

POSITION CONTROL OF SOLAR PANNEL

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ABSTRACT

Photovoltaic systems normally use a maximum power point tracking (MPPT) technique to continuously deliver the highest possible power to the load irrespective of the temperature and irradiation conditions and of the load electrical characteristics. The main difference between the method used in the proposed MPPT system and other techniques used in the past is that the PV array output voltage is used to directly control the position of solar panel, thus reducing the complexity of the system. A simple method of tracking the maximum power points (MPP's) and forcing the system to operate close to these points is presented. This paper details the proposed work to design the solar tracking system based around the microcontroller programmable IC. The solar panel is in the form of array of photovoltaic cells. The operation of the solar panel is actuated by means of the final control element (FCE). The FCE used is stepper motor. For the optimum utilization of solar energy the position of solar panel in the form of photovoltaic array is controlled in accordance with the position of optical electronic sensors located at particular angle of elevation of light rays with respect to ground.

The physical model consists of solar panel in the form of photovoltaic cells; to which the stepper motor with its extended shaft is fabricated. The minimum necessary hardware interfacing circuit associated with microcontroller and the stepper motor is designed and fabricated. The control functions are implemented using 8051Microcontroller based hardware and software. The proposed model resembles the features of solar tracking system, which can be used in usual practice. The experimental results show that the use of the proposed MPPT control increases the PV output power by as much as 10-15% and hence the resulting system has improved high-efficiency, lower cost and can be easily modified to handle more energy sources.

Key Words- Maximum power point tracking, microcontrollers, photovoltaic systems, solar array, battery charging.

I. INTRODUCTION

As Conventional sources of energy are rapidly depleting and the cost of energy is rising, photovoltaic array becomes a promising alternative source. The major advantages associated with PV array are that it is 1) abundant; 2) pollution free; 3) recyclable; 4) installation cost is considerably high and energy conversion is relatively low. To overcome these problems, the following two essential ways are used: 1) increase the efficiency of conversion for solar array and 2) maximize the output power from the array. With the development of technology, the cost of solar array is expected to decrease continuously in making them attractive for

residential and industrial applications. The solar power is used in two particular forms thermal and photovoltaic. The first concentrates sunlight, converts it into heat, and applies it to a steam generator or engine to be converted into electricity. The second form of solar power produces electricity directly without moving parts. The photovoltaic system is composed of cells made of silicon. The power is produced when sunlight strikes the semiconductor material and creates an electric current. The smallest unit of the system is a cell. Cells wired together form a module, and modules wired together form a panel. A group of panels is called an array, and several arrays form an array field. An array of Photovoltaic cells is shown in Fig.1.



Figure 1. Array of PV Panels.

The various methods of maximum power tracking have been considered in photovoltaic power applications [1]-[8]. Of these the perturbation and observation method (P&O), which moves the operating point toward the maximum power point by periodically increasing or decreasing the array voltage, is used in many photovoltaic systems [3]-[6]. In the proposed work one of the P&O method is used to improve the cell's efficiency so as to lower the cost of solar energy. It has been shown that the P&O method works well when the insolation (the total energy per unit area received from the sun) does not vary quickly in time [9].

There are only two primary disadvantages to using solar power: amount of sunlight and cost of equipment. The amount of sunlight a location receives varies greatly depending on geographical location, time of day, season and clouds. This disadvantage is directly eliminated for a tropical country like India, which receives solar insolation for about 300 days in a year. The best way of lowering the cost of solar energy is to improve the cell's efficiency. The efficiency of a solar cell is very low, only about 10% -12%, and hence the solar cells are connected together to form solar module which are further connected together to form solar panels. Several panels are connected to form the solar array. Still the full potential of the array cannot be utilized as the amount of radiation falling on the panel varies according to the position of the sun. The output can be increased further by about 30% by adjusting the orientation of the solar panel according to the position of the sun [10].

In this work based on P&O approach a solar tracking system is designed for position control of solar panel. A solar tracking system comprises of the following main components-

1. Solar panel with sensing elements (LDR).
2. Programmable microcontroller IC (Atmel make 'AT89C51').
3. Associated interfacing hardware for the programmable IC and FCE.
4. Stepper motor (FCE).

The position control of solar panel for maximum utilization of solar energy is carried out in accordance with the perpendicular direction of sun's rays on the solar panel. To achieve this control feature, the 8051 microcontroller programmable chip is used. The stepper motor is used as the final control element. The necessary hardware interfacing and software assembly language programming (8051) is done. The pro-to-type model is designed and fabricated to execute the position control operation of solar panel for the point of view of optimal utilization of solar energy. With the associated in built features of microcontroller like internal ROM, RAM, Timer/Counter and I/O ports, the external hardware interfacing requirements are drastically reduces which in turn reduces the power supply requirements. Hence solar tracking system designed around 8051-Microcontroller programmable device facilitates its use from the point of view of increase in efficiency, lower cost and reliable operation.

