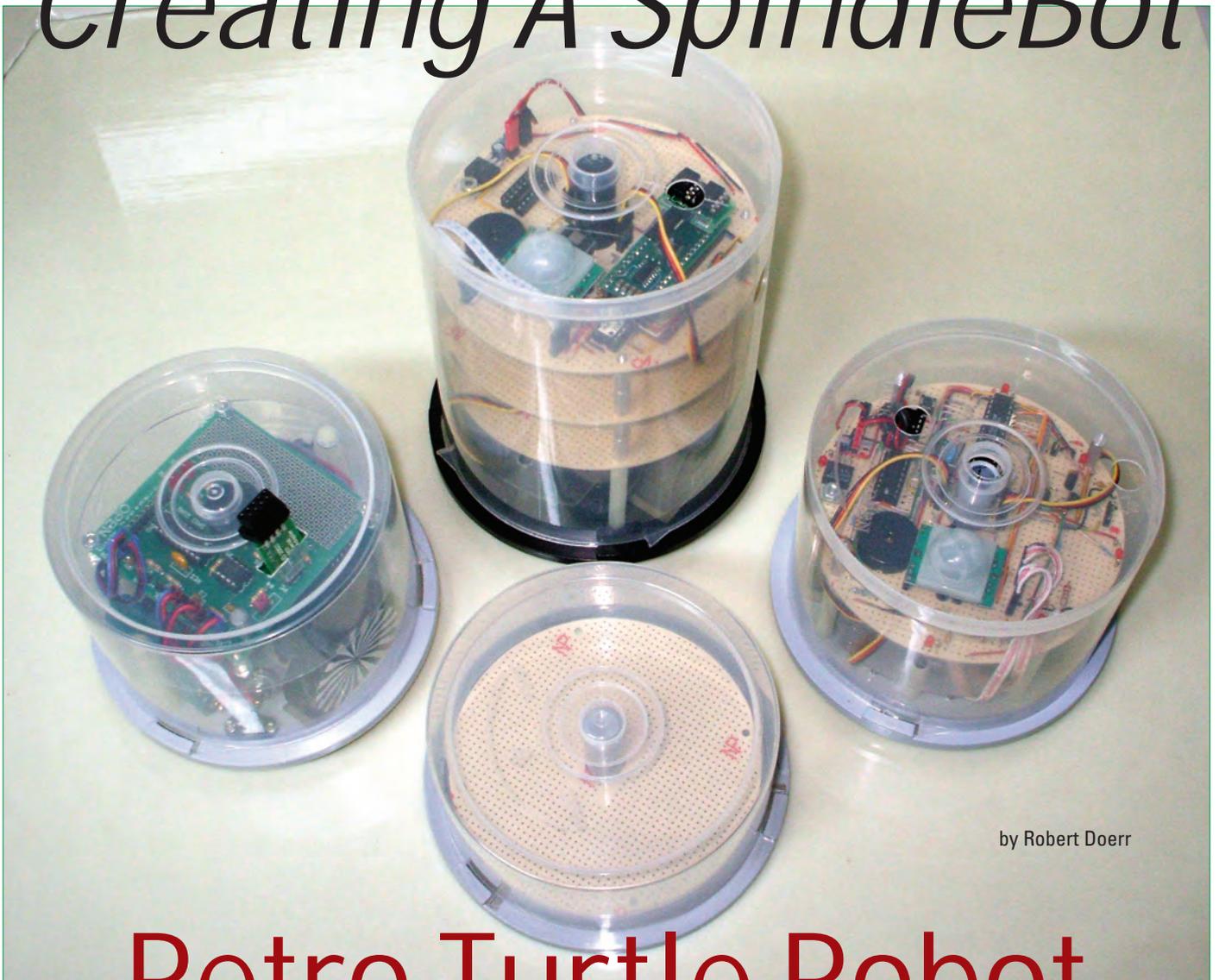


Creating A SpindleBot



by Robert Doerr

Retro Turtle Robot Construction Tutorial

I may be a bit eccentric, but I spend much of my free time working on personal robots from the '80s like the HERO, Androbot, RB5X, Gemini, and Hubot robots. Even so, I like to explore other areas of the hobby and build other robots too. This project all started when I kept looking at a CD spindle sitting on my desk and thought what a great little robot it could make. It kept reminding me of the early turtle robots. The bottom makes a great base for a robot and with the cover in place, it would have the finished retro look I was after. Besides, it is a great way to recycle something that normally is thrown away. During the construction, many other recycled parts were incorporated into the design. Little did I know that this would end up creating a whole new class of small robots: the SpindleBots!

Birth of the SpindleBot

The first SpindleBot prototype started out when I took a day off to clean up around the house. I already had most of the parts on hand and just needed the time to work on the project. For the body, I selected an empty 50 CD spindle case with a standard twist top since it looked like the ideal size. To keep a neat appearance, everything had to fit within the case so the cover could be installed to finish it off. The trick was to figure out the best way to squeeze everything into such a confined space. For the brains, I used an early BASIC Stamp 1 based Sumo board that needed a home. It was a good board to start out with and it just happened to fit within the CD case. The board was meant to drive a pair of standard RC servos like those found on many small robots. That was ideal since those are the motors I intended to use. One reason these are so popular is that they already have a nice motor/gearbox that can be directly connected to a wheel.

Preparing the Servos

This first version of the SpindleBot used a pair of standard Airtronics servos. Like most servos, these had to be modified for continuous rotation. This is a common modification to make. The first part is to disassemble the gearbox and then trim off the stop on the large output gear. That stop prevents the output shaft from turning all the way around. The second is to pull out the potentiometer that normally fits into the output shaft. Once that is complete, the servo will then be able to continuously turn in either direction.

