DEVELOPMENT OF SOLAR DIGITAL THERMOMETER

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This thesis is submitted as partial fulfillment of the requirement for the award of the
Bachelor Degree of Electrical Engineering (Power System)

Faculty of Electrical & Electronics Engineering
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BORANG PENGESAHAN STATUS TESIS♦

JUDUL: **DEVELOPMENT OF SOLAR DIGITAL THERMOMETER**

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Specially dedicated to

My beloved family, my friends and those people who have guided
inspired me throughout my journey of education

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In the name of God, The Most Beneficent The Most Gracious

First and foremost, I would like to thank God the Almighty for His bless toward myself. Without His blessing, I might not be able to complete my final year project entitled “Development of Solar Digital Thermometer”. I able to complete this research project in time as a partial fulfillment of the degree of Bachelor Electrical Engineering (Power System).

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ABSTRACT

Solar energy is one of the renewal energy to generate electricity. It produces electricity by heat engine or photovoltaic cell that converts the solar energy directly into electrical power. Nowadays, solar technology was use for electrical space heating and cooling in active and passive solar buildings, day lighting, hot water, thermal energy for cooking, and high temperature process heat for industrial purposes. In this project, the electric powers that have been produces from the solar panel will be use as an energy source to charge the digital thermometer battery. Mean that, the digital thermometer can operate although there is no sunlight in the period of time. To supply the required voltage to the digital thermometer, a regulator is needed to produce the required output voltage from the batteries. The project includes the analysis about the solar panel that will be used, build the circuit and program for the digital thermometer and develop the charger for the battery. For the digital thermometer, the LM35 had been used to measure the temperature. It can measure the temperature range; 0-99 degree Celsius. PIC 16F872 been used to read the voltage produce from LM35 and display it by seven segment as temperature in degree Celsius. The target of this project is to develop the solar digital thermometer that can show the surrounding temperature.

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ABSTRAK

Tenaga suria adalah tenaga yang boleh diperbaharui dan digunakan untuk menghasilkan tenaga elektrik. Perhasilan tenaga elektrik adalah dari pemanasan panel suria yang mengubah tenaga suria kepada tenaga elektrik. Pada masa ini, teknologi solar digunakan untuk pemanas elektrik, pencahayaan waktu siang, pemanasan untuk memasak dan pemanas bersuhu tinggi bagi industri. Untuk projek ini, tenaga elektrik yang terhasil daripada panel suria akan digunakan untuk mengecas bateri yang akan memberi kuasa kepada termometer digital. Ini bermaksud, termometer digital boleh digunakan walaupun tiada kuasa solar dalam masa tertentu. Voltage regulator digunakan untuk mengehadkan voltan daripada bateri untuk menghidupkan termometer digital. Projek ini merangkumi kerja menganalisis panel solar, mereka dan membina litar dan program untuk termometer digital dan membina pengecas bateri menggunakan sel suria untuk mengecas bateri. Termometer digital menggunakan pengesan suhu LM35 untuk membaca suhu. Ia boleh membaca suhu dalam lingkungan 0 sehingga 99 darjah Celsius. PIC16f872 digunakan untuk membaca keluaran dari LM35 dan memproses data lalu memaparkan suhu pada 7-segmen. Sasaran projek ini adalah untuk menghasilkan termometer digital suria yang boleh membaca suhu persekitaran.

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CHAPTER 1

INTRODUCTION

1.1 Overview

Solar energy is one of the renewal energy to generate electricity. It produces electricity by heat engine or photovoltaic cell that converts the solar energy directly into electrical power. Nowadays, the solar energy has been used widely because the energy has huge potential and it is clean for our environment.

The problem that leads me toward this project is many people didn’t know how to apply renewal energy for the electrical devices. In this project, solar energy will be applied as energy source for the digital thermometer. Other than that, people did not alert of surrounding current temperature that can affect their health, although it is not obvious.

In this project, the electric powers that have been produces from the solar panel will be use as an energy source to charge the digital thermometer battery. Mean that, the digital thermometer can operate although there is no sunlight in the period of time.

To supply the required voltage to the digital thermometer, a regulator is needed to produce the required output voltage. LED will be used as the digital display for the thermometer. The project includes the analysis about the solar panel that will be use, build the charger, regulator and thermometer circuit and program for the digital thermometer.

For the digital thermometer, PIC16F872 will be used to control the digital temperature sensor, LM35 and the output will display using 7 segments. It will be large display and can be seen clearly. The program for the PIC will be compiled CCS C compiler.

1.2 Objective

The objectives of this project are to:

i. To develop the solar digital thermometer that shows surrounding temperature.
ii. To develop battery charger using electric energy from solar panel as energy source.
iii. To built 5V regulator circuit for the digital thermometer.
iv. To display the thermometer reading using large 7segment LED display.

1.3 Scope of Project

The elements that need to be proposed for the project are:

I. The solar panel.
   The specification of solar panel that will be used for this project is 17V, 5 Ampere.
II. Temperature
   The range of the temperature for this project is from 0.5°c to 95°c.
III. Place
   To install the solar digital thermometer, the place that been chosen must be able to get solar energy.

1.4 Problem Statement

The conversational digital thermometer today use battery as it source of energy. It must be replaced after the battery is low. Besides that, the thermometer used only for displays temperature and cannot be integrates with other related circuit. For my project, I used the solar energy to charge the battery that provide power to the thermometer and the thermometer reading is process by PIC microcontroller to display the reading and because of that, it is possible to integrate the thermometer to other related circuit such as temperature controlled circuit.

1.5 Thesis Organization

This thesis consists of 5 chapters all together. The first chapter is the introduction of this project. It is including the overview, objective, scope of project and the problem statement. This chapter explains about overall project in general. Second chapter is the literature reviews where the contents are explain in literature aspect. Chapter 3 discusses about the methodology and chapter 4 is the result of this project. The last chapter will represent the conclusion of this project

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A review of the literature was performed to identify studies relevant to the topic. The keywords that I used in order to complete this literature review are solar energy, charger, voltage regulator, digital thermometer. The sources that I used are from the websites, journals and the previous reports.

2.2 Solar Energy

Solar electricity relies upon man-made devices such as solar panels or solar cells in order to provide a source of clean, and low cost renewable energy [1] means that human can used the solar energy by convert the solar into electric energy by using the solar panel or the solar cells. The semiconductor cell called a photovoltaic, or solar cell absorbs sunlight and transfers it into electricity, typically with 15-20% efficiency [2]. The size of the photovoltaic can affect the amount of electricity produces (Kribus, 2002).

The photovoltaic cells convert light into electric energy in atomic level. Some materials display a property known as the photoelectric effect that causes them to absorb photons of light and release electrons. When these free electrons being captured, an electric current result that can be used as electricity [9].

The photovoltaic cells are made of semiconductor materials, such as silicon. For solar cells, a thin semiconductor wafer is specially treated to form an electric field, positive on one side and negative on the other. When light energy strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of an electric current [9]. The current that that been produced by the photovoltaic cell is actually direct current (DC).

2.3 Charger circuit

A charger includes a battery pack receiving there in a plurality of batteries and having a projection provided with a contacting terminal [8]. The charger that will be used for this project eventually will received 17V and 5A electric from the photovoltaic cell and will charge 12 volt lead-acid battery. There are a lot of chargers in the market nowadays but only certain of it that used solar as the energy source.

2.4 Voltage regulator

A voltage regulator includes a capacitor providing a regulated voltage, a regulation switch for connecting the capacitor to a voltage source and a regulation circuit for closing the regulation switch when regulated voltage is below a first references voltage [7]. The use of voltage regulator is supply required voltage to the device (**Bruno Gailhard, 2002**). In this project, the regulator is use to convert supply from batteries to required voltage for the Digital Thermometer. The input voltage from battery is 12V and the voltage regulator will convert it into required voltage of the circuit, which is 5V. For the voltage regulator circuit, LM7805 is used as voltage regulator.

2.4.1 LM7805

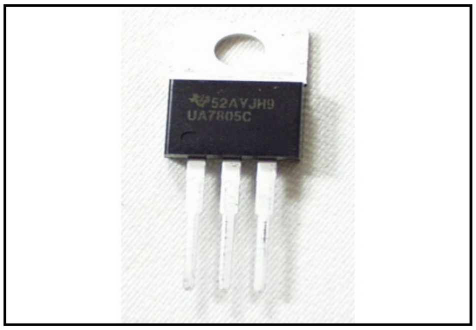

Figure 2.4: LM7805

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Voltage regulator, LM7805 actually having three legs, converts varying input voltage and produces a constant regulated output voltage. The 78XX are designed for positive voltage and the 05 at backside of the series shows the output voltage. The LM7805 series typically has the ability to drive current up to 1A. For application requirements up to 150mA, 78L05 can be used. The component has three legs: Input leg which can hold up to 36VDC Common leg (GND) and an output leg with the regulator's voltage. To get maximum voltage regulation, usually capacitor been added in parallel between the common leg and the output.

2.5 Digital thermometer

In 16th Century, Galileo formulated his "principles of thermo-dynamics" in creating thermometer [3]. The changes in the temperature will change the structure of some materials. As an example, the size of mercury will be increase when the temperature increases. This concept been use in order to create thermometer in 16 century (Glyn Robins).

As the world change, the devices for measuring temperature also change. Nowadays, there are a lot of new device have been found to measured temperature. From the Omega.Com website, it mentions that temperature can be measured via a diverse array of sensors [3]. The sensor will detect the physical characteristic changes to infer temperatures changes. The examples of the devices are thermocouples, resistive temperature devices (RTDs and thermistors), infrared radiators, bimetallic devices, liquid expansion devices, and change-of-state devices.

The resistive temperature device has been definite as a device measuring temperature by the change of the electrical resistance of a metal wire (Houghton Mifflin, 2007). Beside that, other researcher has found the new device to measured temperature. As an example, Nor Aniza Mat Desa, from University Malaysia Perlis (UNIMAP) has used Barium Strontium Titanate (BST) sensor to create digital thermometer for her project.

2.5.1 Temperature Sensor (LM35)

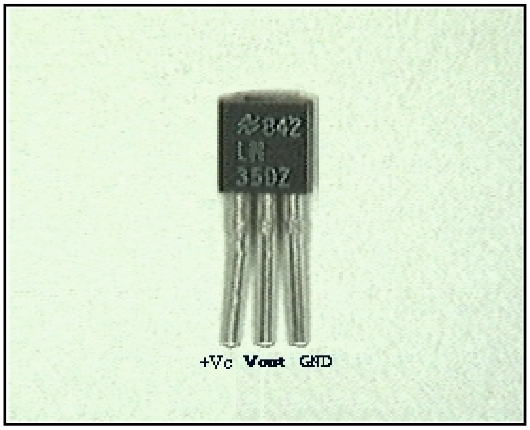


Figure 2.5: LM35

LM 35 is an intergrated temperature sensor that can gives electrical output proportional to the temperature in degree celcius (°C). This sensor can read temperature more accurate than using thermistor. The sensor also sealed to avoid the oxidation and the it can give higher output voltage than thermocouples and doesn‘t need additional voltage amplifier. LM35 can read from -50°C to 100°C and provides +/- 0.4 accuracies in rooms temperature and +/- 0.8 accuries over a range of 0°C to 100°C .

As mentioned above, LM35 provide output voltage proportional to the temperature in Celcius. The output is 0.01/1°C. It mean that if the output is 0.30V, the temperature is 30°C.

2.6 PIC 16F872

The PIC16F872 is a powerful and yet easy-to-program CMOS FLASH-based 8-bit microcontroller made by Microchip Technology. It only has only 35 single word instructions and makes it easy to use. The PIC16F872 features 64 bytes of EEPROM data memory, self programming, an ICD, 5 channels of 10-bit Analog-to-Digital (A/D) converter, 2 additional timers, a capture/compare/PWM functions and the synchronous serial port can be configured as either 3-wire Serial Peripheral Interface (SPI™) or the 2-wire Inter-Integrated Circuit (I^2C™) bus.

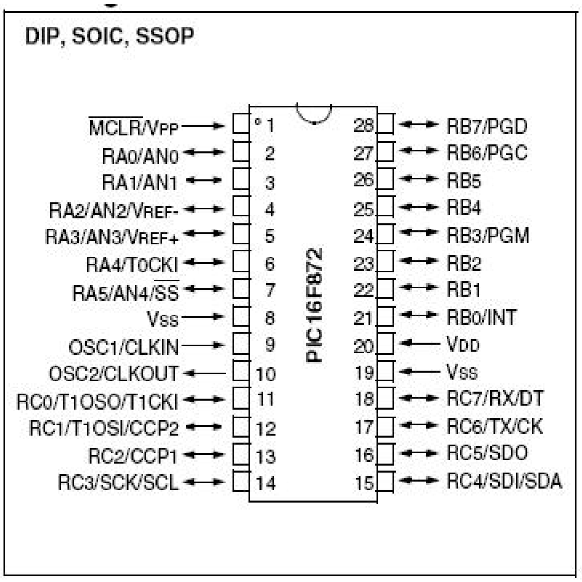


Figure 2.6.1: Pin description of PIC16F872

2.6.1 Programming

Programming is a core activity in the process of performing tasks or solving problems with the aid of a computer [11]. Computer cannot understand the specification given by natural language. Therefore, programming language is used to give instruction to the computer on how to solve the problem.

There is several language that can be use to classified the instruction. “High-level” programming language is one of them. "High-level" programming languages are languages whose syntax is relatively close to natural language, whereas the syntax of "low-level" languages includes many technical references to the nuts and bolts (0's and 1's, etc.) of the computer.

2.6.2 PICkits

THE PICkit is a low cost development kit with an easy to use interface for programming Microchips 8/14/20 pins flash family of microcontroller. It is design to help developers to speed up quickly using PIC microcontroller. It contains low pin count demo board supporting 8/14/20 mid range of microcontroller and the Windows programming selected flash based PIC microcontroller that easy to understand and use. The PICkit also use to write the program written by the programmers into the PIC.

Figure 2.6.2: PICkit

2.7 Digital display

Digital mean displaying numbers rather than scale positions [6]. Based on the definition of digital, the digital thermometer mean the device that can measuring temperature and display it into a numbers scale. 7 segments will be used to display the thermometer reading and by using it, the size of the display can be adjusted easily and it consume low power. Actually, the LED can be used to build large seven segment display

CHAPTER 3

Methodology

3.1 Introduction

This project actually been divided into certain part. It is including the development of solar battery charger, regulator and digital thermometer. The digital thermometer is involving the temperature sensor, PIC controller and it will be display by using LED display.

The figure below shows the energy flow from the solar panel through the charger and the digital thermometer. The electric energy from solar panel will flow to the charger and the charger will charge the battery. Although the regulator seem like to get source from the charger in the block diagram above, but actually the regulator will get the source from the battery and it will by pass the charger. The regulator will produce 5V to supply the digital thermometer.

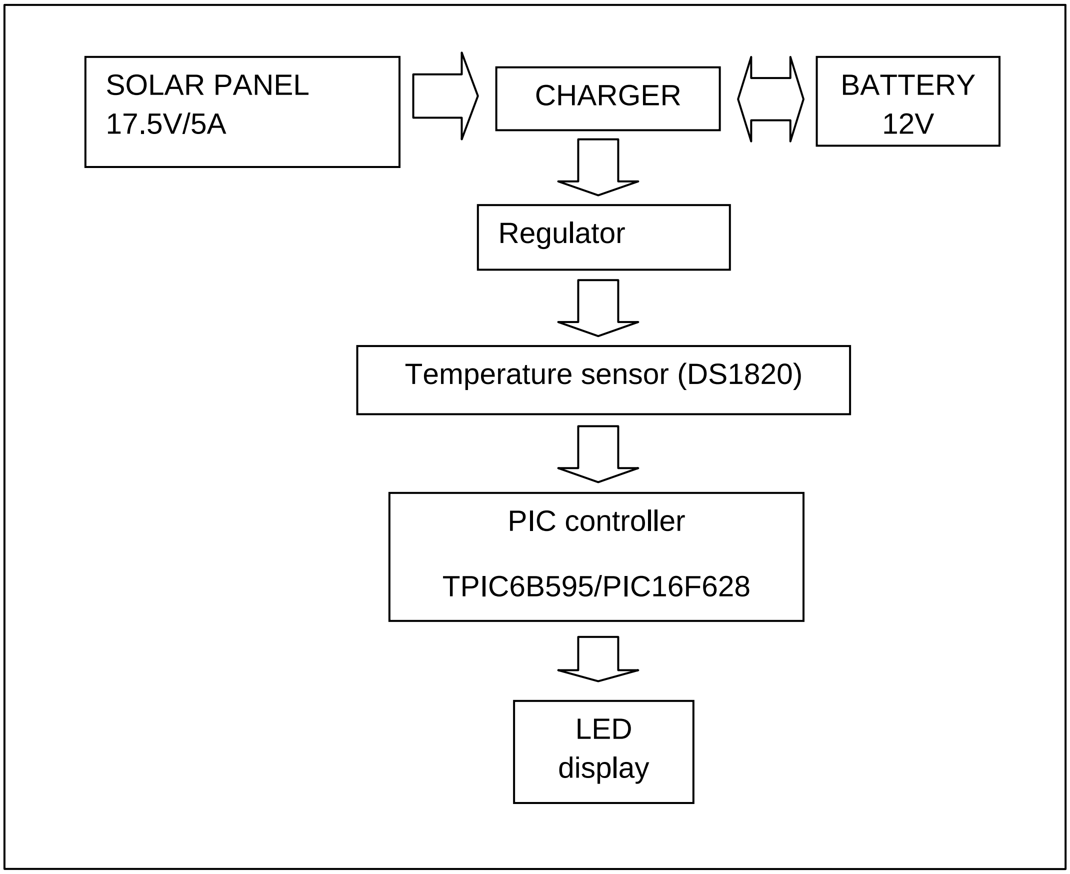


Figure 3.1.1: Block diagram

For the project, the solar panel that will be used are the Sunmodule SW80/RSE. The photovoltaic cell can generate maximum 80 watt and the rated voltage is 17.5 from solar energy. The specification of this photovoltaic cell shows in the table below.

