

ENVIRONMENT FRIENDLY SOLAR CAR

Submitted to

Dr. AKM Abdul Malek Azad
Associate Professor, EEE Department
BRAC University

Submitted by

Md. Golam Shahriar Majumder
Student ID: 06310028
Md. Touhidul Alam
Student ID: 06310021
Md. Ashraf Uddin Ahmed Zubair
Student ID: 06210002

Department of Electrical and Electronics Engineering
April 2010



BRAC University, Dhaka, Bangladesh

DECLARATION

We hereby declare that this thesis is based on the results found by ourselves. Materials of work found by other researcher are mentioned by reference. This thesis, neither in whole nor in part, has been previously submitted for any degree.

Signature of
Supervisor

Signature of
Author

ACKNOWLEDGMENTS

We are very thankful to our thesis coordinator Dr. AKM Abdul Malek Azad of Electrical and Electronics Department of BRAC University for guiding us throughout our thesis work. Special thanks for helping us by giving appropriate advice with the circuit, device and other documentation. Also thanks to Mr. Redwanul Hasan Siddique and Mr. M. Z. Sadi for taking time out of their busy schedules to consider this work and helping us for providing an appropriate guideline. We have worked extremely hard in this thesis and hopefully our work will be appreciated by our supervisor.

ABSTRACT

Now-a-days, dealers of natural resources like fuel, coal etc. are facing a hard time to keep pace with the increasing demand. Therefore, to carry out this demand it is quite necessary to make a new exploration of natural resource of energy and power. Therefore sunlight is now-a-days considered to be a source of energy which is implemented in various day to day applications. Solar energy is being used to produce electricity through sunlight. With the help of this technology we aim to make solar energy powered car in our project. The main component to build a solar car is the solar panel. The solar cells collect a portion of the sun's energy and store it into the batteries of the solar car. Before that happens, power trackers converts the energy collected from the solar array to the proper system voltage, so that the batteries and the motor can use it. After the energy is stored in the batteries, it is available for use by the motor & motor controller to drive the car. We are going to use two set of batteries; one of which will get the electrical energy from the panel to drive the motor and another will be used as a back-up source of energy which will provide required power when there is no sunlight. A microcontroller can be used in this purpose which can switch to the fully recharged battery when it senses that another battery is empty or not providing enough power to drive the motor. Again, we used a complete circuitry to solve the problem of voltage fluctuation due to movement of the sun, earth or cloud etc. We used a voltage comparator, a relay circuit for and a transistor along with a diode for this purpose. Comparator compares the voltage of solar panel and the battery and then it provides the higher voltage to the transistor to activate the relay which provides the required and stable voltage to the car. However, after all these being proceeded, the motor controller adjusts the amount of energy that flows to the motor to correspond to the throttle. The motor uses that energy to drive the wheels. Preliminarily our objective would be to implement our idea on a remote control toy car and afterwards with help of this prototype we can extend our future work on building a actual car powered by the solar energy.

TABLE OF CONTENTS

Topic	Page
TITLE.....	1
DECLARATION.....	2
ACKNOWLEDGEMENTS.....	3
ABSTRACT.....	4
TABLE OF CONTENTS.....	5
LIST OF TABLES.....	7
LIST OF FIGURES.....	8
CHAPTER I. INTRODUCTION	
1.1 A Preview on the Necessity of Solar Energy at Present Situation.....	9
1.2 What is Solar Energy?.....	9
1.3 Distribution of Solar Energy.....	11
1.4 Recent Research on Utilization of Solar Energy.....	12
1.5 Research Objective.....	12
CHAPTER II. ANALYSIS	
2.1 Effect of Load (Weight) on the Car.....	13
2.2 Choosing the Solar Panel.....	14
2.3 Characteristics of Solar Panel.....	14
2.3.1. Measurement of Voltage Rising with respect to Time.....	14
2.3.2. V-I Characteristic.....	15
2.3.3 V – P Characteristic	17

CHAPTER III. INITIAL CONCEPT

3.1 The Plan.....	20
3.2 Challenges.....	21

CHAPTER IV. SOLUTION: THE PROPOSED CIRCUIT MODEL

4.1 Solution to the Problems.....	22
4.2 Collaborating the solutions.....	25
4.3 Circuit Description.....	26

CHAPTER V. PRACTICAL IMPLEMENTATION

5.1 Trial.....	27
5.2 Making the Car Body.....	28
5.3 Outdoor Implementation.....	28
5.4 Possible Drawbacks.....	28

CHAPTER VI. CONVERTER DESIGN FOR A SOLAR CAR

6.1 Project Details.....	30
6.2 Detailed Converter Design.....	30

CHAPTER VII. CONCLUSION

7.1 Observations.....	34
7.2 Future Work.....	34

LIST OF REFERENCES.....	35
--------------------------------	-----------

LIST OF FIGURES

Figure	Page
Fig 1.2.a: During a process called FUSION, four hydrogen atoms combine to form one billion atom, with a loss of matter. This matter is emitted as radiant energy.....	10
Fig 1.3.a: Distribution of Solar Energy.....	11
Fig 1.3.b: Graphical representation.....	11
Fig 2.3.1.a: T-V Curve.....	15
Fig 2.3.2.a: Measurement of voltage and current.....	16
Fig 2.3.2.b: V-I Curve.....	17
Fig 2.3.3.a: V-P Curve.....	18
Fig 3.1.a: The solar panel converts sunlight to electrical energy.....	20
Fig 4.1.a: Using a diode.....	22
Fig 4.1.b: Using a back-up battery.....	23
Fig 4.1.c: Using an OP-AMP comparator.....	23
Fig 4.1.d: Utilizing the OP-AMP comparator along with the relay and the transistor.....	24
Fig 4.2.a: The proposed model.....	25
Fig 5.1.a: The trial show.....	27
Fig 5.2.a: The handmade car.....	28
Fig 5.3.a: Outdoor implementation.....	29
Fig 6.1.a: Model Solar Car System Block Diagram with DC-DC converter.....	30
Fig 6.2.a: TL494 operation.....	31
Fig 6.2.b: Practical converter operation.....	32

LIST OF TABLES

Table	Page
Table 2.1.a: Effect of Load (Weight) on the Toy Car.....	13
Table 2.3.1.a: Measurement of voltage rising with respect to time.....	14
Table 2.3.2.a: V - I rating.....	16
Table 2.3.3.a: V-P rating.....	18

CHAPTER I

INTRODUCTION

1.1 A Preview on the Necessity of Solar Energy at Present Situation

There must be some limits to the ability of the earth to sustain a growing population. Fortunately, population models suggest that the world's population will probably level out at about two to three times the present numbers over the next hundred years. The question is whether the earth's resources are sufficient to sustain that population at a high standard of living for all. In this the key issue is energy.

Now-a-days, dealers of natural resources like fuel, coal etc. are facing a hard time to keep pace with the increasing demand. At one hand, there are more cars or motor vehicles are dominating the transport medium, on the other hand these cars are being dominated by the fuel. As a result, the limited resources are being quashed by the producers and dealers to satisfy this need which is leading us to an uncertain future with having the scarcity of fuel and minerals. So, it is clear that present trends in energy consumption, especially oil, cannot be sustained much longer. Again, in view of the possibility of global warming, these resources are playing a negative role. Therefore, under this circumstances, it is quite necessary to make a new exploration of natural resource of energy and power. But why exploration when the resource is in front of our bear eye. It is effective, less expensive and above all, it is an endless source of energy. With greatly improved energy efficiency, a transition to this energy based economy capable of sustaining the anticipated growth in the world economy, is possible. This effective source is "Solar Energy".

1.2 What is Solar Energy?

Solar energy is radiant energy that is produced by sun. Everyday the sun radiates, or sends out, an enormous amount of energy. The sun radiates more energy in one second than people have used since the beginning of time!

Where does the energy come from that constantly is being radiated from the sun? It comes from within the sun itself. Like other stars, the sun is a big ball of gases- mostly hydrogen and helium atoms. The hydrogen atoms in the sun's core combine to form helium and generate energy in a process called **nuclear fusion**.

During nuclear fusion, the sun's extremely high pressure and temperature causes hydrogen atoms to come apart and their nuclei (the central cores of the atoms) to fuse to become one helium atom. But the helium atom contains less mass than the four hydrogen atoms that fused. Some matter is lost during nuclear fusion. The lost matter is emitted into space as radiant energy.

It takes millions of years for the energy in the sun's core to make its way to the solar surface, and then just a little over eight minutes to travel the 93 million miles to earth. The solar energy travels to the earth at a speed of 186,000 miles per second, the speed of light.

