SOLAR PHOTOVOLTAIC POWER MEASURING SYSTEM UTILIZING PIC MICROCONTROLLER

Moe Moe Myint[1], Zar Ni Maung[2] and San San Wai[3]

Abstract

Solar photovoltaic power measurement systems are important to investigate. Studying the environmental condition of a solar panel will help to improve efficient power collection with a faster rate. Solar panel converts photonic energy into electrical energy. But the conversion speed and properties depend on the type and size of solar panels. Moreover, the current and voltage of the solar panel is also related with luminous, and temperature exerted on it. The circuit is designed to investigate the voltage, current, luminous and temperature of a solar panel. The results will be displayed on an alphanumeric liquid crystal display. The whole system design include an 8-bit PIC microcontroller, an alphanumeric liquid crystal display, a crystal oscillator, a current detector circuit, a voltage divider circuit, a temperature sensor, light intensity sensor circuit and a regulated power supply. A program source code is created to operate the whole circuit. It is converted to machine code and loaded into the memory of PIC microcontroller. The whole circuit is constructed on a printed circuit board. Data collections were made for the circuit to proof the efficiency of various solar panels.

Introduction

The energy of sun is in the form of visible light and infrared light radiation. Plants convert the energy in sunlight into chemical energy through the process of photosynthesis. Humans regularly use this store of energy in various ways, as when they burn wood or fossil fuels or when simply eating plants, fish and animals. Solar radiation reaches the earth's upper layer of atmosphere with the power of 1366 watts per square meter (W/m2). Since the earth is round, the surface nearer its poles is angled away from the sun and receives much less solar energy than the surface nearer the equator.

At present, solar cell plants convert, at best, about 15% of sunlight hitting them into electricity. There are many different technologies which have been developed to make use of solar radiation. Some of these technologies make direct use of the solar energy, while others produce electricity. Especially solar panels convert sunlight into electricity, either directly using photovoltaics or indirectly using concentrated solar power (CSP). Concentrated solar power systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. Photovoltaics converts light inot electric current using the photoelectric effect.

It is very important to obtain maximum energy of the sunlight and changes the energy into electricity in the most efficient method. Therefore, it is important to investigate the properties of solar panel throughout the day by measuring the voltage, current, temperature of solar panel and luminous of incident radiation. In this thesis report, a microcontroller based measuring system was designed and constructed to check the above parameters.

[1] Dr, Associate Professor, Department of Physics, Loikaw University.
[2] Assistance Lecturer, Department of Physics, Loikaw University.
[3] Professor and Head, Department of Physics, Loikaw University.

System Overview

The **SOLAR PHOTOVOLTIAC POWER MEASURING SYSTEM (SPPMS)** is designed and constructed. The whole system consists of four sections sensors, controller, display and power supply. The first section consists of reading the voltage and current of solar panel. Then measure the surface temperature of solar panel and luminous falling on it. Measurement of voltage was made by using a voltage divider circuit and ADC converter function of pic microcontroller. Measurement of current was made by using ACS712 hall-effect current sensor module.

As shown in the block diagram in figure 1, every part of the circuit is illustrated with a block diagram. The system design consists of two photon transducers, one is the solar panel and another is the light dependent resistor. Solar panel is used to convert the solar energy to electrical energy. The light dependent resistor is used to detect the luminous intensity falling on the surface of solar panel. The voltage divider and current sensor circuits are used to detect the voltage output and current output of the solar panel under test. Every sensor peripherals are feed into the analog input pins of PIC microcontroller. The 4MHz crystal oscillator is used to generate clock for the program counter in the microcontroller. Some input switches are used to operate the reset and controlling operating function of the microcontroller. The 16 characters, 2 lines alphanumeric liquid crystal display is used to display the measurement parameters in visible numerical quantities. The system design includes a 5V regulator circuit and the power source is obtained from two 3.7V lithium ion batteries.

