DESIGN AND CONSTRUCTION OF A MICROCONTROLLER – BASED SUN TRACKER

BY

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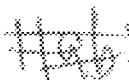
DECEMBER, 2009

DEDICATION

This work is dedicated to Allah, who has been the source of my inspiration, the source of all knowledge and understanding in this world and the hereafter. Also to my late father Mallam Hussaini Sule and my loving mother whose moral and financial contribution can not be overestimated. May almighty Allah reward them both with Jannatul Firdausi ameen.

DECLARATION

I, Habibu Hussaini, declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also hereby relinquish the copy right to the Federal University of Technology, Minna.
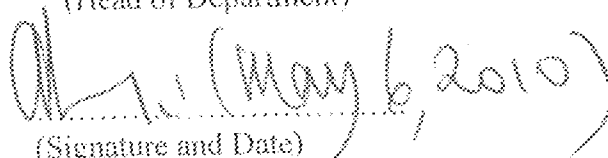
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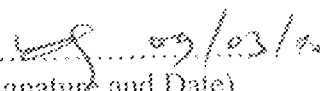Engr. J.A Abolarinwa
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ACKNOWLEDGEMENT

ABSTRACT

This project explores the use of a sun tracking device to improve the efficiency of devices that make use of solar energy. Solar panels help us tap into the immense energy of the sun. However, stationary panels are only optimized for a portion of the day, and only produce a fraction of their maximum power output in the morning and evening. The main impediment to the widespread use of photovoltaic power is the low conversion efficiency and the high cost of solar cells. However, research efforts have been directed towards the use of concentrators and trackers to produce energy in larger quantities. A solar tracking system has been designed to operate on one tracking axis. The tracking is accomplished by a microcontroller and a mechanical assembly to enable the solar cell to seek optimum position for radiant energy. By tracking the sun, the angle of incidence of the sun on the solar panels will be maximized, and the power output from the panels will be near maximum all day. A mechanism for automatic reset and start has been incorporated in the design. The system satisfactory tracks the sun from east to west and reset at sunset, with higher efficiency of conversion compared to the fixed collectors.

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CHAPTER ONE

1.1 INTRODUCTION

The sun is an ever present source of power (energy) of all life on earth. We are living at a time when there is greater awareness of the energy problems facing the world than at any period in history. By going solar, we could be leading the way towards a cleaner world where all our energy demands are tapped from the infinitely free source (the sun) without harming the environment through reducing carbon emission and global warming.

The energy collected by systems that make use of the sun as their source (such as a solar panel) s always dependent in part of the angle of incidence of the sun upon the collector (i.e. panel). Traditionally, most the collectors are mounted on a fixed position, which lives them in a sub- optimal orientation for most of the day. The various movements of the earth make the solar irradiation pattern to vary with time of the day and year. As a result, it becomes impossible to collect maximum irradiation during the day with fixed collectors. Therefore, it becomes obvious that consistent alignment of the collectors must be ensured to always obtain maximum irradiation from the sun. [1]

The sun tracker is an automated system that actually follows the sun for increase power. The tracking was accomplished by a microcontroller. The need to reduce the circuit complexity and other shortcomings of purely electronic system led to the introduction of the microcontroller.

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1.2   AIM AND OBJECTIVE

> The main aim of this project is to apply microcontroller to control a sun tracker.

> To ensure consistent alignment of the collectors surface with the sun to always obtain maximum radiation from the sun.

> To ensure maximum utilization of energy from the sun.

> Due to the continuous demand for multipurpose, multifunctional, less complex and highly flexible process, a microcontroller was incorporated to obtain high efficiency, reliable and easy to use systems.

1.3 METHOLOGY

The sun tracker is an automated system that is tracking the sun at a constant angular velocity, which approximately following the sun's path.

The drive method is as simple as a gear motor that rotates at very slow average rate of one revolution per day (i.e. 15 degrees per hour).

An electronic controller is embedded to coordinate system operation, with a real time clock that is used to infer the "solar time" (hour angle). Tracking adjustment can be made incrementally or continuously.

1.4   SCOPE OF THE PROJECT

A Sun tracking system is designed based on single axis tracking on the equatorial axis for tracking the sun from east to west daily. The system which is time based is to be controlled by the Atmel 8951 microcontroller and its peripheral devices, to provide the

correct pulse sequence for driving a DC motor which is connected to the tracking module consisting of the collector.

In this project design, the sun tracker uses a real time clock to determine the position of the sun and follow its movement. This makes the system design less complex, weather resistant and highly efficient. This project design did not use solar illumination feedback which involves using the observed effects of the sun to attempt to determine its position and follow its movement. Such a system will therefore be weather dependent, error prone n result to an increase in system complexity.

1.5 PROJECT OUTLINE

Chapter one gives a general introduction of what the project is all about, its aims and objectives, methodology and scope of the project.

The previous work done with respect to this project is discussed as the literature review of chapter two.

Chapter three covers the various steps taken in the design and implementation of the project wok and calculations involve.

The tests carried out, result obtained and discussion of such results come under chapter four.

The conclusion and recommendation constitutes chapter five.

CHAPTER TWO

LITERATURE REVIEW

2.1 HISTORICAL BACKGROUND

The earliest known record of the direct conversion of solar radiation into mechanical power belongs to Auguste Mouchout, a mathematics instructor at the Lyce de Tours. Mouchout began his solar work in 1860 after expressing grave concerns about his country's dependence on coal. By the following year he was granted the first patent for a motor running on solar power and continued to improve his design until about 1880. During this period the inventor laid foundation for our modern understanding of converting solar radiation into mechanical steam power.

Mouchout initial experiment involved a glass- enclosed iron cauldron: incoming solar radiation pass through the glass cover, and the trapped ray's transmitted heat to the water. In late 1865, he succeeded in using his apparatus to operate a small, conventional steam engine. By the following summer, he enlarged his invention's capacity, refined the reflector, redesigning it as a truncated cone, like a dish with slanted sides, to more accurately focus the sun's rays on the boiler. Mouchout also constructed a tracking mechanism that enables the entire machine to follow the sun's altitude and azimuth, providing uninterrupted solar reception.

William Adams, the deputy register for the English Crown in Bombay, India built a large rack of many small mirrors and adjusted each one to reflect sunlight in a specific direction. To track the sun's movement, the entire rack could be rolled around a semicircular

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track, projecting the concentrated radiation onto a stationary boiler. The rack could be attended by a laborer and had to be moved only three or four times during the day, or more frequently to improve performance. Adam's legacy of producing a powerful and versatile way to harness and convert solar heat survives. Engineers today know this design as the *Power Tower Concept*, which is one of the best configurations for large scale centralized plants.

As the years wore on, newer methods were designed for collecting power as well as tracking the sun. These included; Engineer Charles Tellier's method of collection without reflection. By 1889 Tellier had increased the efficiency of the collectors by enclosing the top without glass and insulating the bottom. Around 1870, U.S engineer john Ericsson invented a novel method for collecting solar rays known as parabolic trough. A parabolic trough is more akin to an oil drum cut in half lengthwise that focuses solar rays in a line across the open side of the reflector. This type of reflector offered many advantages over its circular counterparts: it was comparatively simple, less expensive to construct, and unlike a circular reflector, it only track the sun in a single direction thus eliminating the need for complex tracking machinery. The downside was that the device's generated energy and efficiencies were not as high as with a dish- shaped reflector. The first commercial Venture was by Aubrey Eneas who began his solar motor experimentation in 1892, and formed the first solar power company (The solar Motor Co.) in 1900. Though the machine did not become a fixture as Eneas had hoped, the inventor contributed a great deal of scientific and technical data about solar heat conversion and initiated more than his share of public exposure. [2]

2.2 PREVIOUS WORKS

Over the years, much developmental work has been carried out in the solar energy domain and the scope of research conducted during the intervening two to three decades is quite diverse and fruitful result being approximating a process of explosion since the first fuel crisis in the earth 1870s and solar research programme began to grow and multiply on many fronts.

The solar energy experts at Denver – based Conergy Americas and officials at California's South San Joaquin Irrigation District (SSJID) have installed what is believed to be the world's first single – axis solar tracking system featuring thin – film cells. The sun tracker is an automated solar panel that actually follows the sun for increased power. The system is capable of rotating over a 160 degrees east to west, the sun tracker will increase the power output of photovoltaic arrays by over 200% by keeping the face of the panels parallel to the sun throughout the day. [3]

Frank Shuman among solar energy pioneers declared more than 80 years ago, the sun is the most rational source of power. Shuman developed a sun tracker which tracks movement of the sun across the sky. The mirrors would turn to keep the rays focused on the tower, where oil was heated to 300 degrees Celsius. The heat from the oil was used to generate steam which then drove a generator capable of providing 10kW of electrical power. That is a fair amount of power . Power generated by harnessing the energy from the sun. Solar one was very expensive to build, but as fossil fuels run out and become more expensive, solar power station may become a better option. [4]

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In the 1950s, the Philips research laboratory in Eindhoven, Holland, conducted a successful large – scale research programme concerned with the fabrication of solar illumination solar tracker, his research achieved an efficiency equal to that of contemporary internal combustion engine. Two Indian scientists, Cihai and Khanna, constructed a sun tracking system in New Delhi using solar position data would look up or calculate the sun's path for a given day, and would follow that path. Such system allow for very good tracking accuracy. However, this approach is also the most complex, and for a system as small as this, such control is not necessary. They used the heat from a parabolic collection surface to develop 1/6 hp hot – air engine operating at 100 – 1200°F. [5]

The past 25 years have witnessed the emergence of various methods of solar energy collection as a result of the improvement in technology witnessed within this period. Some of our brightest engineers have even produced some exemplary designs during the period.

A shadow method for automatic tracking, which is an automatic method that uses 'back- to- back' semi-cylinders to mask solar irradiation was described and presented for publication at the Solar World Congress 1987 in Hamburg by Sode Shinni Nmadu Rumala. [6]

A time-based solar tracking system was also designed based on single axis tracking, on the equatorial tracking axis to track the sun from east to west daily during sun hour periods in October 2006, by Jabir Garba. An open loop control mode was adopted using logic control circuit and suitable interface for the stepper motor and other circuitry. [7]

In April 2008, Audi Ibrahim realized Microprocessor-based solar tracker. The system which is time based is to be controlled by the INTEL8085 Microprocessor and it peripheral devices. [8]

So many projects which have been realized are designed to be of the discrete electronic devices which offer numerous shortcomings like low speed of response, low accuracy and power consumption. In this project, most of these lapses have been done away with.

In this project, modification and improvement was done. Design and implementation of a microcontroller-based sun tracker is realized, offering advantages of high accuracy (very minimal error). The basic innovation in this project is the automatic nature of the sun tracker, which allows the system to comes on during the day (from 6AM to 6PM) and goes off during the night (from 6PM to 6AM) when is not needed to reduce power consumption. Also, the ability of the system to adjust to the time set by the user, thus making it user friendly. A microcontroller was incorporated into the system to reduce the use of discrete components, as result making the system design less complex, straight forward and cheap in terms of cost. Finally the overall system is small in size as compared to earlier design realized which are massive in size.

