Microcontroller Based Single Axis Sun Tracking Control System

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Abstract – Solar power is one of the most powerful renewable energy sources. Solar collectors, PV panels and concentrating collectors should be kept aligned with the sun ray to maximize the collected solar energy. In this paper a solar azimuth tracking control system is designed and implemented. The azimuth tracking axis is tilted by the location latitude angle parallel to the celestial north pole. The control system is based on AT*89S52* microcontroller with a simple control circuit. This embedded control system offers a reliable and inexpensive method of aligning a solar panel with the sun on single axis.

Index Terms – Solar azimuth tracking, microcontroller AT89S52 , on-off control, DC servo motor.

1. INTRODUCTION

Solar energy is more popular than other renewable energy resources to take over the scarcity of hydrocarbon in future [1]. The solar energy systems now are used in many fields of life. The outputs from the solar systems depend on the amount of solar radiation received by the systems. Sun tracking is essential for many solar energy based power systems to improve the system performance. It is essential for concentrator systems, moreover in flat-plate photovoltaic systems, an increase in power output by 30-60% (depending on the location) has been observed by the tracking as compared to the fixed [2].

The solar collectors (flat, parabolic or dish) are rigidly mounted on the tracker surface. The solar trackers may be single or double axis trackers. The tracking mechanism must be reliable and able to follow the sun with a certain degree of accuracy. The required accuracy of the tracking mechanism depends on the collector acceptance angle which will be fixed upon it [3].

The point-focus concentrating (e.g. dish collector) collector has a small acceptance-angle cone that has to be kept pointing at the sun, and so needs a full-tracking mounting. Line-focus concentrating collector (e.g. parabolic trough collector (PTC)) typically has a small acceptance angle in one directional plane and a broader acceptance angle in a plane at right angles to the first one. The large acceptance angle in the one plane does not need tracking, and allows the simplification to one rotational axis in the collector mounting.

In the present work, only azimuth axis tracker is considered. The basic idea of this work is to use low-cost microcontrollers in the sun tracking system control that can contribute to reduction of the cost. The on-off control technique is used in the current system.

A microcontroller is a single-chip computer. It contains memory and I/O interfaces in addition to the CPU. It is cheaper, faster and lower power machine that can handle any control or data processing application. The last versions of microcontroller chips have on chip a flash memory that allows the program memory to be reprogrammed by a memory programming kit [4]. Then it provides a highly flexible and cost effective solution to many embedded control applications.

A microcontroller AT89S52 (89S52 for short) is selected in this system.

2. PROPOSED SYSTEM HARDWARE

The main components of the system are a tracker mount, position sensor, motor driver the microcontroller and a DC linear servo motor. The block diagram of the microcontroller based sun tracking control system is shown in Fig. 1.

The 89S52 microcontroller includes:

- CPU (central processing unit),
- 256 bytes of RAM (Random Access Memory),
- 8K bytes of Flash programmable and erasable read only memory (EEPROM),
- Three 16-bit timer/counters.

The 89S52 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port, and interrupt system to continue functioning. The Power-down mode saves the RAM contents but freezes the oscillator, disabling all other chip functions until the next hardware reset [4].

3. SYSTEM FLOW CHART

Fig. 2 shows the flow chart of the software program that controls the system operation. Once the program starts, all variables are initialized (such as the current position, etc). The program calculates the next solar azimuth angle through the look up table that calculated in advance using sun earth mathematical relationships [5, 6].

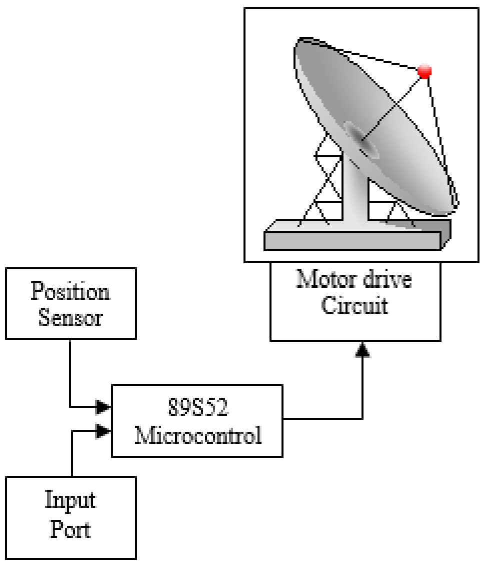

Figure 1 Block Diagram of the 89S52 Based Sun Tracking System.