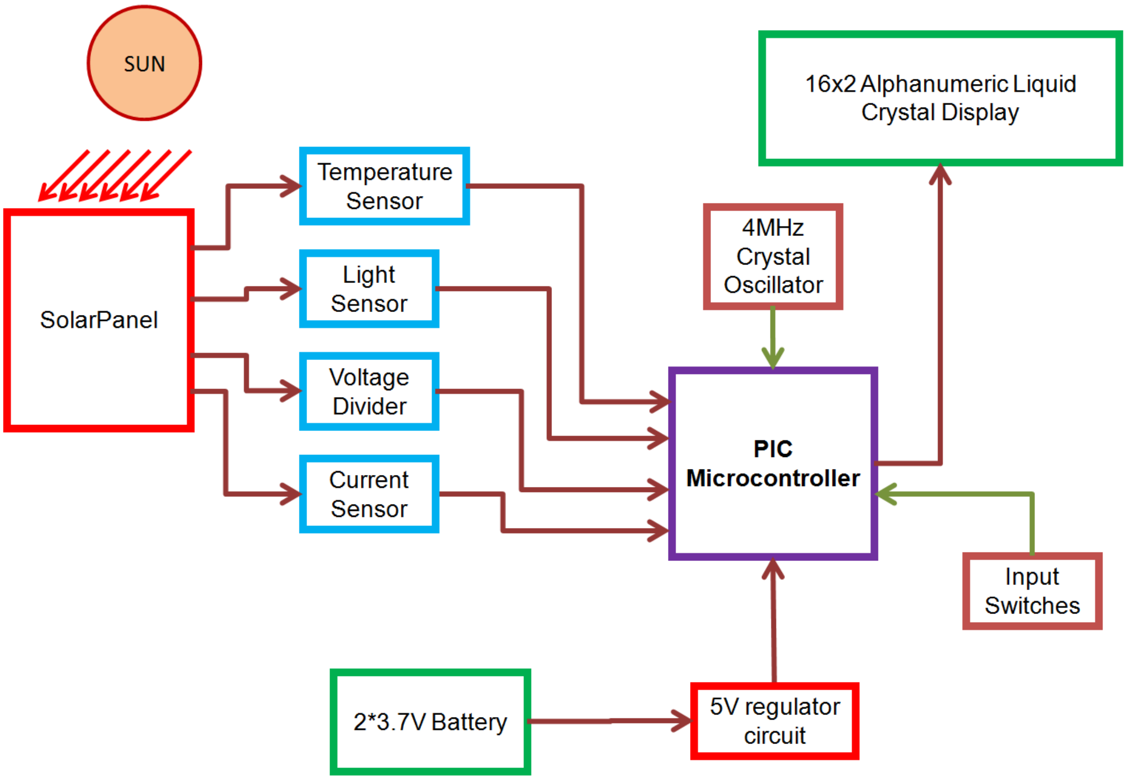

Figure 1 Block Diagram of the circuit

Experimental Detail

Construction of the Circuit

The circuit construction was a handy work for a research student. The component layout of the circuit is as shown in the Fig (above) as component side photo. Construction of the circuit was made in the following procedure;

1. The wire jumper connections
2. Resistors and diodes
3. Crystal oscillator
4. Switches and relay terminals
5. IC socket and transistors
6. Capacitors and regulator IC
7. The green terminals

The pic microcontroller was not directly soldered on the circuit board, the sockets were used. Because, the PIC is required to remove and replace to program and edit, until the solar power investigation circuit was successful. The solar panel terminal wire and sensor terminal were fed to the input of microcontroller through green terminal pins. The components side and soldering side of the circuit are illustrated in figure 2 and 3 respectively.