Model	Sun module SW80 mono/RSE
Rated Max. Power, Pmax(W)	80(±5%)
Open Circuit Voltage, Vsc(V)	21.9
Rated Voltage, Vrated(V)	17.5
Short Circuit Current, Isc(A)	5.00
Rated Current, Irated(A)	4.58
Maximum System Voltage, (V)	715AC

Table 3.1.1: Photovoltaic specification

3.2 Calculation

A calculation need to be done to make sure that the solar panel that has been chosen is suitable and can give enough energy to the load. Determining the power consumption of the load is the first step.

Component	Power/watt	Unit
LM35	0.0220	1
PIC16F872	0.0578	1
Seven segment	0.0360	102

Table 3.1.2: electrical specification of component

Based on the table above, the power consumption for a day can be calculated.

Total load per day = (0.0220+0.0578+102×0.0360) ×24hour

= 90.043watt hour per day

Energy loss =20%

Total load power = total power + 20% Energy loss

= 90.043+ (20% × 90.043)

= 108.05Watt hour per day

3.2.1 Sizing Solar Panel

In order to sizing the solar panel, the peak sunshine of the place where the project took place need to be known. For this project, the place took part in Kuantan, Malaysia. Refers to www.solar4power.com, the peak sunshine in Malaysia is five hours (refers to appendix C).

Solar panel input = 249.864/5 hour peak sunshine

= 50 Watt

Solar panel that will be used can provide maximum 80watt.

Therefore, Unit of Solar = 50/80 …… solar panel input divide by solar panel used

= 0.625 unit ≈ 1 unit

3.2.2 Sizing Battery

Calculation below shows how we can calculate the batteries sizing as in case, there are no sun light in period of time. In the calculation below, I've calculate the sizing of batteries needed if there is no sun in 4 days.

Load = 108.05Wh per day

Ampere hour per day = total load per day divide by Rated Voltage*

= 108.05/17.5

= 6.17 Ah

Energy loss = 20%

Ampere hour per day = 6.174 + 20%

=7.41Ah per day

Battery required = 17.104/0.2 Energy loss

= 85.521 Ah x 4 days backup no sun light

= 342.085 Ah for four days without sun light

Therefore the suitable battery been Selected is 12V 40Ah Lead Acid Battery and 4 batteries needed in this situation.

In other hand, they are other way to sizing the batteries. It is by using solar system calculator from www. energymatters.com . The calculator can calculate the batteries needed for the solar energy system. The calculator result shows below.

Your location:	25000 Kuantan, Pahang, Malaysia
Using data from **Kuantan (AFB) weather station**	
Min. solar irradiation per day	3.58 kWh / m^2
Average solar irradiation per day	5.19 kWh / m^2
Max. solar irradiation per day	5.97 kWh / m^2

Table 3.2.1: Solar irradiation information

Energy usage (per day)	0.208 kWh
Power from other sources (wind, hydro, etc)	0 Ah a day at 12 V

Table 3.2.2: Table of energy

System voltage	12 V
Current required (factoring loss)	19 Ah at 12 V
Solar Panels	5 × 20Watt 12Volt Multi-crystalline)
Solar Charge Controller	1 × 12Volt 6Amp DC Solar Controller
Days of battery backup	4 days
Battery depth of discharge	20 %
Battery bank required (factoring loss)	376 Ah 4 × Lead Acid Battery 6V 210Ah

Table 3.3.3: Solar system

Compared to the calculation using manual method, the calculator result is a little bit different because the rated voltages for the panel are different. It uses 12V while the manual calculations use 17.5V.

3.3 Regulate voltage

Figure below shows the voltage regulator circuit use for this project. I rather used the LM317 then LM715 because by using LM317, the voltage are adjustable.

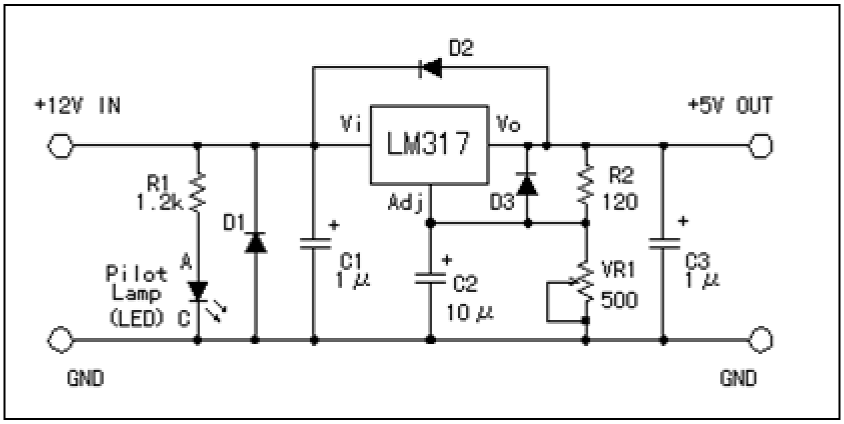
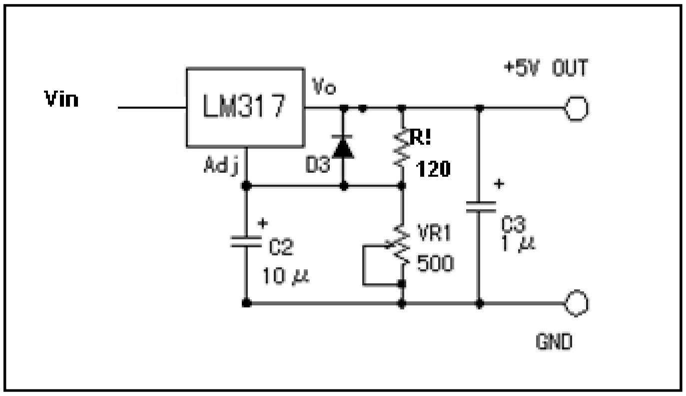


Figure 3.3.1: circuit diagram of 5V voltage regulator

Actually, the reference voltage between Vo and Adj is 1.25V and it is constant. The output voltage can be change by changing the R2. The below formula been used to calculate the output voltage.

$$V_{out} = 1.25(1 + R2/R1) + I_{adj}(R2)$$



For 5V output, and the value of R1 is 120 Ohm, the value of R2 can be calculate as below:

R2 = 120(Vout/1.25 - 1)

R2 = 120 (5/1.25 -1)

= 360 Ohm

500 Ohm Variable resistor been used as R2 in this circuit to get the voltage range from 1.25 to 6.46 in calculation.

For the protection to the circuit, the diode are placed to the circuit. D1 is the protection when the voltage of the opposite polarity is applied to the input. D2 is the protection when the output voltage greater than input and D3 is used when the output voltage falls from the voltage adjustment.

3.4 Development of Charging circuit

The charging circuit basically use to regulate the power flowing from the solar panel or photovoltaic cell to the recharble battery. It is important to have charging circuit for the solar panel to avoid current flowing back to the panel when the battery voltage higher than the solar panel output. The figure below show the shcematic or the charging circuit.

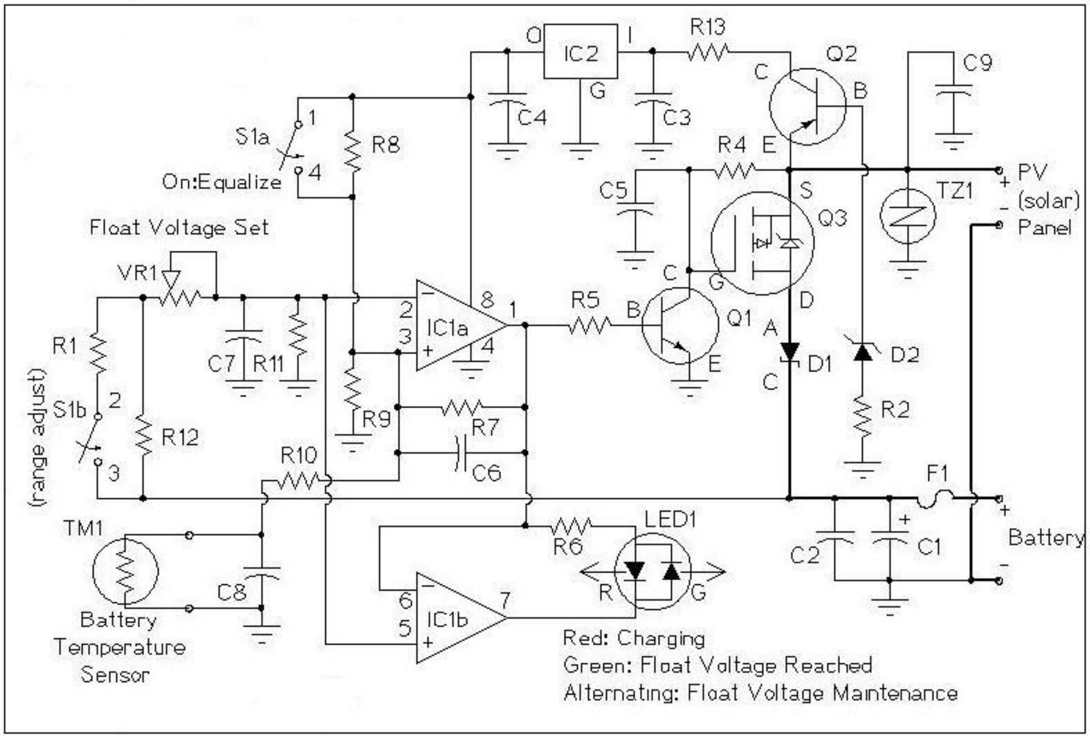


Figure 3.4.1: Charging circuit schematic

3.4.1 Charger operation

Current from the solar panel are flowing into the circuit through Zener diode D1. D1 also prevent the reverse night time current from the battery back to the solar panel. The charging started when Photovoltaic (PV) voltage is high enough to charge the battery. In this case, the PV voltage must greater than 12V.

The current from D1 will turn on transistor Q2. Q2 act as switch to power on the rest of the circuit. IC2, LM7805 will regulate voltage to 5V to give power to the comparator circuit and also provide a reference voltage for comparator IC1a.

Comparator IC1a will turn on when the battery below the desired full voltage and need charging. It will activated and turn on Q1 and Q3 and current from PV panel will flow and start to charge the battery. Q3 is a P-channel Mosfet, this allows the circuit to be wired with a common ground for the solar panel and battery. The heavy line of the circuit shows the solar current loop.

IC1a operates as a comparator based schmidt trigger oscillator, it switches the solar current off and on. Battery voltage oscillates a few tens of millivolts above and below the desired set point because of the switching. This happened when the battery reached it desired full voltage.

The LED is the indicator of the charging session and full charging for the circuit. It is driven by the output between IC1a and IC1b. IC1b has an inverted version of the IC1a signal. Approximate center point needed for pin 5 of IC1b to work as an on-off comparator. It does not require another reference divider circuit because it is connected to the varying IC1a pin 2.

Resistive bridge circuit that is used to compare the battery voltage to a reference voltage coming from IC2/R8/R9 form by the resistors and thermistor on the input side of IC1a . Potential meter will set the voltage point around where the circuit will oscillate during full charging. Resistor R7 give positive feedback to IC1a for a schmidt trigger characteristic. The thermistor provides thermal compensation where the full charges goes up when the temperature goes down.

3.4.2 Alignment of the solar charger

The alignment of the charger used to set the floating voltage of the charger. The step to align the float voltage shown below:

i. Connect the solar panel directly to the battery until the battery is at or above the desired voltage.

ii. Adjust the variable resistor to the float voltage while measure the float voltage. The battery need to charge for a while if the LED is turn red before it reach floating voltage.

iii. The battery is fully charge when the voltage reach floating voltage and LED will display alternating colour.

iv. To set the floating voltage, the board and the battery should be at room temperature. The desired floating voltage for gel set is 13.8V

v. After the battery is fully charge, readjust the floating voltage.

3.5 Development of digital thermometer

The development of digital thermometer divides into 2 stages.

I. Hardware implementation

II. Software implementation

3.5.1 Hardware implementation

In building up a digital thermometer, the main components are LM35 and PIC16f872. LM35 is a temperature sensor that can read temperature from 0°C to 100°C with 0.4 accuracies. The output voltage is proportional to the temperature in °Celsius. The output voltage produce by the output leg of LM35 is 0.01V/°C.

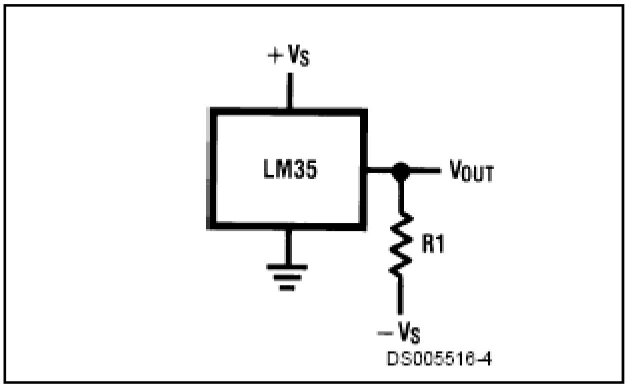


Figure 3.5: Typical connection of LM35

The output from LM35 will be read and convert into digital by PIC16F872. PIC are build up with internal Analog to Digital converter and because of that, there no need external ADC converter for the circuit. PIC16F872 need a references voltage to read and process the voltage output from LM35. In this case, the references voltage that used is 5V from Vcc voltage. The output from LM35 will connected to the AN0 leg at PIC16F872. Table below shows the connection of PIC16F872.

Pin no.	Pin name	Description	Application
1	MCLR/Vpp	Positive supply	Supply the 5Vdc from voltage regulator
20	Vdd	Positive supply	Supply the 5Vdc from voltage regulator
2	AN0	Analog input channel	Input from LM35
8&19	Vss	Ground references	Ground references
9-10	OSCl	Oscillator or resonator	4Mhz cristal
21-27	RB0-RB6	Input /output port	Seven segment1 display
11-17	RC0-RC6	Input/output port	Seven segment 2 display

Table 3.5.1: PIC16F872 pin connection

For this project, the temperature will be display using large seven segment display. 12V voltage needed to supply to the seven segments because of its size. PIC16F872 output voltage only provides 5V and it is not enough to operate the seven segments. For that reason, PNP transistor, 2N3906 is used. Figure below shows the connection of 2N3906 transistor to the seven segments.

