Vex™ Robotics for Beginners

Modesto Jr. College
Summer 2008

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Note: All projects in this course can be built with the Vex™ Starter Kit alone. More fun (and expensive) projects will be introduced in the Intermediate Course.

The Squarebot

Kits needed: 1 Vex Starter Kit

Pieces to cut: none

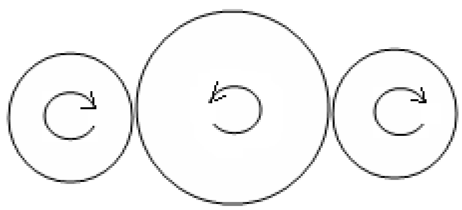
Bill of materials: See the Vex Inventor's Guide, Section 2.

Build Sequence: See the Vex Inventor's Guide, Section 2.

Project Notes and Engineering Principles

Gearing and Direction of Motion

The Squarebot has 3 gears on each side. Watch how the motor *drives* the center gear, and the 2 side gears are *driven*. These wheels will turn in the directions as shown below:



Note that the direction of rotation alternates back and forth from one gear to the next. Thus, gears with an odd number of gears in between (like the end gears shown above, with 1 gear between) will turn in the same direction, while gears with an even number of gears between (including 0) will turn in opposite directions.

Drive Trains (Four-Wheel Drive)

Note that the motor on each side causes 2 wheels to turn, making this a 4-wheel drive robot. As a result, the Squarebot is highly maneuverable – it gets good traction and is easily controlled. It is also relatively fast because of its geared-up configuration (more on that in the next project). Two-wheel and 6-wheel drive are also commonly used. There are other types of drive trains which allow wheels to operate independently of each other or the chassis, including holonomic drives and swerve drives.

The Flexigearbot

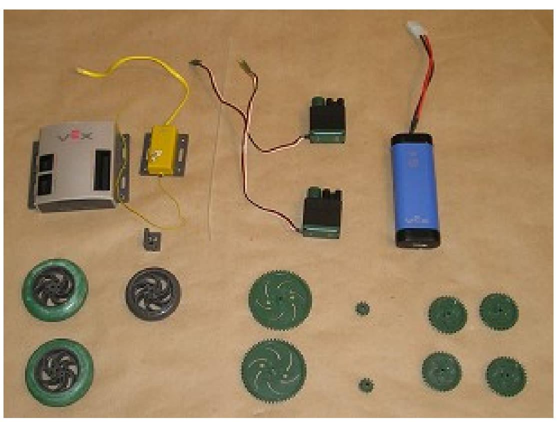
<u>Kits needed:</u> 1 Vex Starter Kit

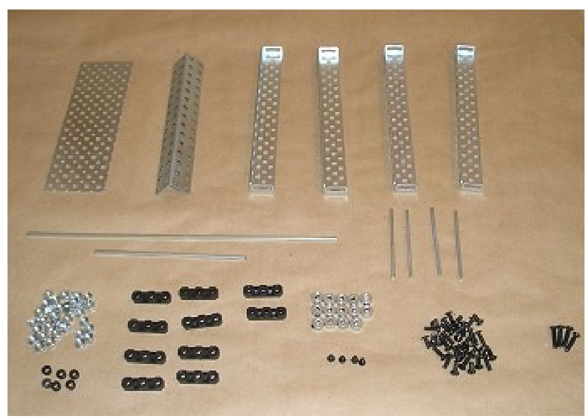
<u>Pieces to cut</u>: Cut one 12" square bar (axle) into 2 X 6" pieces (optional – do not cut if you do not have additional square bars beyond the Starter Kit)

<u>Bill of Materials</u>

1 microcontroller
1 RF receiver module
1 antenna sleeve holder
1 antenna sleeve
2 motor modules (NOT servo motors)
1 battery pack
2 small wheels (with rubber tires)
1 small wheel hub (rubber removed)
2 large (60-tooth) gears
2 small (12-tooth) gears
4 medium (36 tooth) gears

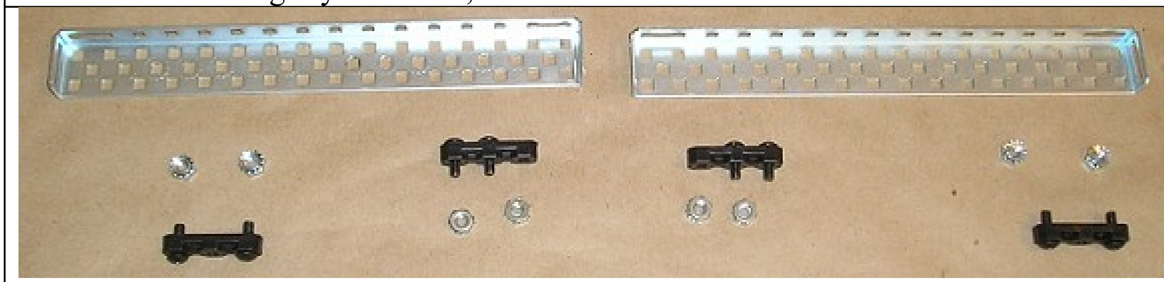
1 metal plate (5" X 15")
1 chassis bumper
4 chassis rails
1 long square bar (6" preferred, but 12" OK)
4 square bars (3")
36 keps nuts
6 small plastic spacers (.182)
10 bearing blocks
14 collars
4 small motor screws (1/4")
32 medium length screws (3/8" or ½"—use the 3/8" in tight corners)
4 long screws (3/4")



