AUTOMATIC SOLAR TRACKER

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Abstract - Energy crisis is the most important issue in today's world. Conventional energy resources are not only limited but also the prime culprit for environmental pollution. Renewable energy resources are getting priorities in the whole world to lessen the dependency on conventional resources. Solar energy is rapidly gaining the focus as an important means of expanding renewable energy uses. Solar cells those convert sun's energy into electrical energy are costly and inefficient. Different mechanisms are applied to increase the efficiency of the solar cell to reduce the cost. Solar tracking system is the most appropriate technology to enhance the efficiency of the solar cells by tracking the sun. A microcontroller based design methodology of an automatic solar tracker is presented in this paper. Light dependent resistors are used as the sensors of the solar tracker. The designed tracker has precise control mechanism which will provide three ways of controlling system. A small prototype of solar tracking system is also constructed to implement the design methodology presented here.

Keywords - LPC2148, ADC, KEIL4-UVision, Flash Magic

1. Introduction

Energy is the prime factor for the development of a nation. An enormous amount of energy is extracted, distributed, converted and consumed in the global society daily. 85% of energy production is dependent on fossil fuels. The resources of the fossil fuels are limited and their use results in global warming due to emission of greenhouse gases. To provide a sustainable power production and safe world to the future generation, there is a growing demand for energy from renewable sources like solar, wind, geothermal and ocean tidal wave. The sun is the prime source of energy, directly or indirectly, which is also the fuel for most renewable systems. Among all renewable systems, photovoltaic system is the one which has a great chance to replace the conventional energy resources.

Solar panel directly converts solar radiation into electrical energy. Solar panel is mainly made from semiconductor materials. Si used as the major component of solar panels, which is maximum 24.5% efficient. Unless high efficient solar panels are invented, the only way to enhance the performance of a solar panel is to increase the intensity of light falling on it. Solar trackers are the most appropriate and proven technology to increase the efficiency of solar panels through keeping the panels aligned with the sun's position. Solar trackers get popularized around the world in recent days to harness solar energy in most efficient way. This is far more cost effective solution than purchasing additional solar panels.

2. Literature Survey

The design of a solar tracking system driven by a microchip PIC 18F452 micro controller is discussed in [1]. The system is based on two mechanisms. The first one is the search mechanism (PILOT) which locates the position of the sun. The second mechanism (intelligent PANELS) aligns itself with the PILOT only if maximum energy possible could be extracted. The design methodology of a microcontroller based simple and easily programmed automatic solar tracker is presented. A prototype of automatic solar tracker ensures feasibility of this design methodology. The designed tracker has precise control mechanism which will provide three ways of controlling system. A small prototype of solar tracking system is also constructed to implement the design methodology presented here.

In addition to tracking, the controller is capable of acquiring photovoltaic and meteorological data from a photovoltaic system and controlling battery/load is discussed in [3]. These features are extremely useful in autonomous PV power systems installed in remote areas for system control and monitoring. Solar tracking can be achieved in closed-loop and open-loop modes, and the controller can provide either six PWM (pulse-width-modulated) signals for a three-phase. Sun position sensing is successfully performed using phototransistors mounted in a simple structure is performed in [4]. Some problems associated with this technique which were successfully overcome are mentioned. An electrical circuit block diagram with description is given as well as the tracking system's performance when connected to a 2.34-m2 cylindrical parabolic collector. With this arrangement, the tracker consumes approx. 1 W of electrical power which is supplied by a small panel of solar cells with a rechargeable battery as a back-up and night time supply.

A parabolic solar cooker with automatic two axes sun tracking system was designed, constructed, operated and tested to overcome the need for frequent tracking and standing in the sun, facing all concentrating solar cookers with manual tracking, and a programmable logic controller was used to control the motion of the solar cooker is described in [5]. The results of the continuous test – performed for three days from 8:30 h to 16:30 h in the year 2008 – showed that the water temperature inside the cooker’s tube reached 90 °C in typical summer days, when the maximum registered ambient temperature was 36 °C. It was also noticed that the water temperature increases when the ambient temperature gets higher or when the solar intensity is abundant.