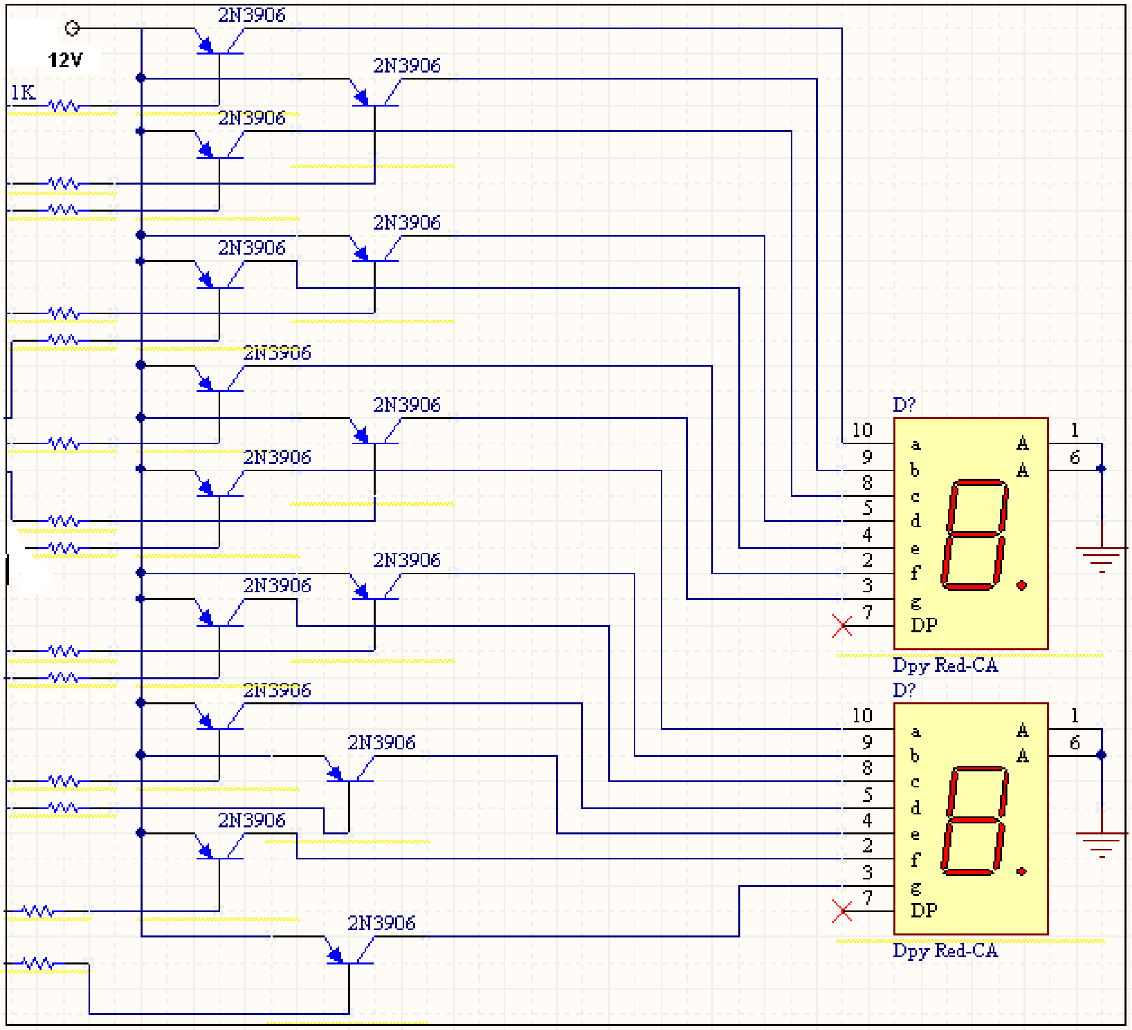
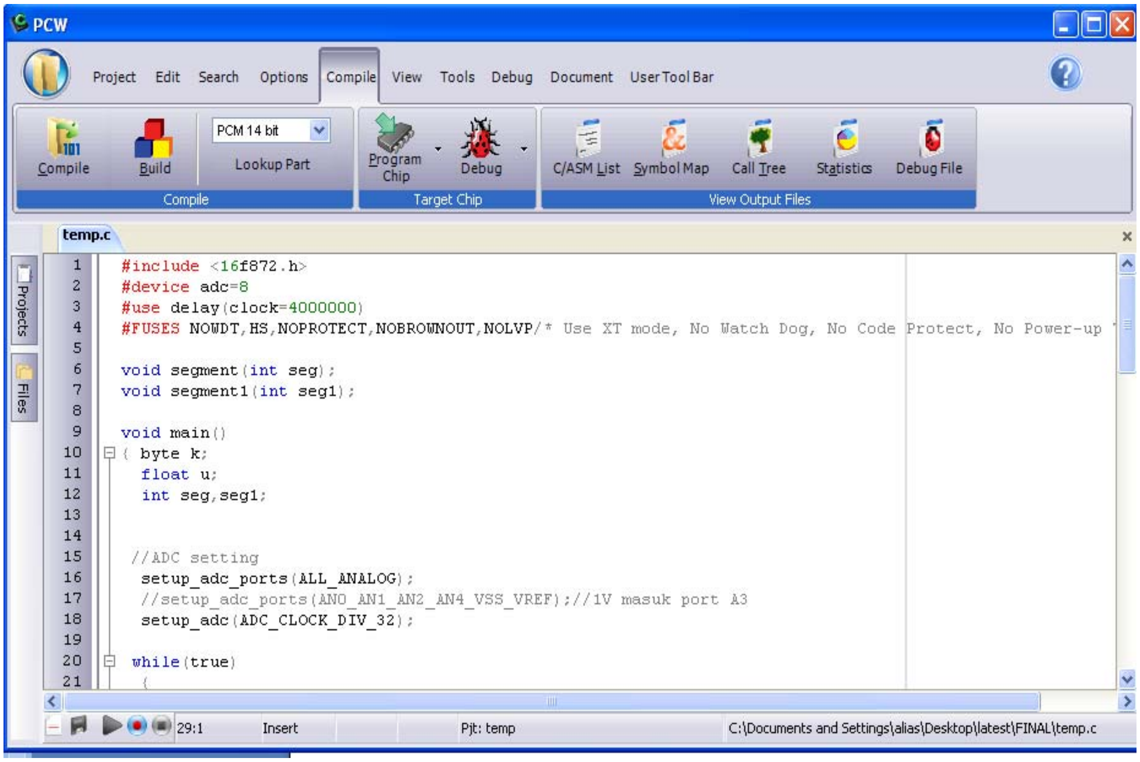


Figure 3.5.1: Connection to 7 segments from 2N3906

3.5.2 Software Implementation

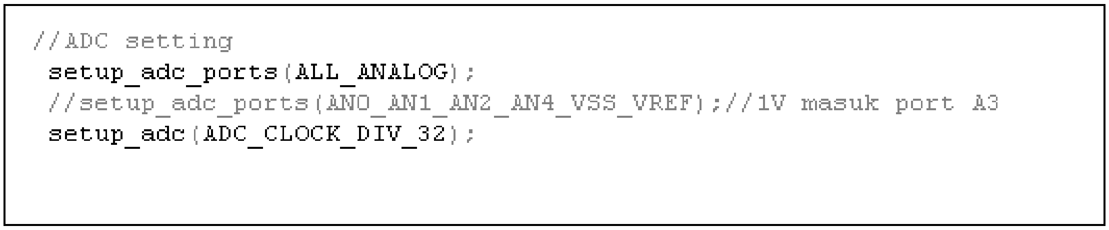
For the software implementation, CCS C programmer is used to build the program for the PIC 16F872. C programmer is chosen because it is one of the easiest languages that can be understood. The C programmer used High-Level language that almost similar to natural language.



```
#include <16f872.h>
#device adc=8
#use delay(clock=4000000)
#FUSES NOWDT,HS,NOPROTECT,NOBROWNOUT,NOLVP/* Use XT mode, No Watch Dog, No Code Protect, No Power-up

void segment(int seg);
void segment1(int seg1);

void main()
{ byte k;
  float u;
  int seg,seg1;


 //ADC setting
  setup_adc_ports(ALL_ANALOG);
  //setup_adc_ports(AN0_AN1_AN2_AN4_VSS_VREF);//1V masuk port A3
  setup_adc(ADC_CLOCK_DIV_32);

 while(true)
  {
```

Figure 3.5.2: Writing the PIC program using CCS programmer

In order to design a program for the PIC, a few command need to be applied so that the PIC can perform the task given. The example of the command shown below:

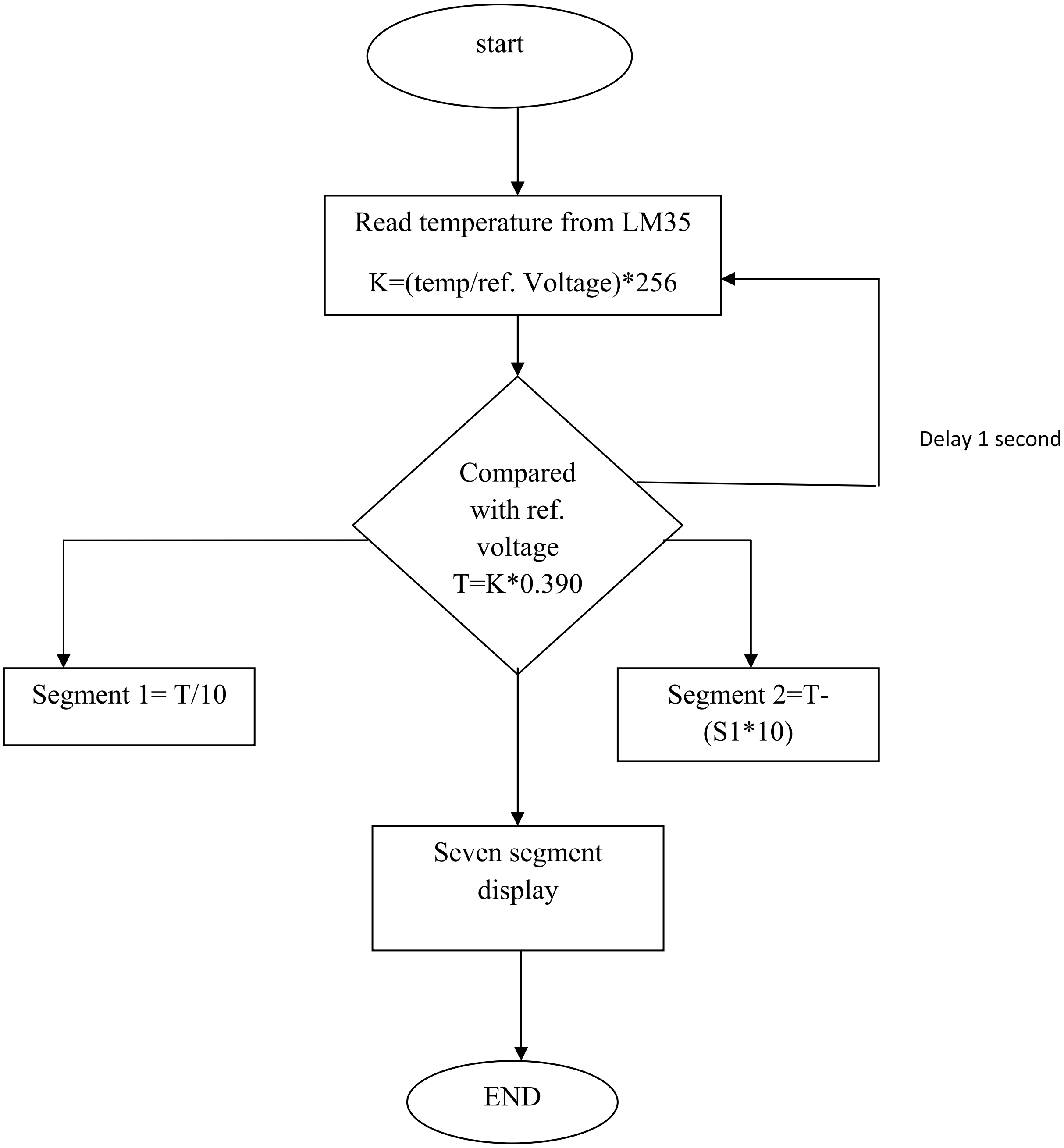


```
//ADC setting
 setup_adc_ports(ALL_ANALOG);
 //setup_adc_ports(AN0_AN1_AN2_AN4_VSS_VREF);//1V masuk port A3
 setup_adc(ADC_CLOCK_DIV_32);
```

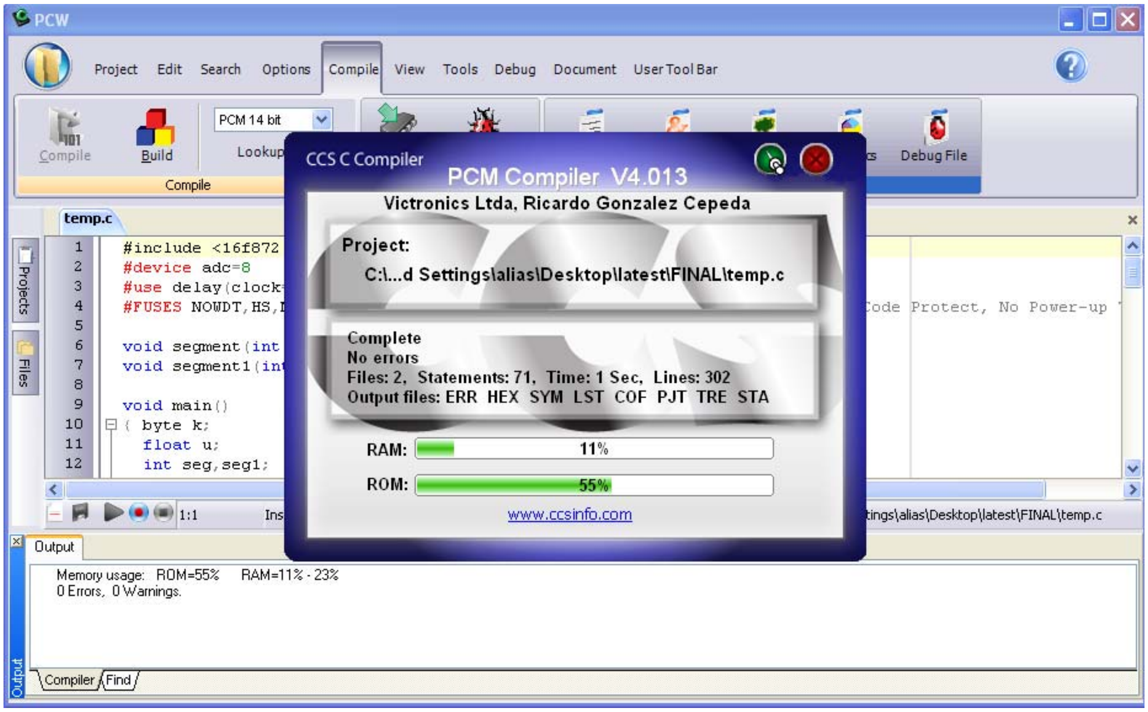
Figure3.5.3: example command to setup PIC ADC port

The command above shows the setup for the PIC analog input. The analog input will read the voltage and it will convert it into binary codes by using 1V as its references voltage.

3.5.2.1 Main Program Flowchart



After completed the program, it must be compiled before the program can be written to the PIC. The CCS compiler is the compiler used to compile the C programming to machines code.



```
#include <16f872
#device adc=8
#use delay(clock
#FUSES NOWDT,HS,I

void segment(int
void segment1(int

void main()
{ byte k;
  float u;
  int seg,seg1;
```

CCS C Compiler

PCM Compiler V4.013

Victronics Ltda, Ricardo Gonzalez Cepeda

Project:
C:\...d Settings\alias\Desktop\latest\FINAL\temp.c

```
Complete
No errors
Files: 2,  Statements: 71,  Time: 1 Sec,  Lines: 302
Output files: ERR  HEX  SYM  LST  COF  PJT  TRE  STA
```

RAM: 11%
ROM: 55%

www.ccsinfo.com

```
Memory usage:   ROM=55%     RAM=11% - 23%
0 Errors,  0 Warnings.
```

Figure 3.5.4: compiling process using CCs compiler

3.5.3 PICkit USB Programmer

PICkit USB programmer is used to write (burn) program into the PIC. The device is design to interface between the computer and the microcontroller (PIC). USB port is used to transfer the data from the computer to the PIC.. Figure 3.7 show the illustrated of the PICkit programmer. There have five components to operate this device, the first one is UIC00A. It is used as a driver to interface between PIC and computer. Mini USB cable and third rainbow cable use to connect between UIC00A with the PIC socket board. Other components are software installation with user’s manual CD and also fifth UIC-S socket board use to hold the PIC.

Figure 3.5.5: PICkit USB Programming

3.5.3.1 Plugging the PIC

To avoid PIC from damage, follow the instruction given in order to plugging the PIC. PIC must be plugging in the UIC-S socket properly because if the wrong instruction used, the PIC will be damage. To program the PIC that less than 18 pins, the switch at the bottom must be at 18 pins side and the microcontroller (PIC) must be put at the UIC-S socket as show in the figure below. When placing the PIC at the UIC-S socket, make sure that the dot mark at PIC is at right hand side as show in the figure (2) below.

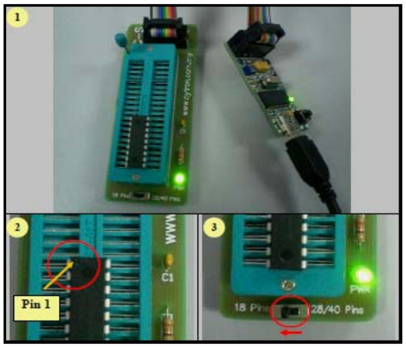


Figure 3.5.6: Plugging 18 pins PIC

To program PIC that have 28 to 40 pins, the switch must be select at the 28/40 pins. Figure 3.5.7 below shows the PIC has the 40 pins put at the UIC-S socket. Place the PIC at the UIC-S socket shown below and make sure that the dot mark at OIC is at the right side as show in figure. Lastly, make sure the switch is select at the 28/40 pins direction.

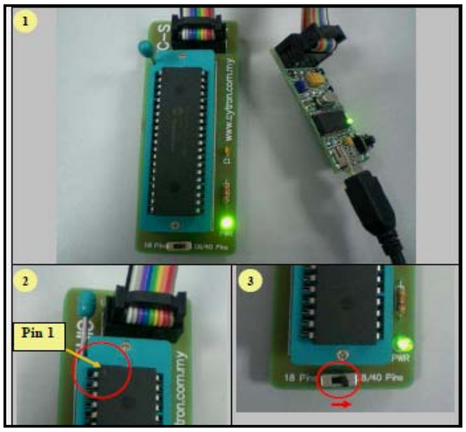
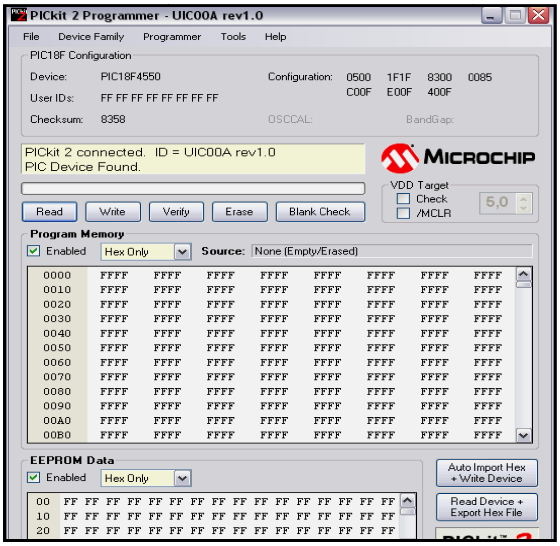


Figure 3.5.7: Plugging 40 pins PIC

3.5.3.2 Program the PIC Microcontroller

The first thing that we need to do before we can program the PIC is to compile the program into Hex file. The compiler that will be use is CCS compiler. The method to compile the program been discussed in chapter 3.5.2. The Hex file is a file where the Sps file is save. Install PICkit to the computer using the instruction that stated in the CD. The icon PICkit appear in the desktop,when the installation was completed. Run the program and it automatically detect the PIC that placed at the UIC-S socket.