CHAPTER THREE

3.1   THEORETICAL BACKGROUND

The circuit design of a microcontroller based sun tracker is carried out in module as represented below.
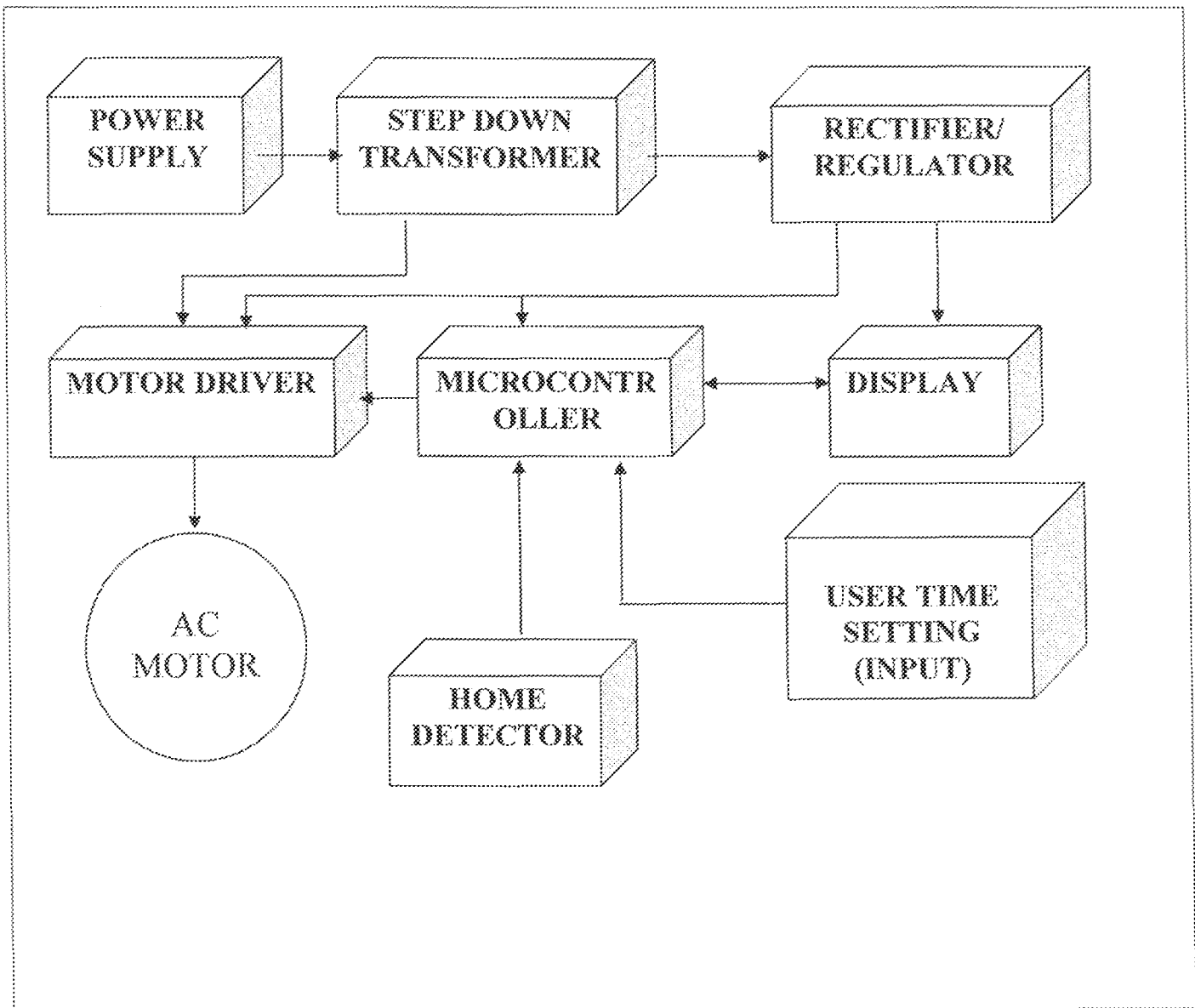
Fig 3.1 Block Diagram of a Microcontroller Based Sun Tracker

3.1.1   POWER SUPPLY UNIT

Most electronic devices require dc voltage to operate. Therefore, batteries are very useful in low power or portable devices but the operating time of such devices is limited unless the batteries are recharged or replaced constantly. The more readily available source of power is the 50Hz, 240v ac outlet. Where a dc voltage is required, a dc power supply circuit may be employed to convert the ac voltage to a dc voltage. A voltage regulation may be incorporated in a power supply circuit in order to eliminate the variation of power supply voltage with changing input current. A typical arrangement for dc power supply is shown below;
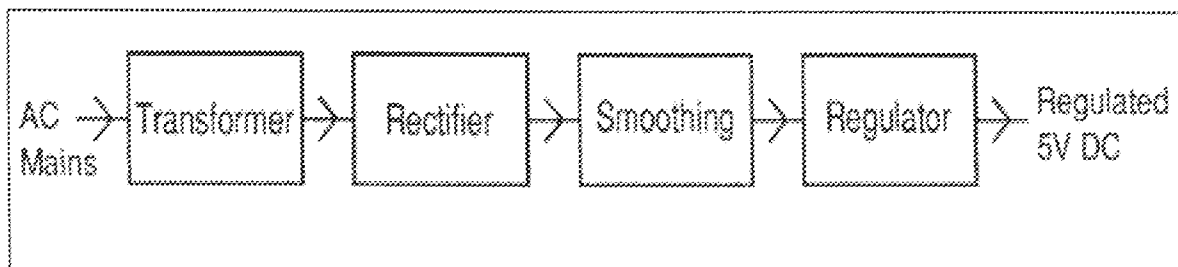
Figure 3.2 Basic Process of a Power Supply System

The process for the conversion of A.C supply to D.C is termed "rectification" which has the following components:

1.   Step-down transformer.

2.   Rectifier.

3.   Filter.

4.   Voltage Regulator.

3.1.1.1   STEP-DOWN TRANSFORMER

This is used to reduce the alternating input voltage to a lower level. In this design a 240v a.c is stepped down to 12v a.c which is then rectified and regulated to 5v d.c.
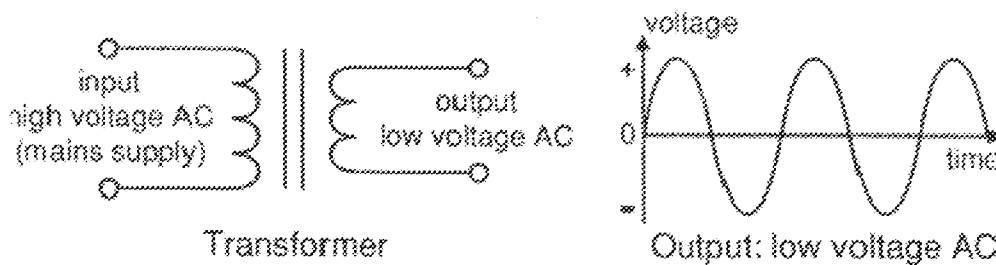
Figure 3.3 Step Down Transformer With Its Voltage Output

3.1.1.2 RECTIFIER

A rectifier is a circuit which employs one or more diodes to convert ac voltage into pulsating dc voltage.

Full wave bridge rectifier circuit is most frequently used for electronic dc power supply. It requires four diodes to convert ac into pulsating dc by eliminating the negative half-cycle of the ac voltage being rectified. The operation is such that; during the positive half cycle of the a.c supply, diodes D_1 and D_3 conducts, while the other two diodes (D_2 and D_4) conducts during the negative half-cycle. The output waveform is shown below;

Fig. 3.4: a full-wave bridge rectifier.

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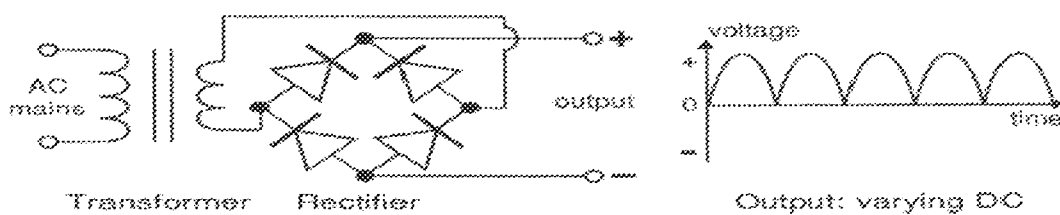
3.1.1.3   FILTER

The function of the filter is to smooth the pulsations present in the output voltage supplied by the rectifier. In practice, no filter gives output voltage that is as ripple-free as that of a battery, but it considerably reduces the ripple to certain extent. A capacitor is used to achieve the filtering as shown below:
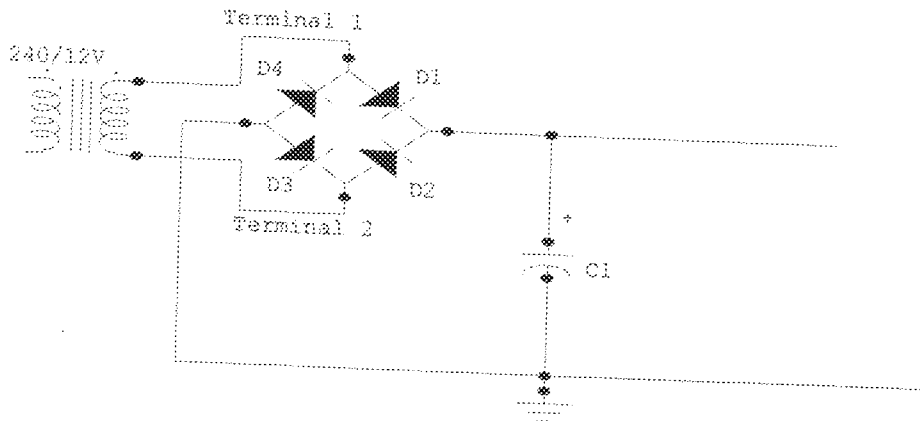
Figure 3.5   Full-Wave Bridge Rectifier
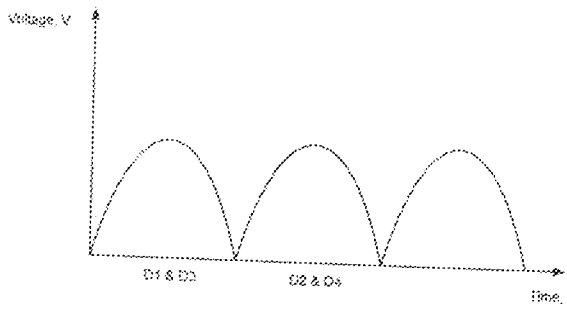
Figure 3.6 Rectified output

3.1.1.4   VOLTAGE REGULATION

In order to keep the terminal voltage of the D.C supply constant, a voltage regulator was used. The regulator used is 7805 since 5V is needed for the system operation. It

maintains a constant D.C supply even when there is a variation of the a.c input from the transformer and when the load varies.

