Design and Fabrication of Automatic Sun Tracking System

Project Report 1990-91

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Certificate

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Certified that the candidate was Examined by us in the project work Viva-Voce Examination held on .... and the University Register Number was ....

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Dedicated To Our
Beloved Parents

Acknowledgement

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Synopsis

SYNOPSIS

The fear of energy crisis always forces one to search for the alternative sources. Since, the last two decades, scientists and technologists are engaged in developing either conventional or non conventional energy sources.

Sun is the main source of energy for many uses. During this period number of solar applications have been reported such as photo votaic and thermal appliances etc.

But the main hurdle for harnessing the solar energy is its tracking, without which overall efficiency will be poor. So, the sun tracker is an important component for any solar application for utilising maximum power efficiency.

Hence, the aim of this project is to analyse the performance of different tracking methods and to design a simple and economical sun tracking device.

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Nomenclature

NOMENCLATURE

Symbols	Description	Units
I_b	Instantaneous beam radiation	W/m^2
I_d	Instantaneous diffuse raditation	W/m^2
I_g	Instantaneous global radiation	W/m^2
LAT	Local apparent time	hours
n	Day of the year	-
t	Time	hours
T	Temperature	°K
I_t	Instantaneous flux incident on top cover of collector	W/m^2
R_b	Tilt factor for beam radiation	-
R_d	Tilt factor for diffuse radiation	-
R_r	Tilt factor for reflected radiation	-
β	Slope or tilt	Degree
δ	Declination	Degree
ρ	Reflectivity	-
θ	Angle of incidence	Degree
ϕ	Latitude	Degree
ω	Hour angle	Degree

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Introduction

Chapter 1

INTRODUCTION

1.1 MAN AND ENERGY

Man has needed and used energy at an increasing rate for his sustenances. For the first time man began to use a new source of energy viz. coal, in large quantities. After the invention of internal combution engines man began to use fossil fuels, oil, natural gas etc. After the second world war man began to use nuclear energy.

Thus every country draws its energy needs from a variety of sources. We can broadly catagorize these sources as commercial and non commercial. The commercial sources include the fossil fuels, hydro electric power and nuclear power. While the non commercial sources includes wood, animal wastes and agricultural wastes.

In the past few years, it has become obvious that the fossil fuel resources are fast depleting and that the fossil fuel era is gradually coming to an end. This is particularly true for oil and gas.

The most serious of the fossil fuels is the harmful effect on the environment. The combustion of fossil fuels has caused serious air pollution problems. So man embarks on the search for alternative sources of energy.

1.2 THE NEED FOR ALTERNATIVES

a. The production of oil and natural gas is likely to touch a maximum before the end of this year. Most of the reserves of these commodities are likely to be consumed by the year 2020.

b. As oil and natural gas become scarcer, a greater burden will fall on coal. It is likely that the production of coal will touch a maximum somewhere between the years 2030 and 2060 for the world as a whole.

c. It should also be noted that in addition to supplying energy, fossil fuels are used extensively as feed stock material for manufacture of organic compounds. As reserves deplete, the need for using fossil fuels exclusively for such purposes may become greater. So we are going for alteratives.

1.3 THE SOLAR OPTION

Solar energy is a very large inexhaustible source of energy. The power from the sun intercepted by the earth is approximately 1.8×10^{11} MW which is many thousand times larger than the present consumption rate on the earth of all commercial energy sources. Thus in principle solar energy could supply all the present and future energy needs of the world on a continuing basis. This makes it one the most promising of the unconventional energy sources.

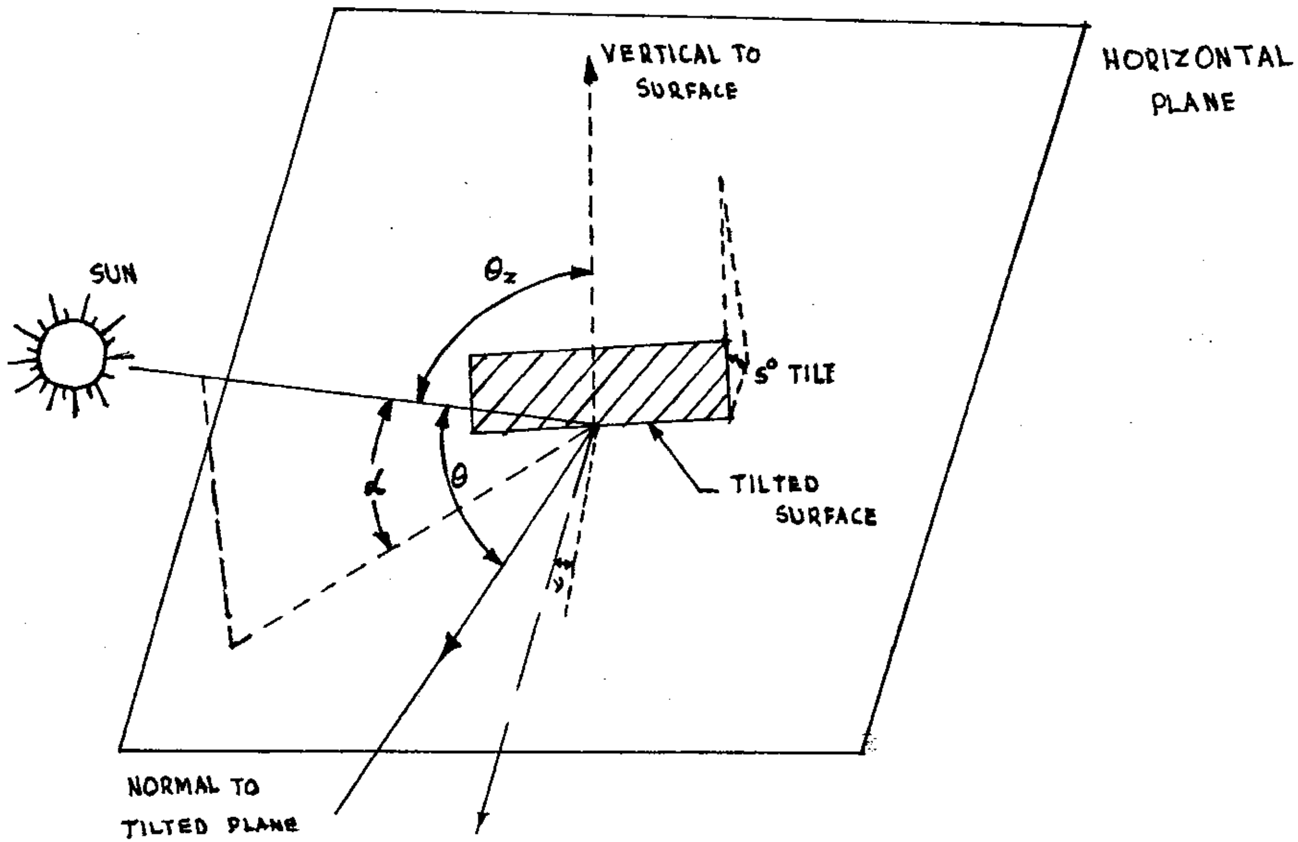
Solar energy has two main advantages. Firstly unlike fossil fuels and nuclear power, it is an anvironmentally clear source of energy. Secondly it is free and available in adequate quantities in almost all parts of the world where ever people live.

1.4 SOLAR RADIATION GEOMETRY

In order to understand what follows for the calculations of solar radiations and to find the beam energy falling on the surface having any orientation, it is necessary to convert the value of the beam flux coming from the direction of the sun to an equivalent value corresponding to the normal direction to the surface, the defenitions of some of the basic terms which are necessary are given below.

a. If θ is the angle between an incident beam of flux I_{bn} and the normal to a plane surface then the equivalent flux falling normal to the surface is given by $I_{bn} \cos \theta$. The angle θ can be related by a general equation to ϕ the latitude, δ the declination, γ the surface azimuth angle, ω the hour angle and β the slope. Each of these is first definded.

b. Latitude : The latitude ϕ of a location is the angle made by the radial line joining the location to the centre of the earth with the projection of the line on the equatorial plane.



VERTICAL TO
SURFACE
HORIZONTAL
PLANE
SUN
θ_z
5° TILT
α
θ
TILTED
SURFACE
NORMAL TO
TILTED PLANE

c. Declination : The declination δ is the angle made by the line joining the centres of the sun and the earth with its projection on the equitorial plane.

d. Logitude : It is the angular distance of the location, measured east or west from the prime meridian.
For example, longitude of coimbatore is 77°o'E

e. The Surface Azimuth Angle : The surface azimuth angle γ is the angle made in the horizontal plane between the line due south and the projection of the normal to the surface on the horizontal plane.

f. The Hour Angle : The hour angle ω is an angular measure of time and is equivalent to 15° per hour.

g. The Slope : The slope β is the angle made by the plane surface with the horizontal. It is taken to be positive for surfaces sloping towards the south and negative for surfaces sloping towards the north.

1.5 SUN TRACKING ARRANGEMENT

Sun tracking is the process of moving continously the absorber, to follow the durational motion of the sun. The tracking should be such that the sun rays falling should be perpendicular to the surface of the receiver.

The rate of which the receiver is to be rotated can be computed from the known pattern of suns movement and orientation. For north south orientation the tracking angular rate will be constant at 15° per hour.

In this project we discuss the preliminary design details of sun tracker working on the principle of detection of light and shadow bands produced by sun's rays passing through slits created for the purpose. The tracker is coupled to logic circuits whose outputs drive a motor controlling the motion of the collector on its line axis.

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Need of Solar Energy and Tracking

Chapter 2

NEED OF SOLAR ENERGY AND TRACKING

This chapter discusses the need for Solar energy and necessity of Solar tracking.

2.1 SOLAR ENERGY

Today in the madern world most of the functions of the society will come to a half in the event of power failures or fuel shortages. The standard of living and all developments depend on the availability of energy and energy consumption. Availability of energy plays a vital role in the progress and economy of the country. The available energy resources for mankind can be classified as

a. Non-renewable sources of energy like coal, petroleum, natural gas, nuclear power.

b. Renewable energy sources such as wood, hydro power, wind power, solar energy.

In the world every country draws its need of energy from these above sources. But the natural resources like fossil fuel is gradually getting depleted. Oil and natural gas will be exhausted in 50 years, followed by coal. So there have been hortage of oil in the world and war in the oil producing and exporting countries has increased oil price steeply.

Due to shortage of oil, there exists an energy crisis. The devoloping countries like India couldn't afford to waste its scarce oil resources and foreign exchange for import of oil, so there is a need for developing energy alternatives.

The important alternative energy resources are Nuclear energy, Wind energy, Solar energy, Tidal energy and Ocean energy.

