BEAM Robotics® Kit #2:

The BEAM Photopopper 4.2 Photovore Robot©

Unlike most robots, this BEAM robot is *solar-powered*, and does not have an off switch. Optical and touch sensors give the palm-sized Photopopper Photovore light-seeking and obstacle-avoiding behaviour. This robot doesn't use a microprocessor or computer "brain", making it straight-forward and easy to construct and tune! (Soldering skill required)

A Complete BEAM Solar-Powered Robot Kit Inside

Produced by

SOLARBOTICS ® Ltd.

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Disclaimer of Liability

Kit Component List
This is what you should find in your BEAM Photovore Photopopper kit:

1 - Printed Circuit Board (the PCB). This will be the body and brains of your Photopopper, so DON'T LOSE IT!

2 - 2.2 kOhm resistors (band colours red, red, red, gold). These tune the Solarengines for optimal performance.

2 - 680 kOhm resistors (band colours blue, grey, yellow, gold). These set the degree of influence the touch-sensors have over the Solarengines.

2 - 2N3906 PNP Transistors (one for each Solarengine).

2 - 2N3904 PNP Transistors (one for each Solarengine).

2 - 1381 Triggers (one for each Solarengine). These are what actually measure the stored power and tell the Solarengine when to fire.

2 - 0.22μF (μF - microfarad) capacitors. These work with the triggers and optics to sense which direction is the brightest.

2 - Photodiode sensor optics. These are essentially the "eyes" of the Photopopper.

1 - 100 kOhm trimmer potentiometer. This is usually called a "trim pot", and is used here to tune the Photopopper optics so it knows what light "straight ahead" looks like.

1 - 4700μF 6.3 volt capacitor. This is where the Solarengine stores the power from the solarcell until the Solarengine fires.

3" - Fine twisted pair of wire to be attached to the solarcell.

2" - Copper wire for structural support

2 - Augat sockets. These look like pins with a little socket on the end. These will be turned into touch-sensors for the Photopopper.

2 - Sensor springs. These will be used with the Augat sockets to be the touch-sensors.

2"- 1/16" Heat-shrink tubing. This will be used in the construction of the touch-sensors and also be used for the wheels for your Photopopper

2 - High-efficiency low-voltage, high-speed coreless motors.

2 - Fuse-clips.

1 - Solarcell. Well, it *is* a solar-powered robot.

1 - Instruction guide. If you don't have this, stop right now and find it. (That's a joke...)

You will require:

   - Basic electronics and soldering skills, as this is not a beginner's kit

   - A soldering iron and solder

   - A multimeter (optional - for testing & debugging purposes)

   - Safety glasses (use whenever there's snipping going on)

   - Matches or a lighter

   - A razor or sharp knife

   - A small flat-head screwdriver

   - Glue (hot glue, epoxy, superglue - whatever you have handy)

   - A pair of needle-nose pliers

   - Wire cutters/strippers

   - A tiny bit of a sense of humour. We will not be held responsible for any joke, good or bad. So take that.

One thing we have to stress - read the *entire manual* before starting construction, as this will decrease the amount of potential errors. And always use the appropriate safety equipment, like safety glasses and a proper soldering-iron holder.

BEAM Robotics Kit #2:
The BEAM Photopopper 4.2 Photovore

Introduction

BEAM Robotics is a relatively new field of robotics where the robot does not have a "traditional" brain (ie: a microprocessor), does not have a "traditional" power source (ie: a battery), and does not look anything like a "traditional" robot (ie: no blinking lights). No microprocessor means there isn't any programming to contend with, or worries about losing all your programming because the battery ran low. Being solar-powered and having no off switch means that a BEAM creature will do what it's designed to do as long as there is sufficient light, regardless if there's a person watching it or not. This means you can leave your robot alone for a while, and when you come back, it may be in a totally new and unexpected position (or for that matter, could be down-right missing)..

The BEAM Photopopper Photovore is a capable little self-contained robot that is powered entirely by solar energy, has light-sensing directional optics (eyes), and a pair of obstacle-avoidance sensors. It uses the latest in high-activity BEAM electronics, utilizing new-technology voltage detection devices that use very little power to monitor power levels in the capacitor. This has been such an improvement over older methods that these new prototypes "popped along" right by the old style photovores, thus the name "Photopopper". The pair of infrared detectors on the robot give it a very directed phototropic (light-seeking) behaviour, making it able to trace outlines around shadows, and be attracted to the brightest sources of light.

Almost every BEAM creature makes use of a circuit called a Solarengine. This is a circuit that digests the energy from a solarcell and turns it into bursts of motion. Your Photopopper Photovore uses two Solarengines, one for each motor. By governing which Solarengine fires, the Photopopper can avoid obstacles and go towards light.

The name BEAM is an acryonym for Biology, Electronics, Aesthetics, and Mechanics. It breaks down like this:

Biology: If you're going to create something from scratch, you model it after successful designs. Soooo, we steal (um, I mean "borrow") many good ideas from Mother Nature. There's some techniques that we can use that nature doesn't have, like using metals, solder, wheels, and some real killer glues. We can't include solarcells in that list because nature turns light into food all over the place. Have you seen those tree-things lately?!? They've got these green, flappy things that hang in the breeze and convert light into energy (truly cool). Your BEAM Photovore was originally inspired by the shape of a small Horse-shoe crab, but it seems to have turned out looking more like a BEAM cockroach...

Electronics: Obviously, it's a whole lot easier for us to solder a few transistors together than it is to hook up muscle tissue and nerve bundles. Silicon electronics provides us with a practial method to create our own life-like creatures, and there's none of that messy blood'n'guts stuff.

Aesthetics: This is just a fancy name for "Gee - that looks cool". If you're going to spend the time to construct an autonomous (self-running) robot, spend a little more time to finish it properly. Hide the wires, tighten the connections, and make the solder joints clean. Besides improving it's appearance, these qualities also will make a robot sturdier and more robust.

Mechanics: Solid, clever mechanics by themselves can replace a microprocessor and many lines of programming. This makes a robot more damage-resistant, and able to survive the unexpected. Too often a robot is based around the computer, with wheels and motors literally strapped to a frame with a computer mounted on the top. Designing BEAM robots means the mechanical layout is just as or more important than the electronics, and usually takes longer to design than anything else.

Critter Overview - Why it Does what it Does

As previously discussed, this BEAM robot uses only solar energy to make its way around the environment you place it in. The solarcell used in this particular application has just enough power to run one of the motors continually in direct sunlight, but what good would this do you when the sun goes behind a cloud, or you want your robot to do something else besides spin in circles? The trick is in the use of the Solarengine. It stores the power generated by the solarcell in a capacitor, which is like a mini-battery, and very efficient. When the capacitor charges up to a particular level (in this instance, between 2.4 and 2.7 volts), the Solarengine activates, and throws all the stored energy from the capacitor to the motor. This makes the motor spin good and fast, much more so than if it were connected to the solarcell by itself.

To make the Photopopper phototropic (attracted to light), the robot has to decide which direction has the most light. This Photovore design uses a pair of light-sensors arranged like a bridge to make this decision. Think of it this way: Imagine a level see-saw with a water bucket at each end. When a raincloud comes near, it starts filling the buckets with water, but the one nearest the cloud fills up faster. As soon as the one bucket fills, it makes it's end touch down and spill out. Using this analogy, the buckets are the light-sensors, the raincloud is the source of light, and the spilling out is the signal for the proper Solarengine to trigger. You will be able to set the "see-saw point" using the trimmer potentiometer so your Photopopper will go straight towards light sources. Or if you want, you can tweak it so that it will "prefer" to turn one way versus the other simply by changing the way the two light-sensors "balance" each other on their electronic see-saw.