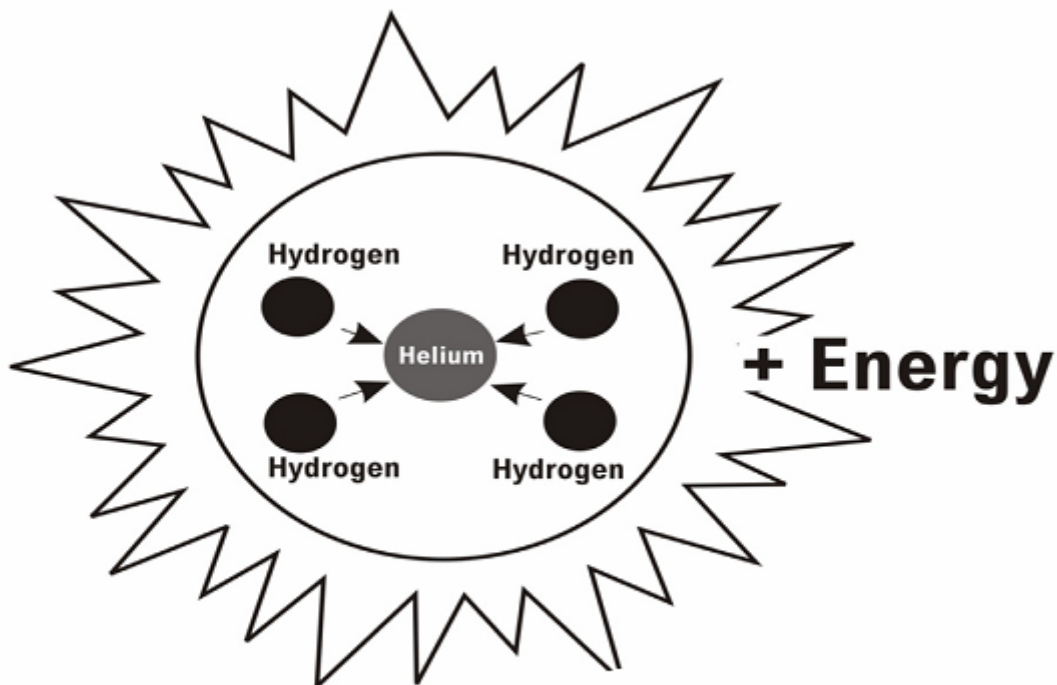


Figure 1.2.a: During a process called FUSION, four hydrogen atoms combine to form one helium atom, with a loss of matter. This matter is emitted as radiant energy.

Only a small portion of the energy radiated by the sun into space strikes the earth, one part in two billion. Yet this amount of energy is enormous. For instance, everyday enough energy strikes the United States to supply the nation's energy needs one and a half years!

Where does all the energy go? About 15 percent of the sun's energy that hits the earth is reflected back into space. Another 30 percent is used to evaporate water, which lifted into the atmosphere, produces rainfall. Solar energy is also absorbed by plants, the land, and the oceans. The rest could be used to supply our energy needs.

1.3 Distribution of Solar Energy

The solar energy is distributed throughout the earth by following way.

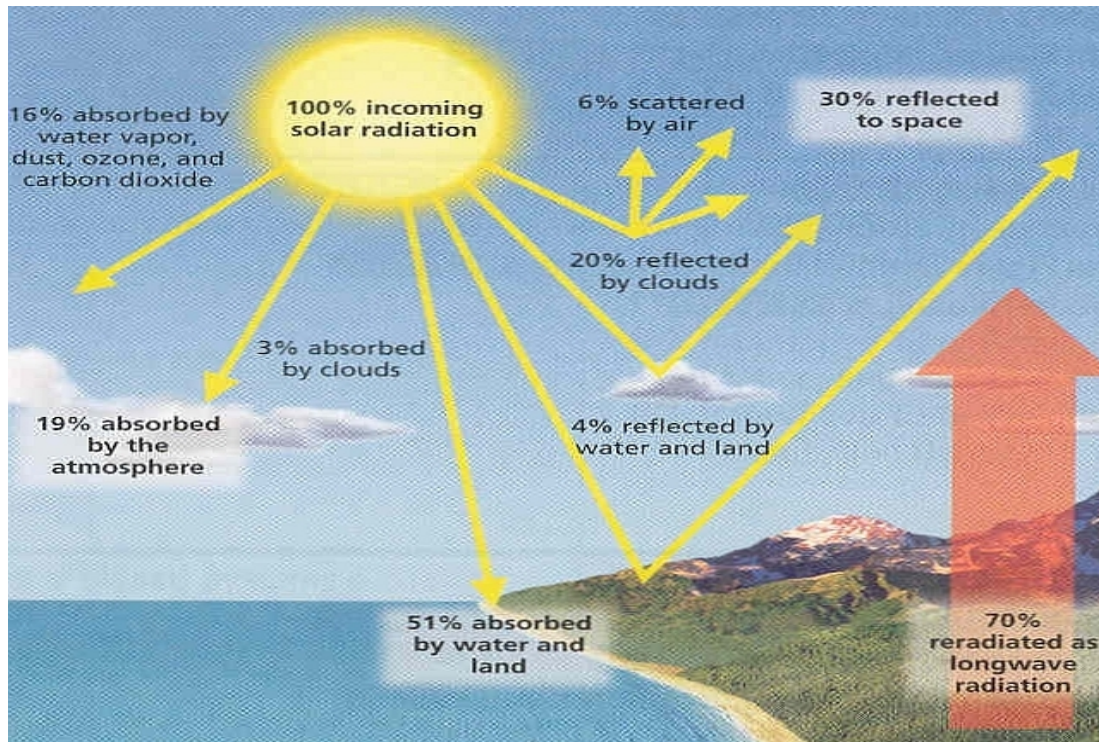


Fig 1.3.a: Distribution of Solar Energy

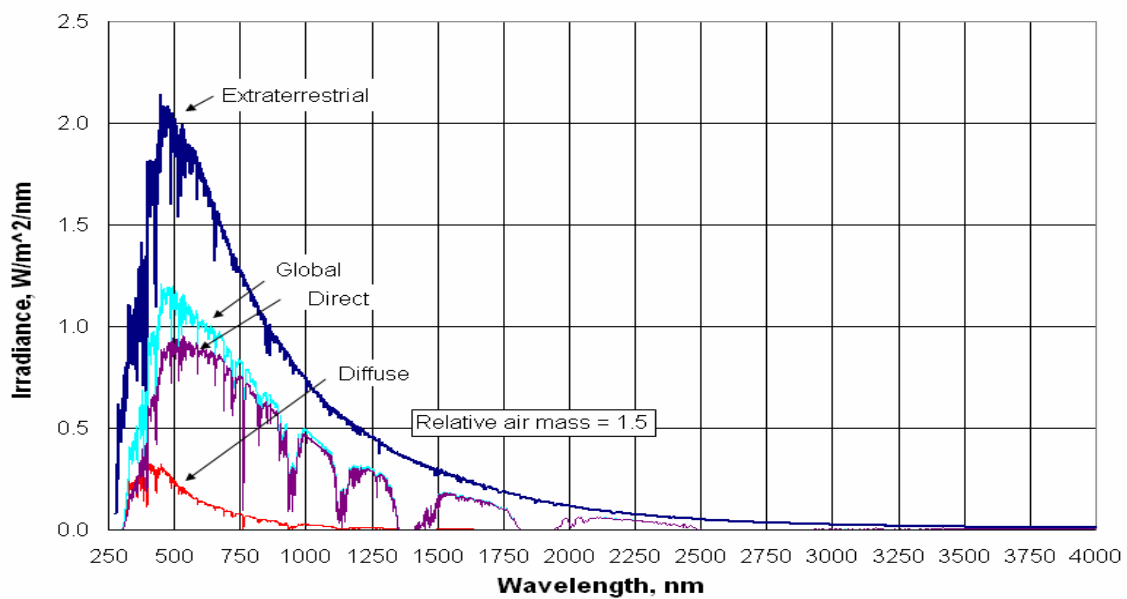


Fig 1.3.b: Graphical representation

1.4 Recent Research on Utilization of Solar Energy

Solar energy refers primarily to the use of solar radiation for practical ends. However, all renewable energies, other than geothermal and tidal, derive their energy from the sun.

Solar technologies are broadly characterized as either passive or active depending on the way they capture, convert and distribute sunlight. Active solar techniques use photovoltaic panels, pumps, and fans to convert sunlight into useful outputs. Passive solar techniques include selecting materials with favorable thermal properties, designing spaces that naturally circulate air, and referencing the position of a building to the Sun. Active solar technologies increase the supply of energy and are considered supply side technologies, while passive solar technologies reduce the need for alternate resources and are generally considered demand side technologies.

Now-a-days, solar technology is being used in so many aspects of our day to day lives such as-

- Architecture and urban planning
- Agriculture and horticulture
- Solar lighting
- Solar thermal
- Water treatment
- Electrical generation
- **Solar vehicles** etc.

1.5 Research Objective

Sunlight is now-a-days considered to be a source of energy which is implemented in various day to day applications. Solar energy is being used to produce electricity through sunlight. With the help of this technology we aim to make solar energy powered car. Preliminarily our objective would be to implement our idea on a remote control toy car and afterwards with help of this prototype we can extend our future work on building an actual car powered by the solar energy which is both cost effective and of course environment friendly. We also intend to solve the problem of voltage fluctuation due to the fact of cloud, earth movement, sun movement etc.

CHAPTER II

ANALYSIS

2.1 Effect of Load (Weight) on the Toy Car

To successfully complete the whole project, initially we need to choose the proper solar panel with appropriate power rating and weight. Because, these things are directly related to the efficiency of the car. So, we did an experiment which involved the load management of the car while driving along with the V-I rating.

