CHAPTER ONE

INTRODUCTION

1.1 General Concepts

Energy security that could be the big Shiny head line for these decades, the steadily increasing of energy consuming will need increasing in energy generating, and here comes our most used sources now like the petroleum sources and coal these sources are drained so it will run short, and the global worming sets off alarm bells, may the next century will be eyewitness for a war, The war of energy, for all of those reasons we need the renewable energy and one of the main sources of the renewable energy is sun or the solar energy, in this project we tried to build a system mechanism that to employ all of the coming sun beam as possible as it could be in instead of that we will get a suitable hike of efficiency which means a greater number of energy generating, and absolutely green and clean , this system mechanism is called the sun tracking or solar tracking .

Solar Tracking System is a device for orienting a solar panel or concentrating a solar reflector or lens towards the sun. Concentrators, especially in solar cell applications, require a high degree of accuracy to ensure that the concentrated sunlight is directed precisely to the powered device. Precise tracking of the sun is achieved through systems with single or dual axis tracking, the sun moves across the sky an electric actuator system makes sure that the solar panels automatically follow and maintain the optimum angle in order to make the most of the sunbeams.

Tracking the sun from east in the morning to west in the evening will increase the efficiency of the solar panel up to 25%.

1.2 Problem Statement

The solar cell panel is usually being fixed and not moveable beside the sun is changing its position during all day time so the solar cell can't make the full use of the sun light, like if we fixed the solar cell in the afternoon time we would not make use of the morning and the afternoon day time which means 25% of sun light day time went like a waste.

1.3 Objectives

The main objective of the project is to solve the problems of limited using of the solar cell, this problem will be solved by using the sun tracking system and then make use of the maximum rate of sun-energy by the cell, therefore to make use of it as much as possible.

1.4 Methodology

The solution of the previous problems is by sensing the sun position by sensors, then process the result of them to send signal to the motors to direct the solar cell panel to its right direction and repeat this operation till the all the reads of the concerned sensors be the same or by pressing switches to send signal to the motors to redirect the solar cell panel manually, this whole process can be represented in three stages:

- Sensing section:

Sensors sensing the sun light which effect on its resister so we can make use this property to know the position of the sun.

- Processing section:

In this section we use microcontroller to process the signals from the sensors and then send signal to the motors depend on the sensors income.

- Operation section:

This section regards the driver and the motors which move depends on the signal revised from the microcontroller to orient the solar panel to its right direction.

1.5 Project Layout

- Chapter one represents a general overview, the problem and the methodology to solve the problem.

- Chapter two views a detailed classification about sensors, microcontrollers, motors,solar cells,and tracking types.

- Chapter three shows the circuit components precisely like(LDR), microcontroller (pic16) and the drive components.

- Chapter four present Installation of the circuit components, the operation of all one of them on the circuit and the programming code.

- chapter five we introduce the conclusion of this project to show what we get from it and some recommendation to make this system work properly also the references.

CHAPTER TWO

GENERAL DIFINITION

2.1 General background

All the world wild stepping as possible to renewable energy and dropping the classical energy sources, and the motivation for that is renewable energy used to be clean, continues and cheap, in the other hand the global warming is counting up, the table below shows the usage of different types of energy sources which figured out by American National Renewable Energy Laboratory. July 2012.

Table (2.1): different types of energy sources usage

Renewable source	Electricity generation capacity (gigawatts)	Electricity generation potential (billion kilowatt-hours)	Renewable electricity as percent of 2012 Electricity use
Wind			
Land- based	10.955	32.784	.809%
Offshore	4.223	16.976	.419%
Subtotal	15.178	49.760	1.227%
Solar			
Photovoltaics	154.856	283.664	6.997%
Concentrating solar power	38.006	116.146	2.865%
Subtotal	192.922	399.810	9.862%
Bioenergy			

Subtotal	62	488	.12%
Geothermal			
Hydrothermal	38	308	.08%
Enhanced geothermal systems	3.976	31.345	.773%
Subtotal	4.014	31.653	.781%
Hydropower			
Existing conventional	78	277	.07%
New conventional	60	259	.06%
Subtotal	138	536	.13%
Total	212.314	482.247	11.896%

There for here in Sudan we have a long sun rising duration, and that would be very encouraging and helpful to generate cheap and clean energy.

Table (2.3): Khartoum, Sudan - Solar energy and surface meteorology

Variable	i	Ii	Iii	Iv	v	Vi	vii	viii	ix	X	xi	xii
Insolation (KWh/ m²/day)	5.10	5.87	5.86	7.46	7.23	7.31	6.93	6.73	6.65	6.16	5.51	4.95
Clearness (0 – 1)	0.64	0.66	0.69	0.71	0.68	0.68	0.65	0.64	0.66	0.67	0.67	0.65
Temp, °C	23.03	24.06	27.62	30.97	30.27	30.84	29.45	29.73	32.19	31.44	28.25	24.57

Wind speed, m/s	5.57	5.72	5.56	5.06	4.50	6.19	6.67	6.23	5.34	4.57	4.13	4.90
Precipitation, Mm	0	0	0	0	3	6	46	68	22	3	0	0
Wet days, d	0.0	0.0	0.1	0.1	0.8	1.3	4.7	4.9	3.1	1.2	0.0	0.0

- These previous data were obtained from the NASA Langley Research Center Atmospheric Science Data Center; New et al. 2002.

2.2 Solar-Cells

A solar cell also called a photovoltaic cell is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect. It is a form of photoelectric cell, defined as a device whose electrical characteristics like current, voltage, or resistance vary when exposed to light; cells can be described as photovoltaic even when the light source is not necessarily sunlight like lamplight and artificial light. The solar cell shown in (figure 2.1).

Figure 2.1: Solar cell

2.2.1 A solar panel

A solar panel is a set of solar photovoltaic modules electrically connected and mounted on a supporting structure. A photovoltaic module is a packaged, connected assembly of solar cells. The solar module can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications. Each module is rated by its DC output power under the standard test conditions, and typically ranges from 100 to 320 watts. The efficiency of a module determines the area of a module given the same rated output - an 8% efficient 230-watt module will have twice the area of a 16% efficient 230-watt module. A single solar module can produce only a limited amount of power; most installations contain multiple modules. A photovoltaic system typically includes a panel or an array of solar modules, an inverter, and sometimes a battery and/or solar tracker and interconnection wiring.

2.2.2 Power inverter

A power inverter, or inverter, is an electronic device or circuitry that changes direct current (DC) to alternating current (AC). The input voltage, output voltage and frequency, and overall power handling, are dependent on the design of the specific device or circuitry.

Typical applications for power inverters include:

- Portable consumer devices that allow the user to connect a battery, or set of batteries, to the device to produce AC power to run various electrical items such as lights, televisions, kitchen appliances, and power tools.
- Use in power generation systems such as electric utility companies or solar generating systems to convert DC power to AC power.

- Use within any larger electronic system where engineering need exists for deriving an AC source from a DC source.

2.2.3 A solar cell

The term "photovoltaic" comes from the Greek φῶς (phōs) meaning "light", and from "volt", the unit of electro-motive force, and the volt, which in turn comes from the last name of the Italian physicist Alessandro Volta, and inventor of the battery (electrochemical cell). The term "photo-voltaic" has been in use in Great British since 1849.

Photovoltaic is the field of technology and research related to the practical application of photovoltaic cells in producing electricity from light, though it is often used specifically to refer to the generation of electricity from sunlight.

