DEVELOPMENT OF WEB-BASED SOLAR PV POWERED WEATHER STATION

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A Report Submitted In Partial Fulfillments of the Requirement of the Degree of Bachelor of Electrical Engineering (Power System)

Faculty of Electrical and Electronics Engineering

University Malaysia Pahang

JUNE 2012

UNIVERSITI MALAYSIA PAHANG

BORANG PENGESAHAN STATUS TESIS♦

JUDUL: **DEVELOPMENT OF WEB-BASED SOLAR PV POWERED WEATHER STATION**

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ACKNOWLEDGEMENT

I would like to express my heartfelt thanks and gratitude to ALLAH, the Most Beneficent, the Most Merciful, the Most Mercy-Giving, the Most Compassionate whom granted me the ability and willing to start and complete this Final Year Project (PSM).

I wish to express my sincere gratitude to my supervisor, Pn. Norazila Binti Jaalam, for her guidance and invaluable advice, which enables me to accomplish this project.

Secondly, my appreciation goes to my family, who has been so tolerant and supporting me all these years. Thanks for their encouragement, love, and emotional support that they had given to me.

I also would like to extend my appreciation to Universiti Malaysia Pahang to help me to be me today and I want to thank to all my friends who were there for me and giving me advices and motivations, regardless of their busy schedules. Their kindness and helpfulness are much appreciated. Lastly, my gratitude goes to anyone who is involved directly or indirectly in this project.

ABSTRACT

The weather station is an important component in achieving optimum plant monitoring and planning. The weather station will be able to measure changes in weather station parameter .In this project, the main objective is to provide real-time measurement weather station monitored system via website. This simple weather station will be powered by solar photovoltaic (PV). Solar PV will be used because it is environmental friendly. The weather station will show environmental parameters like temperature, humidity and rain gauge only. Then, the data will be updated every second in the website development. LabView is software that will be used for user interfacing and NI USB-6216 DAQ card is used to collect data from weather station parameter. This will give a low-cost solution for remote place because no longer need to go to the weather station to check the data that has been received from the weather station.

ABSTRAK

Stesen cuaca merupakan komponen penting dalam pencapaian loji optimum dan perancangan. Stesen cuaca dapat mengukur perubahan dalam cuaca. Dalam data dari parameter stesen cuacaprojek ini, objektif utama ialah untuk menyediakan masa nyata sistem pengukuran stesen cuaca melalui laman web. Stesen cuaca ringkas ini dikuasakan oleh solar PV. Solar PV digunakan kerana ia mesra alam. Stesen cuaca ini akan menunjukkan parameter stesen cuaca seperti suhu, kelembapan, dan tolok hujan sahaja. Kemudian, data dari stesen cuaca akan dikemaskini setiap saat dalam penbangunan dalam laman sesawang. LabView ialah perisian yang digunakan untuk perantaraan pengguna dan kad NI USB-6216 digunakan untuk mengumpul data daripada parameter stesen cuaca. Ini akan memberikan pengurangan kos untuk tempat yang jauh kerana tidak lagi perlu pergi ke stesen cuaca untuk menyemak data yang diterima dari stesen cuaca.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Nowadays, weather station is one of a part of daily life. Weather stations help people to do forecasting to help people in planning social and economy such as tourism, transportation, marine activity and plantation. Some of the weather station is placed in a remote place to monitor weather station parameter at that place. This situation will cause a problem if the place is far from main station that needs to monitor the weather station periodically. To hire someone to monitor the weather station periodically will cost a lot of money. Based on that problem, the web based solar PV powered weather station is developed to overcome that problem.

For this project, a website is develop to monitor the weather station parameter. This simple weather station will monitor temperature, percentage humidity, and water level in rain gauge. A DAQ card, NI USB-6216 is used to collect all weather station parameter. Then, LabView software is used to interface the weather station parameter into computer. Which will allow the weather station parameter being monitored by the computer. Web publishing tool in LabView software is used to enable the weather station parameter viewed in the website. To improve the project, solar PV is used to power the weather station.

1.2 Problem Statement

Some of the weather station need to be placed in a remote place. Nowadays, we can find several type of weather station in a market, but most of the weather station cannot be monitored in remote place. Without a long distance monitoring system, this will cause a problem. An extra cost is needed to monitor the weather station time by time. By developing the web based solar powered weather station, the problem hopefully can be solved.

1.3 Objective

The objectives of this project are;

i. To provide real-time measurement weather station parameter monitored systems via website.
ii. To use software that will synchronize measurement data from sensor and real data measurement.

iii. To build a weather station that can measure temperature, humidity and rain gauge.
iv. To build weather station that can be powered by solar PV.
v. To build a system that more green and reduce cost operation in long term.

1.4 Scope of Project

There are several scope of this project which are:

i. The weather station will measure temperature, humidity and raid gauge only.
ii. The weather station can be monitored via website.

This weather station has three parameters, that is temperature, humidity and rain gauge. All these parameters are measured by receiving data from each parameter sensor and all the parameters can be monitored via website that already design to show the data parameter.

CHAPTER 2

LITERATURE REVIEWS

2.1 Digital weather station

This journal is proposed to build a weather station with a digital display. This weather station is powered by power supply. The analog signal from sensors is convert to digital. The weather station parameter will digital output. The weather station will provide reading parameter for pressure, rainfall, temperature, humidity, wind direction and wind speed and only can display one parameter from the weather station at one time. [1].

2.2 Real-time, Web based energy meter monitoring system for a solar academic building

This paper is using web based to monitor energy meter system for a solar academic building in their universities. It provides real-time data for energy flow from the PV array minutes-by-minutes and also provide the summary performance. Their goals are to monitored total building energy consumption and monitor the performance of PV module and the information is available to everyone using world wide web(www) [2].

2.3 Development of web based power quality

This project is about a development of web based to do power quality monitoring. A computer server is use to monitored data and use internet to upload the monitored data into Tomcat web server. The monitoring software is software which control the power quality trough TCP/IP connectivity and use java technology. Beside that, HIOKI 3196 is use as power quality analyzer and that device have Ethernet and RS232 connectivity [3].

2.4 Monitoring system of a weather station via IP

From this journal, they also develop a monitoring system for weather station. They convert analog signal from sensor to digital to be read by computer via data acquisition card usb-6009 and using LabView application as application software to interface the data from weather station. The difference this project is monitored via. This method can cause a problem when people need to have a certain IP to enable them to monitored the weather station and it will also cause problem when the IP of the weather station is change [4].

2.5 A LabView based Data Acquisition System for Vibration Monitoring and Analysis

Based on this paper, the author using a LabView software to develop a system for vibration monitoring and analysis using data acquisition card (DAQ card). They use the DAQ card to monitor vibration in machine-mounted sensor and do analysis from data that has been collected from DAQ card. For this project, a piezoelectric accelerometer sensor is used to monitor the vibration [5].

2.6 Architecture for Remote Laboratories based on REST Web Services

In this paper, a new architecture for remote laboratories based on REST (Representational State Transfer) web services is proposed. The proposed platform use languages such as HTML, AJAX (asynchronous Javascript and XML) and LabView. A web browser is the client interface and on the server side runs an application based on LabView 8.6 with REST web resources. For this project, they use NI USB-6009 DAQ card and first-order active filter as input to monitored [6].

2.7 Real-time Monitoring System of PLC for Production Line of Coin Cell Battery Based on LabVIEW

This paper proposes a project using LabView software to implement the real-time monitoring system of PLC for production line of coin cell battery. It introduces the principle of its composition and some command formats. The system implements the equipment production monitoring and analysis of field data by using the data processing capabilities and the user friendly interface of Labview software. The experiment proves that the system has high stability and realizes production line real-time monitoring various working parameters [7].

CHAPTER 3

METHODOLOGY

3.1 Block Diagram

Figure 3.1 shows a block diagram of the project which starts with solar panel. The power that generated from the solar panel will transfer to charger controller and the charger will control charging process of the battery. When the battery need to be charged, the charger controller will allow the power from solar panel to charge the battery and when the battery is full, the charger controller will stop the charging process. The battery will supply power to the humidity sensors, temperature sensor, and water level sensor. All the sensors will measure weather parameter and give an analog output voltage. Data acquisition card function is to receive an analog voltage from the sensors and convert it to digital signal. The digital signal then will be transfered to the computer via USB port. In the computer, LabView software is used to read the DAQ card, control and calculate the output from weather station sensor to real value data value and display in front panel. Lastly, the weather station data in LabView front panel will be uploaded to the website via LabView web service.

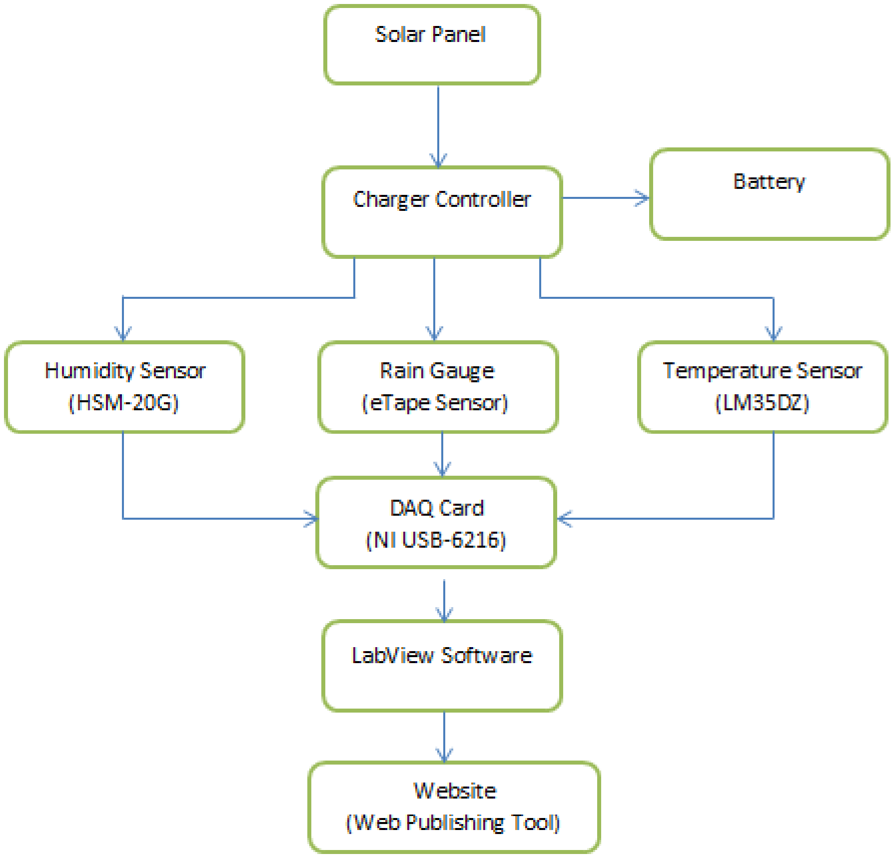

Figure 3.1: Block diagram

3.2 Hardware Connection

Figure 3.2 shows the connection between hardware for the weather station that powered by solar PV. The solar panel and battery connected. The battery then connects to the weather station at positive terminal and negative terminal to power the weather station sensors. Then the sensors output data will be collected by NI USB-6216 (DAQ card) and transmit to the computer.

