ADVANCED SOLAR CAR

CONTENTS:

SECTION 1: GENERAL AND PLANNING INFORMATION

DESCRIPTION – OVERALL VEHICLE

The *ADVANCED SOLAR CAR* is a four-wheeled basic vehicle, driven by an electric motor and powered by a purpose designed solar panel.

This vehicle also has a *SOLAR PANEL POWER CONTROLLER – LOW VOLTAGE (SPPC-LV)*, which helps your vehicle to achieve maximum performance, by the use of an electronic device.

Motion from the motor to the wheels is transferred by the use of gears.

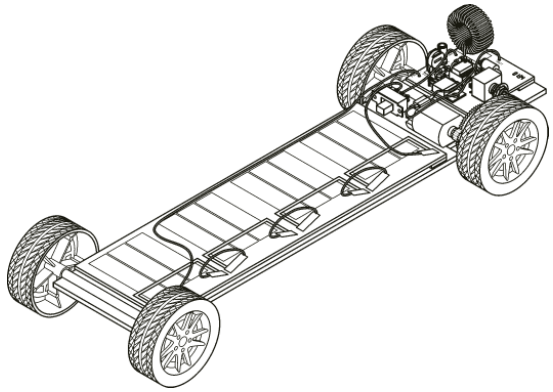

Fig. 1: *ADVANCED SOLAR CAR* with *SOLAR PANEL POWER CONTROLLER (LOW VOLTAGE)*

DESCRIPTION – SOLAR PANEL

The Solar panel is a purpose designed unit, consisting of 4 sections, and these can be connected in series or parallel. The use of 4 sections is ideal for experimentation, as it means that not all 4 have to be connected at the same time – you can connect the sections to provide the amount of volts and amps as required. For example, you could connect only one section, to see how the vehicle will perform. Then connect just 2 sections in series, then 3, and finally all 4. You can then carry out similar tests in parallel.

Thus, the vehicle made from this kit has a lot of scope for various trials and experiments.

DESCRIPTION – SOLAR PANEL POWER CONTROLLER

This kit includes a *SOLAR PANEL POWER CONTROLLER - LOW VOLTAGE*. The *SOLAR PANEL POWER CONTROLLER* is useful, as powering an electric motor directly from a solar panel can be inefficient. The *SOLAR PANEL POWER CONTROLLER* circuit holds the output of the solar panel at a preset voltage, and is able to substantially increase the starting current to the motor.
NOTE: the *SOLAR PANEL POWER CONTROLLER – LOW VOLTAGE* will only work, with ALL the sections of the solar panel connected in SERIES (providing a 6.0 volts).

DESIGN CONSIDERATIONS

GENERAL

The drawings provided are a starting point for the student – they show the prototype vehicle we made.

- Before starting construction, the student needs to carefully plan and layout all of the components. The plan view of our prototype vehicle is shown in the drawing below (Figure 2). However, the concept has scope for variation. Students should design a vehicle to suit their own end usage.
- The exploded view of the car shows the relationship between the various components. The design of the *ADVANCED SOLAR CAR* should be considered as a complete unit, not just as separate parts.

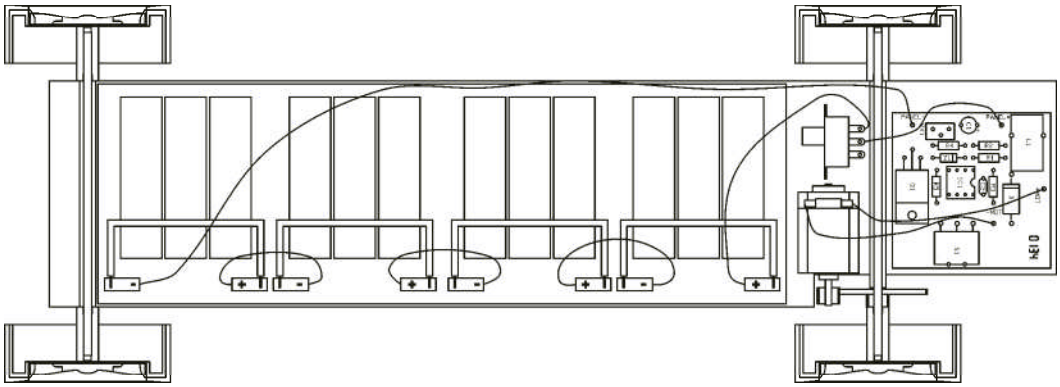

Figure 2 Plan View

When deciding on the platform's size:

- The axle shaft and guide tube length provides an upper limiting factor (for the width).
  Note: Cut-outs may be made in the platform, for the wheels, to allow a wider vehicle to be constructed.
- The platform can be made from any piece of material, even a very narrow one, in which case stability needs to be considered.
- The student needs to determine the material from which the *ADVANCED SOLAR CAR* is to be constructed. Our choice was PVC. Other materials may be used, such as acrylic and plywood.

Other things to consider:

- Use the guide tubes as bearings for the axle shafts.
- This vehicle as shown is basic, but it also allows scope for the student to develop and make a more sophisticated vehicle. Remember – keep the end use in sight.
- The vehicle can only travel in a fixed direction - either straight ahead or in a predetermined circle. This (circular travel) can be achieved by mounting the front axle shaft on an angle.
- Two spur and 3 pinion gears are supplied. This provides the designer with scope, to select the desired acceleration and top speed of the vehicle. A number of combinations are possible with the supplied gears, and provides the designer a choice of different vehicle speeds. Consider the effect of different gear ratios have on either acceleration or top speed.
  - the student should calculate the ratios available.
  - determine which spur gear / pinion gear combination to use.
  - how do these various ratios translate into actual speed? Take into account wheel size and motor speed (how fast does it spin under full sunlight? On an overcast day?).
- Note 1: the maximum motor speed, at maximum efficiency, is approximately 4,500 rpm.
- Note 2: Alternatively, the program *"Crocodile Clips"* is a useful program for simulating the operation of gears, and investigating their operation.

IDEAS FOR INVESTIGATION

This project provides a number of different aspects of the *ADVANCED SOLAR CAR* for investigation. Some ideas are listed below.

- The Solar panel is a purpose designed unit, consisting of 4 sections, and these are able to be connected in series or parallel. The use of 4 sections is useful for experimentation, as it means that you could experiment with the output of the panel in different configurations:
  - only one section to see how much power is output, what speed is attained
  - using between 2 and 4 sections connected in Series
  - using between 2 and 4 sections connected in Parallel.
- Establish conditions for using the solar panel's 4 sections in series or parallel. Set up a test schedule for these experiments. NOTE: This testing should be carried out without the *SOLAR PANEL POWER CONTROLLER*, as the *SOLAR PANEL POWER CONTROLLER – LOW VOLTAGE* will only work, with ALL 4 sections connected in SERIES (ie. between 6 and 12 volts).

- If working in a class, you may wish to assemble a number of these vehicles with different gearing. This will allow you to test the theory / calculations made for the various gearing combinations. This can be tested using a stopwatch over a known length of track (or a variety of distances – to establish when top speed is reached, and what it is)
- How are these speeds affected by having the sections connected in series? In parallel?
- Evaluate the suitability of various materials, such as PVC, acrylic and plywood or balsa wood
- Investigate adding steering. This could be either manual (set the steering in a chosen direction before each use) or controlled (how would you control it? Remote control? Or by a wired controller?). For some ideas on steering, you could look at our *FORKLIFT*, *RADIO CONTROLLED VEHICLE* and *FOLLOW WHITE LINE VEHICLE*.
- You may wish to incorporate forward / reverse operation.

SECTION 2: COMPONENTS & MATERIAL REQUIRED

2. REQUIRED COMPONENTS

2.1 COMPONENTS SUPPLIED (IN THE KIT)

The following components are supplied in the vehicle kit:

1x 1.5-4.5 volt electric motor (flat)
1x Solar panel - 4 x 1.5V, 0.3 Amp (#13)
1x Sliding switch (DPDT) - small
2x 2.5 dia. x 125mm long Steel shaft
2x Guide tube (white) 100mm long
4x 52mm dia.Wheel
1x 50T/10T Spur gear (2.4 mm dia hole)
1x 60T/10T Spur gear (2.4 mm dia hole)
1x 12T Pinion gear– 1.9 mm dia hole
1x 10T Pinion gear– 1.9 mm dia hole
1x 8T Pinion gear– 1.9 mm dia hole