Device: PIC18F4550

User IDs: FF FF FF FF FF FF FF FF

Checksum: 8358

Configuration: 0500 1F1F 8300 0085 C00F E00F 400F

OSCCAL:

BandGap:

PICkit 2 connected. ID = UIC00A rev1.0
PIC Device Found.

VDD Target: ☐ Check ☐ /MCLR 5,0

Program Memory: ☑ Enabled, Hex Only, Source: None (Empty/Erased)

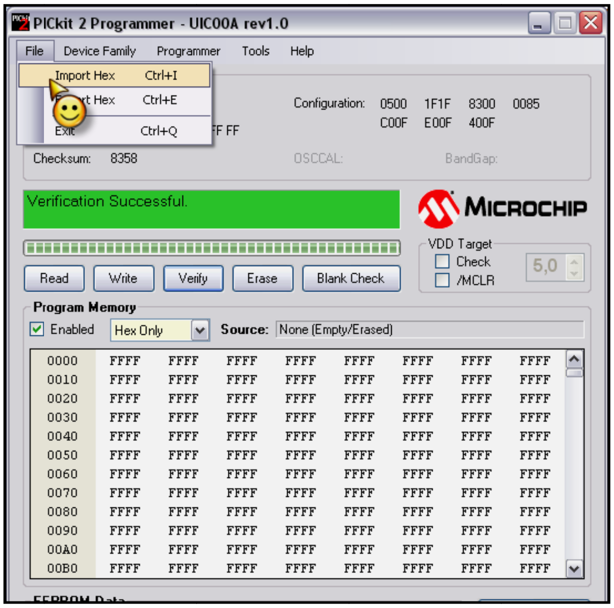
```
0000  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
0010  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
0020  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
0030  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
0040  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
0050  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
0060  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
0070  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
0080  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
0090  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
00A0  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
00B0  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
```

EEPROM Data: ☑ Enabled, Hex Only

```
00  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
10  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
20  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
```

Figure 3.5.8: PIckit Programmer

Before the Hex file imported, the PIC need to blank check first to make sure that there no program exist in PIC. Erase the existing file by click at the erase icon on program. The erase is complete when red LED at UIC00A stops blinking. To verify the PIC is located at the right pins, click at the verify icon. Lastly, click file at the top of the PICkit program and choose import Hex. After Hex file is import the click the write button and the program will be written to the PIC. The red LED is blinking at the UIC00A and when the red led stop blinking, the green LED is turning on, it shows that the program is completely transfer to the PIC.



Configuration: 0500 1F1F 8300 0085
C00F E00F 400F

Checksum: 8358

OSCCAL:

BandGap:

Verification Successful.

VDD Target
☐ Check
☐ /MCLR
5,0

☑ Enabled Hex Only

Source: None (Empty/Erased)

```
0000  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
0010  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
0020  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
0030  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
0040  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
0050  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
0060  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
0070  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
0080  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
0090  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
00A0  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
00B0  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF  FFFF
```

Figure 3.5.9: Verifying process

3.5.4 Summary

This chapter discuss about methodology or step that have been applied for this project. It is including hardware and software implementation. The method briefly explains the hold work that had been done during this project.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

The solar charger and the digital thermometer had been successfully achieving its entire objective. The charger can manage to charge a lead acid battery and the thermometer shows the reading of the temperature in digital form. Several measurements need to make during charging to estimate the time needed for battery fully charge and to show the accuracies of the thermometer. The output of this the measurement will be discussed in this chapter. Graph and table been provided to illustrate the output of the project.

4.2 Charging result

Duration(minutes)	**Voltage(V)**
10	**2.72**
20	**7.75**
30	**9.25**
40	**10.13**
50	**10.89**
60	**11.04**
70	**11.47**
80	**11.54**
90	**11.66**
100	**11.69**

Table 4.2.1: Charging duration

The table above shows the result of the charger. The measurement been took starting from 12 pm where the luminance of sun is maximum. The increase in voltage shows that the charger works and from the table above, time taken for the battery to fully charge can be estimate. The graph below illustrates the changes of voltage over time.

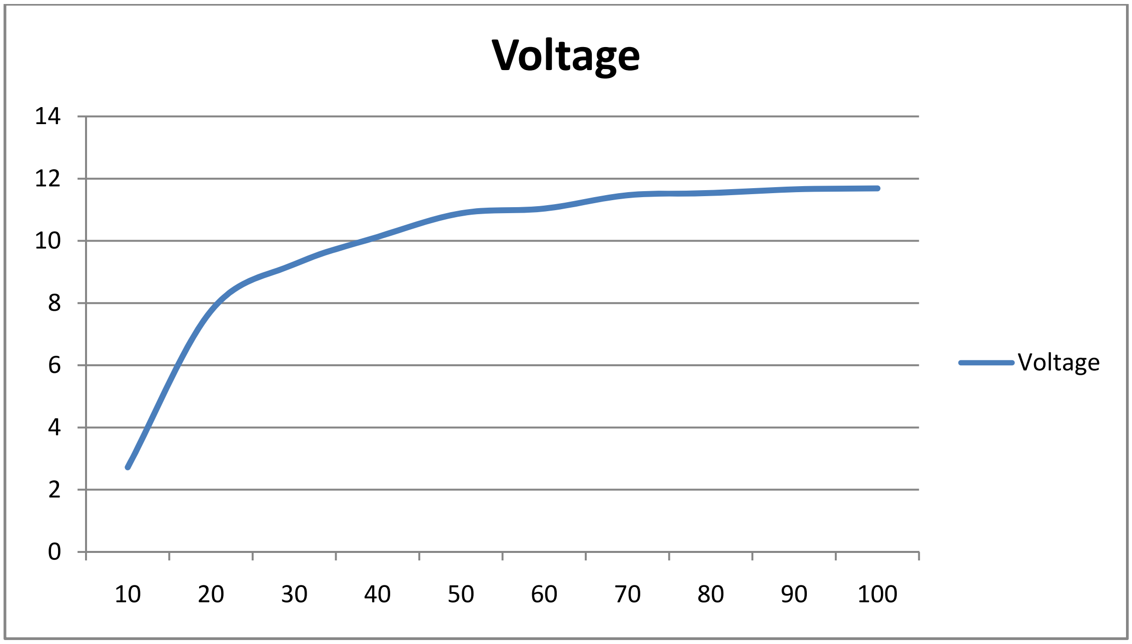


Figure 4.2.1: Analysis of voltage changes in charging process

Based on the graph shown above, the changes of voltage are proportional to duration. In the first 40 minutes, the voltage increase fast, but after 40 minutes, the charging become slower. It means that the voltage is near to the floating voltage. The estimated time for the battery is fully charge is two and a half hours.

4.3 Digital thermometer results

The digital thermometer can read from 1° to 99°celceus. The table below shows the comparison of the output voltage of LM35 and the display temperature of the thermometer. The temperature measured is the room temperature.

Voutput of LM35/V	Digital thermometer reading/°C
0.30	31°C
0.29	29°C

Table 4.3.1: Digital thermometer result

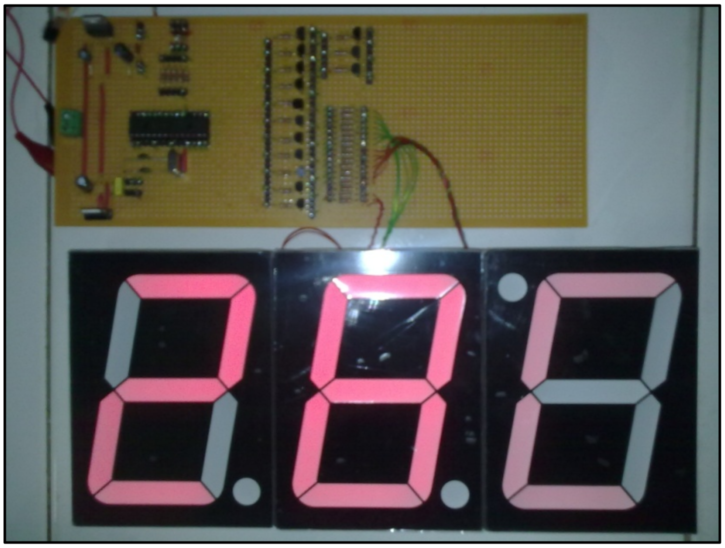


Figure 4.3.1: Digital Thermometer shows the room temperature

4.3.1 Experimenting the Digital Thermometer reading

Based on the datasheet of LM35 (refer appendix D) the accuracy are decrease when temperature are extremely high or low. The accuracy is high in room temperature. The figure below shows the LM35 accuracy and its accuracy in certain temperature based on the datasheet.

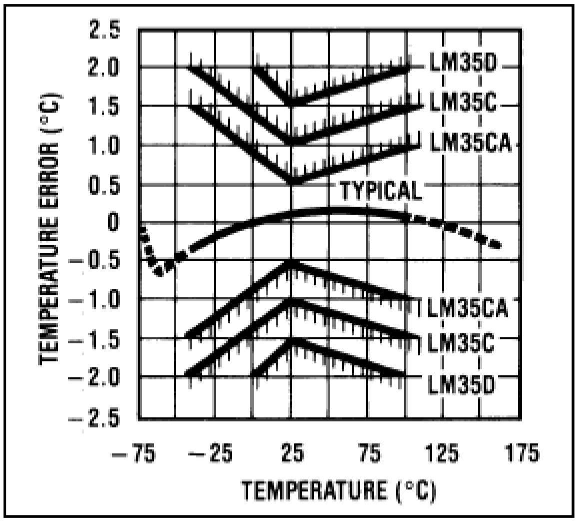


Figure 4.3.2 : LM35 accuracy vs time

Some experiment been done to check the accuracy of the thermometer. Ice and boiling water been used on the experiment. The result of the experiment is shown in table below.

Condition	Thermometer reading	Theorical temperature
Ice cube	1°C	0°C
Boiling water	89°C	100°C

Table 4.3.2: Digital thermometer reading in different condition

The result shows that there are differences between the theorical reading of ice and boiling water and the reading of the thermometer. The reading of the digital thermometer in Ice is nearly to the theorical temperature but the different between the Digital thermometers reading on boiling water to its actual value is huge. It is because in the experiment, the sensor only read the temperature of the surface of the boiling water and not in the water to avoid the water damaging the sensor.

Therefore, based on the experiment of the sensor on ice, the accuracy of the thermometer can be accepted. It could be not accurate if the temperature is less then 0°C.

4.4 Problem and solution

This chapter consists of discussion about the problem occurs during, before and after the process of develop the solar digital thermometer. This cause and effect will discuss in this chapter including the way to overcome the problem.

The first problem that occurs is the sensor to determine the temperature is malfunction. On the first stages of the project, the sensor used to determine temperature is DS1820. The sensor is expensive and difficult to find. The sensor is digital sensor and it is difficult to determine whether it is in good condition or not. Several experiment been conduct to determine the output of the sensor but it return zero result.

Change the sensor used is the best way to solve the problem. After a research, I make a decision to change the sensor to LM35. The sensor is cheaper compared to previous sensor and it is easier to measure the output of the sensor.

Other problem occurs is the temperature is not accurate if the references voltage is not equal to 5V. It is because all the calculation include in the programming used 5V as references voltage. LM7805 can give the 5V fix voltage but the output voltage from LM7805 will not be accurate if the input voltage is not high enough. As example, when the input voltage is 7V or 8V, the output from LM7805 will not equal to 5V.

The solution of this problem is give input voltage of LM7805 more than 9V. The output will be accurate 5V if the input voltage is 4V above the output voltage.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The report views the successfully design and implementation of the solar digital thermometer. The charger is successful to charge the battery from the solar and the battery will supply the digital thermometer that shows the surrounding temperature. The temperature displays in large seven segments.

For overall, process to developed solar digital thermometer has been successful setup. All the objective and scope of the project is achieved.

5.2 Recommendations

Here is some recommendation for this project that should be added in future development:

I. Add automatic switch for the charger that will disconnect the charger automatically when the battery is fully charge. It will make sure that the battery will ever lasting.

II. Use dot matrix as the display of the thermometer. It is more attractive than using seven segments.

III. Integrate the thermometer to other relevant circuit, such as circuit that regulates motor speed. The application is to control fan speed based on the surrounding temperature.

REFERENCES

[1] 14th February 2009, Citing internet source URL

http://www.clean-solarenergy-ideas.com

[2] 14th February 2009, Citing internet source URL

http://www.chipcatalog.com/Microchip/PIC16F872.html

[3] 15th February 2009, Citing internet source URL http://www.omega.com/prodinfo

[4] Houghton Mifflin (2007)The American Heritage® Medical Dictionary Copyright © 2007, Houghton Mifflin Company

[5] 15th February 2009, Citing internet source URL http://www.eidusa.com/Electronics_Voltage_Regulator.htm

[6] NOR ANIZA MAT DESA (2006). BST SENSOR APPLICATION:DIGITAL THERMOMETER, Degree thesis. Retrieved 7Feb2009, from http://dspace.unimap.edu.my/bitstream/

[7] 15th February 2009, Citing internet source URL wordnet.princeton.edu/perl/webwn

[8] Bruno Gailhard(2002). Electrical Design News, US : Cahners Publishing Co. Newton, Massachusetts.

[9] Masaaki Sakaue, Toshiharu Ohashi, Kazuhiro Suzuki, (2001) Patent Application Publication.

[10] 11 February2009, Citing internet source URL http://science.nasa.govheadlinesy2002solarcells.html

[11] 22 February2009, Citing internet source URL http://www.doc.ic.ac.uk/~wjk/C++Intro/RobMillerL1.html

[12] 22 February2009, Citing internet source URL
http://focus.ti.com/docs/prod/folders/print/tpic6b595.html

[12] 24 February2009, Citing internet source URL

http://www.solar4power.com/map7-global-solar-power.html

[13] 27 February2009, Citing internet source URL
http://www.energymatters.com.au/climate-data/saps-calculate-solar.php

[14] 3 Mac 2009, Citing internet source URL

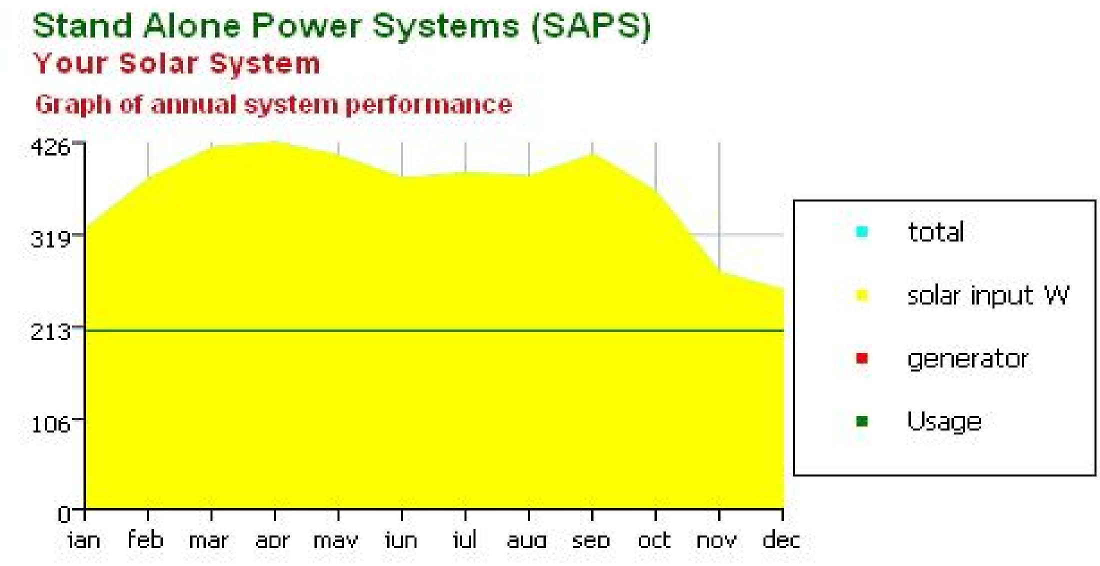
http://www.cirkits.com/spc3/spc3specs.html

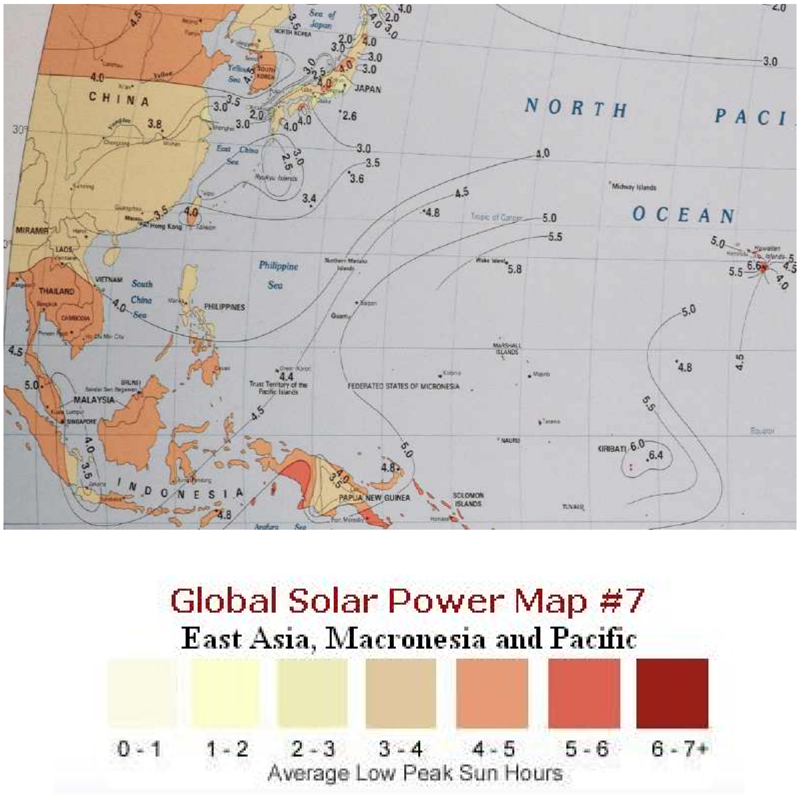
[15] 5 October 2009, Citing internet source URL
http://electronicdesign.com/Articles/Index.cfm?AD=1&ArticleID=2476

[16] October 2009. Cyrton user manual.Cytron technology Sdn Bhd.