II.FORMULATION OF WORK AND SUGGESTED APPROACH

A solar tracking system is designed around 8051 microcontroller. The physical model for maximum utilization of solar energy is comprise of an array of photovoltaic cell in the form of solar panel, stepper motor as FCE, LDR's as a sensor elements, a programmable 89C51 microcontroller IC. The block diagram of proposed system is shown in Fig. 2.

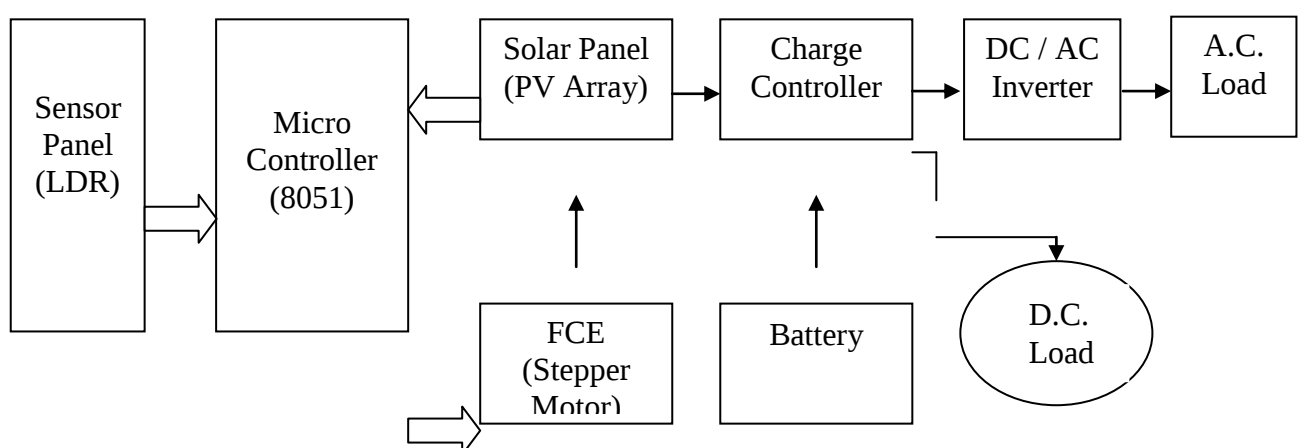


Figure 2. Block Representation of Proposed System

A solar panel in the form of array of photovoltaic cells is used. The basic function of the solar panel is on the lines of the principle of operation of photo voltaic cells. The basic operation of solar cell is that it converts the radiation of sun to useful dc electric power. The array generates power flow towards the battery in order to

charge the battery (lead sulphuric acid battery). The photo voltaic cell consists of thin silicon films of P-type and N-type material simultaneously placed over each other. The design and implementation of the solar system is intended to provide the electrical power for operating the domestic load like a lighting load comprising of 2 – 3 ceiling fans & fluorescent lamps. A dc/ac inverter block is used to meet the requirement of the necessary a. c. electrical load at the appropriate voltage & frequency. The specifications of solar panel in use are as under-

1. Power rating –1KW
2. Voltage rating-230V D.C.
3. Current rating-5.0 Amps.

. The stepper motor is used as final control element to actuate the operation of solar panel. However the microcontroller programmable device executes the desired necessary control action. The stepper motor is a direct digital actuator. It provides an accurate angular positioning in the open loop configuration. The number of control pulses required for specific angular displacement is determined on the basis of step angle. The solar panel is mounted on the extended shaft of the stepper motor. The basic functional operation of the stepper motor is based on minimum reluctance. A Variable reluctance type stepper motor of following specifications is used –

1. Torque= $T=10.0$ Kgf-cm.
2. Voltage Rating =+12 V. D. C.
3. Rated Current= $I=0.8$ Amps.
4. Step Angle= 1.8 (Deg.)

The specifications are determined on the basis of inertia, friction and load torque requirements of solar panel.

In the proposed design of model, Light dependent resistors (LDR) are used as optical sensor elements to sense and realize and then intimate the programmable IC about the intensity of the sunrays in varied direction and angles. The LDR is a special type of analogue sensor that reacts to the change in the light level. The resistance of the LDR changes as different amount of light falls on top window of the device. The resistance decreases as the amount of light falling on it increases. In return in output it provides a varying voltage signal.