The following components are in the *SOLAR PANEL POWER CONTROLLER (LOW VOLTAGE)* kit:

1x	Printed Circuit Board	1x	3.9K Resistor
1x	Zener Diode 1N751	1x	10K Resistors
1x	8 Pin IC Socket	1x	18K Resistors
1x	47μF 25 VW Capacitor	1x	180K Resistor
1x	47pF 100 V Capacitor	1x	6.8K Resistor
1x	Semiconductor TL071	1x	50K Trimpot
1x	Semiconductor MTP3055	1x	SPDT Toggle Switch
1x	Semiconductor SR340	1x	100μH 5 Amp Inductor

2.2 ADDITIONAL REQUIREMENTS

2.2.1. The following material is to be supplied by the student / designer: fine, multi-strand electric hook-up wire; material for the platform (PVC or acrylic sheet, MDF etc), 1mm tinned copper wire, double sided tape, hot glue gun and everything else.
Note: You will need a multi meter and a 1.0 to 2.7 ohm 10 watt resistor (for testing)
2.2.2 if you choose to modify the design, or carry out testing, as described later, our component range has an assortment of items that may be useful. These include: toggle or slide switches, alligator clips & wires and steering components.

Note: it is suggested that, before you commence construction, you check the components supplied in your kit, and ensure that you have everything required.

SECTION 3: HOW THE CIRCUIT WORKS (THEORY)

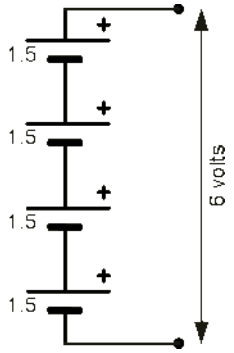

Figure 3
Series Circuit - 6 volts

Silicon solar cells produce electricity when exposed to sunlight (the light of a halogen lamp can also work). Each solar cell generates 0.5 Volt, and the current (amps) generated is proportional to the cell's surface area. The cell's power is rated at "full sunlight". When the sky is overcast, the power of the sun is lower, and the amount of amps produced is less, but the voltage remains the same: 0.5volts.

Each of the sections in the panel has 3 cells, connected in series, to give 1.5 Volt. The panel is designed to be 0.3 Amps at full sunlight.

- At full sunlight, when the solar panel's four sections are connected in series the motor will spin very fast, and the car will run fast. As the sunlight diminishes, the speed will gradually diminish until the vehicle finally stops, because the current is too low.
- When the current is too low, with the sections in series, reconnect the 4 sections in parallel. This gives more current -and the SOLAR CAR will start running again – although slower, due to reduced voltage.

3.1 SOLAR PANEL - WITHOUT A SOLAR PANEL POWER CONTROLLER

- The motor is powered by the solar panel consisting of 4 sections, each of which has 3 cells connected in series. In bright sunlight, each section produces 1.5Volts and 0.3Amps.

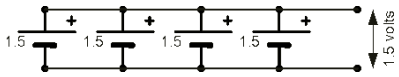

Figure 4
Parallel Circuit – 1.5 volts

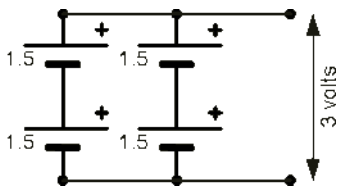

Figure 5 Series & Parallel Circuit – 3 volts

- When the sections are connected in series (Figure 3), in bright sunlight the solar panel produces approximately 6.0V at 0.3A.
- When the sections are connected in parallel (Figure 4) in bright sunlight the solar panel produces approximately 1.5V at 1.2A.
- When the sections are connected in a combination of both series and parallel (in other words – 2 times 2 – as in Figure 5), in bright sunlight the solar panel produces approximately 3.0Volts at 0.6Amps.
- You may choose to connect all the sections, so that they can be switched between the various variants (ie. Series, parallel or the combination).

NOTE: A switch may be used to select the desired operation – the switch would need to provide 3 on positions. However, be aware that the wiring for this could be complex and potentially messy.

