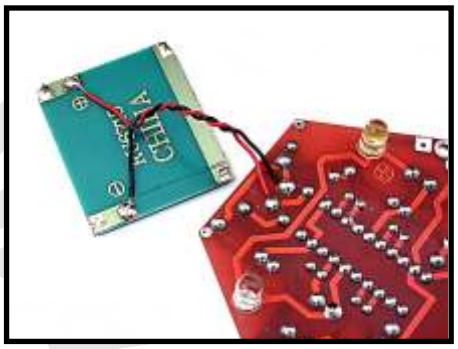
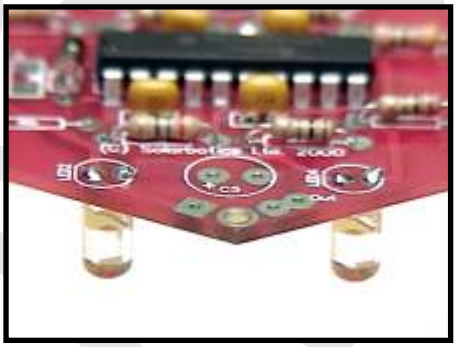
The SOLARBOTICS®

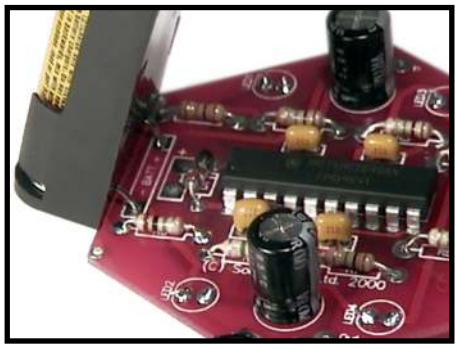
HexPummer©





A Complete BEAM Solar-Powered Night Light Kit Inside

This nocturnal BEAM device charges up all day, and trickles power out all night long as “PUMMs” of light. That means it drives each of its four ultra-bright LEDs by turning on strong, then slowly decaying away. It’s a very smooth, non-digital solar-powered light show that turns itself on in the dark!



SOLARBOTICS® Ltd.

Skill Level:
Beginner
(Soldering Req’d)

2 hrs

Document Revision: January 8th, 2007

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1 - Hexagon Shaped Hex Pummer Printed Circuit Board (PCB)
4 - Clear Ultra-bright LEDs (clear, light-bulb-looking things)
1 - SCC3733 37x33mm Solarcell
2 - 'AAA' Rechargeable Batteries
1 - Chunk of foam double-sided sticky-tape (aka: DSST) for securing the solarcell
1 - 74HCT240 Octal Buffer IC Chip (bug-looking thing)
4 - 0.47µF Monolythic capacitors
2 - 1000µF Electrolytic capacitors (can-thing with two legs coming out one side)
1 - Germanium Diode (little glass thing with two leads)
1 - 100k Resistor (R1) (colored Brown / Black / Yellow / Gold)
4 - 1.0M Resistors (R2, R3, R5, R7) (colored Brown / Black / Green / Gold)
1 - 2.2M Resistor (R8) (colored Red / Red / Green / Gold)
1 - 3.6M Resistor (R6) (colored Orange / Blue / Green / Gold)
1 - 4.3M Resistor (R4) (colored Yellow / Orange / Green / Gold)
1 - 'AAA' Battery Holder
1 - Length of solarcell twisted hookup wire
1 - Suction cup & hook
1 - Set of instructions (if you can't find these, you're in deep trouble - seeing that you are reading it right now!)

Tools Required:

- SAFETY GLASSES. We can't stress this enough. **AT ALL TIMES** wear safety glasses while soldering and working on this kit. Eye injuries ain't worth the risk...
- Soldering iron & necessary accessories (electronics solder, damp sponge, soldering iron holder)
- Set of fine side-cutters or snips for trimming leads and wires
- Wire strippers to prepare the solarcell wires for soldering
- Glue or double-sided sticky tape for mounting the solarcell (epoxy is best; hot-glue acceptable)
- Needle-nose or fine-tip pliers (or technically known as "grabber-nabbers")
- Blue-nosed, three-limbed Bolivian tiger-moth (optional)
- A sense of humor. You're in for a lot of bad jokes...

We strongly suggest you inventory the parts in your kit to make sure you have all the parts listed. If anything is missing, contact Solarbotics Ltd. For replacement parts information.

Just in case you're new to the field of BEAM robotics, let's go through the basics: BEAM is an acronym for the four fundamentals of building relatively simple robots.

Biology - Steal the best ideas that mother nature has come up with so far. Can't beat several million years of development for inspiration.

Electronics - Since we can't (easily) use biochemistry to build our devices, we'll use simple, effective electronics to fulfill our needs. You will rarely find anything as complicated as a microprocessor in a BEAM robot, as we strive to get the most performance out of as little silicon as possible. You will often find a solarcell glommed onto the top of many BEAM devices, and though much less powerful than batteries, they will last for years. This gives solar-powered BEAM devices very long lifetimes where they won't require you watching over their battery status.

Aesthetics - Just another word for "Coolness". If it looks clean, lean, and slick, chances are that it was well built and will last much longer than a device lacking aesthetic appeal.

Mechanics - Clever mechanical design of a robot can make it very effective, much more so than a clumsy design that needs additional electronics to overcome its mechanical limitations. Many BEAM robots are often built out of "recycled technology", otherwise known as techno-scrap (like that broken walkman in your junk-drawer).