Here, we chose a random car and put different bars with different weights on different position (i.e. front hood, roof top/ seat, back hood) of that car. Then we connected the multi-meter to the respective input pins ('+ve' and '-ve') of the battery of that particular car in parallel. Through this process we found out the voltage required to drive the motor of the car at different situation. Again, after that, we connected an ammeter with those respective in series to find out the current flow required to drive the motor of the car.

The result we found out for that random car is like this:

Weight (gm)	Different positions of car	V-I rating				Power rating	
		<i>At full speed</i>		<i>At less speed</i>		<i>At full speed (W)</i>	<i>At less speed (W)</i>
		V (volt)	I (A)	V (volt)	I (A)		
200	Seat	8.21	7.63	6.08	5.41	62.6423	32.8928
	Back	8.27	7.60	6.73	5.29	62.8520	35.6017
	Front	8.23	7.52	6.58	5.28	61.8896	34.7424
400	Seat	8.20	7.38	5.43	4.85	60.5160	26.3355
	Back	7.77	6.76	4.87	3.86	52.5252	18.7982
	Front	7.49	6.68	4.46	3.37	50.0332	15.0302
600	Seat	7.51	6.66	4.30	2.89	50.0166	12.4270
	Back	7.49	6.60	4.12	2.77	49.4340	11.4124
	Front	7.30	6.50	3.96	2.65	47.4500	10.4940
800	Seat	7.30	6.28	3.73	2.48	45.8440	9.2504
	Back	7.15	6.38	3.70	2.49	45.6170	9.2130
	Front	7.30	6.44	3.76	2.45	47.0120	9.2120
1000	Seat	7.07	6.03	3.64	2.35	42.6321	8.5540
	Back	6.98	5.93	3.63	2.40	41.3914	8.7120
	Front	6.90	5.00	3.45	1.90	34.5000	6.5550

Table 2.1.a: Effect of Load (Weight) on the Toy Car

By the way, the battery of that random car was providing 9.6V and 600mAh, voltage and current rating respectively. This experiment gave us the idea about the solar panel we should collect for our future project implementation.

2.2 Choosing the Solar Panel

Since we got the idea about the solar panel we should collect, we spent no time to grab it from the store. In our case, we used a 3W solar panel to drive our handmade three wheeler toy car. We also measured the weight of the solar panel which was about 500gm. We ripped out border coating of the panel to further lessen the weight. This would give the three wheeler less load to take and move more freely.

2.3 Characteristics of Solar Panel

2.3.1 Measurement of voltage rising with respect to time

Now we have the solar panel, so it is important to measure the rise time of the voltage of the panel. As a result we can get the idea about how much time it will take to charge up the battery and use it for further application.

The result we got was as follows:

Time (min)	Voltage (volt)
0	4.43
3	7.45
10	10.32
20	10.53
30	10.78
40	10.91
50	10.97

Table 2.3.1.a: Measurement of voltage rising with respect to time

Corresponding T-V curve was as follows:

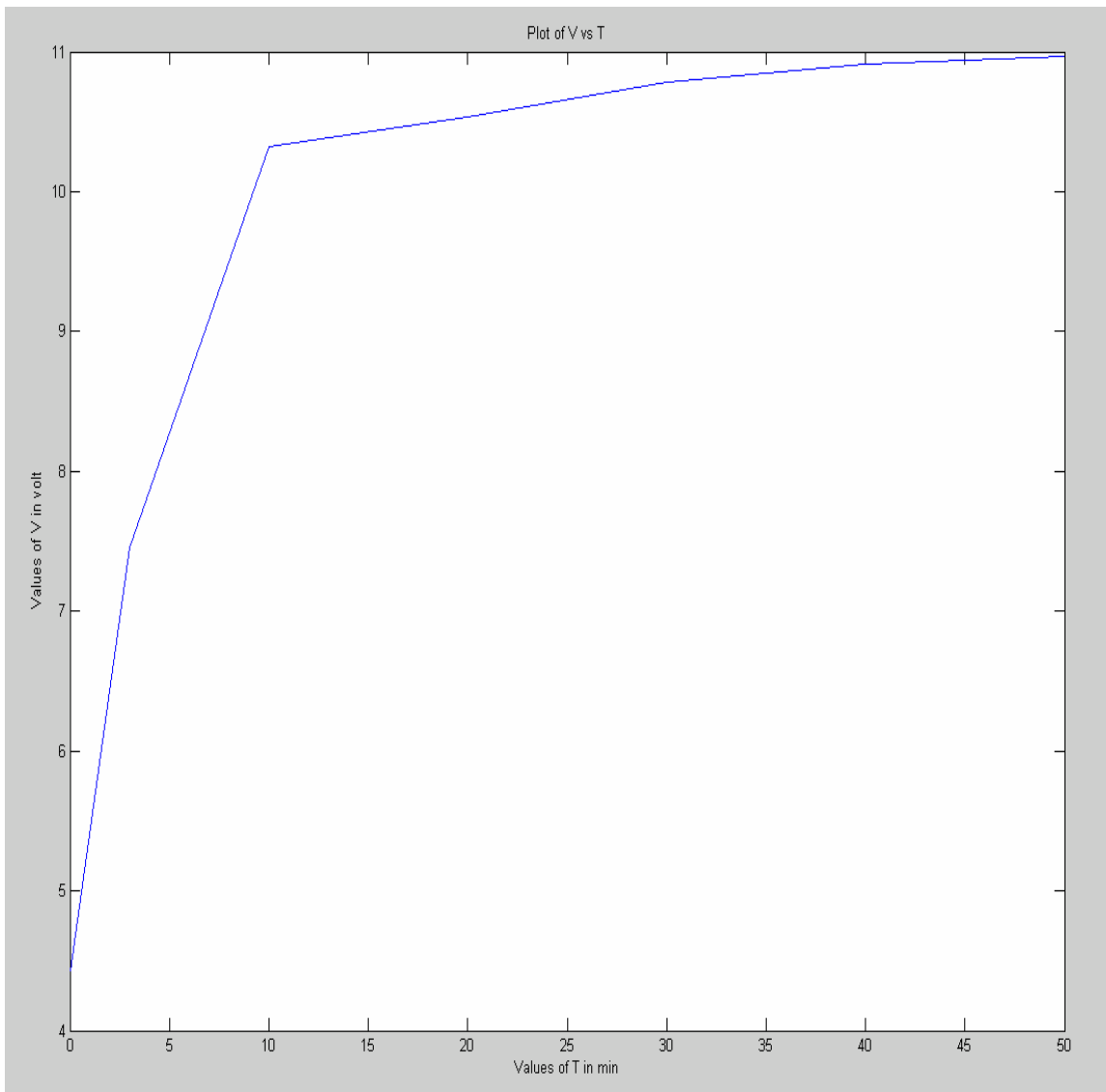


Fig 2.3.1.a: T-V Curve

2.3.2 V - I Characteristic

After collecting the solar panel it is important to measure the V-I rating of the panel for further implementation. So, we went outside in an open place under the sunlight at midday and did the job. We connected different loads with the panel to measure the voltage and current at different loads. But at first we found out the voltage and current at 'without any load' situation.

The whole process is demonstrated below:

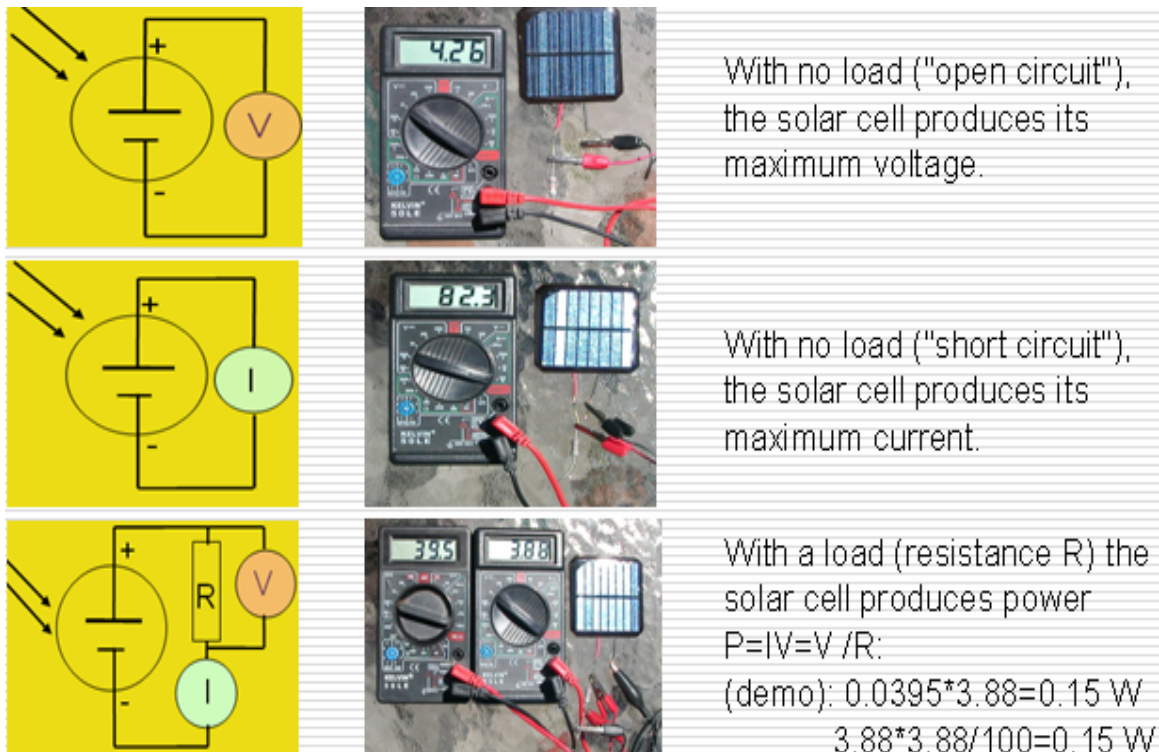


Fig 2.3.2.a: Measurement of voltage and current

The end result of the experiment is as follows:

Load resistance, R (ohm)	Voltage, V (volt)	Current, I (mA)
0	0	170
1.2	0.19	167
7.2	1.18	164
10.5	1.7	162
18.8	3.01	159
30	4.71	157
35	5.39	154
45.2	6.81	150
50.1	6.83	136
122	15.02	122
335	18.76	56
964	19.28	20
3790	19.74	0

Table 2.3.1.a: Measurement of voltage rising with respect to time

The respective characteristic curve was:

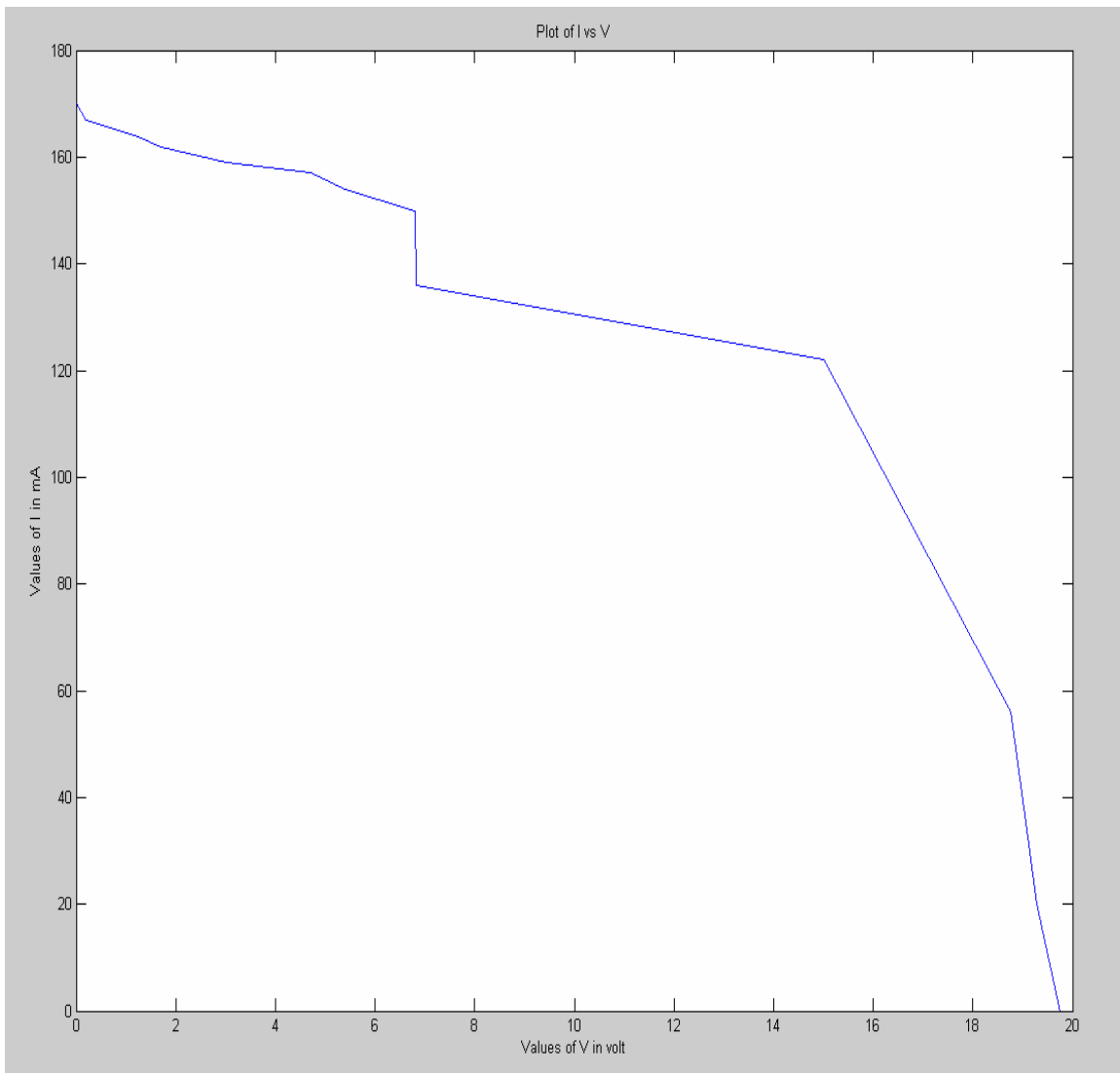


Fig 2.3.2.b: V-I Curve

The curve shows that voltage and current relates reversely with the increasing load.

2.3.3 V – P Characteristic

From the above experiment we can also find the voltage and power relation with this panel which is given below:

Load resistance, R (ohm)	Voltage, V (volt)	Current, I (mA)	Power, P (mW)
0	0	170	0
1.2	0.19	167	31.73
7.2	1.18	164	193.52
10.5	1.7	162	275.4
18.8	3.01	159	478.59
30	4.71	157	739.47
35	5.39	154	830.06
45.2	6.81	150	1021.5
50.1	6.83	136	928.88
122	15.02	122	1832.44
335	18.76	56	1050.96
964	19.28	20	385.6
3790	19.74	0	0

Table 2.3.2.a: V - I rating

Corresponding V-P curve:

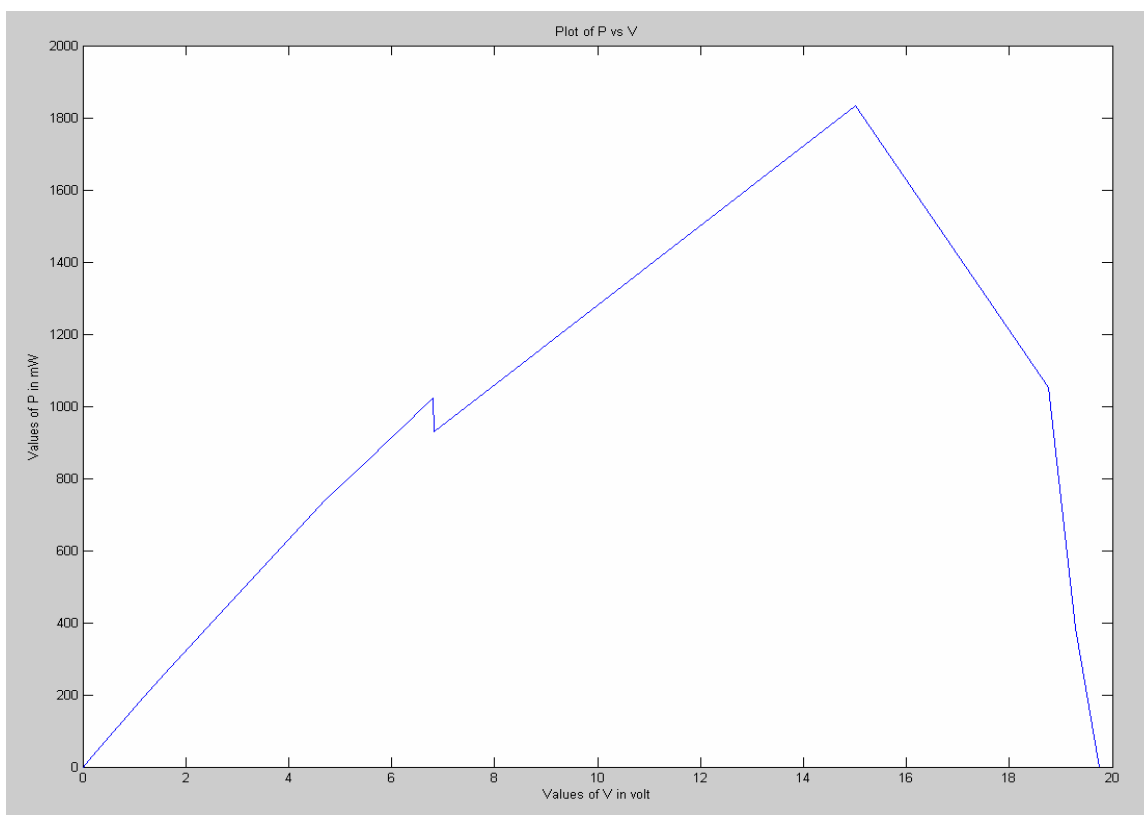


Fig 2.3.3.a: V-P Curve

This curve shows us that the power of panel increases with the load up to a certain level and falls down after that quite rapidly. That means, we cannot use too much load in this project.

CHAPTER III

INITIAL CONCEPT

3.1 The Plan

In our project we are attempting to build a solar car that converts the sunlight into electrical energy. The main component to build a solar car is the solar panel. The solar cells collect a portion of the sun's energy so that power trackers can convert the energy collected from the solar array to the proper system voltage. After the energy is collected in the panel, it is available for use by the motor & motor controller (which was connected to the panel). After all these being proceeded, the motor controller adjusts the amount of energy that flows to the motor to correspond to the throttle. The motor uses that energy to drive the wheels.