3.2 SOLAR PANEL - WITH A SOLAR PANEL POWER CONTROLLER

3.2.1 SWITCH S1 CLOSED

- With switch S1 closed, the motor operates directly from solar power, as the *SPPC* is bypassed.

3.2.2 SWITCH S1 OPEN

- The junction of resistor R1 and zener diode Z1 provide a reference voltage to the op-amp IC1 (pin 2).
- The junction of resistors R2, R4 and RV1 provide an input voltage signal to the op-amp IC1 (pin 3). Variable resistor RV1 allows the circuit to be tuned.
- When the circuit is turned on, capacitor C1 is discharged and transistor Q1 is not conducting. The solar cells charge capacitor C1. When the voltage across capacitor C1 as detected by pin 3 on IC1 exceeds the voltage on pin 2 on IC1, IC1 changes state and switches on transistor Q1.
- When the voltage across C1 drops below the threshold voltage, IC1 stops conducting and switches off transistor Q1.
- The capacitor is then charged, and it is turned off when the capacitor is discharged, providing power to the motor. In bright sunlight this switching will occur very rapidly.

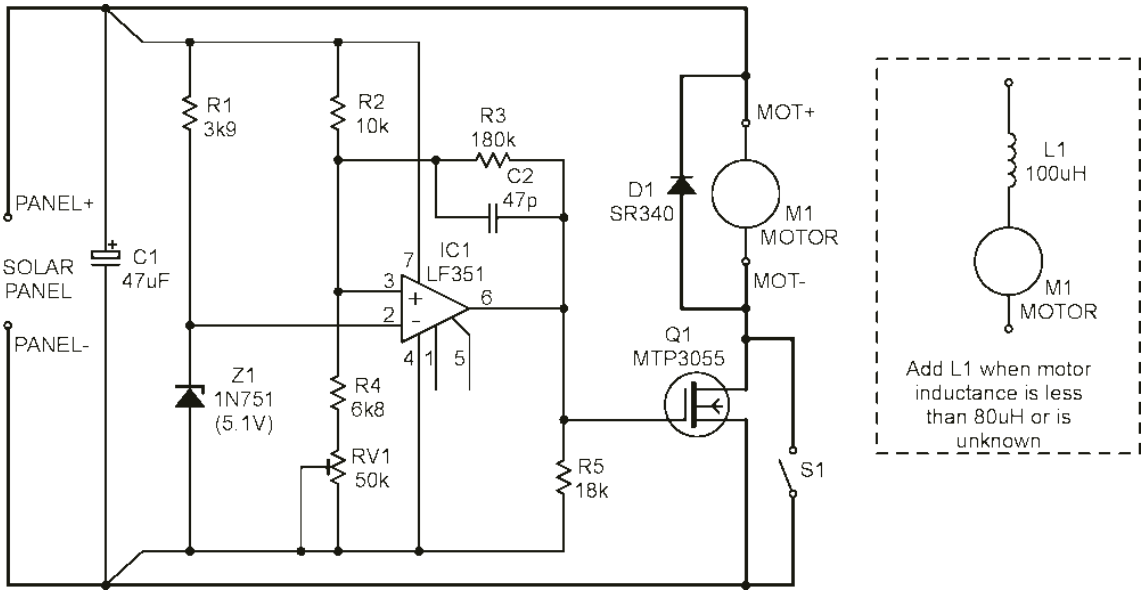

Figure 6 SOLAR PANEL POWER CONTROLLER Circuit

3.3 SPPC - INCREASES THE MOTOR'S STARTING CURRENT

3.3.1 DESCRIPTION

- Powering an electric motor directly from a Solar Panel can be quite inefficient, especially during start up at low motor speeds.
- This *SOLAR PANEL POWER CONTROLLER (LOW VOLTAGE)* circuit holds the output of the Solar Panel at its set voltage point and is thus able to substantially increases the starting current available to the motor. This circuit regulates the input voltage rather than the output voltage. The *SPPC (LOW VOLTAGE)* enables the motor to start and operate at a much lower light intensity than is possible with the motor directly connected to the Solar Panel.
- This electronic device will work with any Solar Panel or combination of solar panels whose VOC voltage (Voltage Open Circuit) is between 6 ½ and 12 volts. Energy consumption by the circuit is 0.04 Watts (approx.)