The operation of a photovoltaic (PV) cell requires three basic attributes:

- The absorption of light, generating either electron-hole pairs.
- The separation of charge carriers of opposite types.
- The separate extraction of those carriers to an external circuit.

2.2.4 Solar tracker

A solar tracker is a device that orients a payload toward the sun. Payloads can be photovoltaic panels, reflectors, lenses or other optical devices.

In flat-panel photovoltaic (PV) applications, trackers are used to minimize the angle of incidence between the incoming sunlight and a photovoltaic panel. This increases the amount of energy produced from a fixed amount of installed power generating capacity. In standard photovoltaic applications, it is estimated that trackers are used in at least 85% of commercial installations greater than one megawatt.

In concentrated photovoltaic (CPV) and concentrated solar thermal (CSP) applications, trackers are used to enable the optical components in the CPV and CSP systems. The optics in concentrated solar applications accepts the direct component of sunlight light and therefore must be oriented appropriately to collect energy. Tracking systems are found in all concentrator applications because such systems do not produce energy unless pointed at the sun.

2.2.5 Basic concept

Sunlight has two components, the "direct beam" that carries about 90% of the solar energy, and the "diffuse sunlight" that carries the remainder - the diffuse portion is the blue sky on a clear day and increases proportionately on cloudy days. As the majority of the energy is in the direct beam, maximizing collection requires the sun to be visible to the panels as long as possible

The energy contributed by the direct beam drops off with the cosine of the angle between the incoming light and the panel. In addition, the reflectance (averaged across all polarizations) is approximately constant for angles of incidence up to around 50 degrees, beyond which reflectance degrades rapidly.

For example, trackers that have accuracies of ± 5 degree can deliver greater than 99.6% of the energy delivered by the direct beam plus 100% of the diffuse light. As a result, high accuracy tracking is not typically used in non-concentrating PV applications.

The sun travels through 360 degrees east to west per day, but from the perspective of any fixed location the visible portion is 180 degrees during an average half day period (more in spring and summer; less, in fall and winter). Local horizon effects reduce this somewhat, making the effective motion about 150 degrees. A solar panel in a fixed orientation between the dawn and sunset extremes will see a motion of 75 degrees to either side, and thus, according to the table above, will lose 75% of the energy in the morning and evening. Rotating the panels to the east and west can help recapture those losses, tracker rotating in the east-west direction is known as a single-axis tracker.

The sun also moves through 46 degrees north and south during a year. The same set of panels set at the midpoint between the two local extremes will thus see the sun move 23 degrees on either side, causing losses of 8.3% A tracker that accounts for both the daily and seasonal motions is known as a dual-axis tracker. Generally speaking, the losses due to seasonal angle changes are complicated by changes in the length of the day, increasing collection in the summer in northern or southern latitudes. This biases collection toward the summer, so if the panels are tilted closer to the average summer angles, the total yearly losses are reduced compared to a system tilted at the spring/fall solstice angle (which is the same as the site's latitude).

There is considerable argument within the industry whether the small difference in yearly collection between single and dual-axis trackers makes the added complexity of a two-axis tracker worthwhile. A recent review of actual production statistics from southern Ontario suggested the difference was about 4% in total, which was far less than the added costs of the dual-axis systems. This compares unfavorably with the 24-32% improvement between a fixed-array and single-axis tracker.

2.2.6 Types of solar collector

Different types of solar collector and their location (latitude) require different types of tracking mechanism. Solar collectors may be:

- Non-concentrating flat-panels, usually photovoltaic or hot-water.
- Concentrating systems, of a variety of types.

Tracking systems may be configured as:

- Fixed collector / moving mirror.
- Moving collector

2.2.7 Theory and construction

Solar modules use light energy (photons) from the sun to generate electricity through the photovoltaic effect. The majority of modules use wafer-based crystalline silicon cells or thin-film cells based on cadmium telluride or silicon. The structural (load carrying) member of a module can either be the top layer or the back layer. Cells must also be protected from mechanical damage and moisture. Most solar modules are rigid, but semi-flexible ones are available, based on thin-film cells. These early solar modules were first used in space in 1958.

2.2.8 The photovoltaic effect

The photovoltaic effect is the creation of voltage or electric current in a material upon exposure to light. The standard photovoltaic effect is directly related to the photoelectric effect, though they are different processes. When the sunlight or any other light is incident upon a material surface, the electrons present in the valence band absorb energy and, being excited, jump to the conduction band and become free. These highly excited, non-thermal electrons diffuse, and some reach a junction where they are accelerated into a different material by a built-in potential (Galvani potential). This generates an electromotive force, and thus some of the light energy is converted into electric energy. The photovoltaic effect can also occur when two photons are absorbed simultaneously in a process called two-photon photovoltaic effect.

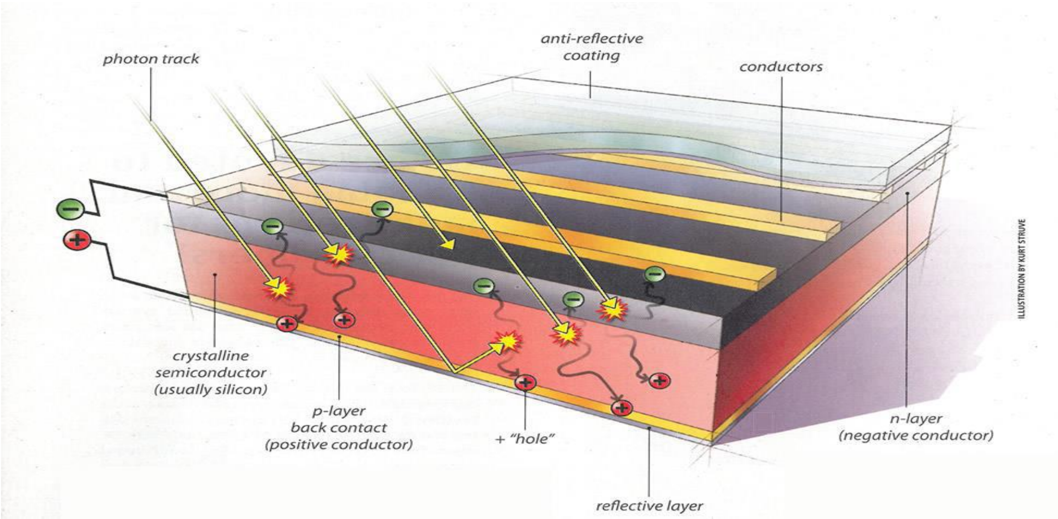

Figure 2.2: How does PV technology work

2.2.9 Polycrystalline silicon

Poly-crystalline silicon, also called poly-silicon, is a material consisting of small silicon crystals. It differs from single-crystal silicon, used for electronics and solar cells, and from amorphous silicon, used for thin film devices and solar cells.

2.2.10 Thin film solar cell

A Thin-film solar cell (TFSC), also called a Thin-film photovoltaic cell (TFPV), is a solar cell that is made by depositing one or more thin layers (thin film) of photovoltaic material on a substrate. The thickness range of such a layer is wide and varies from a few nanometers to tens of micrometers.