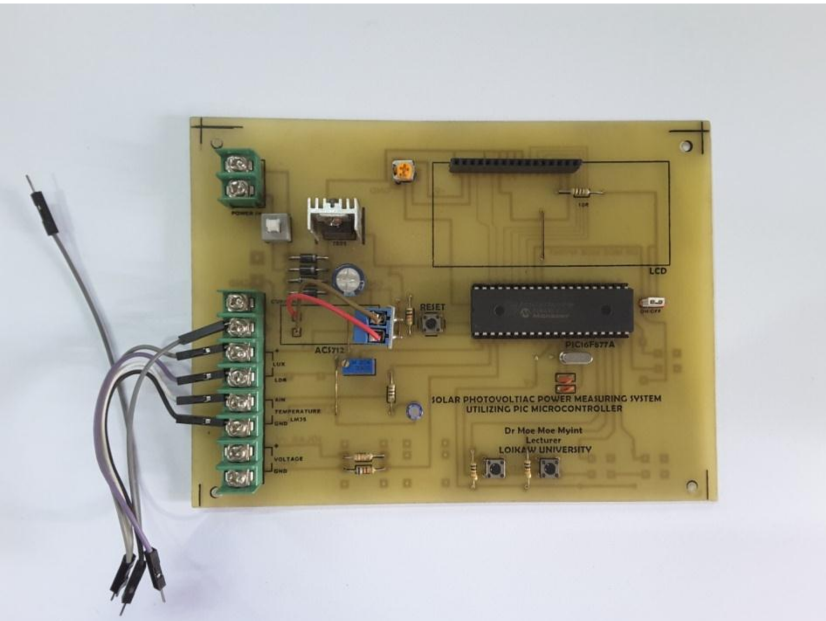

Figure 2 Component side of the main controller board after soldering.