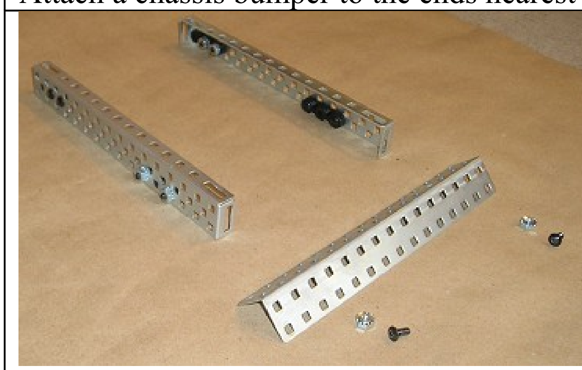


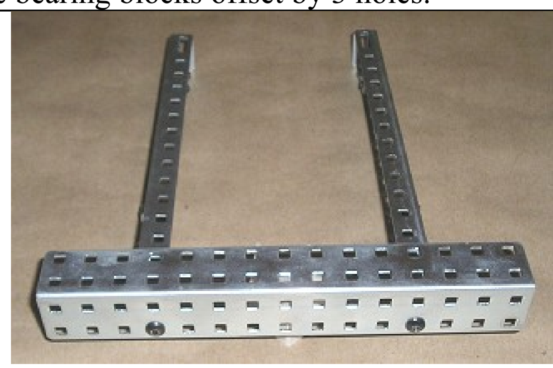
Build Sequence

Attach bearing blocks to the chassis rails as shown. The center pair of blocks is attached to the middle row of holes, closest to the edge with screws facing up. The outer pair of blocks is located in the last row, offset 3 holes from the edge with screws face down. The rails are mirror-image symmetrical, not identical.

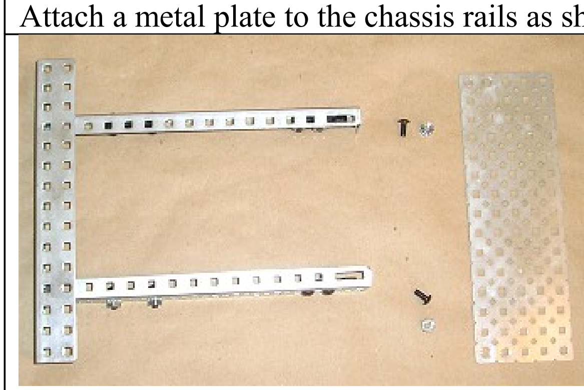


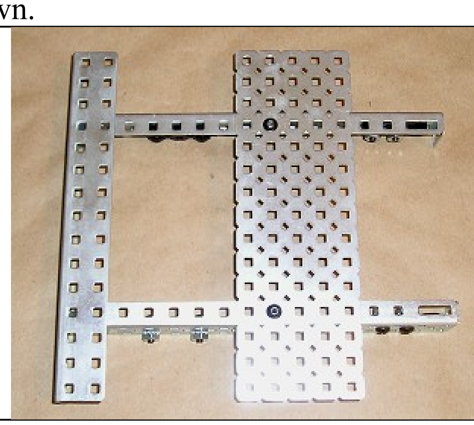
Attach a chassis bumper to the ends nearest the bearing blocks offset by 3 holes.



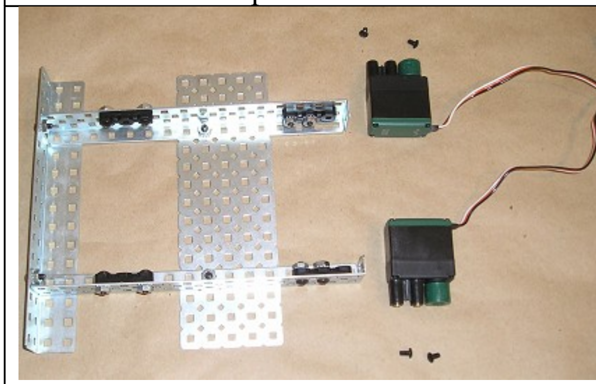


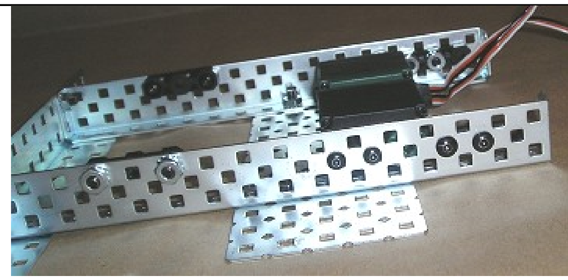
Attach a metal plate to the chassis rails as shown.