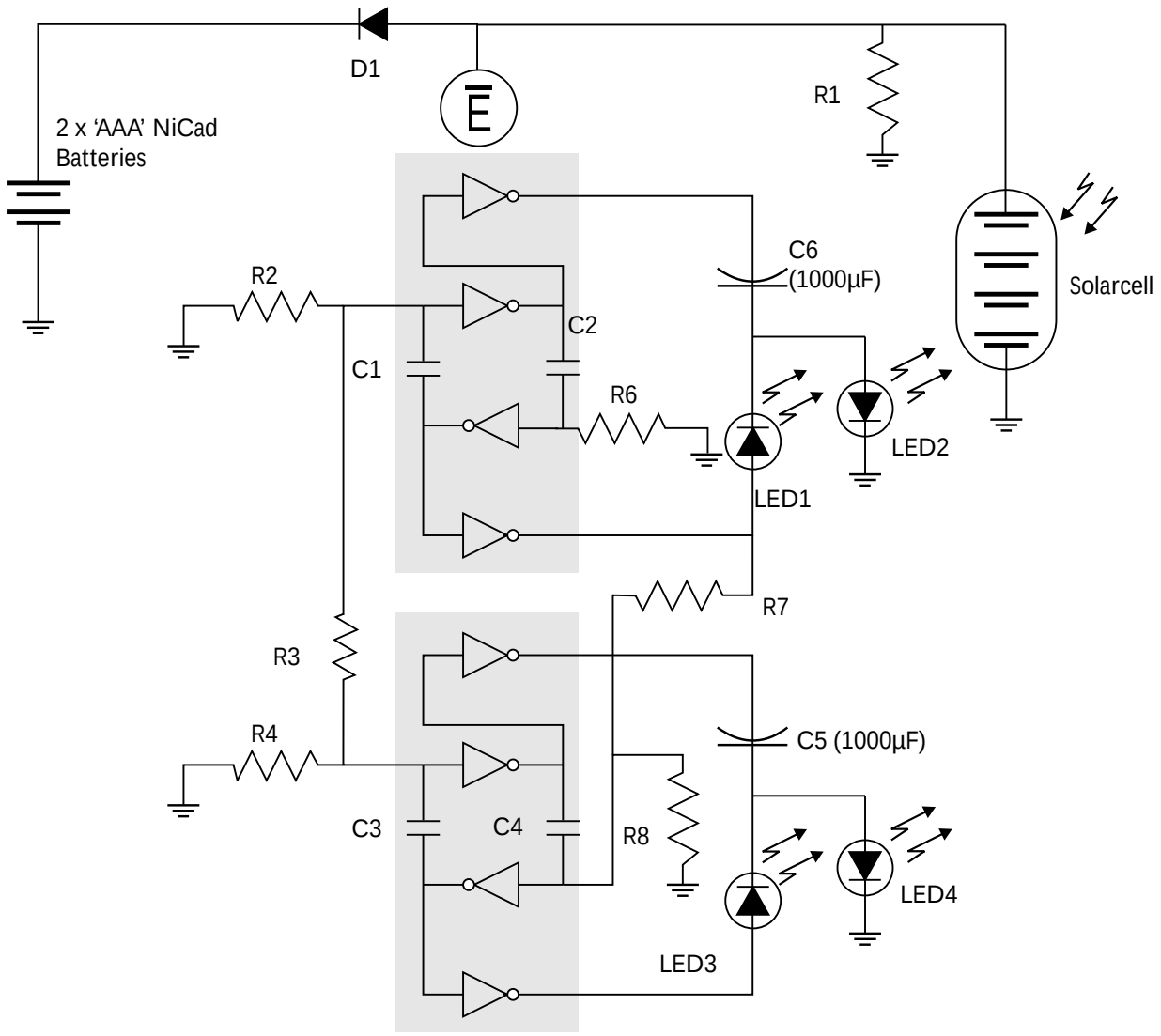
With that out of the way, let's get onto the workings of the Hex Pummer.

Hex Pummer Behavior

We call this a Hex Pummer because, well, um, you see...I use it to cast evil spells on unwitting Prince and Princesses (You know, a "hex" - it's an evil spell....aw, just forget it...). Really poor jokes aside, it's because it's in the shape of a hexagon, a six-sided geometric shape. We experimented with several shapes - squares, triangles, truncated tetrahedrons, but nothing had the same efficiency in shape as the hexagon. If you get six of these together, you can make a "Pummer Plate". Or string them in rows, or parallel lines. Believe me, this is the coolest shape.

"Pummer" - I'll bet that's a word you've never come across before. It's a term coined by Mark Tilden (the Father of BEAM technology) to describe the action of a special type of BLIFNAR (technical term for "**B**linky **LI**ght **F**or **N**o **A**pparent **R**eason"). If you had to describe what this little light did, you *could* say "It exhibits a rapid turn-on action followed by a moderate decay of millicandela output". OR you could say "If you could hear this light, it would say 'PUMmmmm'". Besides, it's much easier to refer to this as a "Pummer" than as a "Device exhibiting a rapid turn-on action (**YAWN*...stretch*) followed by a moderate decay of (*wake me when you finish...Zzznnfzzzz...*) millicandela output".

Technically, we're using what is called a pair of "Grounded Bicore Oscillators" in "charge-pump" configuration. This means we're using one chip to power two pummers, each of which use a simple circuit arrangement to charge up power from the storage batteries to a point where they can make the LEDs (the lights) illuminate in brilliant pulses that slowly die away. If you've ever listened to a camera flash charge up, it makes a climbing, buzzing noise. Camera flashes need very high voltages (near 300 volts!), and they use just a 6 volt source to do it. We're doing the same thing, but in a much smaller scale.

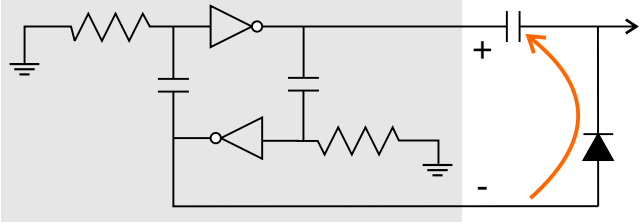


Note: the $\overline{E}$ means "Enable Low", which means it turns on when it receives a zero volt signal

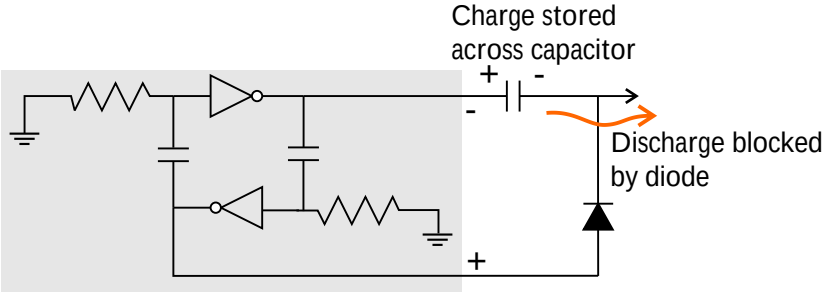
R1 sets the "dark turn-on threshold". Decrease it if you want to turn on earlier (in more light), or increase it so it has to be near pitch black before it activates.

R2 & R4 set how long the LEDs actually turn on; R6 & R8 set how long much time between pulses. Increase R6 & R8 if you want slower plulses.