3.1.2   MICROCONTROLLER

The microcontroller that was used is the ATMEL AT89C51. A microcontroller system is a computer on a chip, which can be used to perform a number of desired tasks as defined or instructed by the programmer, using either assembly language (ASM) or compiler (C-language). It consists of the memory, the input device and the output device. For this project the 8051 family was used, specifically the 8951. The microcontroller block diagram is as shown below.
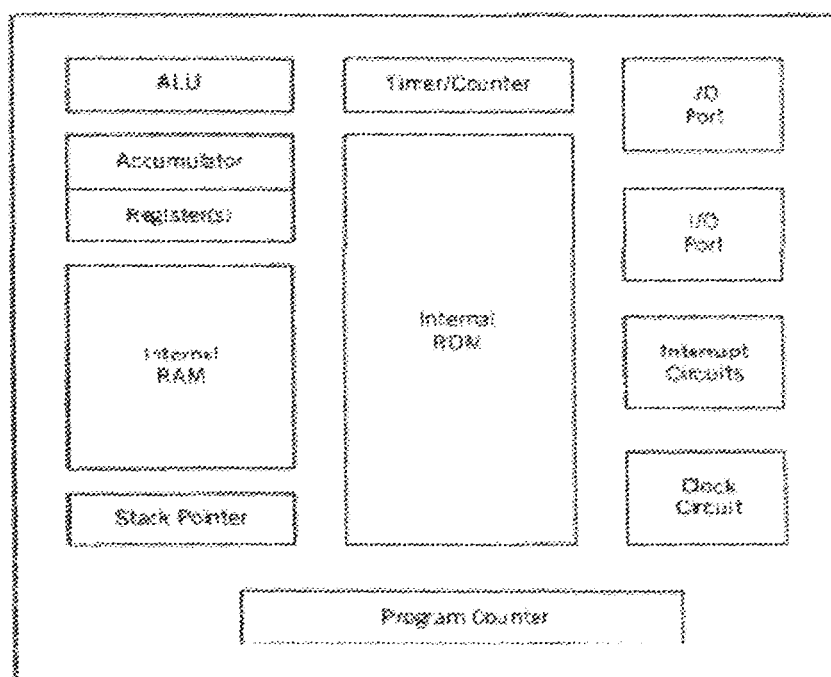
Figure 3.7: Microcontroller Block Diagram

The microcontroller is a semiconductor devise consisting of electronic logic circuits manufactured by using either large scale integration or very-large scale integration technique.

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It is also a programmable logic device designed with registers, flip-flops and timing elements. The microcontroller has a set of instructions which are internally designed and are capable for performing function and making decision to change the sequence of program execution. The microcontroller basically fetch data from the memory and performs the task specified, it also communicates with input/output device to accept or to send data. Generally the microcontroller consist of the arithmetic and logical unit (ALU), the program counter (PC), stack pointer (SP), registers, ROM, RAM, parallel input/output, serial input/output and a clock circuit.
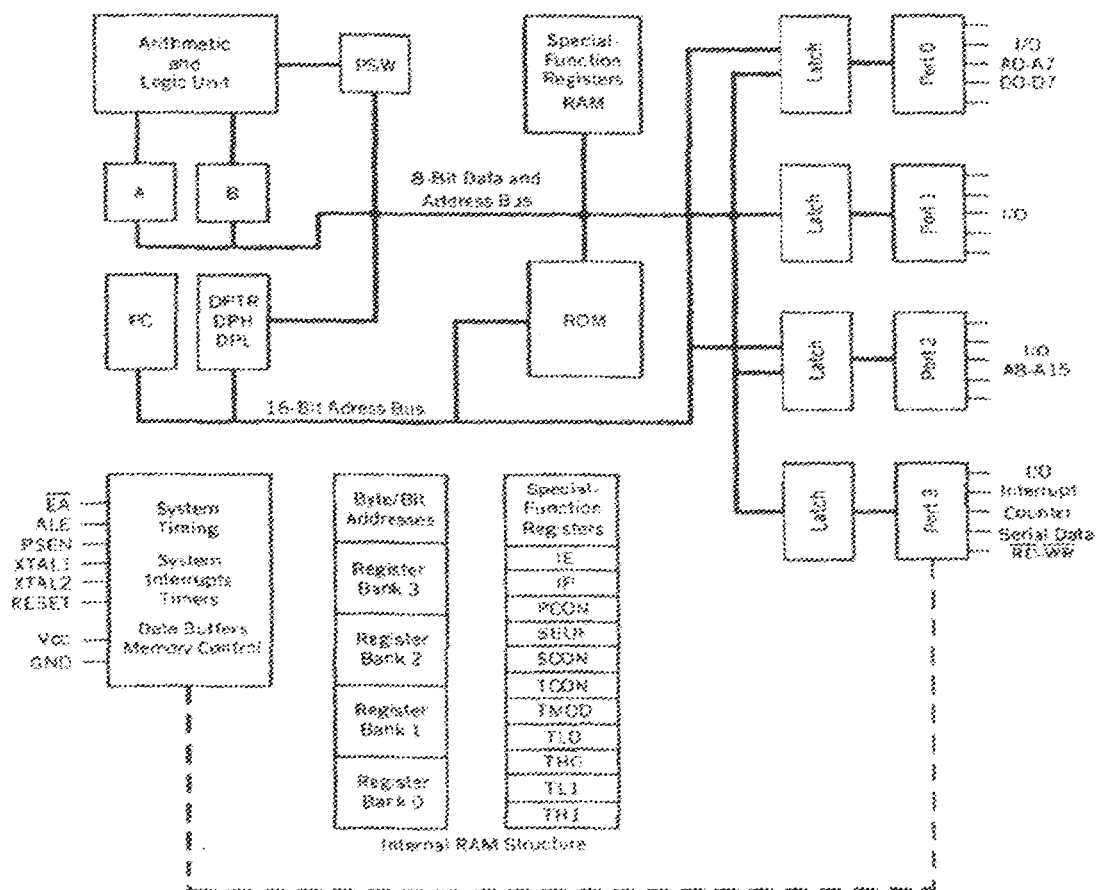
Fig 3.8: Internal Structure Of AT89C51

3.1.2.1 DESCRIPTION OF ATMEL AT89C51

The AT89C51 is a low-power, high-performance CMOS 8-bit microcomputer with 4 Kbytes of Flash Programmable and Erasable Read Only Memory (PEROM). The device is manufactured using Atmel's high density non-volatile memory technology and is compatible with the industry standard MCS-51 instruction set and pin out. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional non-volatile memory programmer.

By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C51 is a powerful microcomputer which provides a highly flexible and cost effective solution to many embedded control applications.

The AT89C51 provides the following standard features: 4 Kbytes of Flash, 128 bytes of RAM, 32 I/O lines, two 16-bit timer/counters, five vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator and clock circuitry.

In addition, the AT89C51 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.

3.1.2.2 PIN DESCRIPTION

The V_{CC} is Supply voltage pin, while the GND is the Ground.

Port 0: It is an 8-bit open drain bidirectional I/O port. As an output port each pin can sink eight TTL inputs. When 1s are written to port 0 pins, the pins can be used as high-

impedance inputs. Port 0 may also be configured to be the multiplexed low-order address/data bus during accesses to external program and data memory. In this mode P0 has internal pull-ups.

Port 0 also receives the code bytes during Flash programming, and outputs the code bytes during program verification. External pull-ups are required during program verification.
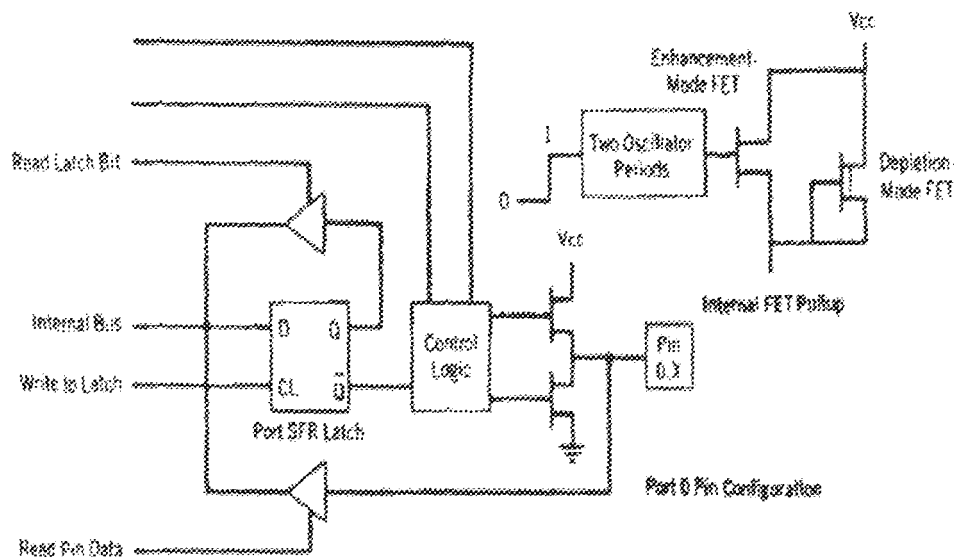
Fig 3.9: Port 0 Configuration

The **Port 1**: is an 8-bit bidirectional I/O port with internal pull-ups. The Port 1 output buffers can sink/source four TTL inputs. When 1s are written to Port 1 pins they are pulled high by the internal pull-ups and can be used as inputs. As inputs, Port 1 pins that are externally being pulled low will source current (IIL) because of the internal pull-ups. Port 1 also receives the low-order address bytes during Flash programming and program verification.
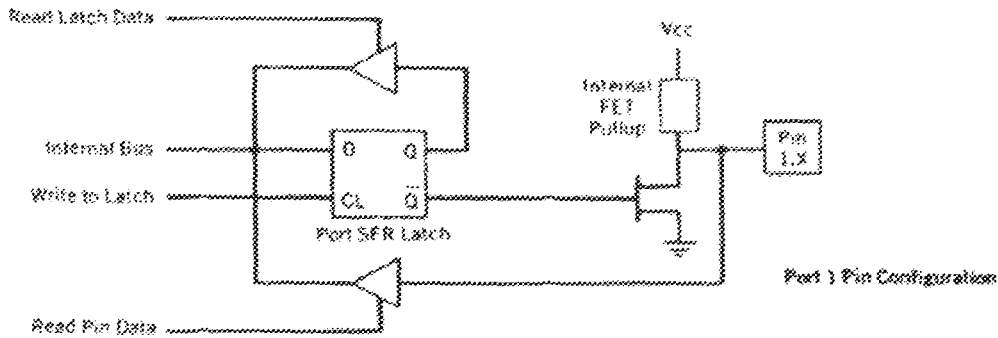
Fig 3.10: Port 1 Configuration

Next is **Port 2**: This is an 8-bit bidirectional I/O port with internal pull-ups. The Port 2 output buffers can sink/source four TTL inputs. When 1s are written to Port 2 pins they are pulled high by the internal pull-ups and can be used as inputs. As inputs, Port 2 pins that are externally being pulled low will source current (IIL) because of the internal pull-ups. Port 2 emits the high-order address byte during fetches from external program memory and during accesses to external data memory that uses 16-bit addresses (MOVX @ DPTR). In this application it uses strong internal pull-ups when emitting 1s.

During accesses to external data memory that uses 8-bit addresses (MOVX @ RI); Port 2 emits the contents of the P2 Special Function Register. Port 2 also receives the high-order address bits and some control signals during Flash programming and verification.
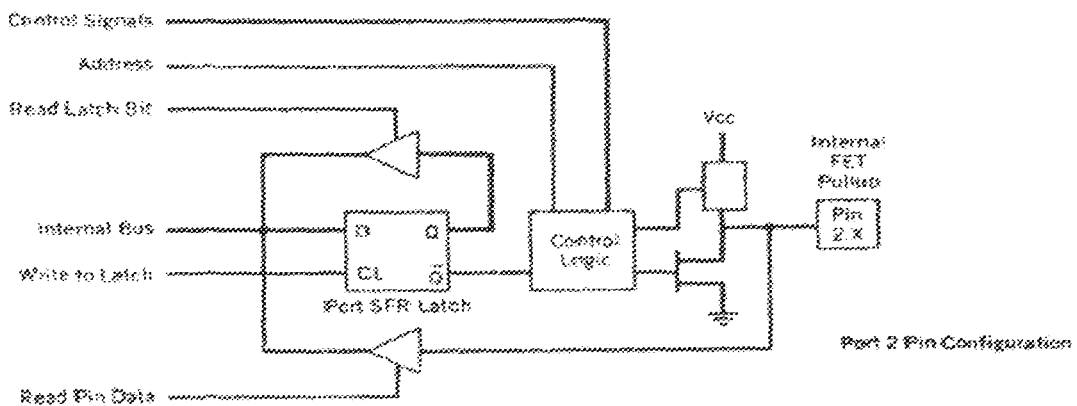
Fig 3.11: Port 2 Configuration

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Port 3: Is also an 8-bit bidirectional I/O port with internal pull-ups. The Port 3 output buffers can sink/source four TTL inputs. When 1s are written to Port 3 pins they are pulled high by the internal pull-ups and can be used as inputs. As inputs, Port 3 pins that are externally being pulled low will source current (IIL) because of the pull-ups.