Many different photovoltaic materials are deposited with various deposition methods on a variety of substrates. Thin-film solar cells are usually categorized according to the photovoltaic material used:

- Amorphous silicon (a-Si) and other thin-film silicon (TF-Si)
- Cadmium telluride (CdTe)
- Copper indium gallium selenite (CIS or CIGS)

- Dye-sensitized solar cell (DSC) and other organic solar cells

2.3 Types of tracker

There is a many types of trackers up to eight like (horizontal, vertical, altitude azimuth, two axis mount, multi mirror reflective, active tracker passive tracker)

2.3.1 Horizontal axle solar tracker

In this type of tracking system, a long horizontal tube is supported on bearing mounted upon the tube and the tube will rotate on the axis to track the apparent motion of the sun through the day. As they do not tilt towards the equator so therefore they are not that much effective in during the winter midday (unless located near the equator), but these tracking system are very much productive in during the spring and summer season when the solar path is high in the sky. The devices are less effective at higher latitudes. The principle advantage is the inherent robustness of the supporting structure and the simplicity of the mechanism. Due to the characteristics of being horizontal the panels can be compactly placed on the axle tube without danger of self-shading and are also readily accessible for cleaning. A single control and motor may be used to actuate multiple rows of panels for active mechanisms.

2.3.2 Vertical axle solar tracker

In this type of tracking system, the panels are mounted on a vertical axle at a fixed, adjustable or tracking elevation angle. Such trackers with fixed or (seasonably) adjustable angles are suitable for high altitudes. This is because at high latitudes the apparent solar path is not especially high but which leads to long days in summer, with the sun traveling through a long arc.shown in (figure 2.5)

Figure 2.3: vertical solar tracker

2.3.3 Altitude azimuth solar tracker

Here the mounting is done in such a way so that it supports the entire weight of the solar tracker and allows it to move in both directions and locate a specific target. The horizontal axis (called the azimuth) allows the telescope to move up and down, the axis, vertical, allows the telescope to swing in a circle parallel to the ground. This mechanism makes it easy as the telescope can swing around in a circle and then lift to the target. As tracking an object from the earth is more complicated due to the rotational movement of the earth. For this reason, computer controlling is required.

2.3.4 Two axis mount solar tracker

In two axis mount, one axis is a vertical pivot shaft or horizontal ring mount that allows the device to be swung to a compass point. The second axis is a horizontal elevation pivot mounted upon the azimuth platform. Using this combination of the two axis any location in the upward hemisphere can be pointed. Such system needs computer control or tracking sensor to control motor drives that orient the panels toward the sun. Shown in figure 2.6

Figure 2.4: Two axis mount solar tracker

2.3.5 Multi-mirror reflective unit

This device uses multiple mirrors in a horizontal plane to reflect sunlight upward to a high temperature photovoltaic or other system requiring concentrated solar power. Only two drive systems are required for each device. Because of the configuration of the device it is especially suited for use on flat roofs and at low altitudes.

2.3.6 Active tracker

It uses motors and gear trains to direct the tracker in the direction of the sun. A controller is used to control the motors and the gear trains so that it moves accordingly and the panel faces the sun in the right direction required.
The active two axis tracker uses a heliostat – movable mirror that reflects the sunlight towards the absorber of a central power station, or a light sensor to track the sun.

2.3.7 Passive tracker

Use a low boiling point compressed gas fluid that is driven to one side or the other to cause the tracker to move in response to an imbalance. As this is a non-precision orientation it is unsuitable for certain types of concentrating photovoltaic collectors but works fine for common PV panel types.

2.3.8 Chronological tracker

It counteracts the earth's rotation at an equal rate as the earth, but in the opposite direction. These trackers are very simple but yet potentially very accurate solar trackers specifically for use with a polar mount. The drive method may be as simple as a gear motor that rotates at a very slow average rate of one revolution per day (15 degrees per hour).

2.4 Microcontrollers

Even at a time when Intel presented the first microprocessor with the 4004 there was already a demand for microcontrollers: The contemporary TMS1802 from Texas Instruments, designed for usage in calculators, was by the end of 1971 advertised for applications in cash registers, watches and measuring instruments. The TMS 1000, which was introduced in 1974, already included RAM, ROM, and I/O on-chip and can be seen as one of the first microcontrollers, even though it was called a microcomputer. The first controllers to gain really widespread use were the Intel 8048, which was integrated into PC keyboards, and its successor, the Intel 8051, as well as the 68HCxx series of microcontrollers from Motorola.

Today, microcontroller production counts are in the billions per year, and the controllers are integrated into many appliances we have grown used to, like

- household appliances (microwave, washing machine, coffee machine, ...)
- telecommunication (mobile phones)
- automotive industry (fuel injection, ABS, ...)
- aerospace industry
- industrial automation

Table 2.4: Comparison of AVR 8-bit controllers (AVR, ATmega, ATtiny)

Controller	Flash (kB)	SRAM (Byte)	EEPROM (Byte)	I/O - PINS	A/D (channels)
AT90C8534	8	288	512	7	8
AT90C8534	2	128	128	3	
AT90LS2343	2	160	128	5	
AT90LS8535	8	512	512	32	8
AT90S1200	1	64		15	
AT90S2313	2	160	128	15	
ATmega128	128	4096	4096	53	8
ATmega162	16	1024	512	35	
ATmega169	16	1024	512	53	8
ATmega16	16	1024	512	32	8
ATtiny11	1		64	5+1In	
ATtiny12	1		64	6	
ATtiny15L	1		64	6	4
ATtiny26	2	128	128		16
ATtiny28L	2	128		11+8In	

The basic internal designs of microcontrollers are pretty similar. Figure 1.4 shows the block diagram of a typical microcontroller. All components are connected via an internal bus and are all integrated on one chip. The modules are connected to the outside world via I/O pins.

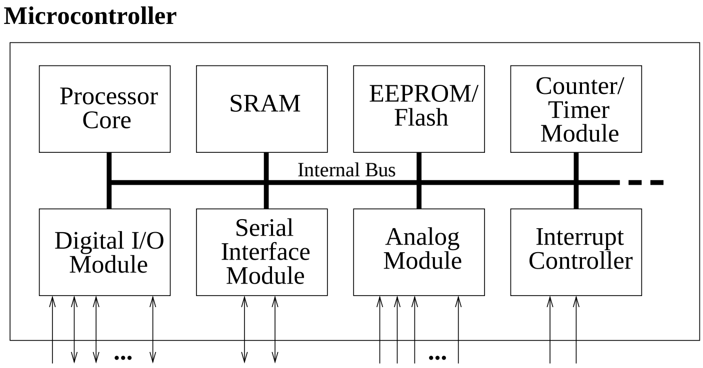

Figure 2.5: Basic layout of a microcontroller

The following list contains the modules typically found in a microcontroller

2.4.1 Processor Core:

The CPU of the controller. It contains the arithmetic logic unit, the control unit, and the registers (stack pointer, program counter, accumulator register,registerfile,...).

2.4.2 Memory:

The memory is sometimes split into program memory and data memory. In larger controllers, a DMA controller handles data transfers between peripheral components and the memory.

2.4.3 Interrupt Controller:

Interrupts are useful for interrupting the normal program flow in case of (important) external or internal events. In conjunction with sleep modes, they help to conserve power.

2.4.4 Timer/Counter:

Most controllers have at least one and more likely 2-3 Timer/Counters, which can be used to timestamp events, measure intervals, or count events. Many controllers also contain PWM (pulse width modulation) outputs, which can be used to drive motors or for safe breaking (antilock brake system, ABS).