R3 & R7 "slave" the two sets together. Omit these if you want a more random pumm behavior.



Stage 1 - Initial charge path



Stage 2 - Outputs flip polarity (+ turns to -, - turns to +)

The operation of this circuit is based around a common circuit arrangement called a “voltage doubler”. The part of the circuit in gray is the oscillator (extra output buffers used in the circuit diagram above not shown), with outputs that flip voltage polarity about every ½ second. The trick to the voltage doubler is in the diode & capacitor arrangement.

At stage 1, the oscillator output is so that the capacitor charges up through the diode. Since an uncharged capacitor looks the same electronically as a piece of wire, the vast majority of the current flow goes to it, rather than out the output line.

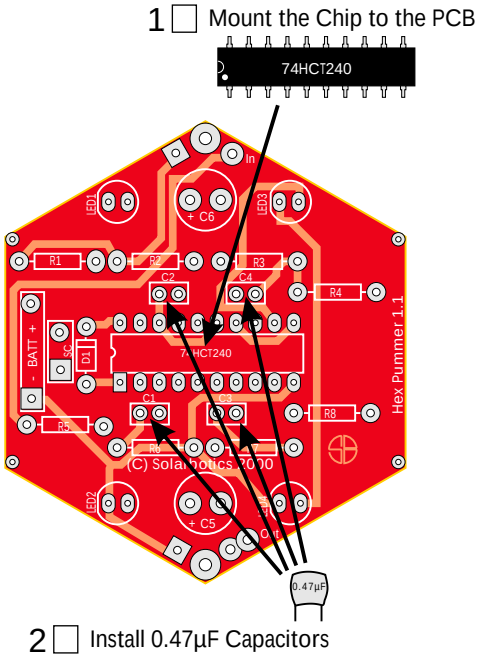
When the polarities swap (stage 2), the capacitor’s charge now sits “on top” of the switched voltage output of the oscillator, like stacking two batteries in series, plus to minus, plus to minus. And (for example) what happens when you stack two 1.5V batteries like this? You get *twice* the voltage - 3V! With the circuit we have here, we’re taking the approximately 2.4V from the power in the nicad batteries, and boosting them up near 4.8V.

You’ll notice that this charge-pump diagram uses a diode. In the actual circuit, this is replaced by the LEDs 1 & 3, and can be easily replaced by regular diodes for just 2 LED operation.

Since there is a diode blocking the capacitor from discharging back into the oscillator, this doubled voltage is forced out the output line. In this case, the doubled voltage is pushed through a LED, which causes the brilliant blast of light you see. If you have an oscilloscope (regular voltmeters are too slow), you can measure the voltage doubling yourself by measuring the voltage output at the ground side of the C5 or C6 capacitor. Take out LED2/4 first, otherwise it’ll eat up the voltage before you can measure it.

Assembly of a Pummer is a pretty straight-forward procedure. Follow the steps, and nobody will get hurt. With a little luck, you may come out with a mastery of the black art of electronics assembly!

If you're not familiar with soldering, first take a look at the **short tutorial on page 8**. Take your time, follow the step numbers, and check off each box as you complete the steps. Just like back in grade 1, right? But this time, the crayons are HOT! BE CAREFUL!

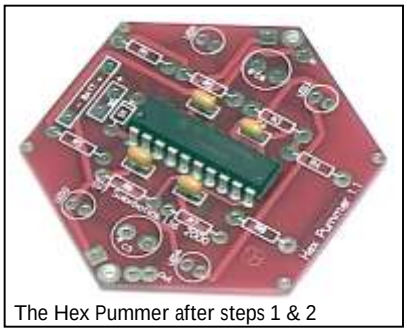


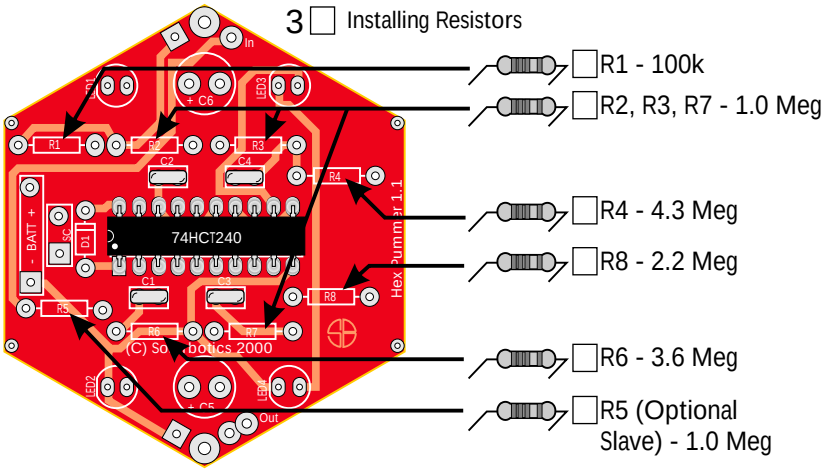
Step 1: Let's start with the 74HCT240 chip. Why? Well, everybody likes to play with the chip first, so lets get it out of the way before you lean on it and stab your hand with 20 itty-bitty chip leg/stabbers.

When installing the chip, make sure the little dot and notch on the end of it match the picture layout of the 74HCT240 on the printed circuit board (PCB). Flip the circuit board over, and solder the legs in place. It helps to fold over 2 or 3 of the chip's legs poking through to hold it in place while soldering.

Step 2: Install the four 0.47µF capacitors in the positions labeled C1, C2, C3, and C4. They won't be labeled "0.47µF" (that'd be too easy). Rather, they're marked with the industry standard number "474" (47 * 10 ^ 4 picofarads, if you must know).

These capacitors don't care which way they get installed. Jam them in, solder them on, and clip off the excess leads poking off the bottom.


The Hex Pummer after steps 1 & 2



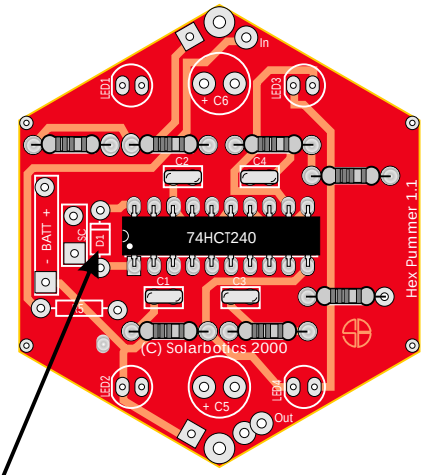
Step 3: Installing the resistors is a pretty straight-forward process. They don't care which way the go in, just as long as they're soldered in the proper spot. Identify them by colour, using the resistor table.