APPENDIX A

SOLAR POWER CHARACTERISTIC





APPENDIX B

PIC PROGRAMMING

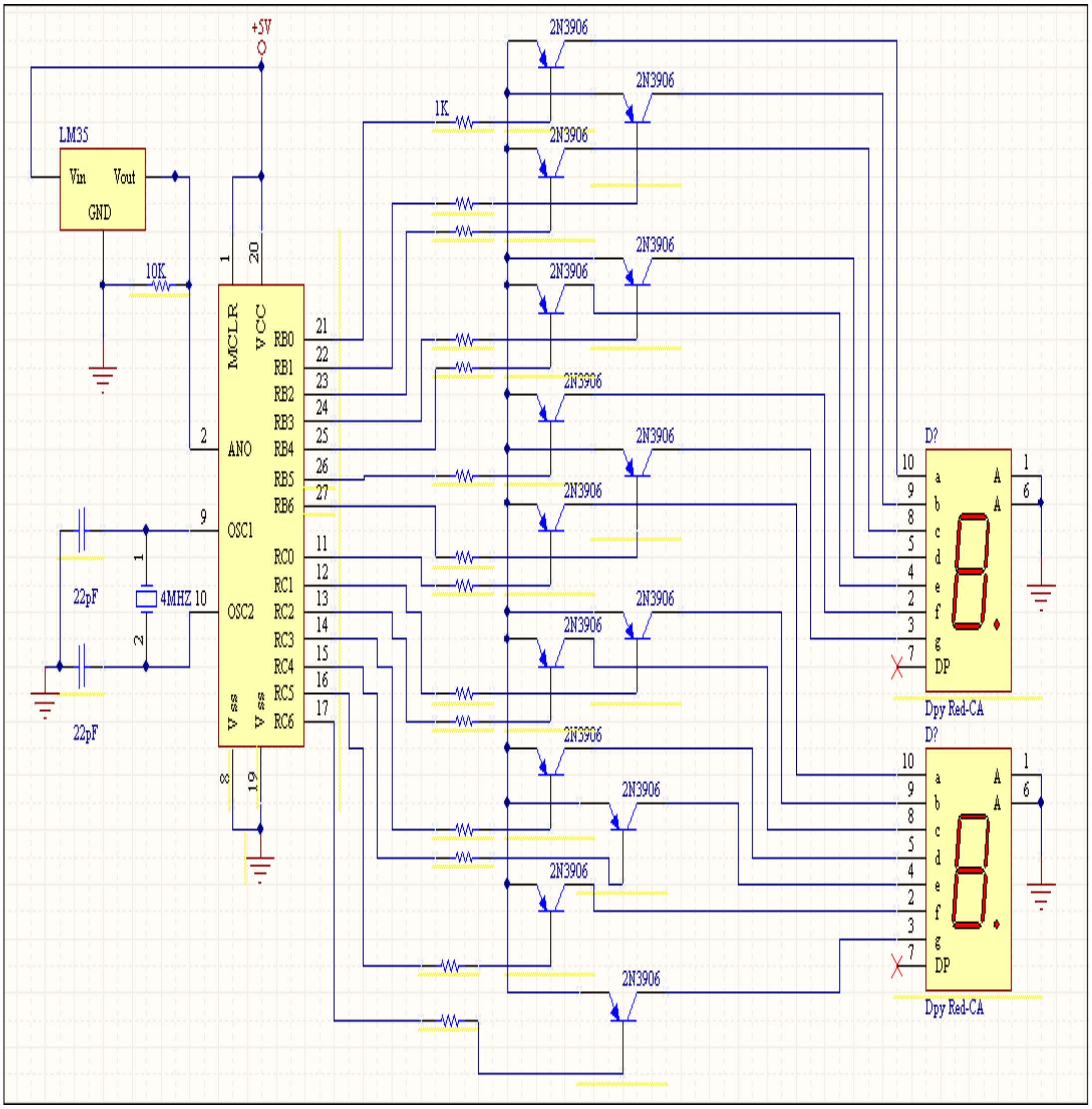
```
#include <16f872.h>
#device adc=8
#use delay(clock=4000000)
#FUSES NOWDT,HS,NOPROTECT,NOBROWNOUT,NOLVP/* Use XT mode, No Watch
Dog, No Code Protect, No Power-up Timer *//
void segment(int seg);
void segment1(int seg1);
void main()
{ byte k;
  float u;
  int seg,seg1;
 //ADC setting
  setup_adc_ports(ALL_ANALOG);
  //setup_adc_ports(AN0_AN1_AN2_AN4_VSS_VREF);//1V masuk port A3
  setup_adc(ADC_CLOCK_DIV_32);
 while(true)
  {
  set_adc_channel(0);
  delay_us(80);
  k=read_adc();
  u=k*1.953;
```

```
  //u=k*0.3906;//utk voltage ref 1V

  seg1=u/10;

  seg=u -(seg1*10);

  segment(seg);

  segment1(seg1);


  delay_ms(1000);

  }

}


void segment(int seg)

{

if(seg==1)output_b(0b0000110);

else{if(seg==2)output_b(0b1011011);

else{if(seg==3)output_b(0b1001111);

else{if(seg==4)output_b(0b1100110);

else{if(seg==5)output_b(0b1101101);

else{if(seg==6)output_b(0b1111101);

else{if(seg==7)output_b(0b0000111);

else{if(seg==8)output_b(0b1111111);

else{if(seg==9)output_b(0b1100111);

                                        else{if(seg==0)output_b(0b0111111);

}}}}}}}}}
```

```
}
void segment1(int seg1)
{
if(seg==1)output_b(0b0000110);
else{if(seg==2)output_b(0b1011011);
else{if(seg==3)output_b(0b1001111);
else{if(seg==4)output_b(0b1100110);
else{if(seg==5)output_b(0b1101101);
else{if(seg==6)output_b(0b1111101);
else{if(seg==7)output_b(0b0000111);
else{if(seg==8)output_b(0b1111111);
else{if(seg==9)output_b(0b1100111);
 else{if(seg1==0)output_c(0b0111111);
}}}}}}}}}
}
```

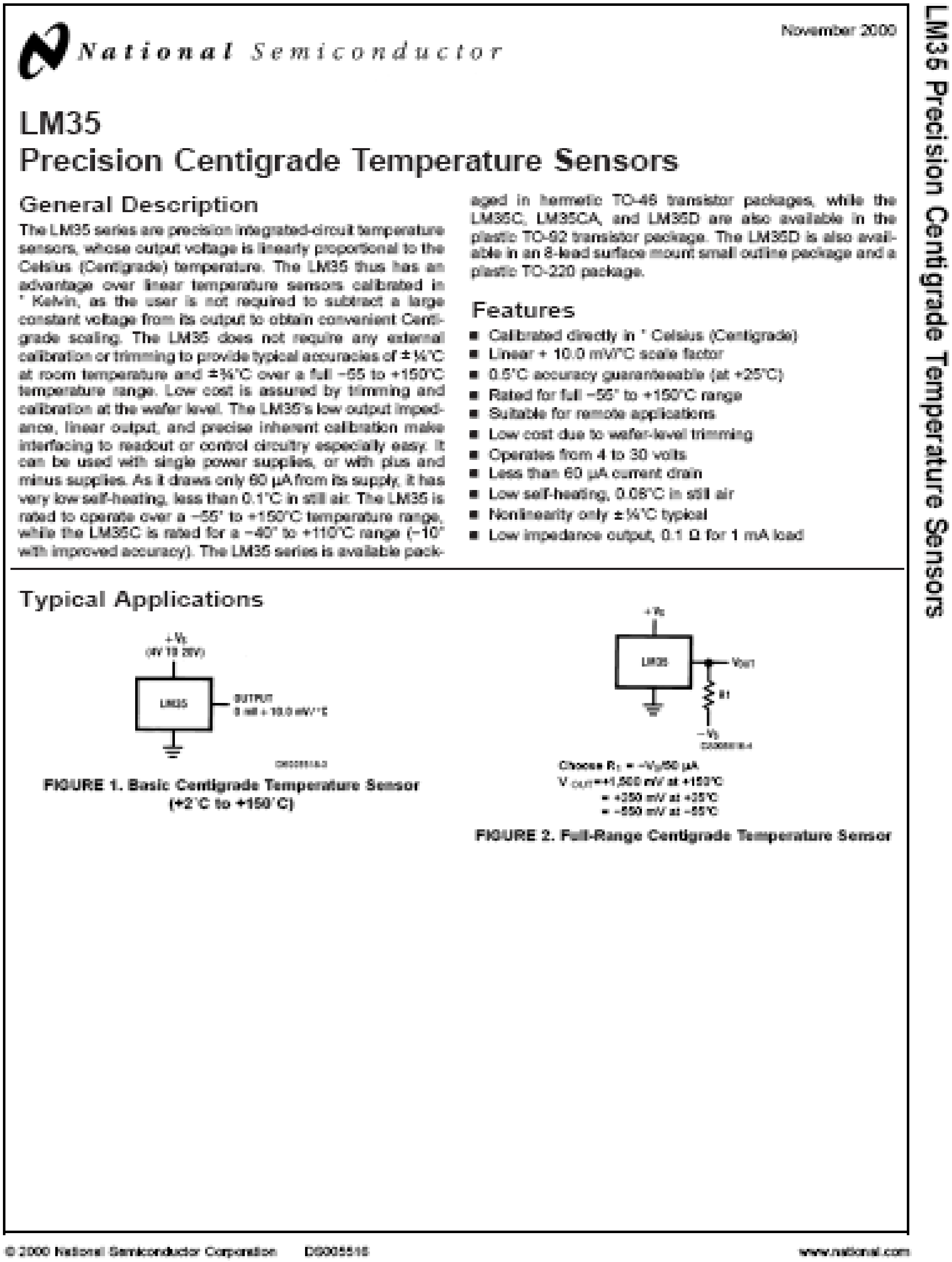
APPENDIX C

SCEMATIC DIAGRAM FOR DIGITAL THERMOMETER



APPENDIX D

LM35 DATASHEET



National Semiconductor

November 2000

LM35 Precision Centigrade Temperature Sensors

LM35

Precision Centigrade Temperature Sensors

General Description

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

Features

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

Typical Applications

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

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

V_{OUT} = +1,500 mV at +150°C

= +250 mV at +25°C

= −550 mV at −55°C

FIGURE 2. Full-Range Centigrade Temperature Sensor

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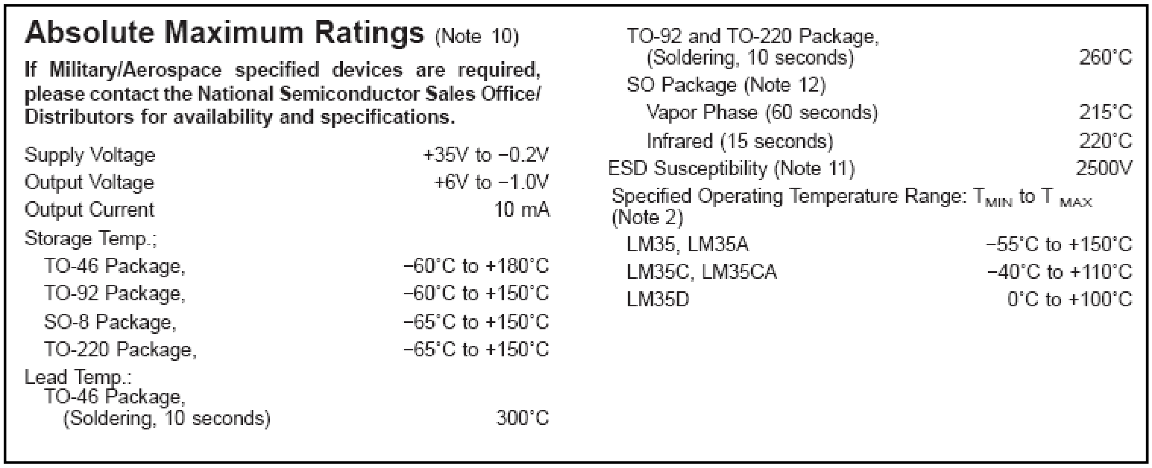
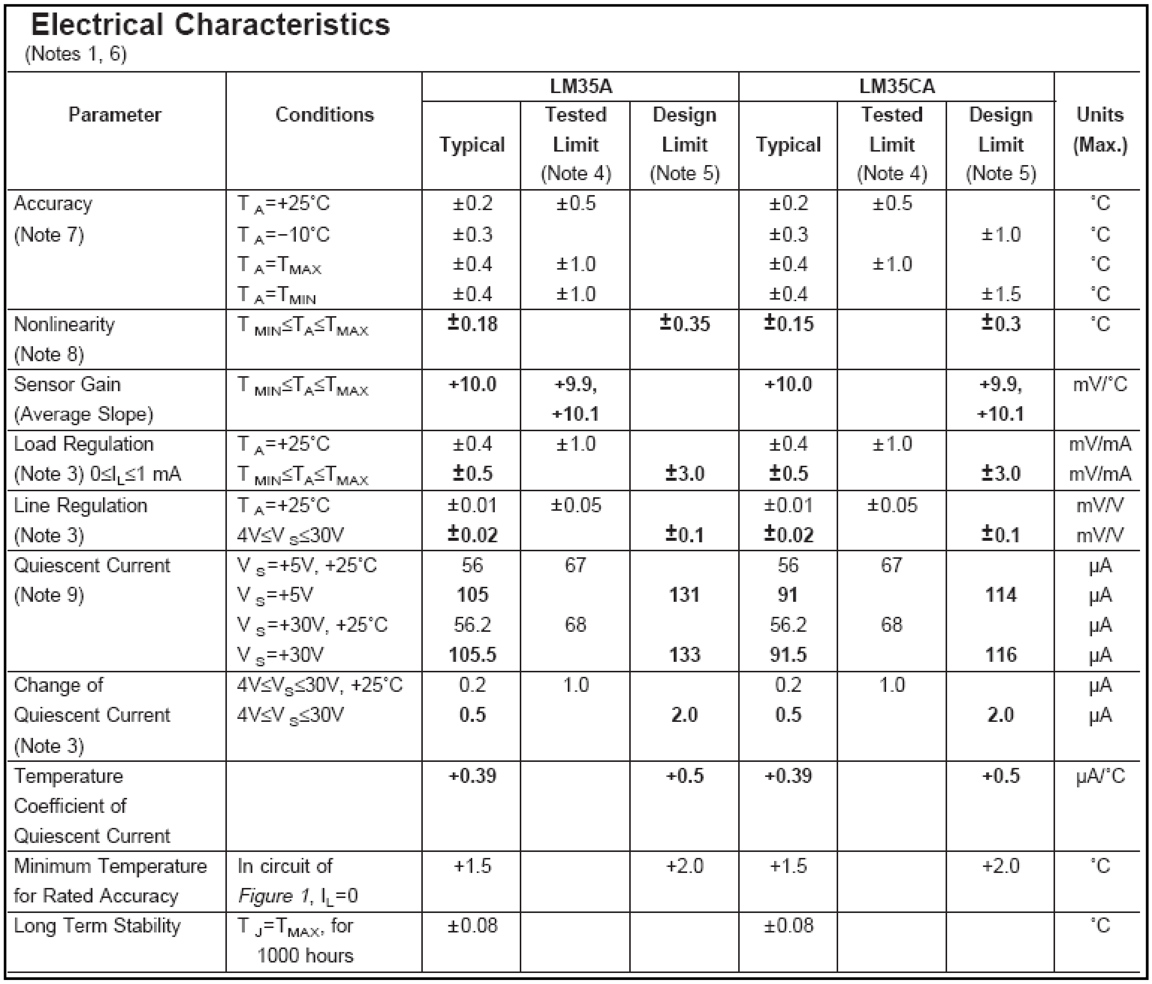