Evergy derived from the sun is one of the most promising options. It can be used directly and indirectly and is considered as a major source to meet the future energy needs. The energy generated with in the sun during thermo nuclear fusion process is 3.7×10^{23} Kw. Out of this only about 1.7×10^{14} Kw reaches the earth. It is approximately 500 times the rate at which power is presently used directly by earths population.

The available amount of solar energy at earth's surface is seasonally changed because the distance between the sun and earth changes. India receives about 200 to 250 w/m^2 on the average.

As the solar energy available at our country is highly sufficient, it can be used as best alternative energy resources.

2.2 SOLAR TRACKING

Concentrating collectors and solar pannels are required to produce high temperatures since it is not possible to obtain, such temperatures with flat plate collectors. Fully tracking solar collectors give 35% to 40% more annual energy output than non-tracking collectors.

So solar tracking systems have gained a lot of attention in recent days.

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Selection

Chapter 3
SELECTION

In this chapter we discuss about different types of tracking and selection of effecient and reliable tracking systems.

3.1 DIFFERENT TRACKING MODES

Totally there are five types of tracking modes with different efficiencies. Here we dicuss different types of tracking modes and their performances.

3.1.1 TRACKING MODE I

The focal axis is east-west and horizontal. The collector is rotated about a horizontal East-west axis and adjusted once every day so that the solar beam is normal to the collector aperture plane at solar noon on that day.

In this case $\delta = (\phi - \beta)$ and

$$\cos\theta = \sin^2\delta + \cos^2\delta \cos\omega$$

3.1.2 TRACKING MODE II

The focal axis is east-west and horizontal. The collector is rotated about a horizontal east-west axis and adjusted contiuously so that the solar beam makes the minimum angle of incidence with the aperture plane at all time.

In this case $(\phi - \beta) = \tan^{-1}(\tan\delta/\cos\omega)$

and $\cos\theta = (1-\cos^2\delta)$

3.1.3 TRACKING MODE III

The focal axis is north-south and horizontal. The collector is rotateed about a horizontal north-south axis and adjusted continuously so that the solar beam makes the minimum angle of insidence with the aperture plane at all times.

Before noon,

$$\text{Cos}\ \theta = [(\sin\phi\ \sin\delta + \cos\phi\ \cos\delta\ \cos\omega)^2 + \cos^2\delta\ \sin^2\omega\ ]^{1/2}$$

$$\text{and}\ \beta = \tan^{-1}\left[\frac{\cos\delta\ \sin\omega}{\sin\phi\ \sin\delta + \cos\phi\ \cos\delta\cos\omega}\right]$$

Afternoon

$$\beta = \tan^{-1}\left[\frac{-\cos\delta\ \sin\omega}{\sin\phi\ \sin\delta + \cos\phi\ \cos\delta\cos\omega}\right]$$

The expression for $\cos\theta$ remains the same.

3.1.4 TRACKING MODE IV

The focal axis is north-south and inclined at a fixed angle equal to the latitude

i.e., $\beta = \phi \quad \therefore \theta = \delta$

The collector is rotated about an axis parallel to the earth's axis at an angular velocity equal and opposite to the earth's rate of rotation (15° per hour).

3.1.5 TRACKING MODE V

The focal axis is north-south and inclined. The collector is rotated continuously about an axis parallel to the focal axis as well as about a horizontal axis perpendicular to this axis and adjusted so that the solar beam is normally incident on the aperture plane at all times.

In this situation, obviously $\cos\theta = 1$

3.2 PERFORMANCE ANALYSIS

Maximum heat flux incident on collector corresponding to 10.00 a.m. IST on February 15th at Coimbatore (11°N, 77°E)

$\therefore \quad n = 46$

$$\delta = 23.45 \sin\left[\frac{360}{365}(284 + n)\right]$$

$$= -13.3^\circ$$

Local apparent time = standard time - 4[standard time longitude - longitude of locaton] + [equation of time correction]

$$LAT = 10hr - 4\,(82.50-77)min + (-14)min$$

$$= 10hr\ 24min\ (10.24)$$

$\therefore$ Hour angle $\omega = 15\,(12-LAT)$

$$= 15\,(12-10.24)$$

$$= 24^\circ$$

3.2.1 MODE I

Angle of incidence of Beam Radiation

$$\cos\theta = \sin^2\delta + \cos^2\delta\cos\omega$$

$$= \sin^2(-13.3) + \cos^2(-13.3) \times \cos(24)$$

$$= 0.9181$$

$$\theta = 23.35^\circ$$

Tilt angle $\beta = \delta - \phi$

$$= (-13.3) - (11)$$

$$= -24.3^\circ$$

Tilt factor for Beam Radiation(R_b) $= \dfrac{\cos\theta}{\sin\delta\sin\phi\ \phi\ \cos\delta\cos\phi\cos\omega}$

$$= \frac{0.9181}{\sin(-13.3)\sin(11) + \cos(11).\cos(-13.3)\cos(24)}$$

$$= 1.1076$$

Tilt factor for Diffused Radiation (R_b) $= \dfrac{1 + \cos\beta}{2}$

$$= \frac{1 + \cos(-24.3)}{2}$$

$$= 0.9557$$

Tilt factor for Reflected Radiation (R_r) $= \rho\left(\dfrac{1 - \cos\beta}{2}\right)$

$$= 0.2\left(\frac{1-\cos(-24.3)}{2}\right)$$

$$= 8.86 \times 10^{-3}$$

Hourly Beam Radiation $I_b = 665\ W/m^2$

Hourly Diffuse Radiation $I_b = 230\ W/m^2$

∴ Total heat flux falling on a collector

$$I_t = I_b R_b + I_d R_d + (I_b + I_d) R_r$$

$$= 665 \times 1.1076 + 230 \times 0.9557 + (665+230) \times 8.86 \times 10^{-3}$$

$$= 946.3 \text{ W/m}^2$$

3.2.2 MODE II

Angle of incidence of Beam Radiation

$$\cos\theta = (1-\cos^2\delta \sin^2\omega)^{1/2}$$

$$= 0.9183$$

$$\theta = 23.3^\circ$$

Tilt angle (β) $= (\phi - \beta) = \tan^{-1}\left(\frac{\tan\delta}{\cos\omega}\right)$

$$\beta = 25.508^\circ$$

Tilt factor for Beam Radiation $R_b = 1.108$

Tilt factor for Diffuse Radiation $R_d = 0.9513$

Tilt factor for Reflected Radiation $R_r = 9.474 \times 10^{-3}$

∴ Total heat flux $= 964.3 \text{ W/m}^2$

3.2.3 MODE III

Angle of incidence of Beam Radiation & Tilt angle

$$\beta = \tan^{-1}\left[\frac{\cos\delta \sin\omega}{\sin\phi \sin\delta + \cos\phi \cos\delta \cos\omega}\right]$$

$$= 25.53^\circ$$

$$\cos\theta = [(\sin\phi \sin\delta + \cos\phi \cos\delta \cos\omega)^2 + \cos^2\delta \sin^2\omega]^{1/2}$$

$$= 0.91847$$

$$\theta = 23.296^\circ$$

Tilt factor for Beam Radiation = 1.1082

Tilt factor for Diffuse Radiation = 0.9512

Tilt factor for Reflected Radiation = 9.764×10^{-3}

$\therefore$ Total heat flux = 964.5 W/m^2

3.2.4 MODE IV

Angle of incidence of Beam Radiation

$$\cos\theta = \cos\delta = \cos(-13.3)$$

$$= 0.9732$$

$$\theta = 13.3^\circ$$

$$\text{Tilt angle } \beta = \phi = 11^\circ$$

Tilt factor for Beam Radiation R_b = 1.172

Tilt factor Diffuse Radiation R_d = 0.9908

Tilt factor for Reflected Ratidation R_r = 1.837×10^{-3}

$\therefore$ Total heat flux = 1008.93 W/m^2

3.2.5 MODE V

Angle of incidence of Beam Radiation

$$\cos\theta = 1$$

$$\therefore \theta = 0$$

Tilt factor for Beam Radiation = 1.2066

Tilt factor for Diffuse Radiation = 0.9568

Tilt factor for Reflected Radiation = 0.00865

$\therefore$ Total heat flux falling on a collector = 1030.16 W/m^2

Description

Chapter 4
DESCRIPTION

In this capter we discuss about the various components of the circuit.

3.1 PHOTO VOLTAIC CELL

Photovoltaic cells are logically just a simple PN-junction usually made of silicon. They are essentially similar in construction to standard diode, but the silicon is exposed to light.

When this silicon surface is shielded from light no current will flow through the cell. But when it is exposed to a bright light a small voltage is generated due to what is known as the photo electric effect. If an illuminated photovoltaic cell is exposed upto a load, a current will flow through the circuit.

The amount of current flowing is dependant on the amount of light striking the surface of the cell. The brighter the light the higher the current available.

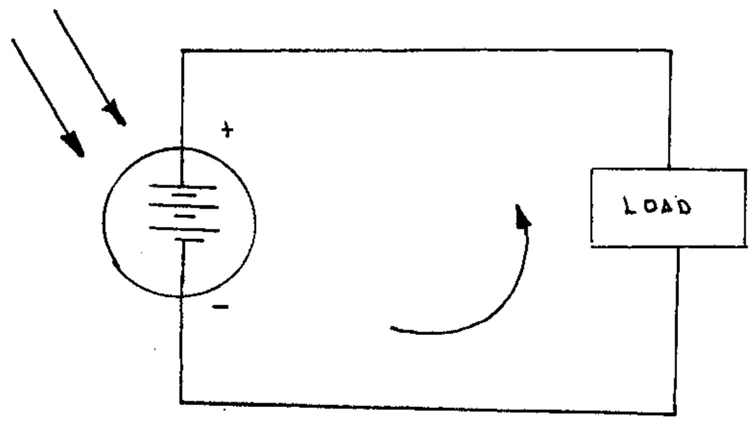
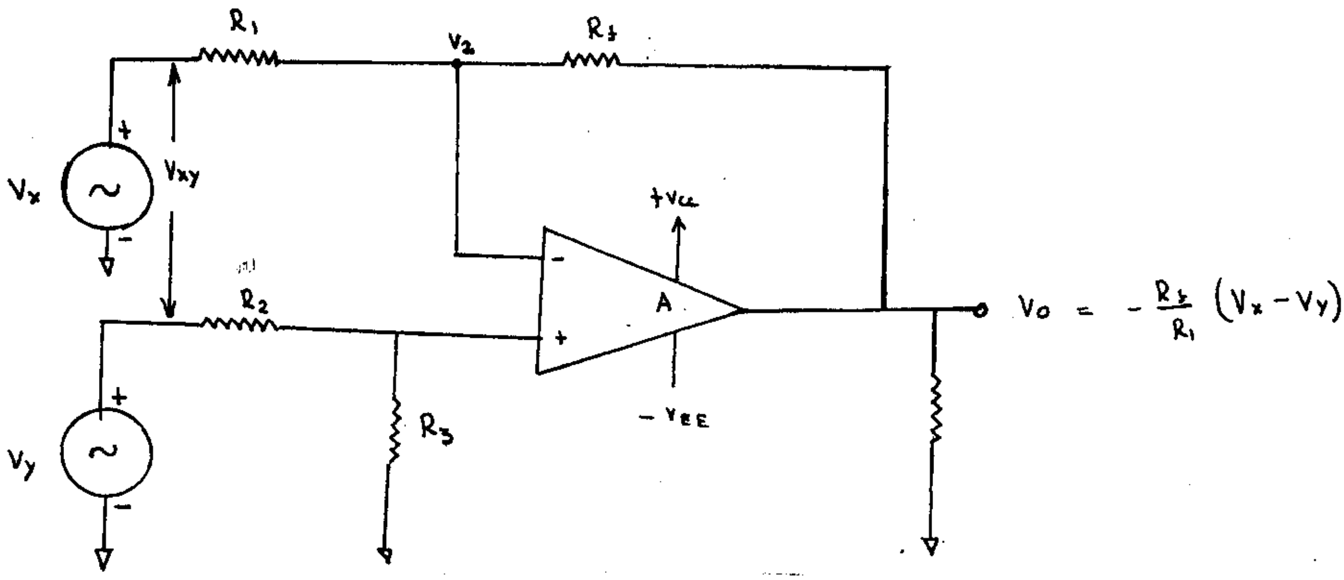