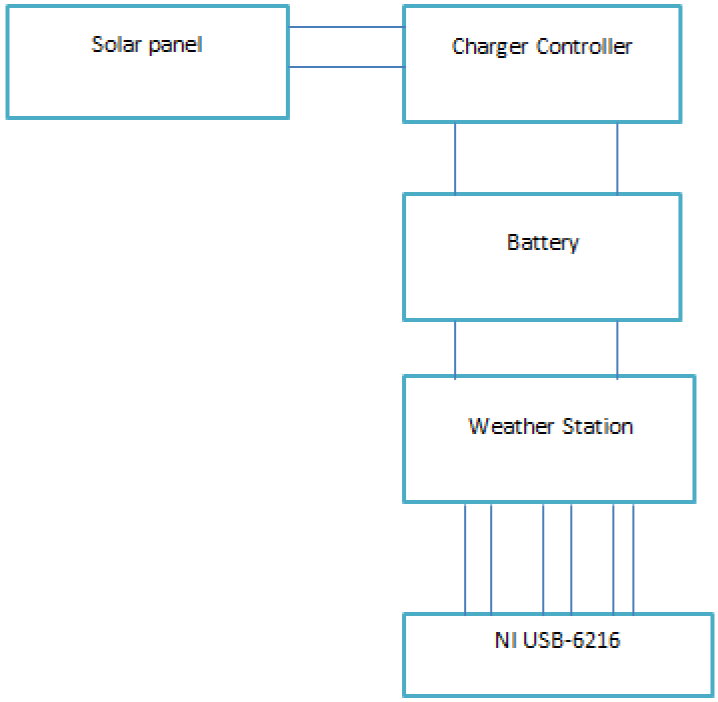

Figure 3.2: Connection between hardware

The complete connection between hardware is show in figure 3.3.

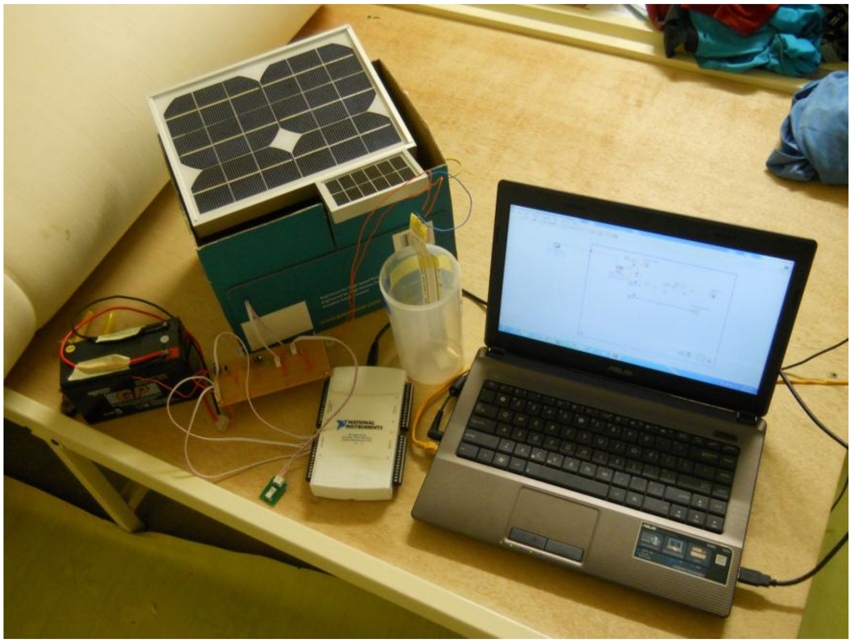

Figure 3.3: complete connection between hardware

3.3 Weather Station Circuit Overview

Figure 3.4 shows the weather station circuit. 12VDC input voltage will powered temperature sensor (LM35DZ) and voltage regulator (L7805). The voltage regulator will convert 12V DC source to 5V DC. 5V output voltage from voltage regulator will powered humidity sensor and water level sensor. Output voltage for each sensor is measured via each resistor.

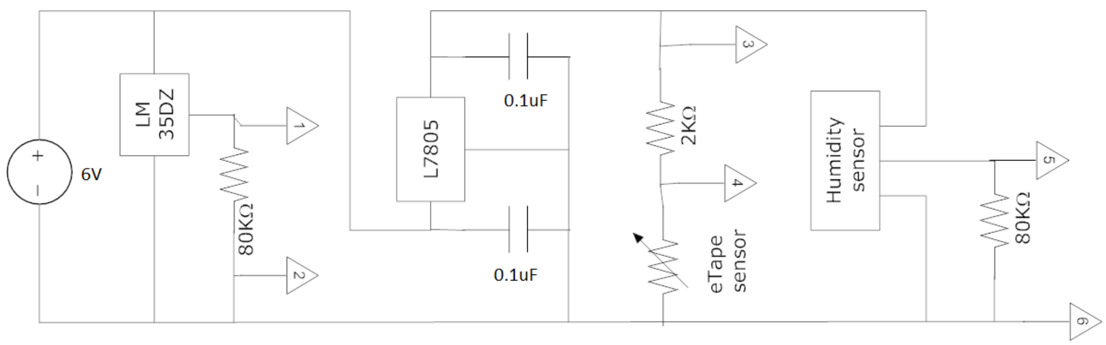

Figure 3.4: Weather station circuit

3.4 Hardware Implementation

3.4.1 Temperature Sensor

For the temperature sensor, LM35DZ in figure 3.5 is used because this sensor can measure temperature more accurately than using thermistor. Besides that, the sensor circuitry is sealed and not subject to oxidation. Lastly, compared to thermocouples, LM35DZ generates a higher output voltage than thermocouples and may not require the output voltage amplified.

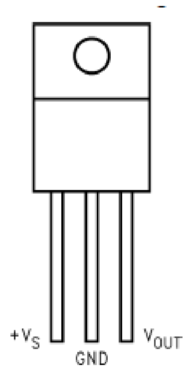

Figure 3.5: LM35DZ overview

Figure 3.6 shows that the output voltage from LM35DZ is proportional to the Celsius temperature. The scale factor is 0.01V/°C. Method to measure temperature from the sensor is by measuring voltage at resistor R_a. Figure 3.7 shows the connection used for the temperature sensor.

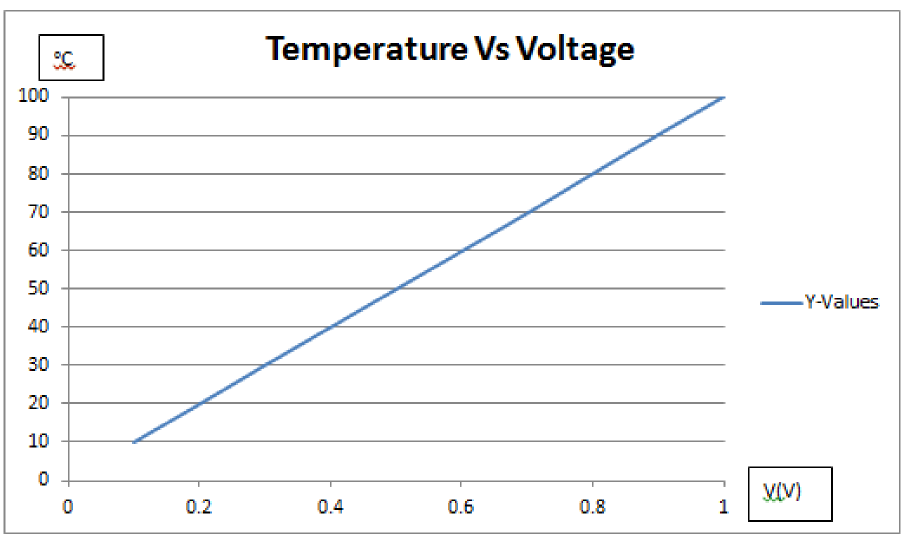

Figure 3.6: Relationship between voltage and temperature

Figure 3.7 shows how the output voltage from temperature sensor is measure. The voltage dissipate voltage at R_a is equal to output voltage from temperature sensor.

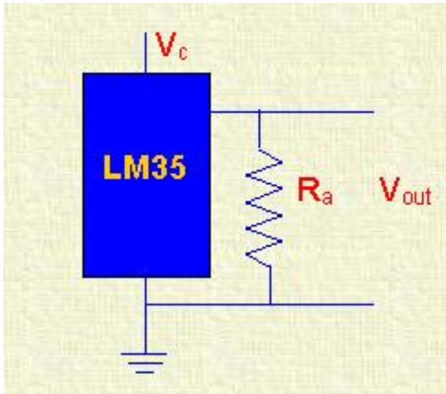

Figure 3.7: LM35DZ circuit connection

3.4.2 Humidity Sensor

HSM-20G humidity sensor module is used to measure percentage of humidity and give an output voltage as value of measurement. Figure 3.8 shows the connection to read voltage output from the humidity sensor. Value for R_2 is 80KΩ. The voltage output is depending on percentage of humidity surrounding. Relationship between voltage output and percentage humidity is display in table 1 and figure 3.9.

