

SMART CAR SEAT

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PROJEK SARJANA MUDA II**

Tajuk Projek : Smart Car Seat
Sesi Pengajian : 2/ 2007/2008

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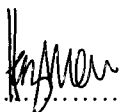
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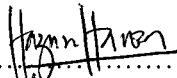
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DEDICATION

I dedicate this to both of my lovely parents and family, a person that love and need most for giving me a support, all my lecturers, all my friends and last but not least the people that contribute directly and indirectly.

ACKNOWLEDGEMENTS

Alhamdulillah, I finally able to complete the final year project and the thesis as well within the allocated time. First of all, I would to take this opportunity to express my appreciation to some organizations and individuals who have kindly contributed to the successfully completion of my final year project in UTeM. With the co operations and contributions from all parties, the objectives of the project, soft-skills, knowledge and experiences were gained accordingly. To begin with, I would like to convey my acknowledgement to UTeM PSM organization members especially my project supervisor, Pn Hazura Binti Haroon for their co operation and involvement from the beginning until the end of my project development. Her effort to ensure the successful and comfortability of students under her responsibility was simply undoubtful. Thanks for the invaluable advices given before, while and after completion of the project. Furthermore, I would like to extend my sincere acknowledgement to my parents and family members who have been very supportive throughout the project. Their understanding and support in term of moral and financial were entirely significance towards the project completion. Last but not list, my appreciation goes to my fellow colleagues in UTeM, especially for those who come from FKEKK. Their willingness to help, opinions and suggestions on some matters, advices and technical knowledge are simply precious while doing upon completion of my final year project.

ABSTRACT

This project is mainly about to design one system which used to detect motion in a vehicle, measured temperature in the vehicle and gives alarm and flash as a output. This system is called 'Smart Car Seat'. The idea to design this system is because many human especially children death in a car because of extreme temperature when they leave alone in a vehicle. The main objectives of this system are to reduce the number of death because of extreme temperature in a vehicle. This system contains of three part of circuit which is motion detector, temperature circuit which can fan automatic and PIC circuit to combine all the circuit. At first , the circuit will check whether vehicle is ON or OFF. This is because this system will only operate when vehicle is OFF. The vehicles battery will used to supply power to the motion detector circuit. When the motion is detected in a car, the output from this circuit will used to power ON temperature circuit. This temperature circuit will measure temperature in the vehicle. When temperature at the vehicle reaches their limit, this circuit will turn the fan, buzzer and LED to gives alarm to people around.

ABSTRAK

Projek ini bertujuan untuk merekabentuk suatu sistem dimana ianya digunakan untuk mengesan pergerakan manusia di dalam kenderaan, mengukur suhu di dalam kenderaan, dan seterusnya menghantar isyarat dalam bentuk bunyi dan cahaya. Sistem ini diberi nama 'a smart car seat'. Idea untuk merekabentuk sistem ini terhasil apabila telah banyak kejadian dimana kanak-kanak mati akibat daripada suhu yang melampau di dalam kenderaan apabila ditinggalkan bersendirian. Objektif utama sistem ini direka ialah untuk merekabentuk sistem yang dapat mengurangkan masalah seperti yang telah disebutkan di atas. Sistem ini terdiri daripada beberapa litar iaitu litar pengesan pergerakan, litar pengukur suhu, litar untuk menjalankan kipas secara automatik dan menggunakan PIC untuk penggabungan litar untuk beroperasi secara bersama. Pada mulanya sistem ini akan mengesan samada kenderaan masih hidup atau telah dimatikan. Ini kerana sistem ini akan berfungsi hanya apabila kenderaan dimatikan. Bateri pada kenderaan akan digunakan untuk menghidupkan sistem ini. Tenaga daripada bateri akan menghidupkan litar pengesan pergerakan. Jika pergerakan dapat dikesan, isyarat akan dihantar untuk menghidupkan litar pengukur suhu. Litar ini berfungsi untuk menentukan berapa suhu di dalam kenderaan tersebut. Apabila suhu telah mencapai had maksimum, maka isyarat akan dihantar untuk menggerakkan kipas secara automatik, menghidupkan buzzer dan LED sebagai amaran kepada orang sekeliling.

TABLE OF CONTENTS

| CHAPTER | TITLES | PAGE NUMBERS |
|----------|----------------------------------|--------------|
| | PROJECT TITLE | i |
| | PENGESAHAN STATUS LAPORAN | ii |
| | STUDENT CONFESSION | iii |
| | SUPERVISOR APPROVAL | iv |
| | DEDICATION | v |
| | ACKNOWLEDGEMENTS | vi |
| | ABSTRACT | vii |
| | ABSTRAK | viii |
| | TABLE OF CONTENTS | ix |
| | LIST OF TABLE | xiii |
| | LIST OF FIGURE | xiv |
| I | INTRODUCTION | |
| | 1.1 Overview | 1 |
| | 1.2 Problem statements | 2 |
| | 1.3 Project Objectives | 2 |
| | 1.4 Scope of Project | 2 |
| | 1.5 Report Structure | 3 |

