessor bus).
4: This buffer is a Schmitt Trigger input when configured in RC oscillator mode and a CMOS input otherwise.

3-TERMINAL 1A POSITIVE VOLTAGE REGULATOR



TO-220



TO-220F

*Pb-free plating product number: LM78XXL

■ DESCRIPTION

The UTC **LM78XX** family is monolithic fixed voltage regulator integrated circuit. They are suitable for applications that required supply current up to 1 A.

■ FEATURES

* Output current up to 1A
* Fixed output voltage of 3.3V,4.7V,5V, 6V, 7V, 8V, 9V, 10V, 12V, 15V, 18V and 24V available
* Thermal overload shutdown protection
* Short circuit current limiting
* Output transistor SOA protection

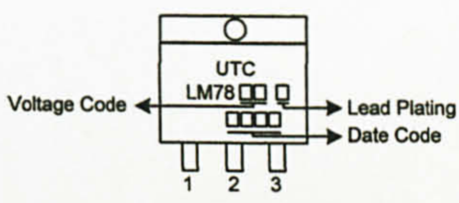
■ ORDERING INFORMATION

Order Number		Pin Assignment			Package	Packing
Normal	Lead Free Plating	1	2	3		
LM78xx-TA3-D-T	LM78xxL-TA3-D-T	I	G	O	TO-220	Tube
LM78xx-TF3-D-T	LM78xxL-TF3-D-T	I	G	O	TO-220F	Tube

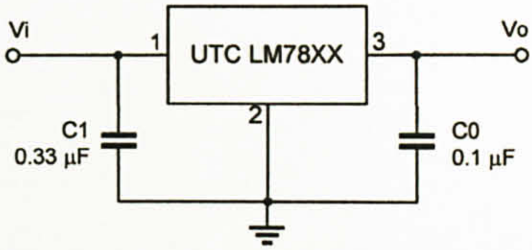
Note: O: Output G: GND I: Input

LM78xxL-TA3-D-T	
(1)Packing Type	(1) T: Tube
(2)Pin Assignment	(2) refer to Pin Assignment
(3)Package Type	(3) TA3: TO-220, TF3: TO-220F
(4)Lead Plating	(4) L: Lead Free Plating, Blank: Pb/Sn
(5)Output Voltage Code	(5) xx: refer to Marking Information

■ MARKING INFORMATION

PACKAGE	VOLTAGE CODE	VOLTAGE CODE	MARKING
TO-220 TO-220F	33:3.3V 47:4.7V 05:5.0V 06:6.0V 07:7.0V 08:8.0V 09:9.0V	10:10V 12:12V 15:15V 18:18V 24:24V	

■ APPLICATION CIRCUIT



Note 1: To specify an output voltage, substitute voltage value for "XX".

2: Bypass capacitors are recommended for optimum stability and transient response and should be located as close as possible to the regulators.