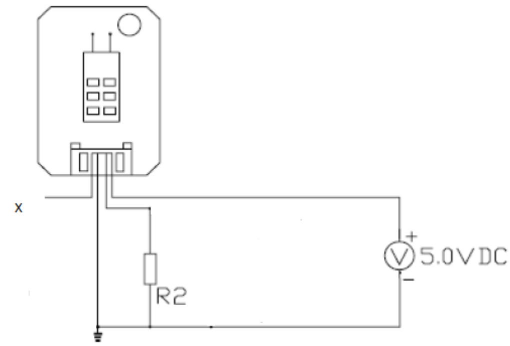

Figure 3.8: HSM-20G connection

Table 3.1: HSM-20G characteristic

Humidity /%	10	20	30	40	50	0	70	80	80
Voltage output (V)	0.74	0.95	1.31	1.68	2.02	2.37	2.69	2.99	3.19

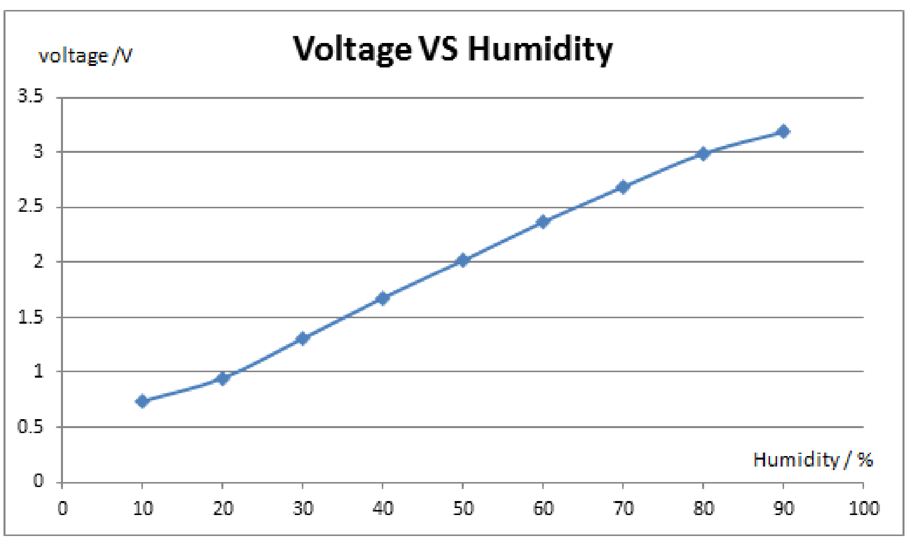

Figure 3.9: Relationship between voltage output and humidity

3.4.3 Water Level Sensor

ETape sensor in figure 3.10 is used to measure rain water level in the rain gauge. This eTape is a sensor that capable to measure the level of water more accurate. The eTape sensor's envelope is compressed by hydrostatic pressure of the fluid in which it is immersed resulting in a change in resistance which corresponds to the distance from the top of the sensor to the fluid surface. The eTape sensor provides a resistive output that is inversely proportional to the level of the liquid. The higher the liquid level, the lower output resistance.

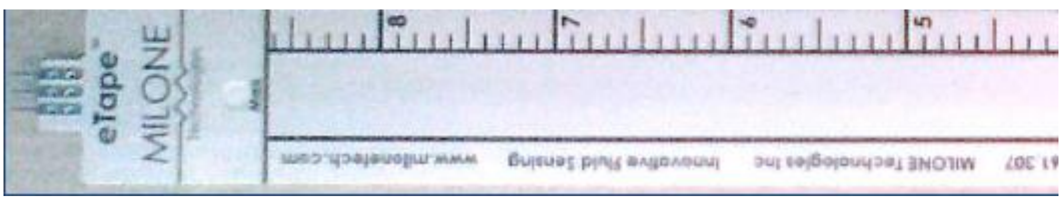

Figure 3.10: eTape overview

Resistance for empty tank is 385Ω and full tank is 60Ω. The change resistance for eTape is 16Ω/cm. The graph of resistance versus water level is shown in figure 3.11. The water level sensor output voltage is determine by applying voltage divider theory using equation (1) :

$$V\,etape = \frac{R\,etape}{R\,etape + R}\;X\,Vcc \tag{1}$$

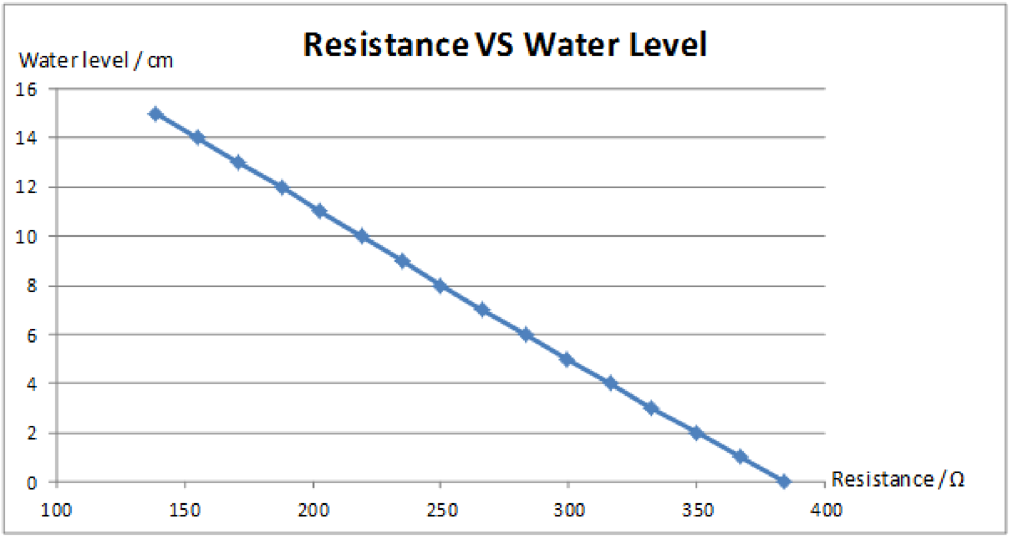

Figure 3.11: Relationship between resistance and water level

3.4.4 NI USB-6216

NI USB-6216 in figure 3.12 is a data acquisition card (DAQ card) from National Instrument. It is use to collect data from weather station sensor and read in computer. The DAQ card will receive analog input from the output sensors, and show the result in LabView visual interface. The NI USB-6216 is a multifunction DAQ card with bus-powered USB is good for laptop user. The DAQ card has 16 analog inputs with 400kS/s sampling rate include two analog outputs, 32 digital I/O, four programmable input ranges (±0.2 to ±10 V) per channel, digital triggering and two counter/timers. The DAQ card also compatible with LabView software and all windows operating system.

Figure 3.12: NI USB-6216 overview

Figure 3.13 shows a connection in NI USB-6216 DAQ card. For temperature sensor voltage output from weather station, analog input AI1+ (AI1) and AI1- (AI9) is used. AI2+ (AI2) and AI2- (AI10) are used to measure analog voltage output from humidity sensor and lastly AI3+ (AI3) and AI3- (AI11) are used to measured analog voltage output from water level sensor.

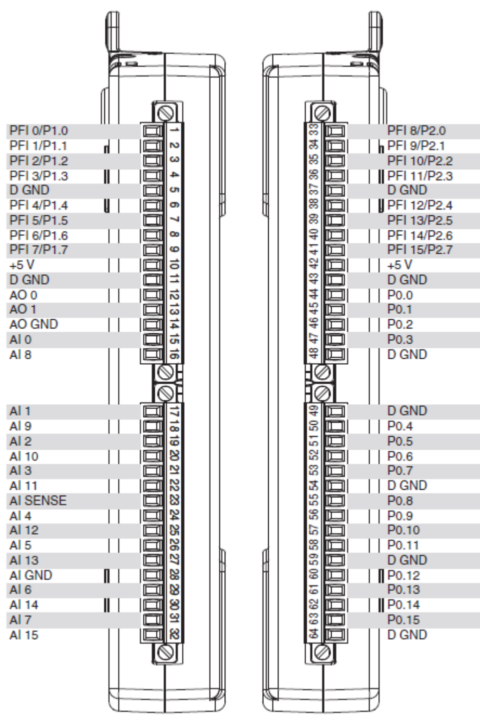

Figure 3.13: NI USB-6216 port

3.4.5 Solar Panel

Solar panel consists of solar cell or also called photovoltaic cell. The solar cell is a solid-state electrical device that converts light energy to electrical energy by the photovoltaic effect. Solar cell for this solar panel in figure 3.14 is monocrystalline. Monocrystalline solar panels are first generation solar technology and have been around a long time, providing evidence of their durability and longevity. Monocrystalline has highest efficiency compared to another type of solar cell such as polycrystalline and thin film but there will be a slight drop off in efficiency of around 0.5% on average per year.

The drawback for this monocrystalline cell is initial cost for this solar panel is higher because the process of making them is one of the most complex and costly. Output voltage output for the solar panel is 12V with 5W power capacity. This solar panel is used to charge the battery to powered the circuit for weather station. This application is very useful in a remote place where there is no electric supply.