PHOTO VOLTAIC CELL Fig(4.1)



DIFFERENTIAL AMPLIFIER Fig(4.2)

3.2 DIFFERENTIAL AMPLIFIER

The fig.(4.2) shows the differential amplifier with one op-amp. The differential amplifier is a combination of inverting amplifiers. That is, when V_x is reduced to zero the circuit is a non inverting amplifier. Where as the circuit is an inverting amplifier when input V_y is reduced to zero.

It has two inputs V_x and V_y. We will, therefore use the superposition theorem in order to establish the relationship between inputs and output. When $V_y = 0$ volts, the configuration becomes an inverting amplifier; hence the output due to V_x only is

$$V_{ox} = -\frac{R_f(V_x)}{R_1}$$

Similarly, when $V_x = 0$ volts, the contiguration is a non-inverting amplifier having a voltage divider network composed of R_2 and R_3 at the non inverting input

Therefore,

$$V_1 = \frac{R_3(V_y)}{R_2 + R_3}$$

and the output due to V_y, then is

$$V_{oy} = (1 + \frac{R_f}{R_1})\ V_1$$

That is

$$V_{oy} = \frac{R_3}{R_2 + R_3} \left(\frac{R_1 + R_f}{R_1} \right) V_y$$

Since $R_1 = R_2$ and $R_f = R_3$

$$V_{oy} = \frac{R_f (V_y)}{R_1}$$

Thus, from above equation, the net output voltage

$$V_o = - \frac{R_f (V_y)}{R_1}$$

or the voltage gain

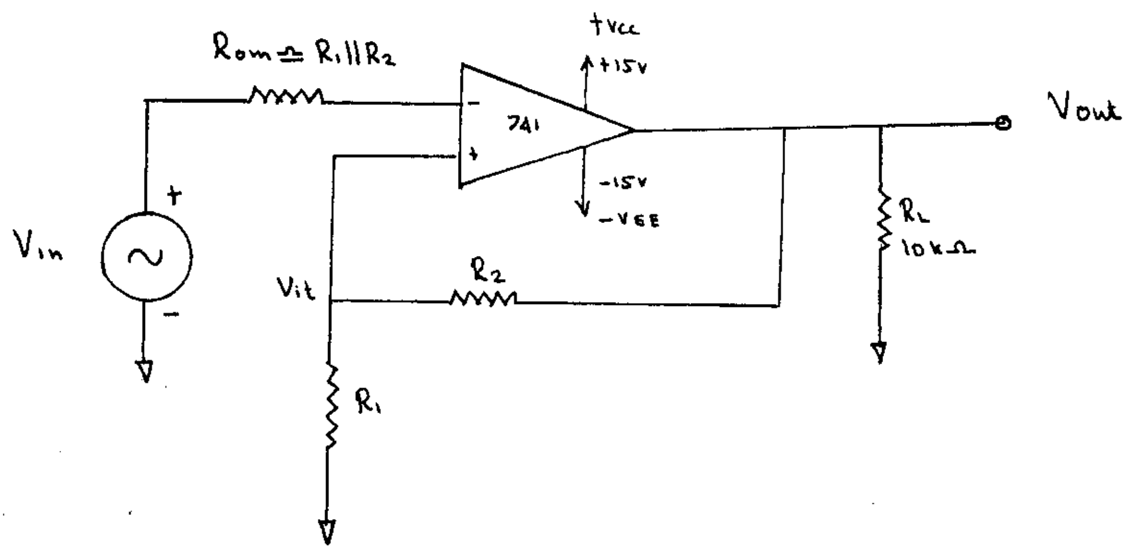
$$A_D = \frac{V_o}{V_{xy}} = - \frac{R_f}{R_1}$$

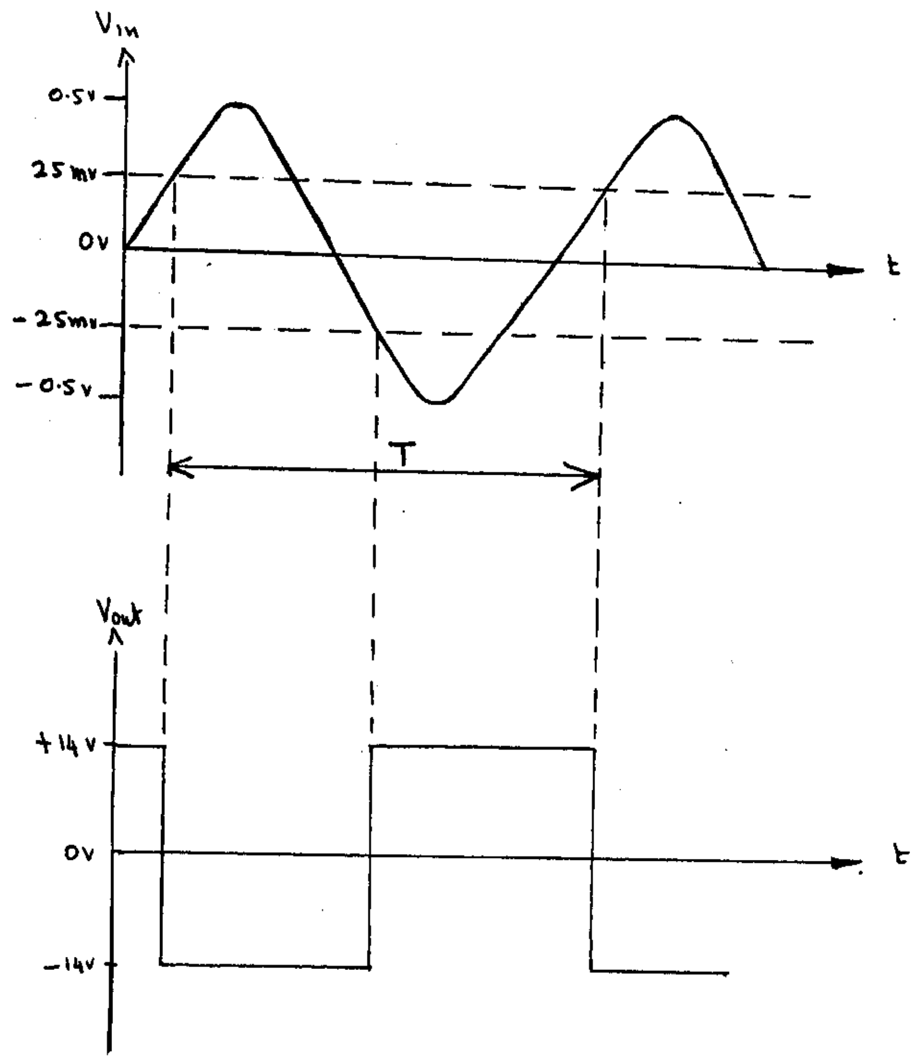
Note that the gain of the differential amplifier is the same as that of the inverting amplifier. For the differential amplifier to perform properly, both R_1 and $(R_2 + R_3)$ can be made much larger than the source resistances. So that the loading of the signal sources does not occur.

4.3 SCHMITT TRIGGER

The fig.(4.3) shows an inverting comparator with positive feedback. The circuit converts an irregular shaped wave form to a square wave or pulse. The circuit is known as the schmitt trigger or squaring

SCHMITT TRIGER Fig(4.3)





circuit. The input voltage V_{in} triggers the output V_o every time it exceeds certain voltage levels called the upper threshold voltage V_{vt} and lowershold voltage V_{it} as shown in above figure. These threshold voltages are obtained by using the voltage divider $R_1 - R_2$, where the voltage across R_1 is a variable reference threshold voltage that depends on the value and polarity of the output voltage V_o. When $V_o = + V_{sat}$ the voltage across R_1 is called uppershold voltage V_{ut}. The input voltage V_{in} in order to cause the output V_o to switch from $+ V_{sat}$ to $- V_{sat}$. As long as $V_{in} < V_{ut}$, V_o is at $+ V_{sat}$ using the voltage divider rule.

$$V_{ut} = \frac{R_1}{R_1 + R_2} (+ V_{sat})$$

On the other hand when $V_o = V_{sat}$, the voltage across R_1 is referred to as lower threshold voltage V_{it}. V_{in} must be slightly more negetive than V_{it} in order to cause V_o to switch from $- V_{sat}$ to $+ V_{sat}$. In other words for V_{in} values greater than V_{it}, V_o is at $-V_{sat}$. V_{it} is given by the following equation.

$$V_{it} = \frac{R_1}{R_1 + R_2} (- V_{sat})$$

Thus, if the threshold voltage V_{ut} and V_{it} are made larger than the input noise voltages, the positive feedback will eliminate the false output transitions. Also the positive feedback, because of its regenerative action will make V_o switch faster between $+V_{sat}$ and $-V_{sat}$.

In above figure,

$R_{om} \simeq R_1 // R_2$ is used, to minimise the offset problems.

The output of the schmitt is square wave when the input is a sine wave. When the input is triangular wave the output of the schmitt trigger is square wave. Where as if the input is a sawtooth wave the output is a pulse wave form.

