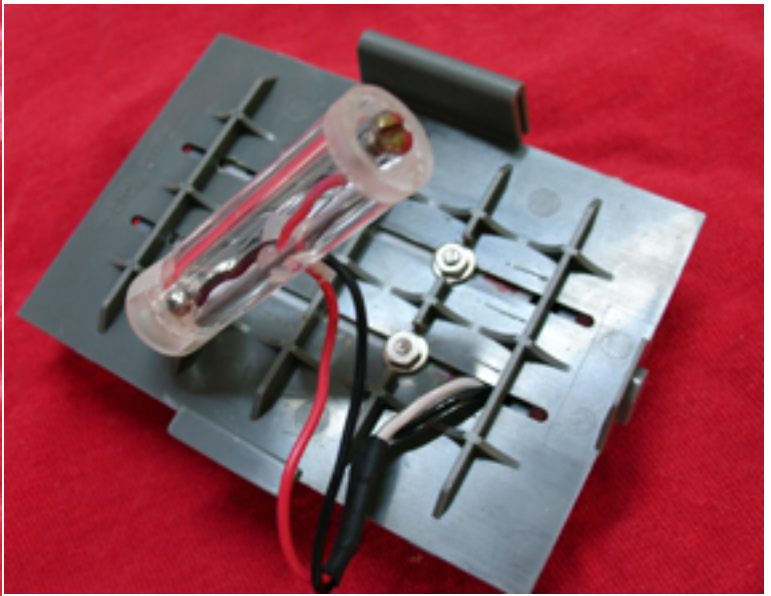


## Precursor: Why Do This Particular Set of Hacks?

After using the LEGO NXT Robotics system for awhile, I discovered that the thing uses batteries fast. To reduce the expense and waste of one use batteries when using the NXT, the alternative of rechargeable batteries is available (these are modular and multifunctional, unlike the LEGO issue rechargeable NXT battery pack system).

However, standard AA-Cell batteries are rated for about 1.6 volts, and the rechargeable Nickle Metal Hydride (NiH) batteries are rated for 1.2 volts. Six alkaline batteries produces 9.6 volts, six NiH batteries produce 7.2 volts. This difference of 2.4 volts can be made up with two more batteries, for a total of eight rechargeable batteries. When powering the three motors, full voltage is desirable. Unfortunately, these are all theoretical values. Also, while under constant use, these values can drop initially then hold at a steady value.

So an expansion of the battery for the NXT is called for. The lightest, simplest way of doing this was to bolt on a Radio Shack two battery AA-Cell battery box, and make a faux battery (shape) with the electrodes connected to the leads of the Radio Shack battery box. (On Hack#1, read step 10 for the drill hole placement, and step 16 for making a faux battery.)



Unfortunately, to use the newly added adjunct battery box, you have remove and replace the lid using a phillips screwdriver. Additionally, it doesn't look like any of the lego design elements, and it only can house two batteries and the faux battery replaces one battery inside the NXT, for a total of seven, not the desired eight batteries. Under testing, at peak charge, seven rechargeable batteries did yield 10.2 volts, very respectable. So, if you are using rechargeables, and don't feel like going through a major hassle to expand your power box, use the above set-up. The hardest part is making the faux battery, which you can design yourself or scroll down and use my method.

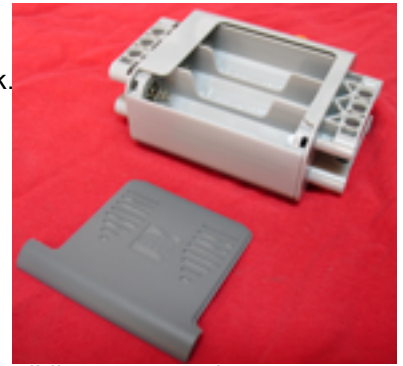
The first hack produces what you see in the picture below. It's an expansion for the NXT that met my personal requirements for look and function. I think that the final product is worth the effort, if you have the skills and the time to make this hack. You can decide for yourself.



# LEGO PowerFunctions Battery Box Hacks

## Statement of Purpose;

There are two functions to this hack of one LEGO PowerFunctions 6-cell battery pack.