| | | |
|-----------|------------------------------------------|----------|
| II | LITERATURE REVIEW | 4 |
| 2.1 | Recent Projects | 4 |
| 2.1.1 | Smart Car Seat | 4 |
| 2.1.2 | Car Seat Safety Project | 7 |
| 2.2 | Negative Temperature Coefficient | 9 |
| 2.2.1 | Temperature Ranges and Resistance Values | 9 |
| 2.2.2 | Sensitivity to Change in Temperature | 10 |
| 2.2.3 | Interchangeability | 10 |
| 2.2.4 | Small Size | 11 |
| 2.2.5 | Remote Temperature Sensing Capability | 11 |
| 2.2.6 | Ruggedness, Stability and Reliability | 11 |
| 2.2.7 | Material and Configurations | 11 |
| 2.3 | LM741 Operational Amplifier | 12 |
| 2.4 | LM555 Timer | 13 |
| 2.4.1 | Schematic Diagram | 14 |
| 2.5 | Peripheral Interface Circuit (PIC) | 14 |
| 2.5.1 | Microcontroller | 14 |
| 2.6 | Power Transistor (BD135) | 17 |
| 2.7 | Temperature sensor | 18 |
| 2.7.1 | LM35 Temperature Sensor | 18 |
| 2.7.1.1 | LM35 Characteristic | 18 |
| 2.7.1.2 | LM35 Operations | 19 |
| 2.7.2 | Thermistor sensor | 19 |
| 2.7.2.1 | Thermistor's sensor characteristics | 21 |
| 2.7.2.2 | Thermistor's sensor samples pictures | 21 |
| 2.7.2.3 | The operations of thermistors sensor | 22 |

| | | |
|------------|---------------------------------------|----|
| III | METHODOLOGY | 27 |
| 3.1 | Overview | 27 |
| 3.2 | Literature Review | 27 |
| 3.3 | Flow Chart | 27 |
| 3.4 | Block Diagram | 28 |
| 3.4.1 | Description of Block Diagram | 29 |
| 3.5 | Motion Detector | 30 |
| 3.5.1 | Description of Motion Detector | 30 |
| 3.5.2 | Flow Chart | 32 |
| 3.6 | Temperature Circuit | 33 |
| 3.6.1 | Temperature Sensor (LM35) | 33 |
| 3.6.2 | LCD Display | 33 |
| 3.6.3 | Flow Chart | 34 |
| 3.7 | Microcontroller Circuit | 35 |
| IV | PROJECT RESULT AND DISCUSSIONS | 37 |
| 4.1 | Hardware part | 38 |
| 4.1.1 | Temperature Circuit | 38 |
| 4.1.2 | Motion Detector | 45 |
| 4.4 | Discussions | 49 |

| | | |
|----------|------------------------------------|-----|
| | | xii |
| V | CONCLUSION & SUGGESTION | 50 |
| 5.1 | Conclusion | 50 |
| 5.2 | Suggestion | 51 |
| | REFERENCES | 54 |

LIST OF TABLE

| NO | TITLE | PAGE |
|-----------|-------------------------------------|-------------|
| 2.1 | Value of Temperature and Resistance | 22 |
| 2.2 | NTC Thermistor Data | 24 |

LIST OF FIGURES

| NO | TITLE | PAGE |
|------|----------------------------------------------|------|
| 2.1 | Block Diagram 1 | 4 |
| 2.2 | Block Diagram 2 | 7 |
| 2.3 | Types of NTC | 12 |
| 2.4 | LM555 Schematic Diagram | 14 |
| 2.5 | Pin Diagram of BD135 | 17 |
| 2.6 | LM35 Temperature Sensor | 18 |
| 2.7 | Thermistor | 19 |
| 2.8 | Graph resistance versus temperature (Kelvin) | 21 |
| 2.9 | Thermistor sensor | 21 |
| 2.10 | Resistance versus Temperature (Kelvin). | 23 |
| 2.11 | Thermistor Resistance/temperature Curve | 25 |
| 2.12 | Thermistor Circuit | 26 |
| 3.1 | Flow Chart | 28 |
| 3.2 | Block Diagram | 28 |
| 3.3 | Block Diagram for Motion Detector | 30 |
| 3.4 | PIR Sensor | 30 |
| 3.5 | PIC16f876A (Microcontroller) Pin Diagram | 31 |
| 3.6 | Flow Chart for Motion Detector | 32 |
| 3.7 | Block Diagram for Temperature Circuit | 33 |
| 3.8 | LCD Display Schematic | 33 |
| 3.9 | Flow Chart for Temperature Circuit | 34 |
| 4.1 | Temperature Circuit Schematic Diagram | 38 |

| | | |
|------|------------------------------------------------------------------|----|
| 4.2 | Connection from Adapter to the Circuit (Temperature Controller) | 39 |
| 4.3 | Connection from Battery to the Circuit (Temperature Controller) | 39 |
| 4.4 | LED Indicator that the Circuit Function (Temperature Controller) | 40 |
| 4.5 | LCD Display the Temperature (Temperature Controller) | 41 |
| 4.6 | LCD Display and LED Indicator Light Up (Temperature Controller) | 42 |
| 4.7 | Complete Circuit Function (Temperature Controller) | 43 |
| 4.8 | Motion Detector Schematic Diagram | 45 |
| 4.9 | Connection from Adapter to the Circuit (Motion Detector) | 46 |
| 4.10 | Connection from Battery to the Circuit (Motion Detector) | 46 |
| 4.11 | Circuit Function (Motion Detector) | 47 |
| 4.12 | Complete Circuit (Motion Detector) | 48 |

CHAPTER I

INTRODUCTION

Chapter I start with background of the project. It is followed by the objectives and scope of the project. The overview method of the project is presented in fourth part and lastly summary of the thesis is described.