A model of neural network and a new type of neural controller are used, aiming to reduce cost and complexity without sacrificing efficiency of traditional, more complex neural net-based solar trackers is approached in [6]. The solution is derived from Mark Tilden’s neural and nervous networks, using a biologic analogy to seamlessly integrate sensors, artificial neurons and effectors in a single, efficient device. The project aims to develop a small pilot tracker – based solar plant for testing purposes and to develop a useable technology for the ever-growing demand for green power. This system is based on two mechanisms for a solar tracking system driven is described in [7]. The first one is the search mechanism (PILOT) which locates the position of the sun. The second mechanism (intelligent PANELS) aligns itself with the PILOT only if maximum energy possible could be extracted. On top of that the main advantage of the technique is that the rotation only takes place, if the energy obtained in the new position is higher then that consumed by the panels during the transition. So there are two mechanisms, one for the search which is mounted on a miniature motor and consumes only small amount of energy. Its role is to locate the best position for maximum energy extraction. The second one is the panels mechanism which rotates to the position when energy extraction is optimal.

3. PHOTOVOLTAIC TECHNOLOGY

The most abundant and convenient source of renewable energy is solar energy, which can be harnessed by photovoltaic cells. Photovoltaic cells are the basic of the solar system. The word photovoltaic comes from "photo" means light and "voltaic" means producing electricity. Therefore, the photovoltaic process is "producing electricity directly from sunlight". The output power of a photovoltaic cell depends on the amount of light projected on the cell. Time of the day, season, panel position and orientation are also the factors behind the output power. The current-voltage and power-voltage characteristics of a photovoltaic cell are shown InFig1.

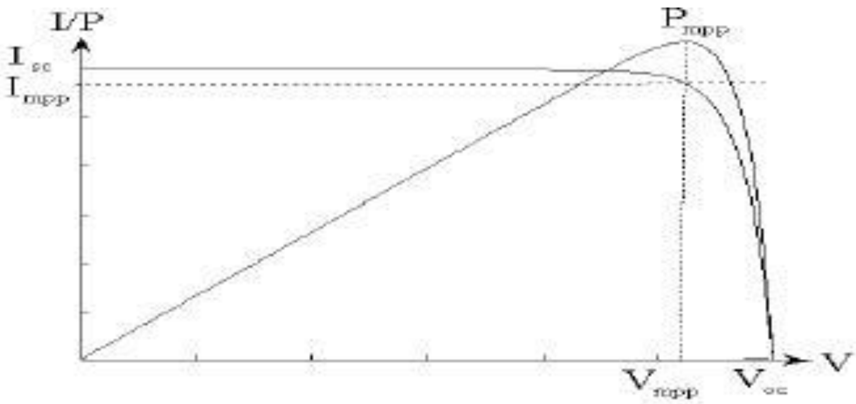

Fig 1. ***I-V* and *P-V* characteristics of photovoltaic cell**

Photovoltaic cells are the smallest part of a solar panel. Solar panel gives maximum power output at the time when sun is directly aligned with the panel.

4.OPERATION OF SOLAR TRACKING SYSTEM

Basically, the sensors can detect the exact location of the sun with the presence of sunlight. However, the weather conditions are not sunny all the time. Therefore, the operation of solar tracking system should include the bad weather condition too such as cloudy day and rainy day. The operation is based on presence of the sun throughout the year. This project provides two ways of operation and control mechanism which are,

- Normal sunny condition

- Bad weather condition
- Bidirectional rotation

The presence of the sun can be identified by knowing the latitude and longitude of the site. So, the sunrise is about 7 a.m. while the dawn about 7p.m. In this project, the system will be started an hour after the sunrise which is 8 a.m. The system will be stopped an hour before dawn which is 6 p.m.

A. Normal Sunny Condition

Two sensors are used to detect the presence of the sunlight. The output voltages from two sensors that represent east and west are compared. The east sensor value and west sensor value is compared. Based on the result obtained from the sensor, the solar panel will track the sun.

B. Bad Weather Condition

On bad weather day, the sensor cannot detect the presence of the sunlight because of the interaction of clouds and dusts. The sunlight that strikes the system will lessen and insufficient voltages will be received by the sensor. It can be difficult to the sensor to determine the exact location of the sun. The problem can be solved by implementing the algorithm for the movement of the solar panel. The rotation of the earth towards the sun is 360º in 24 hours. Every hour, the earth rotate about (360º/24=) 15º. So, to collect data every 15 minutes, the rotation of the earth towards the sun is about 3.75º.