The light-sensors are very good at what they do. They're designed to view a 100 degree angle, and will not let the Photopopper get itself caught in a shadow while there are better sources of light nearby. One of my favourite past-times when I torment (um, I mean observe) my Photopoppers is to herd them around their pen using a shadow cast by my hand, or a book. Sometimes they aren't tricked, and will try to jump through the shadow to where the light looks better!
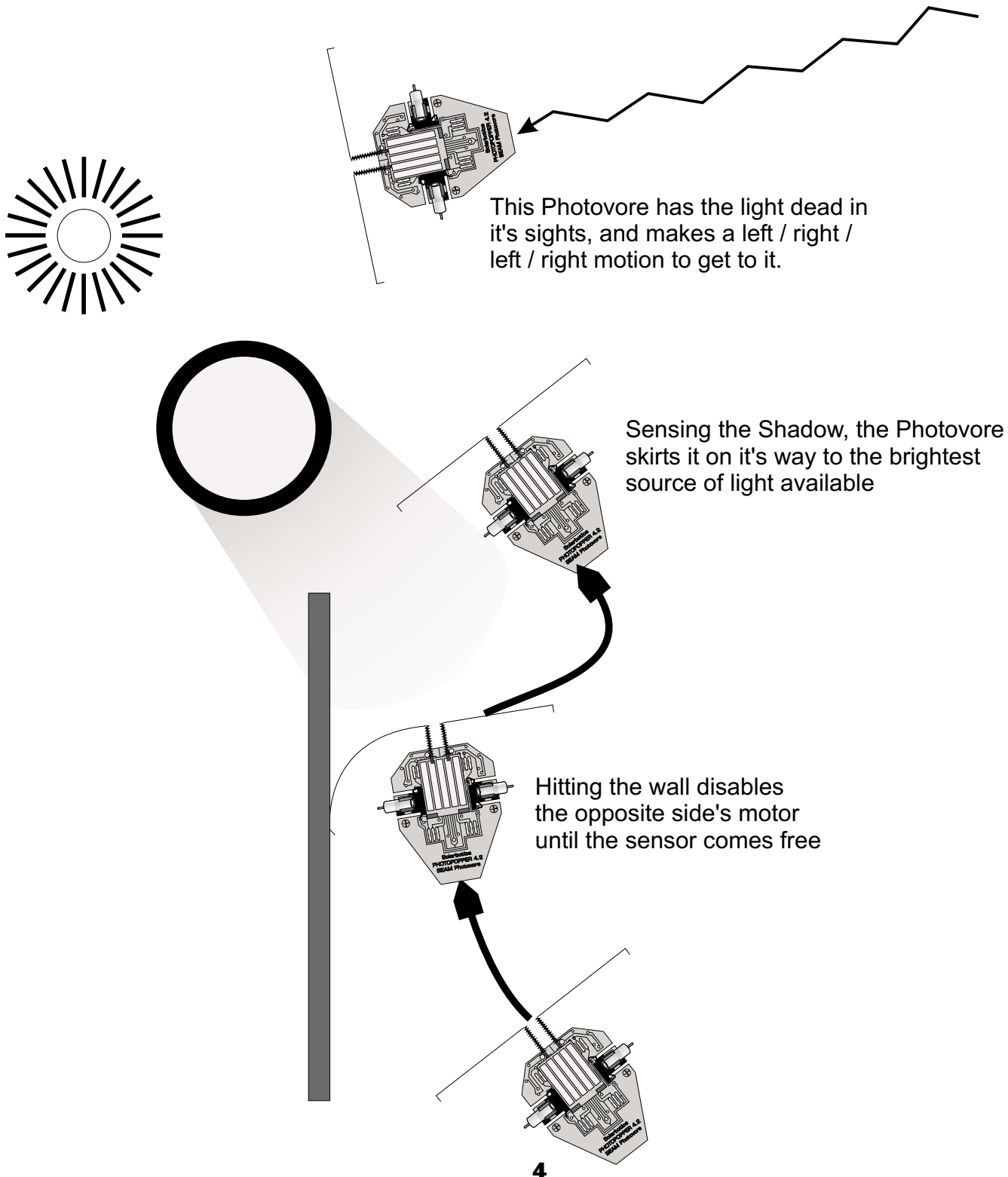
The touch-sensors you will be building will give the Photopopper the ability to avoid obstacles in its way that it didn't "see" with the optics. These sensors work in a simple manner - they shut off the Solarengine controlling the motor on the opposite side. When the Photopopper bumps into something against it's left sensor, it shuts down the right side's motor. This makes the Photopopper pivot around the right motor until the sensor comes free, and then the robot continues on it's merry way.

There is an exception to this rule, and that is when both sensors have been activated. Unfortunately, the Photopopper isn't smart enough to know how to back out of a trouble spot, so in this case it will ignore the touch-sensors and try to bully it's way through the obstacle with brute force. It may not seem like it would have a chance against another BEAMbot or obstacle in a display area, but it will probably surprise you. Slow, but steady, consistant attempts can prove to work quite well. Just don't blame it for knocking your flower vase off the shelf (it was the cat's fault - honest!).
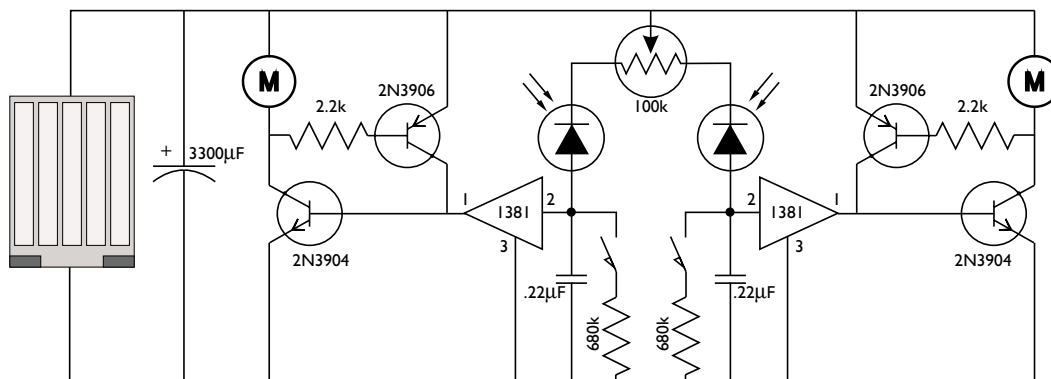
Photovore Behaviours

Your Photopopper is designed to exhibit two main behaviours: Light-seeking and Obstacle avoidance. The primary goal of any Phototropic (light-seeking) robot is to find and maintain access to a source of light (it's primary source of energy). The secondary goal is to keep from getting stuck. Your Photopopper is equipped with optical sensors to find the light, and touch sensors to avoid any immediate obstacles. Interestingly enough, the optical sensors can sense obstacles by the shadow they cast, so your Photopopper may occasionally surprise you with their adeptness.

This Photovore has the light dead in it's sights, and makes a left / right / left / right motion to get to it.

Sensing the Shadow, the Photovore skirts it on it's way to the brightest source of light available

Hitting the wall disables the opposite side's motor until the sensor comes free

4

Assembly - Bringing your Photopopper to *LIFE!*

(insert "maniacal laughter" here)

Step 1: The Solarengine Components
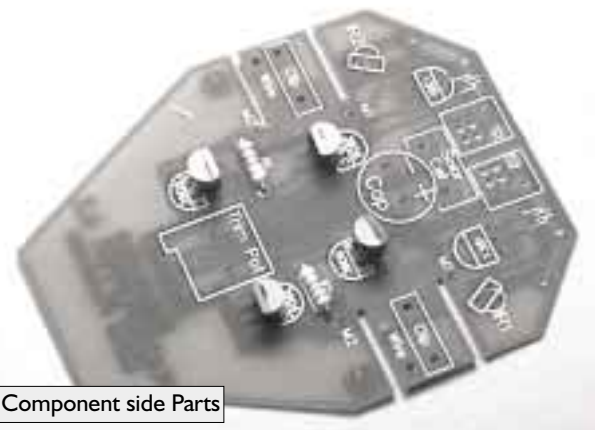

Top View Soldering and Trimming
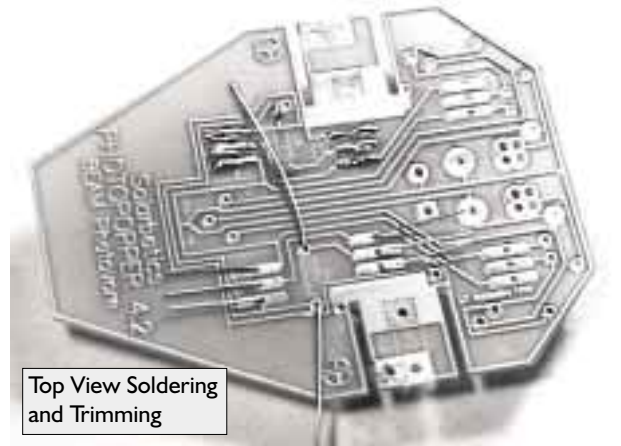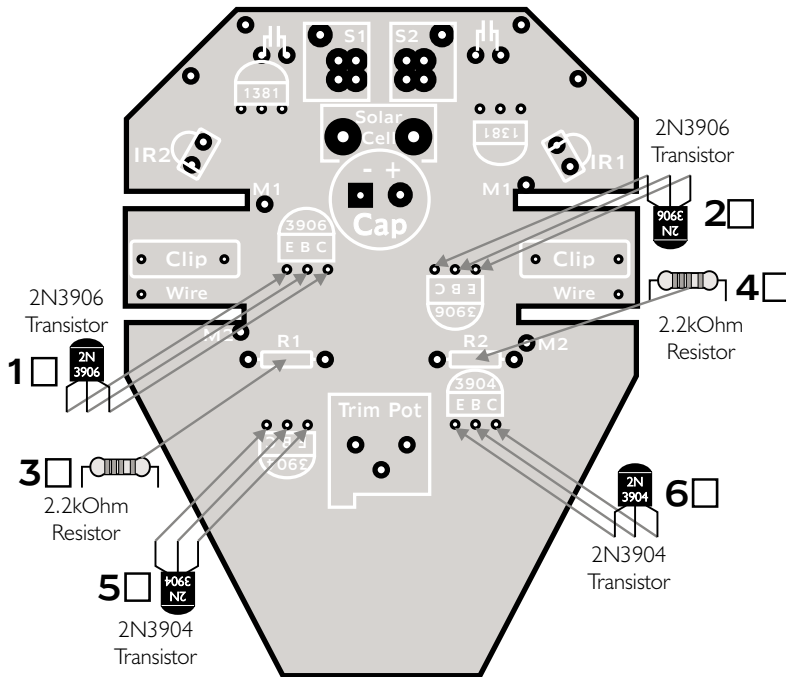
After inserting the part, you may find it useful to fold the leads over so it stays in place, as shown on the lower half of this PCB. After you then solder it in place, trim off the excess leads like as shown on the upper half of this PCB.