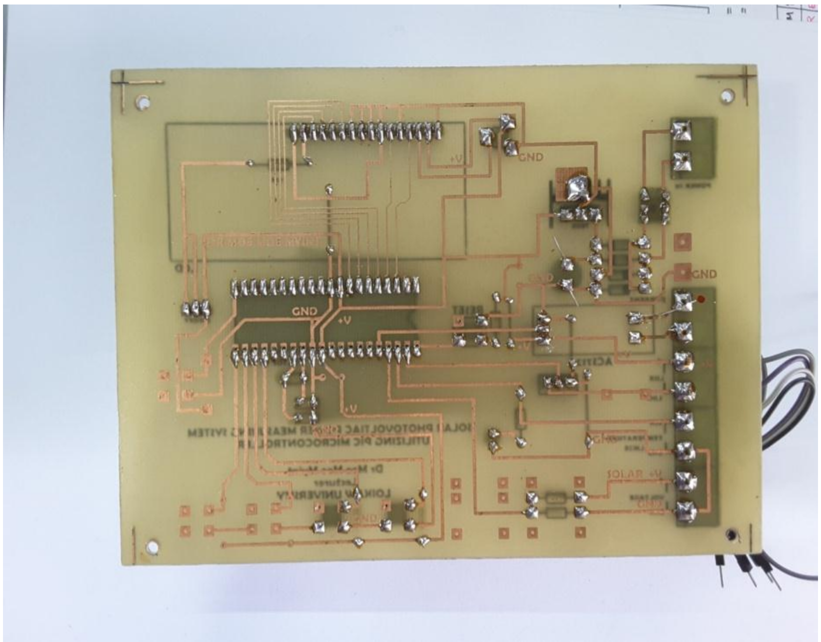

Figure 3 Soldering side of the circuit board after soldering

Circuit Explanation

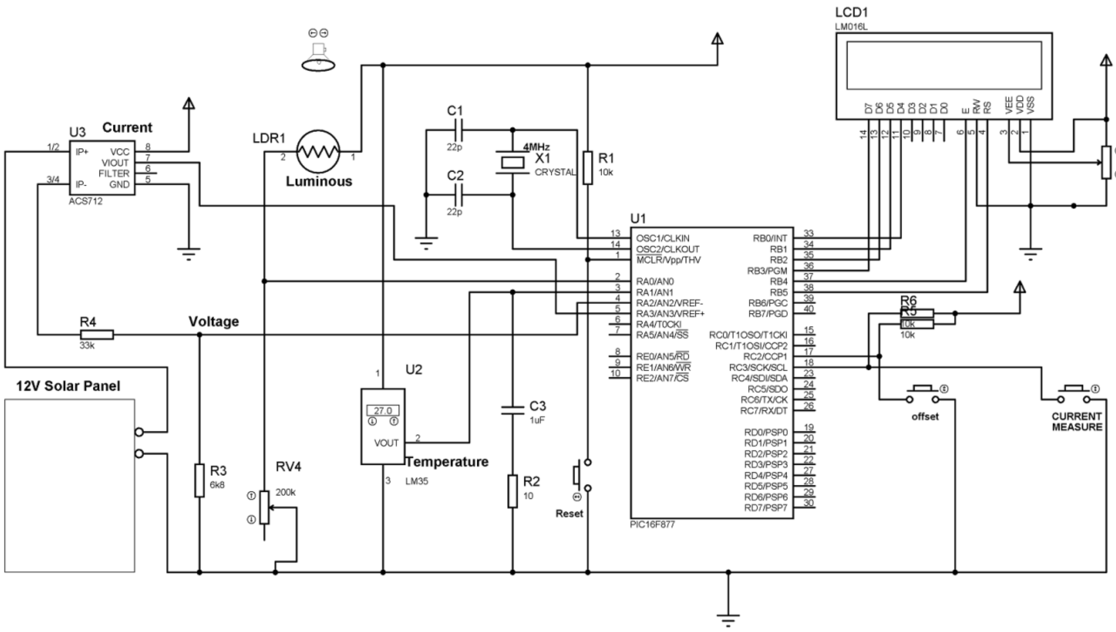

Figure 4 Schematic diagram of solar properties measuring circuit

As shown in the circuit diagram in figure 4, every component in the circuit are connected with the PIC16F877A. There are five I/O ports on the IC and altogether a total of 33 I/O pins on the device, but only 12 of them are used for the circuit. The pin no 1 is MCLR pin and it is pull up with a 10kΩ resistor, the pin is connected with the ground line using a push-to-on switch. It is the RESET switch to restart the program from initial state. Pin 2, 3, 4 and 5 are used as analog input pins and they are connected with the light sensor (LDR), output of LM35 temperature sensor, solar voltage input, and the current sensor (ACS712) respectively.

The output of temperature sensor (LM35) pin 2 is feed into the analog input AN1. But the output signal pin is connected with the ground line via a 1uF capacitor and a 10 Ohm resistor to filter the other electronic noises. Pin 1 of temperature sensor is connected with the 5V supply line and the pin 3 with ground line directly.

The light sensor LDR is connected in series with a 200k variable resistor between 5V power supply and ground line. The junction of LDR and Variable resistor is connected with the AN0 pin of PIC microcontroller. Variation of light intensity falling on the surface of LDR was read as varying voltage with analog input pin.

To measure the voltage output of solar panel, a voltage divider circuit is used. Because the analog input of PIC microcontroller is limited to 5V and the output of solar panel is above 12V level. The resistor R3 and R4 are used as voltage divider and their junction is feed into the analog input AN2 of PIC microcontroller.

The current to voltage converter ACS712 is used to read the solar current level. The input of current sensor pins are connected between the +ve terminal of solar panel to the voltage divider circuit. The voltage output of current sensor pin 7 is feed into the analog input AN3 of PIC microcontroller.

A 4MHz crystal oscillator is connected between pin no 13 and 14 oscillator pins. The pins are again connected with the ground line through 22pF capacitors to generate oscillations for the program counter to execute the program lines.

The MCLR reset pin is connected with the supply line via a 10kΩ resistor (R1). The pin is again connected with the ground line via a push to on switch to create active low reset input to the microcontroller.

A 16 characters 2lines alphanumeric liquid crystal display is used to display the measurement quantities of current, voltage, temperature and luminous on the display. It is connected with the six of port B pins. RB_0 to RB_3 pins are connected with the D4 to D7 of LCD. The RB_4 and RB_5 pins are connected with the E (Enable pin) and RS (Register Select pin) of the LCD respectively. Two more input switches on the right side of the circuit are used to measure current value. They are offset and current measure switches. They are wired as active low input and connected with the RC_2 and RC_3 pins of PIC microcontroller.