■ TYPICAL CHARACTERISTICS

Fig.1 Ambient temperature vs. Power dissipation

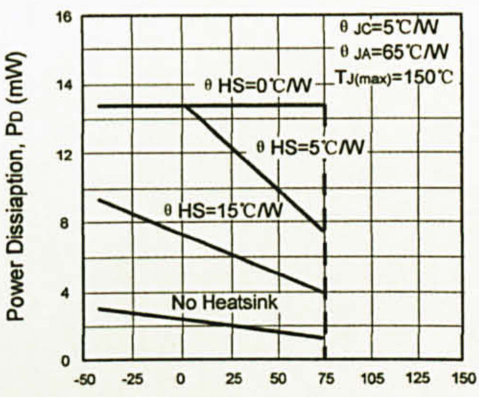


Fig.2 Output Voltage vs. Ambient temperature

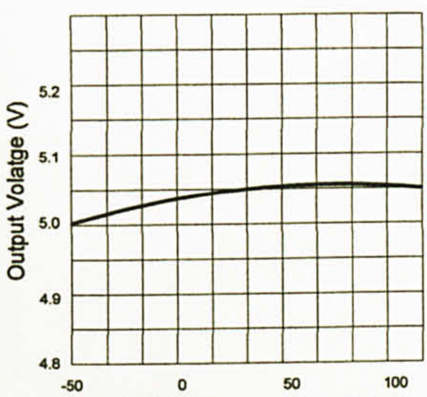
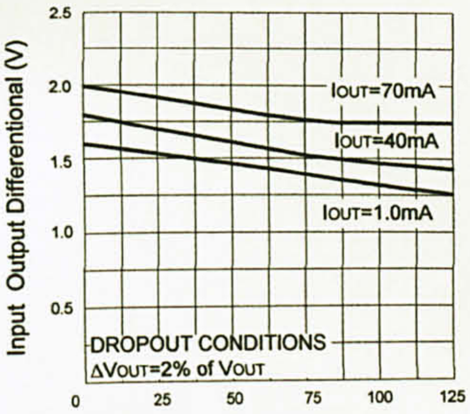


Fig.3 Dropout Voltage



JHD162A SERIES

• ••••••••••••••• •••••••••••••••••• DISPLAY CONTENT•• 16 CHAR x 2ROW

CHAR. DOTS• 5 x 8

DRIVING MODE• 1/16D

AVAILABLE TYPES• •

TN• STN(YELLOW GREEN• GREY• B/W)

REFLECTIVE• WITH EL OR LED BACKLIGHT

EL/100VAC• 400HZ

LED/4.2VDC

• •••••••••••••••••••• ••••••••••••••••• ••••••••

Parameter	Symbol	Testing Criteria	Standard Values			Unit
			Min.	Typ.	Max	
Supply voltage	V_{DD}-V_{SS}	-	4.5	5.0	5.5	V
Input high voltage	V_{IH}	-	2.2	-	V_{DD}	V
Input low voltage	V_{IL}	-	-0.3	-	0.6	V
Output high voltage	V_{OH}	-I_{OH}=02mA	2.4	-	-	V
Output low voltage	V_{OL}	I_{OL}=1.2mA	-	-	0.4	V
Operating voltage	I_{DD}	V_{DD}=5.0V	-	1.5	3.0	mA

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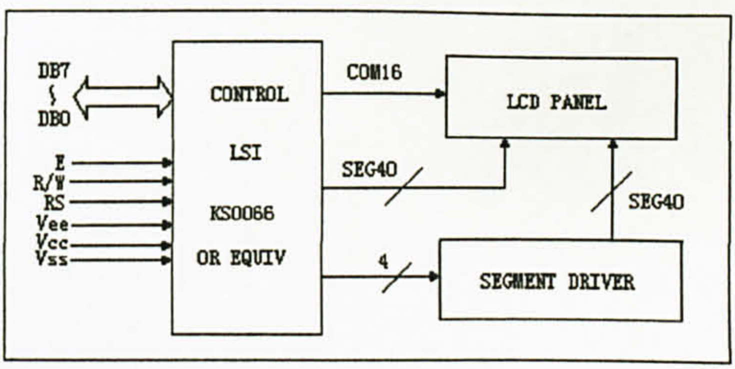