The first thing to do with your Photopopper printed circuit board (PCB) is to install the components necessary to make two functioning Solarengines, one per motor. This part of the circuitry is the "muscle" behind the Photopopper, giving it the ability to dump power to the drive motors.

To make sure you don't miss a step, we've included a box by each step number, so you can check each off as you complete it. You don't have to do this, but you wouldn't want to hurt our feelings, would you? (sniff, sniff...) We've tried to arrange the assembly instructions so you do the same thing in pairs; ie: both 2N3906 transistors, then both resistors, then both 2N3904 transistors. We find it's easier this way, and causes less errors.
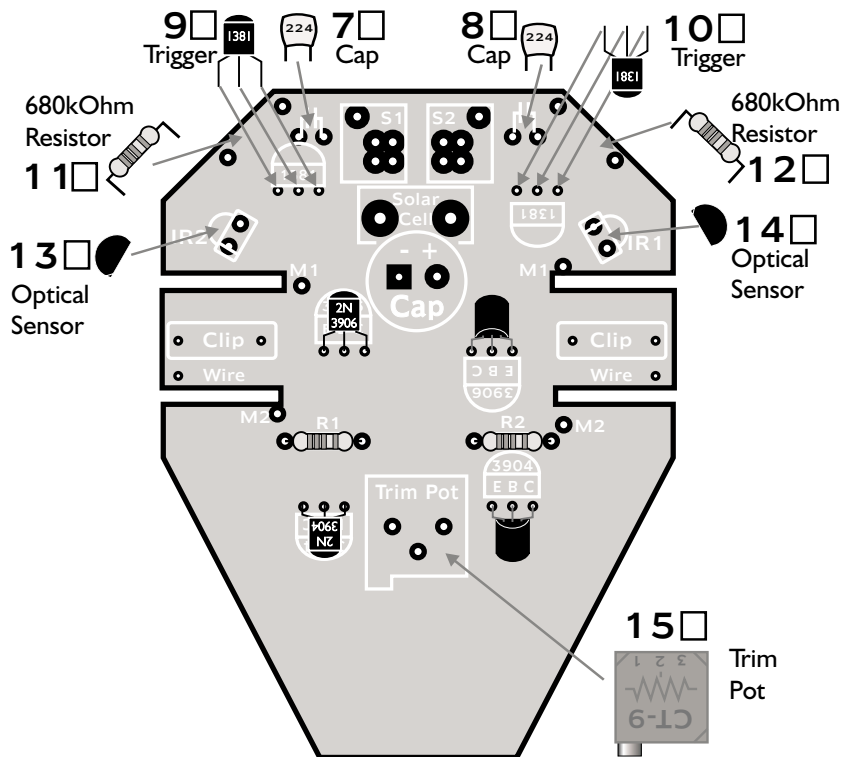
The transistors have to go in <u>exactly</u> as shown. Place each transistor in the correct place facing the same direction as shown on the PCB. The 2N3906 transistors belong to the upper pair of pads (but not the very top set - those are for something else to be installed later), and the 2N3904 transistors belong to the lower pair of pads. Push the transistors in about as far as they can go (see the photo), then bend the legs over on the other side and solder them in place. Make absolutely sure that solder does not bridge across from one pad to the next - this is a very common problem that will keep the Photopopper from working!

Component side Parts

When you finish, the component side of the board should look like this. Make note of the position of the transistors - are yours facing the same way? Also, **MAKE SURE** the transistors are in the right spots, with the 3906's on the top & the 3904's on the bottom. (Sorry to keep harping about this, but it's most simple, stupid mistake to make. I did it myself when preparing this one for the photograph!)

The 2.2k Ohm resistor has four (4) coloured stripes on it - *RED RED RED GOLD.*, It does not matter which way it gets installed, but make sure that it sits flat against the PCB before you solder it down, just like in the photograph. This makes your installation neater, and we wouldn't want you ending up with a Photopopper that looks anything but cool.

Step 2: The "Brains" & "Eyes" of the Photopopper

9☐ Trigger
224 **7☐** Cap
8☐ **224** Cap
10☐ Trigger
680kOhm Resistor **11☐**
680kOhm Resistor **12☐**
13☐ Optical Sensor
14☐ Optical Sensor
15☐ Trim Pot

"Igor! Bring me a brain! And a pair of eyes while you're at it..."

In this step of construction, we're adding the components necessary to give the Photopopper the eyes to see which way has more light, and the brains to turn in that direction. Again, we suggest following the construction sequence, placing the components in pairs.

The small 0.22μF (μF=microfarad) capacitors are labled "224", and don't care which way they go into the holes, just like resistors. Just make sure that they are pretty snug up to the board before you clip the leads - neatness counts (and we're watching....).

The 1381 transistor-like components are the voltage detectors that trigger the Photopopper when there's enough energy stored. Those of you familiar with our "Type-1 Solarengine" Kit will recognize that this is the same job that the Flashing LED (FLED) has, but these 1381's are much more efficient. With these triggers, your Photopopper should be able to travel a meter (3.3 feet) in under two minutes in direct sunlight. Another benefit of this new technology is that your Photopopper will have a greatly enhanced low-light operating capability. You won't need very much light to "feed" this BEAM robot.

The 680 kOhm resistors (colour coded: Blue / Grey / Yellow / Gold) in this part of the circuit are used to balance how much effect the touch-sensors (yet to be built & installed) can override the eyes of the Photopopper. We need this because if the Photopopper gets into trouble and both touch-sensors get activated, it then relies on the eyes to keep trying to get out of the trouble spot. If these resistors weren't in place, your Photopopper would simply give up and then start daydreaming about a vacation in the tropics.

The "eyes" of the Photopopper are infrared photodiodes which look black, but actually aren't. They're a deep, deep red so they filter out most of the visible spectrum of light so it can accurately detect where the strongest light is.

The Trim Pot (short for "Potentiometer") is a tuning device that will let you make your Photopopper track straight and true towards light sources. We'll get into tuning the circuit later, after we're sure the Photopopper is operating correctly.

Here's the 2nd-step completion photograph. Note again that all the components are sitting flush down against the surface of the PCB.

Installed Components

Step 3: The Motor Mounts & Motors

Time to add the motors mounts. These are fuse-clips that securely fit the motors and make mounting easy.
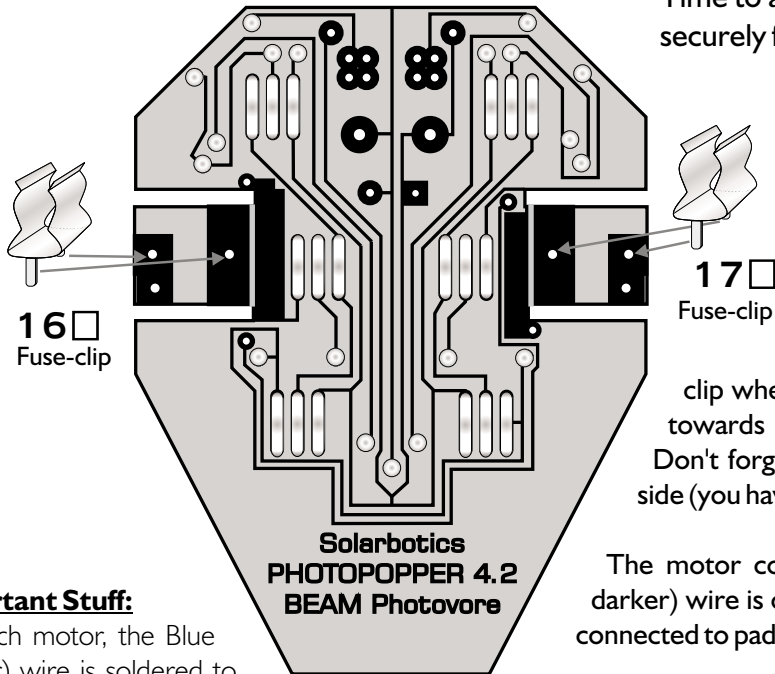
Before you start, make sure you're looking at the top side of the board, where the "PHOTOPOPPER 4.2" text is. Insert the fuse-clips into the holes, and push it right down to the surface of the PCB. Soldering the clips will be a bit harder, as the solder pads are on the top with the clips, so you have to solder from the pad onto the clip (look at the photo). There may be a little alignment lip on the clip where the motor gets mounted. Make sure these are in towards the centre of the board (again, look at the photo). Don't forget to clip the remainder that sticks out of the other side (you have been clipping the excess leads, haven't you?).

16☐
Fuse-clip

17☐
Fuse-clip

Solarbotics
PHOTOPOPPER 4.2
BEAM Photovore

The motor connections are quite straightforward. The blue (or darker) wire is connected to pad M1, and the red (or lighter) wire is connected to pad M2.

Important Stuff:
On each motor, the Blue (darker) wire is soldered to the pad labled M1 on the bottom. The Red (lighter) wire is soldered to the pad labled M2. You can run the wire underneath like in the picture to solder it, or leave it soldered to the pad from the top.

