A CheapBot controller needs a robot body to function. An ideal robot body for the beginner consists of two sheets of Syntra plastic, separated by four bolts. The bottom deck contains the robot controller along with the servo motors and wheels. The top deck contains the switches, indicator LEDs, and battery holders. Since the robot controller is seldom handled, it’s mounted to the bottom deck. This leaves the top deck free for the LEDs, switches, and battery holders, which are frequently manipulated. However, to make it easy to access the I/O ports on the controller, the top deck is only half the length of the bottom deck.

Onwards and Upwards,
Your near space guide

Figure 1. A CheapBot Robot

Materials
Six by 8.5 inch rectangle of Syntra (Bottom Deck)
Three by six inch rectangle of Syntra (Top Deck)
(2) 3/8 inch by 3/8 inch basswood strip 5-3/4 inches long (Motor Rails)
(6) #2-56 nylon-insert locknuts (nylocks)/bolts/washers ¾ inches long
(2) Servo motors *
Servo mounting hardware **
(4) #4-40 flathead bolts/nylocks ¼ inch long
(4) #6-32 bolts/nuts/washers two inches long (Corner Pillars)
1-5/8 inch plastic draw pull handle
#8 sheet metal screw, two inches long
7/32 inch diameter plastic tube (7 inches long) ***
¼ inch diameter plastic tube (1-1/2 inches long) ****
(4) Crimp pins
1 by 5 pin plastic header housing
(2) Plastic peanut butter jar lids
(2) #84 rubber bands
(8) #2-56 bolts/nylocks ¼ inch long

* This is part number GM4 from HVW Tech (www.hvwtech.com)
** Each servo motor comes with a bag of hardware
*** Use a bag of Evergreen 227 tubes or equivalent (available at many hobby shops)
**** Use a bag of Evergreen 228 tubes or equivalent (available at many hobby shops)

Tools
Small drill (a Dremel works well)
Exacto knife
Utility knife (or table saw)
Small screw driver (straight slot and Phillips head)
Ruler (a T-square is better)
Pencil

Bottom Deck (the 6 by 8.5 inch Syntra sheet)

Figures 2 and 3. Mark the locations for the six holes and two lines on the six by 7.5 inch Syntra, as shown above (note, the Syntra should be marked before it is bent).
The bend line on the bottom deck is where it bends at a right angle to form the nose of the robot. The nose provides a bumper to mount circuits like a proximity detector. Behind it is a space where circuits like a line follower PCB can fit. The pencil mark is the location where the forward motor rail will is mounted. The four holes marked with P are where the bolts for the four pillars are mounted to the bottom deck. The hole labeled as M is the opening where the wires from the motors are brought up form the underside of the bottom deck. The hole labeled T is where the #8 sheet metal screw is a mounted for the third wheel or tail of the robot.

Drill 3/16 inch diameter holes for the four pillar holes (P), a ¼ inch hole for the tail hole (T), and a ½ inch hole for the motor wires hole (M). A small drill press is perfect for this, but a Dremel or even an electric hand drill works well.

Figure 4. Use a hot air gun to soften the Syntra along the bend line (do this in an area with ventilation).

Figure 5. The Syntra will be hot, therefore bend it into shape against the right edge of a counter using two wooden blocks.
Figure 6. The robot base will look like this once the Syntra cools.

Mounting Rails for the Motors

![Diagram of motor rail positions]

**Figure 7.** Mark the location of the three holes to be drilled through the motor rails (and the bottom deck).

Place a basswood (or spruce) motor rail on the bottom of the robot base and against the front motor rail line. Note that the wooden motor rail aligns with the front motor rail line on the underside of the bottom deck, but on the tail side of the motor rail line. Don’t mount the motor rail so it takes up space between the motor rail line and the nose of the robot. Leave that 1-1/2 inches free to mount the line follower in the future. Hold the wooden motor rail in place and drill 1/8 inch holes through the three marked locations and the bottom deck. Then attach the front motor rail to the bottom deck with the 3/4 inch long #2-56 hardware.