C. Bidirectional rotation

At day time, the solar tracker will rotate in only one direction from east to west. Variable *I* will count the total rotation in day time and that is approximately calculated as 40 rotations considering 150° rotation. When the sun sets, no more rotation is needed in western direction. For the next day, the solar panel needs to go to the initial position in the morning to track the sun's position again. To do so, the variable *I* that counts the number of rotation in the day time will work out. When the variable (*I*) shows value greater than 40, the tracker stops rotating in the western direction and rotates reversely in the eastern direction to set the tracker to the initial position for the next day. When it goes to initial position, power supply to the tracker will be turned off and the tracker will be in stand by till sunlight in the next morning.

5. Hardware Description

As mentioned in the previous section, LDR's are an accurate 2- pin photo resister sensor. The total hardware block diagram developed in the present work is shown in fig 2. Pin 1 of LDR'sare connected to the power supply (+3.3V). Pin 2 is connected to analog input channel of 10-bit ADC (ADC0.1 and ADC0.2) of LPC2148. The microcontroller consists of two 10-bit ADCs namely, ADC0 and ADC1, with six and eight analog input channels, respectively.

The microcontroller processes the sensor output to compute the luminous of light. This is accomplished by connecting LDR to the analog input channel of the internal ADC0.

The reference voltage of the ADC is the same as the supply voltage to the microcontroller, i.e., 3.3V.

6.BLOCK DIAGRAM

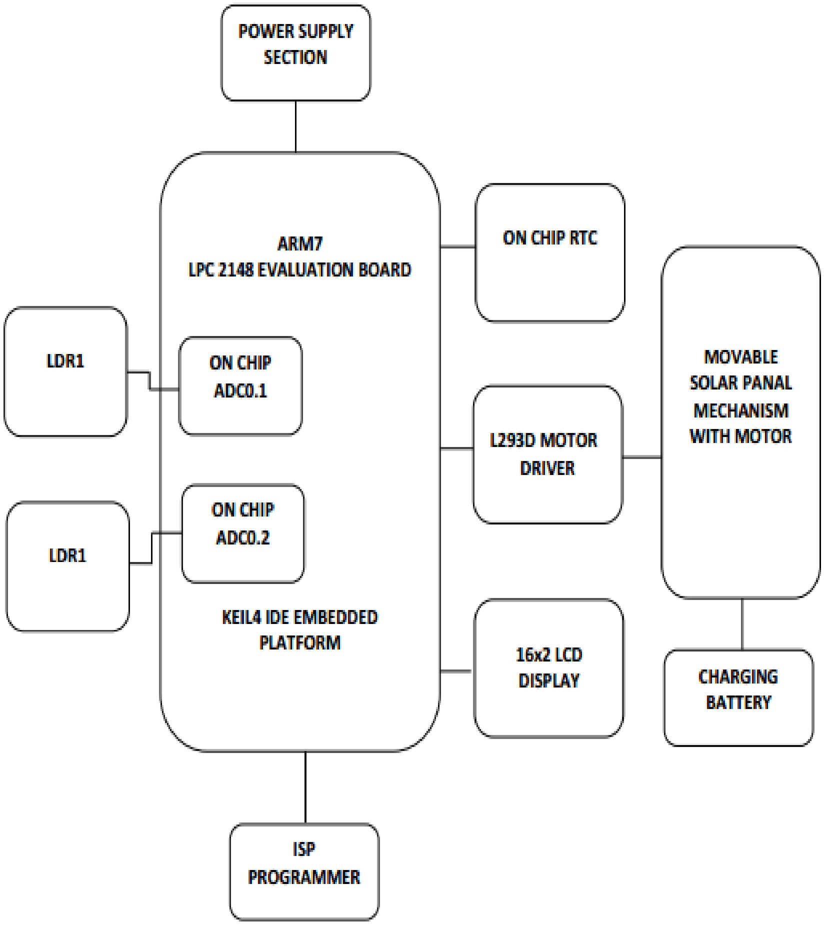

Fig 2. Block diagram of the proposed system

The output voltage from the sensor is converted to a 10 -bit digital number and the internal software converts the digital value into its equivalent luminous and is displayed on the LCD module which is interfaced to LPC2148 in 8-bit mode. The measurement takes a maximum of 100µs to respond to the change in light intensity. The luminous computed over a length of time are stored in the memory of the microcontroller.

Fig.3 shows the overall view of the solar tracking system. It consists of solar panel, solar tracker, movable setup, stepper motor, LDR.