18☐
Motor & Connections

19☐
Motor & Connections
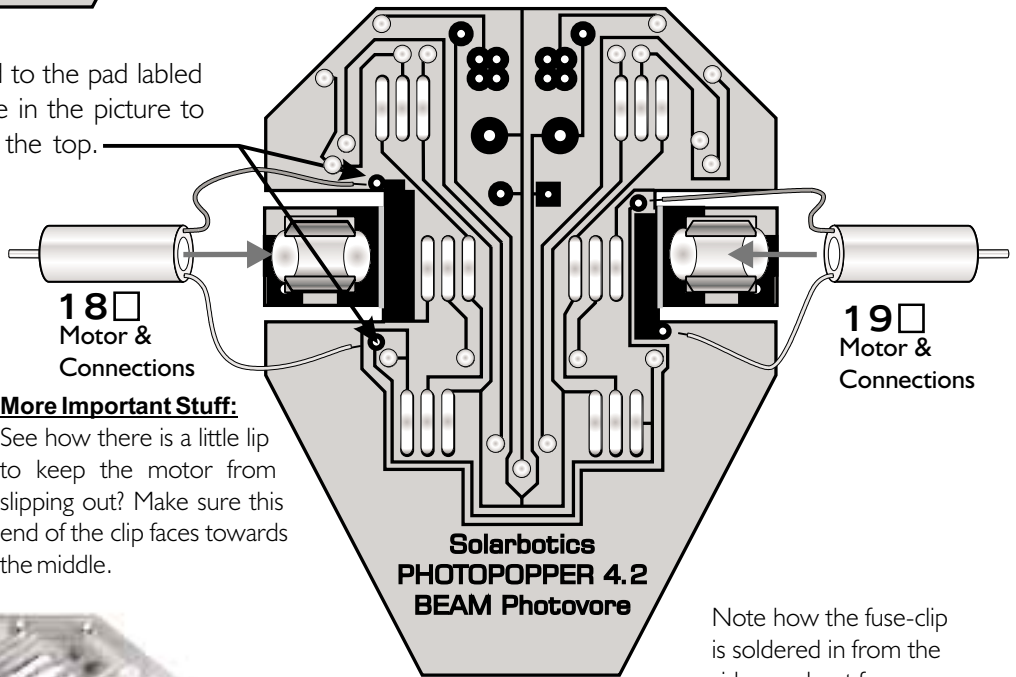
More Important Stuff:
See how there is a little lip to keep the motor from slipping out? Make sure this end of the clip faces towards the middle.

Solarbotics
PHOTOPOPPER 4.2
BEAM Photovore

Note how the fuse-clip is soldered in from the sides, and not from underneath

Motor Mount Detail

7
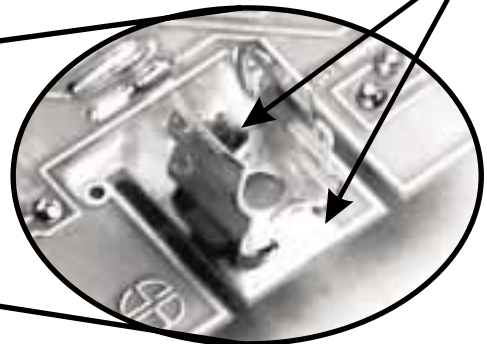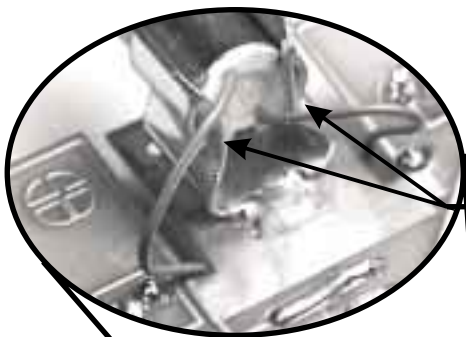
## Step 4: SolarCell Preparation and Installation

1.Solarcell Preparation

Bare Pad

Properly
Tinned Pad
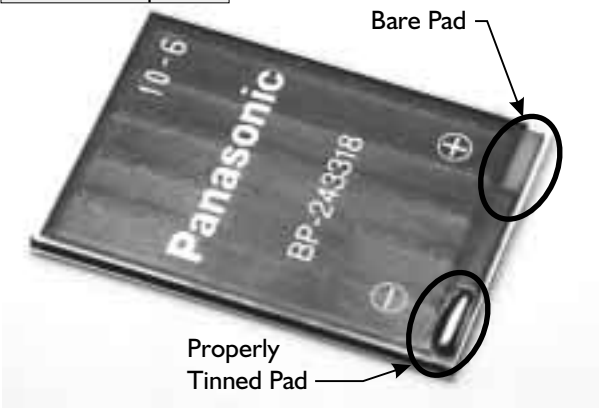
This step isn't the most complicated, but it is one of the most delicate you'll perform in putting your Photopopper together **ONLY IF** *your solarcell doesn't have pre-tinned solderpads*. Otherwise you'll have to perform step 20. So please follow these next steps with due care and diligence, or I'll have to sick my pet frog "Guido" on you...

First "pre-tin" the pads of the solarcell by melting and flowing the solder onto the bare pads. This is the hardest part, as you have to add enough heat to melt the solder to the pad, but not so much as to ruin the pad.

Glue wires down
only in this area

Second, take your twisted pair of wires, and strip 3mm (1/8") of insulation of each wire and fold them into a "T" shape (see the picture). Solder one to each solarcell pad, with the blue (darker) wire going to the negative (-) pad, and the yellow (lighter) wire going to the positive (+) pad. After that, **GLUE** the wires down near the pads! This is very important to do, as the pads are not that strong and you might accidentally yank the soldered wires right off the solarcell. So go do it. Right now. You don't want to know what Guido will do to you if you don't....
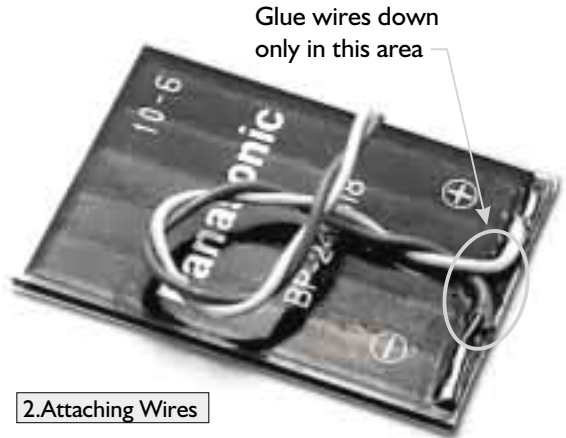
2.Attaching Wires

3.Connecting Solarcell to Photopopper

Negative (black)
connects here...

...and positive (red)
connects here
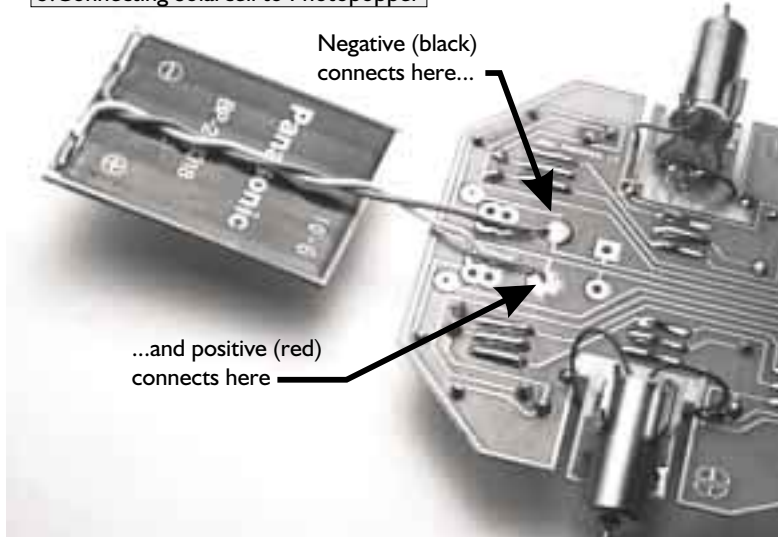
After the glue has dried on the wires & solarcell, add the solarcell to the Photopopper PCB. Simply solder the **red** wire to the **left pad** and the **black** wire to the **right pad**. If you have any problems, the pads are identified on the bottom of the PCB with a little "+" and "-" in the "Solarcell" box.

Don't fold the solarcell onto the PCB yet - we still have to add the power capacitor and do some testing yet.