Furthermore, the PWM output can, in conjunction with an external filter, be used to realize a cheap digital/analog converter.

2.4.5 Digital I/O:

Parallel digital I/O ports are one of the main features of microcontrollers. The number of I/O pins varies from 3-4 to over 90, depending on the controller family and the controller type.

2.4.6 Analog I/O:

Apart from a few small controllers, most microcontrollers have integrated analog/digital converters, which differ in the number of channels (2-16) and their resolution (8-12 bits). The analog module also generally features an analog comparator. In some cases, the microcontroller includes digital/analog converters.

2.4.7 Interfaces:

Controllers generally have at least one serial interface which can be used to download the program and for communication with the development PC in general. Since serial interfaces can also be used to communicate with external peripheral devices, most controllers offer several and varied interfaces like SPI and SCI.

Many microcontrollers also contain integrated bus controllers for the most common (field)busses. IIC and CAN controllers lead the field here. Larger microcontrollers may also contain PCI, USB, or Ethernet interfaces.

2.4.8 Watchdog Timer:

Since safety-critical systems form a major application area of microcontrollers, it is important to guard against errors in the program and/or the hardware. The watchdog timer is used to reset the controller in case of software "crashes".

2.4.9 Debugging Unit:

Some controllers are equipped with additional hardware to allow remote debugging of the chip from the PC. So there is no need to download special debugging software, which has the distinct advantage that erroneous application code cannot overwrite the debugger , Contrary to processors, (smaller) controllers do not contain a MMU (Memory Management Unit), have no or a very simplified instruction pipeline, and have no cache memory, since both costs and the ability to calculate execution times (some of the embedded systems employing controllers are real-time systems, like X-by-wire systems in automotive control) are important issues in the microcontroller market.

To summarize, a microcontroller is a (stripped-down) processor which is equipped with memory, timers, (parallel) I/O pins and other on-chip peripherals. The driving element behind all this is cost: Integrating all elements on one chip saves space and leads to both lower manufacturing costs and shorter development times. This saves both time and money, which are key factors in embedded systems. Additional advantages of the integration are easy upgradability, lower power consumption, and higher reliability, which are also very important aspects in embedded systems. On the downside, using a microcontroller to solve a task in software that could also be solved with a hardware solution will not give you the same speed that the hardware solution could achieve. Hence, applications which require very short reaction times might still call for a hardware solution. Most applications, however, and in particular those that require some sort of human interaction (microwave, mobile phone), do not need such fast reaction times, so for these applications microcontrollers are a good choice.

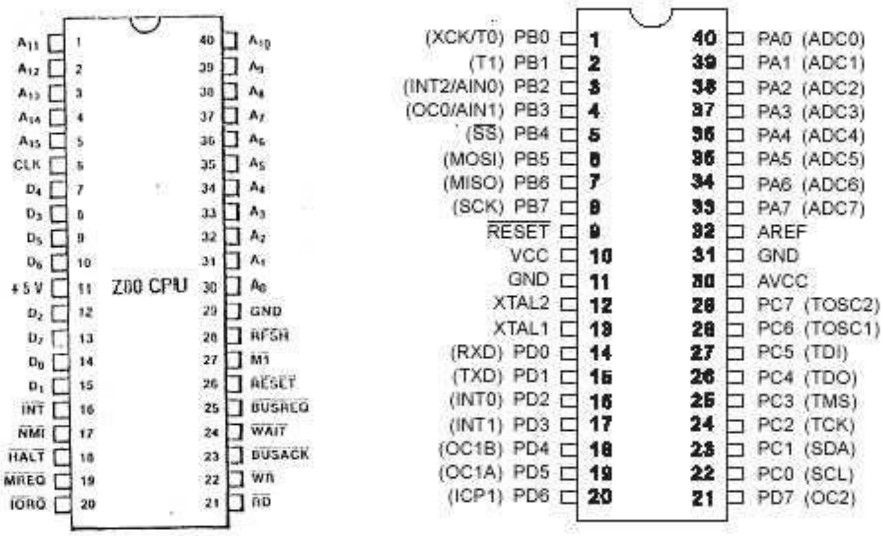

Figure 2.6: Pinouts of the Z80 processor (left) and the ATmega16 controller (right)

Figure 2.7: microcontroller

2.5 Sensors

A sensor is a device that converts a physical phenomenon into an electrical signal. As such, sensors represent part of the interface between the physical world and the world of electrical devices, such as computers.

2.5.1 Basic sensor technology

There are many formats in existence, and there is nothing close to an international standard for sensor specifications. The system designer will encounter a variety of interpretations of sensor performance parameters, and it can be confusing. It is important to realize that this confusion is not due to an inability to explain the meaning of the terms rather it is a result of the fact that different parts of the sensor community have grown comfortable using these terms differently.

2.5.2 Sensor data sheets

It is important to understand the function of the data sheet in order to deal with this variability. The data sheet is primarily a marketing document. It is typically designed to highlight the positive attributes of a particular sensor and emphasize some of the potential uses of the sensor, and might neglect to comment on some of the negative characteristics of the sensor. In many cases, the sensor has been designed to meet a particular performance specification for a specific customer, and the data sheet will concentrate on the performance parameters of greatest interest to this customer.

2.5.3 Sensor performance characteristics definitions

The following are some of the more important sensor characteristics:

- Transfer function: The transfer function shows the functional relationship between physical input signal and electrical output signal. Usually, this relationship is represented as a graph showing the relationship between the input and output signal, and the details of this relationship may constitute a complete description of the sensor characteristics. For expensive sensors that are individually calibrated, this might take the form of the certified calibration curve.
- Sensitivity: The sensitivity is defined in terms of the relationship between input physical signal and output electrical signal. It is generally the ratio between a small change in electrical signal to a small change in physical signal. As such, it may be expressed as the derivative of the transfer function with respect to physical signal. Typical units are

volts/Kelvin, Mill volts/kilopascal, etc... A thermometer would have "high sensitivity" if a small temperature change resulted in a large voltage change.

- Span or dynamic range: The range of input physical signals that may be converted to electrical signals by the sensor is the dynamic range or span. Signals outside of this range are expected to cause unacceptably large inaccuracy. This span or dynamic range is usually specified by the sensor supplier as the range over which other performance characteristics described in the data sheets are expected to apply. Typical units are Kelvin, Pascal, Newton, etc.
- Accuracy or uncertainty: Uncertainty is generally defined as the largest expected error between actual and ideal output signals. Typical units are Kelvin. Sometimes this is quoted as a fraction of the full-scale output or a fraction of the reading. For example, a thermometer might be guaranteed accurate to within 5% of FSO (Full Scale Output). "Accuracy" is generally considered by mythologists to be a qualitative term, while "uncertainty" is quantitative. For example, one sensor might have better accuracy than another if its uncertainty is 1% compared to the other with an uncertainty of 3%.
- Hysteresis: Some sensors do not return to the same output value when the input stimulus is cycled up or down. The width of the expected error in terms of the measured quantity is defined as the hysteresis. Typical units are kelvin or percent of FSO.
- Nonlinearity (often called Linearity): The maximum deviation from a linear transfer functions over the specified dynamic range. There are several measures of this error. The most common compares the actual transfer function with the "best straight line," which lies midway between the two parallel lines that encompass the entire transfer function over the specified dynamic range of the device. This choice of

comparison method is popular because it makes most sensors look the best. Other reference lines may be used, so the user should be careful to compare using the same reference.

