Design of an Efficient Solar Engine Circuit for Autonomous Robotics

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ABSTRACT
The project here is a creation of a solar light following and an obstacle avoiding robot without the use of any complex units like microcontrollers. The control circuit of the robot is designed making use of analog and digital properties of NAND and NOR CMOS IC's. The robot is powered by solar cells and uses power in microwatts for its functioning, making it very efficient in terms of energy. It follows a bumblebee way of locomotion, making it very effective in obstacle aversion. It is seen that this robot is more efficient than any other solar light follower available currently.

Keywords
Pulsating trigger, solar engine, micro power, circuit analysis and design..

1. INTRODUCTION
Robots using solar energy are the most promising new advances in robotics. These robots are self-generative (i.e. do not require an external power source) and save a great deal of energy. But harnessing solar energy in robots has its own disadvantages. Solar power is very irregular and very large panels are required to create small quantities of power. Because of the constraints of weight in robots, we cannot use large solar panels. Also additional circuit needs to be constructed to control the fluctuating parameters due to changes in sun's radiation.

There are various solar robots made in the world, all of which makes use of circuits called as solar engines. The various different types of solar engines are FLED based, zener based, miller engine, fishhook net, Sarah turbot, etc. All of these engines store the solar energy in a large capacitor and discharge the capacitor, on reaching a specific voltage level. This discharged energy is directed to the various elements for utilization. But this causes the capacitor to fully discharge and hence it requires more time to charge to the required voltage level. Also these circuits require some components like IC 1381(voltage detector), which are very expensive and rare to acquire.

Keeping all these shortcomings in mind, we decided to design a control circuit for a robot which is

1. Energy efficient
2. Harnesses the charge of capacitor effectively.
3. No utilization of any specialized components.
4. Can withstand extreme wear and tear.
5. Has very little power consumption.
6. Can be made by anyone without any special expertise.

In this project, we have made an extremely small solar robot which can perform the functions of following light and avoiding obstacles. We have used small polycrystalline solar panels for harnessing solar energy. The circuit designed is very power-efficient as the power generated by the panels is in very less and needs to be utilized at an optimum level. The underlying philosophy of this robot is BEAM robotics. BEAM robotics is a new branch in robotics which assimilates simplicity of circuits and biology in robotics. It stands for biology, electronics, aesthetics and mechanics. Using the various principles and techniques used in BEAM robotics, we designed the robot with greater cost-savings and modeling.

2. DESIGN
2.1 Study of glitches in present solar engines
As stated earlier, all solar robots use capacitor to store energy. These capacitors are completely discharged when a specified voltage level is reached, requiring it more time to charge. But considering the exponential curves of charging and discharging, we figured out that partial discharging of the capacitor and latching the operation of the capacitor in a fixed voltage band, will utilize the power most effectively.

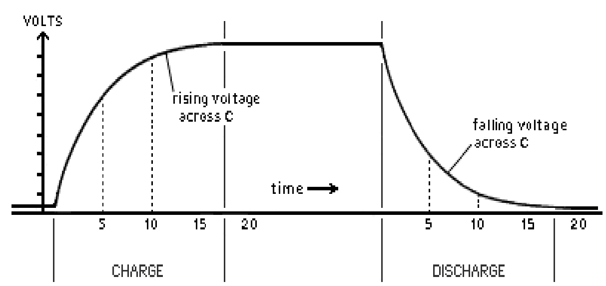

Figure 1. Charging and discharging of capacitor.

As we can observe in figure 1, the charging slope is faster as we go towards the left and reduces towards the right. We decided to latch the voltage in the middle of the slope so that we can get a higher voltage for peroration and the charging- discharging of the capacitor is at a faster rate. For this purpose we use a technique called as 'shocking the bicore.' after 3 volts. This is the lower level of the band. The higher level is decided by the drop across 3 diodes which are around 0.8-1v. So the control circuit activates only after the voltage reaches 3 volts and the operations begin at 3.8-4v. Thus, we have managed to harness the analog properties of cmos ICs for the utility of voltage detection, instead of the