23☐ Solder wires to PCB

Pre-tin solarcell pads **20**☐

Solder wires to solarcell pads **21**☐

Glue wires down to solarcell **22**☐

8
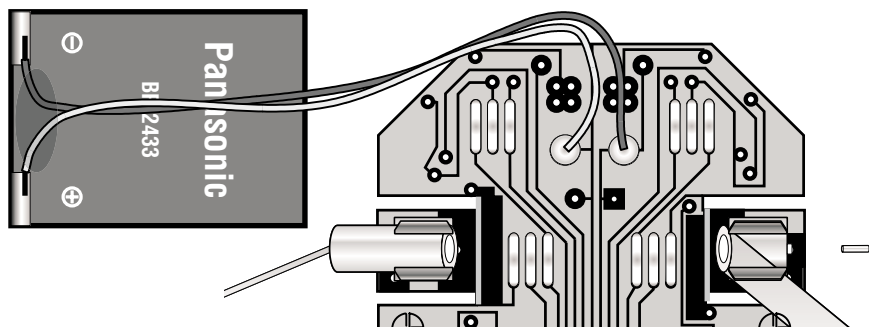
Step 5: Power Capacitor and Initial Activation or, The "IT LIVES!!!" Stage
(insert "jump for joy" here)

Installing the Power Capacitor

Ah, 'tiz time to add the power storage capacitor. Since you've already added the solarcell and all the other necessary components, this step will actually give your Photopopper the "Spark of Life". Successfully completing this step (barring any errors) should result in your robot starting up, and since it has no off switch, it'll try to move towards the light, regardless if you're trying to tweak a trim pot, or add a touch-sensor. Ever try to change the diaper on a baby that doesn't want to be held down? Same sort of situation....

Adding the power capacitor to the PCB requires you to bend the leads of the capacitor down right against the face of the capacitor. Just make sure that you get the polarity correct before you bend. The side with the white stripe is negative (-), and you will want to make sure that the bend looks just like that in the above image. And just like any of the other components, make sure it's held flush up against the PCB when you solder it in place. When everything is finished and tested, you may take a razor and strip the black plastic cover off. It looks like a shiny silver cylinder and adds to the "cool" factor.

Checking the Polarity

You must make sure you get the capacitor polarity correct, otherwise the Photopopper will have sluggish performance at best (or total inactivity at worst). You can see the "+" (positive) and the "-" (negative) marked on this image of the PCB right under the capacitor. Just make sure the lead closest to the stripe on the capacitor goes to the "-" pad.

24☐
Installing the
Power Capacitor

9
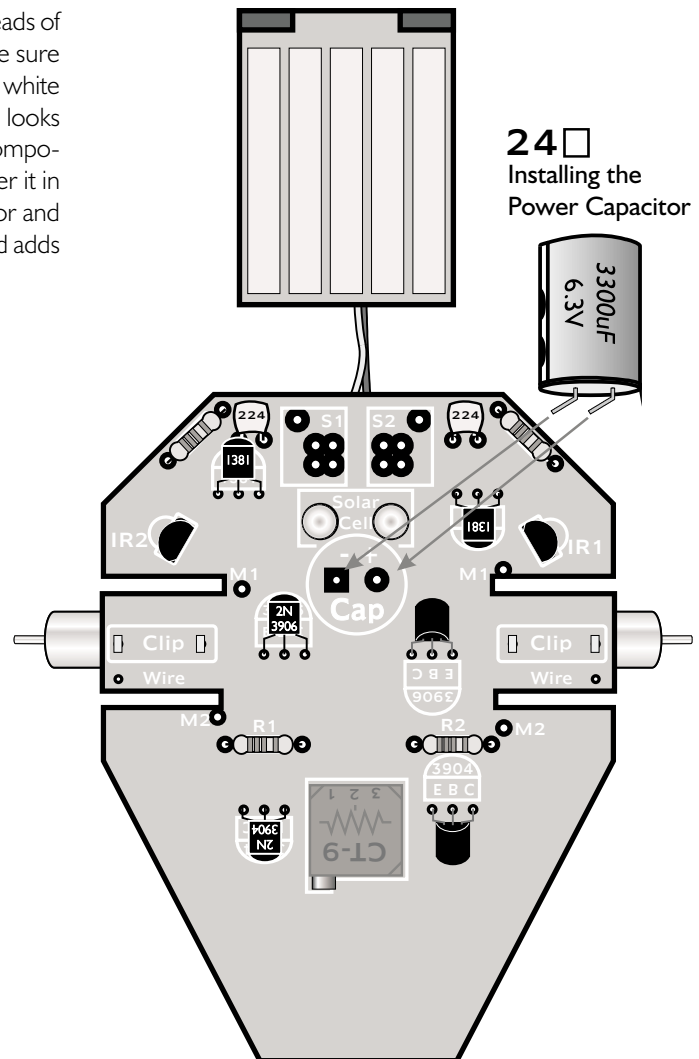
Step 6: Initial Testing and Tuning

As soon as you connect the power capacitor to the PCB and place your Photopopper near a source of light, one of the motors should start pulsing. If so - BRAVO! Congratulations! You're the new proud owner of a partially-complete functioning BEAM Photopopper robot! If not - don't dispair. Any problems can be narrowed down into a few simple checks and resolved.

The first thing to test on your Photopopper at this stage is to see if both solarengines are functional. The trim pot (square box & screw thingy) controls the balancing between the two solarengines, so we'll now show you how to use it.

The trim pot has a small screw mounted on the backside of it (see the image) that you can turn with a small screwdriver. The trim pots we're using for this kit are 20-turn units, meaning it takes a full 20 rotations of the screw to make a complete adjustment from extreme left to the extreme right. You *will not* hear or feel it hit the end of it's travel, so take my word - 20 turns one way will have it at the extreme end of it's travel.

Top View Looking Forward

25 □
Test & Initial Tune

Left Motor

Right Motor

Left Rotation
(Counter-clockwise)

Right Rotation
(Clockwise)

Start by turning the screw completely to the left (counter-clockwise) at least 20 full turns. You should find that the left motor is pulsing consistently. Now do the same to the other side, advancing the screw to the right (clockwise) 20 turns. At this point, the right motor should be pulsing consistently. If all is well, and your motors are exhibiting this behaviour, turn the screw back 10 turns so the trim pot is approximately centered.

Now you should be able to place your Photopopper to the left of a light source and the right motor should activate. As you move it to the front and to the right of the light, the left motor should activate. This is a sure-fire indication your Photopopper is "seeing" the light and trying it's best to move itself closer to it.

Step 6a: Troubleshooting

Hopefully you won't need this section, but if you do, here a few checks and tests to perform if your Photopopper is acting up. Above all else, make sure that there are no *solder-bridges*. This is when solder crosses from one pad to the next - a condition that should **never be allowed to happen**.
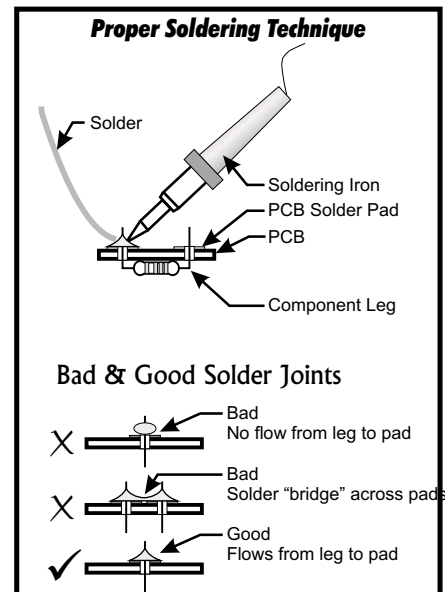
› No movement / action

This can be attributed to many factors. If you have a multimeter, try the tests in the paren-thesis (). Test the following conditions :
- Solarcell hooked up backwards? (voltage positive on pad marked "+")
- Power capacitor hooked up backwards? (voltage climbs only to 1.5-2 volts)
- Motors hooked up to pads "M1" & "M2"?
- Trim pot in place?
- Transistors in correct place and orientation?
- Is it dry? Moisture will interfere with the proper operation of the Photopopper

Only one side works

When only one side works, you can compare it against the side that is working. Check and compare these conditions:
- Motor hooked up to pads "M1" & "M2"?
- Solder bridge from motor pad "M2" to resistor pad? (left motor only)
- Trim pot adjustment turned all the way over to one side?

Proper Soldering Technique

Solder

Soldering Iron
PCB Solder Pad
PCB

Component Leg

Bad & Good Solder Joints

X — Bad
No flow from leg to pad

X — Bad
Solder "bridge" across pads

✓ — Good
Flows from leg to pad

If nothing else works, please contact us. We stand behind our Photopopper kit (if we stood on top, we'd break the solarcell..), so we are always available to troubleshoot it if you have problems you can't solve.