3.3.2 MORE INFORMATION

If you are interested in more information about how a *SOLAR PANEL POWER CONTROLLER* does what it does, there is more information detailed in the *SPPC* Teaching unit for our normal voltage unit – the standard voltage *SPPC* was designed for use in the Model Solar Car Challenge – more information about that is available on the web site www.solarnational.org).

SECTION 4: ASSEMBLY OF THE PCB & COMPONENTS

COMPONENTS FOR MOUNTING ON THE PCB

All the components supplied have to be assembled onto the PCB, with the exception of the 100μH 5 Amp Inductor. The components have to be soldered onto the PCB in the positions as listed in brackets:

1x	Printed Circuit Board (PCB)	1x	Semiconductor LF351 or TL071 (ICI)
1x	Zener Diode 1N751 (Z1)	1x	Semiconductor MTP3055 (Q1)
1x	8 Pin IC Socket	1x	Semiconductor SR340 (D1)
1x	47μF 25 VW Capacitor (C1)	1x	50K Trimpot (RV1)
1x	47pF 100 V Capacitor (C2)	1x	SPDT Toggle Switch (S1)
1x	100μH 5 Amp Inductor (L1)		

1x	3.9K Resistor (R1)	Colour bands:	Orange, White, Red
1x	10K Resistors (R2)	Colour bands:	
1x	18K Resistors (R5)	Colour bands:	Brown, Grey, Orange
1x	180K Resistor (R3)	Colour bands:	Brown, Grey, Yellow
1x	6.8K Resistor (R4)	Colour bands:	Blue, Gray, Red

4.1 MOUNTING COMPONENTS ONTO THE PCB

NOTE: The assembly of all the components should be carried out before soldering the components in place. Begin with the components that sit lowest on the P.C.B..

- **Mount the resistors** in place. Resistors are non-polarised components and do not need to be placed in any particular direction. However, the convention is that horizontal resistors are mounted with the gold band to the right and vertical resistors to the bottom.
- Make sure when mounting the **zener diode Z1 and semiconductor D1** that the negative end (the one with the band) is mounted in the same direction as shown on the P.C.B. Both of these components must be connected the correct way for the P.C.B. to function.

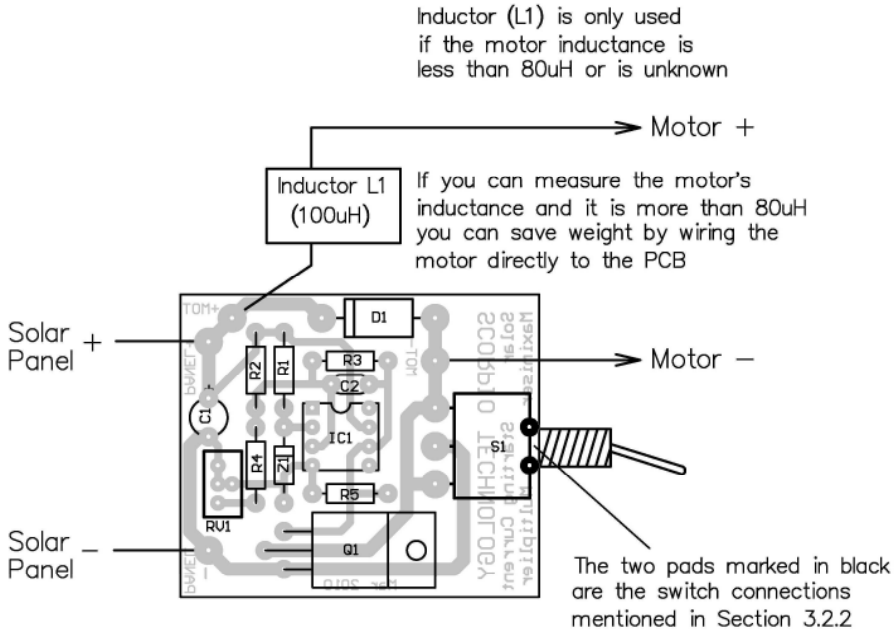

Figure 7 SOLAR PANEL POWER CONTROLLER

- **The IC socket is mounted** next: make sure that the notch on the socket faces in the same direction as indicated on the P.C.B.