Now days, technologies has been assimilate into the whole life without realized. Besides that, these technologies have good and bad impact depend on how to use it. Based on technologies, smart car seat helps community to reduce the number of death because of extreme temperature in the vehicle.

1.1 OVERVIEW

In a recent day, we always heard about a death case because of an extreme temperature in a vehicle. Many researches have been done to overcome this problem. In Europe, they have developed a system to reduce the number of death. However, in our country, it still in development process. Therefore, with this project it will help to give some idea on how to build a system that can overcome this problem. This system is divided into three parts, which are motion

detector circuit, temperature circuit and PIC circuit. In PIC circuit, we need to program it. The programmed is developed by using C++ programming language. C++ has moderate speed of performances and easy to debug.

1.2 PROBLEM STATEMENTS

Each year a number of children die because being left in vehicles for a prolonged period of time. These tragic incidents typically arise when a driver reaches his destination and leaves the car to run a quick errand, forgetting the child is in the car. Infants are particularly susceptible to dehydration and may relatively quickly slip into a comatose state or even worse, suffer a deadly heat stroke.

1.3 PROJECT OBJECTIVES

The objectives of these projects are:

- i. To design a circuit that can detect motion in a car.
- ii. To design a temperature circuit sensor that can measure temperature in a car.
- iii. To design a circuit that can operate fan automatically.

1.4 SCOPE OF PROJECTS

This project is subjected to several scope and limitations that are narrowed down to the study. The scopes are divided to three, which are:

- i. Motion detector
 - a. To detect a motion in a car.

- ii. Temperature circuit
 - a. Use LM35 as the temperature sensor.
 - b. Use LED and buzzer as an output.
 - c. Need to connect to fan and operate automatically
 - d. Temperature limit is 60°Celcuis.

- iii. PIC circuit
 - a. Language to use is C++.

1.5 REPORT STRUCTURE

This report starts with literature review about the negative temperature coefficient, PIC microcontroller, and others component and about material that suitable to create smart car seat. In next chapter, will be discuss the project methodology on the process to build smart car seat circuit. Next chapter show all the result and algorithms. Project hypothesis will be done decide either the project archive the objectives. Lastly, this report has some discussion and conclusion on this overall project.

CHAPTER II

LITERATURE REVIEW

2.1 RECENT PROJECTS

2.1.1 SMART CAR SEAT

This project is developed by Jason Carter, Jeremiah Johnson and Steve Kopchik.

The block diagram of the project as below [1]:

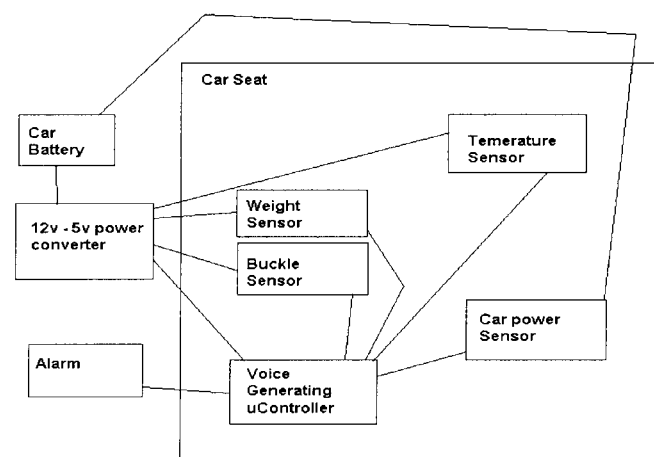


Figure 2.1: Block Diagram 1

2.1.1.1 BLOCK DESCRIPTIONS

a. Car Battery

The Car's Internal Battery. It will be used to drive all sensors and microcontroller as well as the alarm. This will also be used to detect if the car is running or not [1].

b. Power Converter

A power converter is used to reduce the 12v car battery to 5v for safe operation of the sensors and microcontroller. It will be connected to the sensors in order to provide them with power [1].

c. Weight Sensor

A weight sensor used to detect the presence of a child in the car seat. It will output the weight in the car seat to the microcontroller in order for it to decide if the object is a child or not [1].

d. Buckle Sensor

A buckle sensor is used as switch to detect if the car seat has been buckled into the car. It will be the primary on or off switch for the system [1].

e. Temperature Sensor

A temperature sensor is used to detect if the temperature in the car is above the high threshold or below the low threshold. It will output the temperature to the microcontroller to determine if one of these occurs [1].

f. Car Power Sensor

A car power sensor used to detect if the car is on or off. It will detect the amount of power being drained by the car battery. It will alert the processor if the power being drained is below threshold wattage [1].

g. Voice Generating Microcontroller

Combine outputs from all sensors and activate the alarm when necessary. It will also store the recorded message that will alert people in the area of the child in danger [1].

h. Alarm

An alarm used as a simple car alarm that will play the recorded message to alert people in the area of the trapped child [1].