Flowchart

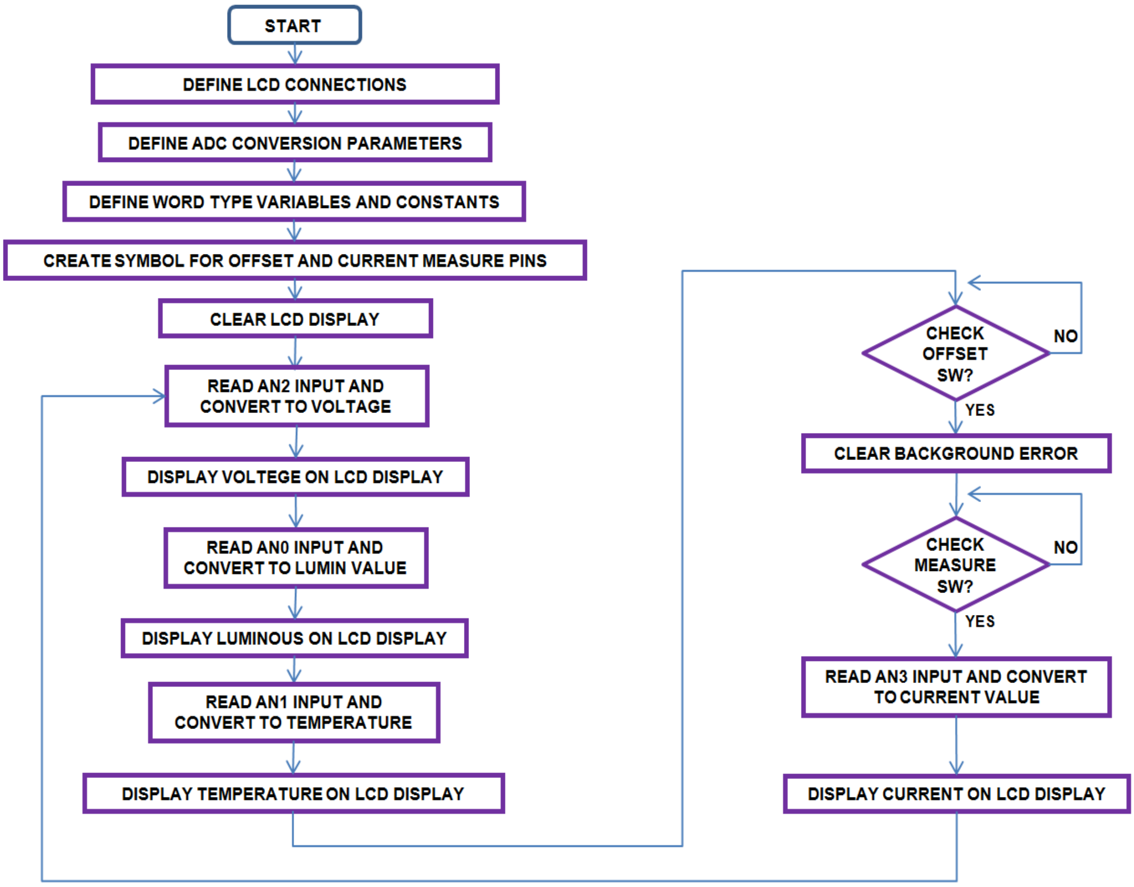

Figure 5 Flowchart diagram of the program.

A flowchart is initially created to carry on programming. As illustrated in the flowchart diagram, the program start by defining LCD connection pins, ADC conversion parameters, word type variables and conversion constants for numerical calculations. Then two input switches for current measure are defined with OFFSET and CURM symbols. Then the LCD is cleared and measuring loop is initiated. The voltage value is read from an2 input and converted to voltage by using conversion constants. Then it is display on the LCD screen. Next, the an0 input is read and converted to luminous value and it is illustrated on the LCD display. Then, the temperature value is read with AN1 input pin and it is converted and display on the LCD. Finally, the current value of the solar panel is measure by using two input switch, offset switch to record the error value and measure switch to read the real current value from AN3 input. Then it is converted and display on the LCD. Then the program loops back to read the voltage of the solar panel, repeatedly.

Circuit Operation and Discussion

The circuit is designed and constructed to measure the voltage, current, temperature and light intensity of a solar panel. Before starting the operation, the temperature sensor and light sensor are assembled on the surface of LCD as shown in the figure 6. It is attached very close to the surface of LCD to achieve accurate measurement of temperature and luminous.