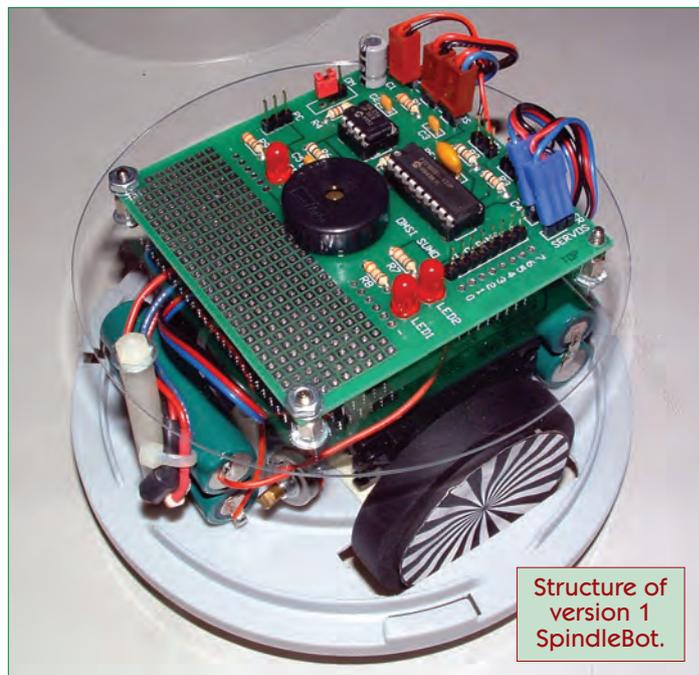
The potentiometer needs to be adjusted for no servo movement while it receives a pulse approximately 1.750 ms in duration which is a centered servo. I've seen some people cut off the shaft of the potentiometer and leave it in place. Others just remove it and instead add a pair of 2.2K resistors, and have the common lead go to where the adjustment would have gone. However, this method is non-adjustable and with the fixed setting all the calibration has to be done in software.

The method I prefer is to bring the adjustment potentiometer outside of the servo. For many servos like the Airtronics and Hobbico, this is easy since they are usually connected via a small three-conductor ribbon cable. All that needs to be done is to cut down the notch where the servo power/signal comes into the servo, and then route the cable with the potentiometer in the area just notched out under the existing servo wiring. With the potentiometer exposed, the servo can easily be calibrated and adjusted at any time to set the center point. A quick Internet search should find detailed instructions on how to modify almost any other servo.

NOTE: One other servo modification is to remove one of the motors and reverse the polarity so it will run in the opposite direction. This way, the pulse width you send to them means the same for forward and reverse on both



Finished version 1 SpindleBot with cover.



Structure of version 1 SpindleBot.



The stop to cut off to modify a servo.



Bottom of version 1 SpindleBot.



Power switch used on SpindleBot.

servos. Otherwise, the pulse widths would mean the opposite from side to side if one motor isn't reversed.

Preparing the Base and Mounting the Wheels

With standard height servos, I had to cut the center spindle off the base in order to make room for mounting. This allowed each of the servos to sit on their side with the bottom of each one nestled up against the other. For the wheels, I used a pair of 2" round rubber feet from an old piece of computer equipment that was being scrapped. Each wheel was glued and then screwed to a standard servo horn. Just about any servo horn will work. The hole in the center allowed me to screw the wheel and servo horn to the servo. That way, it could be removed later if needed.

With the wheels attached, I could then mark the base

Sources

- | | |
|---|---|
| Parallax
www.parallax.com | RadioShack
www.radioshack.com |
| RobotWorkshop
(CDP2 Protoboards)
www.robotworkshop.com | Hobbico
www.hobbico.com |
| Tower Hobbies
www.towerhobbies.com | Empty Spindles
(if you can't wait)
www.americal.com/pd/CABX100.html |

for the clearance holes to allow the main drive wheels to protrude through the bottom of the base. Working with plastic is relatively easy, and a sharp Exacto or other hobby knife will do the job. There are many different techniques for cutting plastic but I usually make a light cut on the outline and then go over it several more times, cutting a little deeper each time. The motors were then mounted to the base with double-sided tape and a cable tie was placed on each one to keep them secure. On the underside of the base, a small slider was used at the front and rear to help keep the robot level. It did double-duty since the screw holding the slider on also secured the 2" standoffs to hold the tray for the BASIC Stamp board. A power switch and connector for a charger were also added on the bottom of the base to wrap that portion up.

There was just enough room left to install four AA NiMH batteries on the base to keep the center of gravity low. Two were in front of the servos and the other two were behind the servos. These were the tabbed versions with the leads soldered directly to the wires. They connect to the power switch and also to a charger jack through a 10 ohm resistor (poor man's current limiting) which will be used with a 7.5V 200 mA unregulated wall transformer. On top of the two 2" standoffs, I used a plastic CD to create a platform to hold the electronics. Often, CD spindles ship with a completely clear plastic CD which is ideal for this. However, any CD or DVD can be used.