2.1.2 CAR SEAT SAFETY PROJECT

This project is developed by Robert Schoonover, Ryan Simpson and Hans Voigt. The block diagram of the project as below [2]:

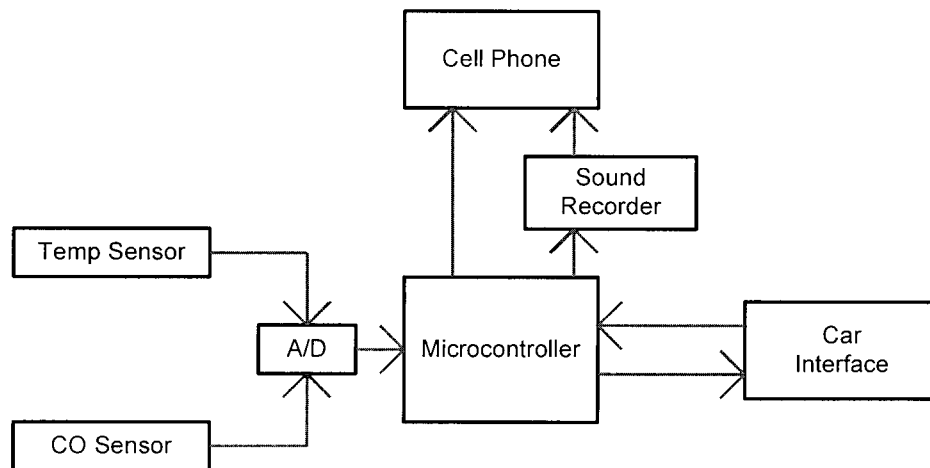


Figure 2.2: Block Diagram 2

2.1.2.1 BLOCK DIAGRAM DESCRIPTION

i. Power Supply Module

A power supply that would take a 12VDC unregulated power supply and provide 5VDC for all of the circuitry. This power supply would be tested at all reasonable voltages one could expect to get from a car battery [2].

ii. Temperature Sensor

The temperature sensor needed to be sensitive in the range of 0° to 102° Celsius. The sensor would need to give a reading that could be read by a microprocessor [2].

iii. Carbon Monoxide Sensor

A carbon monoxide (CO) sensor that could be conditioned to send an alarm to the microprocessor in the event that the concentration of CO was too high. It also needed to be able to run off of the 5V power supply [2].

iv. Microprocessor

The microprocessor needed to be able to take in multiple analog signals for processing and have multiple digital outputs for the car interface. It also needed to be able to communicate over RS-232 to interface with the cellular phone [2].

v. Cellular Phone

The cellular phone needed to be capable of AT modem commands, have an easy interface through its serial port, and have an audio jack. We chose a Motorola GSM T720 phone for testing this part of the project, although a CDMA phone would be better for a finished project since CDMA phones have a much wider coverage area in the United States [2].

vi. Audio Playback Chip

The audio playback had to be able to store a pre-recorded message and then transmit that message upon a signal from the microprocessor. It also had to be able to loop the message continuously to ensure that emergency services would get all the necessary information [2].

vii. Car Remote

The car remote merely had to be an off the shelf module that we could interface with via digital signals. For our proof-of-concept work, we took apart one of our own car remotes [2].

2.2 NEGATIVE TEMPERATURE COEFFICIENT

After time, temperature is the variable most frequently measured. The three most common types of contact electronic temperature sensors in use today are thermocouples, resistance temperature detectors (RTDs), and thermistor. Negative temperature coefficient (after this known as NTC) thermistor are manufactured in variety of sizes and configurations. The chips in the center of the photo can be used as surface mount devices or attached to different types of insulated or uninsulated wire leads. The thermistor element is usually coated with a phenolic or epoxy material that provides protection from environmental conditions [3].

2.2.1 TEMPERATURE RANGES AND RESISTANCE VALUES

NTC thermistors exhibit a decrease in electrical resistance with increasing temperature. Depending on the materials and methods of fabrication, they are generally used in temperature range of -50°C to 150°C , and up to 300°C for some glass-encapsulated units. The resistance value of a thermistor is typically referenced at 25°C (abbreviated as R25). For most applications, the R25 values are between $100\ \Omega$ and $100\text{k}\ \Omega$. Other R25 values as low as $10\ \Omega$ and as high as $40\text{M}\ \Omega$ can be produced, and resistance values at temperature points other as 25°C can be specified. [3]

2.2.2 SENSITIVITY TO CHANGES IN TEMPERATURE

The NTC thermistor's relatively large change in resistance versus temperature, typically on the order of $-3\%/^{\circ}\text{C}$ to $-6\%/^{\circ}\text{C}$. It provides an order of magnitude greater sensitivity or signal response than other temperature sensors such as thermocouples and RTDs. On the other hand, the less sensitive thermocouples and RTDs are good choice for applications requiring temperature spans $>260^{\circ}\text{C}$ and/or operating temperatures beyond the limits for thermistors [3].

2.2.3 INTERCHANGEABILITY.

Another important feature of the NTC thermistor is the degree of interchangeability that can be offered at a relatively low cost, particularly for disc and chip devices. Interchangeability describes the degree of accuracy or tolerance to which a thermistor is specified and produced, and is normally expressed as a temperature tolerance over a temperature range. For example, disc and chip thermistors are commonly specified to tolerances of $\pm 0.1^{\circ}\text{C}$ and $\pm 0.2^{\circ}\text{C}$ over the temperature ranges of 0°C to 70°C and 0°C to 100°C . Interchangeability helps the systems manufacturer or thermistor users reduce labor costs by not having to calibrate each instrument/system with each thermistor during fabrication or while being used in the field. A health care professional, for instance, can use a thermistor temperature probe on one patient, discard it, and connect a new probe of the same specifications for use on another patient without recalibration. The same holds true for other applications requiring reusable probes [3].

2.2.4 SMALL SIZE.

The small dimensions of most bead, disc, and chip thermistors used for resistance thermometry make for a very rapid response to temperature changes. This feature is particularly useful for temperature monitoring and control systems requiring quick feedback [3].