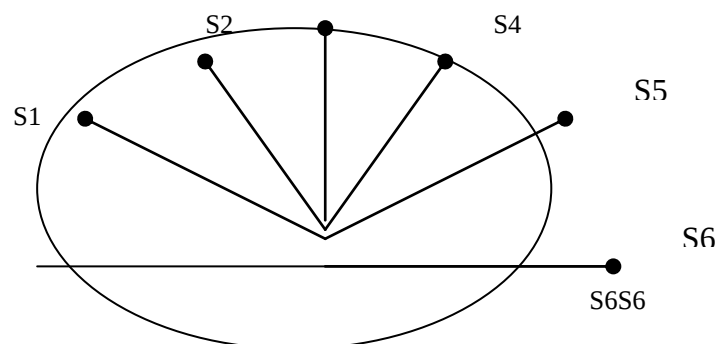


Figure 3. Sensor Panel

In the proposed work in order to determine and adjust the position of the solar panel with respect to the position of the sun, a sensor panel is designed and fabricated. Fig. 3 depicts a sensor panel to accommodate and mount several numbers of LDR as sensors at different angular displacement positions on the semi-circular arc. The

computation of desired position is based on the step angle of the stepper motor i.e. 1.8° . Keeping in view the step-angle; in all '06' No's of LDR are placed on the rim with each and every one of them is approximately 36-degree apart. The LDR sensors receives an optical signal in the form of rays of light incident on it from sun, which in turn provides an analogue input to I/O port pins of 8051 microcontroller. The analogue input is in the form of pulsated d. c. of specific frequency in the tune of several KHz. It is converted to digital format by 8-bit programmable A/D (voltage to frequency) converter.

The 8051 assembly language program does the input scanning and processing to compute the maximum voltage. This data is stored in one of the memory location of an extended EEPROM memory of 8051 microcontroller as a present voltage. The addresses of the various sensor elements are defined in the monitor program. The data content stored at the address of the corresponding LDR device is the binary equivalent of its angular displacement position on the solar panel. This data is then stored in some other memory location of same EEPROM as a present position. The input scanning and processing is done at the preset regular interval of time to reduce the power consumption level in control circuit. Each and every time controller computes the present voltage as well as position and compares it with the previous values. The comparison of voltage measurement determines the direction of rotation of stepper motor and in turn provides the necessary bit pattern at one of its I/O Port-pins to drive the final control element. The comparison of position determines the step angle and in turn the number of pulses required to operate the stepper motor in the determined direction.

III.HARDWARE DESIGN

The microcontroller is programmed either in ideal or power saver mode to perform input scanning and processing at a regular interval of time to save the energy and to reduce the power consumption level in control circuit. A Fig.4. Illustrates an overall hardware interface circuit.

LED displays are used as an external output device for monitoring the output of solar panel. The interfacing of microcontroller with power supplies, LDR sensor panel, solar panel, stepper motor, keyboard interfacing, seven segment LED displays interfacing in continuous scan mode forms external hardware interface design. The major components of hardware interface circuit of the system consists of

1) Power Circuit Block - It provides the power supply requirements for various blocks of hardware interface circuits operating at different voltage levels.

2) The switching control circuit is designed for the rated current of 0.8 Amps. The BC-547 N-P-N transistor Darlington pair with the effective current gain (100x100) is used as a switching element to maintain the minimum base drive current requirement well near to the specified 80 micro-amps for 8051 microcontroller [11].

3) **A/D Converter** –The 8-bit programmable A/D converter is used at I/O Port 1 pins of (Port 1.X) microcontroller to provide binary equivalent of analogue output of various LDR sensing elements placed at different positions on solar panel