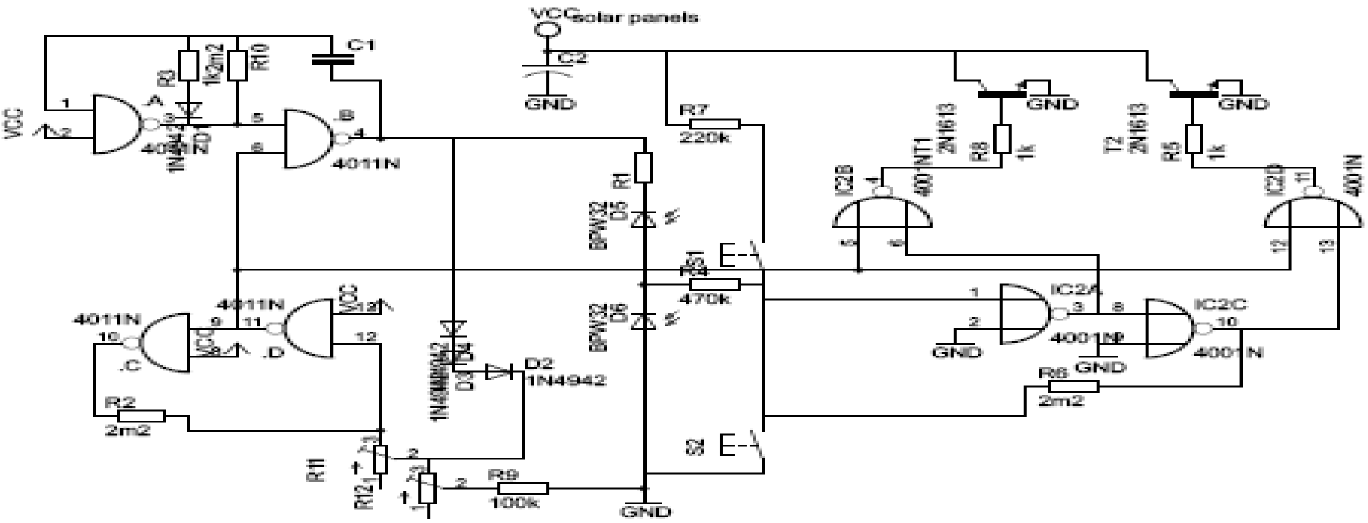

Figure 2. Schematic of control circuit.

usage of rare and expensive ICs like 1381. Hence, the purpose of optimum utilization of capacitor charge and non utility of specialized components were fulfilled.

2.2 Design of the control circuit

The main rationale behind the design of the circuit was that the power consumption of the circuit should be most efficient and effective. Also the robot has a bumblebee manner of locomotion i.e. it moves at right angles, with half circles around a stationary wheel, to the required direction. This movement helps to reduce power consumed as only one motor is required at a time and it is most effective while avoiding walls and other obstacles. In fig 2, we can see a pulse generator built around NAND gates N3 and N4 and voltage monitor built with N1 and N2 gates. These two blocks are the crux of the power efficiency of the circuit. As long as the voltage over the storage cap (4700uF) is lower than the switch-on trigger level, the pulse generator runs, which means that the voltage monitor 'samples' the voltage about 5 times a second, each time for about 1 millisecond. This prevents the rather high current consumption normally associated with having almost any trigger device hesitate between yes and no for a long time. When the solar panel has charged the storage cap to the required level, N1's output becomes about 0V, forcing N3's output to remain high. The low output at N1 causes inputs at N7 and N8 to become low. NOR Gates N7 and N8 will operate only that motor whose second input will have a high voltage. This is another added advantage of using IC. They convert voltage into current, acting as excellent motor drivers. The trigger arrangement of the circuit is now continuously monitoring the stored voltage. It's output will therefore keep one of the motors running until the voltage drops below the switch-off trigger level. Without the feedback from N1 to N3, the motor would be running only for the duration of a sample pulse. Thus the feedback increases the duration of operation of the robot.

Which motor actually runs is determined by the Schmitt-trigger built around the NOR gates N5 and N6. They take their input from the two BPW41 photo diodes and the tactile sensors. Note that the bias current for the photo diodes is also switched by the pulse generator, which makes it possible to use a small bias resistor (2K7) for good performance in full sunlight, without suffering excessive current consumption. There are two presets added in the circuits which adjust the pulse width and height of the sampling pulse. This is beneficial as different motors have different current and voltage requirements and this can help the robot to be compatible with a variety of motors.

Therefore, by assimilating the various properties of IC's, different active and passive components, we succeeded in creating a circuit that has fulfilled every purpose envisioned by us.

3. IMPLEMENTATION

3.1 Verification on breadboard

After the circuit was designed, the various parts of the circuit were taken on a breadboard and implemented to check the various practical parameter changes required in the circuit. Some of the changes in the circuit that were required were noted and the circuit was redesigned with those changes.

3.2 Etching the circuit board

When the circuit was designed, it was converted into electronic form by using PCB wizard, which is created by new wave concepts, for the purpose of circuit drawing and PCB implementation. After the negative (solder side) of the circuit was created, it was printed to scale on a tracing paper. A copper plate, used for etching, was taken and the paper was kept on it. Hot press was kept on the arrangement until the tracks got transferred on the copper side of the plate.