Note: Installation of resistors R3 & R7 are optional. If installed, they guarantee the sequence in which the LEDs pumm. If not installed, LEDs 1&2 will beat out of rhythm with LEDs 3&4, which can be actually kinda nice to look at. If you like things to be a little random and chaotic, leave R3 & R7 out.

After all resistors are installed, trim off the excess component lead from the underside.

You don't have to install R5 unless if you're connecting your Pummer to another one. More about that later...

Resistor Value	Band 1	Band 2	Band 3	Band 4
100k	Brown	Black	Yellow	Gold
1.0 Meg	Brown	Black	Green	Gold
2.2 Meg	Red	Red	Green	Gold
3.6 Meg	Orange	Blue	Green	Gold
4.3 Meg	Yellow	Orange	Green	Gold

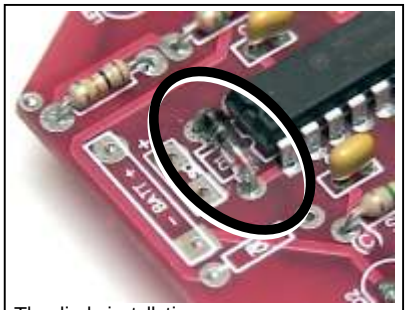


4 ☐ Install the Diode at postion 'D1'

Step 4: The diode you are installing here is a special type - it's a called a "germanium" diode. This is a "deluxe" version of a diode, that lets your Pummer work longer than if just a regular diode was used.

UNLIKE the resistors, the diode does care which way it goes in. Take a close look at it - one end of the glass cylinder has a stripe on it. This is called the "cathode" (yeah, like you really care. You just want to know which way to put it in right? Sigh... and all the work I go through for you... <sniff>).

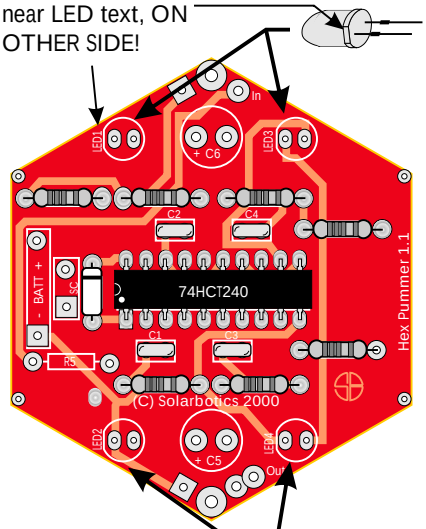
Bend the diode's legs down, right close to the glass body of the diode. Insert the diode with the stripe on the body matching the stripe on the circuit board. Now, the holes may be a little close, so don't use too much force to put it in - you don't want to break it!



The diode installation

Note flat mark goes near LED text, ON OTHER SIDE!

5 a ☐



5 b ☐ Install LEDs on OTHER SIDE!

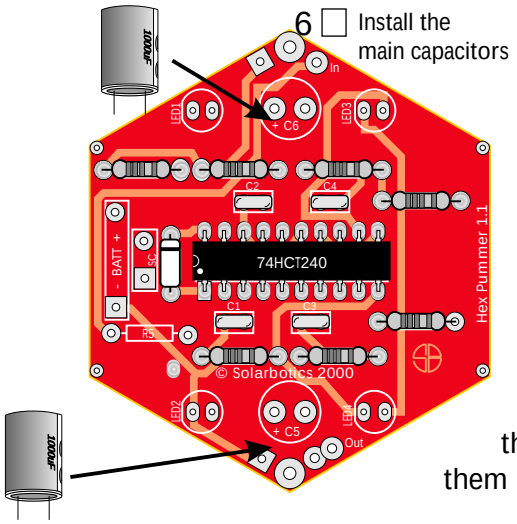

Closeup of LED installation

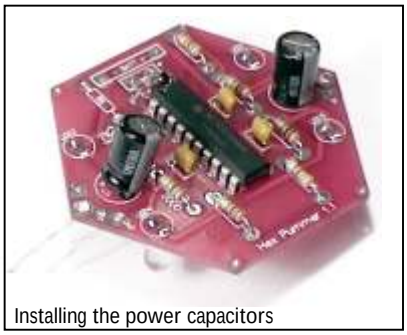
Step 5: Now it's time to install the LEDs (the Light Emitting Diodes). This requires a bit of attention to how they go in - LEDs don't operate when put in backwards. Take a close look at the collar around the edge of the LED. You'll see a flat spot near one of the legs. This is the "cathode" (I'll bet you still don't care about cathodes...), and place it on the circuit board so it matches the flat spot on the LED symbol on the circuit board. Repeat this four times at the places marked "LED1" through "LED4".

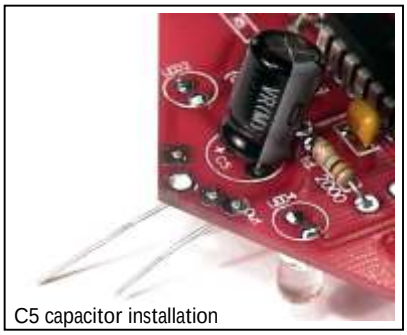
☞IMPORTANT: Mount them on the OTHER SIDE of the circuit board. The other side is what will be the front, where you will want to see the lights blinks!

Your Pummer kit may come with LEDs of different colours. In general, the LEDs may be red, green, orange, or yellow, but since they're called "water-clear", you won't know until you light the LEDs up. DO NOT find out by connecting them directly to a battery! If you MUST know what the colour is, charge up one of the 1000µF capacitors with one or two 1.5V batteries (connect it for about 1 second), then touch the LED legs to the capacitor legs - LED cathode to the capacitor leg nearest the stripe mark on it's body. It will pulse quickly and die. You remember how to tell which LED leg is the cathode, don't you?