- **Mount the 50K (RV1) trimpot** in place.
- Mount **the 47μF** Electrolytic **capacitor** next. This capacitor is polarised: that is, it has positive and negative leads. It must be connected the correct way for the P.C.B. to function. The positive and negative leads can be identified by two methods: (1) the stripe on the body of the capacitor marks the negative lead (2) the long lead is positive. Refer to the P.C.B. to determine the position of the leads.
- Mount **the 47pF disc ceramic capacitor** – this is not polarised and can be mounted in either direction, but it is preferable to mount it with the printed value visible (i.e. facing you).The **MTP3055 power Mosfet** is mounted next. It must be mounted facing in the correct direction or it will be damaged when the P.C.B. is connected to the Solar Cell.

WARNINGS:
- *The Mosfet can be damaged by static electricity. Before handling the Mosfet you will need to discharge any static electricity built up in your body. To do this you need to briefly touch the metal case of an earthed appliance.*
- *The Mosfet MUST be mounted facing in the correct direction or it will be damaged when the PCB is connected to the Solar Cell.*

Using a pair of insulated pointy nosed pliers bend the centre lead out, about 3mm from the two outside leads. Position the leads in their holes so that the metal back is facing towards the picture of the Mosfet on the P.C.B.. Press on the plastic section of the Mosfet and carefully bend it down on to the P.C.B..

4.2 SOLDERING THE COMPONENTS IN PLACE

NOTE: Check that all the components are in their correct positions: it pays to spend some time doing this before soldering the components. It can prevent wasted time later, trying to find out why the circuit doesn't work and unsoldering and replacing damaged or wrongly positioned components.

4.2.1 GENERAL PRINCIPLES

- Turn over the P.C.B. and slightly bend the leads of the components outwards, to prevent them slipping out
- Apply the soldering iron's tip to the lead and track pad at the same time. Heat the joint for 2-3 seconds and then apply the solder to the heated lead and pad on the opposite side to the soldering iron tip. Melt the solder onto the hot pad and lead, not onto the soldering iron.
- Once all the components have been soldered, use a pair of side cutters to cut off the ends of the leads – as close as possible to the solder

4.2.2 FURTHER ASSEMBLY

- After all the soldering has been completed, **insert the TL071 I.C.** in its place in the socket. Ensure the notch on the end faces in the same direction as on the socket. Check that the legs line up with the I.C. sockets holes and press down firmly with your thumb. Note: it may be necessary to push the legs of the I.C. together slightly to line them up with the socket holes.

THE BYPASS SWITCH'S CIRCUIT

- To install the **Bypass (Toggle) Switch** you will need to:
  - solder 2 pieces of 1mm wire (about 20mm long) to one of the switch's centre terminals, and one of the end terminals - along one side of the switch (this means that 2 adjacent terminals have wires connected).
  - Insert the wires into the holes on the PCB.
  - Make sure that the switch sits flat on the PCB, in the position shown on the PCB.

- Solder the wires into their holes on the PCB.

MOUNTING THE BYPASS SWITCH

Note: if not supplied separate from the switch, remove the washer and nut from the toggle switch.

- Use another piece of tinned 1mm wire (about 30mm long) and bend it into a U shape around a 7mm drill.
- Place the wire over the neck of the switch and insert it into the two holes on the edge of the PCB, directly under the neck of the switch.
- Pull the wire down so it sits snugly around the neck of the switch.
- Solder the ends of the wire into position.

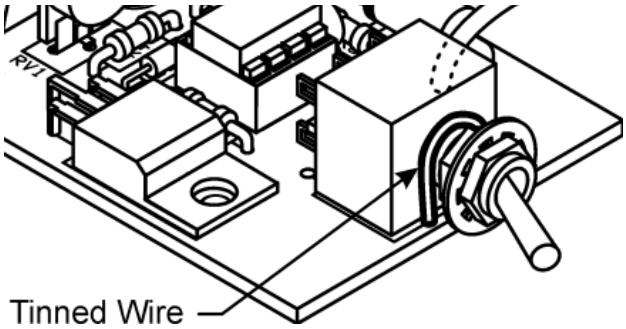

Figure 9: Attaching the Bypass switch

- Place the large flat washer on the switch. Screw the nut up against the washer and tighten it in place.
  Note: this is to hold the switch firmly in place and prevent undue stress on the switch wires when the switch is operated.