- Noise: All sensors produce some output noise in addition to the output signal. In some cases, the noise of the sensor is less than the noise of the next element in the electronics, or less than the fluctuations in the physical signal, in which case it is not important.
- Resolution: The resolution of a sensor is defined as the minimum detectable signal fluctuation.
- Bandwidth: The bandwidth of a sensor is the frequency range between the time correspond to the upper and lower cutoff frequencies.

2.5.4 Light sensors

A Light Sensor generates an output signal indicating the intensity of light by measuring the radiant energy that exists in a very narrow range of frequencies basically called "light", and which ranges in frequency from "Infrared" to "Visible" up to "Ultraviolet" light spectrum. The light sensor is a passive device that convert this "light energy" whether visible or in the infrared parts of the spectrum into an electrical signal output. Light sensors are more commonly known as "Photoelectric Devices" or "Photo Sensors" because the convert light energy (photons) into electricity (electrons). Often used in auto dimming, darkness or twilight detection for turning the street lights "ON" and "OFF", and for photographic exposure meter type applications.

2.6 Stepper Motor

To build the two axis automatic solar tracker, we have used two stepper motors so that we can control the movement of the system more precisely. According to the requirement of the project, both the motors are different in ratings from each other. One of the motors which have a rating of 1.8v and 3.0A is responsible for the rotation of the solar panel. The solar panel will have a freedom of rotation from zero to 180 degrees in order to track the sun throughout the whole day. This stepper motor has a lower rating compared to the other one. Both the stepper motors used for this thesis project has a resolution of 1.8 degree/step. This means that when a pulse is applied to the stepper motor, the shaft will rotate by 1.8 degrees.

The other stepper motor used has slightly higher ratings because it will have to rotate a circular base as well as the panel, the smaller stepper motor and the associated structure. This stepper motor has a rating of 2.6v and 3.1A. This stepper motor will also rotate the base from zero degree to 180 degrees. As we know, that the sun does not always follow the same path throughout the year, so the mechanism that we developed will allow the system to automatically track the sun no matter which ever path it follows.

2.6.1 Characteristics

Stepper motors is a kind of DC motor that is brushless and has discrete rotation unlike DC motors. This ability to rotate in discrete steps allows them to be very precise which makes it suitable for our project. The precision movement also has a very big advantage and that is no feedback system is required. Stepper motors are quite available as they are widely used commercially which makes them less expensive. They are easy to implement and also has longer life. Stepper motors works on the principle of energizing respective electromagnet hence they require additional circuitry in order to make them work.

The figure 2.10 shows the working principle for a stepper motor. As it can be seen that a command is given to the stepper motor and it works accordingly. No feedback system is required hence making the system less complex. More details about the working principle of the motor will be discussed later.

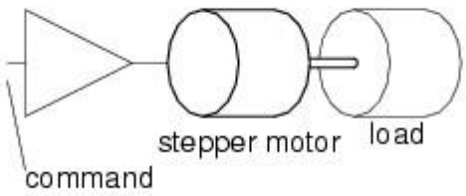

Figure. 2.8: Working principle of stepper motor

Stepper motors are a different kind of motors and they have a unique Torque v/s Speed characteristic (figure 2.11). In general stepper motors have very high torque compared to the other type of motors but this torque decreases rapidly as the speed of the shaft in the motor increases. The torque of the stepper motor remains fairly constant as the speed starts to increase but after a certain “cutoff speed” is reached, the torque starts to decrease rapidly until it becomes zero as the speeds keeps increasing.

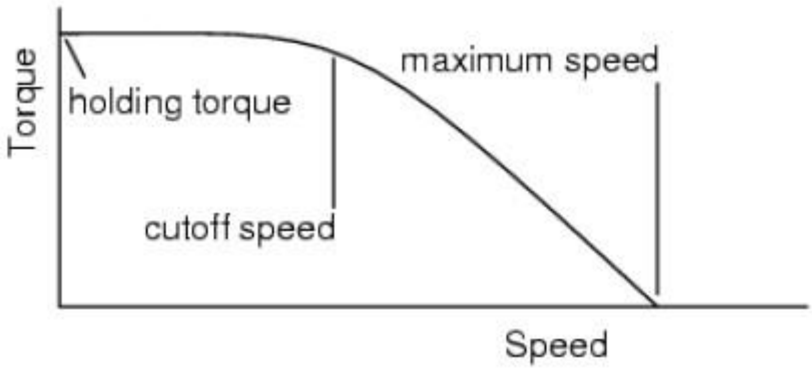

Fig.2.9: Torque vs. speed characteristics curve

2.6.2Working principle

There are many types of Stepper motors available in the market. The three main types are:

1. Permanent magnet (PM) stepper motor

2. Variable reluctance (VR) stepper motor

3. Hybrid synchronous (HS) stepper motor

The electromagnets are energized by an external control circuit, such as microcontroller or even using a computer's parallel port. To make the motor shaft turn, first one electromagnet is given power, which makes the gear's teeth magnetically attracted to the electromagnet's teeth. When the gear's teeth are thus aligned to the first electromagnet, they are slightly offset from the next electromagnet. So when the next electromagnet is turned on and the first is turned off, the gear rotates slightly to align with the next one, and from there the process is repeated. Each of those slight rotations is called a "step". This way the movement of the stepper motor is precise and can be used for high accuracy movement.

CHAPTER THREE

TRACKING SYSTEM COMPONENTS

3.1 Microcontroller pic16

PIC is a family of microcontrollers made by Microchip Technology, derived from the PIC1650 originally developed by General Instrument's Microelectronics Division. The name PIC initially referred to Peripheral Interface Controller. The first parts of the family were available in 1976; by 2013 the company had shipped more than twelve billion individual parts, used in a wide variety of embedded systems.

Early models of PIC had read-only memory (ROM) or field-programmable EPROM for program storage, some with provision for erasing memory. All current models use flash memory for program storage, and newer models allow the PIC to reprogram itself. Program memory and data memory are separated. Data memory is 8-bit, 16-bit, and, in latest models, 32-bit wide. Program instructions vary in bit-count by family of PIC, and may be 12, 14, 16, or 24 bits long. The instruction set also varies by model, with more powerful chips adding instructions for digital signal processing functions.

The hardware capabilities of PIC devices range from 6-pin SMD, 8-pin DIP chips up to 100-pin SMD chips, with discrete I/O pins, ADC and DAC modules, and communications ports such as UART, I2C, CAN, and even USB. Low-power and high-speed variations exist for many types.

The manufacturer supplies computer software for development known as MPLAB, assemblers and C/C++ compilers, and programmer/debugger hardware under the MPLAB and PICKit series. Third party and some open-source tools are also available. Some parts have in-circuit programming capability; low-cost development programmers are available as well has high-production programmers.

PIC devices are popular with both industrial developers and hobbyists due to their low cost, wide availability, large user base, extensive collection of application notes, availability of low cost or free development tools, serial programming, and re-programmable Flash-memory capability.

The 16F877A is one of the most popular PIC microcontrollers and it's easy to see why - it comes in a 40 pin DIP pinout and it has many internal peripherals. The only disadvantage that you could level at it is that it does not have an internal clock source like most of the other more modern PIC's.

The 16F877A is a capable microcontroller that can do many tasks because it has a large enough programming memory (large in terms of sensor and control projects) 8k words and 368 Bytes of RAM. This is enough to do many different projects

The 40 pins make it easier to use the peripherals as the functions are spread out over the pins. This makes it easier to decide what external devices to attach without worrying too much if there are enough pins to do the job.