Absolute Maximum Ratings (Note 10)

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

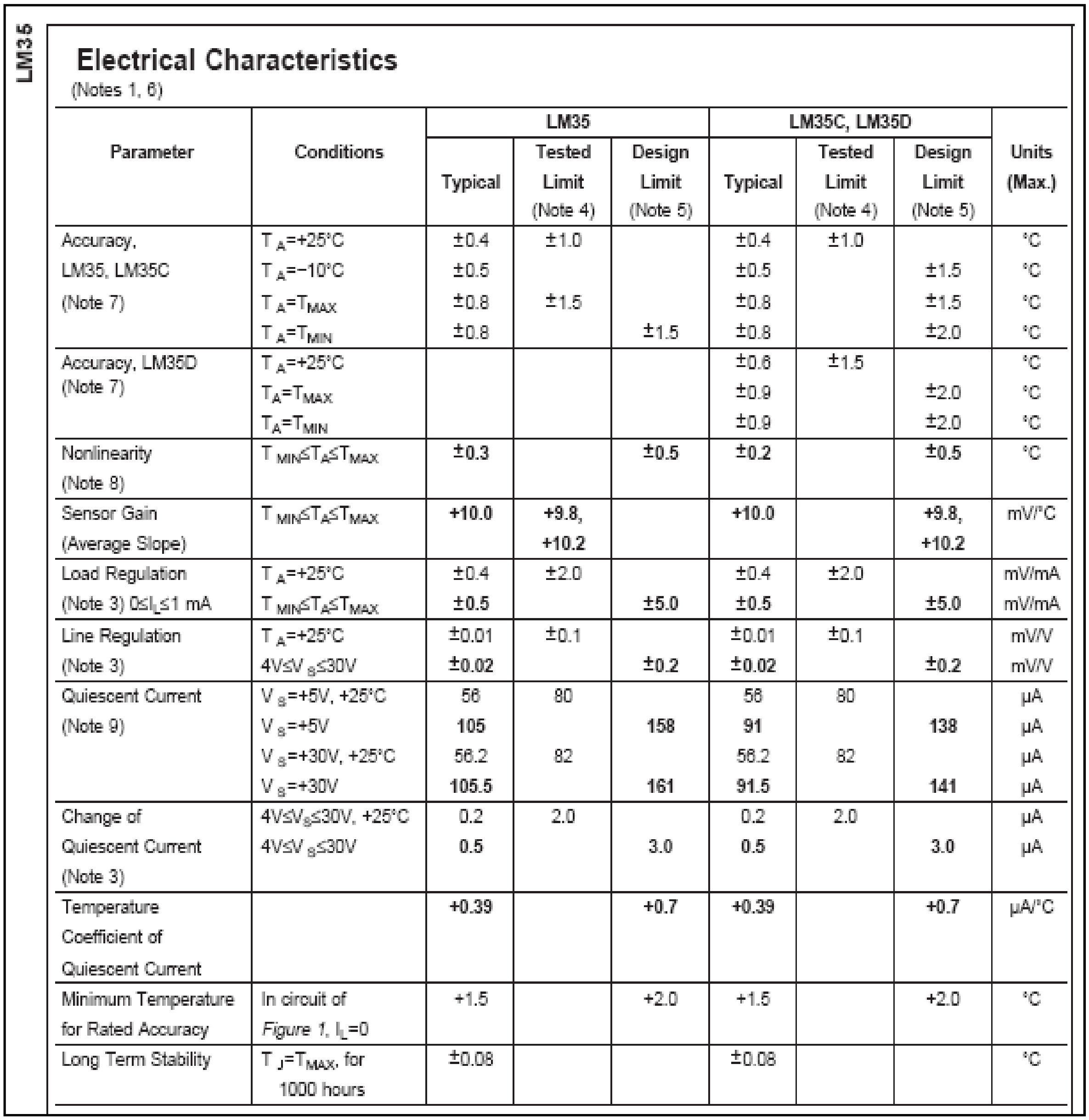
Supply Voltage	+35V to −0.2V
Output Voltage	+6V to −1.0V
Output Current	10 mA
Storage Temp.;	
TO-46 Package,	−60°C to +180°C
TO-92 Package,	−60°C to +150°C
SO-8 Package,	−65°C to +150°C
TO-220 Package,	−65°C to +150°C
Lead Temp.:	
TO-46 Package, (Soldering, 10 seconds)	300°C
TO-92 and TO-220 Package,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



Electrical Characteristics

(Notes 1, 6)

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



LM35

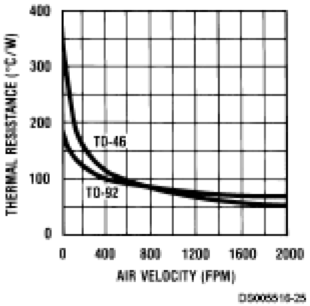
Electrical Characteristics

(Notes 1, 6)

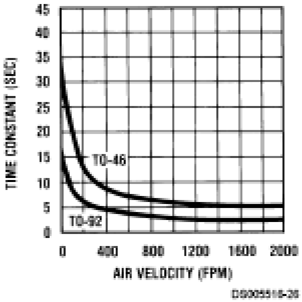
Parameter	Conditions	LM35			LM35C, LM35D			Units (Max.)
		Typical	Tested Limit (Note 4)	Design Limit (Note 5)	Typical	Tested Limit (Note 4)	Design Limit (Note 5)	
Accuracy, LM35, LM35C (Note 7)	T_A=+25°C	±0.4	±1.0		±0.4	±1.0		°C
	T_A=−10°C	±0.5			±0.5		±1.5	°C
	$T_A=T_{MAX}$	±0.8	±1.5		±0.8		±1.5	°C
	$T_A=T_{MIN}$	±0.8		±1.5	±0.8		±2.0	°C
Accuracy, LM35D (Note 7)	T_A=+25°C				±0.6	±1.5		°C
	$T_A=T_{MAX}$				±0.9		±2.0	°C
	$T_A=T_{MIN}$				±0.9		±2.0	°C
Nonlinearity (Note 8)	$T_{MIN}≤T_A≤T_{MAX}$	**±0.3**		**±0.5**	**±0.2**		**±0.5**	°C
Sensor Gain (Average Slope)	$T_{MIN}≤T_A≤T_{MAX}$	**+10.0**	**+9.8, +10.2**		**+10.0**		**+9.8, +10.2**	mV/°C
Load Regulation (Note 3) $0≤I_L≤1$ mA	T_A=+25°C	±0.4	±2.0		±0.4	±2.0		mV/mA
	$T_{MIN}≤T_A≤T_{MAX}$	**±0.5**		**±5.0**	**±0.5**		**±5.0**	mV/mA
Line Regulation (Note 3)	T_A=+25°C	±0.01	±0.1		±0.01	±0.1		mV/V
	4V≤V_S≤30V	**±0.02**		**±0.2**	**±0.02**		**±0.2**	mV/V
Quiescent Current (Note 9)	V_S=+5V, +25°C	56	80		56	80		µA
	V_S=+5V	**105**		**158**	**91**		**138**	µA
	V_S=+30V, +25°C	56.2	82		56.2	82		µA
	V_S=+30V	**105.5**		**161**	**91.5**		**141**	µA
Change of Quiescent Current (Note 3)	4V≤V_S≤30V, +25°C	0.2	2.0		0.2	2.0		µA
	4V≤V_S≤30V	**0.5**		**3.0**	**0.5**		**3.0**	µA
Temperature Coefficient of Quiescent Current		**+0.39**		**+0.7**	**+0.39**		**+0.7**	µA/°C
Minimum Temperature for Rated Accuracy	In circuit of *Figure 1*, I_L=0	+1.5		+2.0	+1.5		+2.0	°C
Long Term Stability	$T_J=T_{MAX}$, for 1000 hours	±0.08			±0.08			°C

Typical Performance Characteristics

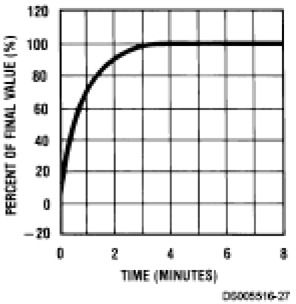
Thermal Resistance Junction to Air



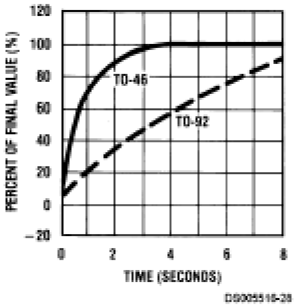
Thermal Time Constant



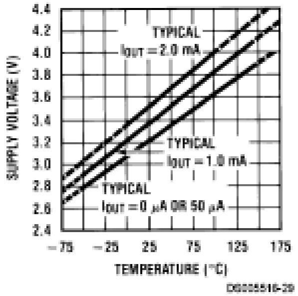
Thermal Response in Still Air



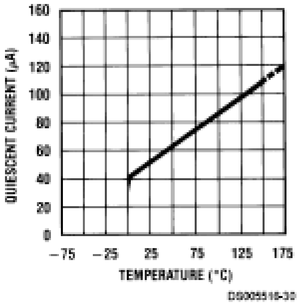
Thermal Response in Stirred Oil Bath



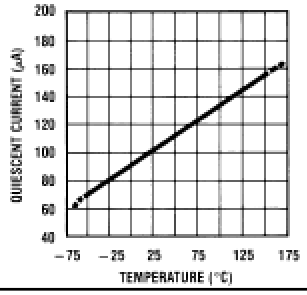
Minimum Supply Voltage vs. Temperature



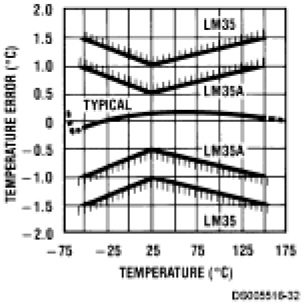
Quiescent Current vs. Temperature (In Circuit of *Figure 1.*)



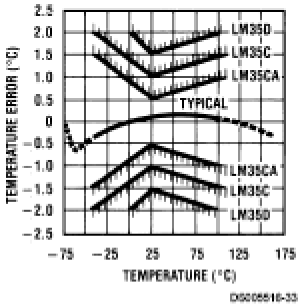
Quiescent Current vs. Temperature (In Circuit of *Figure 2.*)

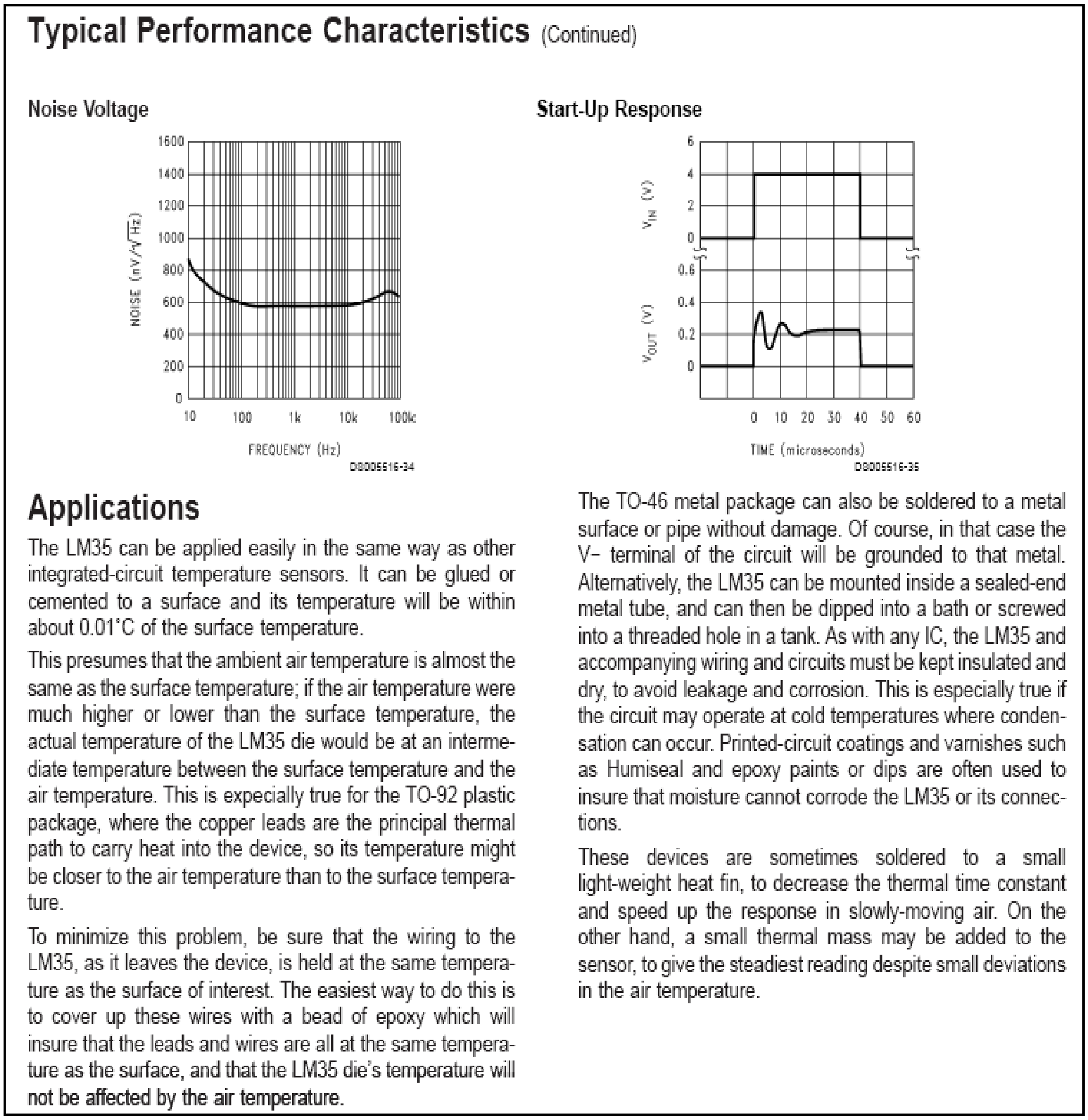


Accuracy vs. Temperature (Guaranteed)



Accuracy vs. Temperature (Guaranteed)





Typical Performance Characteristics (Continued)

Noise Voltage

Start-Up Response

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.

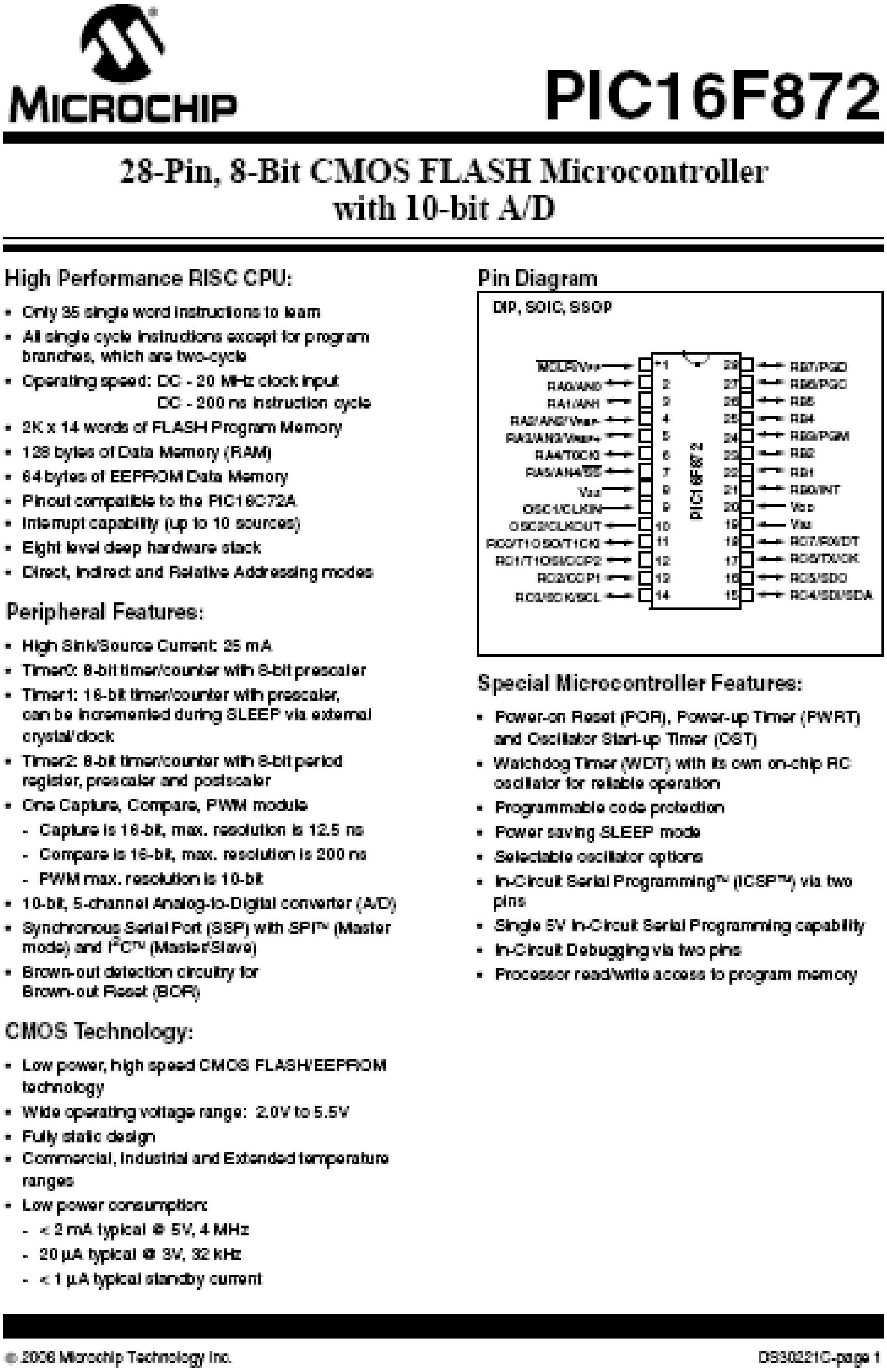
To minimize this problem, be sure that the wiring to the LM35, as it leaves the device, is held at the same temperature as the surface of interest. The easiest way to do this is to cover up these wires with a bead of epoxy which will insure that the leads and wires are all at the same temperature as 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.