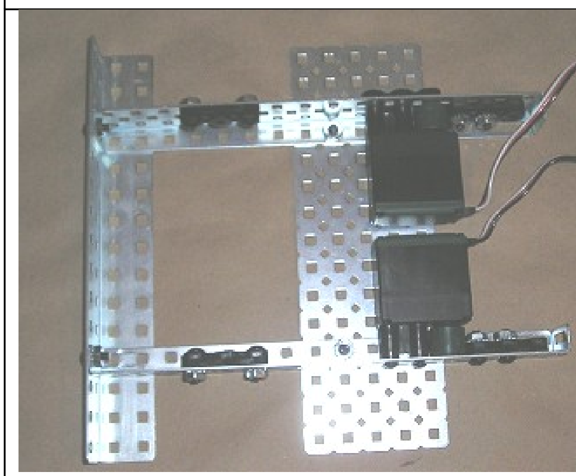




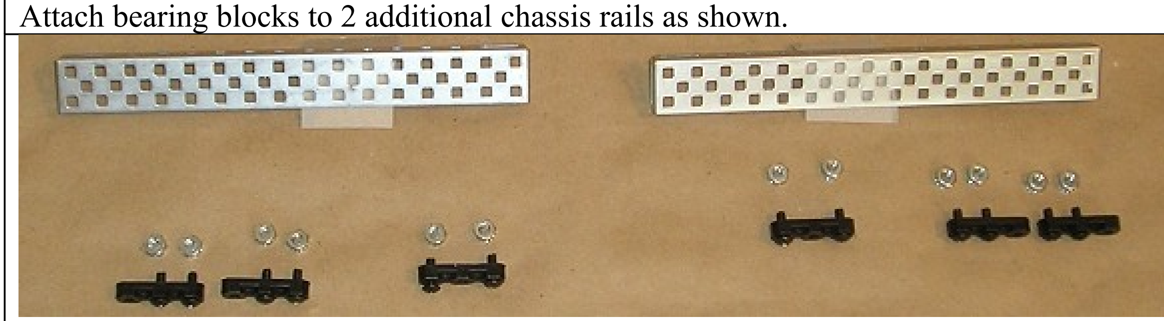
Turn the chassis upside down and attach motors on the inside of the rails.

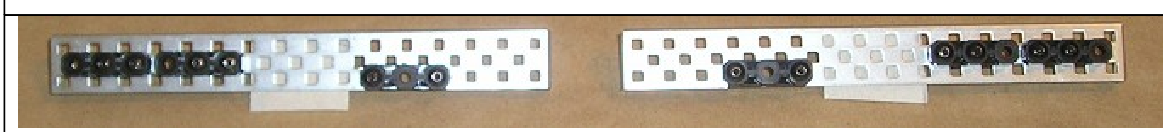




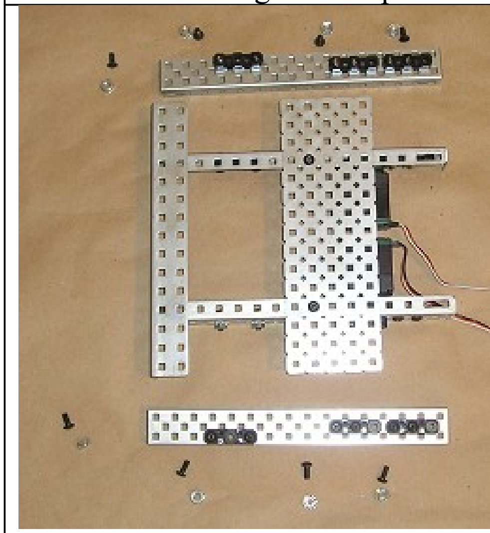


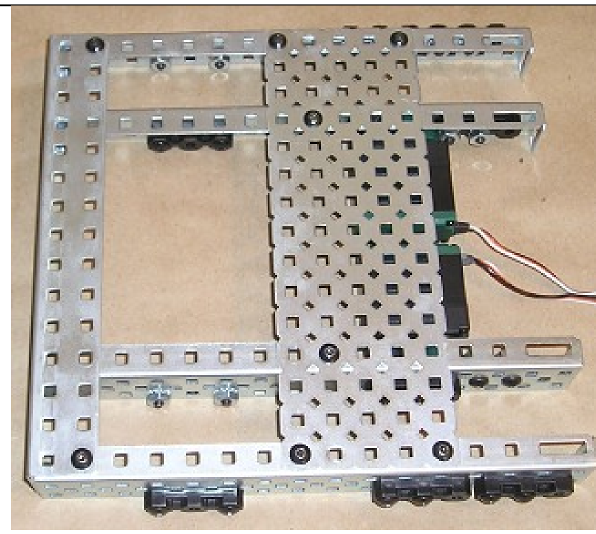
Attach bearing blocks to 2 additional chassis rails as shown.