**Figure 8.** Use two screws from the bag of parts that came with the servo motors to mount the servo motor to the front rail. Note that you’ll just use one screw on each side of the servo motor case.
Figure 9. Mount the servo motors so their power cable is on the tail side of the robot and not the nose side.

Slide the rear motor rail up against the servo motors. You’ll see it doesn’t fit properly because of each motor’s power cable. Use a pencil to mark where the cables lie on the wooden motor rail.

Figure 10. Remove the rail and cut a notch ¼ inch wide centered in the lines you drew for the cables. A small Exacto saw or hack saw works well. Cut the notch around 1/8 inches deep.

Figure 11. Use an Exacto knife to remove the wood in the notch. Don’t cut any deeper than necessary to clear the servo motor power cables.
Figure 12. Hold the rear motor rail against the servo motors and drill its three mounting holes through it and the bottom deck.

Figure 13. Use two more screws to mount the servo motors to the rear motor rail.

Figure 14. The ends of the wires in the servo motor cable will not connect to the robot controller, so you’ll need to crimp connectors onto the end. The crimp pins come on a reel, as shown above. After crimping the cable, the crimped pins snap into plastic crimp housings. One is visible above the reel of crimp pins.
Chances are your crimp housing will come in one piece. Two housings are needed and each housing must accept two crimp pins. A housing like this is called a 1 by 2 housing and it has two pockets next to each other. Each pocket is designed to hold a crimped pin. Cut your housing into two pieces by splitting the housing down the middle of an unneeded pocket (in other words, down the third pocket from the end). Then sand, trim, or file the cut edges until they are smooth. Repeat for a second time to make the second 1 by 2 housing.

The wires in the servo motor come stripped; however, they’re too long. So cut back the stripped ends to half their length. A crimp pin has two pairs of tangs. The wide ones near the opening of the crimp wrap around the bare wire and the narrower, but longer ones wrap around wire insulation.

Figure 15. Insert the bare end of a wire into the opening of the crimp and use pliers to wrap the tangs around the wire as shown above. There are crimpers designed to do this, but in a pinch, needle-nose pliers or even small wire cutters (be careful using wire cutters to crimp) can be used to crimp the pin. Afterwards, apply a tiny drop of solder to the crimp pin at the back end. Do not apply solder near its square opening.

Figure 16. The crimp pins fit snug inside the plastic housing and won’t pull back out because of locking tongues in the crimp and the housing. For the crimp to be properly locked, it must be inserted with the proper orientation. So insert the crimp into the housing with its locking tongue (labeled on the close up of the crimp) on the same side as the locking tongue of the housing. The tongue is most easily identified as the side of the housing with the two openings.
Slide the motor cables onto the right angle motor headers located on the back of the robot controller. It’s not important which motor cable connects to which header, nor is the orientation of the motor cable connector important. The proper driving of the robot is handled in software.

**Wheels (do two times)**

![Peanut butter jar lid](image1)

**Figure 17. A peanut butter jar lid makes the perfect wheel for a CheapBot robot.**

Look at a lid and you’ll see there is a dimple in its center. Place the lid on a scrap piece of board before drilling. Use a 1/8 inch diameter drill bit to drill a hole as close to the center as you can. Drill the hole from the interior side of the lid so that the drill bit does not press and flex the plastic lid. A drill press will make this easier to do, but it can still be accomplished accurately enough if someone can hold the lid still while it’s drill.

![Bolted servomotor horn](image2)

**Figure 18. Bolt a large round servo horn to the center of the lid with a #2-56 bolt and nut. The length of the bolt is not critical as long as it can bolt the two disks together. Then tighten the nut and bolt so the round servo horn cannot rotate while you drill the next hole.**
Figure 19. Make one of the holes in the servo horn larger by drilling through it and the peanut butter jar lid with a 1/8 inch drill bit. Drill one of the four holes that are most distant from the center of the servo horn.