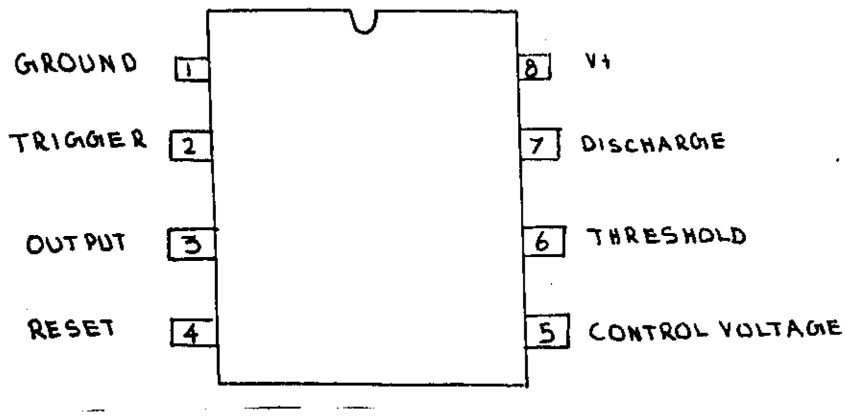
4.4 TIMER CIRCUIT

The most common timer is the 555 which is currently manufactured by several different companies. There are a number of other timer IcS, but they all work in basically same principle.

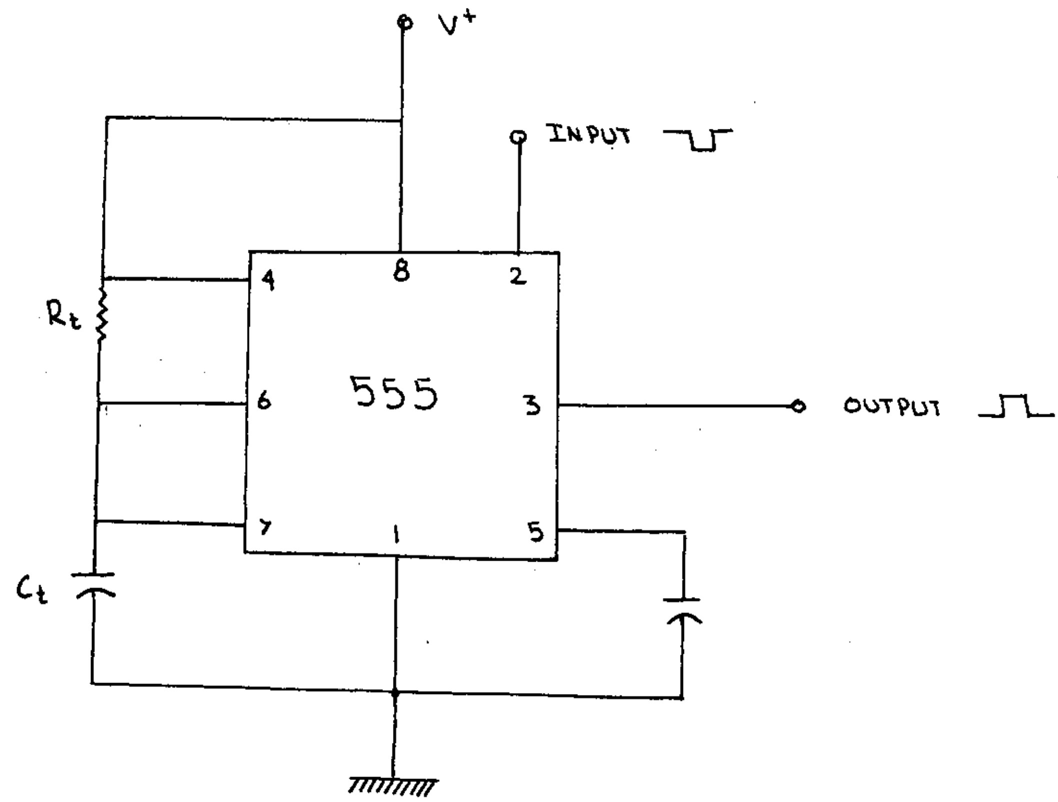
The 555 integerated circuit is available in a number off package styles, but 8 pin DIP version is the most frequently used.

Pin 1 is ground terminal

Pin 2 is trigger input



PINOUT DIAGRAM FOR A 555 TIMER Fig(4.4)



ASTABLE MULTIVIBRATOR Fig(4.5)

Pin 3 - output is usally taken from pin 3

Pin 4 - reset

Pin 5 - left unused in most applications.

It is extremely useful in some case. It is used as a control voltage input.

Pin 6 - Threshold input

Pin 7 - Discharge pin

Pin 8 - It is used to power the circuit.

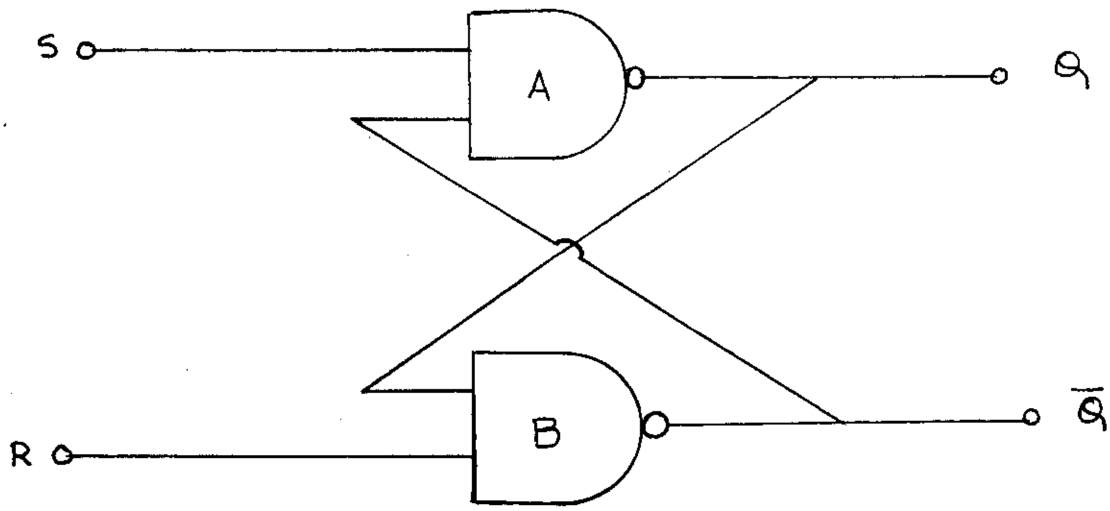
The voltage source for a 555 timer Ic should be between 5 to 15 volts, with 15 volts generally preferred for best results.

4.5 ASTABLE MULITIVIBRATOR

The circuit (4.5) is a self triggering one. The output of this circuit fluctuates between the same two states as the triggered monostable version, but in this circuit neither output state is stable. This circuit is called as astable multivibrator.

4.6 FLIP FLOP

A trigger signal is required to switch the output from one state to the other. This device is called a bistable multivibrator, or a flip flop some times it is also called a latch or a one bit memory.



RS- FLIP FLOP

IN PUTS		OUT PUTS	
R	S	Q	$\bar{Q}$
0	0	DISALLOWED STATE	
0	1	0	1
1	0	1	0
1	1	NO CHANGE - PREVIOUS STATE	

TRUTH TABLE

The figure (4.6) shows set - reset flip flop has two logic inputs. One is labeled S (set) and the other is labeled R (Reset).

Let us assume that when we first turn on this circuit both S and R are a logic 1, and output Q is zero. Ofcourse output Q must be a logic 1.

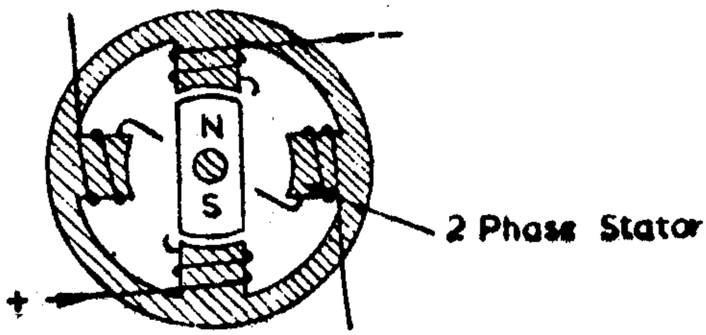
Gate A's input are S (logic 1), and $\bar{Q}$ (logic 1). Gate A is a NAND gate, so its output ($\bar{Q}$) remains at zero. Similarly gate B's inputs are R (logic 1) and Q (logic) so it's output ($\bar{Q}$) remains a logic 1.

If 'S' is changed to a logic zero, the output of gate 'A' (Q) is changed to a logic 1 and the output of gate B ($\bar{Q}$) is a logic zero.

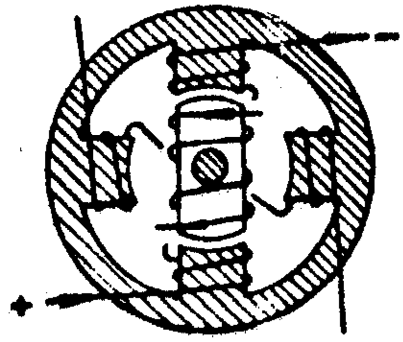
Even if S is now chaged back to a logic 1 state the output states will not change, because of the way they are fed back to the inputs of the gates.

4.7 STEPPER MOTOR

A stepper motor may be described as an actuator that transforms an electrical input pulse in to an incremental mechanical output displacement. It has an eight bit address so that pulses of requencies from 0 to 255 (2^8-1) hertz can be obtained and fed to the stepper motor.



PERMANENT MAGNET ROTOR



ACTIVE ROTOR

The stepper motor rotate or 'step' from one fixed position to the next when pulsed. Common step sizes vary from the range of 0.9° to 30° per step. Stepper motors can also be thought as digital motors.

CONSTRUCTION AND WORKING

the methods of operation and the factors that influence their design can be most effectively studies by making systematic review of the following points.

a. The electromagnetic principles of operation.

b. The number of rotor and stator poles and the number of excitation phases.

c. The drive circuit design

d. The patern of phase excitation

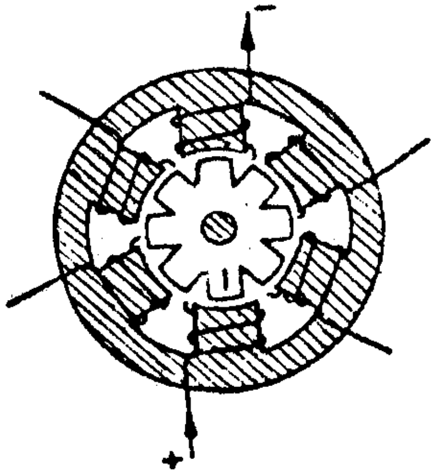
e. The external mechanical load conditions

f. The mothod of control.