One of the main advantages is that each pin is only shared between two or three functions so it’s easier to decide what the pin function.

Figure 3.1: Pin out of pic16f877a

3.2 Light Dependent Resistors

A photo resistor or light-dependent resistor (LDR) or photocell is a light-controlled variable resistor. The resistance of a photo resistor decreases with increasing incident light intensity; in other words, it exhibits photoconductivity.

A photo resistor can be applied in light-sensitive detector circuits, and light- and dark-activated switching ciruits. A photo resistor is made of a high resistance semiconductor. In the dark, a photo resistor can have a resistance as high as a few mega ohms, while in the light, a photo resistor can have a resistance as low as a few hundred ohms. If incident light on a photo resistor exceeds a certain frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the conduction band. The resulting free electrons (and their whole partners) conduct electricity, thereby lowering resistance. The resistance range and sensitivity of a photo resistor can substantially differ among dissimilar devices. Moreover, unique photo resistors may react substantially differently to photons within certain wavelength bands.

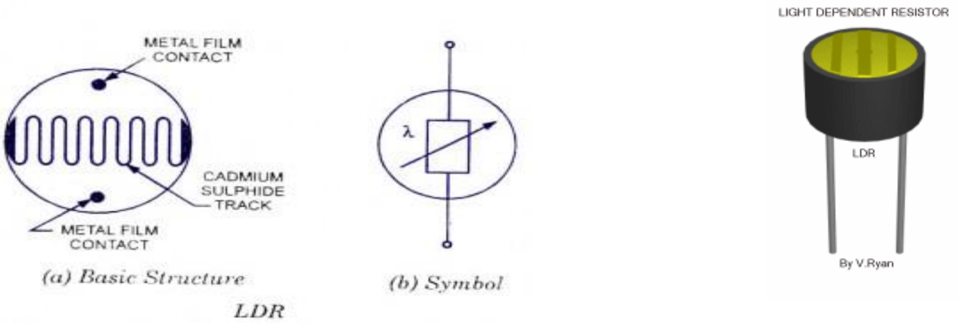

Figure 3.2: Dependent resistor (LDR)

3.3 Driver

The relay driver uln2003 ic is a high voltage and current darlington array ic, it comprises of 7-open collector darlington pairs with common emitters. A pair of darlington is an arrangement of two bipolar transistors. This IC belongs to the family of ULN200x ICs and various types of this family interface to various logic families. This ULN2003 IC is for 5V TTL and CMOS logic devices. These ICs are used as relay drivers as well as to drive a wide range of loads, line drivers, display drivers etc. This IC is also normally used while driving Stepper Motors. The pairs of darlington in ULN2003 is esteemed at 500mA and can withstand peak current of 600mA.In the pin layout, the i/ps & o/ps are provided reverse to each other. Each driver also has a suppression diode to dissipate voltage spikes while driving inductive loads

The ULN2003 is known for its high-current, high-voltage capacity. The drivers can be paralleled for even higher current output. Even further, stacking one chip on top of another, both electrically and physically, has been done. Generally, it can also be used for interfacing with a stepper motor, where the motor requires high ratings which cannot be provided by other interfacing devices.

Main specifications:

-500 mA rated collector current (single output)

-50 V output (there is a version that supports 100 V output)

-Includes output flyback diodes

-Inputs compatible with TTL and 5-V CMOS logic

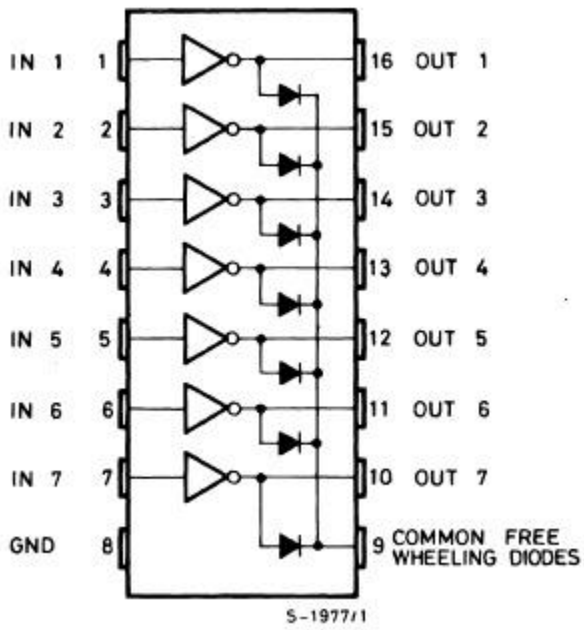

Figure 3.3: ULN 2003 driver

3.4 Breadboard

Breadboards are one of the most fundamental pieces when learning how to build circuits (figure 3.10). Here we will show little bit about what breadboards are, why they are called breadboards, and how to use one. Once you are done you should have a basic understanding of how breadboards work and be able to build a basic circuit on a breadboard.

An electronics breadboard (as opposed to the type on which sandwiches are made) is actually referring to a solder less breadboard. These are great units for making temporary circuits and prototyping, and they require absolutely no soldering.

Prototyping is the process of testing out an idea by creating a preliminary model from which other forms are developed or copied, and it is one of the most common uses for breadboards. If you aren't sure how a circuit will react under a given set of parameters, it's best to build a prototype and test it out. For those new to electronics and circuits, breadboards are often the best place to start. That is the real beauty of breadboards–they can house both the simplest circuit as well as very complex circuits. As you'll see later in this tutorial, if your circuit outgrows its current breadboard, others can be attached to accommodate circuits of all sizes and complexities.

Another common use of breadboards is testing out new parts, such as Integrated circuits (ICs). When you are trying to figure out how a part works and constantly rewiring things, you don't want to have to solder your connections each time.

Figure 3.4: Breadboard

CHAPTER FOUR

FUNCTION AND OPERATION OF SUN TRACKER SYSTEM

4.1 Introduction

In this project we will make the solar panel track the sun position depended on electric circuits that control the movement of the solar panel using special type of motors called stepper motor. The stepper motor is controlled by combination of logic and electric circuits and components starting by microcontroller through the drive circuit of the motor reaching the desired response of the system. In this chapter we will observe how tracking system work.