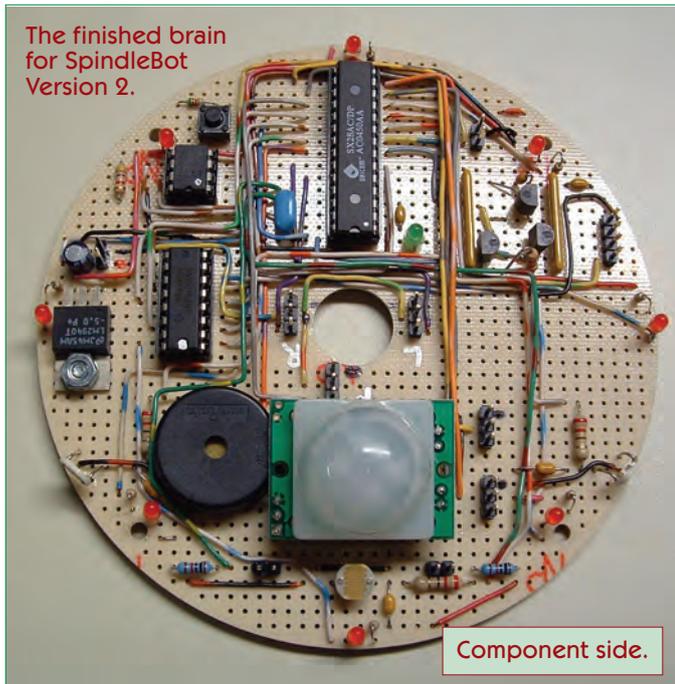
With this tray in place, four short standoffs were used to mount the brains. Running the wires was then a simple task. At this point, it was like any other BASIC Stamp powered robot with a servo drive system. It just had a much more finished look. There is still some room left for future expansion. This little SpindleBot looked okay but I knew it could be improved. It was a good first attempt, but I wanted to make better use of the available area.

Improving the Design – SpindleBot 2.0

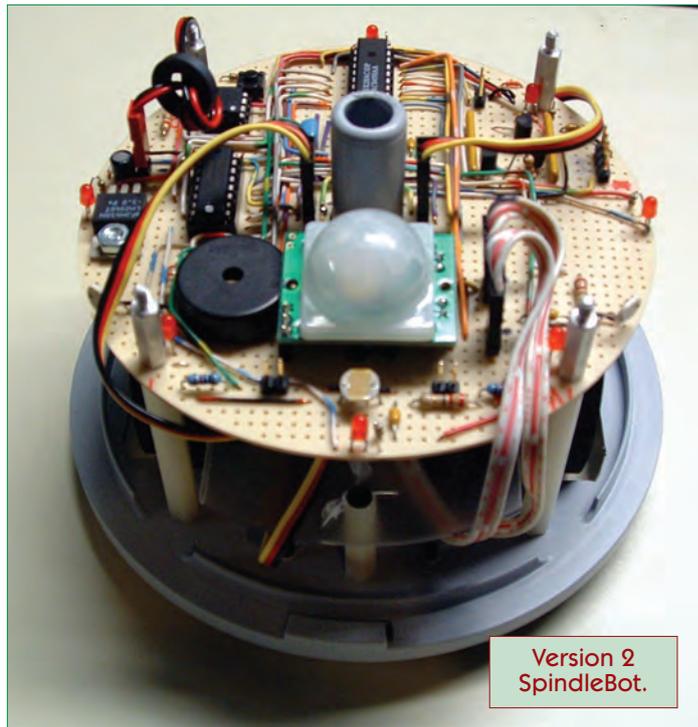
The next version (robot #2) was completely redesigned and improved. It is amazing to see the difference between the original SpindleBot and the next version. There is a lot more packed into the same space, and it has a much more polished look and feel.

This new robot really came together. One of the main variations from the first robot is that I wanted to ensure that the center support for the spindle could be preserved.

The finished brain for SpindleBot Version 2.

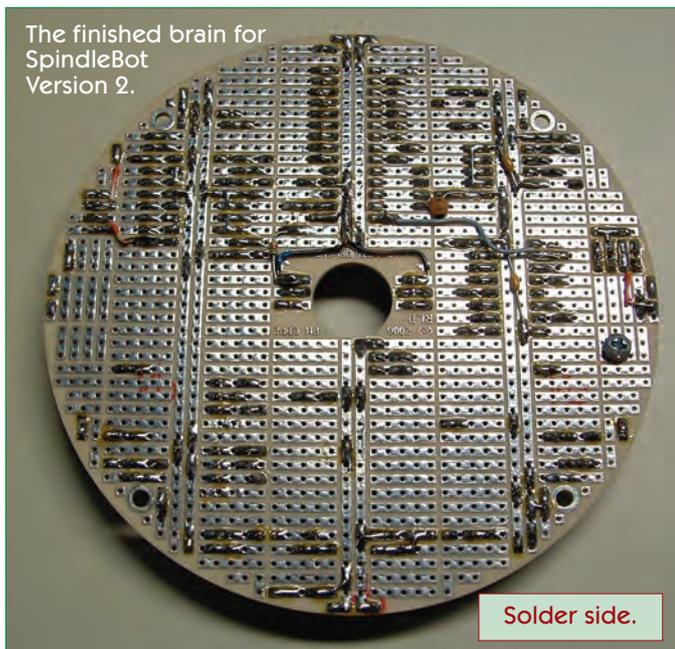


Component side.

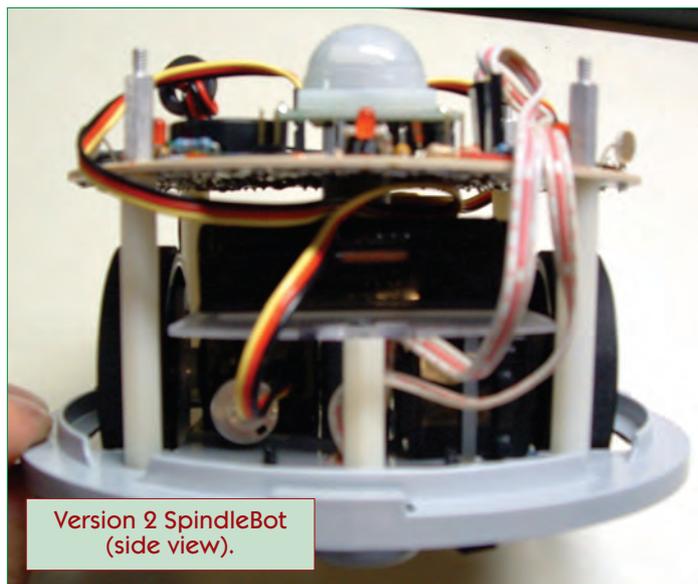


Version 2 SpindleBot.