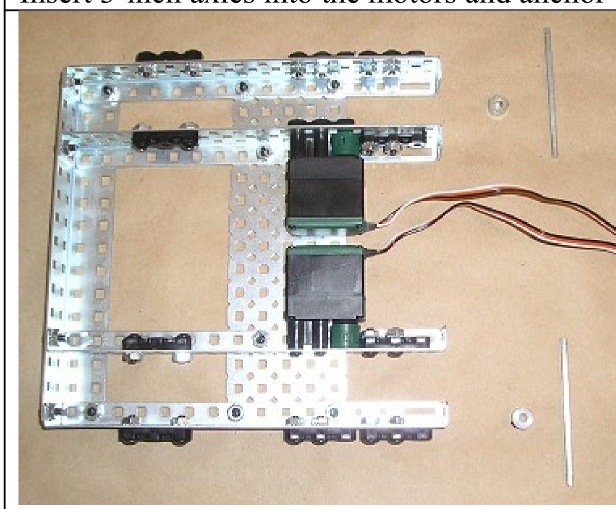


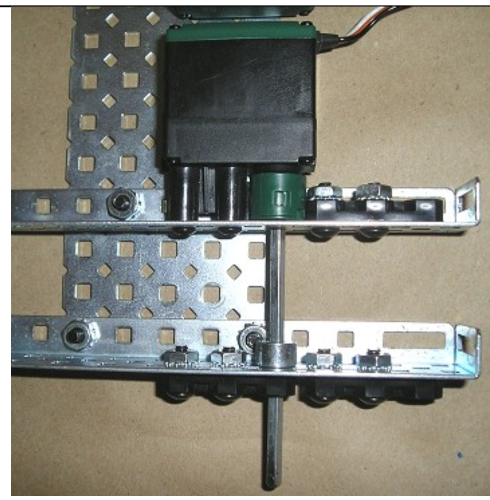
Turn the chassis right-side up and attach the 2 outer rails.



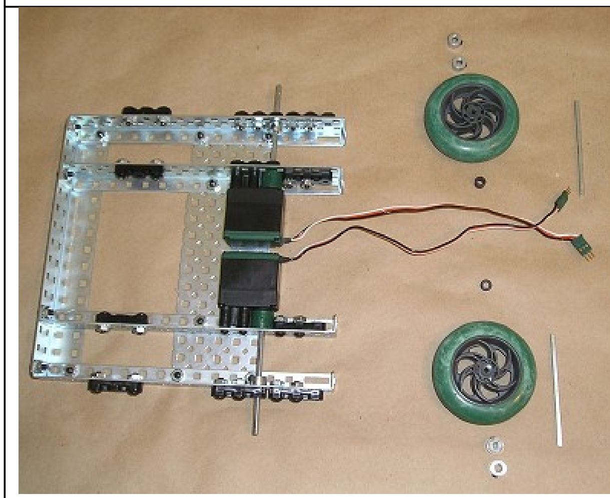


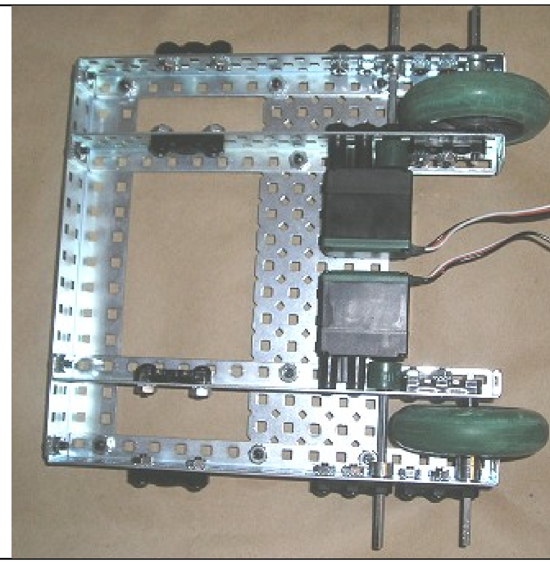
Insert 3-inch axles into the motors and anchor with a collar from inside the chassis.