The demonstration of this initial plan was like this:

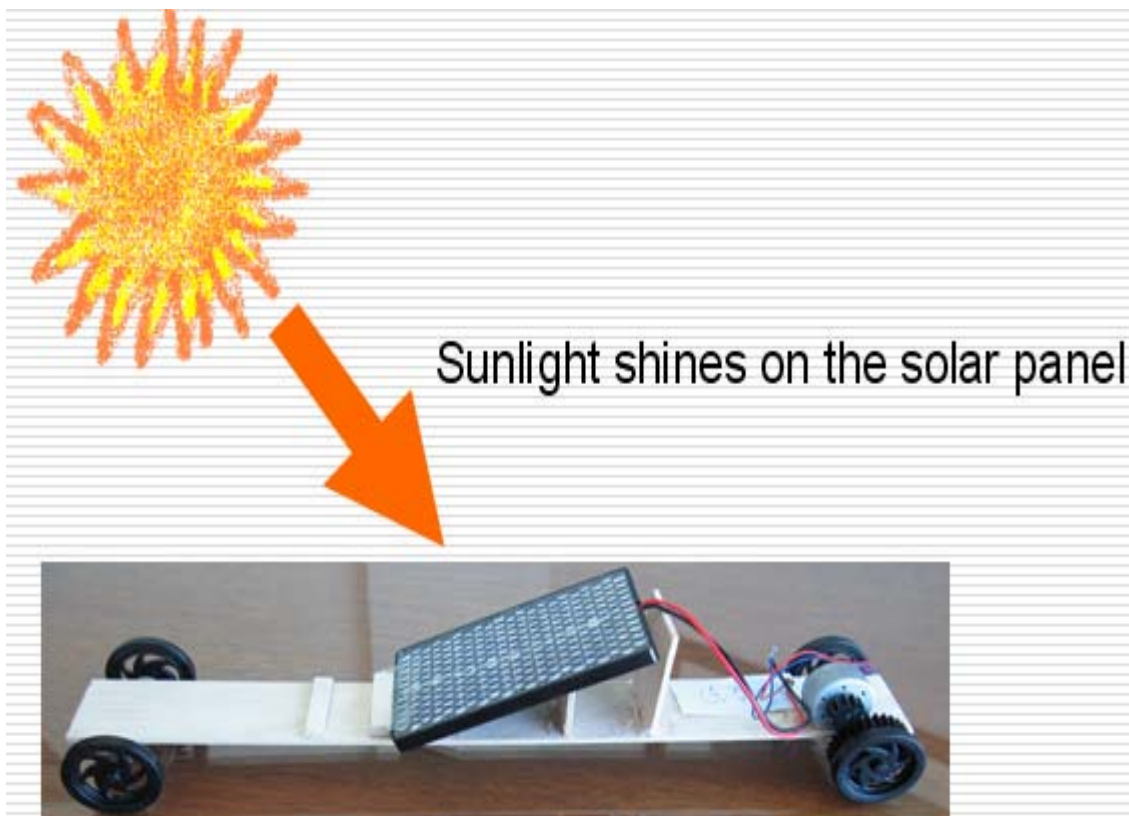


Fig 3.1.a: The solar panel converts sunlight to electrical energy

This process was quite easy to implement but has some major drawbacks.

3.2 Challenges

As stated before, this process has some limitations with it. They are-

- **Taking the input from the panel**

It is not safe to connect the solar panel directly to the motor input. The sun does not provide the same heat to the solar cells so that it is quite impossible to get a constant voltage from the panel. This sudden rise and fall of the voltage may hamper the motor so that the car may not work properly.

- **No back-up source**

There is no back-up source included here. That means, while there is no sunlight the car will not move a bit. This is a serious drawback of this process as we cannot get sunlight all the 24 hours. Then how can we expect it to use in our day to day proceedings?

- **Ensuring bi-input supply**

Even if we use a back-up source like a battery, there is no such way shown here to connect it to the motor of the car. So, having a back-up is not the only solution, ensuring the supply of both the solar and back-up input is also important.

- **Controlling voltage fluctuation**

As stated before, the sun cannot give us a constant voltage all day long. There might be cloud, movement of earth, movement of sun etc. can change the voltage level rapidly which we call fluctuation. As we all know, voltage fluctuation is always a threat to any electrical device, but there is no such way defined here to solve this problem in this plan.

CHAPTER IV

SOLUTION : THE PROPOSED CIRCUIT MODEL

4.1 Solution to the Problems

The above problems can be worked out quite easily by following the subsequent steps:

- **Using a diode**

It is possible to use a diode between the output and the solar panel to take the input. The diode will prevent excessive voltage coming through the panel to the motor.

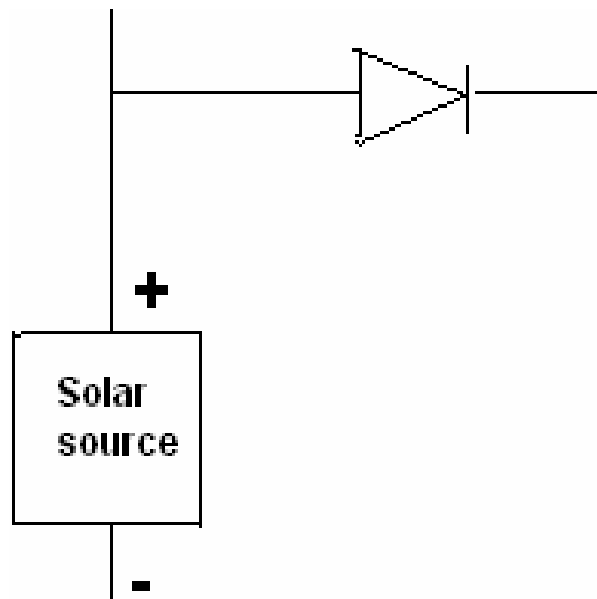


Fig 4.1.a: Using a diode

- **Using a back-up battery**

A rechargeable battery can be used as a back-up source of energy so that whenever there is no sunlight, the car can get the required energy from the

battery to run. By the way, the battery is connected such way that it will not be necessary to charge it from outside source. It will be connected with the solar panel through the diode so that the panel can both charge the battery and provide enough energy to the motor to drive the wheel.

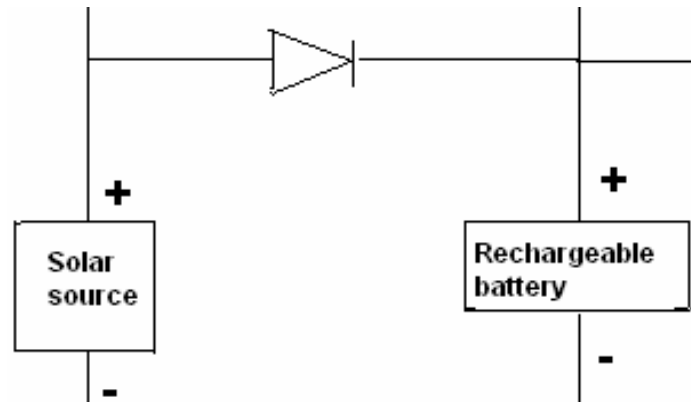


Fig 4.1.b: Using a back-up battery

- **Using an OP-AMP comparator**

To ensure bi-input (solar source and the battery) supply, we can use a comparator OP-AMP. The two input will be connected to the comparator in such way that it compares the voltage of the two sources and give a single, higher output voltage to drive the motor.

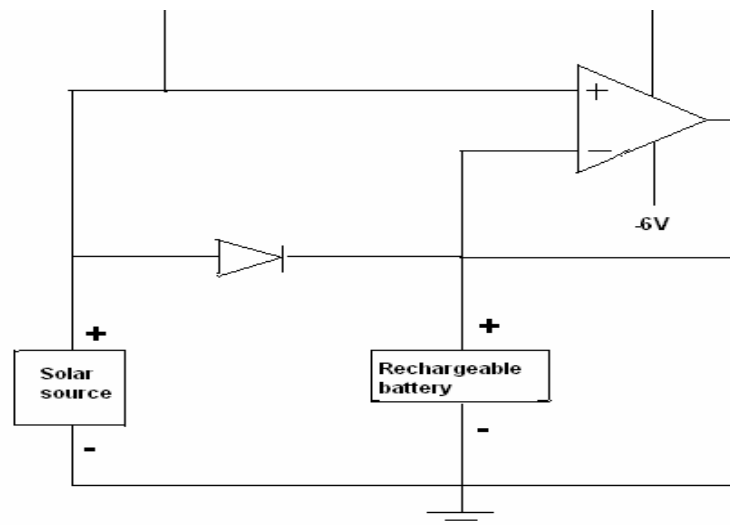


Fig 4.1.c: Using an OP-AMP comparator

- **Utilizing the OP-AMP comparator along with the relay and the transistor**

Voltage fluctuation has been a major problem in a solar system in our country. This fluctuation mainly occurs due to the cloud, earth movement, sun movement etc. This problem can be solved by utilizing the comparator output along with a relay circuit. As we all know, a relay circuit is accommodated with such circuitry so that it can switch into the appropriate voltage source and avoid any halt of voltage supply. Here, the solar source is connected to the 'normally closed' pin of the relay which is connected to the 'common' pin or the output pin of the relay circuit. The battery is connected to the 'normally open' pin of the relay. By the way, the solar panel cannot provide the required current to drive the relay circuit as normally they are driven at a higher current than that of a solar panel provides. That is why, a transistor is used between the comparator output and the relay input because we know transistor multiplies the current. However, if any fluctuation occurs with the solar panel, the relay will switch to the battery to close the circuitry and provide a smooth output. Therefore, we can survive from the difficulty of voltage fluctuation which hampers the operation of the motor and have the car be driven smoothly.