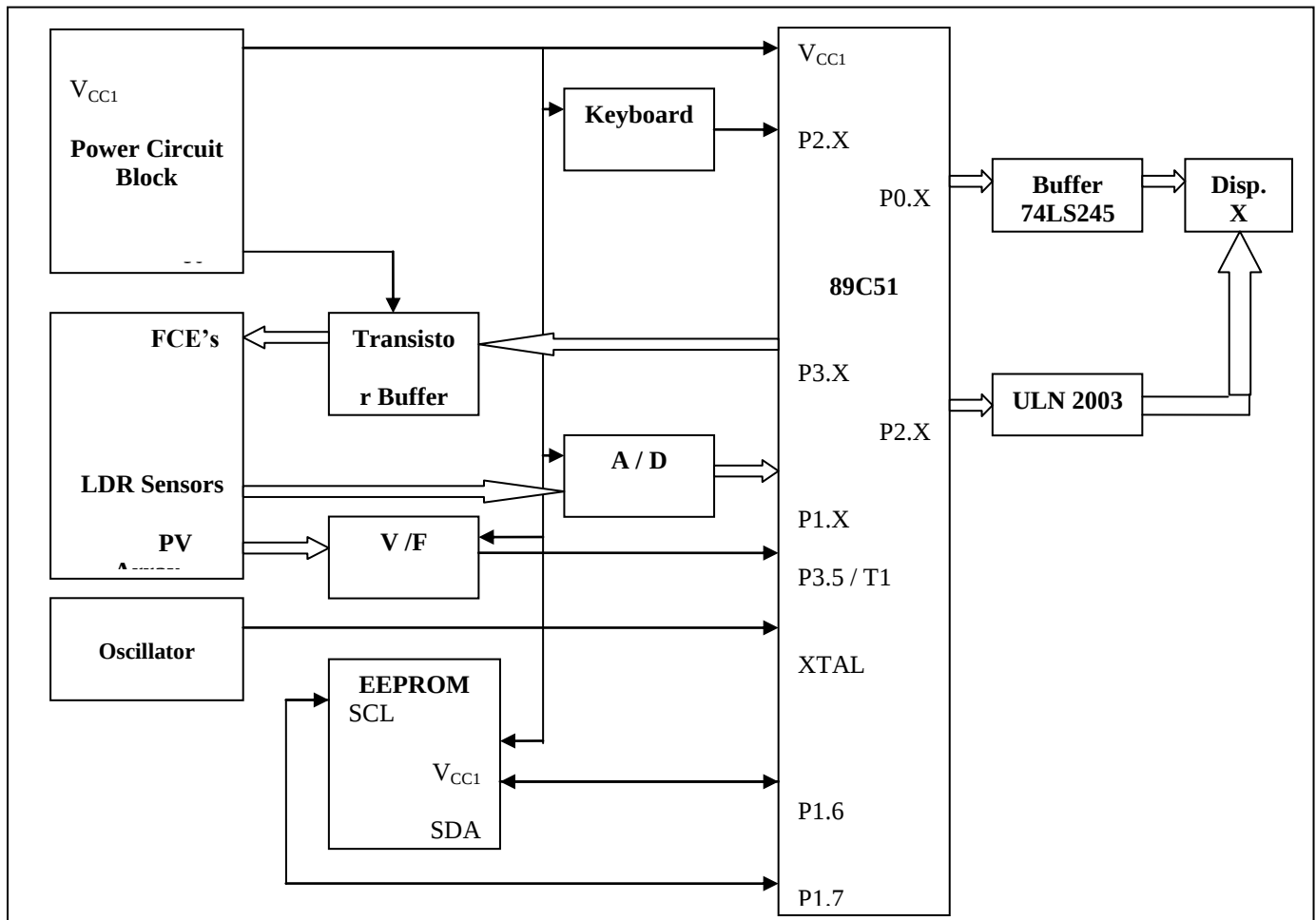


Figure 4. Block Diagram of Hardware Interface of Microcontroller Based Solar Tracking

bit pattern drives the stepper motor as a final control element to actuate the controlled operation of solar panel.

The Transistor driven buffer driver circuit forms an

4) interfacing circuit between the I/O port pins (Port 3.X) of microcontroller and the stepper motor.

4) V/F Converter -The circuit is designed to provide the display of output of solar panel in place of A/D converter. The analogue output of the photovoltaic array is in the form of pulsated d. c. of particular voltage level. The V/F converter is basically designed to convert the voltage level in the form of train of pulse signal of particular frequency in the tune of several KHz. The Figure 5 represents the schematic diagram of V/F control circuit. Solar Panel Output Voltage

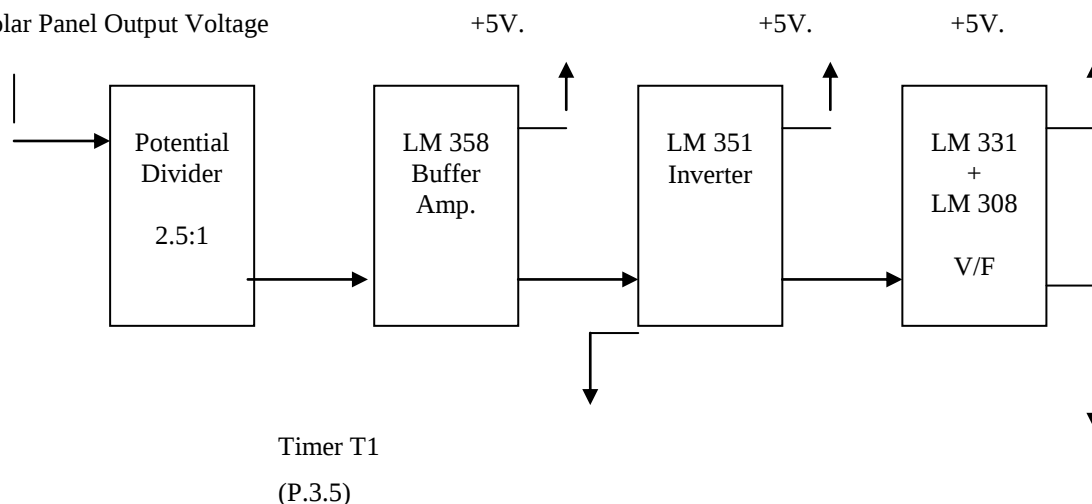


Figure 5. Voltage to Frequency Converter Circuit.