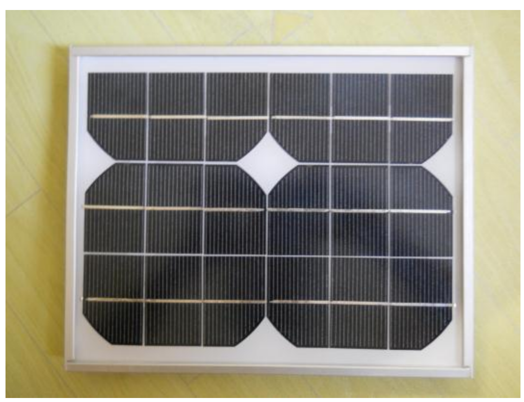

Figure 3.14: Solar panel overview

3.4.6 Charger Controller

Figure 3.15 shows Nixa charger controller. Input voltage for this charger controller is 12-18V and battery that suitable is 12V sealed lead acid. The operating temperature for this charger controller is -20-85^{o}C.

The charger controller main function is to prevent the battery from damage and at the same time increase the lifespan the battery and performance of the battery. The charger controller will regulate voltage input from solar panel when charging the battery to prevent overvoltage. This charger controller is fully automatic and can be used indoor or outdoor. Cut-off charging occur when the battery is fully charged at 15 volt to prevent damage the battery and resume charging when the battery drained or self-discharged. The charger controller also protects the battery being over drained by shutting down the loads when the battery voltage is below 11.5V.

Figure 3.15: Charger controller overview

3.4.7 Battery

For this project, 12V lead acid battery is used. A lead-acid battery in figure 3.16 is an electrical storage device that uses a reversible chemical reaction to store energy. It uses a combination of lead plates or grids and an electrolyte consisting of a diluted sulphuric acid to convert electrical energy into potential chemical energy and back again. The electrolyte of lead-acid batteries is hazardous to health and may produce burns and other permanent damage if contact with it.

Figure 3.16: 12V lead acid battery

3.4.8 Voltage Regulator

A voltage regulator in figure 3.17 is an electrical regulator designed to automatically maintain a constant voltage level. For this project, L7805 is used. These regulators can provide local on-card regulation, eliminating the distribution problems associated with single point regulation. Each type employs internal current limiting, thermal shut-down and safe area protection, making it essentially indestructible. If a heat sinking is applied to the voltage regulator, it can deliver over 1A output current.

Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltage and currents. Circuit for the voltage regulator is shown in figure 3.18.

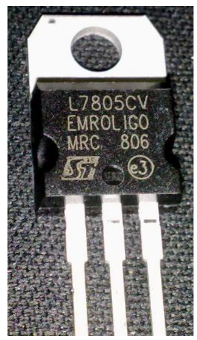

Figure 3.17: 5V voltage regulator

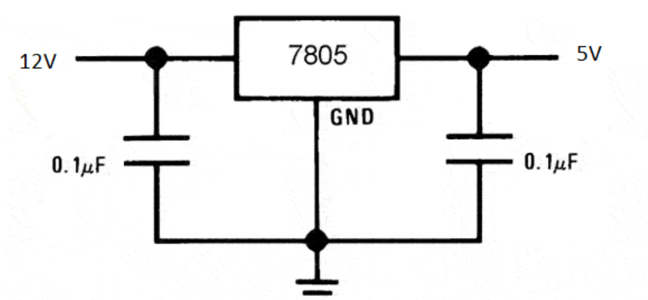

Figure 3.18: Circuit for 5V voltage regulator

3.5 Software Implementation

3.5.1 LabView Software Overview

LabView (Laboratory Virtual Instrumentation Engineering Workbench) is development environment software for a visual programming language from National Instrument Company. LabView software is design for data acquisition, instrument control and data analysis. Programming an application in LabView is very different from programming in a text based language such as C or Basic language. LabView uses graphical symbols (icons) to describe programming actions.

LabView programs / subroutines are called Virtual Instruments (VIs) because the appearance and operation imitate actual instruments. VIs may be used directly by the user or as a subroutine (called sub VI's) of a higher program which enables a modular programming approach. Each VI has two components, that is a block diagram and a front panel. Controls and indicators on the front panel allow an operator to input data into or extract data from a running virtual instrument. The front panel in figure 3.19 can contain knobs, push buttons, graphs, and other controls and indicators.

The block diagram in figure 3.20 shows the internal components of the program. The controls and indicators are connected to other operators and program structures. Each program structure has a different symbol and each data type (eg. integer, double-float and etc) has a different color. Numeric data type cable is shown in appendix A.

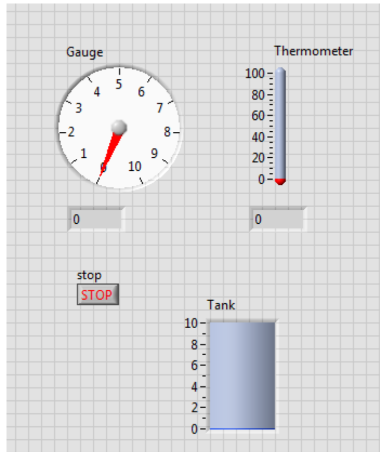

Figure 3.19: LabView front panel

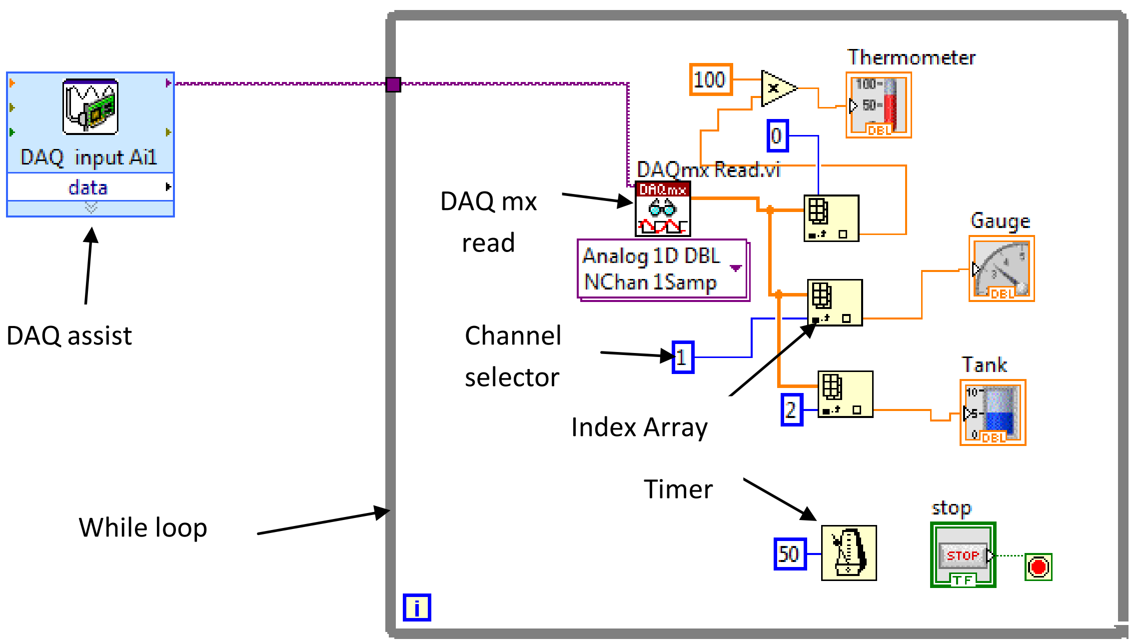

Figure 3.20: LabView block diagram

3.5.2 LabView Web Service

Web services enable on a remote target using standard web-based protocols. A client sends a request to a remote server, and remote server will processes the request and replies with a response, which is then interpreted and displayed by the client application. Below are all components of a Web service:

- Server – An application responsible for parsing a request, executing the appropriate method or action, and sending a response to the client
- Client – An application that sends a request to the server and waits to receive a response, which is then interpreted by the client
- Standard protocols – Web-based protocols such as HTTP route data over physical networks from the client to the appropriate server method and then back to the client
- Network – The physical layer, such as Ethernet or IEEE 802.11, over which data is transmitted

With the LabVIEW web server, VIs can deploy as web services, which invoke via a request from a client using standard HTTP. Unlike options such as LabVIEW remote panels and shared variables, the clients are build to communicate with a deployed VI do not require the LabVIEW run-time engine, which means it can use any Web-based client technology, including common languages such as HTML, JavaScript, and Adobe Flash.

CHAPTER 4

RESULT & DISCUSSION

4.1 LabView Block Diagram

Figure 4.1 shows a block diagram in LabView software for this project. The block diagram is the result applying visual programming language by using LabView software which consist DAQ assistant, array, numeric, block display, and many more. It also shows the flow of the signal that will go from one block to another block until the display block.

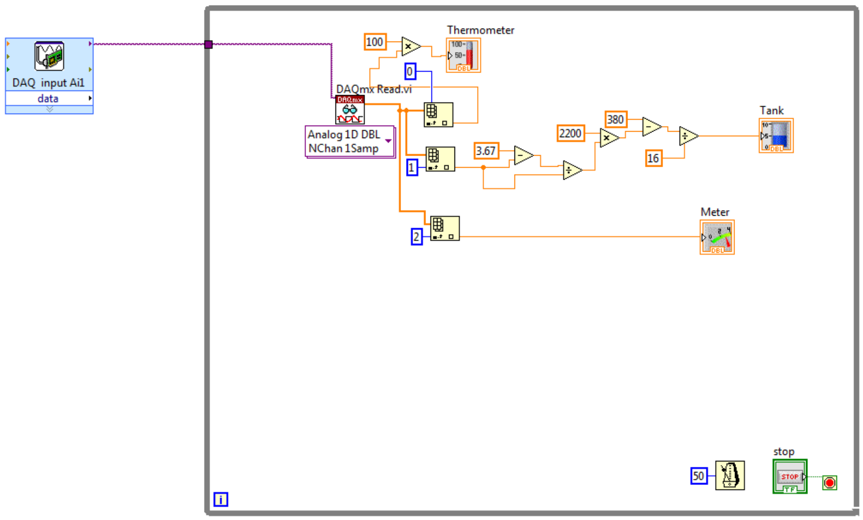

Figure 4.1: Project block diagram

4.2 Block Front Panel

Front panel in figure 4.2 is the result from program that has design in the block diagram in LabView software. The front panel will display the result from the weather station sensors. Figure 4.2 is display temperature, rain gauge water level and percentage of humidity at that current time.