7.SOFTWARE DESCRIPTION

A. KEIL4 UVISION

The present system is implemented by developing a suitable embedded C program using KEIL µVision4 software. This is an integrated development environment (IDE) with embedded C/C++ compiler for ARM which supports simulation and debugging interface. The software developed is compiled and uploaded to the flash memory using Flash utility (PHILIPS).

CONNECTION DIAGRAM

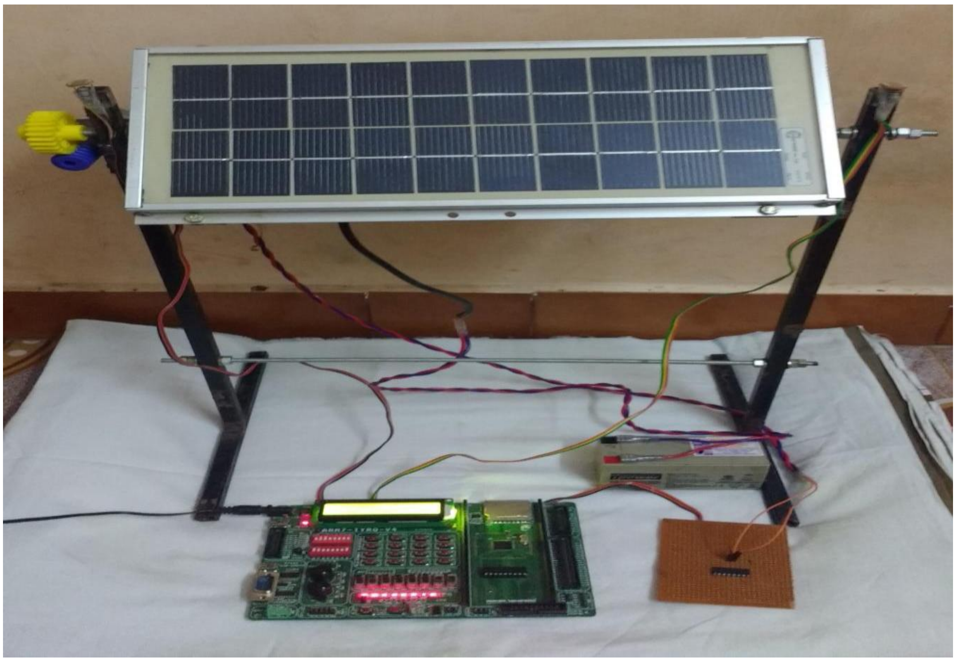

Fig 3. Real View of Solar Tracking System

µVision is a window-based software development platform that combines a robust and modern editor with a project manager and make facility tool. It integrates all the tools needed to develop embedded applications including a C/C++ compiler, macro assembler, linker/locator, and a HEX file generator. µVision helps expedite the development process of embedded applications by providing the following:

- Full-featured source code editor.
- Device Database for configuring the development tool.
- Project Manager for creating and maintaining your projects.
- Integrated Make Utility functionality for assembling, compiling, and linking your embedded applications.
- True integrated source-level and assembler-level Debugger with high-speed CPU and peripheral Simulator.

- Advanced GDI interface for software debugging on target hardware and for connecting to a Keil ULINK Debug Adapter.
- Flash programming utility for downloading the application program into Flash ROM.
- Links to manuals, on-line help, device datasheets, and user guides.

B. FLASH MAGIC

NXP Semiconductors produce a range of Microcontrollers that feature both on-chip Flash memory and the ability to be reprogrammed using In-System Programming technology. Flash Magic is Windows software from the Embedded Systems Academy that allows easy access to all the ISP features provided by the devices. These features include:

- Erasing the Flash memory (individual blocks or the whole device) Programming the Flash memory
- Modifying the Boot Vector and Status Byte Reading Flash memory
- Performing a blank check on a section of Flash memory Reading the signature bytes
- Reading and writing the security bits
- Direct load of a new baud rate (high speed communications) Sending commands to place device in Boot loader mode

Flash Magic provides a clear and simple user interface to these features and more as described in the following sections. Under Windows, only one application may have access the COM Port at any one time, preventing other applications from using the COM Port. Flash Magic only obtains access to the selected COM Port when ISP operations are being performed. This means that other applications that need to use the COM Port, such as debugging tools, may be used while Flash Magic is loaded.

DOWNLOAD THE PROGRAM TO ARM7 CONTROLLER

Using Flash Magic, the Hex file which created by Keil4 software was loaded to ARM7 LPC2148 Microcontroller.