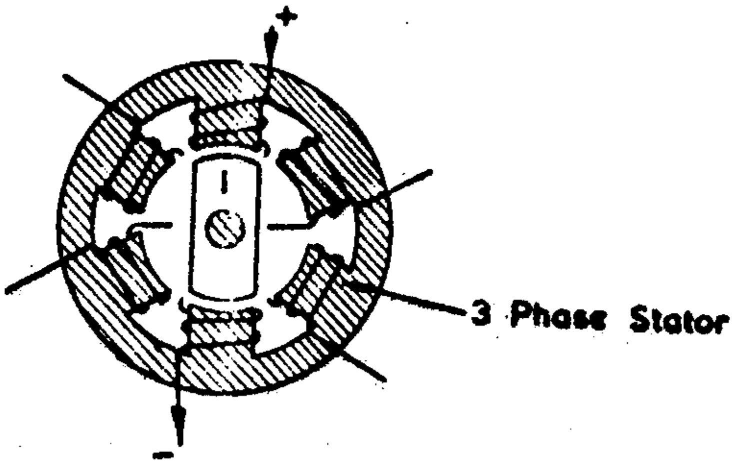
There are three basic classes of electric stepping motor each employing a different design of rotor.

4.7.1 PERMANENT MAGNET ROTOR TYPE

The permanent magnet rotor type is sucessfully employed in small instrument steppers. Its principle of peration is illustrated in fig (4.7) the rotor is shown in elementary bi-polar form and the stator in this example has four poles with two phases of excitation. The stepping action results from the sequential excitation of



MULTI-POLE REACTIVE ROTOR



SIMPLE REACTIVE ROTOR

with three phase six pole stator and a two pole rotor is shown the excitating at a single pole causes the rotor to align itself in to a position where the minimum magnetic reluctance is offered to the magnetic fluxes set up. If the phases are excited sequentilly, the sequence including the reversal of excitation the rotor will index round in 60° increments inresponse to the rotating stator field.

4.7.4 MULTIPOLE REACTIVE ROTOR

The stepping angle is influenced by the number of stator poles. It can also be varied as was seen earlier by the excitation of more than one phase at a time. It should be noted that many stepping motors are required to index through step angles on only a few angles (or) degrees. The remaining fundamental method of reducing the step angle is the use of a multipole rotor. This approach can be utilised in any of the three basic type of rotor design. The principle is shown in fig(4.10) for a variable reluctive motor. The use of an eight pole rotor in this example causes the step angle for single phase excitation to be decreased to 15°. The rotor would consist of a simple soft iron cylinder with eight axial slots. The step angle of a multipole multiphase motor with single phase excitation is given by the expression,

$$\text{Step angle} = \frac{360^{\circ}}{\text{No. of poles} \times \text{No. of phases}}$$

for a permanent magnet rotor.

4.7.5 FEW APPLICATIONS OF STEPPER MOTOR

Numerous potential application of stepping motors exsist in the field of automation.

Stepper motors are used to position the needs in a floppy disc drive unit.

They are also used in X - Y plotters which draws grain under computer control. One stepper motor and belt control the position of the pen in the X-direction and another stepper motor and belt control the position of pen in the Y-direction.

Stepper motor is an unique type of motor used in robots.

On of the main application of stepper motor is in the field of machine tools i.e., they are used for feed control in numerically controlled machines.

The short, stepper motor are used almost any where, movement in increment is needed.

the two phase windings. The stable rotor position at any instant is in the position at maximum magnetic attraction between the permanent magnet and the field set up by excitation of the windings. In this example the change of phase excitation produces a 90° step angle. This can be reduced to 40° by employing a phase excitation sequence in which energisation to numbers one and two phases is alternated. This type of motor has been proved to be relatively on attractive as it is not competitive in the high performance areas of forque and slowing frequency specifications.

4.7.2 ACTIVE ROTOR TYPE

An alternative approach to rotor design is to use an electromagnet insteed of a permanent magnet. This class of motor is termed as active rotor type. Fig(4.8). The need to excite the rotor is an unatractible aspect of this type of motor.

4.7.3 REACTIVE ROTOR TYPE

The over helming majority of electric stepping motors that are useful to the machine tool designer fall in to the third category. The reactive rotor or as it is often termed. The variable reluctance principle employs an electromagnetic rotor material often soft iron. Consider the example shown in fig(4.9). Here a motor

4.8 LOGIC BEQUEWCER

CIRCUIT DESCRIPTION

The circuit consits of two JK master slave flip flops. One flip flop is connected to the other using a NOR gate and the output of the second is fed back to the first JK flip flap using the NOR gate and inverter. The Q and $\bar{Q}$ outputs of each flip flop are given as input to the four phases of the stepper motor. The stepper motor sequence is determined by this circuit.

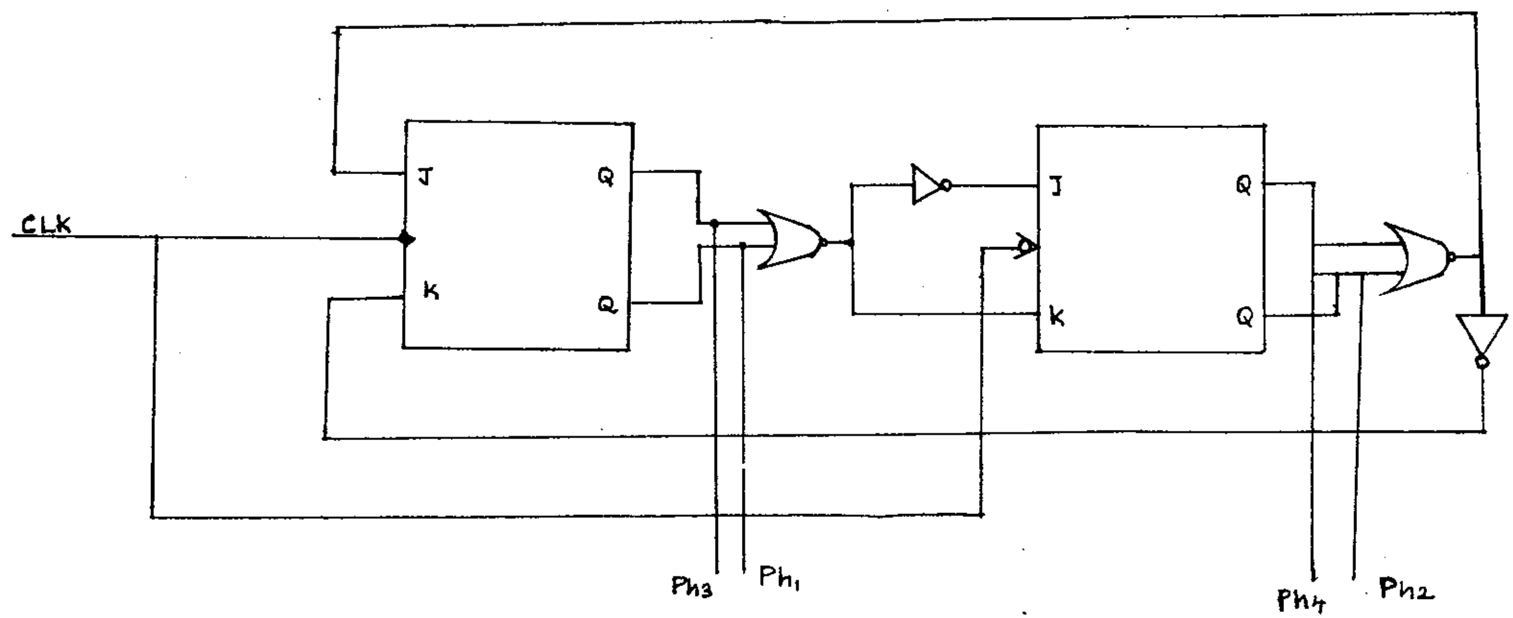
WORKING

Consider initially that J = 1 and K = 0 is the flip flop is reset thus a Q & $\bar{Q}$ output of the 0 & 1 are got respectively. Input of 1 & 0 are given to the second flip flop. This output is again ANDed or NORed and fed back to the first flip flop. Thus the sequence of J=0 and K=1 are fed and the second sequence of pules is obtained. This procedure continuous depending on the clock circuit. These are four pulse sequences to be given to the phases of the stepper motor.

The pulse sequences given to the stepper motor are,

PH1		PH2	
A1	A2	B1	B2
0	1	0	1
1	0	0	1
1	0	1	0
0	1	1	0

LOGIC SEQUENCE CIRCUIT Fig(4.11)



Operation Procedure

Chapter 5

OPERATION PROCEDURE

This Project employs an electronic control circuit for the solar tracking operation. The use of an electronic circuit enables precision tracking with a high degree of accuracy. The description of the various circuit connections used for this purpose are given below.

5.1 OPERATION OF THE BRIDGE CIRCUIT

Photovoltaic cells are used to detect the variations caused by sun's differential shifting of the shadow region. Photovoltaic cells are cells which produce an output votage proportional to the amount of incident light. These cells have very good response characteristics, i.e., even for a slight difference in the incident light the output voltage produced is prominently deducable. Thus as it can be inferred the photovoltaic cells exhibit a linear relationship between the light input and the relative voltage ouput.

Two photovoltaic cells are used for the effective operation. Each of the two photovoltaic cell is placed on a seperate panel. These two photovoltaic cells are connected in the form of a bridge circuit. Thus connecting the photocells in the form of a bridge circuit makes it possible for the production of a difference voltage.

The photocells are connected in such a manner so that they are placed on the opposite arms of the bridge circuit. Depending on the amount of light incident on the photovoltaic cell a corresponding output voltage is produced. The output from the bridge constitues the difference voltage existing between the two cells. The remaining two arms of the bridge contain 10 K resistors.