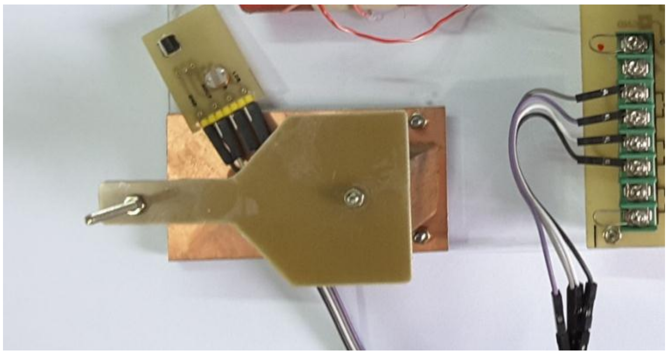

Figure 6 Attachment of temperature sensor and light sensor on the solar panel.

As shown in the figure 7, a 7.2V lithium ion battery pack is connected with the power input terminal near upper left corner of the circuit. The battery power is reduce and regulated with a 7805 (dc 5V) regulator circuit. There is a power on/off switch between the battery terminal and the regulator IC to switch on or switch off the measuring circuit.

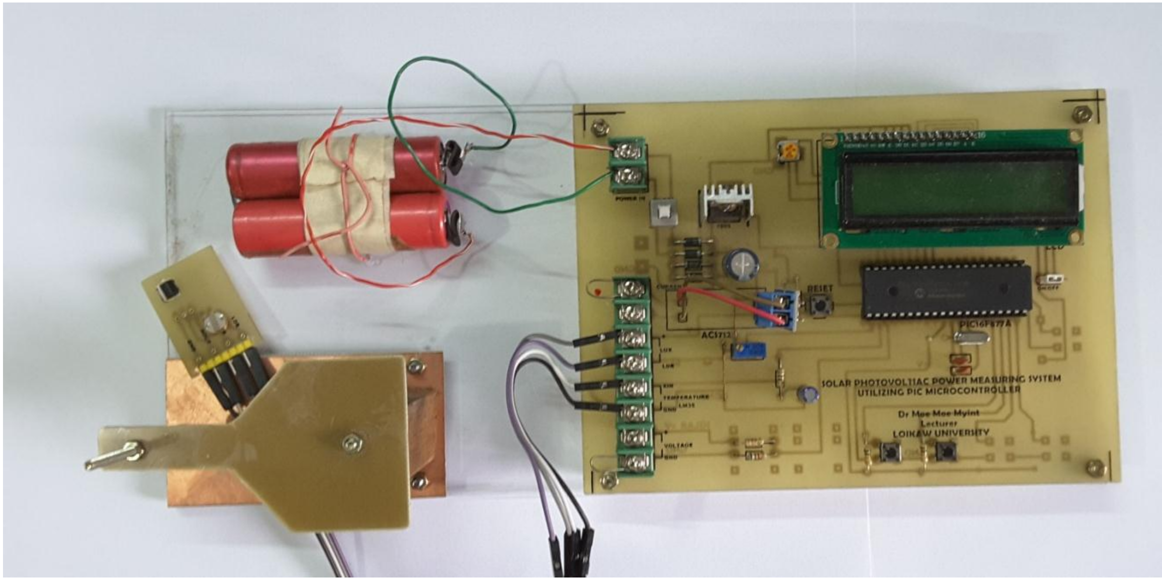

Figure 7 The whole circuit ready to measure solar panel properties.

The LCD display is a 16 characters, 2 lines alphanumeric liquid crystal display and it is positioned on the upper right corner of the circuit. A yellow 10k variable resistor near the LCD is to adjust contrast voltage of the LCD display. Slowly turning the resistor with a small screw driver will appear clear characters on the LCD. The PIC16F877A microcontroller is below the LCD, and it is the heart of the circuit. A program coding was created with PIC BasicPro programming language and converted to machine code. Then the codes are loaded into the memory ROM of PIC to operate the whole circuit. An on/off jumper beside the IC is used to operate the back light of the LCD display. There is a reset switch on the left side of the PIC. It is used to reset the whole circuit operation. There is a 4MHz crystal oscillator and two 22pF capacitors near pin 13 and 14 of the PIC microcontroller. It is used to operate 1 micro second clock for program counter. The ACS712 is the current sensor and it is located in the middle left of the circuit. On the lower right side of the circuit board, there are two more input switches for offset and current measure inputs.

