

Electronic Implementation of Sun Algorithm

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Abstract

Implementation of Solar Position Algorithm (SPA) on an electronic platform is presented. The system consists of a microcontroller and a real time clock. Solar angles according to the SPA were calculated on a computer for 5 years (for each minute). The calculated solar angles indexed according to the time and downloaded to secure digital (SD) through the microcontroller based SD card read/write system. Solar angles for any given time can be retrieved by providing the time index to the look up table recorded in the SD card. 5 MB of space is required to store such a data set for one year. The performance of this system was evaluated by interfacing to a manual sun tracking system of a parabolic trough solar concentrator. It was found to be that the maximum variation of the focal line is 1.5 cm and it is within the full acceptance angle of 3.8°.

1. Introduction

Number of methods are being used to track the path of the sun for maximizing the capturing of energy in most of the solar energy harnessing systems. Depending on the technique used to find the position of the sun, solar trackers can be classified as active or passive. The active trackers sense the solar radiation to locate the sun while the passive trackers calculate solar angles relative to the earth using mathematical algorithms. Of the two techniques, the passive solar angle calculation is the more reliable and effective method since there is no effect for the calculation from environmental factors such as cloud cover. There are different solar positioning algorithms that have been developed, and the Solar Position Algorithm (SPA) for solar radiation applications developed at National Renewable Energy Laboratory (NREL) is the most accurate SPA to the date. The objective of this study is to implement the SPA on a microcontroller based electronic system as a sun tracking system for a parabolic trough solar thermal energy concentrator being developed at the Department of Physics, University of Colombo.

2. Methodology

The main controller of the tracking system is a PIC18F452 microcontroller. A Maxim DS1305 Real Time Clock (RTC) and a SD memory card read/write system are connected to the microcontroller in order to get the time and to store data respectively. Figure 1 shows the basic block diagram of the system. The RTC communicates with the microcontroller via SPI interface. The RTC was preprogrammed with the local time and was set to update the time at each minute. The SD card system communicates with the main controller through RS232 interface. When this system is in the writing mode, the data on its RS232 port is written into the SD card at the given specific memory location. When the system is in reading mode the stored data can be read by providing the address of the data array.

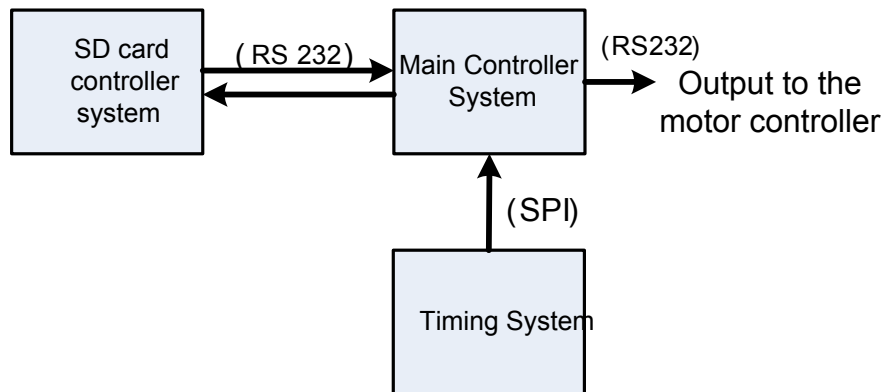


Figure 1: Basic block diagram of the system

The position of the sun relative to the surface of the earth can be expressed by two angles called solar azimuth (Γ) and elevation (e). Equations (1) and (2) are used to calculate the topocentric elevation and the azimuth angles using this algorithm.

$$e = \text{Arc sin}(\sin \varphi * \sin \delta' + \cos \varphi * \cos \delta' * \cos H') + \Delta e \quad (1)$$

$$\Gamma = \text{Arc tan2}\left(\frac{\sin H'}{\cos H' * \sin \varphi - \tan \delta' * \cos \varphi}\right) \quad (2)$$

where, H' is the topocentric local hour angle, δ' is the topocentric sun declination, φ is the observer's geographical latitude and Δe is the atmospheric refraction correction