5.2 OPERATION OF THE DIFFERENTIAL AMPLIFIER

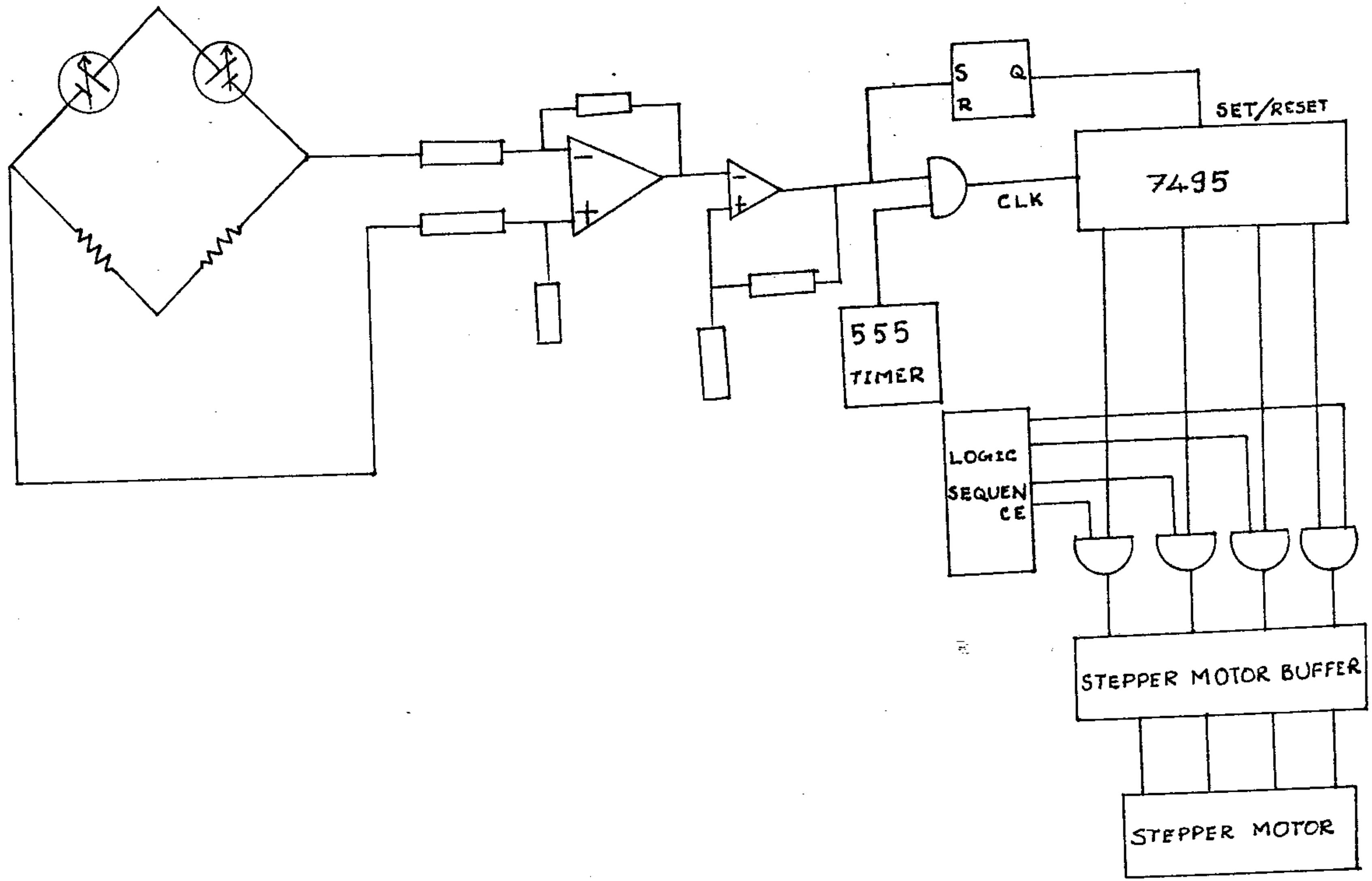
The output from the bridge is fed to a differential amplifier. The differential amplifier used in this project is LM 741 op-amp. The chip details are provided in the Appendix. The differential amplifier is designed for a gain of twenty.

In the differential amplifier the difference between the two output voltage is amplified. In this project the amount of light incident on the cell depends upon whether the cell is in the shadow region or brighter region. On the basis of the amount of light incident a proportional output voltage is produced. Thus the two cells have a different output voltage if they are exposed to different light regions. The output voltage from the cells which form the output of the bridge are given to the differential amplifier inputs. Thus the difference voltage existing between the cells is amplified by the differential amplifier with a gain of twenty. The amplification process is employed for the sake of setting a higher voltage level for the schmitt trigger. The amplified difference voltage is applied to the schmitt trigger.

5.3 OPPERATION OF THE SCHMITT TRIGGER

Schmitt trigger is constructed with the help of LM 741 op-amp. The schmitt trigger or the squaring circuit is constructed with an op-amp using a positive feedback. The input voltage triggers the output everytime the input exceeds a certain voltage level called the threshold voltage. The positive feedback provides a regenerative action which causes faster switching of the output with respect to the input voltage level. Once the schmitt trigger is triggered it remains at the supply voltage level a long as the input remains above the threshold voltage. The threshold voltage in this case is fixed at IV reference voltage, thus whenever there is an amplified signal output from the differential amplifier the schmitt trigger is triggered. The output of the schmitt trigger is given to an AND gate.

CIRCUIT DIAGRAM Fig(5.1)



5.4 OPERATION OF 555 TIMER AS ASTABLE MULTIVIBRATOR

The 555 timer is used as an astable multivibrator. The astable multivibrator often called a free-running multivibrato, is a rectangular - wave generating circuit. This circuit unlike the monostable multivibrator does not require an external trigger to change the state of the output, hence the name free-running. The output of the astable multivibrator is a square wave with constant time period. The duty cycle of the square wave is 50%. The frequancy of the astable multivibrator is fixed at 1 KHZ.

5.5 OPERATION OF THE AND GATE

The output of the schmitt trigger and the constant continuous square wave output of the 555 astable multivibrator are applied to the input terminals of a two input AND gate (7408). The AND gate is an high input AND gate which implies that the output of the AND gate is high (1) only when both the inputs of the AND gate are also high (1). Even when one of inputs is low (not present at the input) the output of the AND gate is also low or zero. Applying this principle of the AND gate operation the AND gate output is high whenever the schmitt trigger output is high, because the astable multivibrator provides a continuous square wave to one of the AND gate input terminals. Thus during this instant the output of the AND gate is a clock signal of 1KHZ.

5.6 OPERATION OF THE 4-BIT SHIFT REGISTER

The output signal from the AND gate, which constitutes the clock signal of 1KHZ when there is a schmitt trigger output is fed to the clock output of the 4-bit shift register. The shift register operates in the serial in parallel out fashion.

The output from the schmitt trigger is directly connected to a RS-flip flop. This RS-flip flop is used for setting and re-setting the shift register inputs. When there is an output from the schmitt trigger the RS-flip flop is set and thus this flip flop output which is connected to the input of the 4-bit shift register is also set. Thus as the first bit of the 4-bit shifter register is set (1), the other bits are set sequentially in accordance with the clock pulse. Thus each clock pulse shifts the 1 from one bit to another.

The shift register has a parallel output and hence the four outputs are connected to four different AND gates. The other input of the AND gate is connected to the logic sequence of the stepper motor.

5.7 OPERAITION OF STEPPER MOTOR USING LOGIC SEQUENCE

The output from the 4-bit shift register and the logic sequence is connected to the same AND gate. Thus each bit of the shift register along with the specific logic sequence is connected to a particular AND gate. Thus four different AND gates are employed for the four different outputs.

The logic sequence is generated using two flip flops (JK master plane). These flip flops are connected with exclusive OR gates and AND gates. The logic sequence is generated using an astable multivibrator of required frequency using a 555 timer. This clock is given to the JK flip flop for counting operations. The flip flop changes states depending on the clock.

The pulse sequence is generated.. These pulses are then given to the phases of the stepper motor which magnetises the coils for rotation. The time duration required for the shadow to fall on the cell due to variations in the amount of light incident on the cell is fixed at 7.2 mins. Thus if the tracking unit is placed out for tracking the shadow of the shadow maker will fall over the cell only after 7.2 mins. Once the shadow falls over a cell and light variations are tracked the electronic circuitry accomplishes the task of rotating the stepper motor by 1.8°. Thus for a time interval of 7.2 mins the stepper motor is also rotating by the same angle. The shaft of the stepper motor is attached with the panel. Thus as a result of the light variations incident over the cell the stepper motor is rotating by a fixed angle which is turn aligns the panel to the required position.

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Design Procedure

Chapter 6
DESIGN PROCEDURE

In this chapter we discuss the preliminary design details of suntracker working on the principle of deflection of light and shadow bands produced by sun rays.

6.1 DESIGN OF SHADOW MAKER

Speed of motion of the sun = 15° per min

Speed of the stepper motor = 1.8° per pulse

The time taken by the sun to move 1.8° is calculated as follows

$$\frac{1.8}{15} \times 60 = 7.2 \text{ min}$$

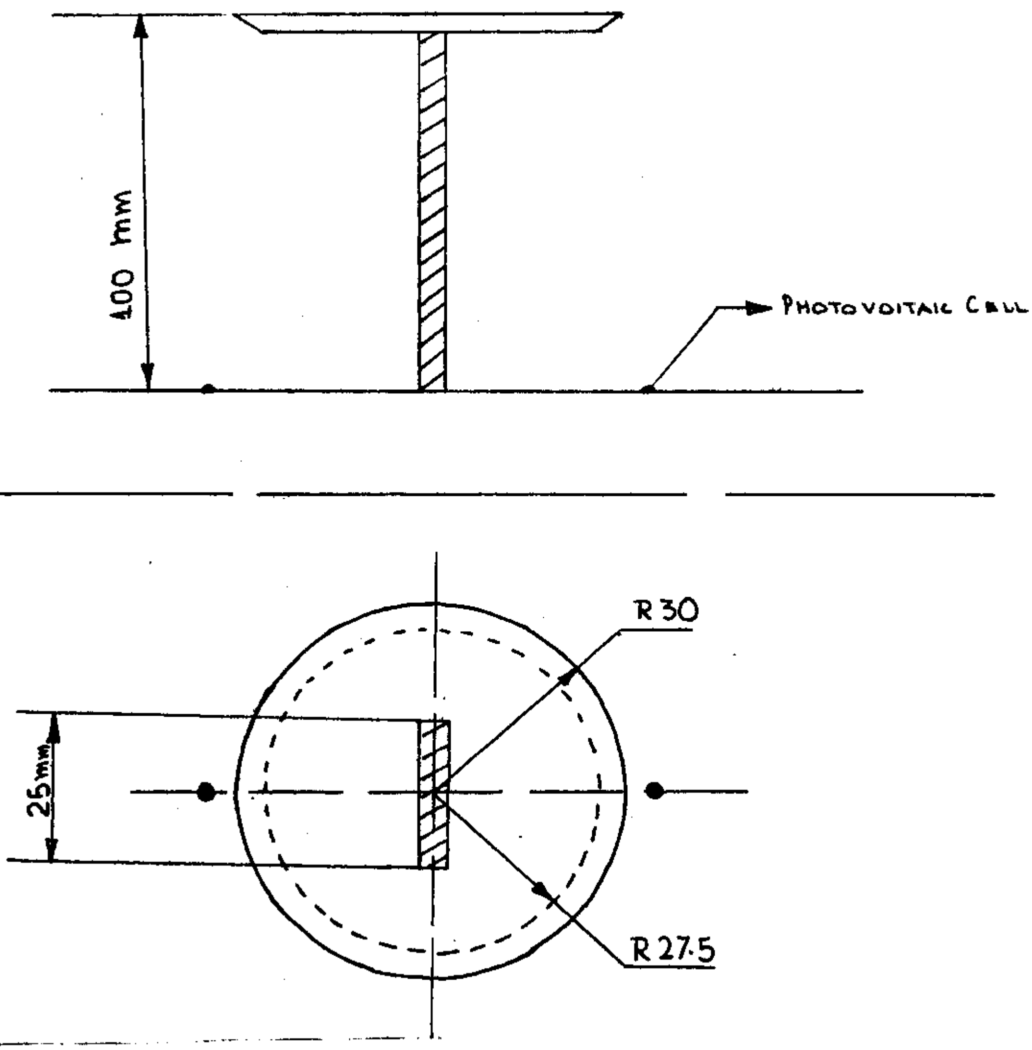
So we have to design the shadow maker such that for every 7.2 min, the shadow will fall on any one of the photo voltaic cell. For this purpose we design a shadow maker as shown in fig.(6.1).