**Hack#1:** The first is to use the three most accessible AA-Cell battery mounts and their sliding cover and corresponding bezel/casing to mount onto the exterior of the lid of an NXT battery box. The function will require the use of a false but connecting battery in the NXT. This will create an 8-cell set-up.

8-Cell, serial battery boxes, using 1.2 volt NiMH batteries should produce a nominal voltage of 9.6 volts, comparable to the intended set of 6 alkaline cells. However, in order to avoid confusion, a warning label for all modified battery boxes, indicating that ONLY 1.2 volt rechargeable batteries should be used, needs to be created and printed.

**Hack#2:** The second is to create a D-Cell 8 battery pack, with all of the connecting and controlling hardware from the original PF pack. This includes the PowerFunctions power connector, switch, indicator LED, and the end affixing hardware, and is mentioned here because it uses most of the remains of the PowerFunctions Battery Box not used in Hack #1.

## **Critical Safety Notes !!!**

- Always cut away from yourself, especially your fingers!
- When making these items, wear safety equipment, eye-protection, a face shield, ear protection, a particle mask.
- Work in a well ventilated space.
- If you are uncomfortable doing a procedure, ask an adult for help, or research it, or don't do this hack!
- Read through all of the directions BEFORE STARTING.
- You are liable all of your own actions.

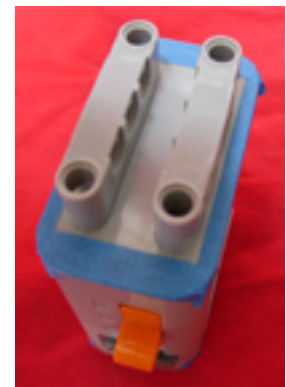
## Hack #1 AA-Cell Battery Compartment Extender for the NXT

You will need these and supplies tools;

- A zona type saw
- A small vise
- A small phillips head screwdriver
- A hobby knife (not shown)
- Gray semi-gloss spray paint (not shown)
- 1/8" thick acrylic scraps
- Flux, rosin core solder, and a soldering iron
- 3/16" thick acrylic scraps
- Weld-On #16 (thick solvent plastic glue)
- Weld-On #4 (thin solvent plastic glue)
- 1 pc. PowerFunctions battery box (to be HACKED !!)
- A needle applicator bottle (for the thin glue, not necessary but very handy, not shown) (You can use a small paint brush instead.)
- Sand paper, 100, 220, 320 grits
- 8-32 thread tap.
- 1pc. 4-40 nut
- 1pc. 8-32 nut
- An electrical continuity tester

- A metal straight edge
- A pin vise and 3/32" (approximate size) drill bit
- Some masking tape
- 4-40 thread tap
- 2pc. 8-32 x 1/4" flat-headed phillips screw
- 2pc. 4-40 x 3/16" pan-headed slotted screw
- 4 pc.s 4-40 x 3/16" (or 1/4") allen headed cap screws and matching allen wrench

- 6" each black and red (or white) insulated wire 22-26 gauge
- 2pc. Acrylic tube, 1/2" O.D. (outer diameter), 1/4" I.D. (inner diameter) by 1.575" (or 1-9/16") long.
- Pliers



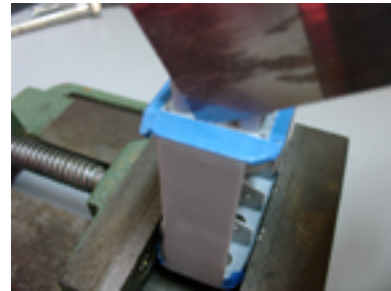
## PowerFunctions Box Initial Cutting Steps;

(The PowerFunctions battery box that was hacked had the serial number 29K7)

- 1) Remove slide-off battery covers
- 2) Mark end areas to be cut, with tape.



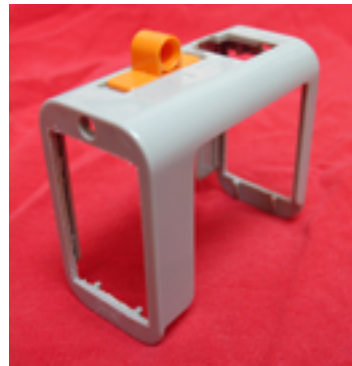
**3)** Drill four holes at the corners then, start to cut marked areas with zona saw and a thin straight edge (cut as deep as possible while staying within the lines, the finish cuts are made in another stage).