Step 7: Adding the Wire Crossmember & Motor Wheel-Sleeves

Now that your Photopopper is operational, we'll bend the PCB so it can move on a flat surface. By using the PCB as the body in addition to the holding the electronics, the Photopopper is much lighter than traditional robots. When you are done with this step, you will have a functional light-seeking robot, but don't stop here - continue on and finish with the obstacle-avoidance touch-sensors.
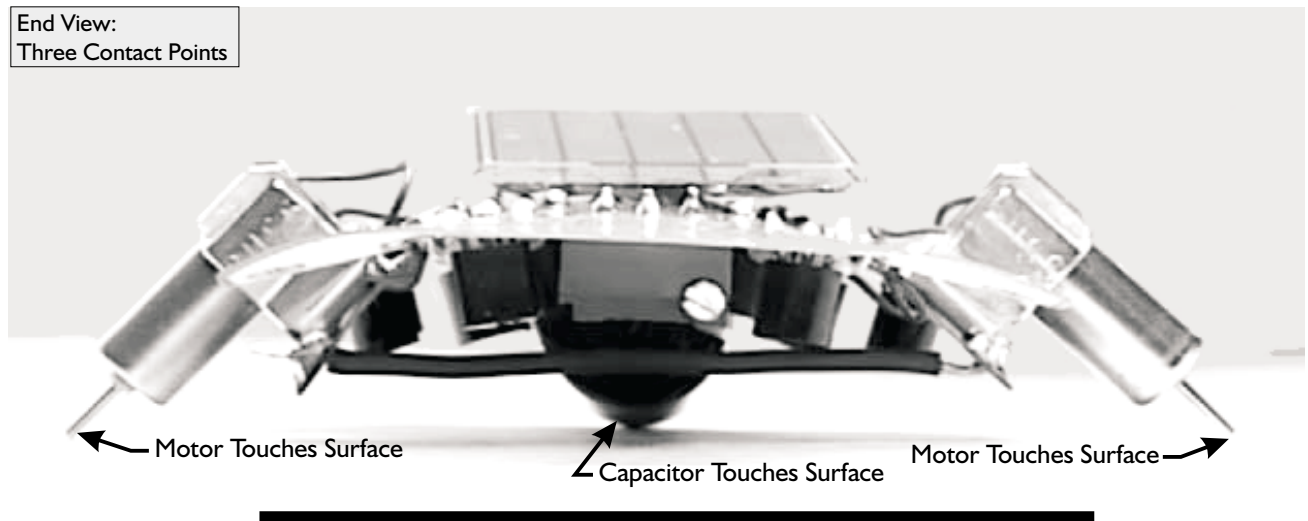
Take the 5cm (2") wire and strip off 5mm (3/8") from each end. Attach one end by pushing it through the hole labled "Wire" and bending it over. After you solder it in place, flex the PCB enough so that you can put the other end of the wire through the other "Wire" labled hole, and solder that one in place. In developing this instruction guide, I found it quite difficult to bend the board for this step, so we've pre-bent it far enought that the final bend should be a minor task for you. When finished, trim the excess wire.

When finished, your Photopopper should look like the one below. The motor shafts and the capacitor should all be touching at the same time. If it rocks on the capacitor and only one motor shaft touches, you will have to de-solder one end of the support wire and push it further through the hole and re-solder.

26☐
Bottom View:
Adding the Cross-brace Wire

End View:
Three Contact Points

←— Motor Touches Surface

∠Capacitor Touches Surface

Motor Touches Surface—→

The motors on your Photopopper are very high-quality, high-speed motors. To utilize these motors properly, you need to add wheel-sleeves to the output shafts, which will dramatically improve the mobility of your Robot.

27☐

1. Start by positioning the motor so it is pointing slightly upwards. As the sleeve shrinks, it will snug down towards the motor.

2. Cut a 10mm (3/8") length of heat-shrink tubing, and slide it over the end of the motor up to the white plastic washer.

3. Shrink it with a match or lighter so it snugs down onto the shaft.

4. Clip off the excess tubing near to the end of the motor shaft.

Repeat for the other motor.

Step 8: Touch-Sensor Preparation

The touch-sensors used on the Photopopper are unlike almost any other switch you may have seen. These are *omni-directional* switches, which have a unique ability in that they activate when touched from almost any direction. They are also very robust and sturdy, unlike regular switches that snap and break when they are flexed from the single direction for which they are designed. Did I mention that they were also inexpensive and relatively easy to make? Just wait and see how simple they are...
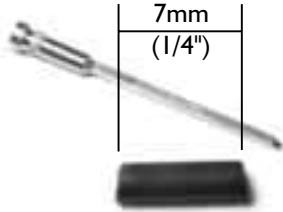
1.Augat Socket Pin and Heat-Shrink Tubing
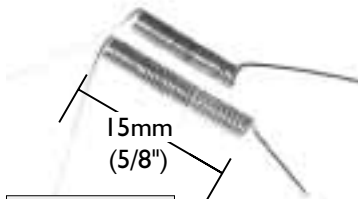

2.Slip Tubing onto Socket Pin

3.Shrink Tubing with match

First find the plastic heat-shrink tube that came in your kit and clip off <u>only</u> 7mm (1/4") and slip it onto the Augat socket (picture 1). Make sure that it doesn't completely cover the end, as you will be soldering to that later (picture 2). Then shrink the tubing by applying heat to it (match works fine), but don't bath it in the flame (picture 3). Gently heating will make it snug down onto the pin. If you see smoke, that's too much heat!

4.Cut tubing below neck (leave in place)

5.Stretch Spring


6.Push Spring onto Pin

After the tubing is shrunk, carefully cut the tubing below the neck of the socket pin and leave it in place (picture 4). This new segment will be used to tune the sensitivity of the touch-sensor. Take a spring wire, and stretch it out to about 15mm so you can just see between the coils (picture 5). Then push the spring onto the pin up to the tubing, but not over the end. If this causes some problems, try twisting the spring while pushing it on so it threads onto the tubing.

7.Slide Tuning Segment Down

Lastly, reach between the spring coils with your knife and slide the cut tubing segment down the pin to about 1/3 the pin's length.
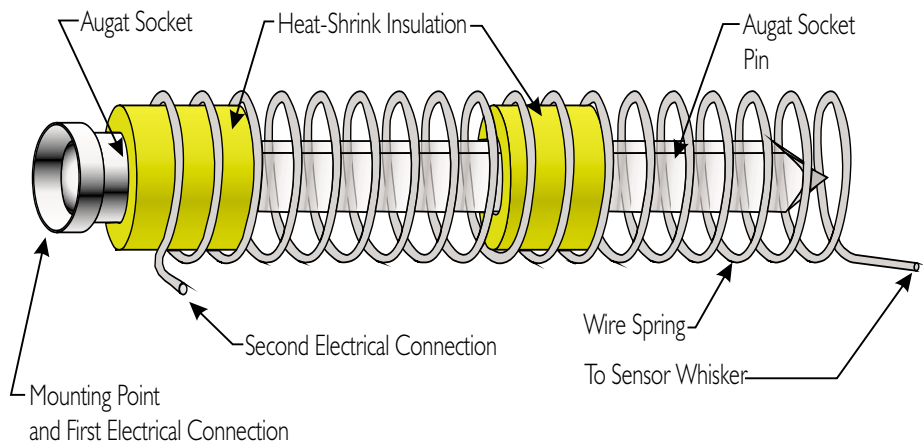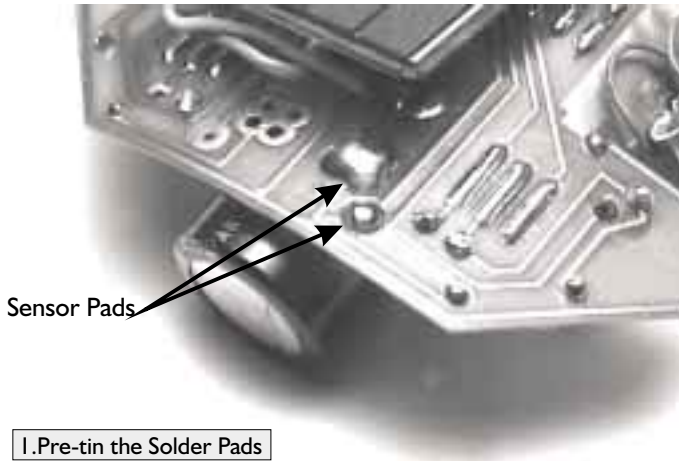

28☐

Step 9: Touch-Sensor Installation

(♪feelings...nothing more than feelings...♪♪)

This is the last physical step in the assembly of your Photopopper - installing the two touch-sensors you just finished building. As good as the optics are in your robot for finding and tracking light, they are not that good at seeing obstacles, so the touch-sensors are necessary for fundamental obstacle avoidance.

1.Pre-tin the Solder Pads

Sensor Pads

2.Solder the Pin Collar and the Spring Lead

Good!   Bad...
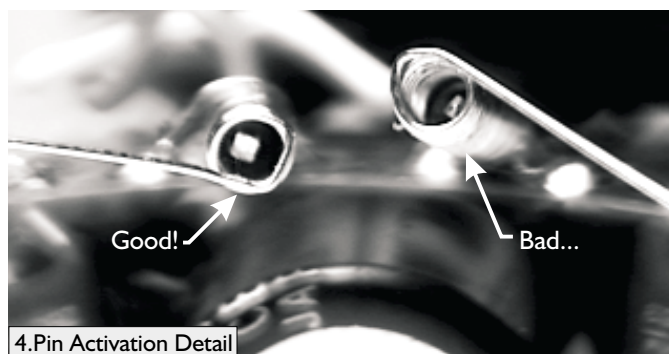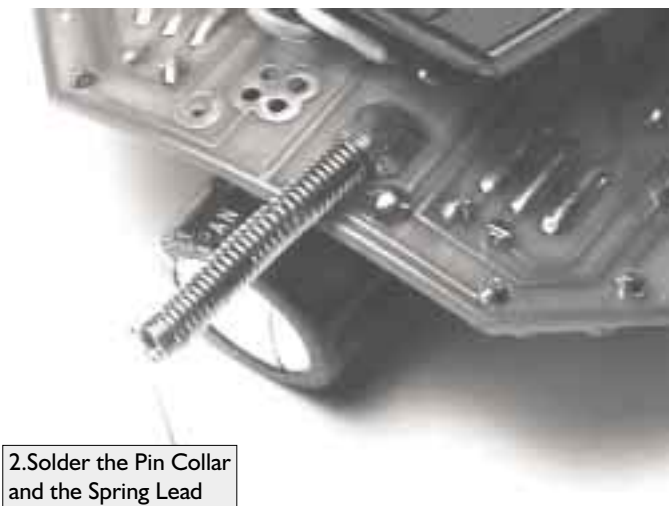
4.Pin Activation Detail

Image 4 shows how the touch-sensors should look from straight head-on. If your touch-sensor is bent when at rest, bend the whole pin & spring so the pin sits dead in the center, not touching the spring at all. When your Photopopper bumps into something, the spring will bend and contact the pin, closing the circuit that will make your robot turn away from the obstacle.