LEDs installed on UNDERSIDE of Circuit Board



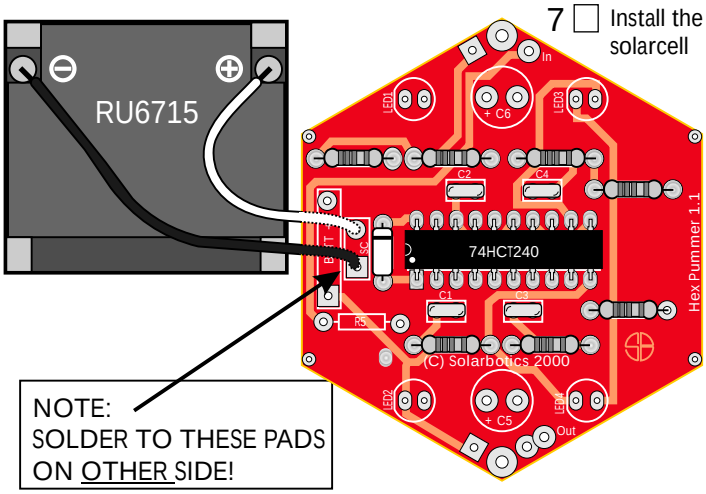

Installing the power capacitors


C5 capacitor installation

Step 6: Time for the main power storage capacitors. These hold the charge-pumped power, and release them in a burst to the LEDs, giving them their blast of light. These capacitors are polarity sensitive - putting them in backwards is a no-no!

Identify the negative leg of the capacitor by the stripe on the body of the capacitor. Alternately, the longer leg is the positive leg. Anyways, put the capacitor in with the longer leg through the hole nearest the '+', in positions C4 and C5.

Do this for the top and bottom capacitors, and snip off the excess lead from underneath.

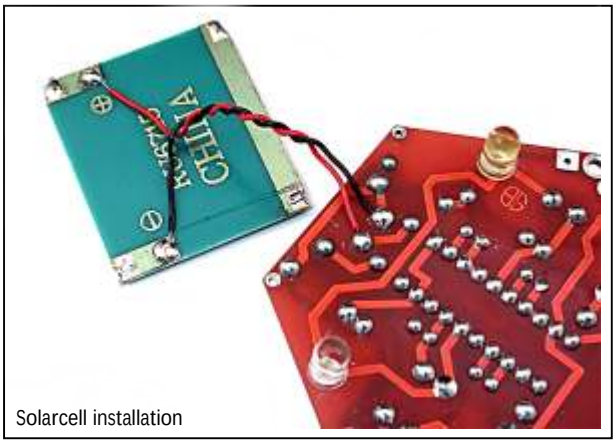


Step 7: The solarcell in your kit is pretty robust, but I wouldn't use it to scrape the scum off your bathroom tile, ok? It's epoxy-encapsulated for protection and long life - treat it nice, and it'll be nice back to you.

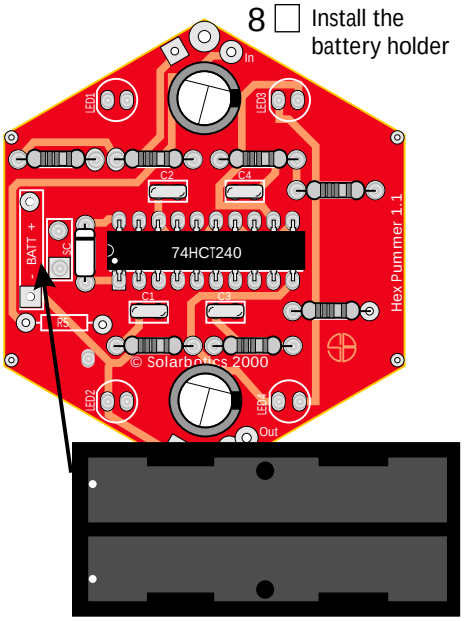
Find the twisted-pair wire (black & red) and strip off the ends so a bit of wire is exposed. I mean just a bit, like 3~5mm (that's about 1/8" ~1/4" to our 'merican friends). Solder these ends to the solarcell, black to negative (-), red to positive (+).

After you have the wires attached to the solarcell, you can strip and solder the other ends to the pads in the box labeled "SC" (for "Solar Cell" - clever, eh?). Again, black to negative ('-', the square pad), red to positive ('+', the round pad)). SOLDER THESE WIRES TO THE PADS ON THE OTHER SIDE. It's not an absolute necessity, but it will make mounting your solarcell easier, as the other side is where it will be!

If you want to make your installation a bit neater, trim the wire back so it just pokes out about 2cm (about 3/4") from the solarcell before soldering it on. it'll mount much cleaner to the circuit board when you glue the solarcell down.


Solarcell installation

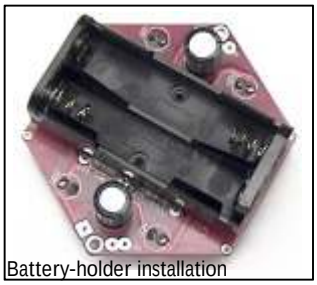
8 ☐ Install the battery holder



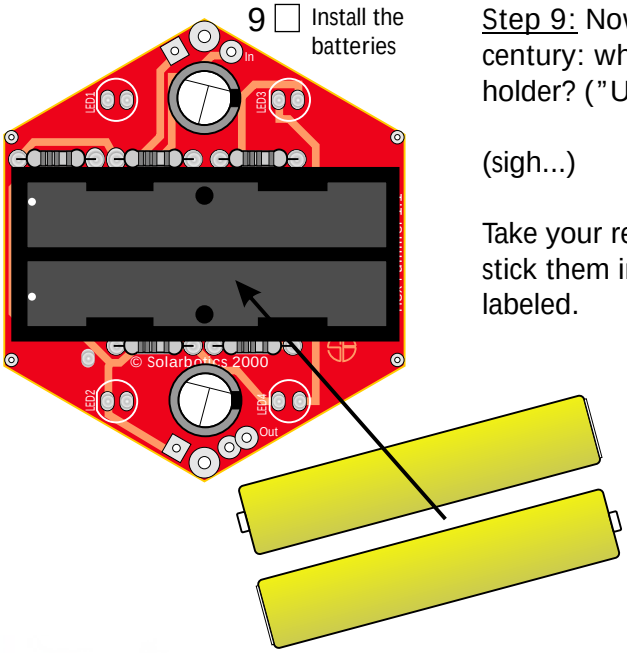
Step 8: Slap that bad-boy battery holder down in the only place it'll fit - the position labeled 'BATT' (clever, these labels, eh?). Install it so that it sits directly down on top of the 74HCT240 chip, then solder it in place (flip the whole thing over to solder).