The finished brain for SpindleBot Version 2.

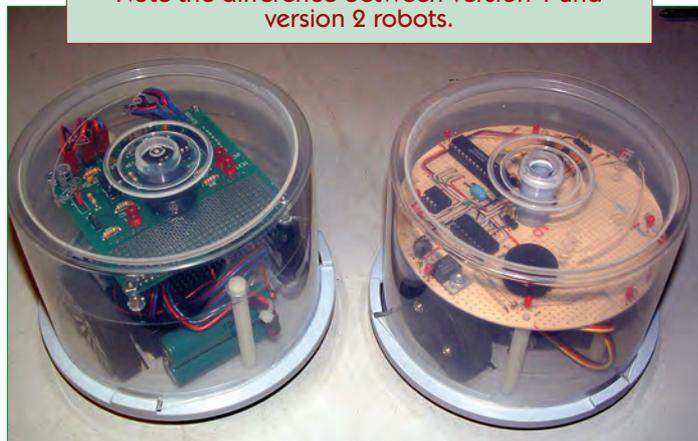


Solder side.



Version 2 SpindleBot (side view).

Note the difference between version 1 and version 2 robots.

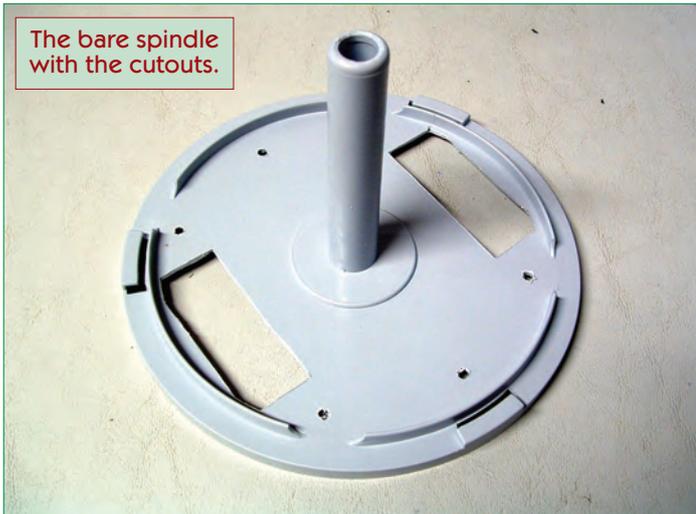


(The reason this is important will become clear later in the article.) On this robot, the internal structure was built up in layers. The base holds the servo motors, the power switch, and charging connectors. The next level holds the batteries. Like the first robot, the top level will hold the brains of the robot. As the design matured for making a SpindleBot, I was able to create an easy to use template in pdf form that shows where the holes should be drilled for the supports, the cutouts for the wheels, and where to trim down the CD/DVD for the battery tray.

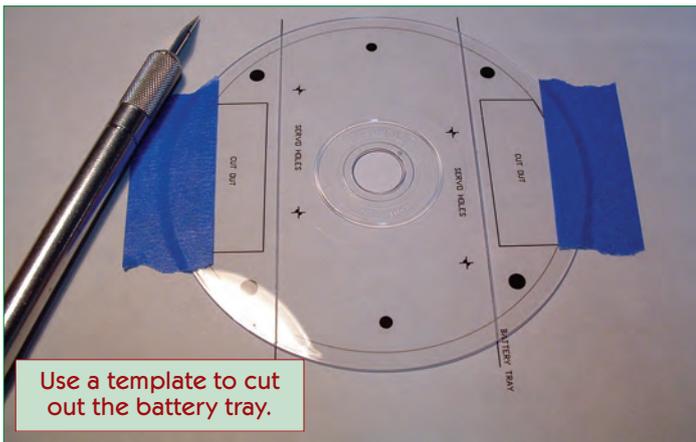
NOTE: During the process of designing and building the SpindleBots, I came across a great source for small robot wheels. They are the large paper feed rollers from HP inkjet printers. They are the perfect size for use in a SpindleBot



Note how to place the template on the base to mark holes.



The bare spindle with the cutouts.



Use a template to cut out the battery tray.



Finished battery tray.



These are from HP inkjets and are used for the robot wheels.



Lots of wheels from recycled printers.

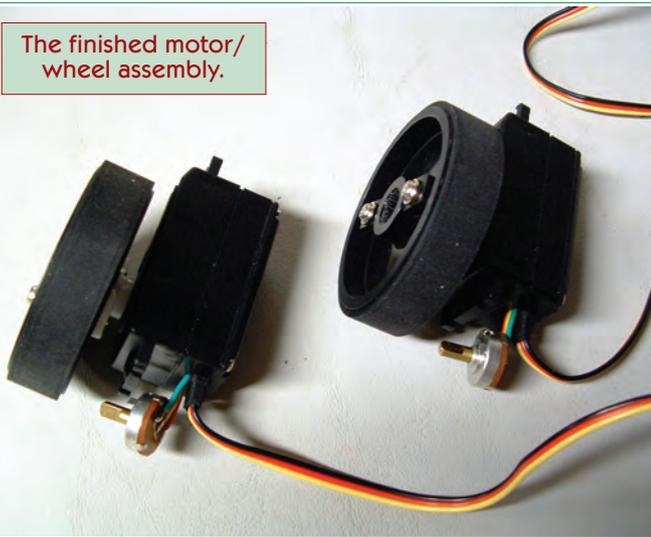


These horn drill gauges help to drill holes in wheels.