Port 3 also serves the functions of various special features of the AT89C51: P3.0 RXD (serial input port), P3.1 TXD (serial output port), P3.2 INT0 (external interrupt 0), P3.3 INT1 (external interrupt 1), P3.4 T0 (timer 0 external input), P3.5 T1 (timer 1 external input), P3.6 WR (external data memory write strobe), P3.7 RD (external data memory read strobe). Port 3 also receives some control signals for Flash programming and programming verification.

The **RST** pin is a Reset input. A high on this pin for two machine cycles while the oscillator is running resets the device, while the **ALE/PROG** is Address Latch Enable output pulse for latching the low byte of the address during accesses to external memory.
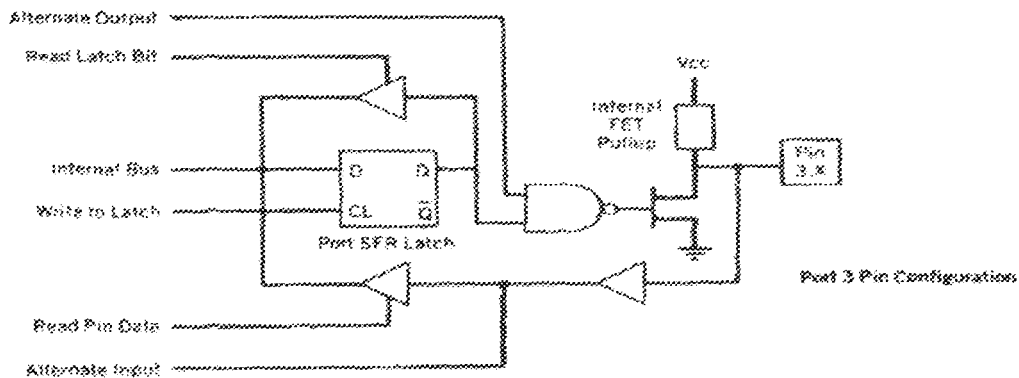
Fig 3.12: Port 3 Configuration

This pin is also the program pulse input (PROG) during Flash programming. In normal operation ALE is emitted at a constant rate of 1/6 the oscillator frequency, and may be used for external timing or clocking purposes. Note, however, that one ALE pulse is

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skipped during each access to external Data Memory. The *PSEN*, which means Program Store Enable, is the read strobe to external program memory. When the AT89C51 is executing code from external program memory, PSEN is activated twice each machine cycle, except that two PSEN activations are skipped during each access to external data memory. For the *EA/VPP* (External Access Enable), EA must be strapped to GND in order to enable the device to fetch code from external program memory locations starting at 0000H up to FFFFH. Note, however, that if lock bit 1 is programmed, EA will be internally latched on reset. EA should be strapped to VCC for internal program executions. This pin also receives the 12-volt programming enable voltage (VPP) during Flash programming, for parts that require 12-volt VPP. [9]

3.1.2.3 OSCILLATOR CHARACTERISTICS

All digital computer systems are driven by some form of oscillator circuit: the 8051 is certainly no exception. The oscillation circuit is the 'heartbeat' of the system and is crucial to correct operation. For example if the oscillator fails, the system will not function at all; if the oscillator runs irregularly, any timing calculations performed by the system will be inaccurate. As a general rule, the speed at which your application runs is directly determined by the oscillator frequency. One popular measure of specifying performance in a quantitative manner is the number of machine instructions that may be executed in one second, usually expressed in 'MIPS'(Million Instructions Per Second). A minimum of 12 oscillator cycles is required to execute a machine instruction. The original 8051 had a maximum oscillator frequency of 12MHz and therefore a peak performance of 1 MIP. More modern (standard) 8051 devices allow the use of clock speed well beyond the 12 MHz limit of the original devices.

A crystal oscillator circuit generates sinusoidal oscillations across an LC tank, which is converted into a square waveform, often using a biased analog inverter. This inverter trips at a designed trip point and amplitude of the input waveform. The performance characteristics of a crystal oscillator generally depend on both the particular cut and the mode of vibration. Each cut-mode combination is considered as a separate piezoelectric element and the more commonly used elements often are designated with letter symbols.

XTAL1 and XTAL2 are the input and output respectively, of an inverting amplifier which can be configured for use as an on-chip oscillator, as shown in Figure 2.17(a). Either a quartz crystal or ceramic resonator may be used. To drive the device from an external clock source, XTAL2 should be left unconnected while XTAL1 is driven as shown in Figure 2.17(b). There are no requirements on the duty cycle of the external clock signal, since the input to the internal clocking circuitry is through a divide-by-two flip-flop, but minimum and maximum voltage high and low time specifications must be observed. [10]
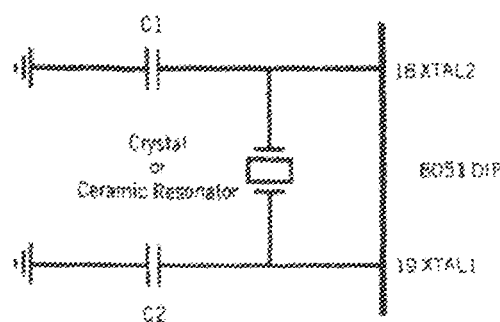
Fig 3.13 (a): Crystal Oscillator Circuit
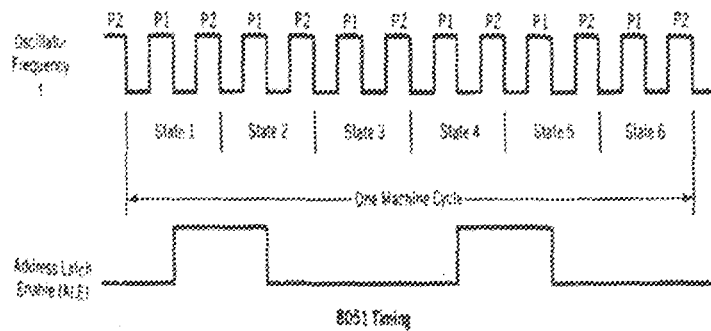
(b):AT89C51 Timing Diagram

3.1.3 OPTICAL ISOLATORS (MOC 3023)

Optical isolators are designed to electrically isolate one circuit from another while allowing one circuit to control the other. The usual purpose of isolation is to provide protection from high voltage transients, surge voltages and low level electrical noise that could possibly result in an erroneous output or damage to the device. Such isolators allow interfacing of circuits with different voltage levels and different grounds etc.

An Optical isolator consists of a light source such as LED and a photodetector and is available in a standard IC package. When LED is forward biased, the light produced by it is transferred to the photodetector which is turn ON thereby producing current through the external load.

It can be used in applications where a low-level input voltage is required to latch a high voltage relay for activating some kind of electro-mechanical device. [11]

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3.1.4 POWER TRIAC

A triac has three terminals A1 (anode), A2 (anode) and G (gate). The gate is closer to anode A1. A triac is nothing but two inverse parallel- connected SCRs (Silicon Controlled Rectifiers) with a common gate terminal. One fundamental application of power triac is to control ac power to a load by switching ON and OFF during positive and negative half cycles of the input ac power and for motor speed control. [11]

3.1.5 A.C MOTOR

An electric motor is a machine which converts electric energy into mechanical energy. As a general rule, conversion of electrical power into mechanical power takes place in the rotating part of an electric motor. In D.C motors, the electric power is conducted directly to the armature (i.e. rotating part) through brushes and commutator. Hence, in this sense, a D.C motor can be called a conduction motor. However, in A.C motors, the rotor does not receive electric power by conduction but by induction in exactly the same way as the secondary of a 2- winding transformer receives its power from the primary. That is why such motors are known as induction motors. [11]

3.1 DESIGN AND IMPLEMENTATION

The sun tracker system was built around the under listed subsystems.

1. System power supply
2. 8 – Bit 89C51 System Controller
3. AC Motor Driver
4. 4 – Digit 7 - Segment Display
5. Tracker's Mechanical Assembly

The system was designed to meet the following requirements.

❖ To provide an automated tracking of the sun in its east – to – west trajectory across the sky.

❖ To provide an automatic positioning of the collector plate as a function of the time set by the user.

❖ To provide a 24 – hour digital clock corresponding with the movement of the sun.

3.2.1   SYSTEM POWER SUPPLY

A DC supply of 5V was required for the control logic and 15V AC for the motor. Both the 5V and 12V supplies were derived from a 220V/15V step down transformer. The 15V AC was rectified into DC by a fullwave bridge rectifier before regulation as shown below in fig. 3.0.
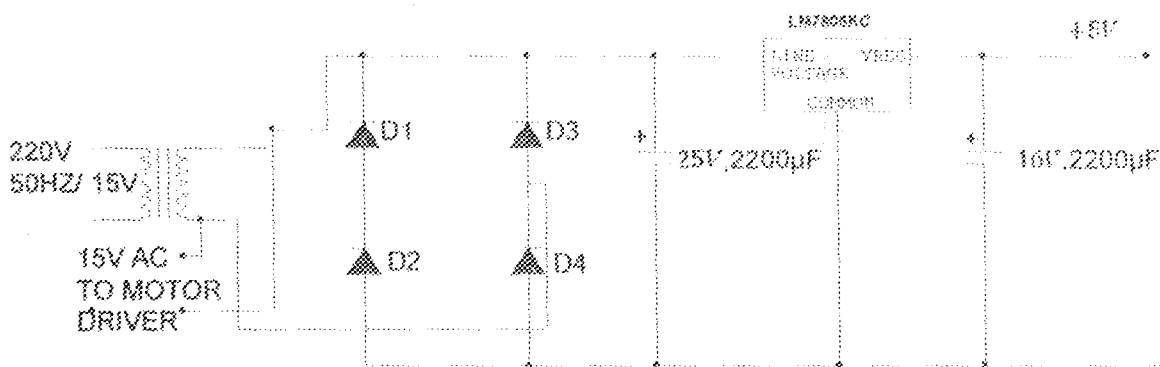
Fig. 3.14 System Power Supply

The raw 15V AC was fed into a BT139/ power – triac, a power switch to control the motor current. It was also converted into a DC voltage by a bridge rectifier as diagramed in fig 3.0. The rectified DC had peak amplitude given by the expression

$$V_{DC} = V_{RMS}\sqrt{2} - 1.4$$

For a 15V RMS voltage on 240V AC line condition.

$$V_{DC} = 15\sqrt{2} - 1.4 = 19.81V$$

The smoothing capacitance across the 19.81V DC rail was deduced from the relation:

$$Q = CV = It$$

$$C = \frac{It}{V} \qquad \text{Where I} = \text{Maximum load current}$$

$$I = \frac{1}{F} = \frac{1}{2F} \; (FVBR)$$

$$V = \text{maximum peak} - \text{peak AC ripple voltage}$$

The maximum ripple voltage was determined by the minimum input voltage needed by the 7805 fixed output voltage regulator to maintain regulation. This was 7V (from the manufacturer's datasheet). The load current was fixed at 1A (the actual current consumption is less than this).