It sends a suitable control signal through the output port. It waits for the second step (Idle mode). At the end of the day checking the program compares the system time with sun-set time T_{ss} and if the both times are equals, the system goes to the position of the next day at the east and stow.

4. SUN TRACKING CONTROL SYSTEM SETUP

The azimuth tracking axis will be tilted by the location latitude angle, parallel with the celestial North Pole. The solar incidence angle (solar declination) changes with the seasons due to the tilt of the earth axis of rotation and the rotation of the earth around the sun. Then the tilt angle of azimuth axis is corrected or readjusted seasonally based on the change of sun declination angle change.

The 89S52 microcontroller is the heart of the system. It accepts digital inputs from I/O port 0 which the day number of the year and it then go back to lookup table to determine set point and at what time it should be started. The controller accepts the digital input signal from the position sensor through I/O port 3 and then calculates the error signal. The 89S52 outputs the corresponding digital control signal to orient the sun tracking signal through I/O port 3.

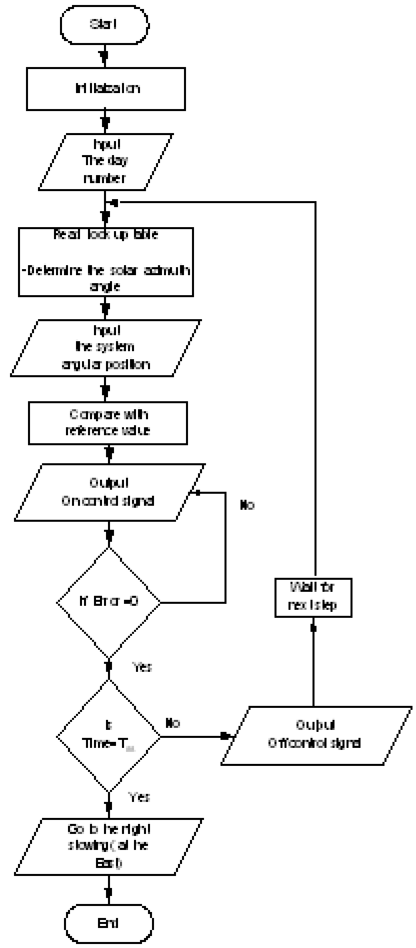

Figure 2 System Flowchart

4.1. Sun tracking control board

The Schematic diagram of the control board, shown in Figs 3 and 4, consists of two identical circuits to drive the motors. Each of them consists of one transistor (2N2222), normal off relays, resistors of 3.9 k ohm, diodes (GA 101). The switching transistors are controlled by the digital output of the I/O of the 89S52. The digital output of the 89S52 is used to bring one of two transistors into the on mode (switch mode) to apply a specific DC voltage with assigned polarity of the motor through circuit relays. The direction of the angular motion is controlled by which transistor is turned on. The diodes are connected across the motor to protect the transistors from the generated high voltage (-L di/dt) from the armature of the motor when one transistor goes off. The 78L05 and 78L12 regulators provide a stable 5V and 12V supplies for the 89S52 and the transistors respectively. The control software is contained in the preprogrammed 89S52. Fig. 5 shows photo of the 89S52 based solar tracking control board and Fig. 6 shows the programming kit. While Fig. 7 shows the solar tracker.