**4)** Unscrew and remove interior battery box, by sliding away from switch assembly/chasis.

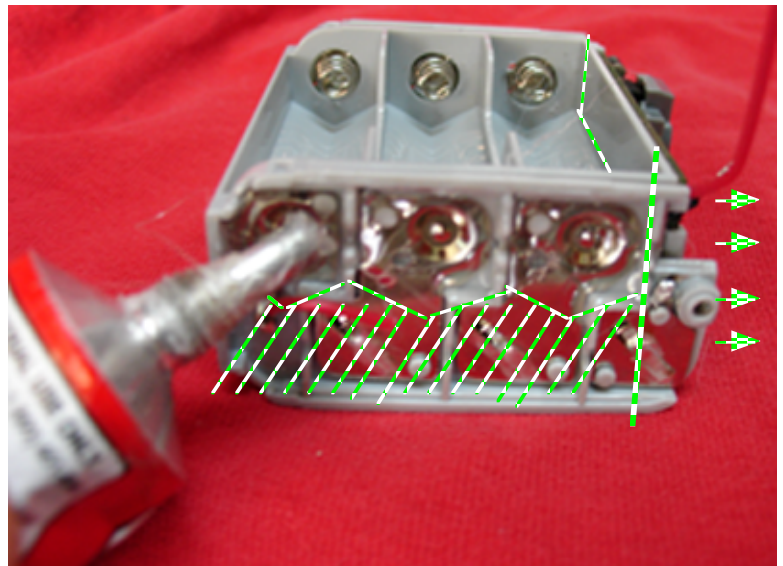
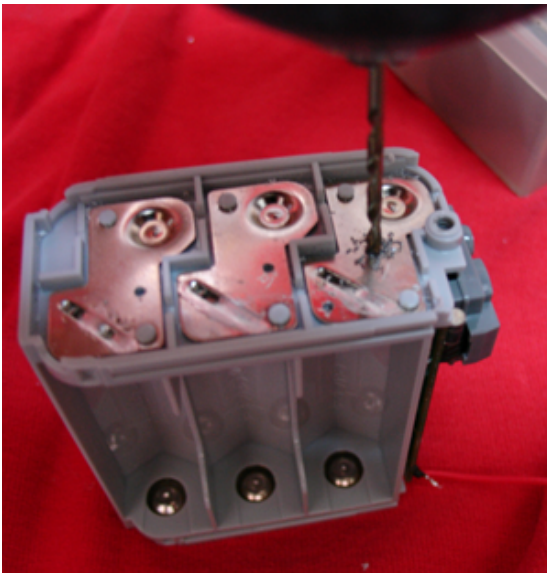


**5)** Finish the cuts started earlier.

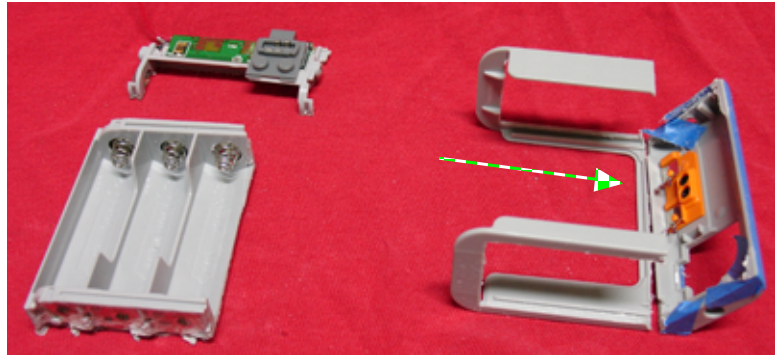
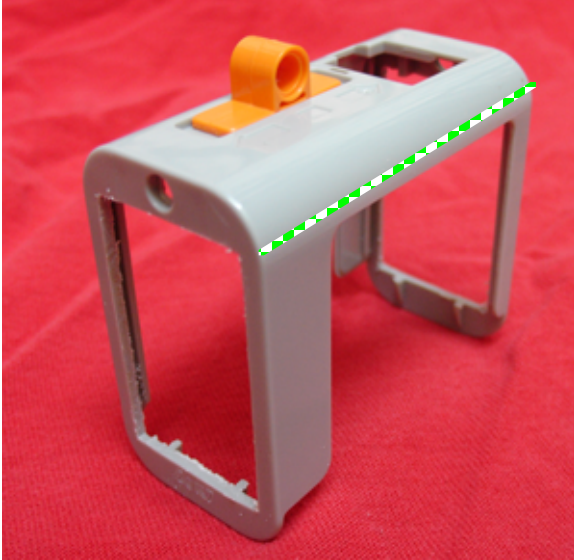