Given a minimum input voltage of 7V for the regulator, the maximum ripple voltage is thus 19.81 − 7 = 12.81V. Therefore, calculating

$$C = \left(\frac{1 \times \frac{1}{2} \times 50}{12.81} \right) = 780\mu F$$

The above value of capacitance is the minimum required to meet the projected power supply requirement. This was however increased to 2200µF for enhanced performance. The smoothened DC voltage was regulated down to 5V by 7805 regulator and buffered by a 1000µF capacitance before powering the system.

3.2.2 SYSTEM CONTROLLER

For intelligence and flexibility, software driven approach was implemented. This implementation necessarily required the incorporation of a programmable device. An 8- bit microcontroller was used. The AT89C51 has the following characteristics: It s a low power,

high performance 40-pin DIP, 8 bit microcontroller with 4 kilobytes of in-system reprogrammable flash memory, 128 bytes of SRAM and 32 programmable I/O lines. The device was run- off a 12MHz clock source. Since microcontroller characteristic frequency was internally divided down by 12, the effective system operating frequency is 1MHz yielding an instruction execution time of 1 microsecond (1μs).

The system controller was programmed to execute the following functions:-

1. Provide a real time clock operation to serve as reference for every motor control operation.

2. Provide automatic collector plate adjustment on an hourly basis.

The controller was interfaced with other system components as outlined below.
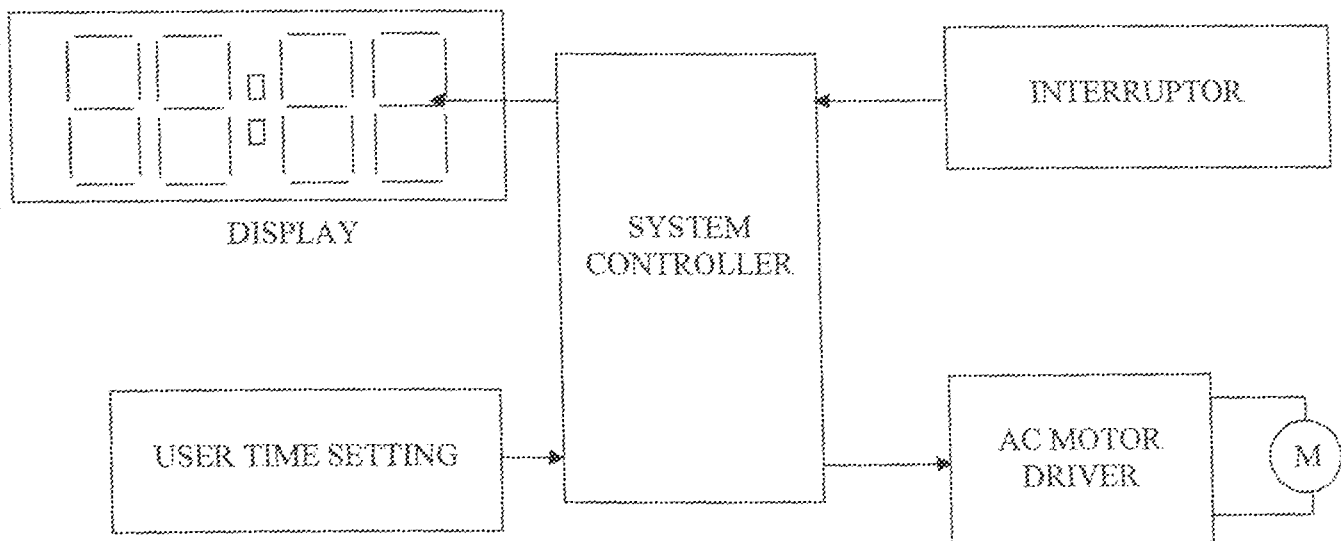
Fig 3.15 Controller– System Interface

The controller executed the system control software that was modularized to enable easy updateability and separation of functions. The software was divided into major blocks that implemented the following:-

❖ System initialization

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* Keypad scanning

* Computation of the step count needed to position the collector plate.

* Detection of maximum west – oriented excursion and return to the left (east – oriented) positioning.

* Maintenance of system time.

The control signal generated by the microcontroller was decided by the logical output of the different routines making up the control software.

3.2.3 MOTOR CONTROLLER

A geared – down AC motor was used to provide precision positioning of the collector. The motor was power switched by a BT139 power triac gated ON/OFF by an MOC3023 opto – triac as shown below.
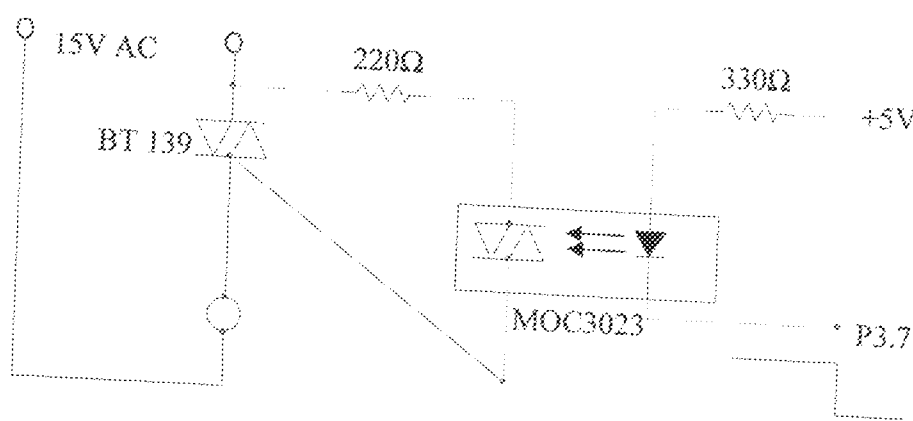
Fig. 3.16 Triac Ac Motor Driver

A power triac provided the motor current control functionality. Motor turn ON was via an MOC3023 optocoupler activated by P3.7 of the system controller. P3.7 was directly controlled by software.

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The motor used had a 2.5RPM characteristic, corresponding to 15° per second. Thus, to move the motor through, say, 60°, the motor was run for 4 seconds and turned off.

Though no position detection mechanism was used to make sure that the motor was positioned as designed, tests run on the system confirmed that the software control routine worked well.

3.2.4   4- DIGIT 7 – SEGMENT DISPLAY.

For visual interactivity with the user a display was incorporated in the design work. The display provided a visual presentation of the system time to the user and also enables presetting.

A common – anode arrangement was used since it allows current to be sunk through the LEDs by the microcontroller. The digits were multiplexed to reduce wiring complexity. The digits were individually driven by a PNP anode driver as shown below:
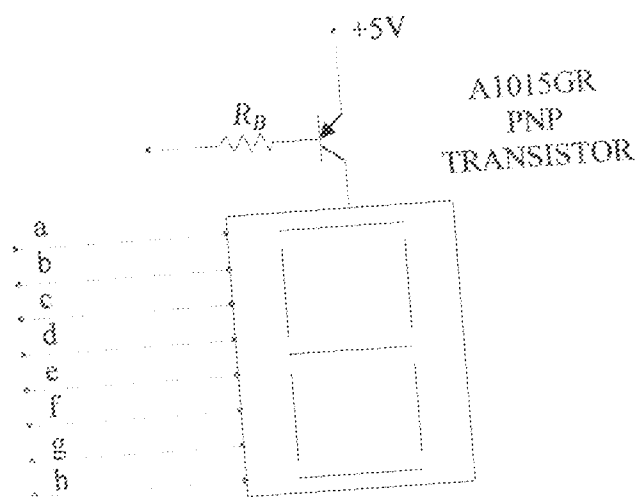
Fig 3.17 Common – Anode Display

The continuous current through each segment was fixed at 10mA. For an n-digit display, the current through each segment is computed as $I_f \times n$, where n is the number of digits in the display, I_f = forward continuous current.

For a 4- digit display and an I_f of 10mA, the pulsed segment current is thus, $4 \times 10mA = 40mA$. The peak digit current (with all LEDs on) is thus $40mA \times 8 = 320mA$. I_C of each anode switch is thus 0.32A. For the A1015GR transistor used, $I_c = \beta I_B$. Where $\beta = 150 - 250$. A measured β of 220 was noted in the transistor lot.

$$0.32 = \beta I_B \qquad I_B = \frac{0.32}{220} = 1.45mA$$

$$R_B = \left(\frac{V_{CC} - V_{BE}}{I_B}\right)$$

$$R_B = \left(\frac{5 - 0.7}{1.45}\right) = 3\ K\Omega$$

A value of 4.7KΩ was chosen instead.

3.2.5 MECHANICAL ASSEMBLY.

A wooden platform was used for the tracker. Wood was chosen due to its low cost and easier workability. The assembly is detailed below. A reversible AC motor was not available, so a unidirectional type was incorporated.

At power up, the software automatically position the collector plate facing full east, at the system default time of 6AM. Every one hour the motor is run for one second to step it through 15°. Tracking was effected from 6AM to 6PM.

$$\text{Total tracking time} = 12 \text{ hour} = 180°$$

$$1 \text{ hour} = 15°$$

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Since the motor rotates through 900°/ 60 seconds = 15°/ second, positioning was very easy then. The control software also provided facility for the user to position the collector to align with the sun's angle of inclination at any time o the day.
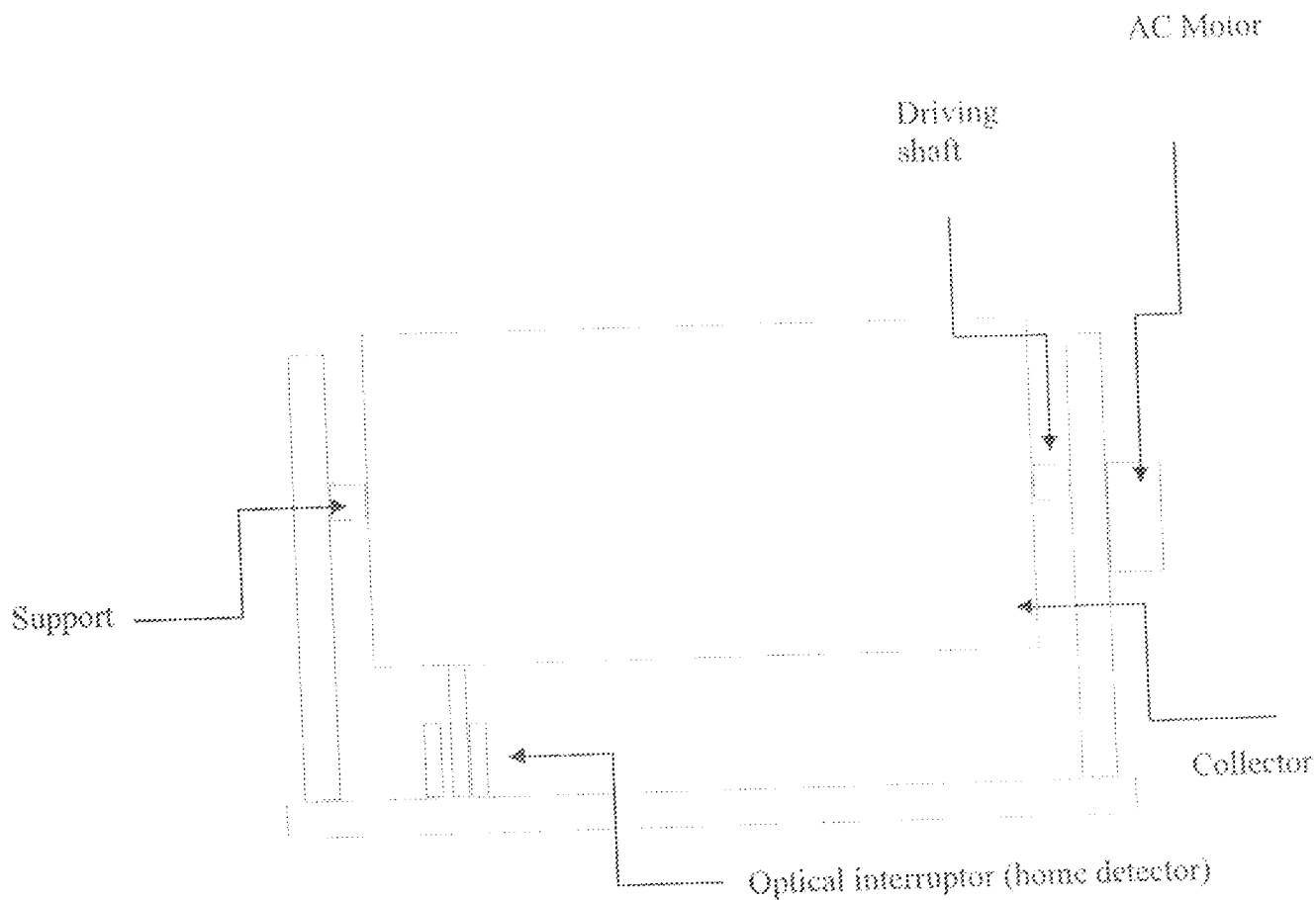
Fig. 3.18 Tracker Assembly

For example, the collector has homed and the time default to 6AM, but the time of the day is say 12 mid day. The collector can be positioned to align with the sun by the user adjusting the hour variable of the system time to 12. The software computes the flow time of motor current as shown below.