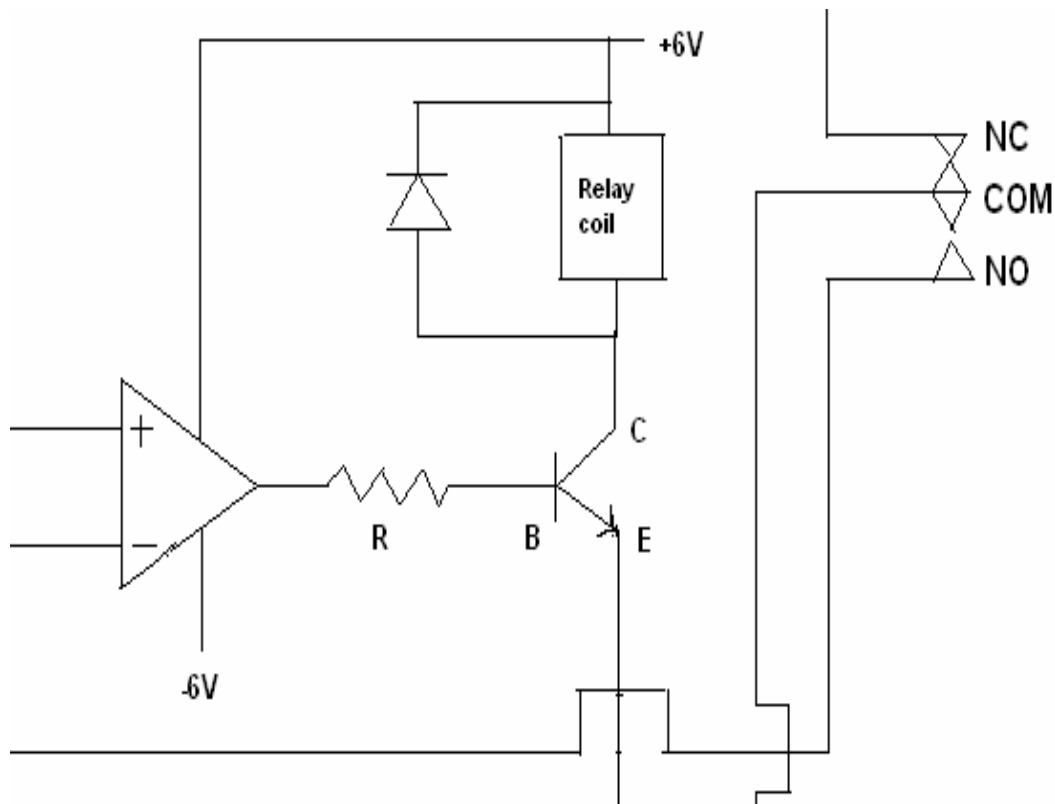


Fig 4.1.d: Utilizing the OP-AMP comparator along with the relay and the Transistor

4.2 Collaborating the solutions

Now, we need to collaborate the whole 'solution' idea into one specific circuit. To do that we need to collect following equipments:

- A 3W solar panel
- A rechargeable battery
- Two diodes
- An OP-AMP comparator
- Two 6V batteries (may be rechargeable)
- A relay circuit
- A transistor
- A DC motor
- An Aluminium plate (as car body) along with three wheels.

Collecting all these components and combining them together we get the following circuitry.

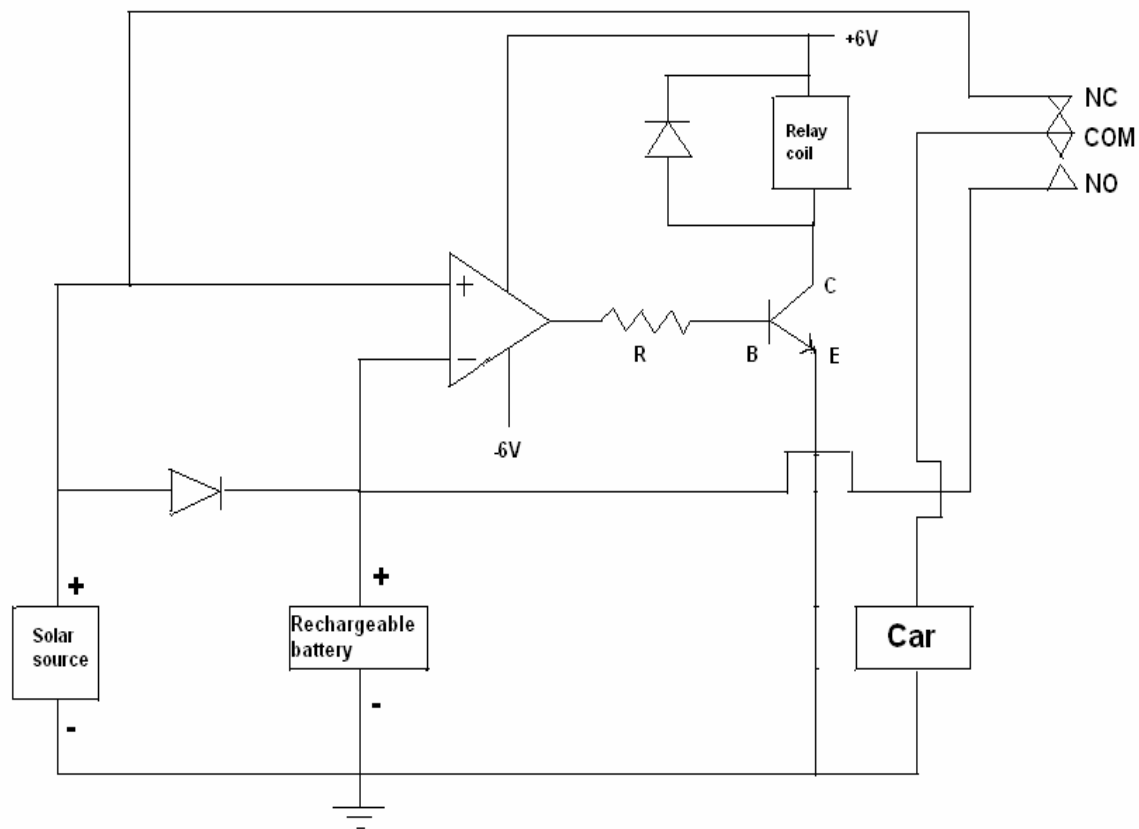


Fig 4.2.a: The proposed model

4.3 Circuit Description

Here, the solar panel and the rechargeable battery is connected in a parallel connection with a diode in between them. The diode is used so that whenever the battery is not over-charged. Again, these two sources are connected to the comparator so that the comparator can compare their voltages and provide a single higher output the circuit. Here, two 6V batteries needed to be used for biasing purpose. After that, comparator output is connected to the transistor to multiply the current to drive the relay circuit on. Now, getting the required energy, the relay turns on and does the switching operation according to the respective input. The 'common' pin of the relay circuit which is the output of the relay circuit is connected to the car's motor. As a result, the car is getting enough electrical energy to drive it's wheel and run along.

CHAPTER V

PRACTICAL IMPLEMENTATION

5.1 Trial

The proposed circuit model has been implemented on a bread-board as a trial of the main project. Here, we have used different voltage regulator sources in stead of the solar panel, the rechargeable battery and biasing batteries and used other components as they are. Then, we connected the whole circuit's output to that random car and found out that the circuit is working properly and the car is running smoothly even though we were changing the voltage every now and then.