8. RESULTS

The sun tracker uses a CdS photocell for light detection. A complementary resistor value of 1 KΩ was used to construct the LDR circuit. In this configuration, the output voltage will increase as light intensity increases.

The complementary resistor value should be chosen such as to achieve the widest output range possible. Photocell resistance was measured under dark conditions, average light conditions, and bright light conditions. The results are listed in Table 1.

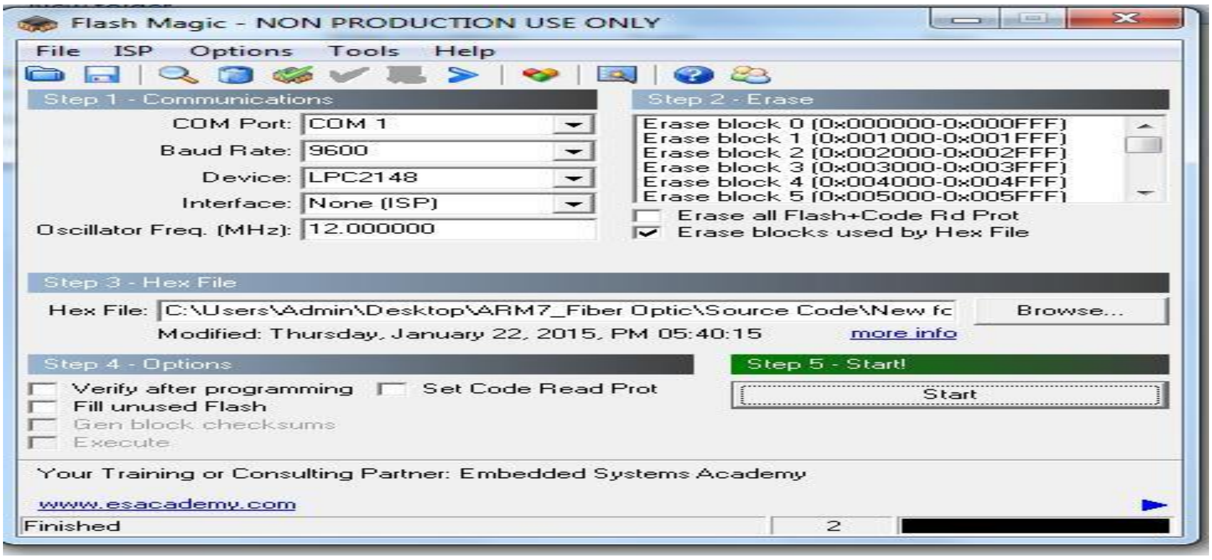

Fig 4. Download code to flash memory

Table 1 – Photocell Resistance Testing Data

Measured Resistance	Comments
50 KΩ	Dark (black vinyl tape placed over cell)
4.35 KΩ	Average (normal room lighting level)
200 Ω	Bright (flashlight directly in front of cell)

The selected 1K complementary resistor resulted in the following minimum and maximum voltages.

Minimum = 3.3 V × (50 KΩ / (50 KΩ + 1 KΩ)) = 3.23 V

Maximum = 3.3 V × (200 Ω / (200 Ω + 1 KΩ)) = 0.55 V

Thus, an output swings of 2.65 V results. While this is not ideal, it was determined to be sufficient for the project and additional amplification was not pursue

Fig 5 shows the initial output. At initial condition, the system in sleep mode with time.

Fig.5.LCD Output Initial condition

Fig 6. shows the Output in normal weather condition. In this stage the mode is in active state. This stage will occur when the weather condition is in normal.

Fig 6.LCD Output Normal weather condition

Fig 7. LCD Output Bad weather condition

Fig 7. shows the Output in Bad weather condition. In this stage the mode is in Inactive state. This stage will occur when the weather condition is in Bad.

9. CONCLUSION

The paper has presented a means of tracking the sun's position with the help of microcontroller. Specially, it demonstrates a working software solution for maximizing solar cell output by positioning a solar panel at the point of maximum light intensity. The prototype represents a method for tracking the sun both in normal and bad weather condition. Moreover, the tracker can initialize the starting position itself which reduce the need of any more photo resistors. The attractive feature of the designed solar tracker is simple mechanism to control the system. The solar tracker also provides lucrative solution for third world countries to integrate it into their solar system with a comparatively low cost through software based solution. Though the prototype has limitations in hardware areas as an initial set up, still it provides an opportunity for improvement of the design methodology in future.

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