The converted pulses are given to the Timer T1 at pin P3.5 of port 3. The timer T1 is programmed to set in counter mode to count the number of pulses as a measure of output voltage of solar panel.

a. LED Display / Keyboard Interface - In all 'Six' no's of common cathode (CC) type seven segment LED numeric displays are used to indicate the event counting function. All of them are time multiplexed to operate in scan mode. The multiplexing approach overcomes the problem of power consumption faced in static display approach. To match and drive the base current signal in the tune of milliamps for the conduction of about 70 milliamps of current through the inbuilt transistor of LED displays from an output port lines (P2.X) of output port2 of 89C51 microcontroller, an ULN-2003 octal I/O bus driver is used.

A Six-key layout, Lead-per-key keyboard configuration is used. The bit pattern at I/O port pins of I/O port2 i.e. P2.X and in turn common cathode (CC) selection of LED displays are updated in every 2.5msecs. Thus for Six No's of LED displays each LED display is scanned after every 15msecs. In effect the keyboard has 3 keys viz. k2, k3 and k4 and the debounce time, when a key is pressed or released is considered as 45 milliseconds. The other common lead of the keys is connected to P2.6. The status of keys whether they are pressed or released is determined by scanning the logic level at pin P2.6 after every 2.5msecs. The status of one particular key is confirmed by scanning the logic level at pin P2.6 after every 15msecs for three cycles. If at each cycle the logic level at the pin P2.6 is low, then key is considered as a valid key. The 16 bit Timer/Counter 'T0' register is kept busy to handle these internal time chores. It is set in a Timer mode by appropriate setting/resetting of bits in a TCON and TMOD registers with the suitable programming instructions.

b. SERIAL EEPROM (INTEGRAL I²C BUS) INTERFACE

The 8-bit binary equivalent of maximum voltage as a present/previous voltage and the data content of the corresponding addressed LDR sensing element is first stored in the memory register of 128-byte internal RAM. The further processing of 8 bit (byte) data is done as per the execution of code-bytes of 8051 assembly language program stored in the internal 4K bytes of Flash memory (PEROM). To prevent loss of data under power failure, the serial EEPROM is interfaced with 89C51. The serial 24C04A EEPROM device [12] is interfaced with a standard two wire (P1.6-SDA / P1.7 - SCL) serial interface to 89C51 microcontroller. The standard two wire serial interface connections are shown in Fig.4. Only one 8 Pin-Dip 24C04A EEPROM device is connected to the bus.

Oscillator- Quartz crystal or ceramic is used as resonators. The max and min. frequency range is from 1 megahertz to 16 megahertz.

The associated discrete electronic components and integrated circuits IC's along with '89C51' microcontroller device are hardwired and fabricated on same PCB.

IV.8051 ASSEMBLY LANGUAGE SOFTWARE DESIGN

The 8051 assembly language programming is done using Personal Computer. The 'AT89C51' code memory array is programmed byte by byte in high voltage programming mode (V_{pp}/12V) with 'AT89' series programmer [13]. The programmer supports all flash memory microcontroller functions including code READ, code WRITE, Chip ERASE etc. The programmer is connected to an IBM P. C. compatible host computer through one of the host's parallel ports. An integral power supply and external transformer produce required operating voltages. Before programming the "AT89C51" the address data and control signals are set up according to the flash programming mode]. The 8051 assembly language programming is designed to achieve the following features-

- 1) Input scanning and processing of LDR sensing elements to compute the maximum voltage. This data is stored in one of the memory location of an extended EEPROM memory of 8051 microcontroller as a present voltage.
- 2) The generation of several internal software driven time delays interrupts for the continuous scanning of all 'Six ' No's of numeric LED displays and 'Six' No's of keys on six-key layout lead-per key keyboard configuration.
- 3) The Standard Two-Wire Serial Data Interface Serial EEPROM (RD/WR) programming for the storage of present and previous values of voltages and data contents of the appropriate addressed LDR sensor elements.
- 4) The generation and execution of several code-conversions for the display of output voltage of solar panel, display of the preset time interval, reset etc. for the controlled operation of the position control of solar panel.
- 5) The generation and acknowledgement of various key settings for the controlled operation of the process.

The graphical representation of the execution and processing of codes and data byte of the 8051 assembly language program is provided in the main program flow chart. TIMER T1 is programmed in counter mode for input scanning and processing. TIMER T0 is programmed in timer mode for Display and Keyboard Scanning.