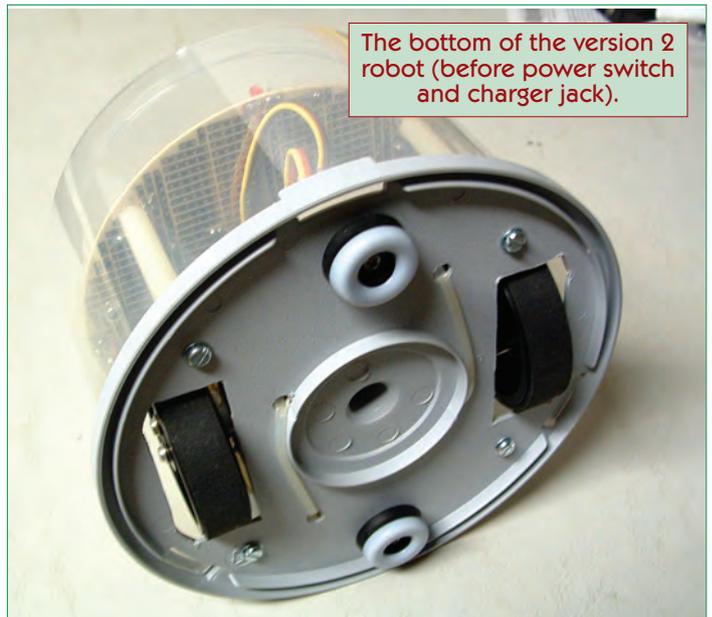
Note how the wheels are attached to the servo horn.



The finished motor/wheel assembly.



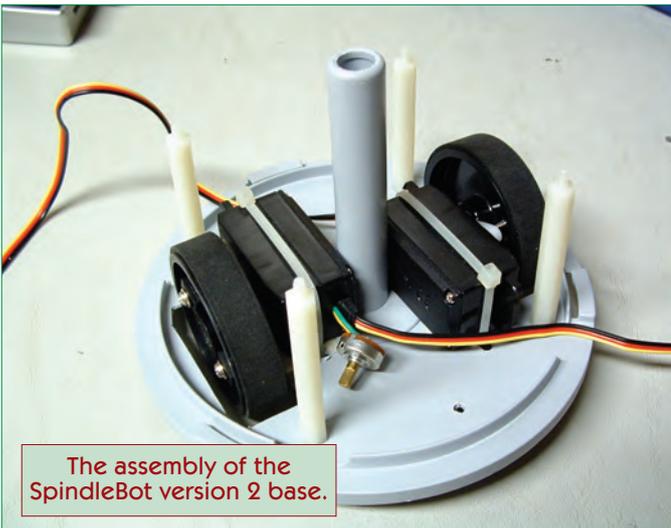
The bottom of the version 2 robot (before power jack and charger jack).



Low profile servos used on V2 and newer SpindleBots.



The assembly of the SpindleBot version 2 base.



etc., that can be re-purposed. Pull one of these printers apart and see what you can re-use!

NOTE: To make it easier to mount the wheels to the servo horns, I picked up a pair of Futaba horn drill gauges (part numbers FUTM2400 and FUTM2401) which helps ensure that the spacing for the holes is correct.

In order to keep the center spindle in place, it wasn't going to be possible to use standard servos. Luckily, there are a variety of servos available. The solution was to use a pair of low-profile Aileron servos for the drive. They are just short enough to provide the clearance needed to keep the center spindle. They are secured to the base with double-sided tape and cable ties like the first robot. For the main drive wheels, I used some of the large feed rollers from an

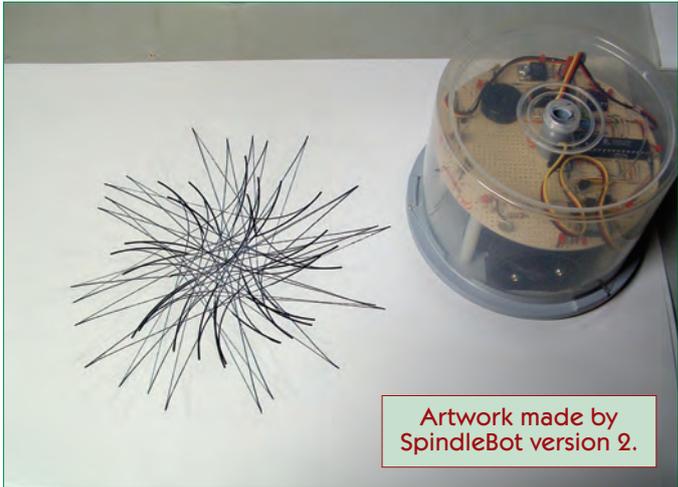
and provide excellent traction. There are normally three of these pressed onto the rear shaft in the printer. Removing them isn't hard. The method I use is to open a vise just slightly wider than the shaft, and then use a hammer to drive the shaft out. Once you've liberated the wheels, they are screwed and glued to the servo horn. It is easy to find used inkjet printers very cheap or often free. There are also many other useful parts such as optical sensors, encoders,



Sliders used at front and rear of SpindleBot base.



CDP2 prototype board (available from author, see Sources).



Artwork made by SpindleBot version 2.



Battery holders and charging plug.

old HP inkjet printer. The size is perfect for the SpindleBot and the traction is outstanding. The new wheels are easier to source, as well. The rest of the base is the same with the power switch, charging jack, and sliders all on this level.

A pair of 1" standoffs is used to mount a CD/DVD that has been trimmed down on two sides to clear the wheels. This second level holds the batteries and provides an upgraded 6V supply for the robot. There are two battery holders used. These are attached with double-sided tape. To ensure they sit level, I used a larger drill to counter-sink

each of the two mounting holes. This way, it won't interfere with the screws. The front holds two AA NiMH batteries and the rear one has three AA NiMH batteries. The extra weight towards the back of the robot helps favor the rear slider so it normally ends up touching the ground.