APPENDIX E

PIC 16F872 DATASHEET



MICROCHIP

PIC16F872

28-Pin, 8-Bit CMOS FLASH Microcontroller with 10-bit A/D

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
- 2K x 14 words of FLASH Program Memory
- 128 bytes of Data Memory (RAM)
- 64 bytes of EEPROM Data Memory
- Pinout compatible to the PIC16C72A
- Interrupt capability (up to 10 sources)
- Eight level deep hardware stack
- Direct, Indirect and Relative Addressing modes

Peripheral Features:

- High Sink/Source Current: 25 mA
- 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
- One Capture, Compare, PWM module
  - 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, 5-channel Analog-to-Digital converter (A/D)
- Synchronous Serial Port (SSP) with SPI™ (Master mode) and I^{2}C™ (Master/Slave)
- Brown-out detection circuitry for Brown-out Reset (BOR)

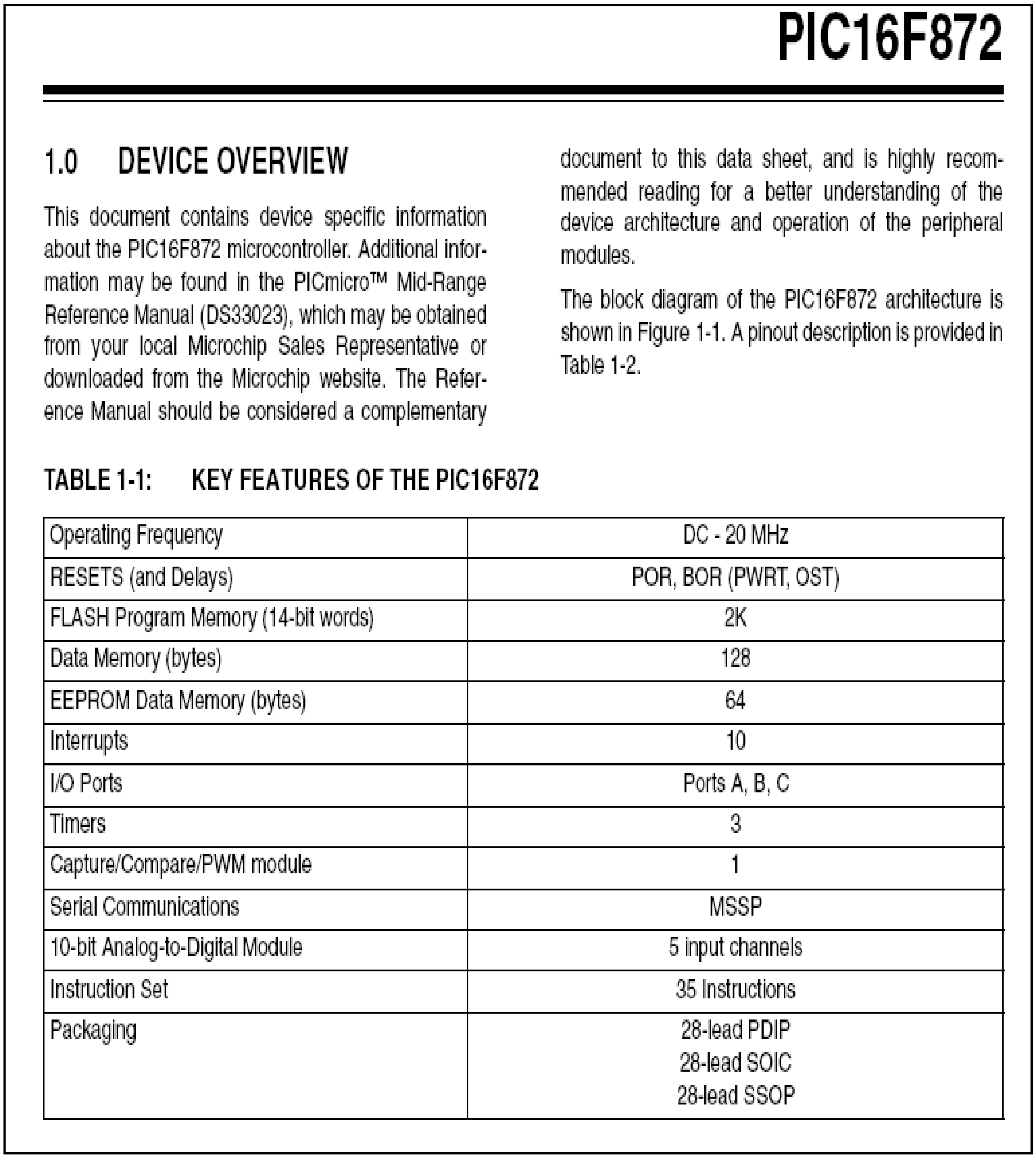
CMOS Technology:

- Low power, high speed CMOS FLASH/EEPROM technology
- Wide operating voltage range: 2.0V to 5.5V
- Fully static design
- Commercial, Industrial and Extended temperature ranges
- Low power consumption:
  - < 2 mA typical @ 5V, 4 MHz
  - 20 µA typical @ 3V, 32 kHz
  - < 1 µA typical standby current

Pin Diagram

Special Microcontroller Features:

- 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
- 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



PIC16F872

1.0 DEVICE OVERVIEW

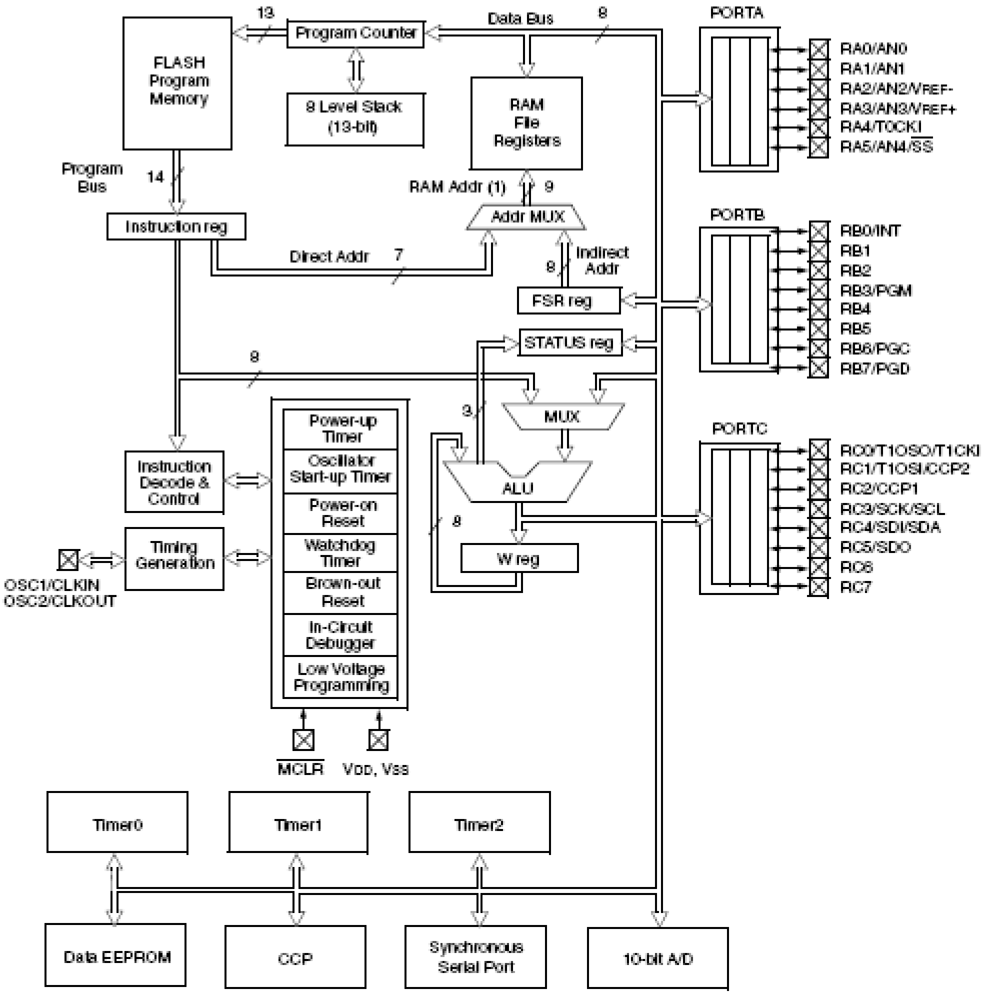
This document contains device specific information about the PIC16F872 microcontroller. Additional information may be found in the PICmicro™ Mid-Range Reference Manual (DS33023), which may be obtained from your local Microchip Sales Representative or downloaded from the Microchip website. The Reference Manual should be considered a complementary document to this data sheet, and is highly recommended reading for a better understanding of the device architecture and operation of the peripheral modules.

The block diagram of the PIC16F872 architecture is shown in Figure 1-1. A pinout description is provided in Table 1-2.

TABLE 1-1: KEY FEATURES OF THE PIC16F872

Operating Frequency	DC - 20 MHz
RESETS (and Delays)	POR, BOR (PWRT, OST)
FLASH Program Memory (14-bit words)	2K
Data Memory (bytes)	128
EEPROM Data Memory (bytes)	64
Interrupts	10
I/O Ports	Ports A, B, C
Timers	3
Capture/Compare/PWM module	1
Serial Communications	MSSP
10-bit Analog-to-Digital Module	5 input channels
Instruction Set	35 Instructions
Packaging	28-lead PDIP 28-lead SOIC 28-lead SSOP

FIGURE 1-1: PIC16F872 BLOCK DIAGRAM



Note 1: Higher order bits are from the STATUS register.

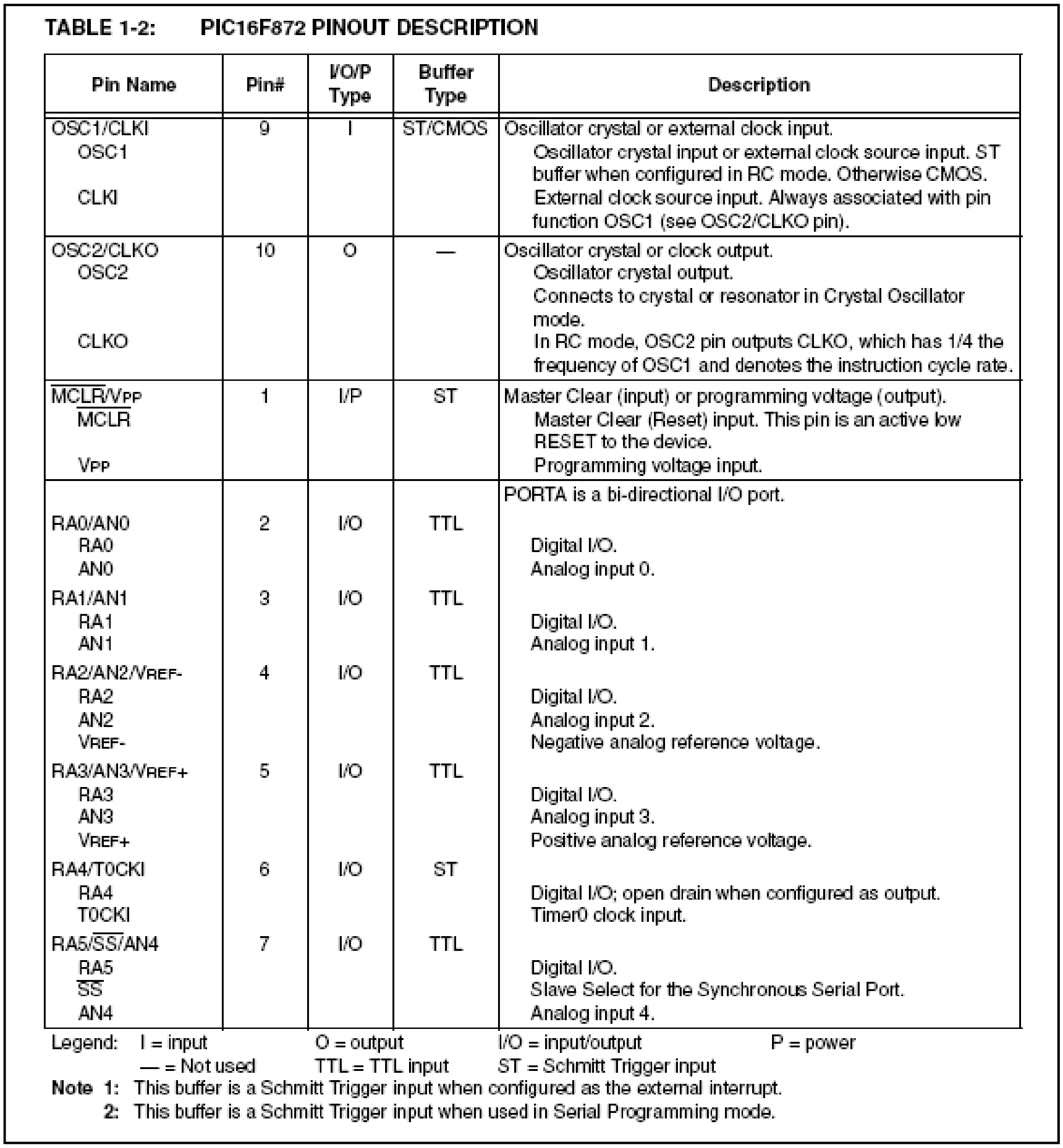


TABLE 1-2: PIC16F872 PINOUT DESCRIPTION

Pin Name	Pin#	I/O/P Type	Buffer Type	Description
OSC1/CLKI OSC1 CLKI	9	I	ST/CMOS	Oscillator crystal or external clock input. Oscillator crystal input or external clock source input. ST buffer when configured in RC mode. Otherwise CMOS. External clock source input. Always associated with pin function OSC1 (see OSC2/CLKO pin).
OSC2/CLKO OSC2 CLKO	10	O	—	Oscillator crystal or clock output. Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode. In RC mode, OSC2 pin outputs CLKO, which has 1/4 the frequency of OSC1 and denotes the instruction cycle rate.
$\overline{\text{MCLR}}$/VPP $\overline{\text{MCLR}}$ VPP	1	I/P	ST	Master Clear (input) or programming voltage (output). Master Clear (Reset) input. This pin is an active low RESET to the device. Programming voltage input.
				PORTA is a bi-directional I/O port.
RA0/AN0 RA0 AN0	2	I/O	TTL	Digital I/O. Analog input 0.
RA1/AN1 RA1 AN1	3	I/O	TTL	Digital I/O. Analog input 1.
RA2/AN2/VREF- RA2 AN2 VREF-	4	I/O	TTL	Digital I/O. Analog input 2. Negative analog reference voltage.
RA3/AN3/VREF+ RA3 AN3 VREF+	5	I/O	TTL	Digital I/O. Analog input 3. Positive analog reference voltage.
RA4/T0CKI RA4 T0CKI	6	I/O	ST	Digital I/O; open drain when configured as output. Timer0 clock input.
RA5/$\overline{\text{SS}}$/AN4 RA5 $\overline{\text{SS}}$ AN4	7	I/O	TTL	Digital I/O. Slave Select for the Synchronous Serial Port. Analog input 4.

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.