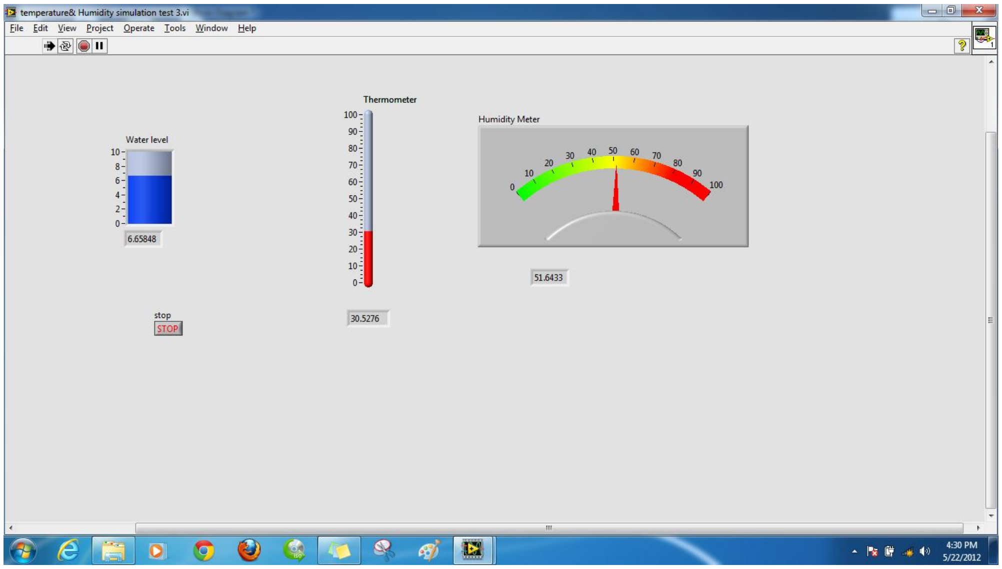

Figure 4.2: Project front panel

4.3 Weather Station Monitoring Via Website.

Figure 4.3 shows the weather station is being monitored via website. LabView provide web service by using web publishing tool. The website can be viewed using any web browser but Microsoft Silverlight and Flash Player must be installed in the computer first in order to view the website. Web address to view the website for example is http://NaMiA-PC:8000/Untitled%201.html. Beside that the website can be used using local host address like http://127.0.0.1:8000/Untitled%201.html and internet IP address like http://10.51.11.11:8000/Untitled%201.html. The data from the weather station can be updated every second and depending on the setting.

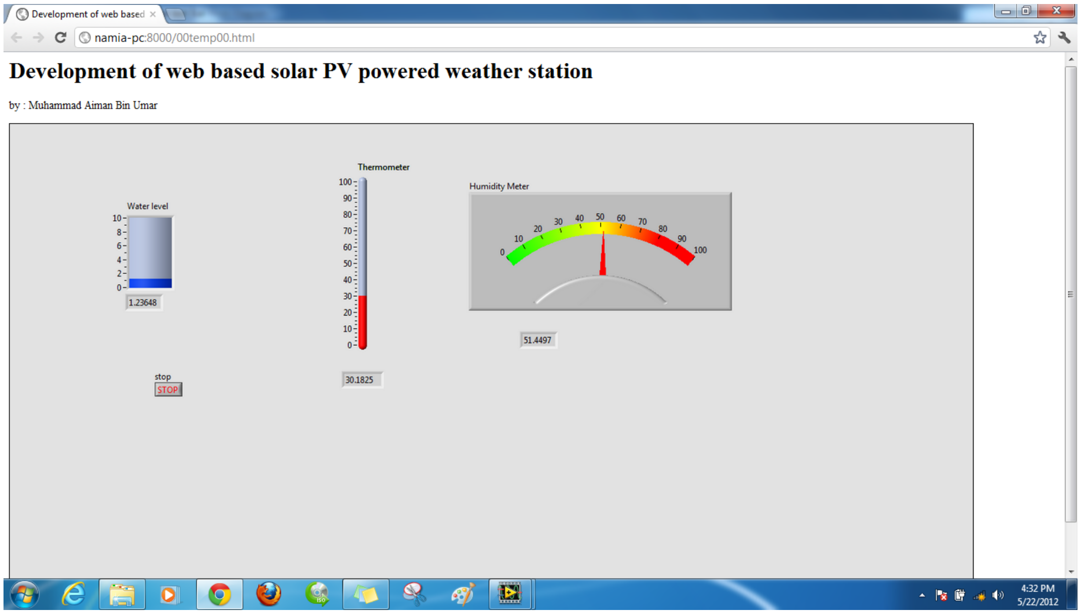

Figure 4.3: Project front panel via website

4.4 Battery Charging Analysis

Table 4.1 shows result from analysis battery charging. The battery is a lead acid type with 12V voltage rating and 1.2Ah current rating. The battery takes two hour and 45 minutes to charge from 12.14V to 13.08V (full charged). The solar PV power rating is 5W. A multimeter is used to measure the voltage and current.

Time, minutes	Voltage battery, Vbat	Current DC, Idc
15	12.14	0.39

30	12.45	0.40
45	12.62	0.40
60	12.70	0.41
75	12.79	0.41
90	12.90	0.40
105	13.21	0.40
120	13.06	0.40
135	13.00	0.40
150	13.02	0.41
165	13.08	0.40
180	13.08	0.40
195	13.08	0.40

Table 4.1: Battery charging analysis

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

As conclusion the project was a successfully developed. This project can do real-time measurement for weather station monitoring systems via website. This weather station project can measure temperature, humidity percentage level and rain gauge water level. This weather station also can be powered by solar PV. This will help the environment greener and will reduce an operation cost for weather station for a remote place.

5.1 Recommendation

For the future development of project, the web-based solar PV powered weather station can be improved by adding wireless system to the project. Wireless system for this project is most recommended because by using wireless system, there is no longer cable that attach between the weather station and DAQ card. That can allow the weather station setup more far from place where the computer and DAQ card is keep.

This project also can be improved by adding more weather station parameter like wind speed and wind direction parameter. Since NI USB-6216 have 16 analog input, this DAQ card can support up to 8 weather station parameter.

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[2] John H., Philippe S., Scott Gould, “REAL-TIME, WEB BASED ENERGY MONITORING SYSTEM FOR A SOLAR ACADEMIC BUILDING” Stanford University, April/Mei 2003.

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APPENDIX A

Numeric data type cable

Terminal	Numeric Data Type	Bits of Storage on Disk	Approximate Number of Decimal Digits	Approximate Range
SGL	Single-precision, floating-point	32	6	Minimum positive number: 1.40e-45 Maximum positive number: 3.40e+38 Minimum negative number: -1.40e-45 Maximum negative number: -3.40e+38
DBL	Double-precision, floating-point	64	15	Minimum positive number: 4.94e-324 Maximum positive number: 1.79e+308 Minimum negative number: -4.94e-324 Maximum negative number: -1.79e+308
EXT	Extended-precision, floating-point	128	varies from 15 to 20 by platform	Minimum positive number: 6.48e-4966 Maximum positive number: 1.19e+4932 Minimum negative number: -6.48e-4966 Maximum negative number: -1.19e+4932
CSG	Complex single-precision, floating-point	64	6	Same as single-precision, floating-point for each (real and imaginary) part
CDB	Complex double-precision, floating-point	128	15	Same as double-precision, floating-point for each (real and imaginary) part
CXT	Complex extended-precision, floating-point	256	varies from 15 to 20 by platform	Same as extended-precision, floating-point for each (real and imaginary) part
FXP	Fixed-point	64, or 72 if you include an overflow status	varies by user configuration	varies by user configuration
I8	Byte signed integer	8	2	-128 to 127
I16	Word signed integer	16	4	-32,768 to 32,767
I32	Long signed integer	32	9	-2,147,483,648 to 2,147,483,647
I64	Quad signed integer	64	18	-1e19 to 1e19
U8	Byte unsigned integer	8	2	0 to 255
U16	Word unsigned integer	16	4	0 to 65,535
U32	Long unsigned integer	32	9	0 to 4,294,967,295
U64	Quad unsigned integer	64	19	0 to 2e19
	128-bit time stamp	128	19	Minimum time: 01/01/1600 00:00:00 UTC maximum time: 01/01/3001 00:00:00 UTC

APPENDIX B

Data sheet

National Semiconductor

July 1999

LM35
Precision Centigrade Temperature Sensors

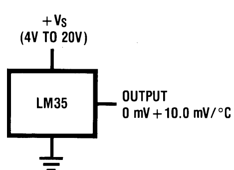
General Description

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

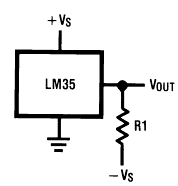
- Calibrated directly in ˚ Celsius (Centigrade)
- Linear + 10.0 mV/˚C scale factor
- 0.5˚C accuracy guaranteeable (at +25˚C)
- Rated for full −55˚ to +150˚C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60 µA current drain
- 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



DS005516-3

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



DS005516-4

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

V_{OUT}=+1,500 mV at +150˚C

= +250 mV at +25˚C

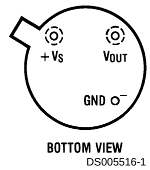
= −550 mV at −55˚C

FIGURE 2. Full-Range Centigrade Temperature Sensor

TRI-STATE® is a registered trademark of National Semiconductor Corporation.