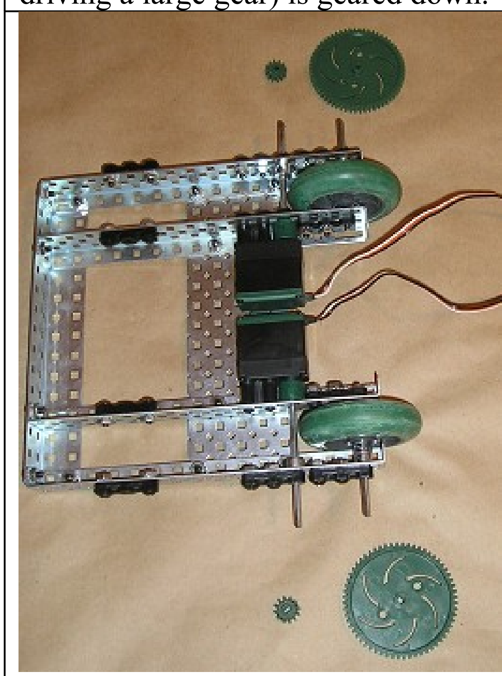


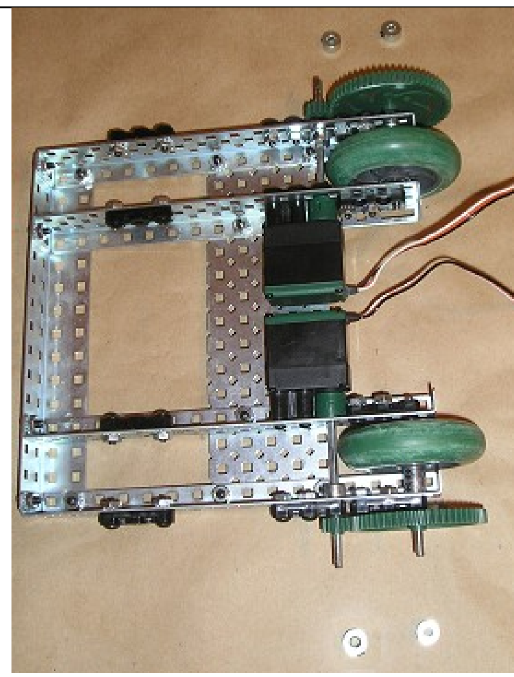
Attach the wheels, using 2-inch axles. Anchor with 2 collars outside and 1 small spacer on the inside of the wheel.

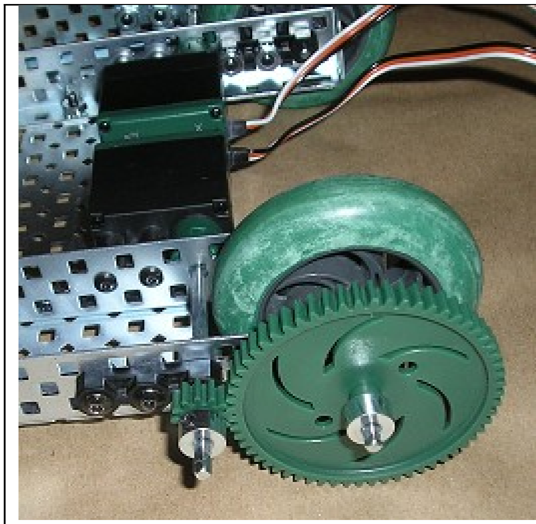




Attach the gears, anchoring with collars on the outside. This configuration (small gear driving a large gear) is geared down.

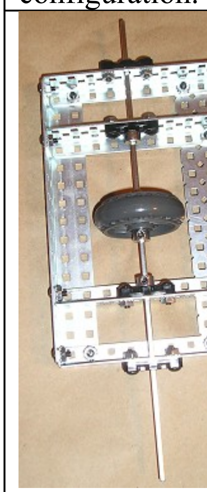




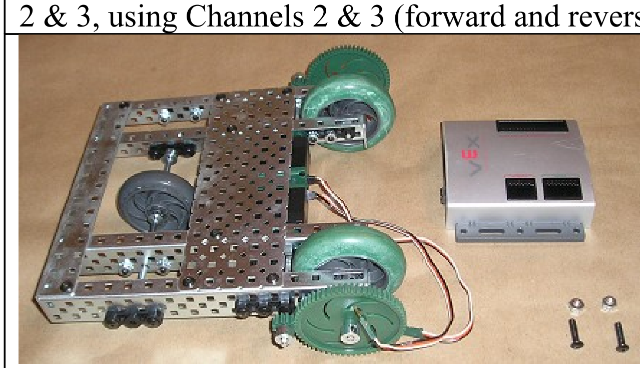


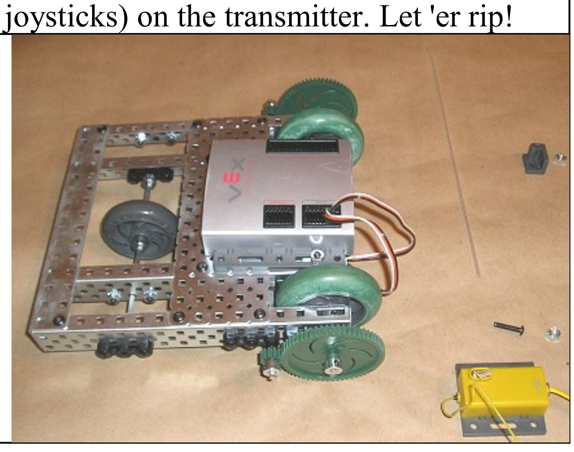
Attach the castor wheel, anchoring with collars next to the wheel and inner rails. The 6-inch axle is preferred (making the outer bearing blocks extraneous), but a 12-inch axle may be used if to avoid cutting