TABLE 1-2: PIC16F872 PINOUT DESCRIPTION (CONTINUED)

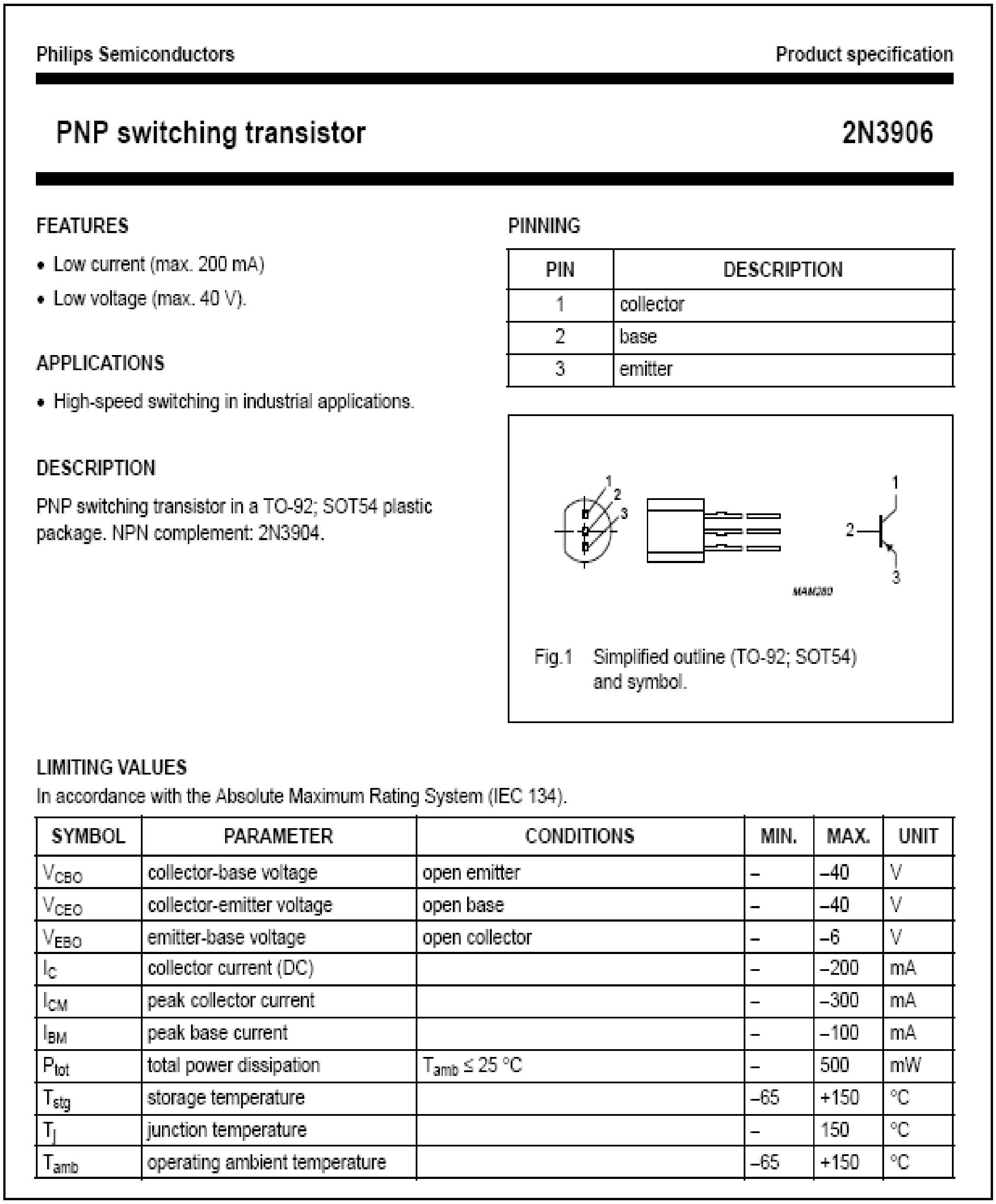
Pin Name	Pin#	I/O/P Type	Buffer Type	Description
				PORTB is a bi-directional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs.
RB0/INT	21	I/O	TTL/ST(1)	
RB0				Digital I/O.
INT				External interrupt pin.
RB1	22	I/O	TTL	Digital I/O.
RB2	23	I/O	TTL	Digital I/O.
RB3/PGM	24	I/O	TTL	
RB3				Digital I/O.
PGM				Low voltage ICSP programming enable pin.
RB4	25	I/O	TTL	Digital I/O.
RB5	26	I/O	TTL	Digital I/O.
RB6/PGC	27	I/O	TTL/ST(2)	
RB6				Digital I/O.
PGC				In-Circuit Debugger and ICSP programming clock.
RB7/PGD	28	I/O	TTL/ST(2)	
RB7				Digital I/O.
PGD				In-Circuit Debugger and ICSP programming data.
				PORTC is a bi-directional I/O port.
RC0/T1OSO/T1CKI	11	I/O	ST	
RC0				Digital I/O.
T1OSO				Timer1 oscillator output.
T1CKI				Timer1 clock input.
RC1/T1OSI	12	I/O	ST	
RC1				Digital I/O.
T1OSI				Timer1 oscillator input.
RC2/CCP1	13	I/O	ST	
RC2				Digital I/O.
CCP1				Capture1 input/Compare1 output/PWM1 output.
RC3/SCK/SCL	14	I/O	ST	
RC3				Digital I/O.
SCK				Synchronous serial clock input/output for SPI mode.
SCL				Synchronous serial clock input/output for I^{2}C mode.
RC4/SDI/SDA	15	I/O	ST	
RC4				Digital I/O.
SDI				SPI Data In pin (SPI mode).
SDA				SPI Data I/O pin (I^{2}C mode).
RC5/SDO	16	I/O	ST	
RC5				Digital I/O.
SDO				SPI Data Out pin (SPI mode).
RC6	17	I/O	ST	Digital I/O.
RC7	18	I/O	ST	Digital I/O.
VSS	8, 19	P	—	Ground reference for logic and I/O pins.
VDD	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.

APPENDIX F

TRANSISTOR 2N3906 DATASHEET



Philips Semiconductors **Product specification**

PNP switching transistor 2N3906

FEATURES

- Low current (max. 200 mA)
- Low voltage (max. 40 V).

APPLICATIONS

- High-speed switching in industrial applications.

DESCRIPTION

PNP switching transistor in a TO-92; SOT54 plastic package. NPN complement: 2N3904.

PINNING

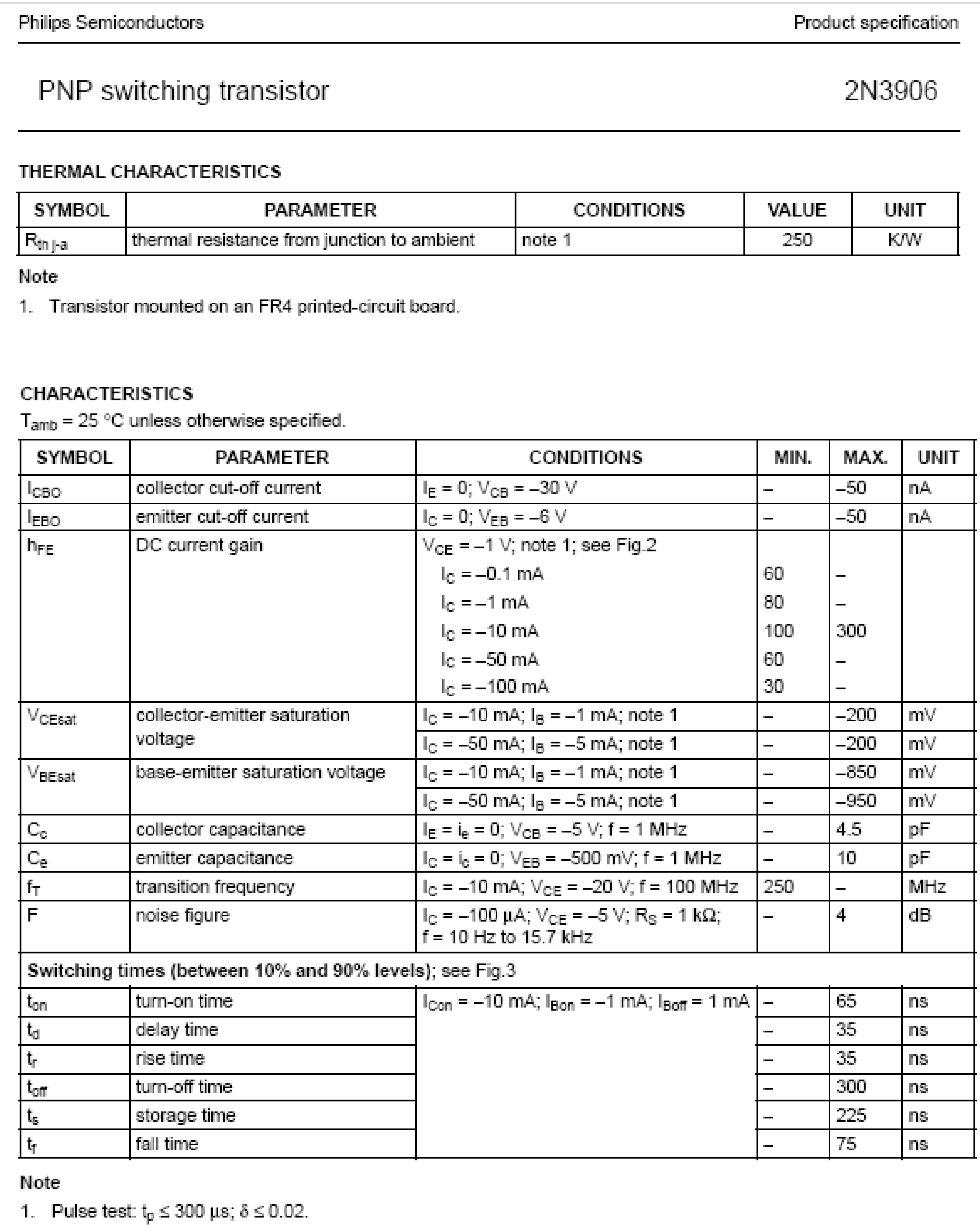
PIN	DESCRIPTION
1	collector
2	base
3	emitter

Fig.1 Simplified outline (TO-92; SOT54) and symbol.

LIMITING VALUES

In accordance with the Absolute Maximum Rating System (IEC 134).

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_{CBO}	collector-base voltage	open emitter	–	–40	V
V_{CEO}	collector-emitter voltage	open base	–	–40	V
V_{EBO}	emitter-base voltage	open collector	–	–6	V
I_C	collector current (DC)		–	–200	mA
I_{CM}	peak collector current		–	–300	mA
I_{BM}	peak base current		–	–100	mA
P_{tot}	total power dissipation	$T_{amb} \leq 25$ °C	–	500	mW
T_{stg}	storage temperature		–65	+150	°C
T_j	junction temperature		–	150	°C
T_{amb}	operating ambient temperature		–65	+150	°C



PNP switching transistor 2N3906

THERMAL CHARACTERISTICS

SYMBOL	PARAMETER	CONDITIONS	VALUE	UNIT
$R_{th\ j\text{-}a}$	thermal resistance from junction to ambient	note 1	250	K/W

Note

1. Transistor mounted on an FR4 printed-circuit board.

CHARACTERISTICS

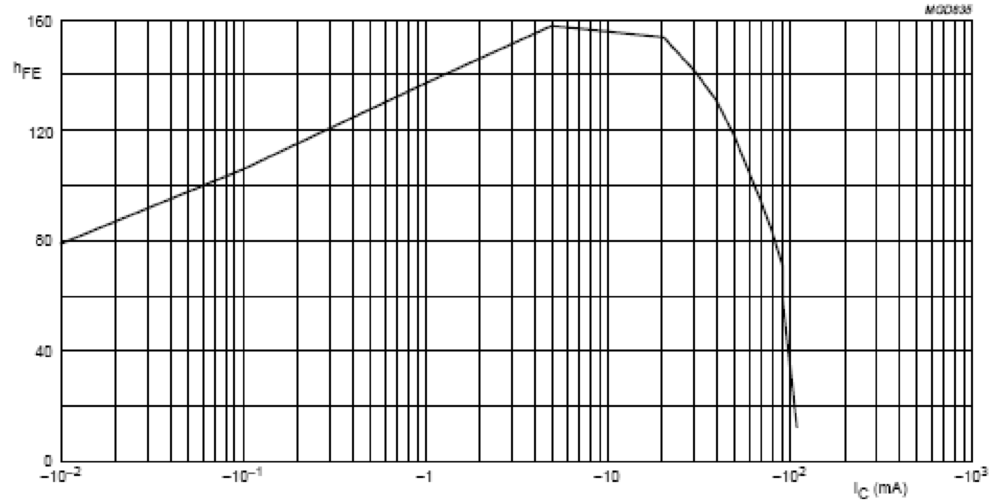
T_{amb} = 25 °C unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
I_{CBO}	collector cut-off current	$I_E = 0$; $V_{CB} = -30$ V	–	–50	nA
I_{EBO}	emitter cut-off current	$I_C = 0$; $V_{EB} = -6$ V	–	–50	nA
h_{FE}	DC current gain	$V_{CE} = -1$ V; note 1; see Fig.2			
		$I_C = -0.1$ mA	60	–	
		$I_C = -1$ mA	80	–	
		$I_C = -10$ mA	100	300	
		$I_C = -50$ mA	60	–	
		$I_C = -100$ mA	30	–	
V_{CEsat}	collector-emitter saturation voltage	$I_C = -10$ mA; $I_B = -1$ mA; note 1	–	–200	mV
		$I_C = -50$ mA; $I_B = -5$ mA; note 1	–	–200	mV
V_{BEsat}	base-emitter saturation voltage	$I_C = -10$ mA; $I_B = -1$ mA; note 1	–	–850	mV
		$I_C = -50$ mA; $I_B = -5$ mA; note 1	–	–950	mV
C_c	collector capacitance	$I_E = i_e = 0$; $V_{CB} = -5$ V; f = 1 MHz	–	4.5	pF
C_e	emitter capacitance	$I_C = i_c = 0$; $V_{EB} = -500$ mV; f = 1 MHz	–	10	pF
f_T	transition frequency	$I_C = -10$ mA; $V_{CE} = -20$ V; f = 100 MHz	250	–	MHz
F	noise figure	$I_C = -100$ µA; $V_{CE} = -5$ V; $R_S = 1$ kΩ; f = 10 Hz to 15.7 kHz	–	4	dB
Switching times (between 10% and 90% levels); see Fig.3					
t_{on}	turn-on time	$I_{Con} = -10$ mA; $I_{Bon} = -1$ mA; $I_{Boff} = 1$ mA	–	65	ns
t_d	delay time		–	35	ns
t_r	rise time		–	35	ns
t_{off}	turn-off time		–	300	ns
t_s	storage time		–	225	ns
t_f	fall time		–	75	ns

Note

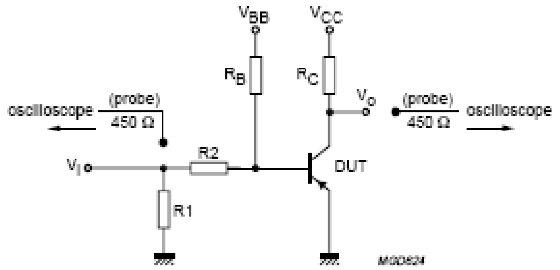
1. Pulse test: $t_p \leq 300$ µs; $\delta \leq 0.02$.

PNP switching transistor 2N3906



V_{CE} = 1 V.

Fig.2 DC current gain; typical values.



V_i = −5 V; T = 500 μs; t_p = 10 μs; t_r = t_f ≤ 3 ns.
R1 = 56 Ω; R2 = 2.5 kΩ; R_B = 3.9 kΩ; R_C = 270 Ω.
V_{BB} = 1.9 V; V_{CC} = −3 V.
Oscilloscope input impedance Z_i = 50 Ω.

Fig.3 Test circuit for switching times.

APPENDIX G

COST OF PROJECT

FAKULTI KEJURUTERAAN ELEKTRIK & ELEKTRONIK

UNIVERSITI MALAYSIA PAHANG (UMP)

BORANG PEMBELIAN KOMPONEN/BAHAN PSM

Sila isi secara **bertaip** dalam **3** salinan dan hantar bersama **1** salinan litar projek berkaitan

Komponen yang rosak kerana kecuaian pelajar tidak boleh diganti

Nama Pelajar: MOHD ALIAS SANI BIN YAACOB		**Nama Penyelia: En. Ruhaizad Ishak**
ID No: **EC06024**	**Tajuk Projek: Development of Solar Digital Thermometer**	**PSM 1/ PSM 2** (tanda yang berkenaan)

bIL `	**Bahan/Komponen**	**Spesifikasi**	**Anggaran Harga / unit**	**Kuantiti**	**Anggaran Harga**
1`	IC	2272CP	3.00	1	3.00
2	Voltage regulator	19TQ015	2.50	2	5.00
3	Diode	19TQ015	2.00	2	4.00
4	Transistor	2N3904, &IRF9Z34N	2.00	4	8.00
5	led		0.10	2	0.20

6	capacitor	33p	0.15	2	0.30
7	fuse	5amp	1.00	1	1.00
8	Deep switch		1.00	1	1.00
9	7 segment	3”x4”	RM30	3	RM90
10	Resistor	2.2k	0.10	1	0.10
11	Resistor	10k	0.10	1	0.10
12	Resistor	100k	0.10	1	0.10
13	Resistor	750	0.10	1	0.10
14	Resistor	75k	0.10	1	0.10
15	Resistor	1k	0.10	15	1.50
16	Resistor	220	0.10	15	1.50
17	Resistor	300k	0.10	1	0.10
18	PIC	PIC16F872	12.00	1	12.00
19	Temp. sensor	LM35	8.00	1	8.00
20	kristal	4Mhz	8.00	1	8.00
21	Capacitor	470uF/16V	1.50	2	3.00
22	Capacitor	0.01uF	0.15	4	0.60
23	Capacitor	47uF	0.15	3	0.45
25	Capacitor	0.1uF	0.15	8	1.20
26	transistor	2N3906	1.50	15	22.50
				total	Rm 171.85

APPENDIX H

PICTURE OF SOLAR DIGITAL THERMOMETER