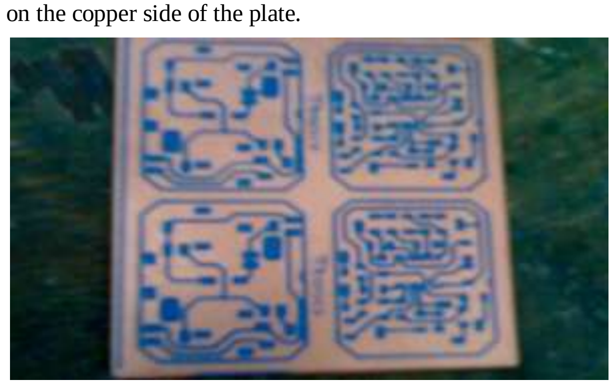

Figure 3. The tracks of the solder side were transferred to the copper plate

After the tracks are transferred, the plates were dipped in ferric chloride solution. The part which is not covered with paint reacts with ferric chloride and the tracks are left intact. This is the etched circuit board of the robot.

Figure 4. The copper boards after treatment with ferric chloride.

For greater help while soldering, we decided to get the circuit tinned from a small scale workshop. An etched printed circuit board made our circuit more compact and less heavy which is a great advantage.

3.3 Soldering and debugging

All the components were properly soldered with the help of a soldering iron and wire. A fine tip soldering iron was used for neater and better solder joint. Special care was taken while soldering the pager motors as they are sensitive to heat. The circuit worked in the first attempt, so there was no debugging required. The presets had to be adjusted for proper switching.

3.4 Making the tactile sensor

The tactile sensor is used to detect any obstacle in the path. As the power consumption of the circuit has to be small, we decided to use basic tactile switches for the purpose of tactile sensors. Two wires were taken and were uniformly curled. They were soldered along with a small wire so that both the wires are close but they don’t make contact. This is the tactile sensor. When an obstacle will move the longer wire, the two wires will make the connection in the circuit and procrastinated movements will be perceived by the robot.

4. MECHANICS

The robot follows a bumblebee technique of locomotion. The fig 5 explains how the motion takes place with respect to the motor.

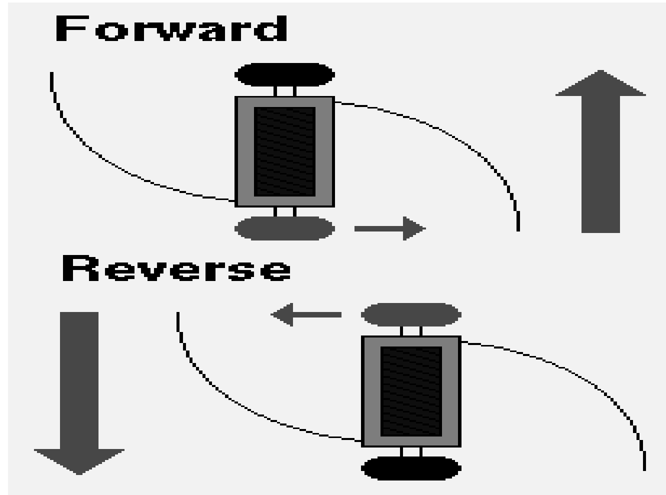

Figure 5. Movement of motors with respect to the destined direction.

When the motor has to go forward or reverse, only one motor is used for the motion instead of two. One may feel that this movement is very time inefficient but on analysis it is found that it is not. When we see the collective motion of the robot towards light, we see that it follows the shortest path without deviating from it but reaches it along the diameter as shown in fig 5.

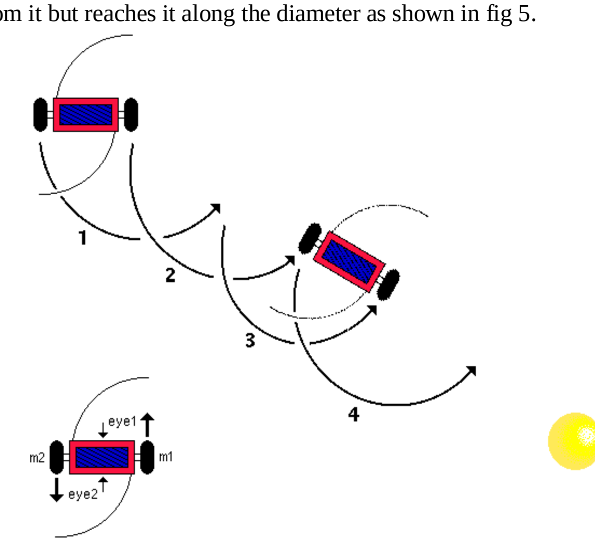

Figure 6. Motion of robot towards light.