These battery-holder leads are pretty strong, and will be the only support they need. If you wish, you can glue the holder to the '240 chip for additional support later.


Battery holder installation closeup


Battery-holder installation

9 ☐ Install the batteries

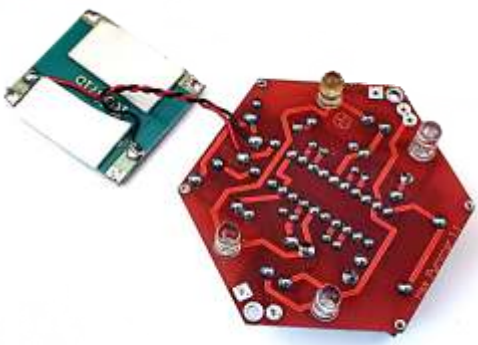


Step 9: Now for the question of the century: what do you put in a battery holder? ("Ummm... turkey leftovers?")

(sigh...)

Take your rechargeable batteries and stick them in the way the holder has labeled.

The battery installation



Step 10: Assuming that your Pummer is showing signs of life, the only thing left to do now is to glue down your solarcell to the other side of the PCB. We personally like double-sided foam sticky-tape, but epoxy or hot-glue works well in a pinch. Cut the tape in half, and put two pads on the back of the solarcell. Test fit it, and if all looks good, peel off the backing and stick'er down!

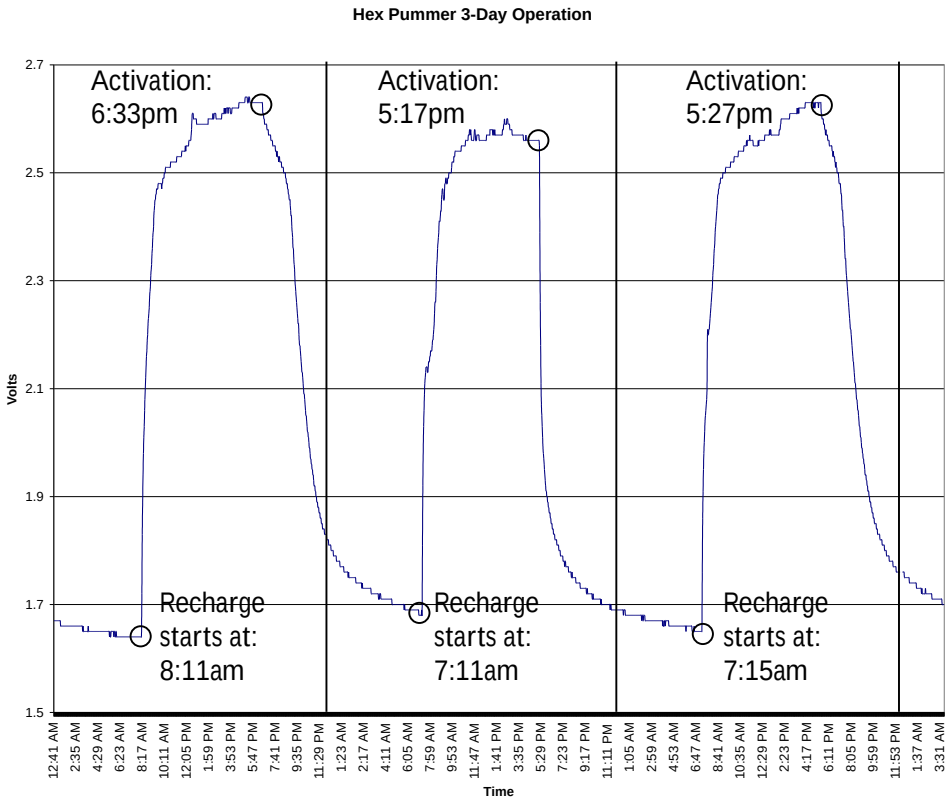
Alternately, you can use a stiffer wire for your solarcell attachments, and make it do double-duty as an adjustable solarcell-holder. A bit harder to work with, but if you want that solarcell pointing someplace else other than straight up, this answer works well.

Your Hex Pummer is now officially complete. Great. You've put the batteries in; *now* what? Well, if your batteries arrived with any sort of charge, you should be able to cover up the solarcell, and see the LEDs start to operate. Nothing happening? Try standing in a closet. Still nothing? Are you standing in the closet *without* your Pummer? Leave the closet, and go get the Hex Pummer, and try again!

If your device isn't operating after finishing assembly, you'll most likely have batteries that need to charge up. A quick charge in sunlight or under a halogen or incandescent lamp 30cm away (1 foot) for about a ½ hour should give you some results. If you aren't that patient, you can even use (gasp!) regular AAA batteries to power it up. Regular batteries will run this device for many days, up to weeks at a time (but of course, they won't recharge). Remember, you have to trick the Hex Pummer into believing it's dark - cover the solarcell to test the operation.

If your device *still* fails to cooperate, recheck your installation. LED 1 & 2 work together, as do LED 3 & 4, so if either one of the LEDs in each pair are wrong, that pair will fail totally. Also make sure your solder job is neat, tidy, and clean of flux. If you are using water-soluble flux, you ***must*** wash off your circuit board. Use some hot water and an old toothbrush to clean the flux-gunk out from between the solder joints, top and bottom. Then blow out the water under the chip, and leave it dry (hey - why not under a nice, warm, nicad-recharging light?).

Like any other Nicad battery, they like to go through complete charge/discharge cycles. Fortunately, the Hex Pummer (for the most part) does exactly this. It take approximately four hours of direct sunlight for the batteries to fully charge. That means even if you place your Hex Pummer in a location where it gets only reflected light, or sees only overcast daylight, it will most likely store up enough energy to Pumm when it gets dark.