As with the solarcell, you must first "pre-tin" the solder pads to guarantee an easy installation. Start by adding heat to the solder pads, and add enough solder to totally cover the holes on the pads (image 1).

Re-heat the solder on the large pad and place the touch-sensor's pin collar into the solder and let it cool (use a holding tool - it'll get hot!). Be careful not to let the solder from this pad touch anywhere on the spring. Then re-heat the solder on the small single pad and push the sensor wire into the solder. Trim off any excess wire (image 2).

Lastly, make sure that
a) The spring is only on the insulation and not touching the pin, and
b) The solder on the large pad touches only the pin collar
(see image 3)

29☐ Touch Sensor Installation

3.Solder Detail

There - your Photopopper is now physically finished. You can now shape the touch-sensor extension wires into something you think will allow it to efficiently interact with its environment. We can't help you too much with the best shape, as there are hundreds of ways to bend them, and no way of telling which way is best besides lots and lots of testing. If you find a particularly great shape, let us know!
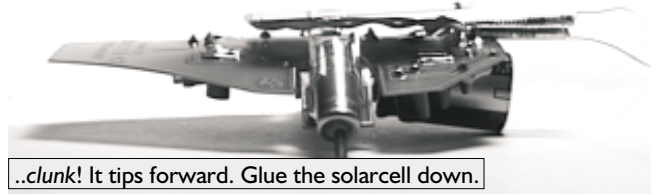
Next, we perform the final tests and tuning!

Step 10: Final Assembly, Tuning and Touch-Ups

This is the very final thing you have to do before you can start thoroughly playing with, ummm - I mean *examining,* your Photopopper's behaviour.

Move the solarcell forward until....
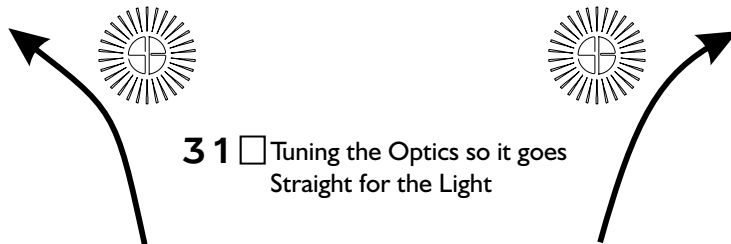
30 ☐ Balancing the Photopopper

..clunk! It tips forward. Glue the solarcell down.

Up until now you may have noticed that we haven't glued the solarcell down in place. There's been a good reason for that - balance. Now that you have everything installed, you can now find the optimum position for the solarcell. Best way to do this is to move the solarcell until the Photopopper balances just forward of the wheels. When it does, glue the solarcell in place.
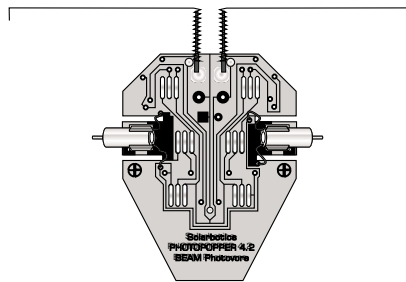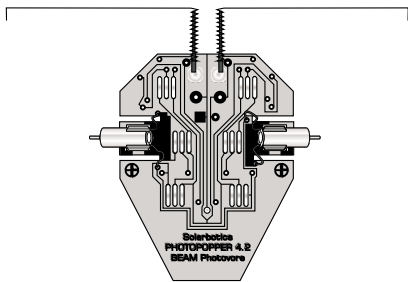
Balancing the Photopopper like this is good for several reasons. When the Popper moves, it will tend to do a bit of a "wheelie", lifting the power capacitor off the surface. This lowers friction and increases the performance. Also, I've found that when the sensors get stuck in something, the Popper's tilting backward motion helps free it up.

We're going to use the trim pot to fine-tune your Photopopper so that it is *very* directional and will head directly towards the brightest source of light in the vicinity.

Start by placing your Photopopper near some very directional, single-source light, like on a sunny desktop or a table with a single light bulb. It should make a bee-line towards the source of the light. If you get a left or right side preference behaviour (see the images), then turn the trim pot a 1/2 turn in the direction of the "slower" motor. As you get close to the "sweet spot" on the trim pot, the Photopopper will start tracking very near dead-straight for the light source. Once tuned, it shouldn't need tuning every again!

31 ☐ Tuning the Optics so it goes Straight for the Light

When the Photopopper is properly tuned, it will pivot around one motor until it is zoned in on the source of light it wants, then will start alternating steps in a "left / right / left / right" pattern.

Lastly, you may need to adjust your touch-sensors. If you find that your Photopopper is acting erratically when it triggers on one side, the sensor may be set too sensitive. You can reduce the sensitivity by sliding the tuning sleeve forward towards the pin tip. This means the sensor must bend more before it activates. Experiment over time to see what sensitivity works best for your Photopopper.

Now that you're done, try putting shadows and obstacles in front of it, and see what happens!

If your Photopopper prefers the left, rotate the trim pot to the left.

If your Photopopper prefers the right, rotate the trim pot to the right.

Photovore Competitions

Once you are familiar with the behaviour and operation of your Photopopper, you may want to enter it in the official *BEAM Photovore Competition.* This is one of the events held as part of the annual *BEAM International Robot Games,* and is usually quite interesting. Interested? Here are the fundamental rules, but you may eventually want to get a full copy of the rules from us or the BEAM governing body.

Object:
Within a 150mm (6") cube, build a device that is self contained, solar powered, and goal seeking. Your only power source is a solarcell with a maximum area of 2442 mm^2 (3.79 in^2). The robot competitor will have to face off against other devices in a well-lit competition area, having to avoid obstacles and race to the middle. Once there, have your robot dominate the light pool until the end of the 5 minute round. First to the center circle wins a half point, and the one closest to the very center at the end of round wins a full point.

Restrictions:
1 -The competing device must initially fit within the boundaries of a 150mm (6") cube.

2 -The maximum allowable solar cell surface area cannot exceed 2442 mm^2 (3.79 in^2).

3 -No batteries (rechargeable or otherwise) are be allowed on the Photovore competitor, only verifiable electrical capacitors. No other form of power source (chemical, mechanical, animal, etc.) is allowed. The competitor must extract all the energy it uses from solar cells on its chassis.

4 -Devices are forbidden to exhibit deliberately destructive behavior.

5 -Although devices are allowed to touch or follow walls and hazards, they are forbidden to intentionally damage the "world" in any way.

The Robot "World":
In addition to ambient lighting, the arena will be illuminated by a single 250 watt halogen lamp located and aimed directly down towards the center of the goal circle.

Each of the competitor robots can start from any of the four corner squares at zero stored-energy potential. The robots will have to contend with the four black posts mounted on the arena, and the shadows they cast.

2001 Competition at the Western Canadian Robot Games
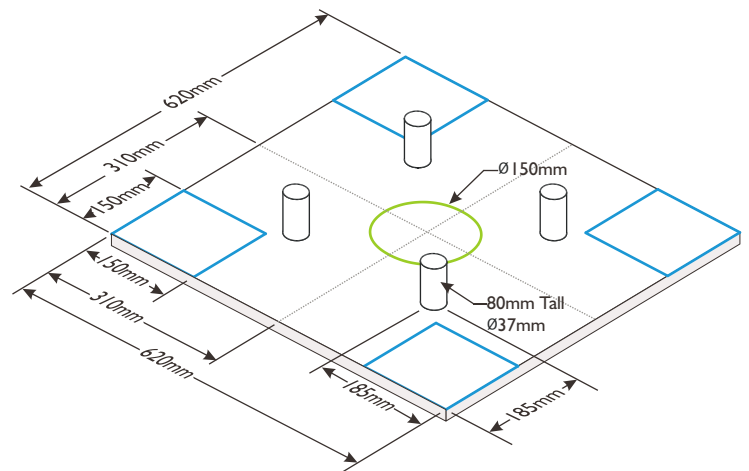
Competition Platform

The Wrap Up...

Although interesting to watch by itself, you may eventually want to try placing it in an environment with other BEAM creatures and robots. When there are more than just one or two robots interacting, patterns and behaviours may emerge where there were none before. Not that this is a way for us to promote the purchasing of 2, 3 or even two dozen more photovores (well, that *would* be nice...), but it is true that behaviours are easier to recognize when you have several creatures to observe.