Connection Diagrams

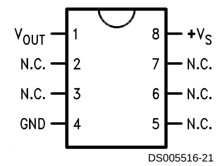
TO-46
Metal Can Package*



*Case is connected to negative pin (GND)

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

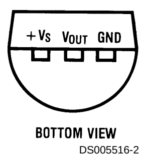
SO-8
Small Outline Molded Package



N.C. = No Connection

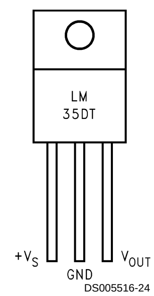
Top View
Order Number LM35DM
See NS Package Number M08A

TO-92
Plastic Package



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

TO-220
Plastic Package*



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

Order Number LM35DT
See NS Package Number TA03F

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

Electrical Characteristics

(Notes 1, 6)

Parameter	Conditions	LM35			LM35C, LM35D			Units
		Typical	Tested Limit (Note 4)	Design Limit (Note 5)	Typical	Tested Limit (Note 4)	Design Limit (Note 5)	(Max.)
Accuracy,	T_A=+25˚C	±0.4	±1.0		±0.4	±1.0		˚C
LM35, LM35C	T_A=−10˚C	±0.5			±0.5		±1.5	˚C
(Note 7)	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	T_A=+25˚C				±0.6	±1.5		˚C
(Note 7)	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	T_A=+25˚C	±0.4	±2.0		±0.4	±2.0		mV/mA
(Note 3) 0≤I_L≤1 mA	T_{MIN}≤T_A≤T_{MAX}	**±0.5**		**±5.0**	**±0.5**		**±5.0**	mV/mA
Line Regulation	T_A=+25˚C	±0.01	±0.1		±0.01	±0.1		mV/V
(Note 3)	4V≤V_S≤30V	**±0.02**		**±0.2**	**±0.02**		**±0.2**	mV/V
Quiescent Current	V_S=+5V, +25˚C	56	80		56	80		µA
(Note 9)	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	4V≤V_S≤30V, +25˚C	0.2	2.0		0.2	2.0		µA
Quiescent Current (Note 3)	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

Note 1: Unless otherwise noted, these specifications apply: −55˚C≤T_J≤+150˚C for the LM35 and LM35A; −40˚≤T_J≤+110˚C for the LM35C and LM35CA; and 0˚≤T_J≤+100˚C for the LM35D. V_S=+5Vdc and I_{LOAD}=50 µA, in the circuit of *Figure 2*. These specifications also apply from +2˚C to T_{MAX} in the circuit of *Figure 1*. Specifications in **boldface** apply over the full rated temperature range.

Note 2: Thermal resistance of the TO-46 package is 400˚C/W, junction to ambient, and 24˚C/W junction to case. Thermal resistance of the TO-92 package is 180˚C/W junction to ambient. Thermal resistance of the small outline molded package is 220˚C/W junction to ambient. Thermal resistance of the TO-220 package is 90˚C/W junction to ambient. For additional thermal resistance information see table in the Applications section.

Note 3: Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the internal dissipation by the thermal resistance.

Note 4: Tested Limits are guaranteed and 100% tested in production.

Note 5: Design Limits are guaranteed (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.

Note 6: Specifications in **boldface** apply over the full rated temperature range.

Note 7: Accuracy is defined as the error between the output voltage and 10mv/˚C times the device's case temperature, at specified conditions of voltage, current, and temperature (expressed in ˚C).

Note 8: Nonlinearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the device's rated temperature range.

Note 9: Quiescent current is defined in the circuit of *Figure 1*.

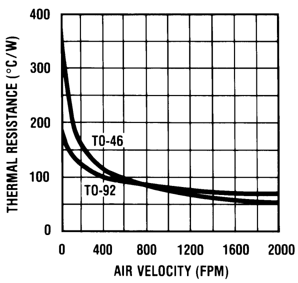
Note 10: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions. See Note 1.

Note 11: Human body model, 100 pF discharged through a 1.5 kΩ resistor.

Note 12: See AN-450 “Surface Mounting Methods and Their Effect on Product Reliability” or the section titled “Surface Mount” found in a current National Semiconductor Linear Data Book for other methods of soldering surface mount devices.

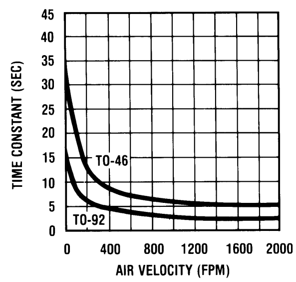
Typical Performance Characteristics

Thermal Resistance Junction to Air



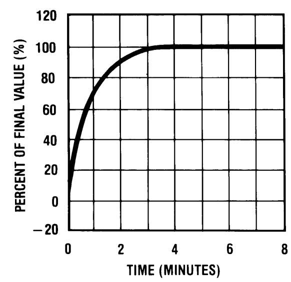
DS005516-25

Thermal Time Constant



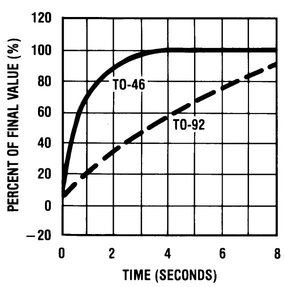
DS005516-26

Thermal Response in Still Air



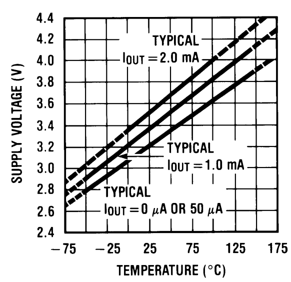
DS005516-27

Thermal Response in Stirred Oil Bath



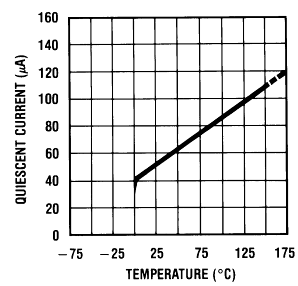
DS005516-28

Minimum Supply Voltage vs. Temperature



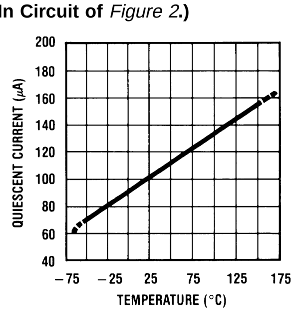
DS005516-29

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



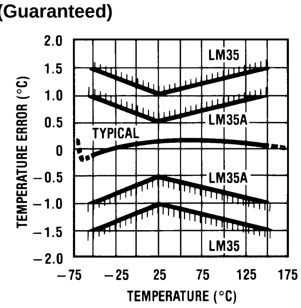
DS005516-30

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



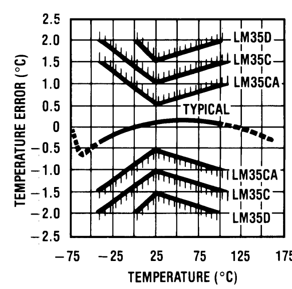
DS005516-31

Accuracy vs. Temperature (Guaranteed)



DS005516-32

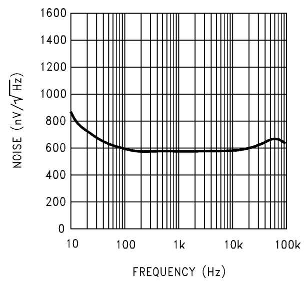
Accuracy vs. Temperature (Guaranteed)



DS005516-33

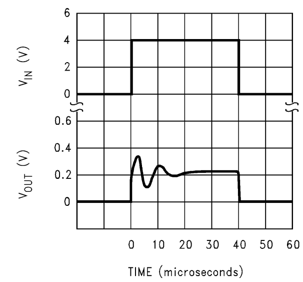
Typical Performance Characteristics (Continued)

Noise Voltage



DS005516-34

Start-Up Response



DS005516-35

Applications

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

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

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

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

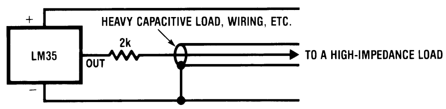
These devices are sometimes soldered to a small light-weight heat fin, to decrease the thermal time constant and speed up the response in slowly-moving air. On the other hand, a small thermal mass may be added to the sensor, to give the steadiest reading despite small deviations in the air temperature.

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

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

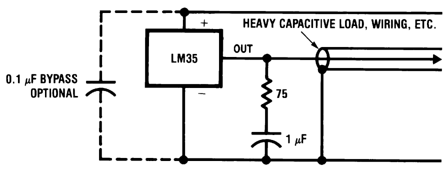
*Wakefield type 201, or 1" disc of 0.020" sheet brass, soldered to case, or similar.
**TO-92 and SO-8 packages glued and leads soldered to 1" square of 1/16" printed circuit board with 2 oz. foil or similar.

Typical Applications



DS005516-19

FIGURE 3. LM35 with Decoupling from Capacitive Load



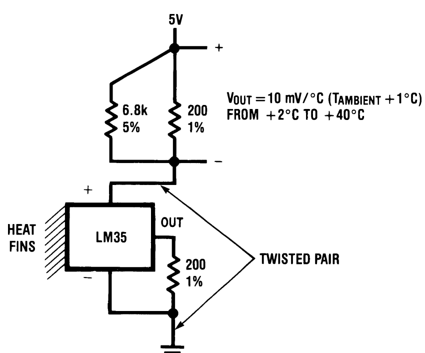
DS005516-20

FIGURE 4. LM35 with R-C Damper

CAPACITIVE LOADS

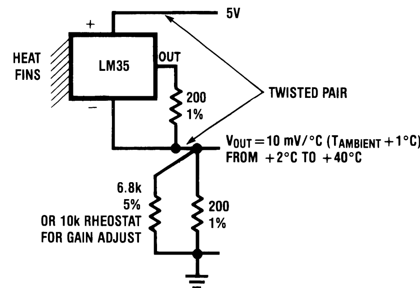
Like most micropower circuits, the LM35 has a limited ability to drive heavy capacitive loads. The LM35 by itself is able to drive 50 pf without special precautions. If heavier loads are anticipated, it is easy to isolate or decouple the load with a resistor; see *Figure 3*. Or you can improve the tolerance of capacitance with a series R-C damper from output to ground; see *Figure 4*.