3. Results

Solar angles were calculated using the above equations for a time period of 5 years with one minute of time intervals by implementing the SPA on a computer. These angle values were then used to derive the required tracking angle for the PTC and arranged them with time as a lookup table. This lookup table is then downloaded to an SD memory card using the SD memory controller through the RS232 interface of the computer. The memory inside the SD card is indexed according to the time and any data from the memory can be retrieved by the time value. The time produced by the RTC is read by the main controller and fetch the corresponding solar angles from the SD card.

This system was then interfaced to a manual sun tracking system of a parabolic trough concentrator (PTC). This PTC is aligned in the North-South direction and free to rotate around its horizontal axis. The actuator system of this module consists of a DC servo motor and a gear system and the motor is controlled by a PI controller. According to the dimensions of this module, it has a full acceptance angle of 3.8° . Therefore the maximum acceptable variation of the focal line of the system can vary ± 2 cm from the center of the receiver tube. This deviation of the focal line was measured to evaluate the performance of the tracking system as shown in Figure 2. According to the Figure 2, the maximum deviation of the line is 1.5 cm which is in the acceptable range.

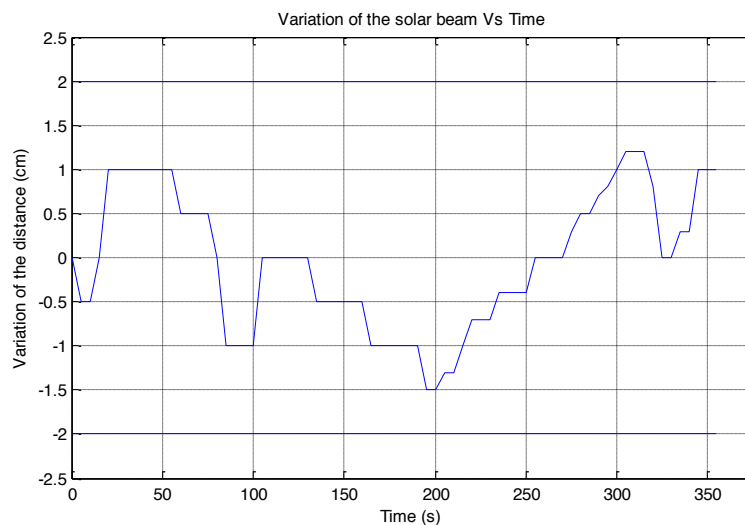


Figure 2: Variation of the solar beam relative to the center of the receiver

4. Discussion and Conclusions

In order to calculate solar azimuth and zenith angles using an electronic system, equations (1) and (2) should be implemented on it and there are about 40 other equations that should be solved before feeding data to those equations. Implementation of such a lengthy calculation inside a microcontroller is not practical due to the limitation of program memory and the processing power. Therefore pre-calculation of solar angles using a computer and having them in a lookup table stored in a SD memory can be considered as an efficient alternative method. Angle data for one hour can be stored in one data array of 512 bytes of the memory card with one minute time intervals. Therefore, the memory requirement for one day is 13 kB and only 5 MB is needed for the storage of data for one year. Hence, solar angle data for a long period can be stored in a memory with small capacity.

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Evaluation of temperature dependence of oscillating frequency of an internal RC oscillator of a microcontroller as a temperature sensor

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Abstract

A novel, low cost and reliable method of using a microcontroller has been tested and evaluated for measuring temperature. Most of the microcontrollers come with a Watch Dog Timer (WDT) which is clocked by an internal Resistor Capacitor (RC) oscillator. The oscillating frequency of the RC oscillator depends on the temperature. The time-out periods (in counts) of WDT of Microchip PIC16F877A microcontroller were measured at different temperatures by means of a LM35 sensor from National Semiconductor Inc. It is found to give a good linear relationship (correlation coefficient $R^2=0.997$) between time-