Solar Cells Orientation System Using Microcontroller

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ABSTRACT

This work describes a design of control system to orientation the solar cells using Atmel Flash micro-controller (AT89C51). The solar elevation angles over the course of a year are calculated for any position depending on longitude and latitude using C++ program. The software is convert the angles into its equivalent value of steps according to the resolution of the step motors and save the result in Hex file. The Hex file is loaded on EEPROM by EPROM programmer. The solar cells holder step motors will receive the data of sun position and will move to it.

Keywords: *Sun position, micro-controller, AT89C51, C++.*

1. INTRODUCTION

As fuel prices go up, solar cells can be used as an alternative source of energy. The purpose of the solar cell is to capture energy from the sun and to turn this energy into electrical energy. The efficiency of the power transfer depends on many parameters. One of these parameters is the direction of the solar cell with respect to the sun [4]. The direction of the solar cell faces makes a difference in the amount of light hitting it. Solar irradiance varies with respect to time of day, and the day of year for the same position. Boletis, et al [3] introduce a new concept of a solar cell powering with integrated Global Positioning System (GPS) for micro robots. In this paper we design a control system to orientation the solar cell to sun direction depending on the longitude, latitude, hour and minute of the solar cells position using micro-controller. This place of solar cell will set the cells to give maximum power.

2. SOLAR POSITION CALCULATION

Numerous algorithms are now available on the world-wide-web for computing solar elevation angles over the course of a day or year for any position on the Earth [8].

The Earth rotates on its axis and it revolves around the Sun in an elliptical orbit. The area swept by the Earth-Sun radius is constant, as predicted by Kepler's Law of Planetary Motion. To perform calculations associated with the flux density of solar radiation on flat surfaces, we must be able to evaluate the angle of the sun from any position on Earth at any time of the day. Such a calculation involves computing the angle between a vector normal to a specified point on Earth and a projection from the Sun. This computation is complicated by the fact that the Earth rotates on its polar axis once a day and the Earth revolves around the Sun once a year.

To compute the sun's elevation with respect to the horizon (or its complement, the angle with to the zenith) and its azimuth angle we apply concepts derived from three-dimensional geometry. The important coordinates to know include [6, 7]:

1. time of day
2. longitude
3. latitude

The Earth is a rotating sphere. The Earth rotates around its north-south axis once every 23 hours, 56 minutes and 4 second. It can also be stated that the Earth rotates on its axis 2π radians in one day. Over the course of an hour it rotates π/12 radians or 15 degrees. The hour angle, (*h*), is defined as:

$$h = \frac{2\pi t}{24} \qquad \ldots 1$$

The local sun noon is calculated by:

$$lsn = 12.0 + \left(\frac{ltm - xcoor}{15.0}\right) \qquad \ldots 2$$

Where (*ltm*) is local time meridian and (*xcoor*) is longitude (in DD) for the site. The declination of the sun (*dec*) is calculated by [7]:

$$dec = 23.45 \times \sin\left(360 \times \left(\frac{284 + jday}{365}\right)\right) \qquad \ldots 3$$

Where (*jday*) is the julian date for the calculation. The solar altitude angle (*salt*) is calculated by:

$$salt = \sin^{-1}((\sin(lat) \times \sin(dec)) + (\cos(lat) \times \cos(dec) + \cos(ha))) \qquad \ldots 4$$

where;

lat: latitude of site.

ha: hour (floating from hr & min)

The solar azimuth angle is calculated by:

$$sazi = \sin^{-1}\left(\frac{\cos(dec) \times \sin(ha)}{\cos(salt)}\right) \qquad \ldots 5$$

3. HARDWARE DESIGN

Figure 1 illustrates a block diagram of the solar cell orientation system (SCOS), which consists of four main parts: micro-controller, two step motors, external data memory and display.

Microcontrollers often are called embedded controllers. The single chip micro-controller used in the

(SCOS) hardware implementation was the Atmel flash micro-controller AT89C51 [2].

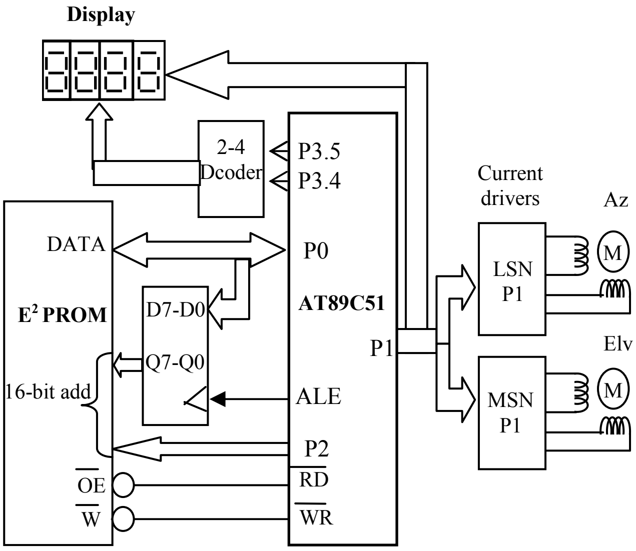

Figure 1: Block diagram of the solar cell orientation system

It provides hardware features and instructions that make it a powerful and cost effective controller for use in computation and communication, industrial and consumer applications [1].