Take height of the disc from photo voltaic cell as 10cm Therefore from fig.(6.2)

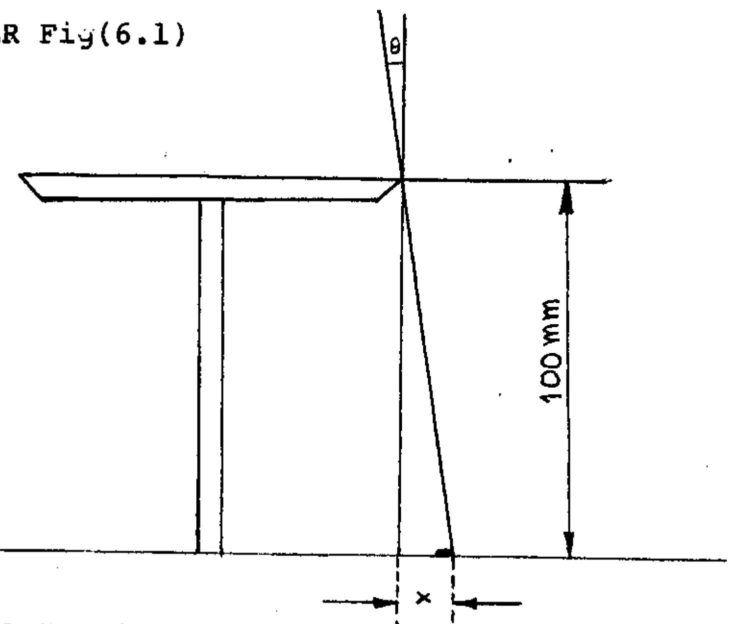
$$\text{Tan } \theta = \frac{X}{10} \quad : \quad \text{Tan } 1.8 = \frac{X}{10}$$

$$X = 0.314 \text{ cm}$$

$$= 3.14 \text{ mm}$$



SHADOW MAKER Fig(6.1)



SHADOW MAKER Fig(6.2)

Therefore the distance of the photo valtic cell from the centre

= 33.14 mm

Here sharp edge circular disc is used as shown in fig(6.2) to avoid refraction of sunlight.

6.2 SHAFT

Shaft is a rotating machine element which is used to transmit power from one of its end to another. The power is delivered to the shaft by some tangential force and the resultant torque or torsional moment set up with in the shaft permits, the power to be transfered to various machines linked up to the shaft.

6.2.1 STRESSES IN SHAFTS

The following stresses are induced in the shaft,

a. Bending Stresses (Tensile and Compressive) due to the forces acting upon machine elements like gears, pulleys etc., as well as due to the weight of the shaft itself.

b. Shear Stresses due to the transmission of torque. (i.e due to torsional load)

c. Compined torsion and bending.

6.2.3 MATERIALS USED

The material used for ordinary shafting is mild steel high strength is required an alloy steel such as nickle, nickle chromimum or chrome-vanadium steel is used.

6.2.4 SHAFT DESIGN

Torque that can be transmitted by the stepper motor = 7 kg cm

Since the shaft is subjected to twisting moment only, the diameter of the shaft is calculated using the HORIZON EQUATION.

$$\frac{T}{J} = \frac{f_s}{r}$$

Where T = Twisting moment acting on the shaft.

J = Polar moment of inertia = $\frac{\pi}{32} d^4$

f_s = Tortional shear stress.

r = Distance between neutral axis and outer most fibre = d/2

$$\therefore \quad T = \frac{\pi}{16} f_s d^3$$

Shear stress for mild steel = 37 kgf/mm^2

According to maximum stress theory

Safe stress(f_s) = Max shear stress x ½

= 37 x ½ = 18.5 kgf/mm^2

= 1850 kgf/cm^2

∴ twisting moment,

$$7 = \frac{\pi}{16} \times 1850 \times d^3$$

d = 0.26 cm

Assuming factor of safety = 3

Therefore d = 0.26 x 3

= 0.804 cm

= 8.04 mm

For the purpose of safety the next standard size is selected.

i.e., d = 10 mm

6.3 BEARING

A bearing is a machine element which support another machine element. It permits a relative motion between the contact surfaces of the members, while carrying the load.

Anti friction bearings are mostly used in industries and their distinct features over sliding bearings are,

a. Low frictional movement and heat generation.

b. Low starting resistance.

c. High load capacity per unit width of bearing.

d. Easy maintanance and less consumption of lubricants.

On the basis of shape of rolling elements, antifriction bearings are either ball bearings or roller bearings.

6.3.1 MATERIALS USED

Since the rolling elements and the races are subjected to high local stresses of varying magnitude with each revolution of the bearing, therefore the material of the rolling element should be of high quality. The balls are generally made of high carbon chromium steel. The balls are manufactured by hot forging on hammers from steel rods. They are then heat treated, ground and polished.

6.3.2 BEARING DESIGN

Axial load on bearing F_a = 9.8 kg

Radial load on bearing F_r = 1.9 kg

Equivalent bearing load $P = (X\ F_r + Y\ F_a)\ S$

Where X = Radial factor

Y = Thrust factor

S = Service factor

Then $F_a/F_r = 9.8/1.9 = 5.15$ and assume

$F_a/C_o = 0.04$ from ball bearing 62 series.

Corresponding to F_a/C_o, $e = 0.24$

Since $F_a/F_r > e$

$X = 0.56$ and $Y = 1.8$

There is no impact load acting on the bearing

∴ service factor $S = 1.5$

∴ Equivalent bearing load $P = (X\ F_r + Y\ F_a)\ S$

$= (0.56 \times 1.9 + 1.8 \times 9.8) \times 1.5$

$= 28.056$ kg

Assume life of bearing = 16,000 hours.

Loading ratio $C/P = 2.29$ (for minimum rpm)

$$\therefore \quad C = 2.29 \times 28.056$$

$$= 64.2 \text{ kgf}$$

Selecting the next higher value of C from Design data book i.e., 400 Kgf. Therefore bearing number selected is SKF 6200.

$$d = 10 \text{ mm}$$

$$D = 30 \text{ mm}$$

$$B = 9 \text{ mm}$$

6.4 SHAFT COUPLING

Shaft coupling are used in machinery for several purposes, the most common of which are the following:

a. To provide for the connection of shafts of units that are manufactured separately such as a motor and generator and to provide for disconnection for repair or alternations.

b. To provide for misalignment of shafts or to introduce mechanical flexibility.

c. To introduce protection against overloads.

d. To alter the vibration characteristics of rotating units.

The saft coupling should have following requirements:

a. It should be easy to connect or disconnect.

b. It should transmit the full power of the shaft.

c. It should hold the shafts in perfect alignment.

d. It should have no projection parts.

6.4.1 FLANGE COUPLING DESIGN

A flange coupling usually applies to a coupling having two seperate cast iron flanges. Each flange is mounted on the shaft end and keyed to it. One of the flange has a projected portion and the other flange has a corresponding recess. This helps to bring the shafts in to line and to maintain alignment. The two flanges are coupled together by means of bolts and nuts.

Shaft diameter = 10 mm (from shaft design)

Torque transmitted by the shaft = 7 kg-cm

Allowable shear stress for

shaft, bolt and key material = 400 Kgf/cm^2

Allowable crushing stress for

bolt and key = 800 Kgf/cm^2

Minimum shear stress for cast iron = 80 Kgf/cm^2

6.4.2 DESIGN FOR HUB

Outer diameter of hub D = 2d = 2x10 = 20mm

Length of hub L = 1.5d = 1.5x10 = 15mm

Let us now check the induced shear stress for the hub material which is cast iron. Considering the hub as a hollow shaft, we know that torque transmitted

$$T = \frac{\pi}{16} f_{sc} \frac{D^4 - d^4}{D}$$

$$7 = \frac{\pi}{16} f_{sc} \frac{2^2 - 1.5^2}{2}$$

$$f_{sc} = 6.52 \text{ kg/cm}^2$$

Since the induced shear stress for the hub material (cast iron) is less than the permissible value of 80 Kgf/cm^2, therefore the design of hub is safe.

6.4.3 DESIGN FOR KEY

From data book, for 10mm diameter shaft

Width of the key W = 4 mm

Thickness of key t = 4 mm

Length of key l = L = 15 mm

Consider the key in shearing. We know that the torque transmitted

$$T = lW\, f_{sk}\, d/2$$

$$7 = 1.5 \times 0.4 \times f_{sk} \times \tfrac{1}{2}$$

$$f_{sk} = 23.33 \text{ Kgf/cm}^2$$

Considering the key in crushing. Then torque is given by

$$T = 1 \times t/2 \times f_{sk} \times d/2$$

$$7 = 1.5 \times 0.4 \times ½ \times f_{ck} \times ½$$

$$f_{ck} = 46.66 \text{ Kgf/cm}^2$$

Since the induced shear and crushing stress in the key are less than the permissible stress, therefore the design for key is safe.

6.4.4 DESIGN FOR FLANGE

Thickness of flange t_f = 0.5d = 0.5x10 = 5 mm

We know that torque transmitted

$$T = \frac{\pi D^2}{2} \times f_{sc} \times t_f$$

$$7 = \frac{\pi 2^2}{2} \times f_{sc} \times 0.5$$

$$f_{sc} = 2.23 \text{ Kgf/cm}^2$$

Since the induced shear stress in the flange is less than 80 Kgf/cm^2, therefore the design of flange is safe.