NOTE: In order to make the best use of space for the electronics, a new prototype PCB (printed circuit board) was created to leverage this form factor — the CDPCB. The first board in the series is the CDP2 which is a single-sided PCB that is very easy to work with. With standard .100" hole spacing, it can handle a wide variety of components and microcontrollers. There were times when I needed to isolate sections of the foils underneath. This is a simple process that can be accomplished with either a hobby knife or by lightly using a drill bit that is slightly larger than the width of the pad you want to remove.

The top level holds a CDP2 CD-protoboard which contains all the electronics for the robot. During the construction, I wanted to try using an OEM BASIC Stamp chip. It was all wired by hand on the protoboard using solid phone wire. I've found that wire is very easy to work with, and you can often get lengths of that wire for free. This board uses a standard host of sensors that you'd find on any Stamp style robot like the Boe-Bot or original Scribbler 1



Version 3 SpindleBot (bottom view).

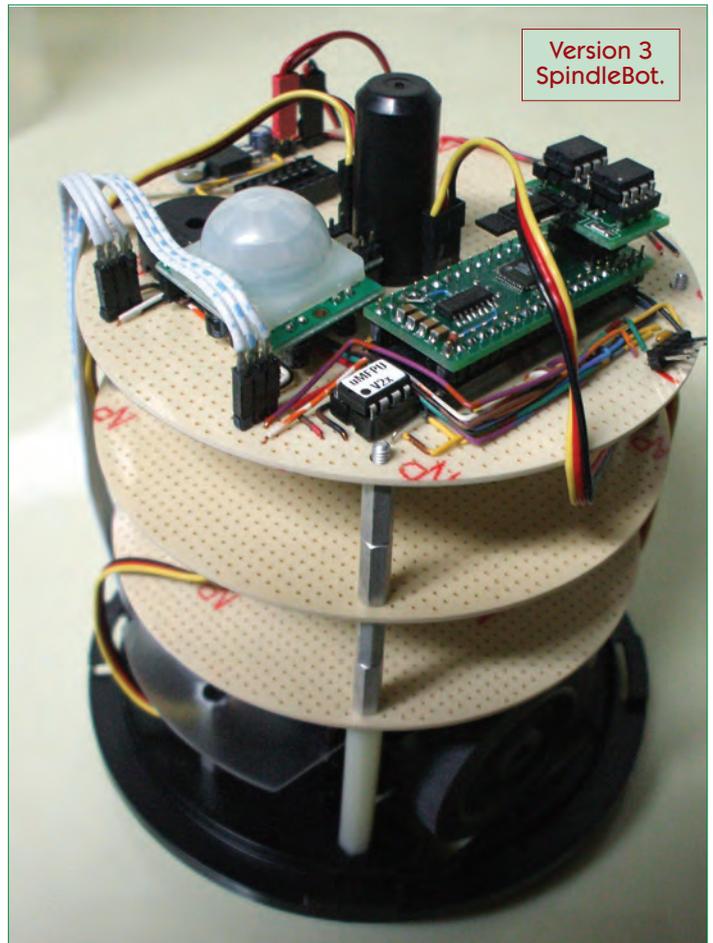
robot. On this SpindleBot, I used a PIR motion sensor and three CDS photoresistors. The outputs are configured to drive two main drive servos, a small piezo speaker, an optional pico servo for pen up/down, and a 74HC595 shift register to control a set of eight LEDs for some cool lighting effects. Most of these are optional, and you can use whatever sensors you want when you build your own version.

The top center of the CD case and the top center of the Spindle were drilled out. This hole allows for a pen to be placed in the center of the robot so it can draw while moving. When drilling into plastic, you need to be very careful not to crack it. To start, just use a small drill to make a pilot hole. Any drill bit 1/8" or less will do. Then, follow up with a Unibit or stepped drill to enlarge the hole. The stepped drills are much less likely to damage the plastic. If you try using a larger drill bit, it will more often than not break the plastic instead of making a proper hole.

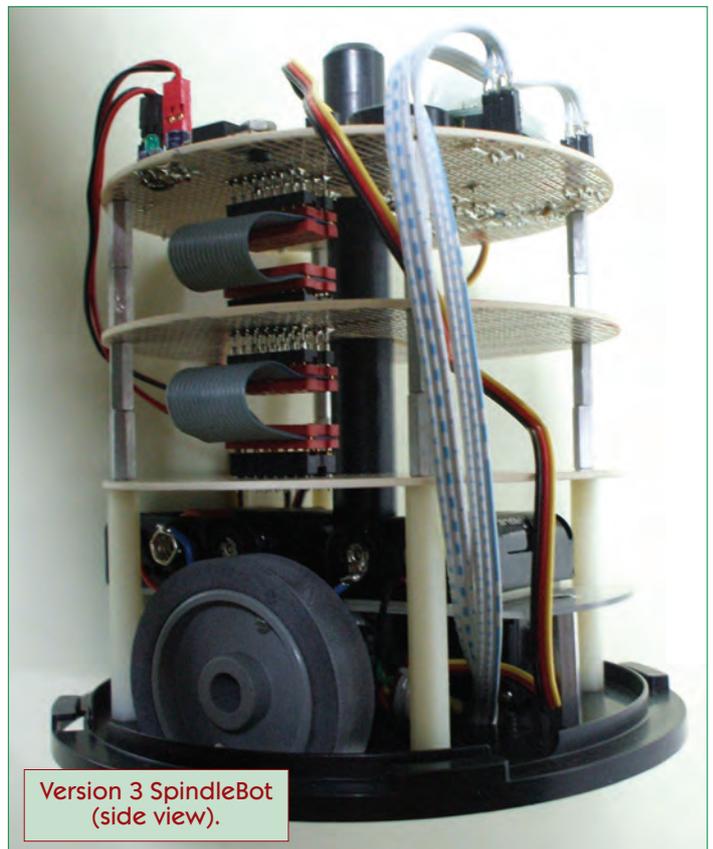
When using a 25 or 50 CD spindle, a small pico servo can be added to raise/lower the pen. Since they are so small and the pens are light, it can be attached to the top cover of the CD spindle with double-sided tape. For a more secure mounting, small aluminum angle brackets with screws are an excellent option. An example program that I wrote to test my robot turns the robot into an art bot. It has been a popular demo whenever I have shown off SpindleBots at local schools. I've also tried Scribbler 1 code which worked with some minor modifications to the motor control code and adjustments to pin assignments to match my board.