(New time - Old time) × Number of steps / hour

$$= (12 - 6) \times 1$$

$$= 6 \text{ seconds}$$

Before the motor is run for the time calculated above, the collector is first homed. Motor current is then gated on for 6 seconds, and gated off. The collector is now aligned. Positioning is also effected by adjusting the minute's variables of the system time.

3.2.6   OPTICAL INTERRUPTOR.

To detect collector home position an optical interruptor was used. The interruptor was designed around an LED illuminating an LDR and the light source broken by a work piece attached to the collector.
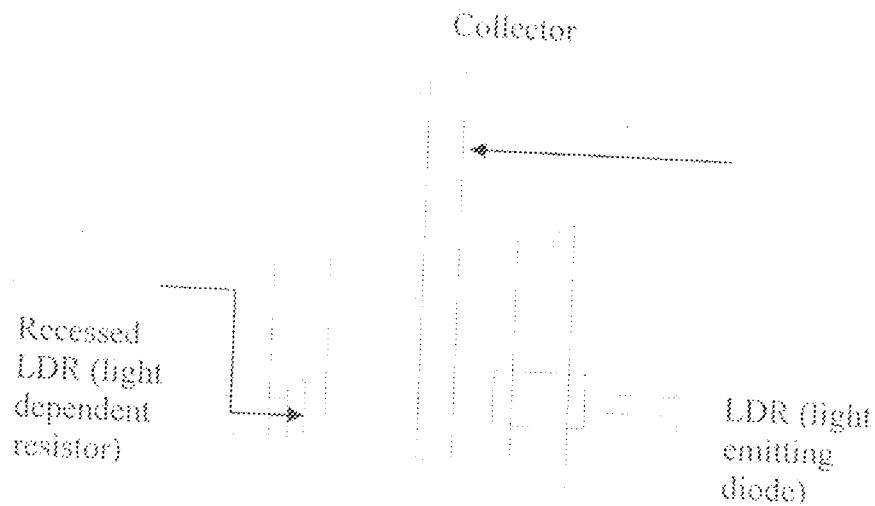
Fig. 3.19 LED- LDR optical interruptor

The LDR was connected to the comparator circuit shown below.
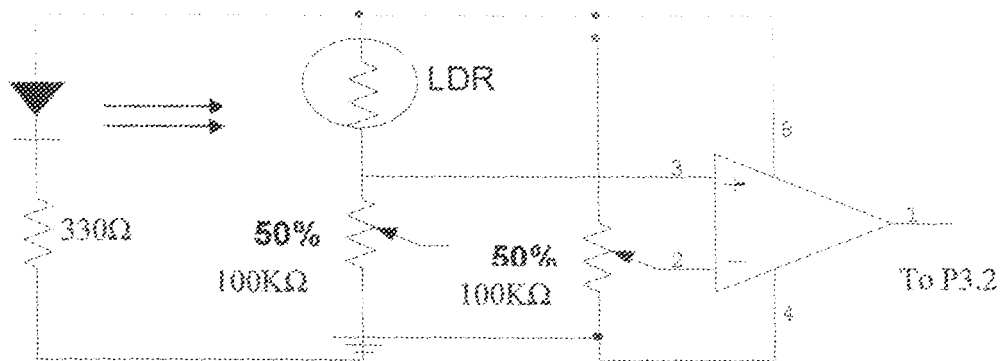
Fig. 3.20 comparator waveform conditioner

When the collector is not homed, the light emitted by the LED falls directly on the LDR and the potential at the non – inverting input of the LM358 amplifier is higher than the reference voltage set by the 100kΩ resistance on the inverting (-) input. The comparator output is thus high.

When beam discontinuity occurs due the plastic coming between the LED and LDR, the potential on the non – inverting input falls lower than the potential on the inverting (-) input. The comparator switches its output low, interrupting the controller and stopping the motor. Other software operations can thence resume from there.

It should be noted that when it is 1800 hour (that is 6PM), the system returns the collector to the home position, and does nothing until 6AM at which time it commences tracking.

3.3 SOLAR GEOMETRY

Availability of solar energy is accompanied with so many erratic characteristics and unpredictabilities which are caused by the motion of our planet, including the earth's

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revolution around the sun, the earth's daily rotation about its own axis, and tilt of that axis with respect to the plant of the earth's orbit. The distinct motions predictably yield characteristic effects. In fact, the mean distance between the earth and the sun is 1.4×10^9 meters and due to eccentricity of the earth's orbit, this distance varies by $\pm 1.7\%$. An interesting fact regarding this is that the earth is farthest from the sun during the summer months in the northern hemisphere and closest during the winter season. This variation in earth's orbit causes little variance in the amount of radiation to which it is exposed.

The extreme annual changes in the earth's radius of elliptical orbit only amount to some 2%, thus allowing the consideration of the orbit as circular without introducing various errors. Observing the sun's motion from position on the earth's surface for sufficiently regular patterns of daily movement across the sky of course, the patterns do vary gradually through out the years. The position of the sun at any chosen instant can be defined fully in fig 2.14 using two angles that measured from a fixed location, one of these angles is called the solar altitude and the other is the azimuth and both depend upon time of the year, time of the day and latitude of the point of reference. [12]
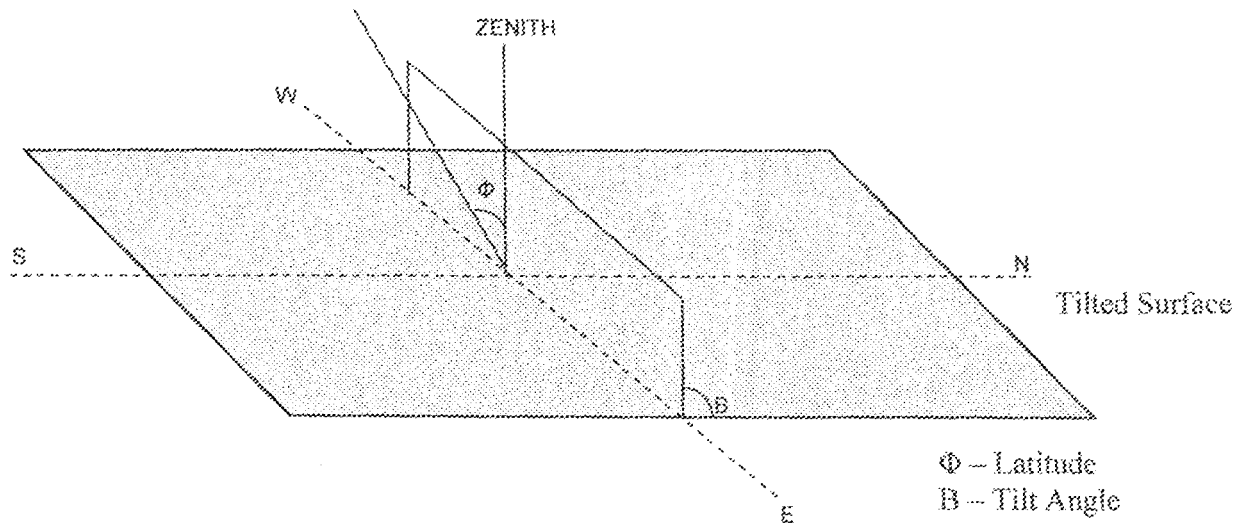
Fig 3.21: Solar Position Angles

3.4 SOLAR POSITION

One should not become overly concerned about the "haphazard" factors involved in solar availability. Superimposed on the unpredictabilities, there are strong cyclic behaviors that provide the observer with a foundation of precise regularity. These behaviors are caused by the motions of our planet, including the earth's annual revolution around the sun, the earth's daily rotation about its axis, and tilt of that axis with respect to the planet of the earth's orbit. These distinct motions predictably yield characteristic effect (Regino, 1978).

In and of itself, the yearly orbit of the earth cause little variance in the amount of solar radiation to which it is exposed. The extreme annual changes in the earth's radius of elliptical orbit only amount to some 2% allowing us to think of the orbit as circular without serious error. An interesting fact regarding this is that the earth is farthest from the sun during the summer months in the northern hemisphere (95.90 million miles) and closest during the winter season (89.83 million miles). A schematic diagram of this is shown in fig. Earth's

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changing season are not caused by our orbit alone, but rather by that orbit in conjunction with another feature of the earth, its "tilt".

The equator of the earth is tilted some $23^{0}.27'$ with respect to an imaginary, but precise, planet in space – the "ecliptic". This plane is defined by earth's orbit, and in turn defines the sun equator.
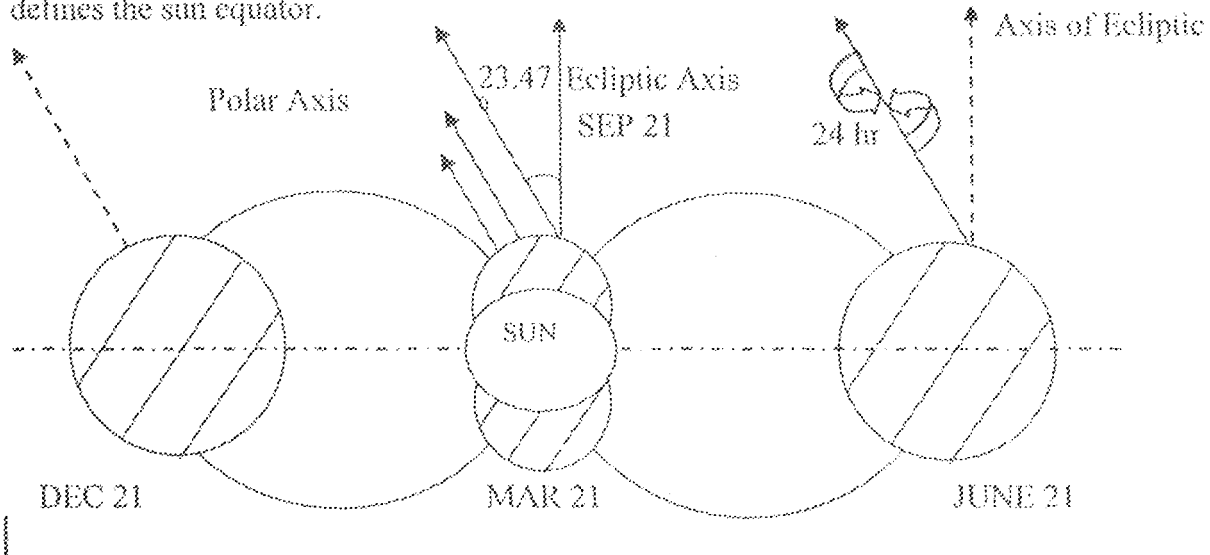
Fig 3.22: Motion of the earth about the Sun

As we circle the sun a slight variation occurred daily, the angle between the earth – sun line (on the ecliptic) and the equatorial plane (of earth). This angle called the solar declination δ (delta), varies continuously. The variation of delta causes the earth to present a slight different face to the sun each day, and it is the motion responsible for those seasonal changes in the weather available each year. It also causes the mysterious annual lengthening and shortening of the intervals between sunrise and sunset, in spite of the earth's very regular daily rotation above its own axis. [12]

3.4   DEFINITION OF ANGLES OF SOLAR RADIATION

➢ Zenith Angle (θ_z): Is the angle subtended by a vertical line to the zenith (that is point directly overhead) and the line of sight to the sun.