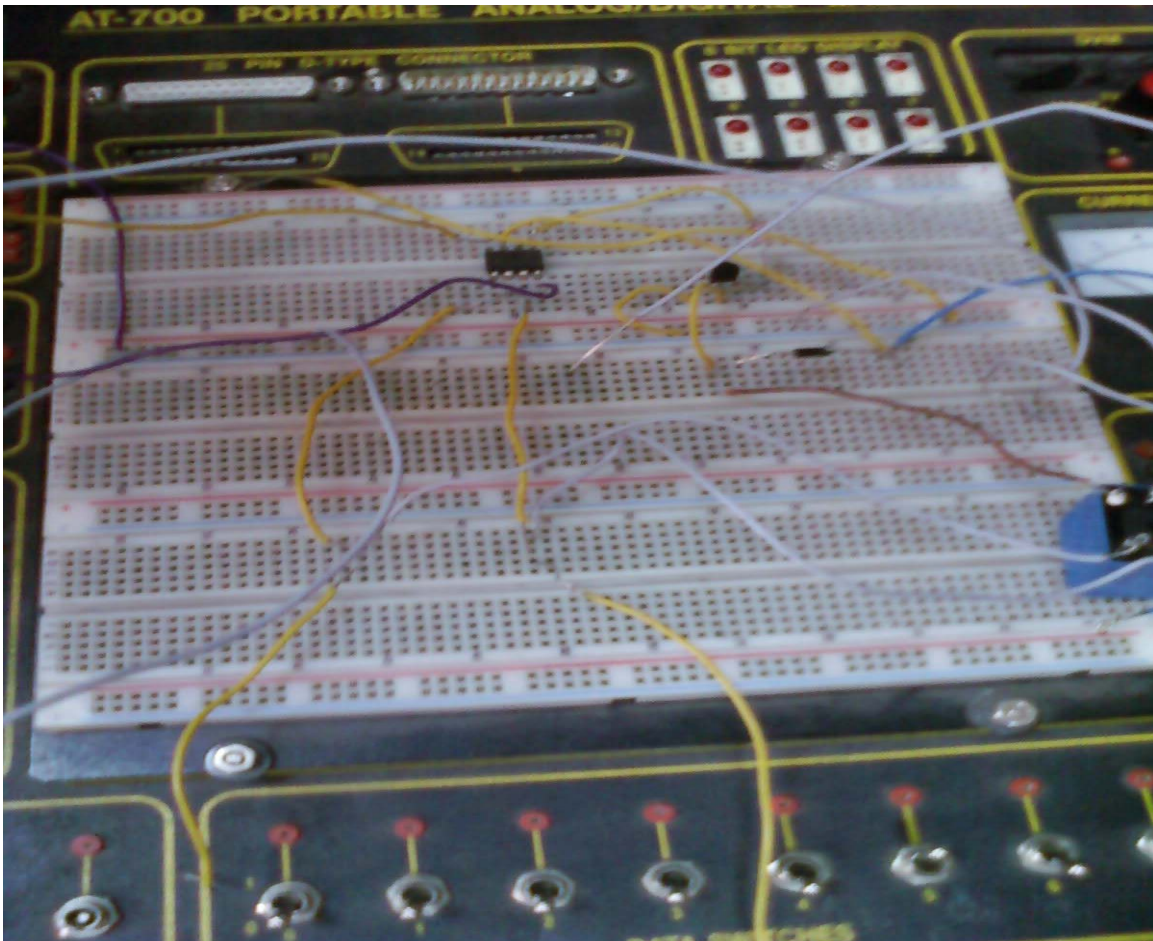


Fig 5.1.a: The trial show

5.2 Making the Car Body

To make the car body, we collected a very light Aluminium plate which was inches long and inches wide. It was gm in weight. We cut the plate at different places smoothly to set the wheels. We already collected some wheels, so after that we set those wheels the plate by setting two of them at back and one of them at front. To rotate the wheels smoothly, we put the motor at back of the plate with the wheels. Then we connected a gear train along with the motor to drive the wheels. At front part, we used an iron stick to go through the wheel so that it can rotate easily. There we get our required car body to use it in further application.

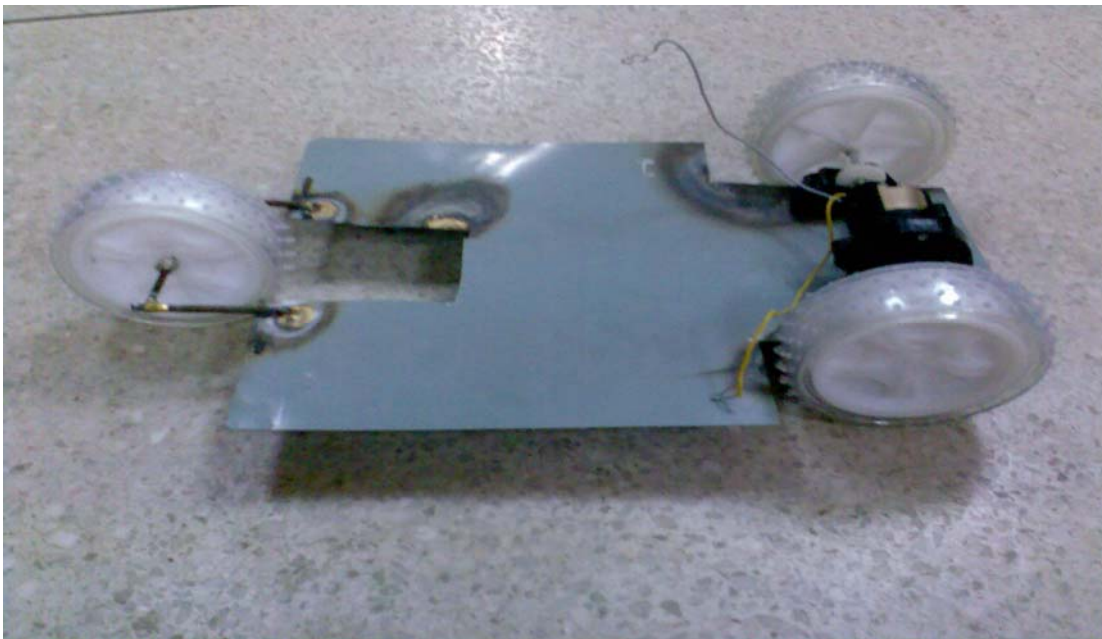


Fig 5.2.a: The handmade car

5.3 Outdoor Implementation

This project is basically an outdoor project. So, took our proceedings from inside the laboratory to outside of it. For this, we chose the rooftop of our BRAC University building. We chose this place because the rooftop this building is quite an open place and sunlight is available there for all day long unless any natural cause stands between.

The end result was quite convincing. We found that the car is moving so very fast when connected to the circuit without any load. When we put the solar panel and

the whole circuit board, it is still moving but at a lower speed. But, nonetheless, the main job has been done.



Fig 5.3.a: Outdoor implementation

5.4 Possible Drawbacks

Although the whole project was quite a successful one, there might be some problems arise in future. They are-

- **Getting excessive voltage supply:** which may hamper the motor operation.
- **Getting Inadequate current flow:** so that the motor may not be able to rotate the wheels.
- **Inability to take the load:** even if there is enough current flow to drive the wheels but it may be insufficient to take the load and run along.

To get rid of these above troubles, we can use a DC-DC converter model for the car and use it to lessen the voltage and increasing the current. This will be discussed in the next chapter.

CHAPTER VI

CONVERTER DESIGN FOR A SOLAR CAR

6.1 Project Details

Let, we require to design, build and demonstrate a dc-dc converter that matches the output from a 10W solar panel to a permanent magnet DC motor. Now we get the 10W solar panel mounted on an aluminium chassis along with the dc motor, a gearbox (7:1) and a servo for steering the vehicle. The servo is an on-board item, which can be powered from an auxiliary battery source. By the way we cannot alter any mechanical characteristics of the car and the problem can only be solved by designing and building electronics.

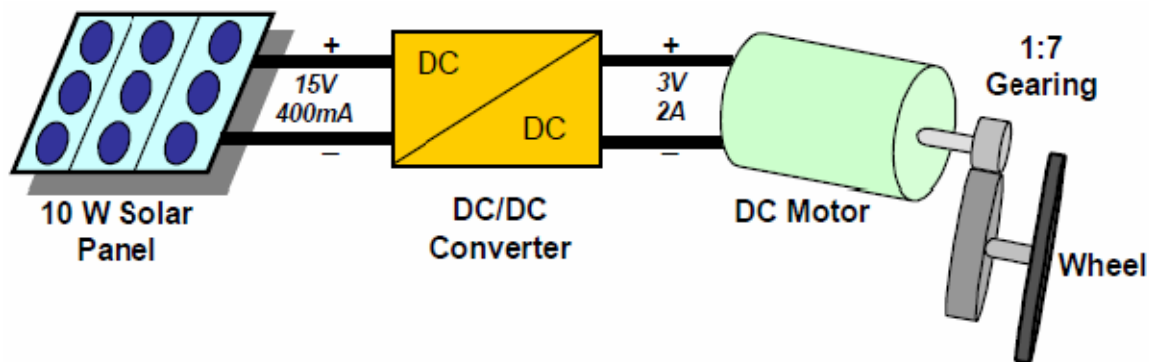


Fig 6.1.a: Model Solar Car System Block Diagram with DC-DC converter

The solar panel and the DC motor have been deliberately selected so that there is an impedance mismatch. Therefore if the solar panel is directly connected to the motor the car would not move even under extreme sunlight conditions. The only way for the car to move is if power electronics is used. The solar panel has a 10W rating, but the motor needs 6W power to rotate the wheel smooth and fast. The output voltage of the panel is approximately 15V at a maximum current of 400mA. The motor can operate from a low voltage of 3V and draws around 2A on starting. Therefore a voltage step down ratio of 5:1 is required at start-up, but this requirement for high current soon disappears as the car gathers speed.

6.2 Detailed Converter Design

Before any detailed electronic design can take place each we must determine the

DC motor and solar panel characteristics. For this project the key characteristics required of the motor are its starting current and the terminal voltage required to produce maximum speed when the solar panel is operating at its maximum power point.

Now, following a very simple set of experimental measurements to determine panel voltage and current (power) under various sunlight conditions, we can soon devise a simple strategy for control of the solar panel terminal voltage to maintain maximum output power from the panel. Let the maximum power can be obtained if the panel terminal voltage is maintained at about 15V.