Creating the Ultimate SpindleBot

The latest version of the SpindleBot is even more refined. It uses one of the tall 100 CD spindles for its body. The construction is exactly the same as the shorter SpindleBot but has room for more levels of electronics and batteries. The CDPCB boards can be stacked on standoffs to



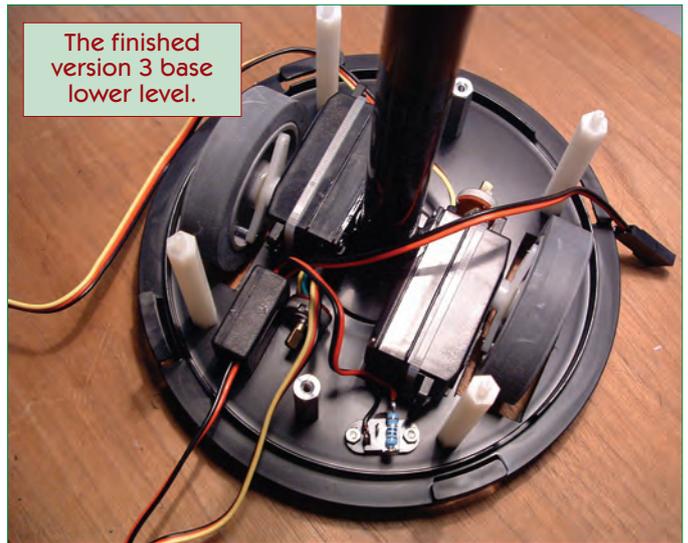
Version 3 SpindleBot.



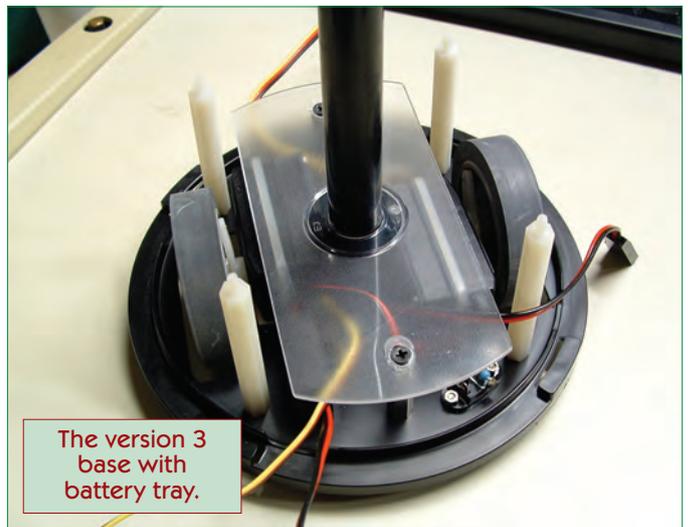
Version 3 SpindleBot (side view).



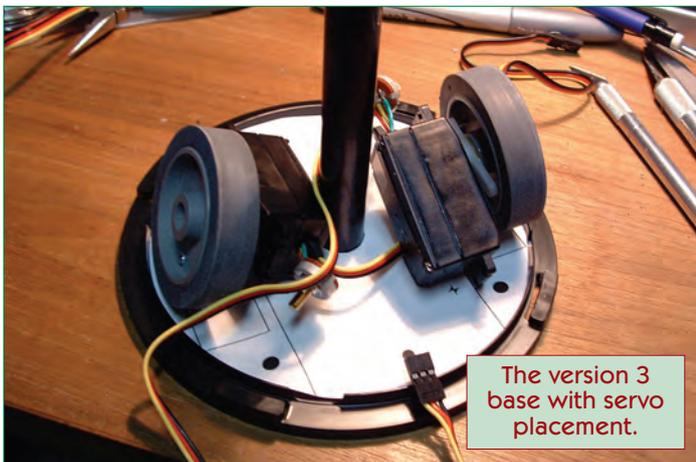
Battery monitor.



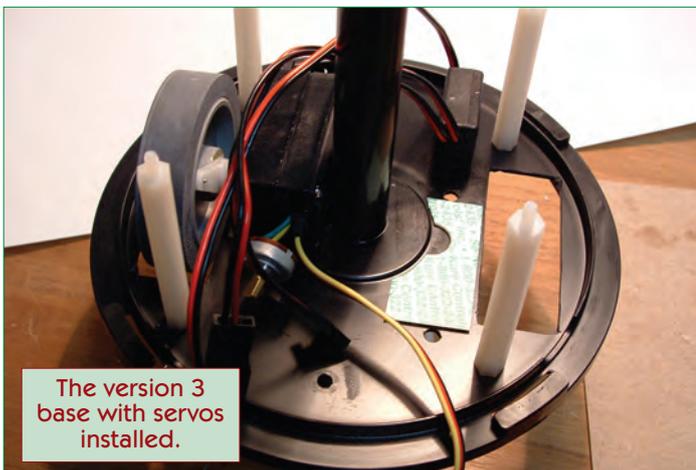
The finished version 3 base lower level.



The version 3 base with battery tray.