CONNECTING THE *SPPC* TO THE SOLAR PANEL, MOTOR AND INDUCTOR

- **Hook up wire** (14 strands of 0.2mm diameter wire) can now be soldered to the PCB to connect it to the solar panel and the motor. Try and keep the wires as short as reasonably possible.
  HINT: Make sure you use Red wire for Positive and Black for Negative.

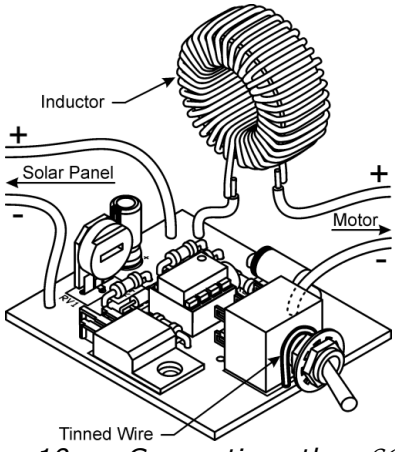

Figure 10: Connecting the SOLAR PANEL POWER CONTROLLER

- **The 100μH Inductor (L1)** is not mounted on the PCB. L1 must be used if the motor connected to the SPPC has an <u>inductance of less than 80μH</u>, or its inductance is unknown.
  - the Inductor is connected between the PCB and the motor. This can be carried out in one of 2 ways: (1) using 2 short wires, one from the PCB to one of the inductor's legs, and the second from the other leg to the motor (2) by soldering one of the inductor's legs into the PCB mounting hole, and using a wire from the other leg to the motor.
    Note: it isn't important which motor terminal the Inductor is connected to.

SECTION 5: TESTING AND SETUP

LIGHT SOURCE:

When testing, different light sources could be used to provide light to the solar panel. The easiest two to use are:

- The sun. This is a variable light source, and to know what sunlight intensity is available – the easiest way is to use a calibrated solar panel to measure the sunlights intensity (our #10 panel is useful for this)
- A flood light – a halogen light of 500 watts is a cheap option. If you use such a lamp directly facing the panel and about 300mm away, you can expect light equivalent to about 50% sun.CAUTION: the lamp puts out more heat than the sun, so only illuminate the panel for about 40 seconds – then allow the panel o cool down.

WARNING: Insufficient lighting or low intensity sunlight can be misleading – it can produce enough power to operate the *SPPC*, but not enough power to drive a solar car.
COMMENT: when testing the *SPPC*, the only way to check that it works, is by using a meter (as detailed below) – that will show the increased performance when the *SPPC* works.

MEASURING THE OUTPUT
NOTE: ALL tests should be performed at the same solar panel illumination level.

- Connect the solar panel to the PCB, making sure that positive (+) and negative (-) go in their correct positions. Use some plastic tape wrapped around the motor shaft to prevent it from turning.
- Use a current meter set to the 10 Amp DC range and connect it in series with the motor.
  - If a current meter is not available, use a 0.51Ω 5 watt resistor in series with the motor. Then use a voltmeter to read the voltage produced across the resistor by the motor current, the 2 Volt setting should be suitable.
- Expose the solar panel to your chosen light source. Adjust RV1 on the PCB to obtain a maximum reading on the meter. **Do not expose the solar panel for more than 30 seconds at a time because the motor rotor winding may overheat**. Wait about 5 minutes to let the motor cool down before repeating or checking the setting.
- The preferred method, if you wish to avoid the possibility of overheating the motor, is to substitute a 10 watt 1 to 2.7 Ohm resistor in place of the motor. A voltmeter can then be connected directly across the resistor and used to obtain the maximum reading.

WARNING: *Do not attempt to connect the SOLAR PANEL POWER CONTROLLER to a standard power supply under any circumstances. Damage to the Mosfet will occur very quickly.*

HINT: The maximum power voltage point of a solar panel changes with both the temperature of the solar panel and the sun's intensity. You may wish to make adjustments under various conditions to obtain the best compromise.