2.2.5 REMOTE TEMPERATURE SENSING CAPABILITY.

Thermistors are well suited for sensing temperature at remote locations via long, two-wire cable because the resistance of the long wires is insignificant compared to the relatively high resistance of the thermistor [3].

2.2.6 RUGGEDNESS, STABILITY, AND RELIABILITY.

As a result of improvements in technology, NTC bead, disc, and chip thermistor configurations are typically more rugged and better able to handle mechanical and thermal shock and vibration than other temperature sensors [3].

2.2.7 MATERIALS AND CONFIGURATIONS

Most NTC thermistors are made from various compositions of the metal oxides of manganese, nickel, cobalt, copper, and/or iron. A thermistor's R/T characteristic and R₂₅ value are determined by the particular formulation of oxides. Over the past 10 years, better raw materials and advances in ceramics processing technology have contributed to overall improvements in the reliability, interchangeability, and cost-effectiveness of thermistors [3]

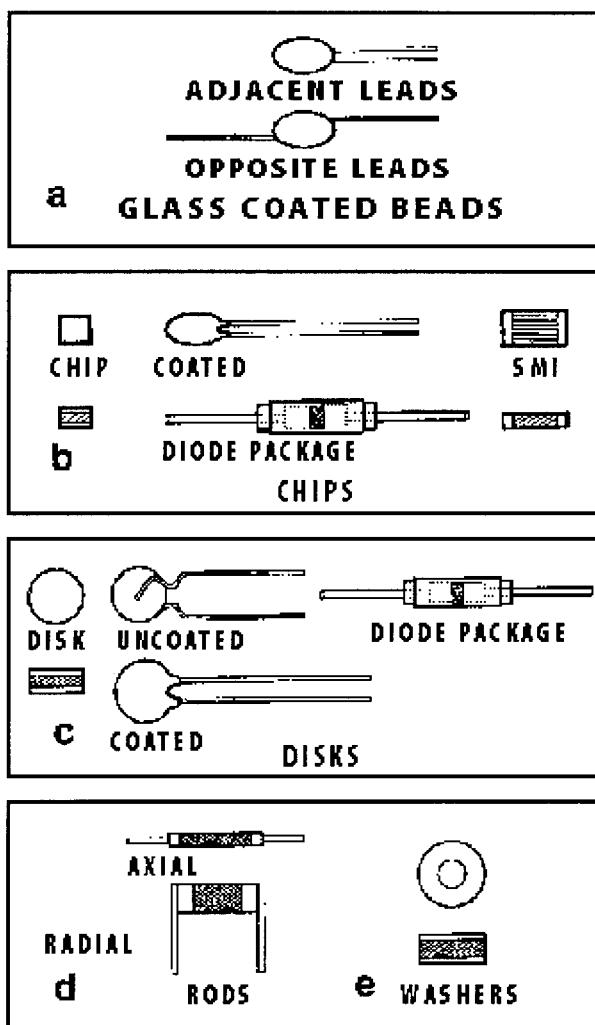


FIGURE 2.3: TYPES OF NTC

2.3 LM741 OPERATIONAL AMPLIFIER

The LM741 series are general-purpose operational amplifiers, which feature improved performance over industry standards like the LM709. They are direct, plug-in replacements for the 709C, LM201, MC1439 and 748 in most applications. The amplifiers offer many features, which make their application nearly foolproof: overload protection on the input and output, no latch-up when the common mode range is exceeded, as well as freedom from oscillations.

The LM741C/LM741E are identical to the LM741/LM741A except that the LM741C/LM741E have their performance guaranteed over a 0°C to a 70°C temperature range, instead of -55°C to +125°C [3].

2.4 LM555 TIMER

The LM555 is a highly stable device for generating accurate time delays or oscillation. Additional terminals are provided for triggering or resetting if desired. In the time delay mode of operation, one external resistor and capacitor precisely control the time. For astable operation as an oscillator, the free running frequency and duty cycle are accurately controlled with two external resistors and one capacitor. The circuit may be triggered and reset on falling waveforms, and the output circuit can source or sink up to 200 mA or drive TTL circuits.

i. FEATURES

- a. Direct replacement for SE555/NE555
- b. Timing from microseconds through hours
- c. Operates in both astable and monostable modes
- d. Adjustable duty cycle
- e. Output can source or sink 200 mA
- f. Output and supply TTL compatible
- g. Temperature stability better than 0.005% per °C
- h. Normally on and normally off output
- i. Available in 8 pin MSOP package