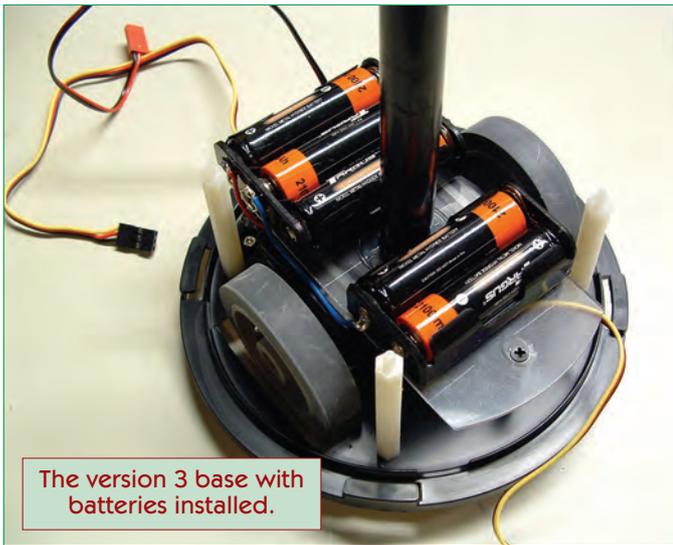
The version 3 base with servo placement.



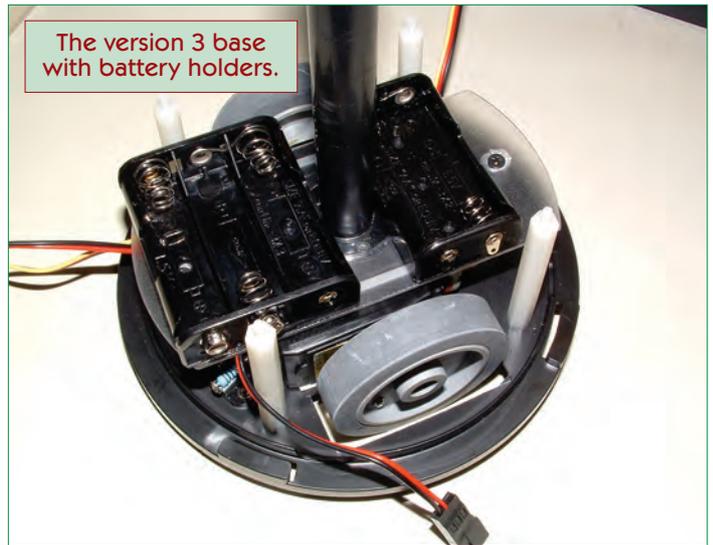
The version 3 base with servos installed.

Parts List

ITEM	DESCRIPTION
1	50 CD (1/2 height) or 100 CD (full height) spindle case
2	Short (Aileron) servos, Hobbico CS-59 or Tower Hobbies TS-59
2	Large paper feed rollers from a recycled HP inkjet printer
2	Small gliders w/spacers
1	Regular CD or DVD to trim for the battery tray
2	1" 4-40 or 6-32 hex spacers w/screws
4	2" 4-40 or 6-32 hex spacers w/screws
1	Dual AA battery holder
1	Triple AA battery holder
1	Controller of your choice (BASIC Stamp, SX48 OEM, Propeller, PICAXE, Arduino, etc.)
2	Parallax line sensors
1	Parallax motion detector
3	CDS sensors
1	Piezo speaker
1	Battery voltage monitor
1	Power switch assembly (Futaba, Airtronics, etc.)
1	Pico servo for optional pen up/down
1	Charging jack and optional current-limiting resistor
1	CDCB for control logic (more for full height robots)



The version 3 base with batteries installed.



The version 3 base with battery holders.

get at least two more boards on the robot. This version switched to a 40-pin OEM style BASIC 2p40 Stamp, but was upgraded to accept a Propeller processor for even higher performance. Just about any processor could be used if you have one you're more comfortable with.

In order to keep tabs on the battery voltage, I picked up a small voltage monitor meant for RC equipment. It is switchable for either 4.8V or 6V. This can go on the back of the second level and mounts to the battery holder. With it installed, it is easy to tell how the battery is doing and it provides a cool display. It clearly shows the load on the battery increase whenever the servos are moving, and when other circuits are active that draw a noticeable amount of current.

Now with a slick platform, it was time to expand upon that. For line following, a pair of the QTI line sensors were added under the base at the front of each of the SpindleBots. Some of the self-tapping screws recycled from an HP inkjet printer were used to secure the QTI sensors to the underside of the base. There are lots of options for sensors these days. With the tall 100 CD spindle, you can build a robot bristling with a wide array of sensors. One of the next things I plan on adding will be small XBee modules to let all the SpindleBots talk to one another and work as a group.

I haven't tried using a 10 CD/DVD or 25 CD/DVD spindle but I'm sure that someone will make one into an interesting robot. To help classify any new SpindleBots out there, I'm going to put forth the following size guide which is very reminiscent of the old floppy standard: 25 CD/DVD case 1/4 height; 50 CD/DVD case 1/2 height; and 100 CD/DVD case full height. I recently spotted a short 10 CD/DVD spindle case. I guess that could be classified as a 1/8th height spindle.

That's a Wrap

There is now a whole new class of robots that you can build, and I think these will be great in a classroom environment. In a classroom setting, it could help teach an

interesting way to recycle and/or re-purpose many parts. Those that can't be used could be identified by the material type (metal, plastic, etc.) and then recycled. It would help teach students about the types of materials used to construct an inkjet printer and how those same materials can be recycled.

If you build your own SpindleBot, I would enjoy seeing a picture of your robot or hearing from you. Whether you are building robots for school or just a hobby, I hope you find building your own SpindleBot as fun and rewarding as I did. **SV**



Different size spindles to use for making a SpindleBot.