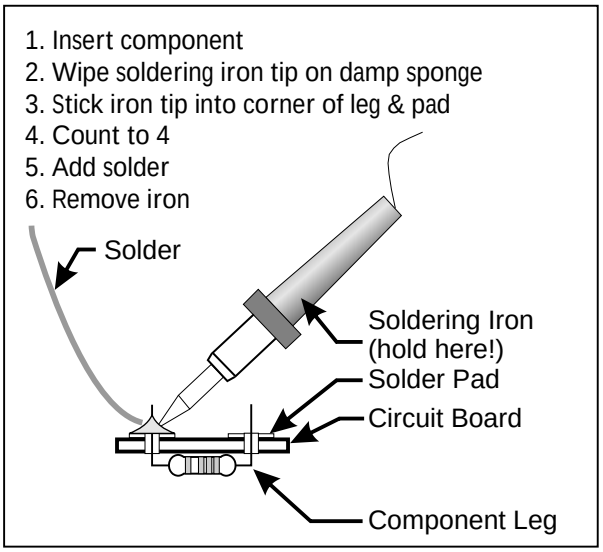
The great thing about the Hex Pummer design is that it uses practically any amount of energy to Pumm the LEDs to some degree. Even on a very weak charge, you can still see the LEDs weakly doing their Pumm-thing. In truth, you will see the most intense operation during the first hour of operation, which will slowly decrease in intensity for the remainder of the night.

Soldering! If you have never soldered before, it could be an intimidating concept. After all, you're being asked to take a scalding-hot piece of metal, and use it to *melt* metal onto delicate electronic components!

It is actually a pretty straight-forward process. We've taught 8-year old kids to solder (with supervision), so there's no reason why *you* can't wrap your head around this skill.

The trick is heat. Heat is good. Too often, new students are scared by the concept of all this heat in a small space. Well, what is really hot to you and me (the soldering iron), is actually just a sunny day at the beach for the components.

A successful solder connection can almost be guaranteed if you remember you are heating *two* pieces of metal, not just one. Here's the basic procedure:



1) Put the component leg through the solder pad hole (snugged up close)

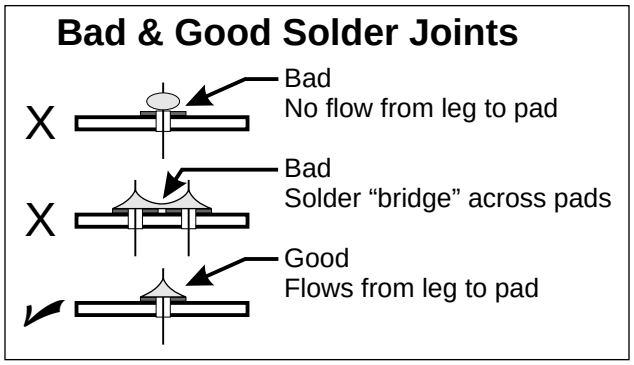
2) Wipe off the tip of the soldering iron on a damp sponge so it's shiny and clean. It transfers heat better when it's clean.

2) Holding the soldering iron like a pencil *(not* at the tip! Hot metal, remember?), jam the tip into the corner where the leg comes through the hole. This means the soldering iron tip is heating *both* the leg **and** the solder pad.

3) Count to 4. This heats up the parts.

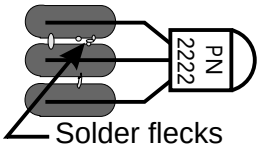
4) While *keeping the soldering iron in place,* add solder to the *other side* of the leg. At this point, both the leg and pad will be hot enough that they will melt the solder into a nice connection. You'll probably notice some yellow or clear goop appear when you solder. Don't worry, this is *flux,* and it is in the solder to help make a good, clean connection.

Do **NOT** treat the soldering iron like a brush. That is, **DON'T** melt solder to the tip, and then try to smear it onto the connection. You're a electronics enthusiast, not a painter!



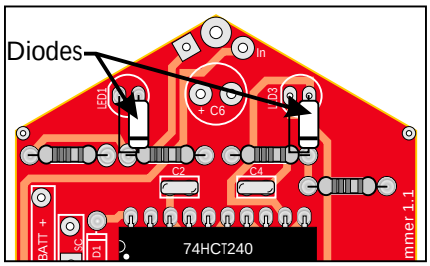
If you mess up, don't worry. You can reheat the solder and bang it loose with a quick snap onto a pad of paper (*please* use eye protection at all times). If you get two solder pads fused together, use the soldering iron like a pen, and "draw" a line between the pads. The solder will remelt, and flow off to the sides.

The final check for any solder joint is the "wiggle test". Firmly grip each component and gently rock it side-to-side. *Any* movement of the component legs on the other side of the board means the joint isn't firm, no matter how good it *looks.* Reheat and apply more solder to the joint.



One of the most common errors is to accidently "bridge" the pads between components. Make sure that there aren't any tiny flecks of solder or wire between the pads.

2 LED Operation - Now, why would you want to run only two of the four LEDs? Well, two take half as much power. That means you'll get much brighter Pummers running for longer than if all four were in operation.



Diodes instead of LEDs for 2-LED operation

If you want to convert your Hex Pummer into dual-LED operation, you simply **replace** the LEDs at positions LED1 and LED3 with diodes (diode bar closest the flat spot on the LED picture). Regular 1N914 or 1N4148 silicon diodes (the most common types) will work just fine, but you will get a *little* more performance if you can use "germanium" type diodes (1N34). They're somewhat more expensive (around $1 each), but if you want to squeeze every last erg of energy out of your Hex Pummer, that's what you want to use.

Slaving Operation - If you happen to have more than one Hex Pummer, you can connect them together and get the lights operate in sequence. Rather than having a collection of LEDs firing off at random times, you can have a smooth series of Pumms across several Hex Pummers. In theory, there is no limit to how many you can link up, or what shape you can build with your Hex Pummers.


Installing the R5 slave resistor (1meg)

Remember resistor pad R5? We didn't install anything there during assembly, as it's only needed for slaving one Hex Pummer to another. If you are going to now slave two together, you have to install that 1.0 Meg resistor on **one** of the pummers.

You have a 'Master' Hex Pummer that sets the beat for all the 'Slave' Pummers that follow it. Each of the slaves need this resistor installed at position R5.

Once you have soldered in the slaving R5 resistor, you can now link up the master to the slave.

1) Voltage Ground Connection: Simply make an electrical connection from one square pad on one Hex Pummer to the square pad on the other Hex Pummer. This connects the "ground" lines, which give the two devices a common voltage reference point. In the picture, the ground is soldered to the wire that is actually tying the two Pummers together.

2) Signal Connection: Just run a wire from the pad labeled "Out" on the master to the pad "In" on the slave. That's it! Now your Pummers are set up to coordinate the sequence they now activate their LEDs!