**6)** Snip red & black wires, close to where they attach to the battery connectors. Unscrew and remove the electronics board.  
**7)** Drill some holes in just the metal of the battery connector plates, and use Weld-On 16, a heavy body, solvent based glue, on top of and through the newly drilled holes and around the perimeter of the backing plates of the battery connectors. Allow to cure for ~~24~~ 8 hours. Apply a second application of glue.

**8)** After the glue has dried, cut away and preserve the electronics and slide switch assembly. In a series of straight lines, cut away the battery compartment to be used's other side, metal and plastic, using a dremel with an abrasive cut-off disk for the metal, and the zona saw for the plastic (note the orientation in the picture, as the three battery chambers furthest from the switch are to be preserved).



9) The remaining chasis is not symetrical, in several ways. When cutting the portion that houses the orange slide switch and the corresponding electronics, the short paralel edge is the cutting guide, but the other side has an extra 1/8-inch which needs to be saved with sides of the chasis for the next step.

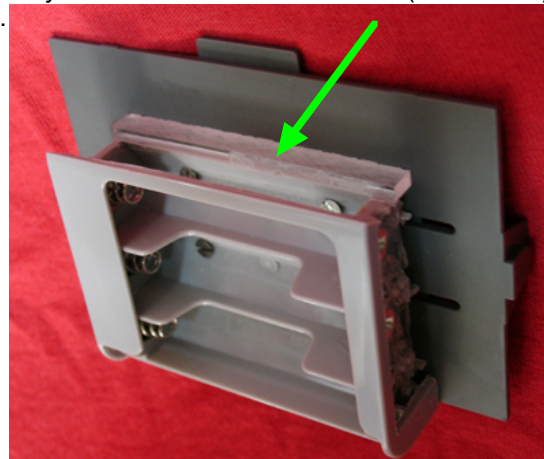


10) After cleaning the mating groves of any debris left from the cutting procedures, slide the battery pack **fully** back into the chasis side with the 1/8" strip still attached. Using the Weld-On 4, glue the battery pack to the chasis sides. Allow to cure for 24 hours. Cut then sand the bottom edge (near the large rounded edge) and slightly flatten the bottom of the new battery box by sanding it on a flat surface. Locate the position for four holes on the two bottom ridges of the pack, farthest from th. Make a pencil mark in the center of each ridge. To each side of that pencil mark, measure 9/16" and make a mark. Drill four holes in the bottom of the battery pack using the 3/32" drill bit.e large rounded edge.



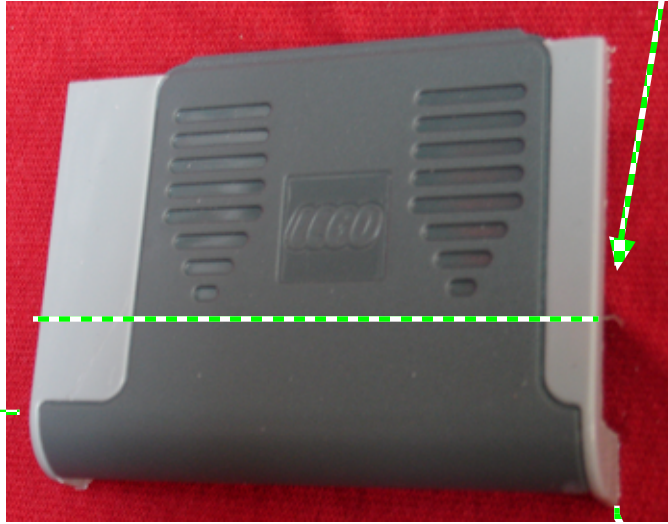
11) Get the battery box cover plate from an NXT. Remove some of the interior structure to accomodate some nuts and washers for attachment to the modified PowerFunctions battery box. Screw the partially completed PF box to the NXT lid using 2-56 screw hardware, 4 hex nuts, 4 washers and 4 flat-headed, phillips screws 1/4"(?) long. For now, unscrew and seperate the two components.