When connecting with the solar power terminal, the positive terminal of solar panel is connected with the positive terminal of current input (marked with a red dot). The current output pin is connected with the There are eight green terminals on the lower left edge of the circuit board to read the four different parameters of the solar panel. The first two terminals are to read the current. Second two terminals are to measure light intensity. The third two terminals are to read the LM35 temperature sensor output. The remaining two terminals are used to read the voltage of the solar panel. positive terminal of voltage input. The voltage ground pin is connected with the ground terminal of solar panel. The lux input and lm35 temperature input are simply connected with the LDR and LM35 sensor outputs.

As explained in the program, the voltage of solar panel is read with AN2 pin. But the solar panel output under the sunny day is larger than 25V. Therefore, a voltage divider is used to limit the input voltage. In this case, 33k and 6.8k resistors are used. Therefore, the maximum limit of voltage input can be 6 times larger than 5V. Therefore, conversion constant Conv7 is 6. But for the ADC conversion resolution, 10bit AD converter is chosen. Therefore, each quantize voltage level is 5000mV/1024, which is 4.88mV. But in the PIC BasicPro programming, decimal values are not able to handle in calculations. Therefore, in the calculations, conversion constants Conv1, Conv5 and Conv9 are taken as integer 4. The other remaining decimal value of 0.88 is multiply with 100 and become 88 for Conv2, Conv6 and Conv10. But for the temperature measure, conversion constant 4.88 is again multiply with 10 since the LM35 datasheet illustrated the temperature measurement is 10mV/C. Therefore, the conversion becomes 48.8 and Conv3 is taken 48 as its constant.

In measuring the current value, it is not as simple as measuring other parameters. Because, the sensor is very sensitive and it is always detecting background magnetic fields since the ACS712 is a hall-effect sensor application. Therefore, a background current value was measured and stored in a register (ACSOFFSET) by pressing offset input switch. While making offset it is important to remove the current input pin from the solar positive terminal. Then the wire is reconnected and measure the current by pressing the measure input switch. In this case, the value of ACSOFFSET was subtracted from the new measurement value. Then the system display accurate current measurement in mA.

The measurement data of a solar panel was made in April and recorded value of parameters were illustrated in the following table.

Month	date	time	type of solar	voltage	current	light	temperature
April	1.4.2019	8am	10Watt Ring Solar Panel	25V	500mA	2000 lux	32C

Conclusion

The solar power is the best and pure resource of nature's gift. The power of solar can be directly apply for the plants in photosynthesis, thermal conduction energy, sun drying the food, salt production, removing germs and virus. Moreover, the photons of solar rays can be converted to electrical energy by using solar photovoltaic cells. They are known as solar energy applications. Therefore, solar panels are produced in some of the countries all over the world. But they are expensive and not powerful enough to provide for a city. Therefore, a large area of solar panels are combined and stored in large storage cells. Therefore it is important to investigate the properties of a solar panel. The solar panel properties investigating circuit is designed, constructed and collected data to compare the various types of solar panels. The measurements are made for voltage, current, luminous and temperature. According to the results, suitable type of solar panel can be chosen for the applications.

Acknowledgements

The authors would like to thank Dr Htay Aung Pro-rector and Dr Soe Myint Thein, Pro-rector of Loikaw University, for their kind permission to carry out this research work. We also grateful to thank Professor Dr San San Wai, Head of Department of Physics, Loikaw University, for her encouragement to do this work. We wish to express my thanks to all our colleagues in the Department of Physics, Loikaw University, for providing suggestions in this research.

References

Microchip Technology Incorporated (1999) “PIC 16F676 Instruction Set” New York : Microchip Technology)

Marston R.M. (1996) “Modern CMOS Circuit Manual” (London : B H Newnes)

Nick Dossis (3/2002) "Everyday Practical Electronics" (London : Wimborne Publishing)

Sid Katzen (2000) “The Quintessential PIC Microcontroller” (Berlin :Springer)

Sinclair I. R. (2001) “Practical Electronics Handbook” (London : B H Newnes)

Thomas l. Floyd (1996) “Electronic Devices” (New Jersey : Prentice-Hall)