SECTION 6: MAKING THE VEHICLE

6.1 FABRICATION AND INITIAL ASSEMBLY

- Cut the platform material to the required size.
- Cut the steel shafts to the required length and de- burr the ends.
- Press the selected spur gear (50 tooth or 60 tooth) onto the rear shaft, with enough of the shaft protruding, through the gear, for the wheel to be pushed on.
  Hint: use a piece of wire to measure the depth of the hole in the wheel
- Insert the shafts into the guide tubes. Press the wheels onto both shafts.
- Install the pinion gear onto the motor's shaft.

NOTE: Do not push the gear too far, or it will rub on the motor casing.

HINT: Place the end of the shaft (where it exits the motor) on a hard surface, and push the propeller down.
WARNING: Don't just push the motor down by hand as this can push the motor armature out of its bearings and jam the motor.

6.2 MECHANICAL ASSEMBLY

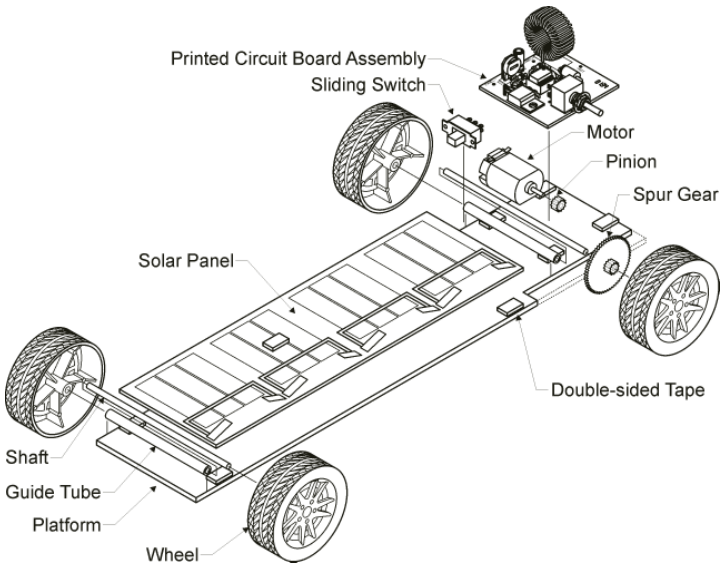

Figure 9 Exploded View

- Attach the solar panel to the platform, in the position chosen, using double-sided foam tape.
- Attach the pre-assembled front axle (guide tube, shaft and wheels) to the platform with hot glue.
  NOTE: Ensure that the shaft guide tube is at right angles to the car's platform and both guide tubes are parallel to each other, so that the car travels straight ahead– unless you have chosen for the vehicle to travel in a circular path.
- Attach the pre-assembled rear axle (guide tube, shaft and the wheels and gear assembly) to the platform with hot glue.
- Use hot glue or double-sided foam tape to attach the motor to the platform. The pinion gear should engage the spur gear's larger diameter gear, and the motor and wheels should turn freely.
- Attach the switch to the chassis using hot glue or double-sided foam tape.

WARNING: if using Hot glue, be very careful, as it can burn you if you get it on yourself.

6.3 WIRING

- You may wish to carry out a range of experiments, using the various combinations of the solar sections (series, parallel or a combination). If so, you would need to retain the ability to change the connections as and when required. If this is the case, we recommend that the connections are made using alligator clips and wires, rather than soldering leads in place.
- If you have decided on a specific solar section configuration (in accordance with the circuit schematics shown in Section 2), solder wires between the sections of the solar array, switch and motor.
  REMINDER: the *SPPC* only works with the solar sections wired in series.
  WARNING: Take care when soldering to prevent burns.
  NOTE: When soldering wires, strip a short piece of insulation from the end of the wire, twist the strands and use a hot soldering iron (approx. 350°C) to apply solder.
- Test the operation of your solar car.
  - If the car goes in reverse, swap the wires connected to the motor, and solder them in place.
  - If the car goes forward as expected, solder the motor's wires in palce.

  Congratulations! This completes the *ADVANCED SOLAR CAR*.

HAVE FUN!