12) Make two strips of plastic 0.100" (1/8") x 0.210" x 2.275", glue one to base of the PF battery box (not the NXT lid !), on the side opposite of the direction the lid slides on the battery box. Glue the second one (not shown), oriented 90 degrees, and glue the long edges of the sencond to the first strip.

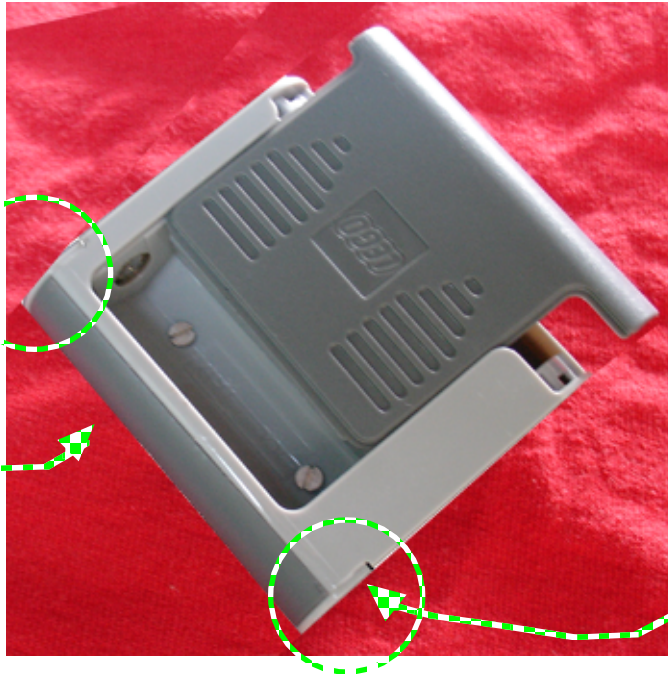




**13)** Using one of the PF lids and the scrap sides, glue them together, and allow to cure. With the large radius edge as the top, turned upside-down, measure the same height as the PF battery box, mark and cut a line to make a cover for the exposed side of the box.



**14)** Move the newly cut piece, and note the extended flange that is not cut off, and overlaps the other parts. This will make the seam stronger. Glue in place using the Weld-On 4. Allow to cure for 24 hours. Sand the bottom, so the newly attached parts are flush with the bottom.



**15)** Flux, and solder the battery connectors in a serial fashion, including a black and red set of long leads (3") for use with the faux AA-Cell battery. Check the electrical continuity of the circuits to make sure the connections all work.

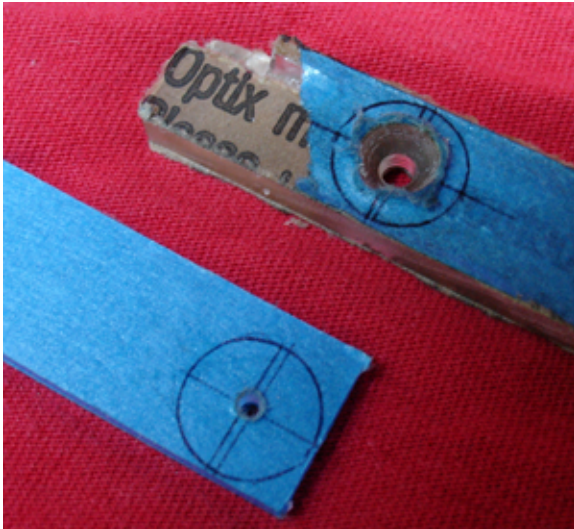
**16) Build two faux batteries. You will need the following additional supplies:**

- 2pc. 8-32 x 1/4" flat-headed phillips screw
- 2pc. 4-40 x 3/16" pan-headed slotted screw
- 1/8" thick acrylic scraps
- 3/16" thick acrylic scraps
- 2pc. 3" piece of red or white insulated wire 22-26 gauge.
- 2pc. 3" piece of black insulated wire 22-26 gauge.
- 2pc. acrylic tube, 1/2" O.D. (outer diameter), 1/4" I.D. (inner diameter) by 1.575" (or 1-9/16") long.
- 1pc. 4-40 nut
- 1pc. 8-32 nut
- flux, rosin core solder, and a soldering iron

**TIP:**When drilling holes in acrylic, use WD-40 or another very thin lubricant, as a cutting fluid. This will keep the plastic from overheating, melting, or cracking. Use soap and water to remove the lubricant, but dry thoroughly when done.