So far we have sufficient knowledge to determine the dc-dc converter transfer ratio required at start-up and also for running to produce maximum speed from maximum power. Now, to initiate the practical phase of the project work, we need to collect a copy of the data sheet for a low cost PWM control chip, TL494, and an associated laboratory sheet. The laboratory sheet takes them step-by-step through the process of setting up the PWM control chip on a breadboard and producing open-loop single and double-ended switching outputs.

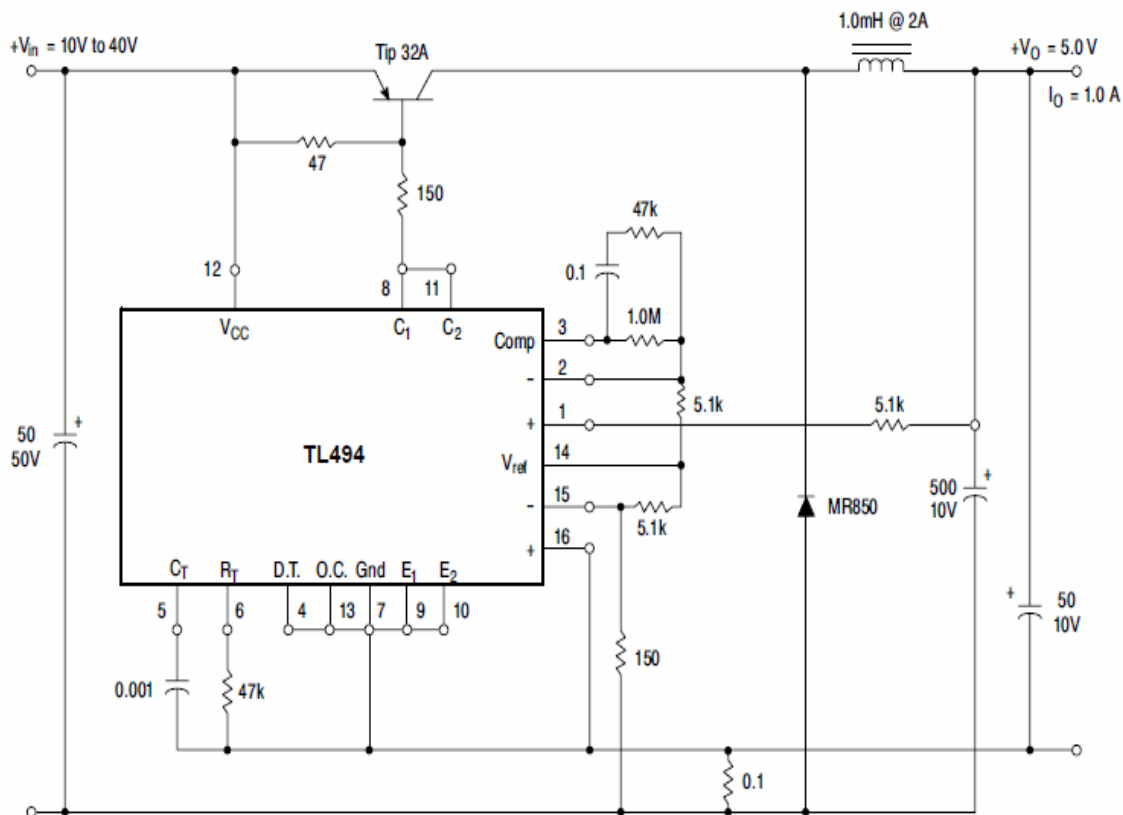


Fig 6.2.a: TL494 operation

Throughout this design and construction part of the project one can use simulation (usually Pspice) to test one's design calculations.

The final steps in the design process relate to closing the control loop. We need to decide what it really needs to control. This decision is based on the knowledge that maximum power can only be achieved at around 15V output, and it doesn't really matter how the rest of the circuit is if maximum power is not injected to the converter then it simply won't achieve a very satisfactory outcome.

Design of the control loop provides a few surprises. It is not the classical feedback control loop discussed in the textbooks, where an output is measured and compared to a reference to control an output. In this case, an input is measured and compared to a reference to control an input. This subtle difference is sufficient to force us to carefully think through the logic of our control strategy. If the solar panel voltage rises for example, should the duty cycle rise or fall? How should the error amplifier be used? Is the reference connected to the positive or the negative input of the error amplifier?

It is required to build the converters on Vero board or bread board. Each board is attached to the underside of the car using Velcro strips. This allows boards to be attached and detached quickly and easily for testing. We must provide standard push fit connectors for the connections to the solar panel and the DC motor. The example converter shown in figure also has wire loops which are added for the laboratory review so that currents can easily be sampled.

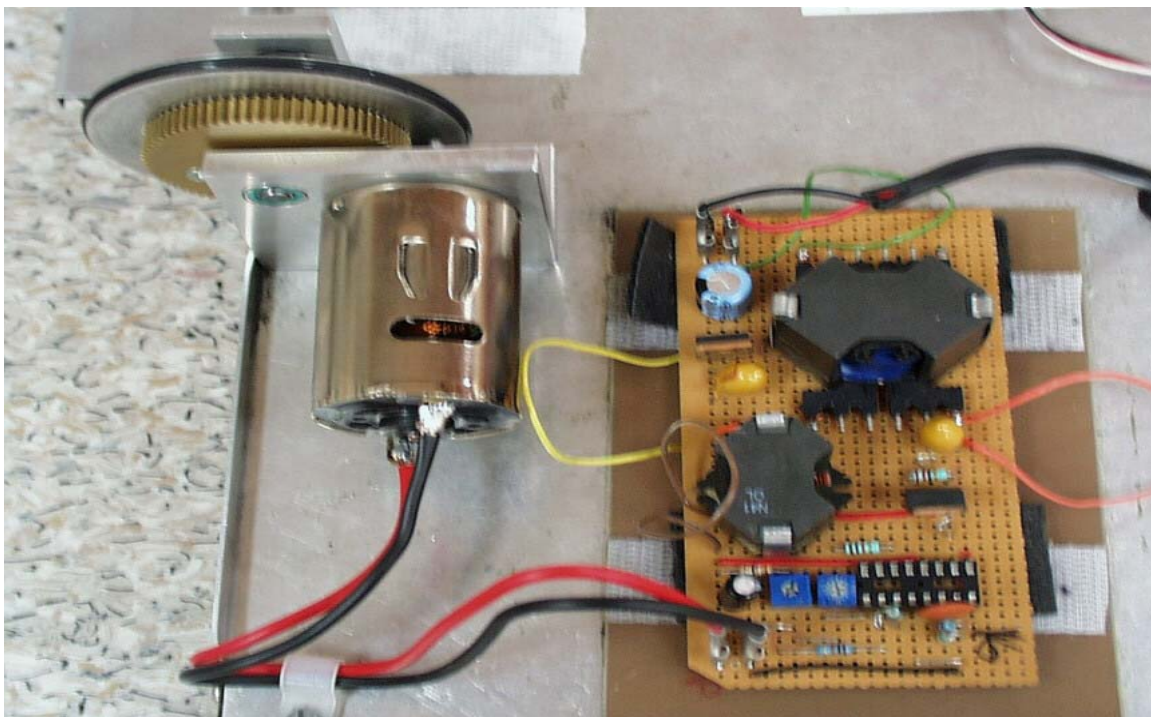


Fig 6.2.b: Practical converter operation

Thus, we can get the proper lower voltage and higher current supply which is suitable for the motor to rotate the wheels smoothly with the load and thereby, it solves the problems discussed in chapter V.

By the way, we used our own panel which was a 3W panel to experiment this process. Well, the result was quite satisfactory as it was reducing the voltage and increasing the current as stated earlier.

CHAPTER VII

CONCLUSION

7.1 Observations

From the above project, we can come up to some certain observations. They are as follows:

- The solar panel and the battery are providing the associate voltage to the comparator.
- The OP-AMP comparator is providing the proper output voltage so that the relay is working.
- The converter is providing adequate V-I supply.
- The motor is driven by the solar energy.

These observations give us a clear picture of having an effective and efficient environment friendly solar car.

7.2 Future Work

Since the relay and other devices are working and giving the required output to drive the handmade car, it is quite expected that it is going to work when the circuit will be implemented on the actual car. We just need to make sure that we get the appropriate solar panel, take the voltage-current-power rating accurately, make the proper connection with the proper chip (IC) and other circuitry.

In fine, it can be said that to cope up with the increasing demand of the fuel, it is quite necessary to alter our demand into the solar energy. It is cheap, efficient, supplied by an endless source of energy- the sun and of course free from any environmental damage.

So, finally, we hope, it is not very far away that day when a great percentage of world's people will use the discussed technology and turn their car into or get their own '**Environment Friendly Solar Car**'.

LIST OF REFERENCES

cat.inist.fr/?aModele=afficheN&cpsidt=3154783	9
www.need.org/needpdf/infobook_activities/SecInfo/SolarS.pdf	10
www.pages.drexel.edu/~brooksdr/DRB_web	11
http://en.wikipedia.org/wiki/Solar_energy	12, 16, 20
http://www.elec.canterbury.ac.nz	30, 32
www.alldatasheet.com/datasheet-pdf/pdf/28817/TI/TL494D	31