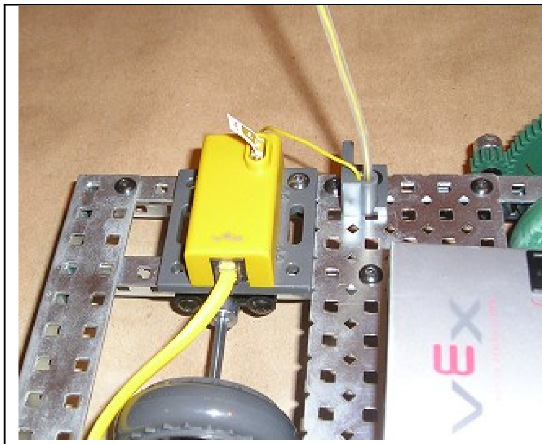
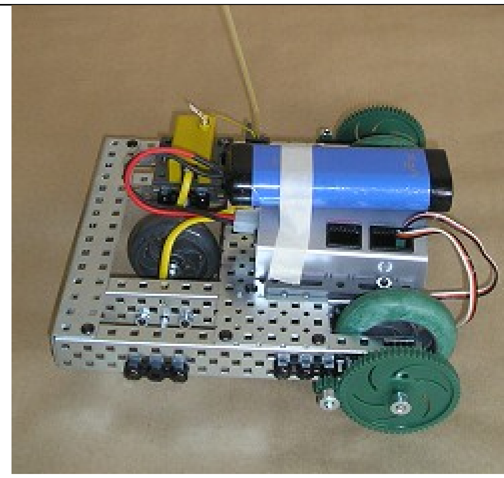
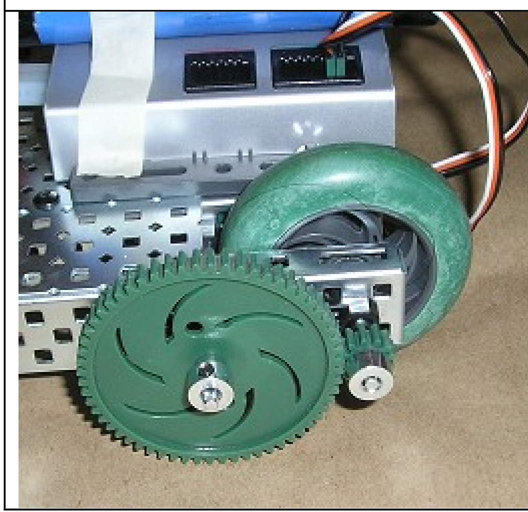
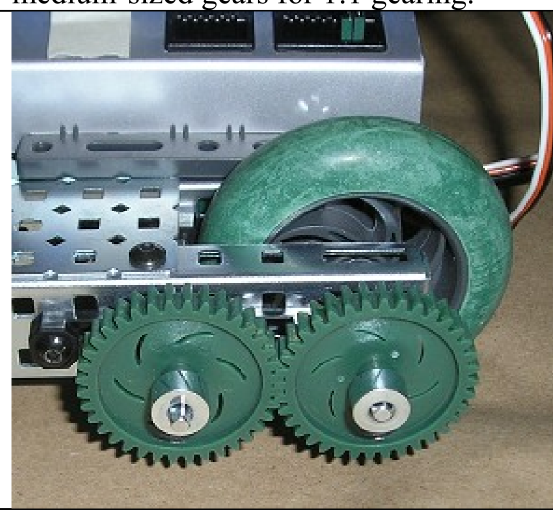
Alternate axle configuration.



Attach microcontroller, RF module, antenna, and battery. Plug motor wires into Motor Ports 2 & 3, using Channels 2 & 3 (forward and reverse joysticks) on the transmitter. Let 'er rip!





	
Alternate configurations:	
Exchange the gears for a geared-up bot.	Replace the large and small gears with 2 medium-sized gears for 1:1 gearing.
	

<u>Project Notes and Engineering Principles</u>

Gear Ratios

The speed of a robot largely depends on 1) how fast the motors are turning, 2) the size of the wheels, and 3) the gear ratio connecting the driving motor to the driven wheels. For example, suppose a motor is connected to an axle which turns a 60-tooth (large) gear. A single rotation moves this gear through 60 teeth. If this gear is coupled with a 12-tooth gear, one rotation will drive the small gear through 60 teeth. However, since only 12 teeth are needed to produce a single rotation of the small gear, this gear will make 5 complete rotations every time the large gear turns once. This means that the wheel will rotate 5 times as fast as the motor. Causing the driven axle to move faster than the drive axle is called *gearing up*. While going faster may seem like a good thing, you can't get something for nothing, and what is gained in speed is lost in *torque*, or strength of turning.

The Flexigearbot has 3 configurations: geared up, geared down, and geared a 1:1 (same) ratio. Try all 3 and test your robots for different parameters such as speed, ability to climb a slope, ease of turning around obstacles, and effectiveness on different surfaces, like tile, carpet, and gravel.

One factor that biases the outcome should be noted: the large gears are almost the same size as the small wheels, and if the gears touch the ground (likely to happen on soft, uneven surfaces like carpet), the friction will work against the wheel motion or with it. When geared up, the gears oppose the wheel motion; when geared down, they assist it.

Quiz question: What type of gearing does the Squarebot use?