2.4.1 SCHEMATIC DIAGRAM

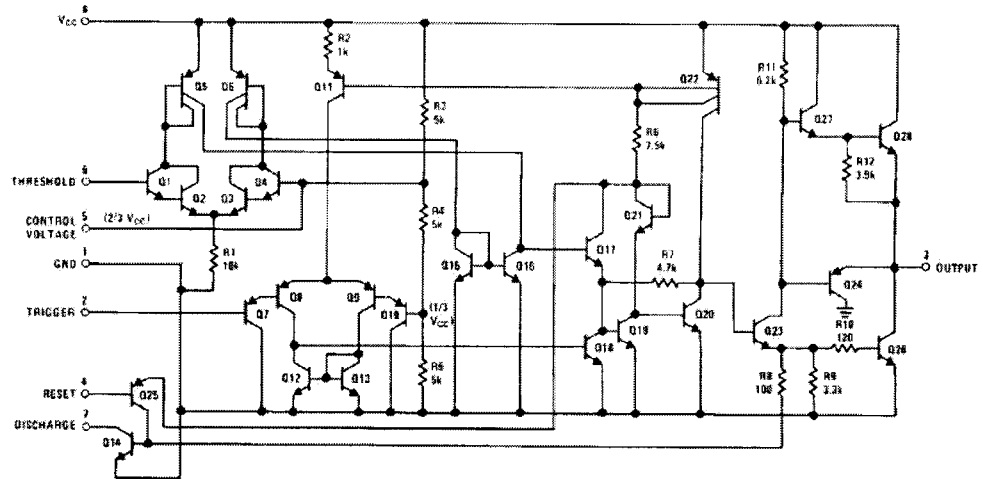


Figure 2.4: LM555 Schematic Diagram

2.5 PERIPHERAL INTERFACE CIRCUIT (PIC)

2.5.1 MICROCONTROLLER

A microcontroller is an inexpensive single-chip computer. Single chip computer means that the entire computer system lies within the confines of the integrated circuit chip. The microcontroller on the encapsulated sliver of silicon has features similar to those of our standard personal computer. There are many different brand of microcontroller available in the market now such as Atmel, Rabbit, Intel, Motorola, Phillips, Microchip and others [4].

The type of microcontroller that will be used in this project is PIC 16F876A. The PIC16F876A family of low cost, high performance, CMOS, fully static, 8 bit microcontroller. PIC16F876A devices have enhanced core feature, eight level deep stacks, and multiple internal and external interrupt sources. The separate instruction and data buses of the Harvard architecture allow a 14 bit wide instruction word with a separate 8 bit wide data bus. A total of 35 instructions

(reduced instruction set) are available. Additionally, a large register set is used to achieve a very high performance level [4].

The PIC16F876A family has special features to reduce external components, thus reducing cost, enhancing system reliability and reducing power consumption. The devices with Flash program memory allow the same device package to be used for prototyping and production. In circuit, reprogram ability allows the code to be updated without the device being removed from the end application. This is useful in the development of many applications where the device may not be easily accessible, but the prototypes may require code updates [4].

The PIC16F876A fits perfectly in applications ranging from high speed automotive and appliances motor control to low power remote sensors, electronic locks, security devices and smart cards. The Flash/EEPROM technology makes customization of application programs (transmitter codes, receiver frequency, and security code) extremely fast and convenient [4]

The serial in system programming feature offers flexibility of customizing the product after complete assembly and testing. This feature can be used to serialize a product, store calibration data, or program the device with the current firmware before shipping. The small footprint packages make this microcontroller series perfect for all applications with space limitations. Low cost, low power, high performance, ease of use and I/O flexibility make the microcontroller use has been considered [4].

Control system of an appliances always being the most challenging part for most students who are interested in building a simple to control home appliances. PIC16F876A belongs to a class of 8-bit microcontrollers of RISC architecture. Its general structure is shown on the following map representing basic blocks. In Program memory (FLASH) it is for store a written program. Since memory made

in FLASH technology can be programmed and cleared more than once, it makes this microcontroller suitable for device development [4].

EPROM is data memory that needs to be saved when there is no power supply. It is usually used for storing important data that must not be lost if power supply suddenly stops. For instance, one such data is an assigned temperature in temperature regulators. If during a loss of power supply this data was lost, we would have to make the adjustment once again upon return of supply. Thus our device loses on self-reliance [4].

RAM is data memory used by a program during its execution. In RAM are stored all inter-results or temporary data during run-time. For PORTA and PORTB are physical connections between the microcontroller and the outside world. Port A has five, and port B has eight pins. CENTRAL PROCESSING UNIT has a role of connective element between other blocks in the microcontroller. It coordinates the work of other blocks and executes the user program [4].

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 operation. So a write to a port implies that the port pins are first read, and then this value is modified and written to the port data latch [4].

Each of the PORTB pins has a weak internal pull-up. A single control bit can turn on all the pull-up. 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. Four of PORTB pins, RB4-RB7, have an interrupt on change feature. Only pins configured as inputs can cause this interrupt to occur. The pins values in input mode are compared with the old value latched on the last read of PORTB [4].

PIC16F876A has 28 pins. It is most frequently found in a DIP18 type of case but can also be found in SMD case, which is smaller from a DIP. DIP is an abbreviation for Dual in Package. SMD is an abbreviation for Surface Mount Devices suggesting that holes for pins to go through when mounting aren't necessary in soldering this type of a component [4].

2.6 POWER TRANSISTOR (BD135)

BD135 is used for controlling the DC brushless fan with sufficient current. Following Figure 2.5 shows the pin diagram of BD135 [6].