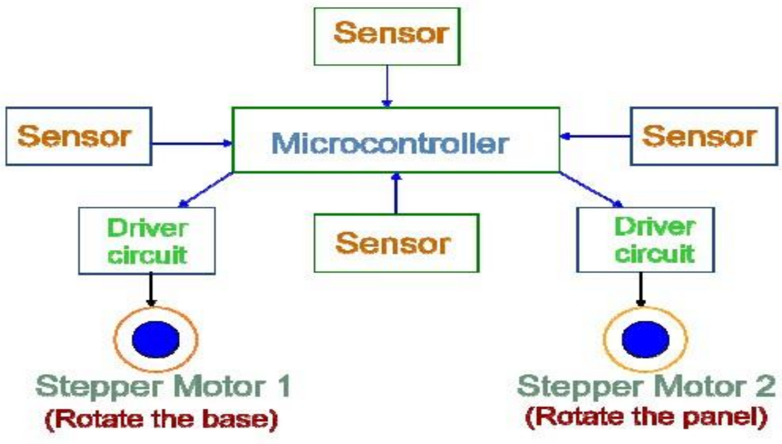

Figure 4.1: description of solar tracking system

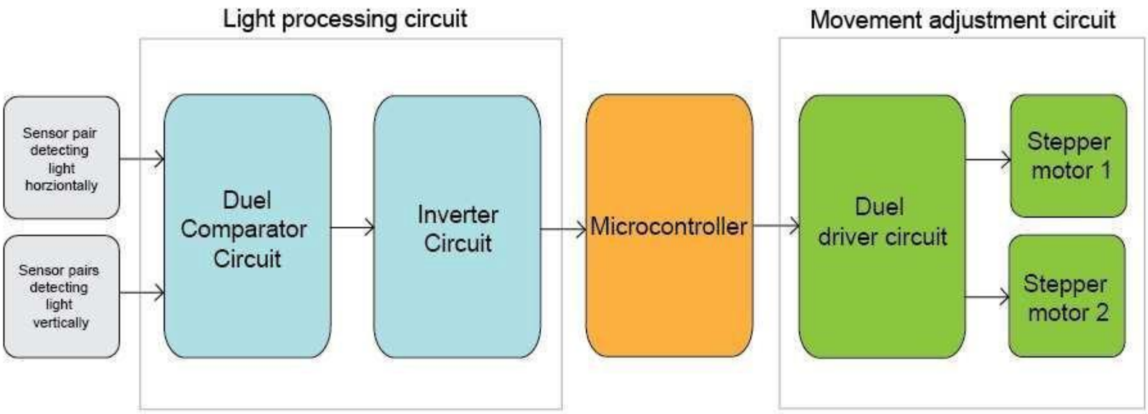

Figure 4.2: how the tracking system works

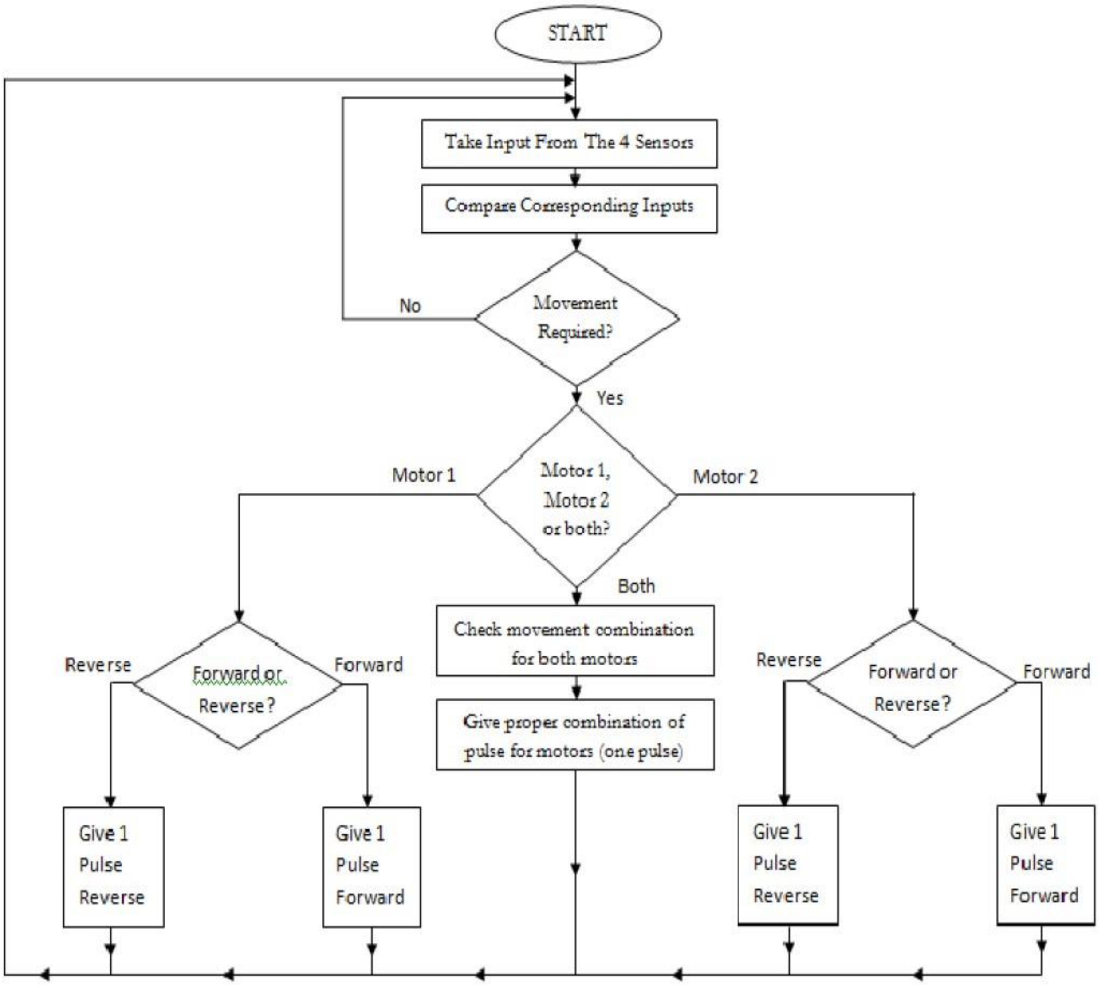

Figure 4.3: flow chart of the tracker

4.2 Structure and Connectivity

We have there the driver circuit and the sensing circuit connection so the out of the driver circuit connected to the stepper as shown in the connection diagram