Connecting master (top) to slave (bottom)

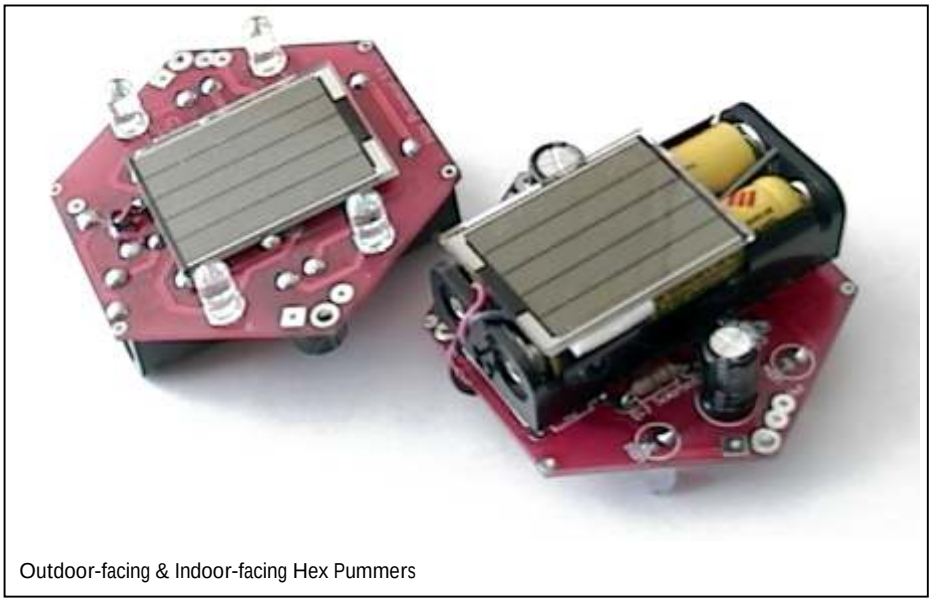
HEX PUMMER - DISPLAY

Your Hex Pummer is now complete - now what do you do with it? Well, putting it on display is always a good idea. Do with it what you will - put it on your car rear dashboard (put blue LEDs in it - makes traffic line up behind you for miles!), hang it in your window, dangle it from your pets collar...I won't tell anyone.

Here's some basic technique you can use to display your Hex Pummer. Feel free to expand on the concept!

Facing outwards is easy - just hang the pummer so both the solarcell and LEDs point towards the great outdoors.

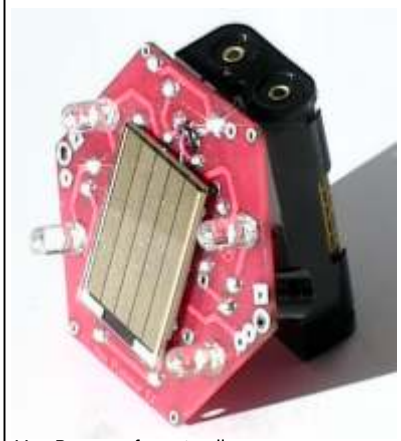
Facing inwards requires a bit more work, as you want the solarcell pointing towards the best light source. The answer? Flip the side the solarcell is on! Just glue the solarcell down to the top of the battery holder, leaving the face with all the purrrrdy lights facing inwards.



Outdoor-facing & Indoor-facing Hex Pummers

Outwards facing LEDs

Inwards-facing LEDs



Hex Pummer free-standing

Liked the HexPummer? Want more?

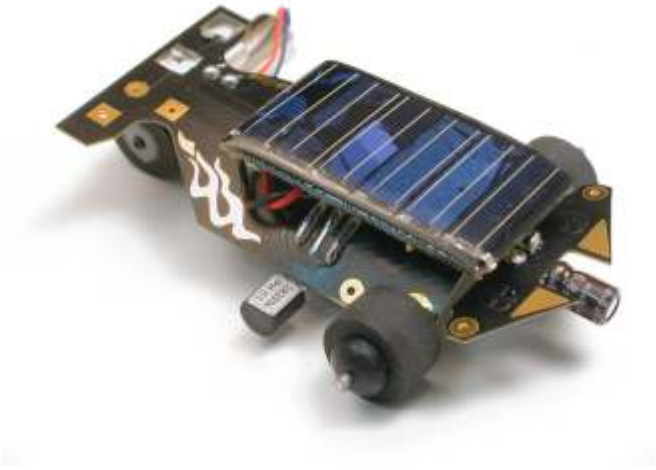
There are several more kits Solarbotics offers for any skill level!

The SunSwinger Pendulum uses the unique BEAM "force-coil" circuit to drive this eye-catching window or desk ornament. Designed for solar power, it can also run from batteries or any 3V+ DC power supply (ideal for dark cubicles!).

K PN Pendulum. $29.50USD/CAD

The SolarSpeeder 2 Kit is a very quick Solaroller that can cover 3 meters (10 feet) in under 40 seconds in direct sunlight. Simple to construct and a blast to watch, this is a great kit for all beginners!

K SS Solarspeeder $27.50USD/CAD

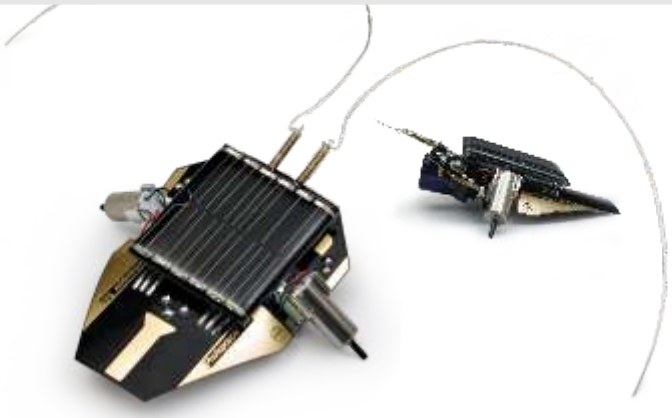


Herbie the Mousebot is a 9-volt battery-powered robot that loves to chase flash light beams. If there are several Herbies in the same area, they can be configured to chase each other! These little robots are so quick, you have to run to keep up to them!

K HM Herbie the Mousebot $39.95USD/CAD

Like the Mousebot, the *K PP Photopopper* seeks light and avoids obstacles but is solar powered! It's pretty quick, covering a meter per minute (that's 3.3 feet!). Newly upgraded with better electronics and gold circuit board!

K PP Photopopper $45.00USD/CAD



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