PINNING

| PIN | DESCRIPTION |
|-----|--------------------------------------------------------|
| 1 | emitter |
| 2 | collector, connected to metal part of mounting surface |
| 3 | base |

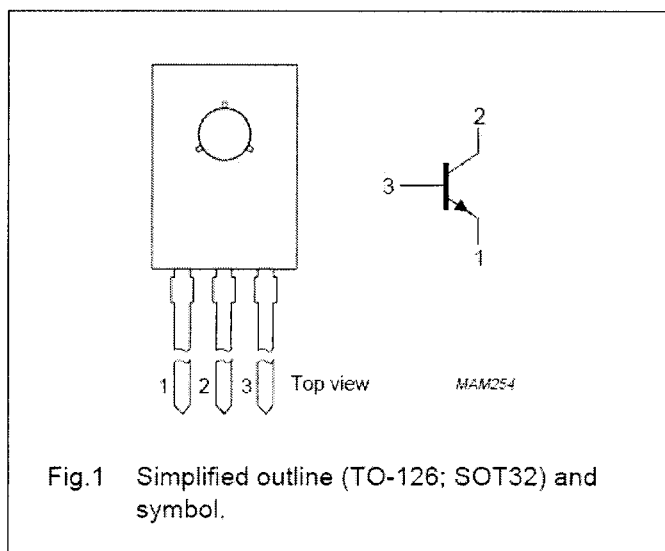


Figure 2.5: Pin Diagram of BD135

2.7 Temperature Sensor

2.7.1 LM35 temperature sensor

The LM35 is an integrated circuit sensor that can be used to measure temperature with an electrical output proportional to the temperature (in °C).

2.7.1.1 LM35 characteristics

- a. Can measure temperature more accurately than a using a thermistor.
- b. The sensor circuitry is sealed and not subject to oxidation, etc.
- c. The LM35 generates a higher output voltage than thermocouples and may not require that the output voltage be amplified.

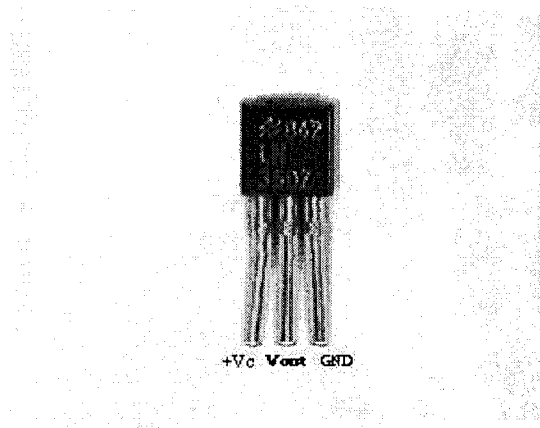


Figure 2.6: LM35 Temperature Sensor

2.7.1.2 LM35 Operations

- a. It has an output voltage that is proportional to the Celsius temperature.
- b. The scale factor is $.01V/^{\circ}C$
- c. The LM35 does not require any external calibration or trimming and maintains an accuracy of $\pm 0.4^{\circ}C$ at room temperature and $\pm 0.8^{\circ}C$ over a range of $0^{\circ}C$ to $+100^{\circ}C$.
- d. Another important characteristic of the LM35DZ is that it draws only 60 micro amps from its supply and possesses a low self-heating capability. The sensor self-heating causes less than $0.1^{\circ}C$ temperature rise in still air.

2.7.2 Thermistor

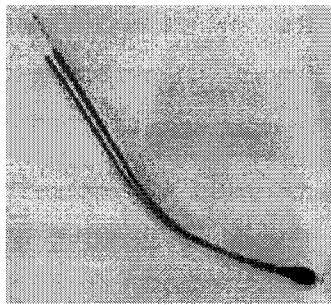


Figure 2.7: Thermistor

A thermistor is a type of resistor used to measure temperature changes, relying on the change in its resistance with changing temperature. Thermistor is a combination of the words thermal and resistor [7].

The relationship between resistance and temperature is linear (i.e. make a first-order approximation), then:

$$\Delta R = k\Delta T \quad (2.1)$$

Where:

ΔR = change in resistance

ΔT = change in temperature

k = first-order temperature coefficient of resistance

Thermistors are inexpensive, easily-obtainable temperature sensors. They are easy to use and adaptable. Circuits with thermistors can have reasonable output voltages not the millivolt outputs thermocouples have. Because of these qualities, thermistors are widely used for simple temperature measurements. Thermistor not used for high temperatures, but in the temperature ranges where they work are widely used [7].

Thermistors are temperature sensitive resistors. All resistors vary with temperature, but thermistors are constructed of semiconductor material with a resistivity that is especially sensitive to temperature. However, unlike most other resistive devices, the resistance of a thermistor decreases with increasing temperature. That's due to the properties of the semiconductor material that the thermistor is made from. For some, that may be counterintuitive, but it is correct. Here is a graph of resistance as a function of temperature for a typical thermistor. Notice how the resistance drops from 100 kW, to a very small value in a range around room temperature. Not only is the resistance change in the opposite direction from what you expect, but the magnitude of the percentage resistance change is substantial [7].

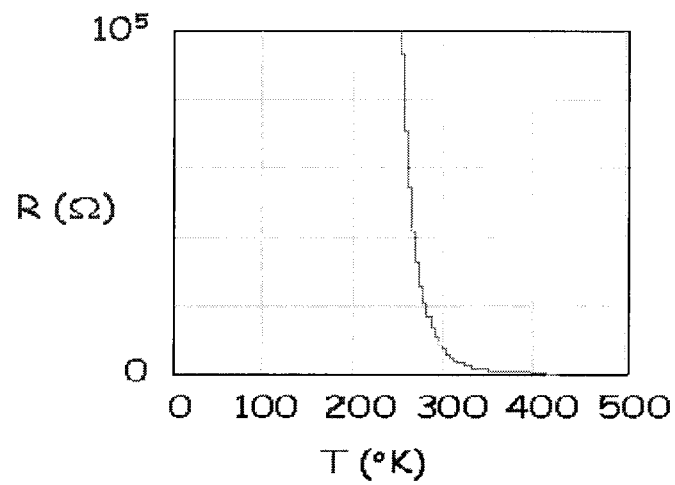


Figure 2.8: Graph resistance versus temperature (Kelvin)