Two-wheel Drive

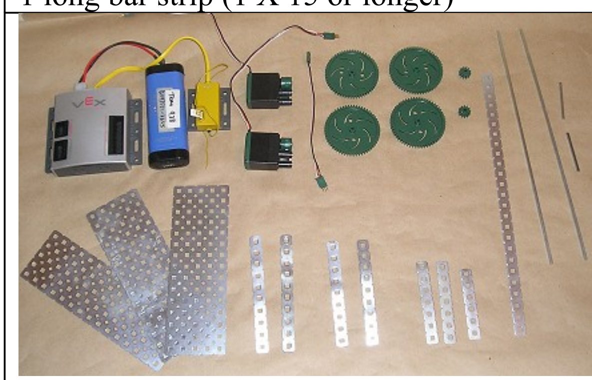
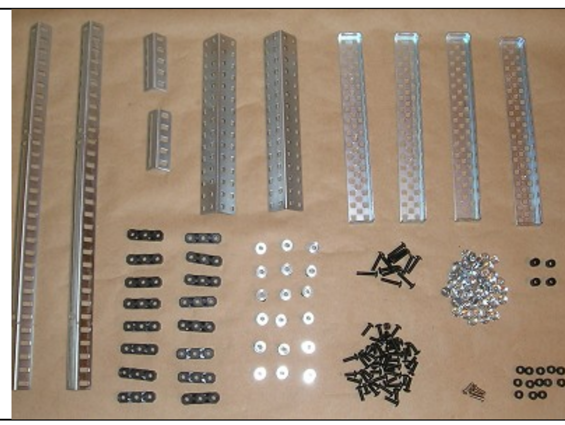
This robot has 2 powered wheels and a "dead" castor wheel. Not surprisingly, 2-wheel drive robots are often called castorbots. Castors may be pivoting castors, like those on a swivel chair, or they may simply be a low-friction object that drags on the ground (sometimes called a *skid*). Rubberless wheels, omniwheels, and bearing blocks are often used for castors. Because of the lack of traction, castorbots tend to be more difficult to maneuver than 4-wheel drive robots.

Animal Grabber – Part 1: The Gripper

Kits needed: 1 Vex Starter Kit (plus 1 extra plate 5 X 15 holes, if available)

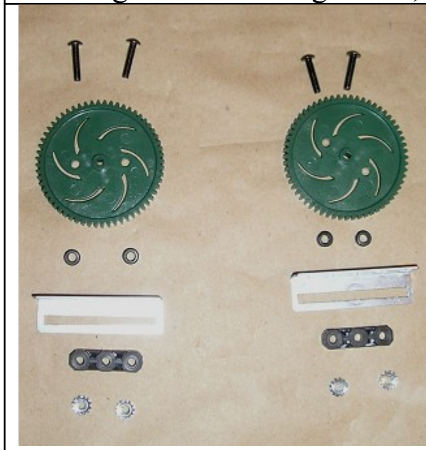
Pieces to cut: Cut 2 long bars (15 hole) into 10 + 9 + 6 holes
Cut one piece (6 holes) off another long bar
Cut two pieces (2 ½ ") off 2 angle bars (15" original length)

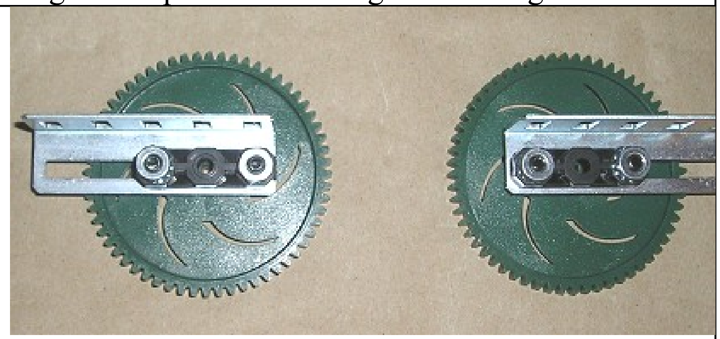
Bill of Materials (for Parts 1 and 2)

1 microcontroller 1 RF receiver module 1 battery pack 2 motor module 1 PWM extension cable 4 large (60-tooth) gears 2 small (12-tooth) gears 2 square bars (12") 2 square bars (2") 2 or 3 plates (5"X15") – 3rd is optional 2 long bar strips (1 X 10 hole) 2 long bar strips (1 X 9 hole) 3 long bar strips (1 X 6 hole or longer) 1 long bar strip (1 X 15 or longer)	2 angle bars (15" or shorter) 2 angle bars (2 ½ ") 2 chassis bumpers 4 chassis rails 16 bearing blocks 18 collars 12 long screws (3/4") 47 medium screws (3/8" or ½ ") 59 keps nuts 4 long motor screws 4 large spacers 13 small spacers
	