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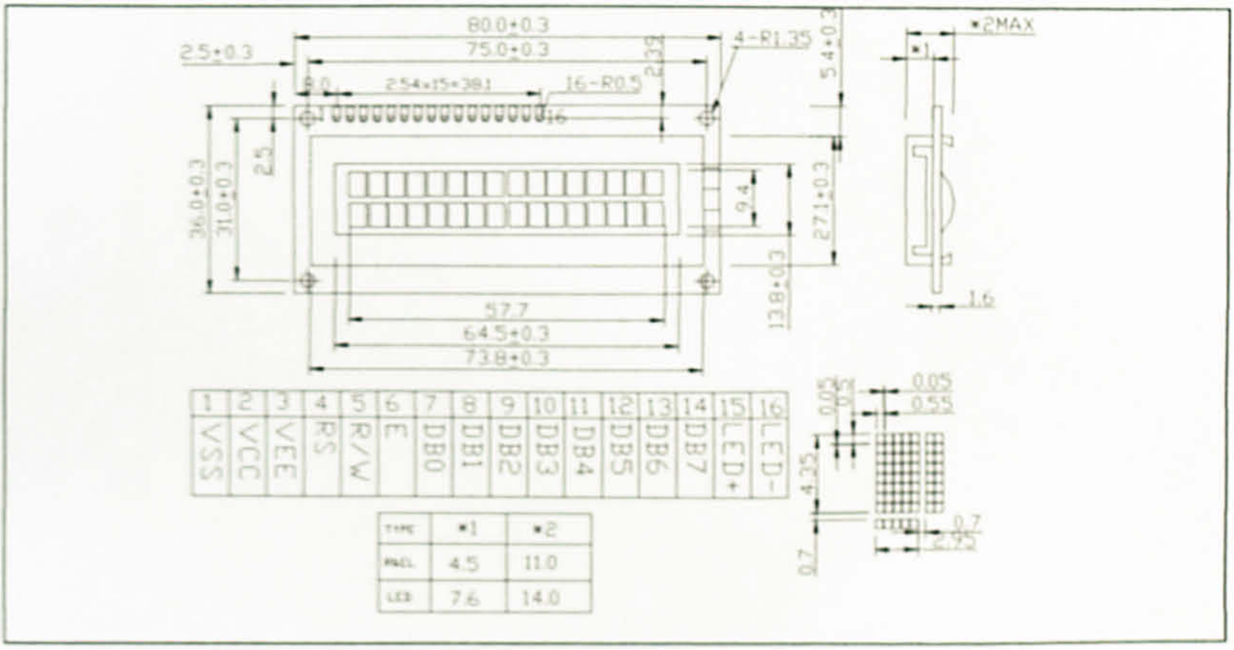
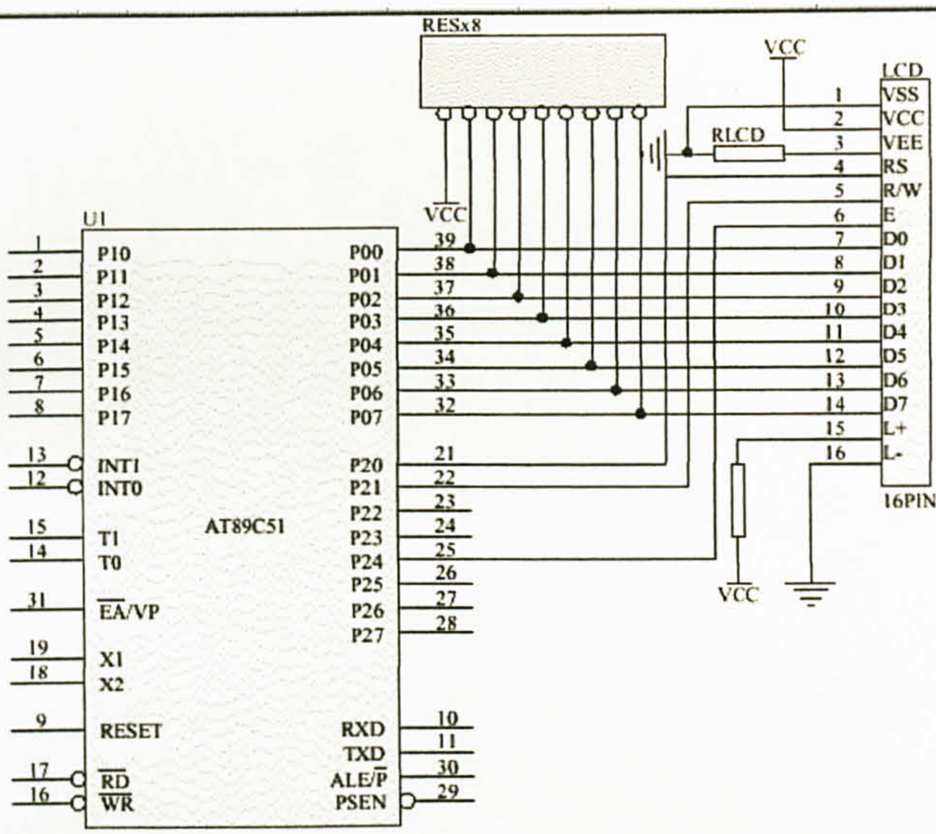


1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
VSS	VCC	VEE	RS	R/W	E	DB0	DB1	DB2	DB3	DB4	DB5	DB6	DB7	LED+	LED-

■ AC Characteristics Read Mode Timing Diagram

Connection



CGROM