Two step motors are used in this design to control the angle direction. Step motor (M1) is used to adjust the azimuth angle and the step motor (M2) for elevation (altitude). M1 and M2 are receiving their coil drive sequence on the least significant nibble (LSN) of port 1 (P1), and the most significant nibble (MSN) of port 1 (P1) respectively from microcontroller. At the end of each day (sunset) the step motors will reset to the new location for the next day. Four seven segment are used to display the current step motors position. The display system consists of four seven-segment common cathode displays which are multiplexed using (P0) to emit data. The ports (P3.4) and (P3.5) are used to select one display at a time. This method provides a reducing in the total current.

4. SOFTWARE DESIGN

The necessary software related to the SCOS includes the necessary programs needed with the hardware given in previous sections. The software is implemented using two levels of programming languages, the 8051 assembly language and the C++ high level language. The main program has been implemented in the AT89C51 machine language using the µVision editor and tested by the debugger program named Dscope[5].

The flowchart of the main program is shown in Figure 2. When the system is run, the first thing to do is to enter the local time and date of the position. Then a 'get_angl' subroutine is called by the main program. The job of this routine is to get the azimuth and elevation angles from database.

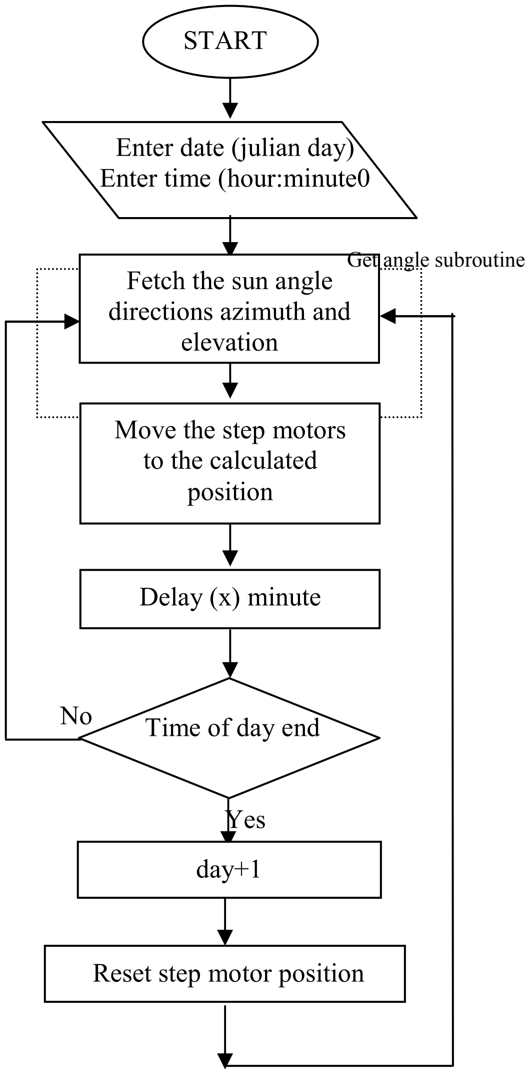

Figure 2: Flowchart of the microcontroller main program.

Calculating and entering (manually) the large database (sun direction angles) is a tedious and tiresome work. Therefore off-line automatic sun angle generation software (ASAG) is implemented in separate software package. Consequently, a high-level language program (C++ language) was used in order to calculate the data for required positions.

The database was built for the site using the solving for the equations in section 2 using C++ program. The software will convert the angles into its equivalent value of steps according to the resolution of the step motors as follows:

$$steps=360/res \quad \ldots 6$$

The final result of this program is saved in data file (in hexadecimal format) and it loaded on EEPROM by EPROM programmer.

The two step motors will move to the calculated positions and wait for (x) minutes. After the delay is finished the process will repeat for the next positions. The waiting time, delay (x), depend on the geographical position and the design of the solar cell, where it limited by field of view for the cells with respect to sun.

5. CONCLUSION and SUGGESTIONS

A solar cell orientation system is presented and designed in hardware and software in this paper. It can be concluding that the use of microcontroller make the system more reliable low cost effective, and can be operates as stand alone system with the solar cell boards to find the optimum (best) sun direction. Also the system is popular to operate any where. This can be done by entering the longitude and altitude of the required location in the high level program C++ to generate the data file to be used by the SCOS system.

It is suggest that the system can be modified to download directly the output data file in the system, which eliminate the need to use an EPROM programmer. This is can be done by connecting the system to the PC via serial port. Also the equations used to determine the sun angles can be implemented in the microcontroller, consequently this will cancel the need for high level language program to generate the sun angle direction. Finally the system can be developed by making use of Global Positioning System (GPS). This will eliminate the need for entering manually the longitude and altitude for any location.

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