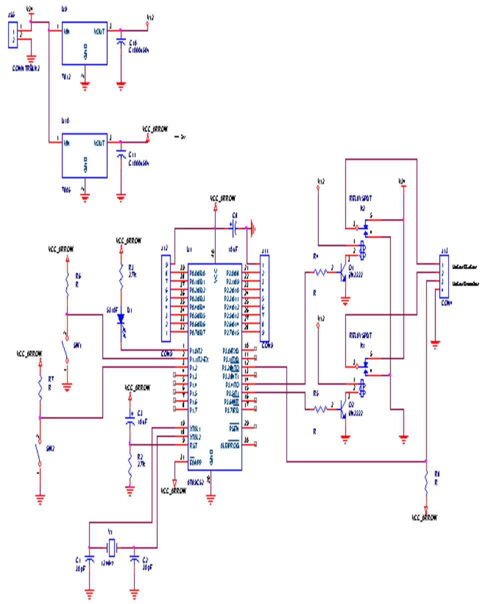

Figure 3 Schematic Diagram of the 89S52 board.

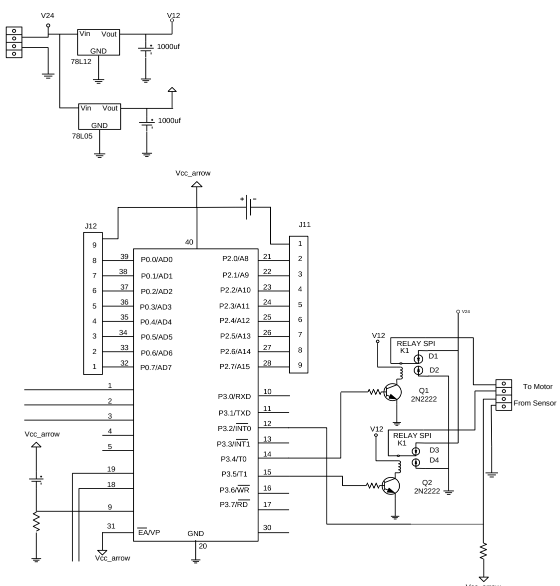

Figure 4 Zoomed View of the above Circuit.

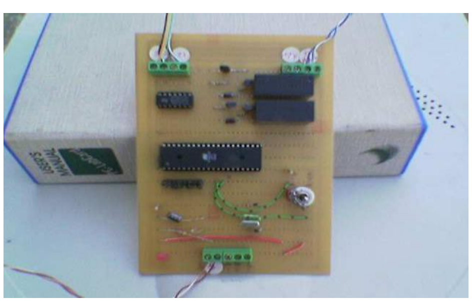

Figure 5 Photo of the 89S52 Control Board.

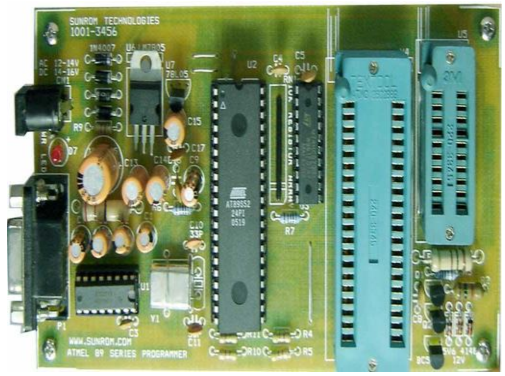

Figure 6 Photo of Atmel 89 Series Programming Kit.

4.2. Programming of 89S52 flash

The 89S52 is normally shipped with the on-chip Flash memory array in the erased state (that is, contents = FFH) and ready to be programmed.

To program any nonblank byte in the on-chip Flash Memory, the entire memory must be erased using the Chip Erase Mode. Before programming the 89S52, the address, data and control signals should be set up according to the Flash programming mode table and Flash Programming and Verification Waveforms [6].

Figure 7 Back Side of the Solar Tracker.

The programming kit is connected to a com1 of a host computer using a standard RS232 serial port.

The programmed 89S52 chip is introduced into the programming kit. The baud rate is set to 9600 baud, 8-data bit, and no parity. The control program is compiled into a Hex using an appropriate software programming before the 89S52 programming. Fig. 8 shows the schematic diagram of the flash Programming and verification respectively.