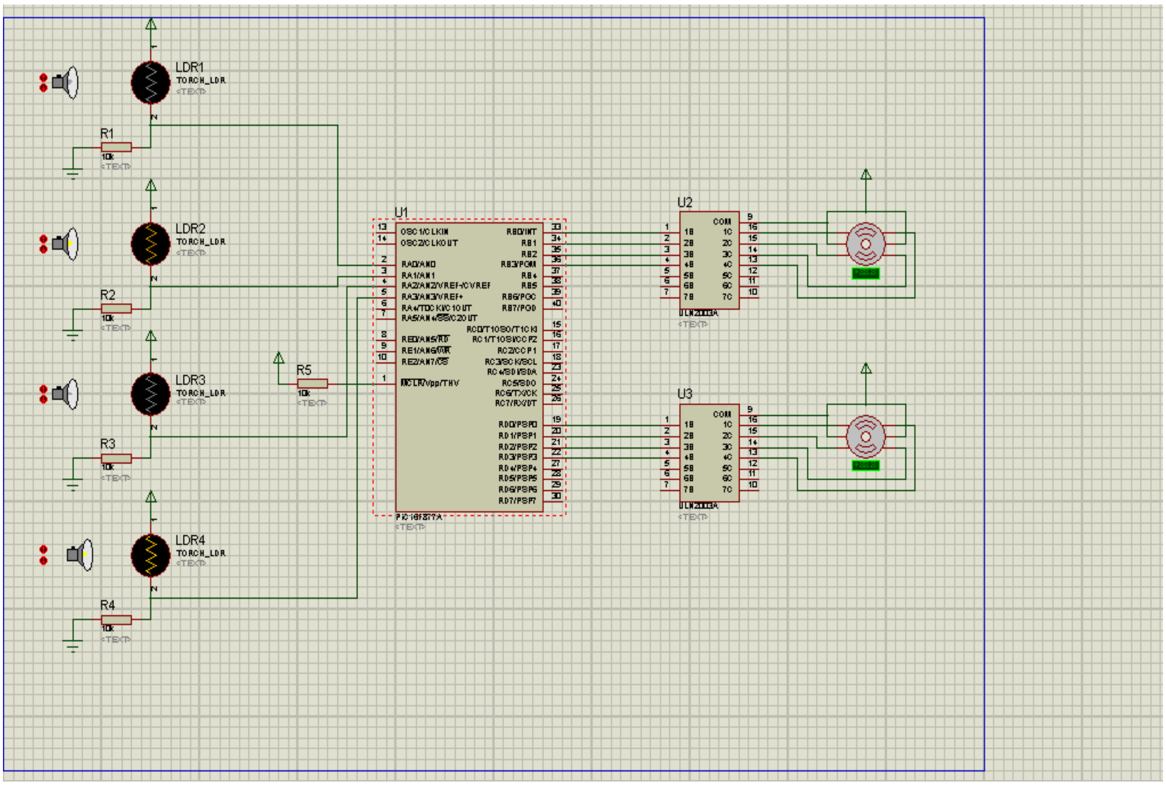

Figure 4.4 Circuit diagram of solar tracking system

4.3 Operation of tracking system

Operation the solar panel position is controlled automatically depending on the reading of the six LDR's two of them for north and south axis, the other four for east-west axis. The microcontroller receives the signals from LDR's in voltage form and after processing decide the suitable action that makes the panel in vertical position with the sun light as far as possible. The motion mechanism of concerned stepper motor is done when one of LDR reading is more than the average of the all LDR's in the same axis, until all the reading of the same axis is equaled then the motor will stop. generally, for any reason.

When auxiliary LDR's signal reach to the microcontroller the stepper motor moves depending of the LDR signal until receiving signal from the top LDR's.

4.4 The program of Microcontroller

The microcontroller has been programmed by micro c with the following "C "language:

```
int A;
int B;
char n [7] ;
int H;
int L;
char n1 [7] ;
int E;
int G;
char n2 [7] ;
int U;
int K;
char n3 [7] ;
int tolerance = 10;
int tolerance1 = 10;
void main() {
  ADCON0 = 0X01;            // RA0 as Analog Input;
  ADCON0 = 0X02;            // RA1 as Analog Input;
```

```
ADCON0 = 0X03;             // RA2 as Analog Input;

ADCON0 = 0X04;             // RA3 as Analog Input;

TRISA0_bit = 1;            // Make RA0 as input;

TRISA1_bit = 1;            // Make RA0 as input;

TRISA2_bit = 1;            // Make RA0 as input;

TRISA3_bit = 1;            // Make RA0 as input;

TRISb = 0x00;              // Configure PORTb as output

PORTb = 0x00;

TRISd = 0x00;              // Configure PORTb as output

PORTd = 0x00;


while (1){

 A=adc_read(0);

 B=A/10;

 inttostr (B,n);


 H=adc_read(1);

 L=H/10;

 inttostr (L,n1);


 E=adc_read(2);

 G=E/10;
```

```
inttostr (G,n2);


U=adc_read(3);
K=U/10;
inttostr (K,n3);


if((abs(B - L) <= tolerance) || (abs(L - B) <= tolerance)) {
PORTb = 0x00;
delay_ms(200);
 }
else {
 if(B > L){
 PORTb = 0x03;
 delay_ms(200);
 PORTb = 0x06;
 delay_ms(200);
 PORTb = 0x0C;
 delay_ms(200);
 PORTb = 0x09;
 delay_ms(200);
 PORTb = 0x00;
 }
```

```
if(L > B){
PORTb = 0x0C;
delay_ms(200);
PORTb = 0x06;
delay_ms(200);
PORTb = 0x03;
delay_ms(200);
PORTb = 0x09;
delay_ms(200);
PORTb = 0x00;
}
}

if((abs(G - K) <= tolerance1) || (abs(K - G) <= tolerance1)) {
PORTd = 0x00;
delay_ms(200);
}
else{
if(G > K){
PORTd = 0x03;
delay_ms(200);
PORTd = 0x06;
```

```
  delay_ms(200);
  PORTd = 0x0c;
  delay_ms(200);
  PORTd = 0x09;
  delay_ms(200);
  PORTd = 0x00;
  }
  if(K > G){
  PORTd = 0x0c;
  delay_ms(200);
  PORTd = 0x06;
  delay_ms(200);
  PORTd = 0x03;
  delay_ms(200);
  PORTd = 0x09;
  delay_ms(200);
  PORTd = 0x00;
  }
  }
}}
```

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This project has presented a means of controlling a sun tracking array with an embedded microcontroller system. Specifically, it demonstrates a working software solution for maximizing solar cell output by positioning a solar array at the point of maximum light intensity and it represented by LDR which have been used to detect sun position by sensing the light and give the signal to the microcontroller. which control the cell panel movement by sending a signal to the stepper motor. The microcontroller programmed by " C " language to give the required system.

5.2 Recommendations

- Use mechanical design needs less torque to move a group of solar panels that can generate more renewable energy with minimum losses in power, and that by connecting these panels in one shaft for each direction that moves by a servo motor.
- Feeding the system with energy from the cell rather than separate power supply will make the tracking system more reliability.
- It is fit with Sudan considering the geographic position and weather condition.
- Provide the tracker system with higher voltage stepper motor with higher torque to avoid heating problems and the weight problems that we faced in this project.
- It’s better to use the linear actuators, which will reduce the losing of power throw belts, and gives a better accuracy.

- Try this project using fuzzy logic, and connect the system to PC interface screen.

REFERENCES

[1] Helianthus – a Low Cost High Efficient Solar, Tracking System Using AVR Microcontroller, (International Journal of Scientific & Engineering Research, Volume 3, Issue 10, October-2012 1 ISSN 2229-5518).

[2] Introduction to Microcontrollers **(**Courses 182.064 & 182.074) Vienna University of Technology Institute of Computer Engineering Embedded Computing Systems Group February 26, 2007) by (Gunther Gridling, Bettina Weiss).

[3] SEIA solar energy industries association (website).

[4] HYBRID STEPPING MOTORS & DRIVERS (2 phase KH , 3 phase KT/KR) datasheet.

[5] Katsuhiko Ogata, "Modern Control Engineering_ 4th Edition",

Prentice hell, 2002.

[6] (Design and Development of Mechanical Solar Tracking System)- Monika R. Gajadharane, Niranjan A. Gijare, Madhura H. Joshi, Suraj P. Kanase, Mr. Dayanand A. Ghatge, Mr. Sagar A. Band - International Journal of Advanced Engineering, Management and Science (IJAEMS) - [Vol-2, Issue-6, June-2016] - ISSN: 2454-1311- (Infogainpublication.com).

[7] A study on automatic dual axis solar tracker system - International Journal of Technical Research and Applications e-ISSN: 2320-8163, sept-oct 2013- PP. 77-85

[8] Fabrication of Dual-Axis Solar Tracking Controller Project- Nader Barsoum - Curtin University, Sarawak, Malaysia - 2011, 2, 57-68

doi:10.4236/ica.2011.22007 Published Online May 2011

[9] Design and Implementation of a Sun Tracker with a Dual-Axis

Single Motor for an Optical Sensor-Based Photovoltaic System - Jing-Min Wang and Chia-Liang Lu - Department of Electrical Engineering, St. John's University - Sensors 2013, 13, 3157-3168; doi:10.3390/s130303157 – open access.