➢ Latitude (ϕ): Is the angular position north or south of the equator.

➢ Declination (d): Is the angular position of the sun at solar noon with respect to the plane of the equator.

➢ Tilt Angle (β): Is the angle between the surface in question and the horizontal ($0^0 < \beta < 180^0$)

➢ Hour Angle (w): Is the angular displacement of the sun east or west of the local meridian due to radiation of the earth on its axis at 15^0 per hour.

➢ Angle of incidence (θ_1): Is the angle between the beam radiation on a surface and normal to the surface.

➢ Solar azimuth angle (Ts): Is the angular displacement from South of projection of the beam radiation on the horizontal plane.

3.5 OPTIMUM ORIENTATION OF A FLAT COLLECTOR

For the sake of obtaining maximum radiation at solar noon for a given day, the flat collector should be set in such a way that the angle of incidence is zero that is the beam radiation from the sun should be orthogonal to the collecting surface as shown in fig 2.5.2
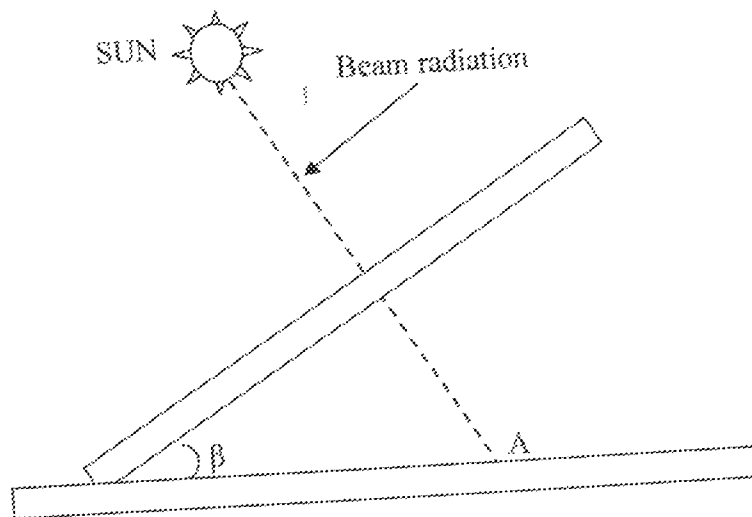
Fig 3.23: Flat collector

β = Tilt angle (slope)

A = Solar Altitude

Mathematically:

$\theta = 90A$ and $A = 90 - L + \delta$ - 2.0

Where

      L = local latitude δ = declination

The declination is given by:

$\delta = 23.44 \sin(360 \times 284 \div \frac{x}{360})$ - 2.1

N = the day of the year.

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A generally acceptable orientation for flat collectors is that, the collectors should always point towards the direction of the solar beam (that is $\theta = 0$). The optimum direction of a fixed flat collector is perhaps not obvious, however a suitable collector orientation for most purposes is facing the equator (e.g. due south in the northern hemisphere) with a slope (tilt angle) equal to the local latitude. [12]

3.7 SOLAR TRACKING

Since the various movements of the earth make radiation pattern to vary with the time of the day, year (seasonal) and so on, it become impossible collect maximum radiation during the day with fixed collectors. Therefore it becomes obvious that consistent alignment of the collectors must be ensured to always obtain maximum illumination from the sun. In some applications, most especially for concentrators, tracking become expedient to obtain maximum energy conversion. In the application of photovoltaic cells, solar tracking enhances concentrators' efficiency. Automation of the solar collector could be obtained where the unit can operate without the need of human intervention. Such system can track the sun so that the collector receives maximum radiation at all time.

3.7.1 SINGLE AND DUAL AXIS TRACKING

In most application that requires tracking, one axis tracking (East to West) is utilized and this becomes justifiable when cost is considered. However, for higher concentrations and high precision applications, two orthogonal tracking may be required. The rotation of the earth about its axis is the most noticeable in solar radiation collectors, while the impact of other movements has very gradual effects which are mostly neglected in many applications without introducing much error. This makes single axis tracking more acceptable, as it

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represents a relatively high investment, and it still finds application in special areas like research work and high precision tracking applications.[13]
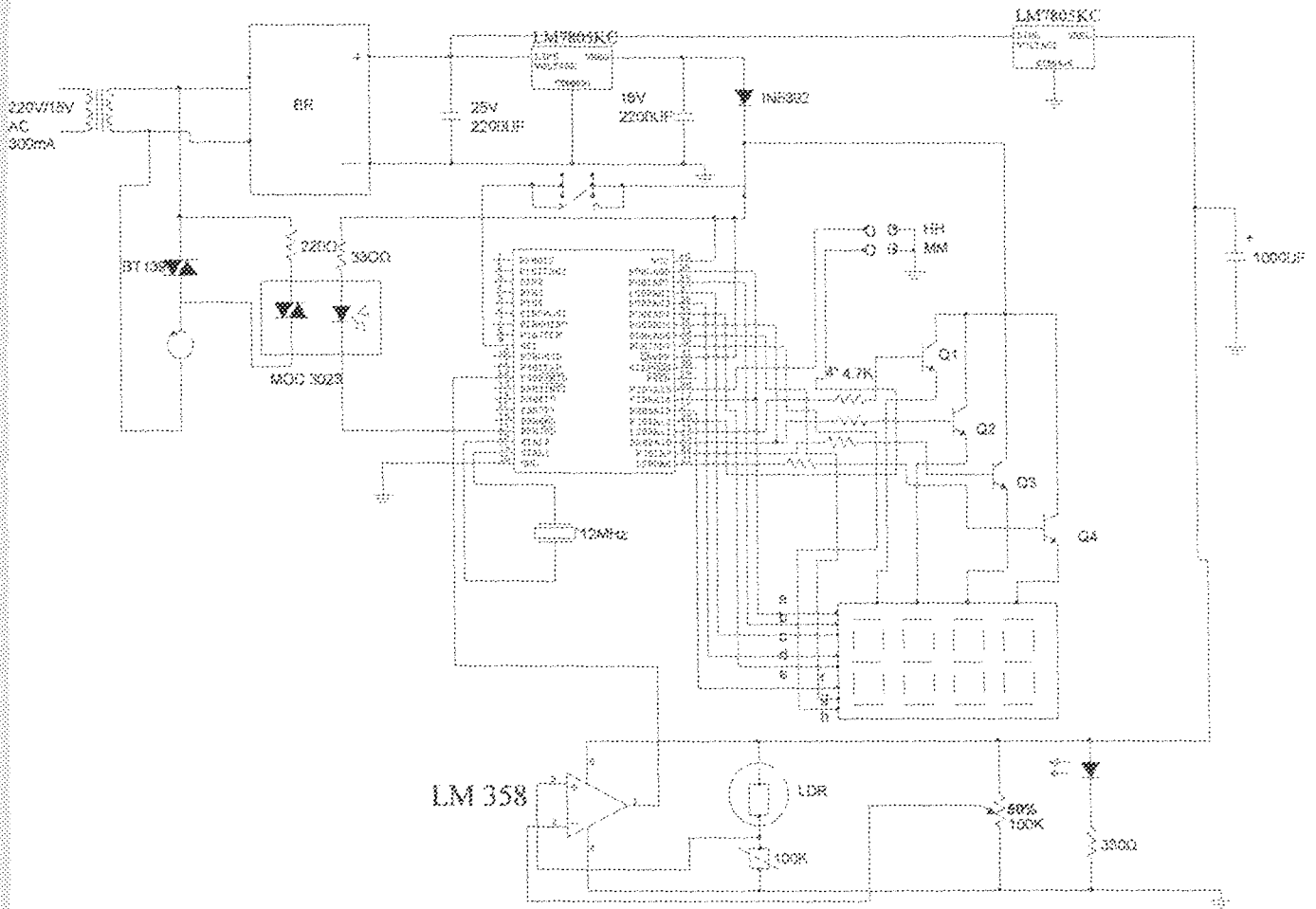
Fig. 3.24: Complete System Circuit Diagram

CHAPTER FOUR

TESTS, RESULTS AND DISCUSSION

4.1 TESTING

The construction was done in units; the first involves the design and acquisition of the circuit diagram. To ease the construction procedure and troubleshooting, the circuitry was segmented into functional blocks. The circuit was first tested on breadboard but due to the complexity of realizing the circuit, the work was fully shifted to a Vero board. After series of mistakes and series of adjustment on the circuit, the final circuit was realized.

The Vero board was first scrapped with a razor blade for operation to encourage smooth and neat soldering of the component on the board. This was followed by the final construction. On completion of the construction, a thorough test and assessment of the component connection were carried out.

The following steps were followed;

> Continuity and connectivity test were taken using a multimeter while the circuit was not powered and the various pins layouts well mounted on board.

> The construction was tested module by module.

> The programmed microcontroller was not verified with the circuit at the stage of testing until the final testing.

> A test was carried out to ensure that both the crystal and the reset circuit of the microcontroller are working. The 89C51 is inserted in the circuit, and the ALE

pulse is checked with an oscilloscope to verify the ALE frequency is 1/6 of the frequency. This gave the desired result.

> The motor controller circuit was tested next to ensure that it could rotate in the clockwise , anti clockwise as well as stop positions with minimal noise by replicating the action of the microcontroller. After the whole system units (Electrical and mechanical) had been coupled, the sun tracker was then tested.

> The time test was done and all time subroutines were in working mode.

> The software testing was done to confirm the operation of the main program and the delay subroutine of the proper sequence of lighting at the intersection under various conditions. For the purpose of testing the Programmer Circuit, the LED indicator test was first carried out to confirm the circuitry. Next, an ATMEL AT89C51 was used to write a simple programme. The programme was debugged for errors and corrected. It was successful.

The tools and materials as well as instruments used during the testing and the construction of the project are briefly discussed below:

1. The breadboard: This is a temporary board for circuit testing with tiny sockets that allows for electronic components (i.e. resistors, capacitors, ICs e.t.c) to be plugged in easily without damaging the component. The breadboard was used for pre- construction testing of circuit and sub- circuits before the components were soldered on Vero board.

2. Digital Multimeter: This device (instrument) was used for the Measurement of electrical quantities such as resistance, voltage and current. It is also used to test the circuit sections for continuity.

3. The Vero board: This is a perforated board on which electronic components can be inserted and soldered permanently. It was used for permanent construction of the project prototype from the circuit diagram.

4. Wires and Connectors: Wires were used during the testing stage of the project on the breadboard to connect the components together as well as the different sub- units of the circuit; they were also used during the soldering of components on the Vero board. Copper wire was used.