When the LM35 is applied with a 200Ω load resistor as shown in *Figure 5*, *Figure 6* or *Figure 8* it is relatively immune to wiring capacitance because the capacitance forms a bypass from ground to input, not on the output. However, as with any linear circuit connected to wires in a hostile environment, its performance can be affected adversely by intense electromagnetic sources such as relays, radio transmitters, motors with arcing brushes, SCR transients, etc, as its wiring can act as a receiving antenna and its internal junctions can act as rectifiers. For best results in such cases, a bypass capacitor from V_{IN} to ground and a series R-C damper such as 75Ω in series with 0.2 or 1 µF from output to ground are often useful. These are shown in *Figure 13*, *Figure 14*, and *Figure 16*.



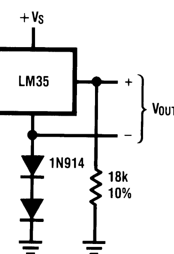
DS005516-5

FIGURE 5. Two-Wire Remote Temperature Sensor (Grounded Sensor)



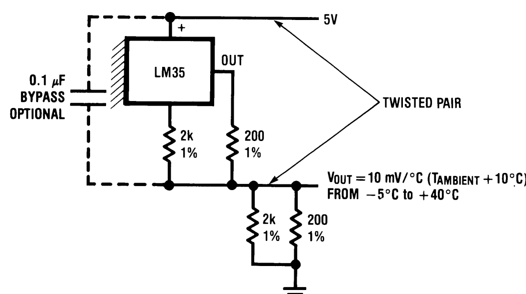
DS005516-6

FIGURE 6. Two-Wire Remote Temperature Sensor (Output Referred to Ground)



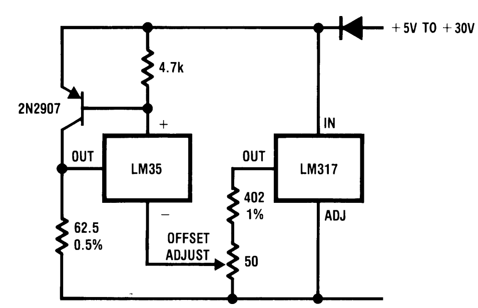
DS005516-7

FIGURE 7. Temperature Sensor, Single Supply, −55˚ to +150˚C



DS005516-8

FIGURE 8. Two-Wire Remote Temperature Sensor (Output Referred to Ground)



DS005516-9

FIGURE 9. 4-To-20 mA Current Source (0˚C to +100˚C)

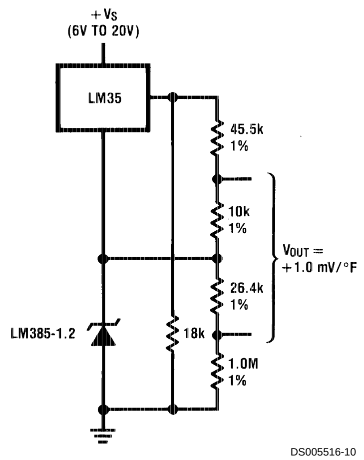


FIGURE 10. Fahrenheit Thermometer

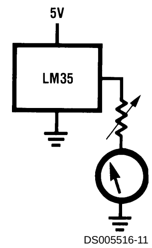


FIGURE 11. Centigrade Thermometer (Analog Meter)

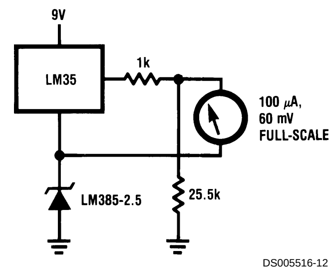


FIGURE 12. Fahrenheit ThermometerExpanded Scale Thermometer
(50° to 80° Fahrenheit, for Example Shown)

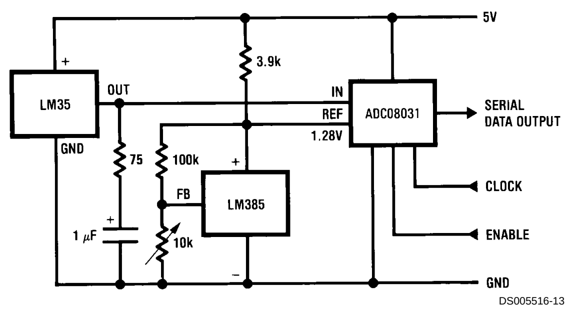


FIGURE 13. Temperature To Digital Converter (Serial Output) (+128°C Full Scale)

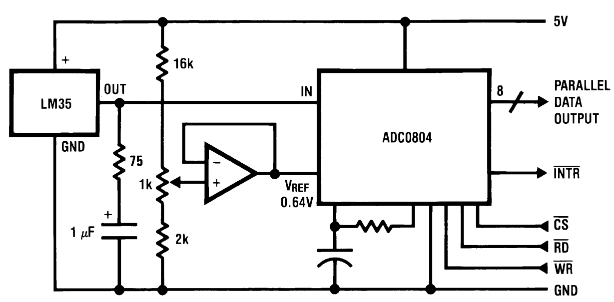
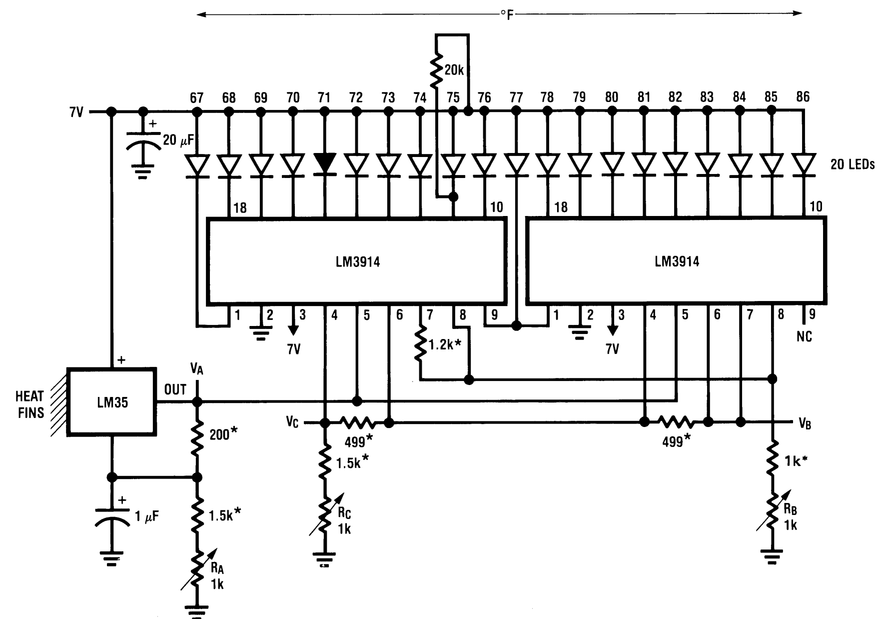


FIGURE 14. Temperature To Digital Converter (Parallel TRI-STATE™ Outputs for Standard Data Bus to μP Interface) (128°C Full Scale)

Typical Applications (Continued)



*=1% or 2% film resistor
Trim R_B for V_B=3.075V
Trim R_C for V_C=1.955V
Trim R_A for V_A=0.075V + 100mV/˚C x $T_{ambient}$
Example, V_A=2.275V at 22˚C

FIGURE 15. Bar-Graph Temperature Display (Dot Mode)

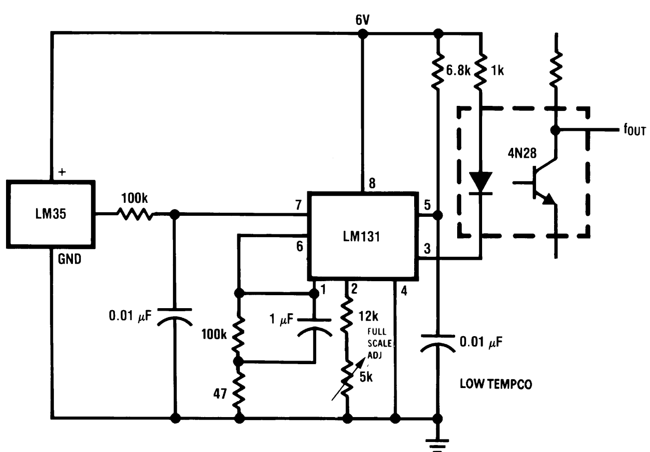
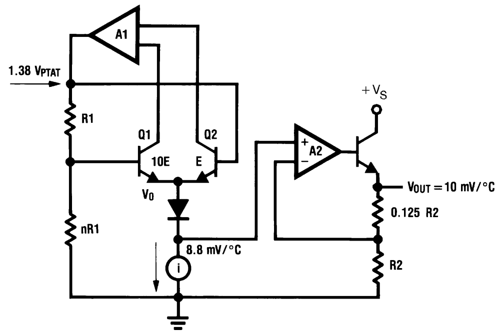


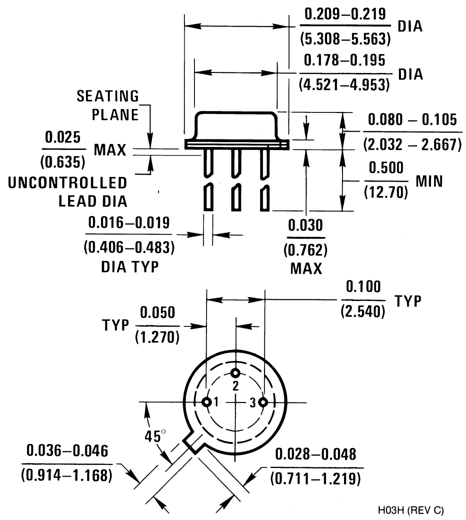
FIGURE 16. LM35 With Voltage-To-Frequency Converter And Isolated Output (2˚C to +150˚C; 20 Hz to 1500 Hz)