On the 1/8" thick acrylic, layout two 1/2" diameter circles, mark the centers, drill and tap threaded holes with the 4-40 tap. Rough cut the circles and glue each one onto one end of each of the tubes, using the Weld-On 4.

On the 3/16" thick acrylic, layout two 1/2" diameter circles, mark the centers, drill and tap threaded holes with the 8-32 tap. Counter sink the hole to more than accept the flat head screw, so when it is screwed in all the way, it sits below the surface of the acrylic. Rough cut the circles and glue each one onto one end of each of the tubes, with the counter-sunk surface facing outwardly. Allow the glue to cure for 24 hours. Then finish sand the disks to mate with the sides of the tube. In the middle of the side of the tube, drill a 1/4" hole. With the hobby knife, scrape the edges (inside and out) of the holes to eliminate the sharp edges.



To protect the threads on the screws, screw them into a nut, and hold the nut with the pliers. With coarse sandpaper, rough up the ends of the threaded ends of the screws. Apply flux, and heat with a soldering iron for several minutes while holding with set of pliers. Apply a small amount of solder. Do this to all of the screws, keeping the solder off of the threads. Strip all the ends of the wires by about 1/4", flux, and melt a small amount of solder. On each wire, near the very end, make a 90 degree bend. Solder one red/white wires' bend end to one 4-40 screw. Solder the bent end of each black wire to one 8-32 screw.



Screw in the screws into the appropriate holes, feeding the wires through the hole in the side of the faux battery.

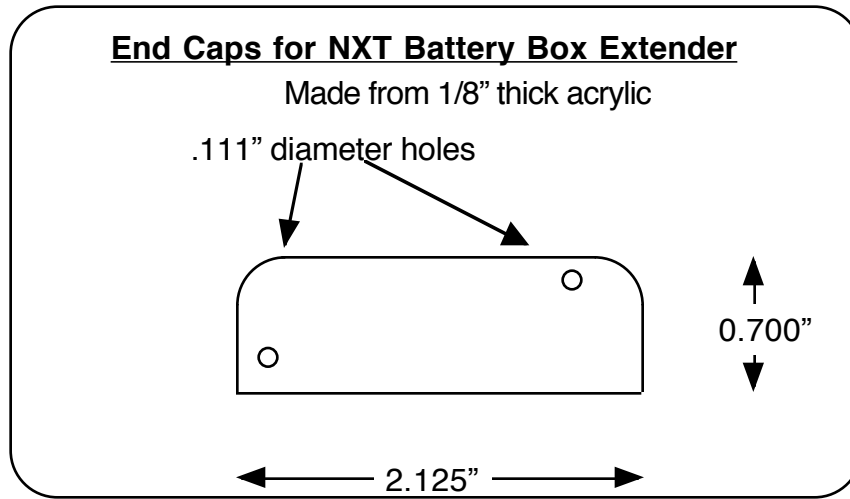
For making one of the batteries a simple spacer battery, put a piece of heatshrink tubing on one of the wires, slide it away from the bare solder, solder the two wires together, check the electrical continuity of the circuits to make sure the connections all work, put the heatshrink tube over the solder joint, heat it to shrink it, and stuff the wire into the interior of the cylinder. You now possess one faux AA-cell battery. **Do NOT** repeat this procedure for the second faux battery.

**17)** Using the layout shown below, make to end plates out of 1/8" (or slightly thinner) acrylic sheet.

Cut the rectangular dimensions of the two pieces first. Then using double stick tape, and aligning the edges, tape the two pieces together.

**TIP:** This is a method that can save you time in the future too, as you only have to make most of the cuts and drill holes once, not twice. You can stack more than two parts at a time too.