In the future, we're hoping that many more photovores of different sizes and shapes are constructed by BEAM enthusiasts. As the photos on the back page show, they come in all shapes and sizes. The Photopopper is just one of many successful design layout ideas that have "come across the desk". If you have your own idea of how a solar powered photovore should look and behave, pursue it. After all, the *Turbot 2* (on back page) is a very non-traditional photovore, but has proven to be very aggresive and effective, at the expense of its difficulty of construction (don't contact us for "how to build it" details - we don't have them!).

We hope that you've had fun working on your Photopopper, and now that it is finished, you should expect to enjoy it for another 10 or 20 years. Mind you, that only is true if it manages to escape the occasional cat or baby that may take interest in its wanderings.

If you find you're having more problems with your Photopopper than what you can handle, *please* contact us before sending it back so we can give you appropriate shipping instructions.

If you are interested in finding out more about BEAM Robotics, the BEAM Robot Games and what other products we have to offer, please contact us at:

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Fax: (403) 226-3741
Website: http://www.solarbotics.com
Email: help@solarbotics.com
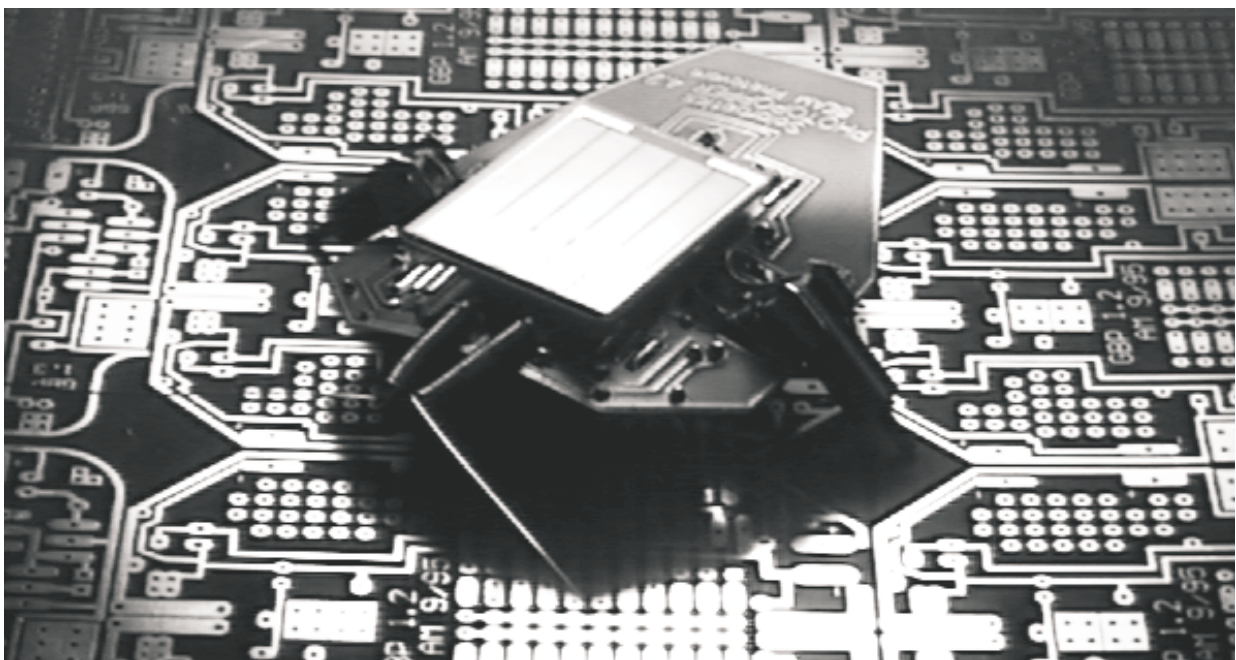
A Brief History of...Photovores!

The **Photopopper 4.2 Photovore** is one of latest in a string of solar-powered robots designed to seek out and maintain access to sources of light. The Grand-daddy of them all is the original *BEAMant* 3.0 (fig 1), which used a modified greeting card timer as it's "brains". This was followed by designs using dual Type-1 Solarengines, like the *PHD 1.0* (fig 2). New geometry using flagella (arms) instead of wheels was successfully experimented with in designs like *Turbot 2.0* (fig 3) and the *Turbot 3.0* twins (fig 4). New advances in low-power electronics resulted in the expermental *Photopopper prototypes 4.0* (fig 5) and *4.2b* (fig 6). This kit uses the best techniques learned from all these prototypes!

Figure 1: BEAMant
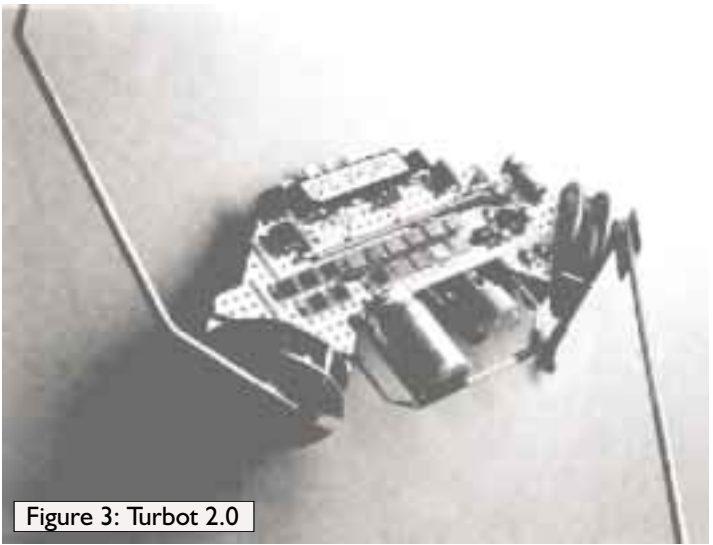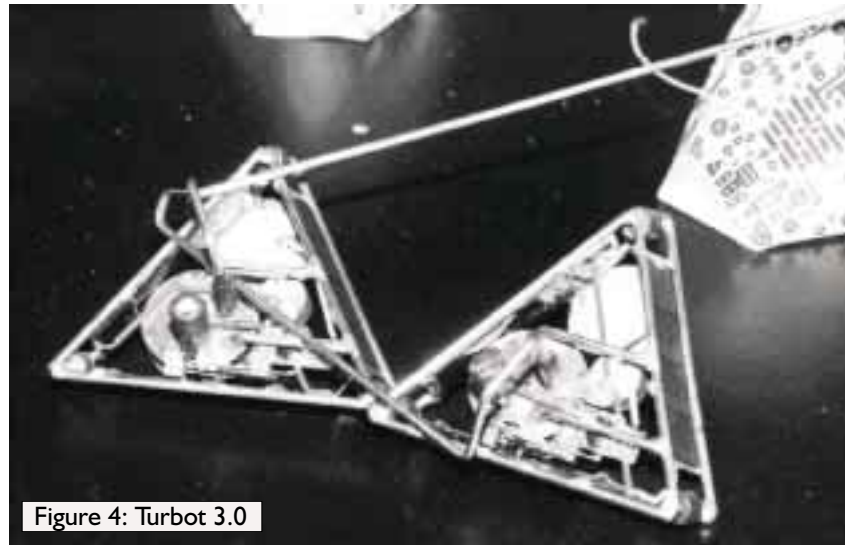

Figure 2: PHD 1.0

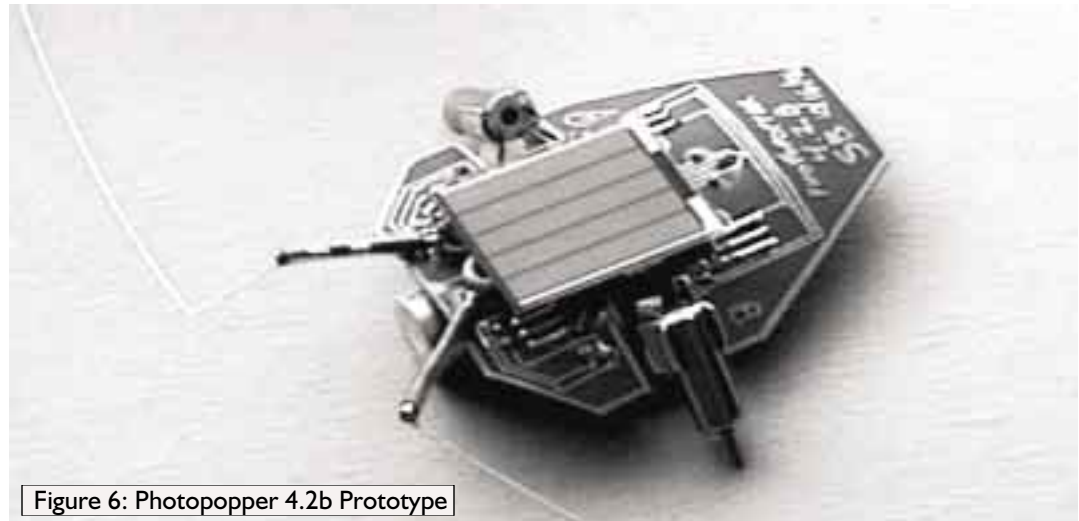Figure 3: Turbot 2.0

Figure 4: Turbot 3.0

Figure 5: Photopopper 4.0

Figure 6: Photopopper 4.2b Prototype