2.7.2.1 Thermistor Sensor Characteristics

- a. They are inexpensive, rugged and reliable.
- b. They respond quickly

2.7.2.2 Thermistor's Sensor Samples Picture

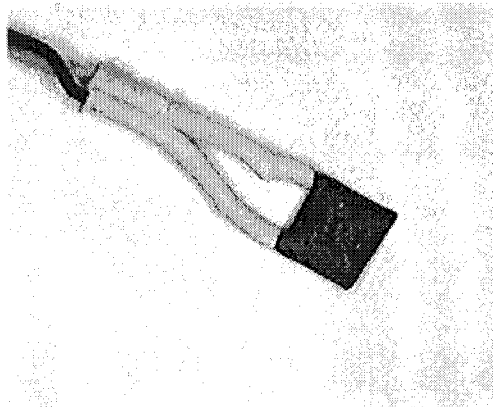


Figure 2.9: Thermistor sensor

2.7.2.3 The Operations of Thermistors Sensor

A Thermistor is a temperature dependent resistor. When temperature changes, the resistance of the thermistor changes in a predictable way. The Steinhart-Hart equation gives the reciprocal of absolute temperature as a function of the resistance of a thermistor. Using the Steinhart-Hart equation, can calculate temperature of the thermistor from the measured resistance. The Steinhart-Hart equation is [8].

$$1/T = A + B \cdot \ln(R) + C \cdot (\ln(R))^3 \quad R \text{ in } \Omega, T \text{ in } ^\circ\text{K} \quad (2.2)$$

The constants, A, B and C can be determined from experimental measurements of resistance, or can be calculated from tabular data. Here are some data points for a typical thermistor from "The Temperature Handbook" (Omega Engineering, Inc., 1989).

Table 2.1: Value of Temperature and Resistance

| T (°C) | R (Ω) |
|--------|--------|
| 0 | 16,330 |
| 25 | 5000 |
| 50 | 1801 |

Using these values, can get three equations in A, B and C.

$$(1/273) = A + B \ln(16330) + C (\ln(16330))^3$$

$$(1/298) = A + B \ln(5000) + C (\ln(5000))^3$$

$$(1/323) = A + B \ln(1801) + C (\ln(1801))^3$$

This set of simultaneous linear equations can be solved for A, B and C.
Here are the values computed for A, B and C.

$$A = 0.001284$$

$$B = 2.364 \times 10^{-4}$$

$$C = 9.304 \times 10^{-8}$$

Using these values will compute the reciprocal, and therefore the temperature, from a resistance measurement.

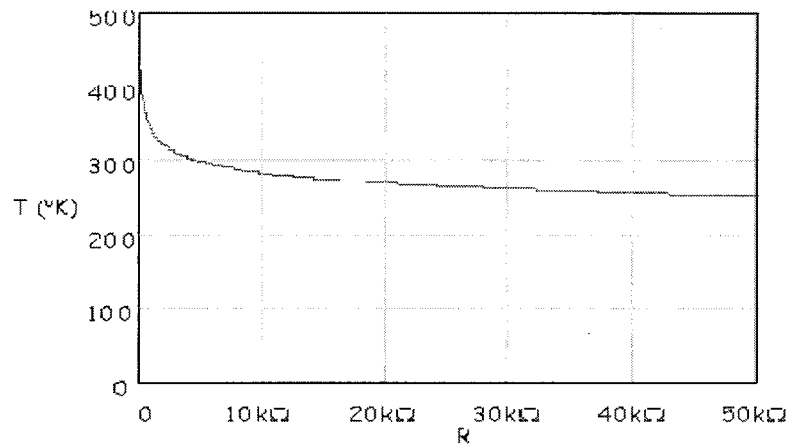


Figure 2.10: Resistance versus Temperature (Kelvin).

Of all passive temperature measurement sensors, thermistors have the highest sensitivity (resistance change per degree of temperature change). Thermistors do not have a linear temperature/resistance curve [8].

Table 2.2: NTC Thermistor Data**Typical NTC thermistor data**

| Temp °C | R/R₂₅ | Temp °C | R/R₂₅ |
|----------------|-------------------------|----------------|-------------------------|
| -50 | 39.03 | 30 | 0.8276 |
| -40 | 21.47 | 40 | 0.6406 |
| -30 | 12.28 | 50 | 0.5758 |
| -20 | 7.28 | 60 | 0.4086 |
| -10 | 4.46 | 70 | 0.2954 |
| 0 | 2.81 | 80 | 0.2172 |
| 10 | 1.82 | 90 | 0.1622 |
| 20 | 1.21 | 100 | 0.1299 |
| 25 | 1 | 110 | 0.09446 |

Data for a typical NTC thermistor family is shown in Table above. This data is for a Vishay-Dale thermistor, but it is typical of NTC thermistors in general. The resistance is given as a ratio (R/R_{25}). Often, many thermistors in a family will have similar characteristics and identical temperature/resistance curves. A thermistor from this family with a resistance at 25°C (R_{25}) of 10K would have a resistance of 28.1K at 0°C and a resistance of 4.086K at 60°C. Similarly, a thermistor with R_{25} of 5K would have a resistance of 14.050K at 0°C [9].