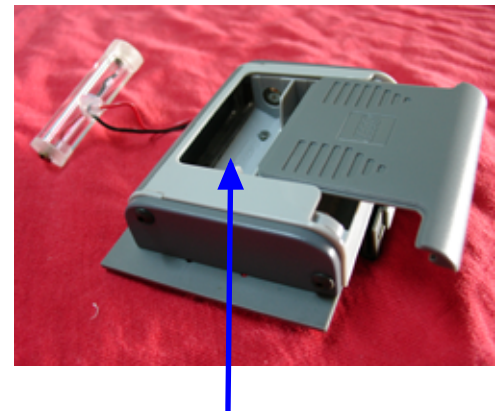
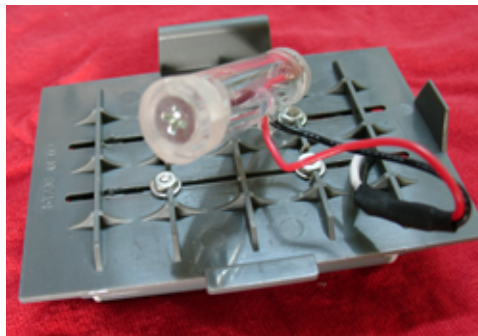
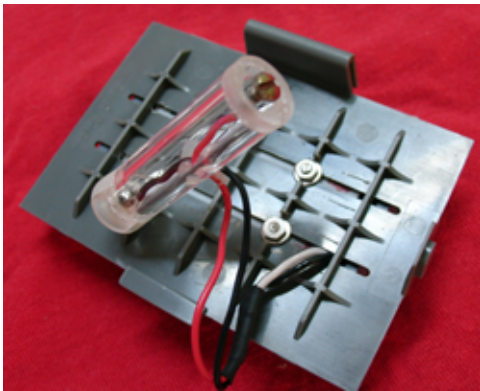
Then mark and drill the holes, cut the radius on the two corners, and sand (first with rough, then smooth sandpaper) a radius around the edge (so it will match the look of the rest of the box) of the plates on the top, sides and radiused corners. Separate the pieces and remove the tape. The final two products will not be identical, but rather mirror images of each other.



Use the caps to cover the exposed wiring/metal plates. You will notice that the holes in one cap lines up with bits of the battery box chassis. If it doesn't then switch caps. The sanded edges of the caps should be facing outward. Use the caps as a drill guide and drill holes for preparation for the 4-40 threaded holes. Then thread the holes. Do this to each side of the battery box.

Using two light coats, paint the end caps. Allow to dry, and screw into place using the allen headed cap screws.

**18)** Feed the wires from the newly created battery box through the vent slots of the NXT battery box lid, from the outside of the lid. Using the remaing faux battery, the solder and soldering gear, and some heat shrink tubing, connect the faux battery to the new battery box. Check the electrical continuity of the circuits to make sure the connections all work. Using the nuts and screws, reattach the new battery box to the outside of the NXT battery box lid.



Load the "spare", self contained faux battery into the most recessed battery recepticle in the new battery box.

Your new NXT battery box expansion is now ready for use with 1.2 volt rechargeable batteries~

**19)** Reassemble the slide switch assembly, and screw it together. Place to the side for Hack #2.



## Hack #2:D-Cell PowerFunctions Battery Box Replacement

### Hack NXT Battery Box Extender Parts & Supplies List:

<u>Part Name</u>	<u>Manufacturer</u>	<u>Part ID #</u>	<u>Cost per part</u>	<u>Quantity</u>	<u>Total Cost</u>
#2 washers	n/a	n/a		4	\$
2-56 hex nuts	n/a	n/a		4	\$
2-56 x 3/16" flat-head, phillips screw	n/a	n/a		4	\$
4-40 x 1/4" cap-head, allen, black screw	n/a	n/a		4	\$
LEGO PowerFunctions battery box remnants from Hack#1	LEGO				

### Hack D-Cell Battery Box Parts list:

<u>Part Name</u>	<u>Manufacturer</u>	<u>Part ID #</u>	<u>Cost per part</u>	<u>Quantity</u>	<u>Total Cost</u>
4 battery D-Cell Holder	Radio Shack	2700396	$\$1.89 + 0.15 =$ \$2.04	2	\$4.08