Block Diagram

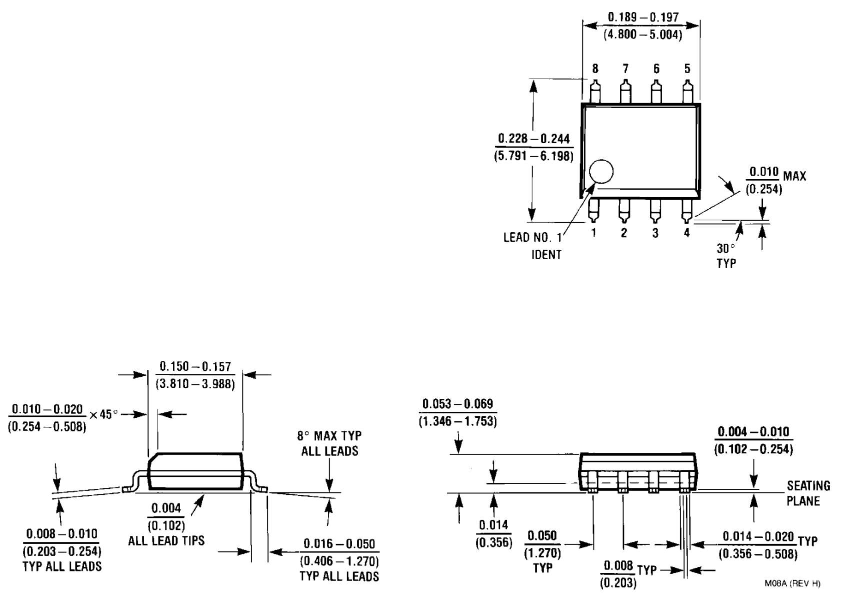


DS005516-23

Physical Dimensions inches (millimeters) unless otherwise noted

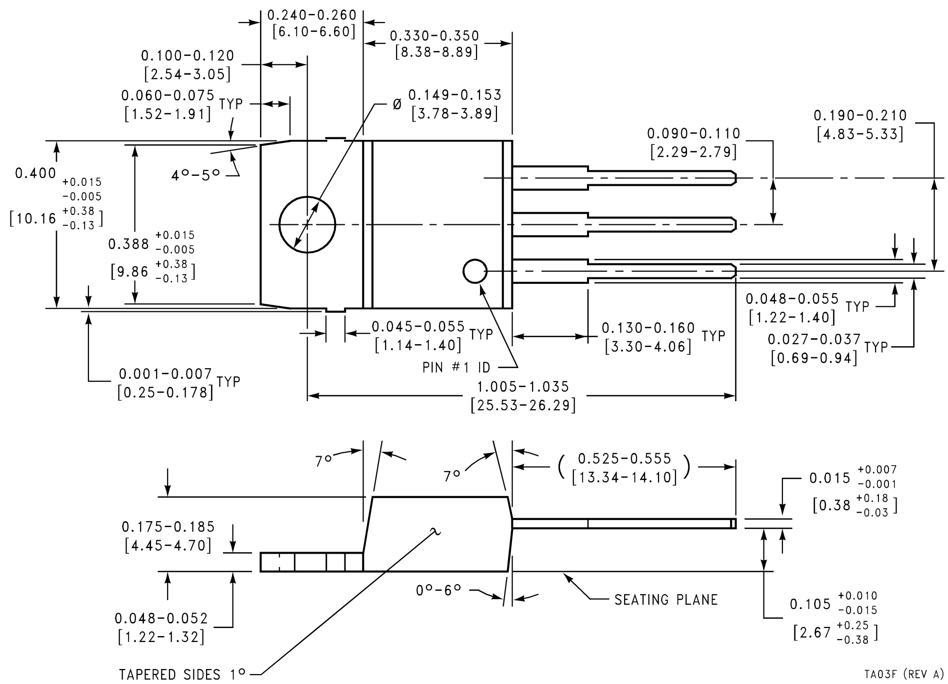


TO-46 Metal Can Package (H)
Order Number LM35H, LM35AH, LM35CH, LM35CAH, or LM35DH
NS Package Number H03H

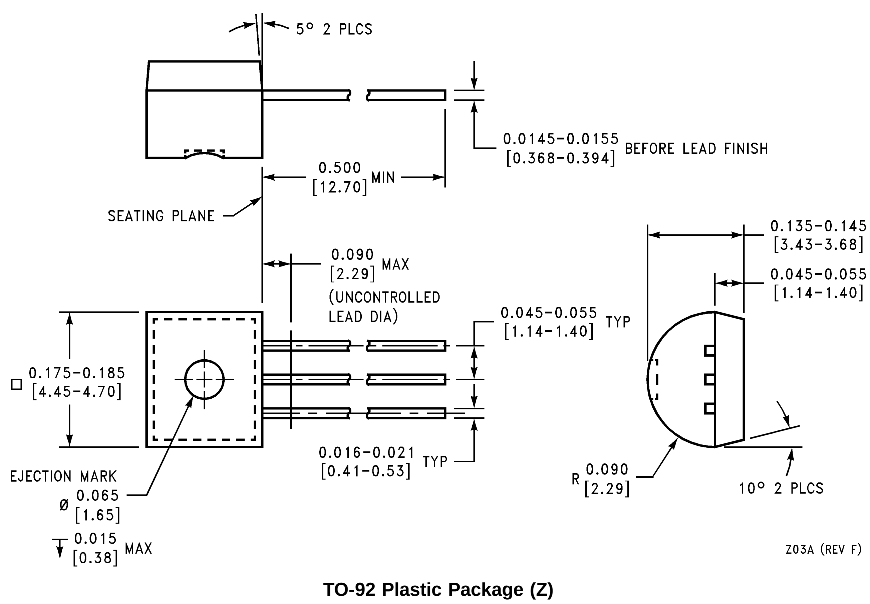


SO-8 Molded Small Outline Package (M)
Order Number LM35DM
NS Package Number M08A

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



Power Package TO-220 (T)
Order Number LM35DT
NS Package Number TA03F



TO-92 Plastic Package (Z)
Order Number LM35CZ, LM35CAZ or LM35DZ
NS Package Number Z03A

Notes

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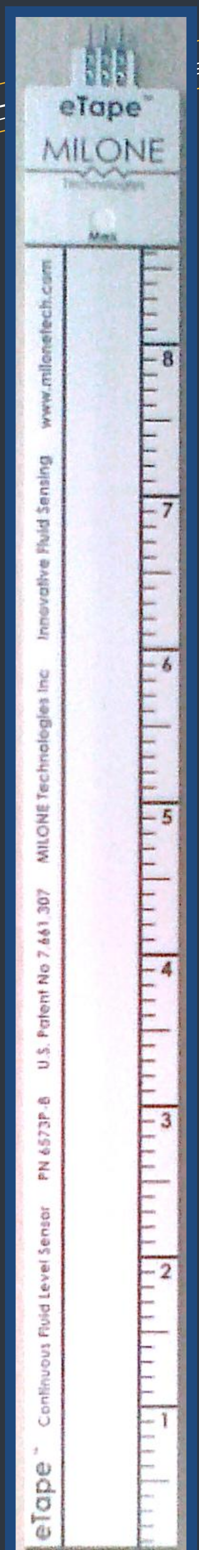
Fax: 81-3-5639-7507

eTape™

Continuous Fluid Level Sensor
PN-6573P-8



Description

The eTape sensor is a solid state, continuous (multi-level) fluid level sensor for measuring levels in water, non-corrosive water based liquids and dry fluids (powders). The eTape sensor is manufactured using printed electronic technologies which employ additive direct printing processes to produce functional circuits.

Theory of Operation

The eTape sensor's envelope is compressed by hydrostatic pressure of the fluid in which it is immersed resulting in a change in resistance which corresponds to the distance from the top of the sensor to the fluid surface. The eTape sensor provides a resistive output that is inversely proportional to the level of the liquid: the lower the liquid level, the higher the output resistance; the higher the liquid level, the lower the output resistance.

Specifications

Sensor Length: 10.1" (256.5mm)

Thickness: 0.015" (0.381mm)

Active Sensor Length: 8.6" (218.4mm)

Sensor Output: 385Ω empty, 60Ω full, ± 10%

Resolution: 1/32 inch (0.794mm)

Resistance Gradient: 40Ω /inch (16Ω /cm), ± 10%

Width: 1.0" (25.4mm)

Connector: Solder Tabs (middle pin inactive)

Substrate: Polyethylene Terephthalate (PET)

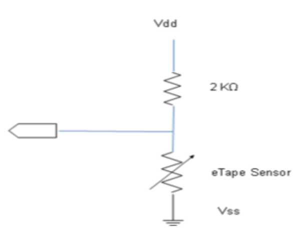
Actuation Depth: Nominal 1 inch (25.4mm)

Temperature Range: 15°F - 140°F (-9°C - 60°C)

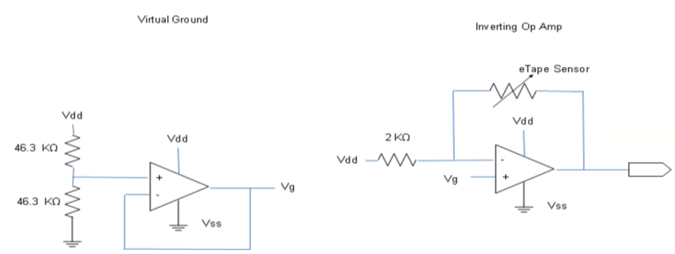
Power Rating: 0.5 Watts (VMax **=** 5V)

Sample Circuits

Simple Voltage Divider Circuit



Active Resistance to Voltage converter
Using an inverting Op Amp and Virtual Ground



Custom Applications

The eTape sensor can be manufactured in custom lengths to fit any application. Contact Milone Technologies if you have an application that requires specific length, configuration or output characteristics.

Innovative Fluid Sensing

MILONE
Technologies

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