5. Wire cutters / strippers: These tools were used to cut wires to the desired size before use, as well as to strip off insulation wire in other to expose the conductor for proper and neat soldering.

6. Soldering Iron: This is a low power heating element typically in range of about 40 Watts. It provides the heat needed to melt the lead, so that it can be used for the connection of the components permanently on the Vero board. It is usually connected to the AC mains.

7. Soldering Lead: This is a metal (lead) wire, low melting. It is used to electrically connect components and wires in fixed position on the Vero board.

4.2   RESULTS

Table 4.1: Experimental result

TIME OF THE DAY	COLLECTORS ORIENTATION (In degrees)	DURATION OF CURRENT PULSE SENT TO MOTOR (in seconds)
6AM	Vertically facing the east-ward direction.	0
7AM	15	1
8AM	30	2
12 MIDDAY	90	6
3PM	135 east and 45 west.	9
5PM	165 east and 75 west.	11
6PM	Back to the home position and tracking stops until 6AM.	12

4.3 DISCUSSION OF RESULTS

At system power ON, the software automatically position the collector plate facing the east, at the system default time of 6AM. Every one hour the motor runs for 1second to step it through 15°. If the system time is not adjusted, the collector's orientation is hence adjusted every 1 hour to align it with the sun's angle of inclination. If the system time is however adjusted, to prevent accumulation of mechanical errors, the collector initially returns to the home position, the software then computes the degree of rotation by subtracting 6 from the set time. The collector is hence positioned correspondingly. At 6PM, the software automatically returns the collector to the home position until 6AM, 12 hour later, when tracking commences again.

Generally, the programmed values were found to conform to experimented values with a very precise real time clocking system.

4.4 PROBLEMS ENCOUNTERED

After the program for the project was written, programming the chip to the design specification was a difficult task. Logical errors were discovered in the program and were ascertained to be the reason why the program could not work. Also, subroutines were added after the initial design ideology. A step by step approach was made on the program by a direct interface to a programming board and the circuitry for the project.

CHAPTER FIVE

5.1 CONCLUSION

The project was carried out and tested to conform to the design analysis of the circuitry and the program indicating a successful project. From the testing and results obtained, it can be seen that the tracker satisfactorily tracks the sun during the preset periods, resets after, and "hibernates" during night time and resumes at a preset period.

The tracker is an option when a higher cell output is required, rather than investing in the increase of more cells, which is by far more expensive.

5.2 RECOMMENDATION

In the design and construction of a microcontroller based sun tracker, the system satisfactorily tracked the sun. However due to seasonal changes the system could be expanded to accommodate both elevation and lateral tracking.

The system could also be modified to source its own power directly from the sun or from the one generated by the solar panel that could be mounted on top of the collector. Then it would be completely self - driven.

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APPENDIX

```
INCLUDE 89c51.mc
;*********************
stack EQU 80
;*********************
;
control_port EQU p2
data_port EQU p0
digit1_dx BIT p2.0
digit2_dx BIT p2.1
digit3_dx BIT p2.2
digit4_dx BIT p2.3
;*********************
;
digit1 DATA 8
digit2 DATA 9
digit3 DATA 10
digit4 DATA 11
;*********************
;
count1 DATA 12
count2 DATA 13
count3 DATA 14
count4 DATA 15
;*********************
;*********************
;
interval DATA 16
hour DATA 17
minutes DATA 18
seconds DATA 19
temp1 DATA 20
temp2 DATA 21
mask DATA 22
dx_ctrl DATA 23
temp2 DATA 24
count10 DATA 25
count_a DATA 26
count_b DATA 27
;*********************
;*********************
;
run_motor BIT 00h
step_once BIT 01h
step_flag BIT 02h
home_Flag BIT 03h
;*********************
;*********************
;
home_in BIT p3.2
```

```
hour_key BIT p3.5
minute_key BIT p3.6
home_dx BIT p2.5
triac_dx BIT p3.7
;*****************************
;***************************
;
dx_port EQU p2
;******************************
;****************************
;
step_size EQU 1
;****************************
;

org 0000h
AJMP start_up

org 0003h
RETI
;
org 000bh
AJMP tf0_isr;
;
org 0013h
RETI
;
org 001bh
AJMP tf1_isr
;
org 0023h
RETI
;****************************
;****************************
;
org 0030h
start_up:       CLR ea
                MOV sp,#stack
                ACALL sys_init
;********************************
;*********** ****************
;
main:           CALL show_time
                call step_motor
                ACALL scan_key
                SJMP main
;*********************************
;*********************************
;
sys_init:       MOV hour,#06h
                MOV minutes,#0
                ;MOV interval,#15; change later
```

```
            MOV interval,#1
            MOV mask,#11111111b
            MOV seconds,#60
            MOV count3,#200
            MOV count4,#20
            MOV tmod,#22h
            MOV th0,#6
            MOV tl0,#6
            MOV th1,#6
            MOV tl1,#6
            SETB tr0
            CLR step_once
            CLR step_flag
            CLR home_flag
            MOV ie,#10001010b
            ACALL home_motor
            RET
;*****************************************
;*****************************************
scan_key:   jb home_flag, scan3   ; do not scan key if either operation in progress!!!
            jb step_flag, scan3

            JB hour_key, scan2
scan_a:ACALL adjust_hour
            JNB hour_key, scan_a
            ACALL pos_motor

scan2: JB minute_key, scan3
scan_b:     ACALL adjust_minute
            JNB minute_key, scan_B

scan3: RET
;*****************************************
;*****************************************
home_motor: JNB home_dx, exit_home
            SETB home_flag
            CLR step_Flag
            call start_motor
home_loop:  call show_time
            JB home_dx, home_loop

exit_home:  CLR home_Flag
            call stop_motor
            call long_delay
            RET
;*****************************************
```

```
;*******************************************
pos_motor:          ACALL home_motor
                    MOV A, hour
                    CJNE A,#06h, chk1
                    RET

chk1:               JNC skip2
                    RET

skip2:      CJNE A,#18, chk3
back2:      RET

chk3:               JNC back2
                    MOV A, hour
                    CLR C
                    SUBB A,#06h
                    MOV B,#step_size
                    MUL ab
                    MOV R7, A
                    ACALL new_pos
                    RET

;*******************************************
;*******************************************
tf0_isr:    PUSH psw
                    PUSH acc
                    DJNZ count3, exit_isr
                    MOV count3,#200
                    DJNZ count4, exit_isr
                    MOV count4, #20
                    MOV A, mask
                    CPL acc.7
                    MOV mask, A
                    DJNZ seconds, exit_isr
                    MOV seconds,#60
                    ACALL adjust_time
                    DJNZ interval,exit_isr
                    ;MOV interval,#15          ; testign alone.change to 60 later
                    MOV interval,#1
                    SETB step_once

exit_isr:           POP acc
                    POP psw
                    RETI

;*******************************************
```

```asm
;***********************************************
show_long:          MOV R6,#100
show3:          ACALL write_screen
                    DJNZ R6, show3
                    RET
;***********************************************
;***********************************************
seg_table:          DB
11000000b,11111001b,10100100b,10110000b,10011001b,10010010b,10000010b,11111
000b,10000000b,10010000b
;***********************************************
;***********************************************
step_motor:          JNB step_once, exit_step_motor
                    CLR step_once
                    MOV A, hour
                    CJNE A,#06h, chk1a
exit_step_motor:     RET


chk1a:          JNC skip2a
                    RET


skip2a:          CJNE A,#18, chk3a
back2a:              ACALL home_motor
back2b:              RET


chk3a:          JNC back2b
skip_this:          MOV R7,#step_size   ; number of pulses to step in an hour
                    ACALL new_pos
                    RET
;***********************************************
;*****,*****************************************
new_pos:            setb step_flag
                    clr home_flag
                    call start_motor
                    call start_motor_timer
                    RET
;***********************************************
;***********************************************
start_motor_timer:   MOV tl1,#06h
                        MOV count_a,#250
                        MOV count_b,#16
                        CLR tf1
                        SETB tr1
```

```
                         RET
;************************************
;************************************
;
stop_motor_timer:        CLR tr1
                         CLR tf1
                         MOV tl1,#06h
                         RET
;************************************
;************************************
;
START_MOTOR:             CLR TRIAC_DX
                         RET
;************************************
;************************************
;
STOP_MOTOR:                    SETB TRIAC_DX
                         RET
;************************************
;************************************
;
adjust_time:   MOV A, minutes
                         INC a
                         CJNE A,#60, adjust10
                         MOV minutes,#0
                         MOV A, hour
                         INC A
                         CJNE A,#24, adjust11
                         MOV hour,#0
                         RET

adjust10:                MOV minutes,A
                         RET

adjust11:                MOV hour,A
                         RET
;************************************
;
write_screen:  MOV R0,#digit1
                         MOV dx_ctrl,#11111110b
write_loop:              MOV data_port,@R0
                         MOV dx_port, dx_ctrl
                         call dly_show
                         MOV dx_port,#0ffh
                         INC R0
                         MOV A, dx_ctrl
                         SETB C
                         RLC A
                         MOV dx_ctrl, A
                         CJNE R0,#digit1+4, write_loop
                         RET
```

```
;************************************
dly_show:        MOV R5,#200
                 DJNZ R5,$
                 RET
;************************************
show_time:       PUSH dpl
                 PUSH dph
                 PUSH 01h
                 MOV DPTR,#seg_table
                 MOV R0,#hour
                 MOV R1,#digit1
show1:     MOV A,@R0
                 ACALL get_7seg
                 MOV @R1, A
                 INC R1
                 MOV @R1,B
                 INC R0
                 INC R1
                 CJNE R1,#digit1+4,show1
                 ACALL put_dp
                 POP 01h
                 POP dph
                 POP dpl
                 ACALL show_long
                 acall show_long
                 acall show_Long
                 RET
;************************************
;************************************
get_7seg:        mov b,#10
                 DIV ab
                 PUSH acc
                 MOV A,B
                 MOVC A,@a+dptr
                 MOV B, A
                 POP acc
                 MOVC A,@a+dptr
                 RET
;************************************
;************************************
put_dp:          MOV A, digit2
                 ANL A,mask
                 MOV digit2, A
                 MOV A, digit3
                 ANL A,mask
                 MOV digit3, A
```

```
                    RET
;***********************************************
;***********************************************
;
adjust_hour:   MOV seconds,#60
                    MOV A,hour
                    INC A
                    MOV hour, A
                    CJNE A,#24, adjust2
adjust3:            MOV hour,#00h
                    ACALL show_time
                    RET

adjust2:            JNC adjust3
                    ACALL show_time
                    RET
;***********************************************
;
;***********************************************
;
adjust_minute:MOV seconds,#60
                    MOV A, minutes
                    INC A
                    MOV minutes, A
                    CJNE A,#60, adjust4
adjust5:            MOV minutes,#00h
                    ACALL show_time
                    RET

adjust4:            JNC adjust5
                    ACALL show_time
                    RET
;***********************************************
;***********************************************
;
tf1_isr:        DJNZ count_a, exit_tf1
                    MOV count_a,#250
                    DJNZ count_b,exit_tf1
                    MOV count_b,#16
                    DJNZ R7,exit_tf1
                    call stop_motor
                    call stop_motor_timer
                    CLR home_flag
                    CLR step_flag
                    CLR tr1
exit_tf1:        RETI
;***********************************************
;
;***********************************************
;
long_Delay:        MOV R2,#10
reset1:        MOV R3,#0
```

```
reset2:        MOV R4,#0
                   DJNZ R4,$
                   DJNZ R3, reset2
                   DJNZ R2, reset1
                   RET
```