The 89S52 programming algorithm is as follow,

1. Input the desired memory location on the address lines.

2. Input the appropriate data byte on the data lines.

3. Activate the correct combination of control signals.

4. Pulse $ALE/\overline{PROG}$ (Address Latch Enable) once to program a byte in the Flash array or the lock bits. The byte-write cycle is self-timed and typically takes no more than 1.5 ms. Repeat steps 1 through 4, changing the address and data for the entire array or until the end of the object file is reached [7].

5. EXPERIMENTAL RESULTS AND DISCUSSION

The azimuth axis has a resolution of 0.01 degree/pulse (i.e. no. of pulses /degree=100 pulses/deg.). The reference inputs to the controller are developed to be 0.1° and sample of an actual sun tracking for 10 minutes.

As shown in Fig. 9 , the responses of the tracking control system are different for the same sequential 0.1° step input, which shows different steady error due to the system inertia and disturbances. Tracking accuracy within 0.4° is achieved. Fig. 10 shows the system response of the sun path tracking for 10 minutes sample inputs.

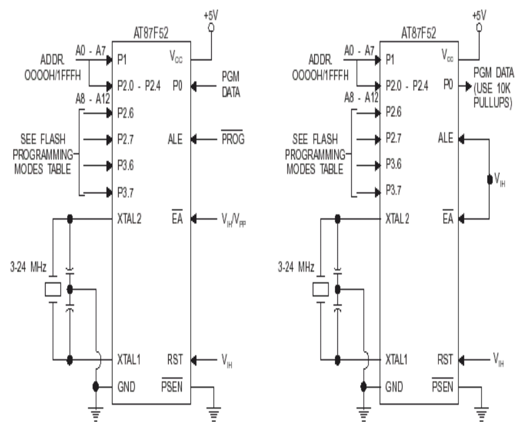

Figure 8 a. Flash Programming b. Flash Verification [7].

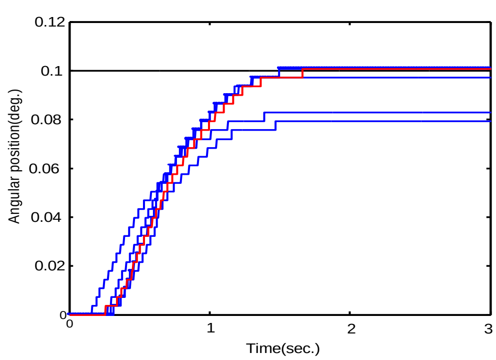

Figure 9 Different Responses for the 0.1 Step Input.

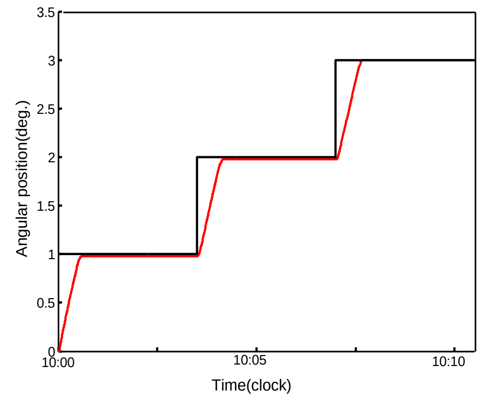

Figure 10 System Response for 10 Minutes Tracking.

6. CONCLUSION

The sun tracking system is developed based on 89S52 microcontroller. The tracking control circuit that used in this system is simple and inexpensive. The microcontroller 89S52 can be embedded into the system, which can make it easy to transport and to work at remotes areas. The experimental results show that the sun tracking system, using On-off controller is accepted when the tracker mount is carrying flat PV panels.

7. FUTURE WORK

As expected from the observing our experiments results that the tracking system doesn't work well in the presence of disturbances (e.g. load torque disturbance and wind torque disturbance). The system performance will not be accepted when the tracker carries a concentrating solar collector to align its focal area with sun. Research into solving this problem would be followed applying advanced microcontroller based intelligent controllers.

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