V.EXPERIMENTAL RESULTS

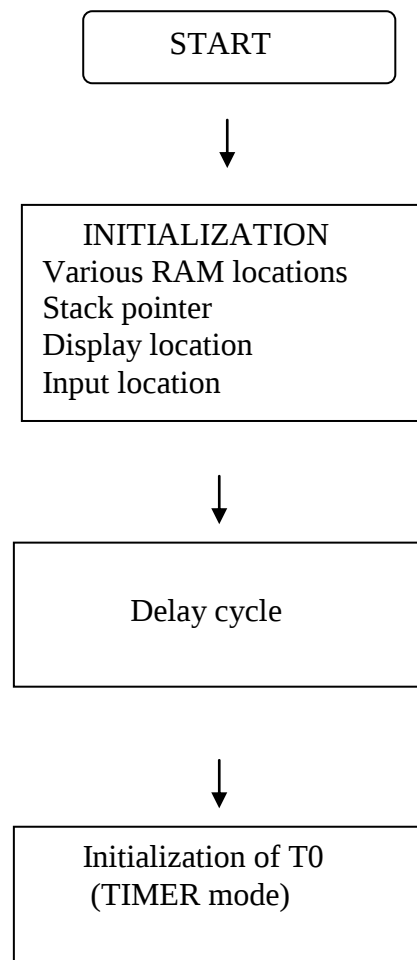
Various hardware and software tests listed below are performed before executing the position control operation of solar panel under microcontroller.

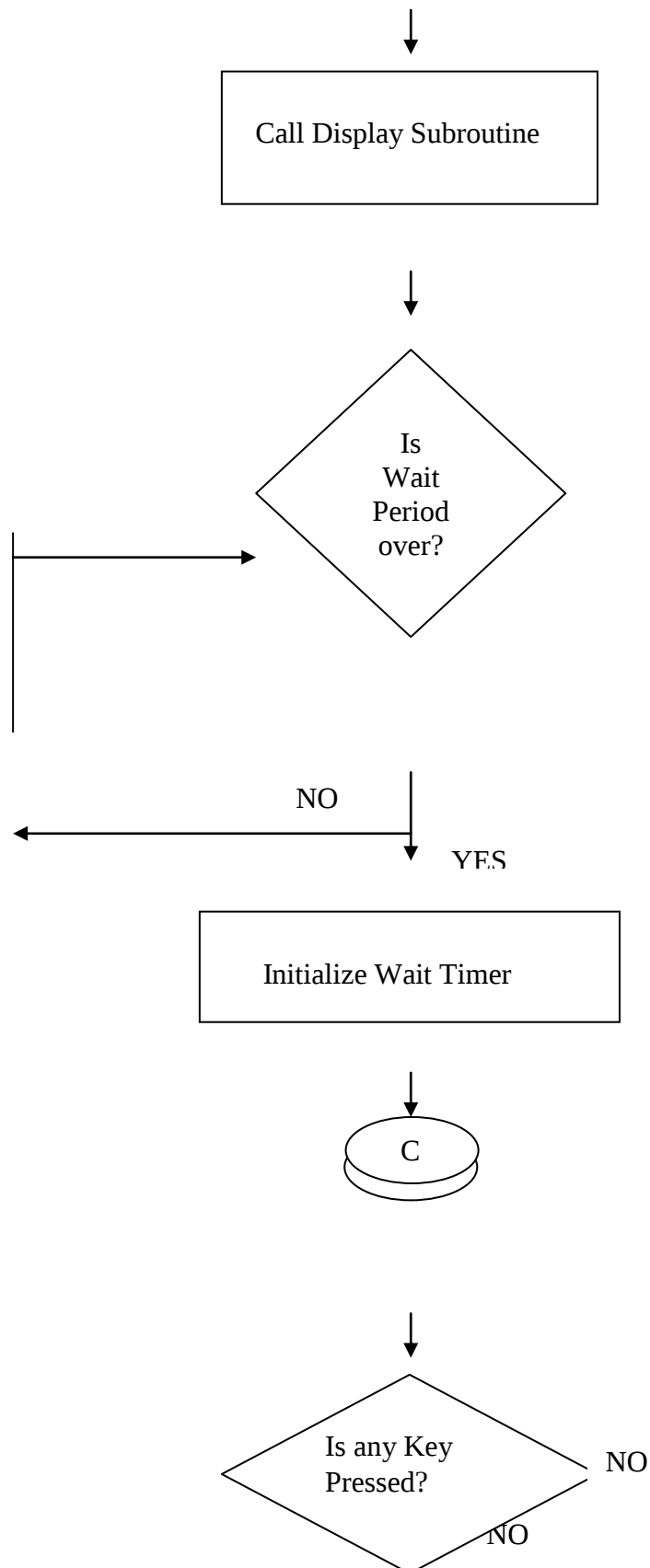
- 1) Typical hardware tests comprise of regulated D. C. power supplies, ALE test for 8051 microcontroller programmable IC on CRO.
- 2) A software test is performed to verify the performance of LED numeric displays operating in scan mode. Similarly another software test is performed to verify the key check in continuous scan mode for valid key.