This motion is of utmost importance for avoiding obstacle. It follows along the obstacle and moves around it, keeping one tactile sensor in contact, thus covering the shortest path to avoid the obstacle. Fig. 7 gives a series of illustrations to show its obstacle avoiding motion.

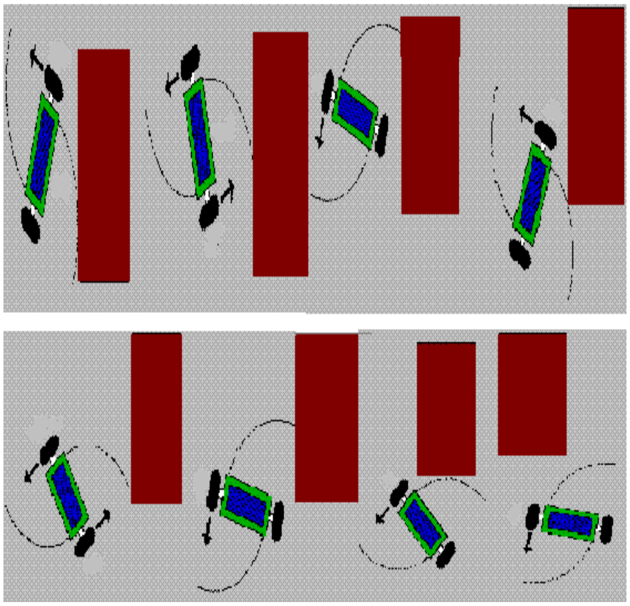

Figure 7. Set of illustrations showing the motion of the robot during obstacle aversion.

Each tactile sensor is a part of the circle having the opposite wheel as its center. Therefore, we observed that the bumblebee motion will be apt for the robot. It must be noted that simple circuit change can be made in order to operate it in a normal locomotion movement.

5. RESULTS

Solar panels are very expensive, so first we tested the robot by simulating the solar panels using a voltage source and a series resistor as shown in fig 8.

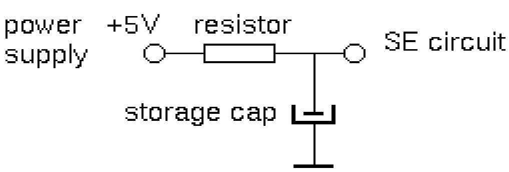

Figure 8. solar panel simulation

When we simulated the circuit, it gave a very high switching efficiency and excellent power consumption. The circuit was functioning perfectly by taking in only 300 micro amperes of current. Therefore, we can see that the power consumed by the circuit is very miniscule. The robot was giving a decent rate of 3-4 bursts per 5 seconds.

With the morning sun less than 30 degrees above the horizon, its horizontal solar panel supplies enough power for one burst discharge per second. When the sun gets higher, robot prototype achieved nice amount of torque and locomotion, obtaining a speed of over 2-4 cm per second, which seems pretty good given the weight (78 and 98 grams), and the small size of the solar panel.

Even in full sunlight, it keeps looking for something better while trying to avoid shadow patches. It is done by pointing the photo diodes to the ground as shown in fig 9 and the robot truly backs away from obstacles without reversing motors. In low ambient light conditions, you still get the occasional step, as the thinking part uses only about 20 micro amperes current or less.

The robot required very little current and could function even in the shadows. But the speed reduces drastically in the shadow as compared to in presence of light. The bumblebee motion is executed flawlessly and the path it follows isn't too long or lethargic.

Thus, we can say that the designed robot had fulfilled all the objectives assigned to it in an effective manner.

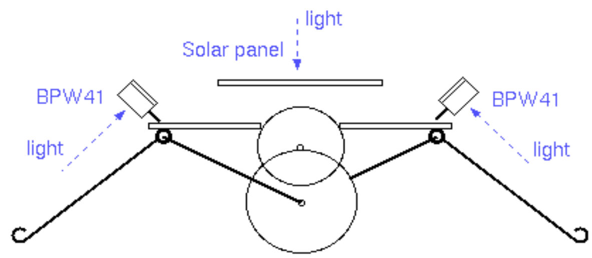

Figure 9. Placement of photodiodes and solar cell.

6. CONCLUSION

A robot was constructed which used solar energy to follow light and avoid obstacles. It fulfilled all the expectations of the solar engine hypothesized. The circuit is energy as well as cost effective. It gives very satisfactory performance and shows movement even in very low ambient light conditions. All the short comings of the solar engines were overcome by the circuit used in the robot. These kinds of robots are completely independent i.e. they are autonomous and have a renewable energy source. So these robots can be ideally used for exploration purposes.

7. REFERENCES

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