Figure 20. Drop a #2-56 bolt through the hole you just drilled to prevent the servo horn from spinning. Then drill out the remaining three holes of the servo horn.
Figure 21. Remove the #2-56 bolts and servo horn from the lid and enlarge center hole with Exacto knife until it’s around to 5/16 inch diameter (in other words, large enough for the black bolt in the servo to pass through). Spin the Exacto knife in full 360 degree turns or else the enlarged hole will be oval rather than circular.

Figure 22. Mount the servo horn to the peanut butter lid with four #2-56 bolts ¼ inch long and nuts. It’s better to use nylon-insert lock nuts (nylocks) in place of the flat nuts shown in the picture above.

Figure 23. Wrap a #84 rubber band around rim of the lid for traction.
Third “Wheel” or Tail Dragger

The proper length for the tail dragger bolt depends on the diameter of the peanut butter jar lids, however, for typical lids, a bolt two inches long is correct. Drive the screw through the tail hole in the bottom deck. Cut a ¼ inch plastic 1-1/4 inches long and slide it over the bolt. Then screw on the plastic drawer pull.

Figure 24. The tail dragger wheel will look like this when complete.

Top Deck (the three by six inch Syntra sheet)

Figure 25. Mark and drill four holes in the Top Deck as illustrated above. Use a 3/16 inch drill bit for these holes. These four holes will line up with the four pillar holes in the bottom deck.

Drive #6-32 bolts, two inches long through the holes. Cut pieces out of the ¼ inch diameter plastic tubing. Cut the pieces 1-5/8 inches long and keep them as close to the same length as possible. Then slide a plastic tube over each bolt and bolt the Top Deck to the Bottom Deck.

The battery holders and toggle switches attach to the Top Deck. And at a later time, you may want to attach sensors, like a beacon locator, to the Top Deck also.

Place the robot controller’s two battery holders, side-by-side on the Top Deck. Mark the center of two of each battery holder’s bolt holes on the Top Deck. The robot controller’s
toggle switches mount between two side pillars, so use a straight edge to draw a line between the centers of two pillar bolts. Now remove the Top Deck from the Bottom Deck and drill holes for the toggle switches and battery holders. If the robot controller used subminiature toggle switches for power, then drill 7/32 inch diameter holes into the Syntra Top Deck for the toggle switches. Since the battery holders are bolted with #4-40 bolts, use a 5/32 inch diameter drill bit to drill their holes into the Syntra.

Figure 26. Drilling holes for the toggle switches and battery holders

Put the battery holders back on top of the Top Deck and use two #4-40 flathead screws and nuts to bolt each battery holder down. Flatheads sit flush to the surface of the battery holder and will not try to push the batteries out of the battery holder like a round head bolt will. For a more permanent attachment, use #4-40 nylocks in place of the nuts. Then bolt the Top Deck back on to the Bottom Deck. Remove the nuts on the collars of the toggle switches and set the nuts aside. Pass the switches from the underside of the Top Deck through the toggle switch holes. Orient the toggle switches so that their bats lean in the same direction when the toggle switches are in the off position, then tighten the nuts on the collars of the toggle switches. Don’t over-tighten the nuts or you could break the toggle switches.

Figure 27. Installing the second toggle switch to the Top Deck.
Testing the CheapBot Robot Body
Flip the toggle switches to the off position and insert cells into the battery holders. Now flip on the switches and you should observe the robot controller LEDs light up.

Now download the Drive Robot code into the robot controller and verify the robot drives forwards and backwards, as well as turns left and right. Observe the operation of the robot, as chances are you’ll have to rename the subroutines used to drive the robot.

Finally, you may want to manage your robot’s cabling by using wire twist ties or spiral wrap.