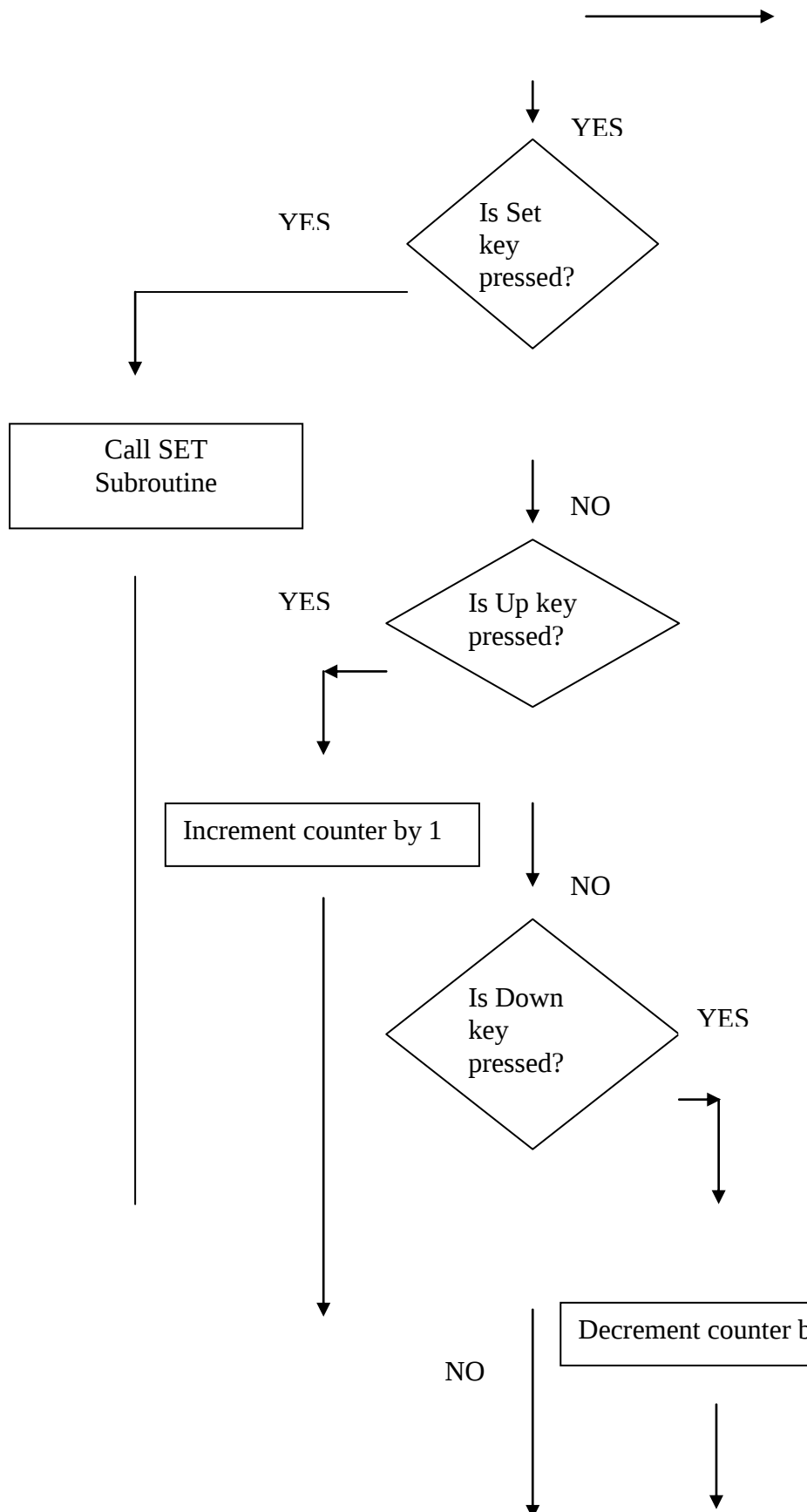
VI.CONCLUSION

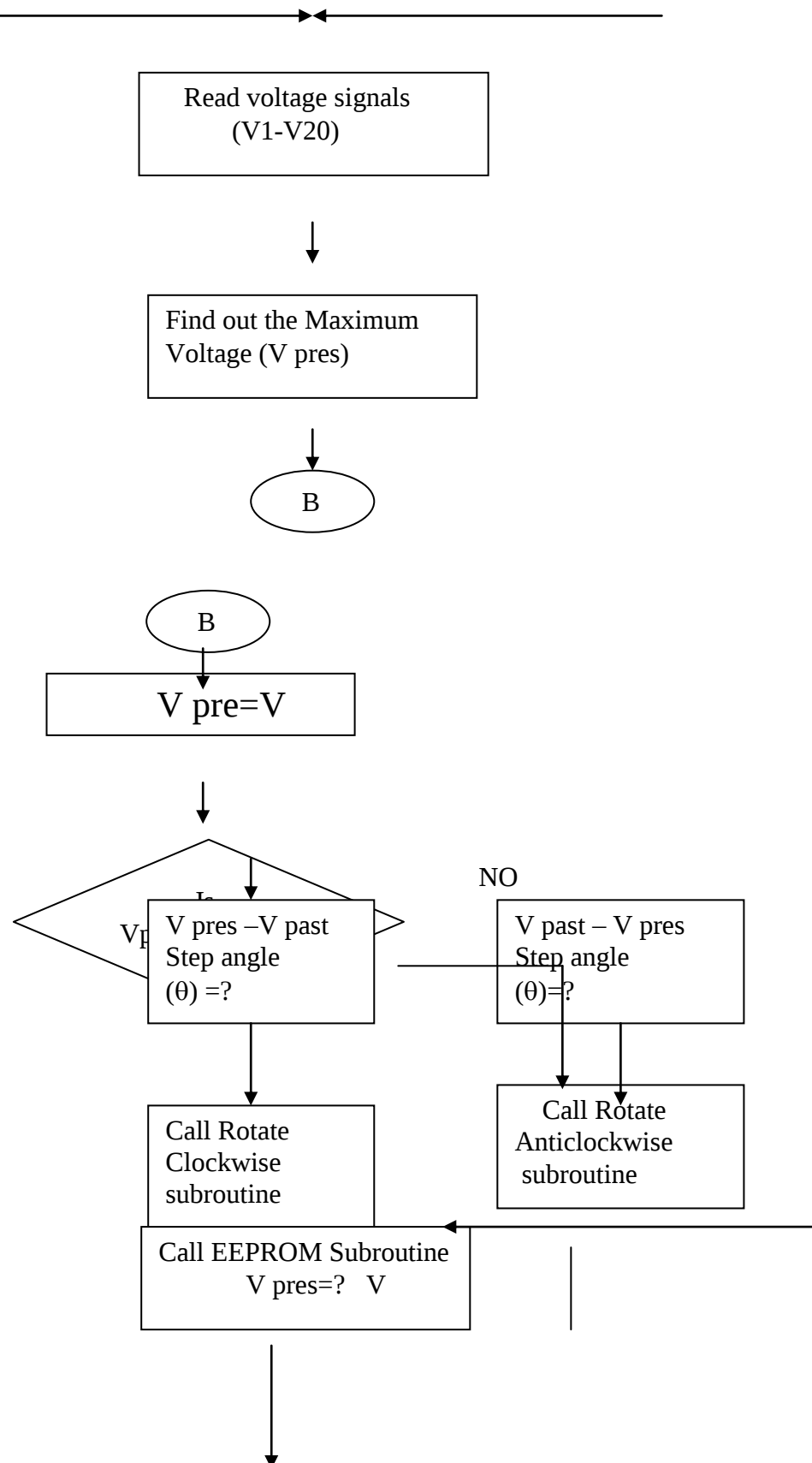
An experimentation work is done for the physical verification of the designed pro-to-type system. Performance test is carried out under direct sunlight throughout the day hours. The model is operated to meet the lighting load requirement for 2-3 flora scent lamps and one ceiling fan for the experimentation cause. The test results confirm the performance of solar tracking system designed around 8051 microcontroller satisfactory.

1. Main Program. Flowchart:









YES

POP Accumulator A, B

RETURN

Table 1. Performance Test

Sr. No.	Approx. Position of Sun (Light Source)	Set Time Interval (60 Min.)	Approx. Position of Solar panel (θ)	Step/Control Pulses (Clk/Anticlk) (Y)	Angular Position (Deg.) $1.8 \times (Y)$	Solar Output Voltage (Volts)
1.	East 0	9.00 a.m.	108/36	40 Anticlk	-72	230V
2.	1	10.00 a.m.	36/36	0	0	230V
3.	2	11.00 a.m.	36/72	20 Clk.	+36	230V
4.	3	12.00 a.m.	72/108	20 Clk.	+36	230V
5.	West 0	01.00 p.m.	108/144	20 Clk.	+36	230V
6.	1	02.00 p.m.	144/144	0	0	230V
7.	2	03.00 p.m.	144/144	0	0	230V
8.	3	04.00 p.m.	144/180	20 Clk.	+36	230V

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