6.4.5 DESIGN OF BOLT

Let d_1 = Nominal diameter of bolts

Assume number of bolts = 2

Pitch circle diameter D_1 = 3d = 3x10 = 30 mm

Then torque transmitted

$$T = \pi \tfrac{1}{4} \times (d_1)^2 \times f_{sb} \times n \times D_1 \times \tfrac{1}{2}$$

$$7 = \pi \tfrac{1}{4} \times d_1^{\,2} \times 400 \times 2 \times 0.3 \times \tfrac{1}{2}$$

$$d_1 = 0.27 \text{ cm}$$

Assume coarse threads, the nearing standard size of the bolt is M5.

6.4.6 OTHER PROPERITIES OF FLANGE

Outer diameter of flange $D_2 = 4d$

$= 4 \times 10$

$= 40$ mm

***

Cost Estimation

COST ESTIMATION

DESCRIPTION	Nos	COST
		Rs.
STEPPER MOTOR	1	750.00
PHOTO VOLTAIC CELL	2	60.00
ELECTRONIC COMPONENTS	-	150.00
BEARINGS	2	50.00
COUPLING	1	30.00
SHAFT (M.S)	-	40.00
BEARIN CAPS (M.S)	2	20.00
MATERIAL FOR FRAME WORK	-	75.00
MACHINING COST	-	100.00
	TOTAL COST	1275.00

Merits and Demerits

Chapter 8

MERITS AND DEMERITS

MERITS

1. Maximum energy is received by using this tracking arrangement.
2. Power required is less because instantaneous tracking is done.
3. Intial investment is very less.
4. Weight of the system is very less.
5. The resetting of obsorber at nights, for the use of next day is avoided, by providing limit switches in the system.
6. Maintanance needed is less.
7. Lubricants are not needed.

DEMERITS

Due to the practical difficulties in designing the shadow band there is possibility of 0.5° variation in tracking.

***

Application

Chapter 9

APPLICATIONS

This type of tracking system can be used whereever solar systems are used. Using tracking arrangement in different solar applications, the efficiency of the system is increased. The tracking system can be effectively used in the following areas in the field of solar energy.

a. In solar lighting, sun tracking is effectively used. Using M-75 pannel a 13 watts lamps can be used for 17½ hours with tracking arrangement and only 12 hours with out tracking.

b. In solar water pumping also, tracking system is used. The efficiency of the solar water pump is 58% with tracking system and 37% without tracking system.

c. In space craft, solar pannel with tracking system is effectively used because, intensity of sunlight in space is much more greater than that on the earth's surface.

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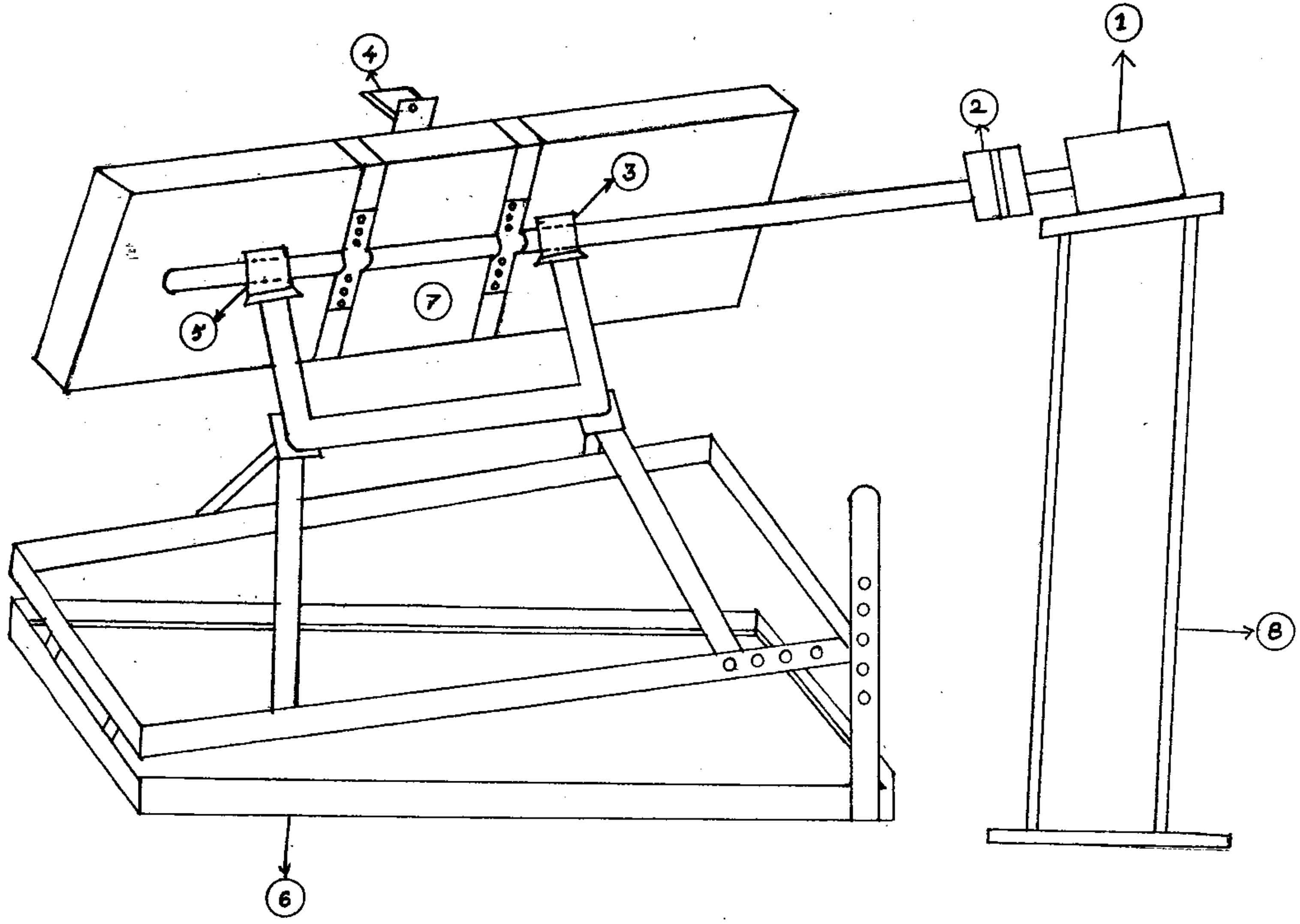
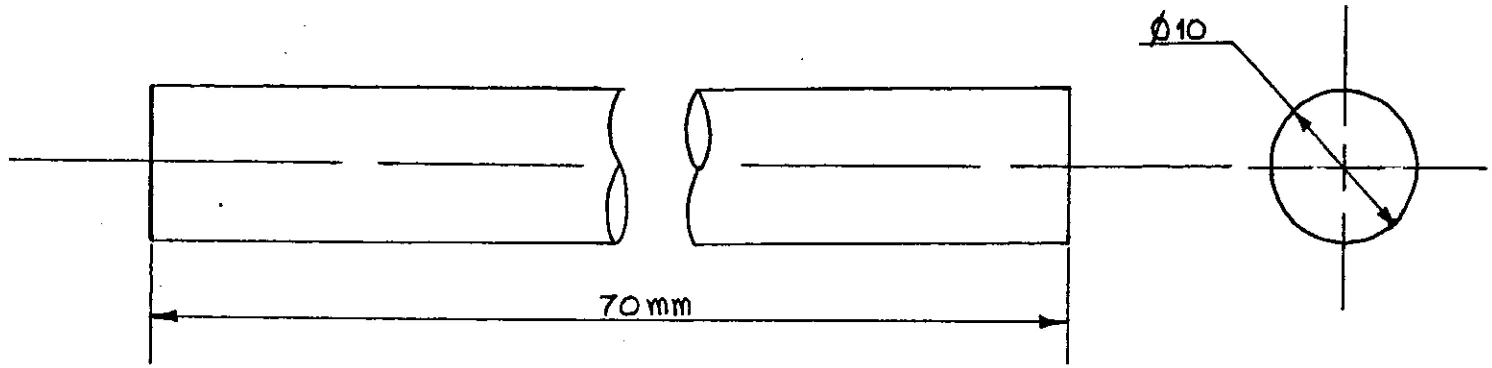
Conclusion and Developments

Drawings



1. STEPPER MOTOR
2. COUPLING
3. BEARING
4. SENSOR
5. SHAFT
6. FRAME
7. PANEL
8. STAND

ASSEMBLY



KCT	PROJECT	
SCALE 2:1	SHAFT	
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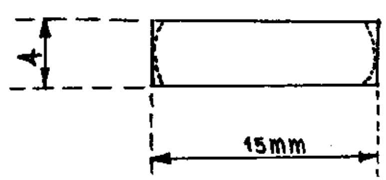
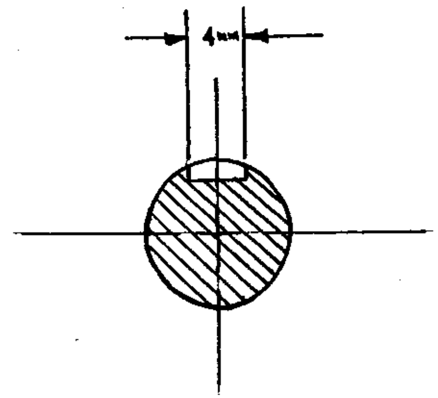
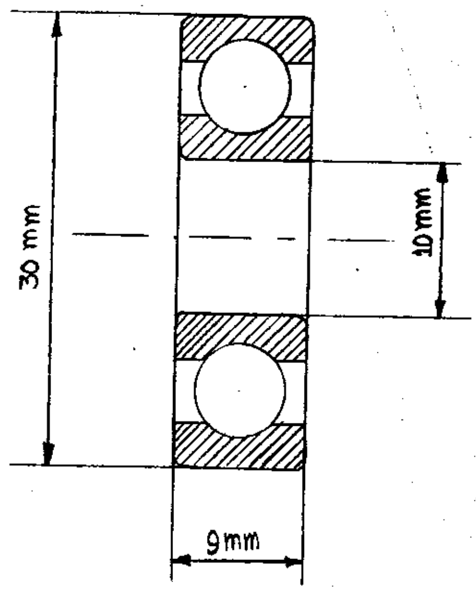




KCT	PROJECT
SCALE 2:1	KEY
20-1-91	



KCT	PROJECT	
SCALE 2:1	BEARING	
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