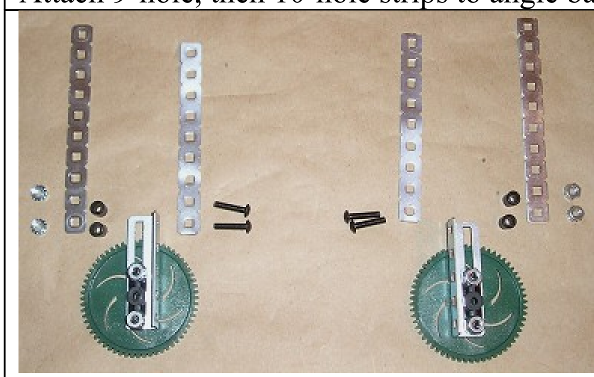
Build Sequence

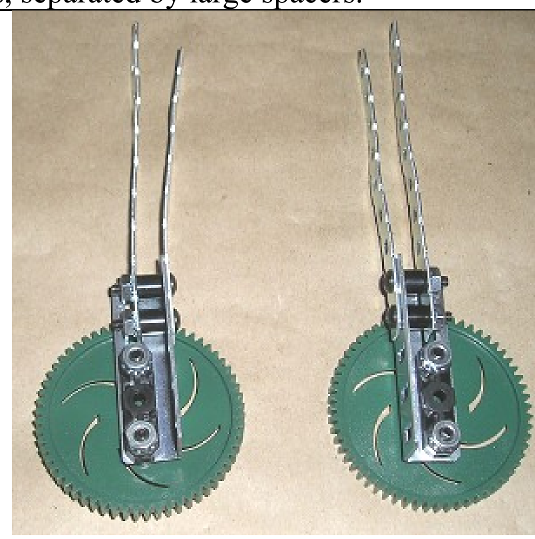
Attach gears to 2½" angle bars, placing small spacers between gears and angle bars.



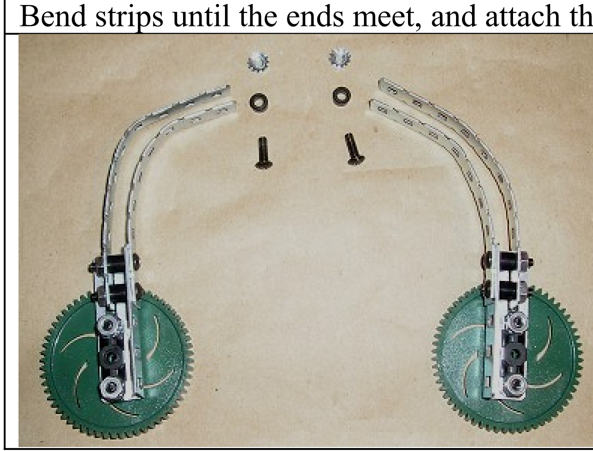


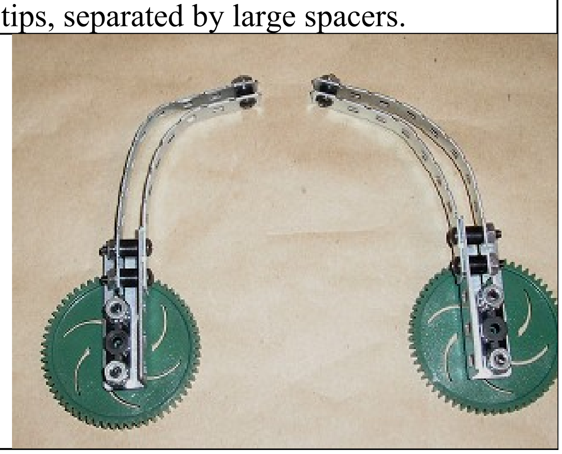
Attach 9-hole, then 10-hole strips to angle bars, separated by large spacers.



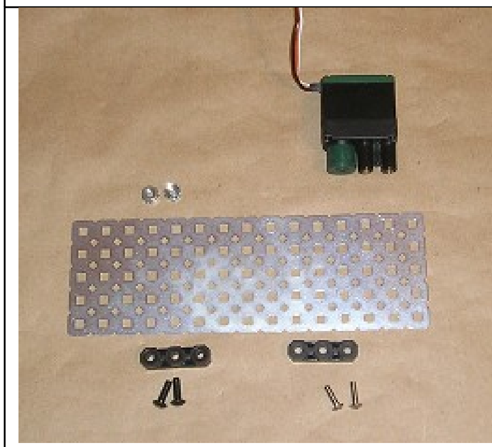


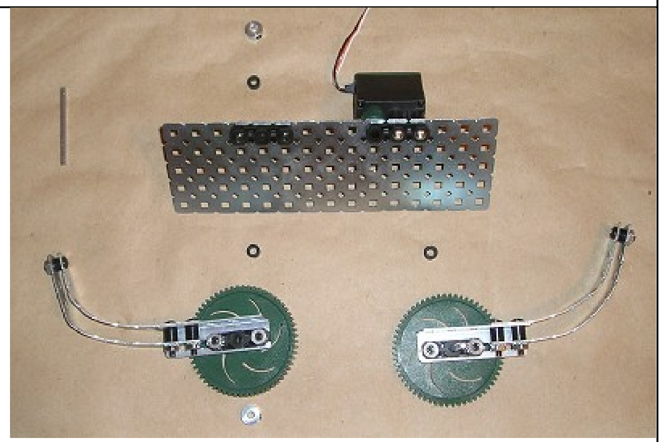
Bend strips until the ends meet, and attach the tips, separated by large spacers.

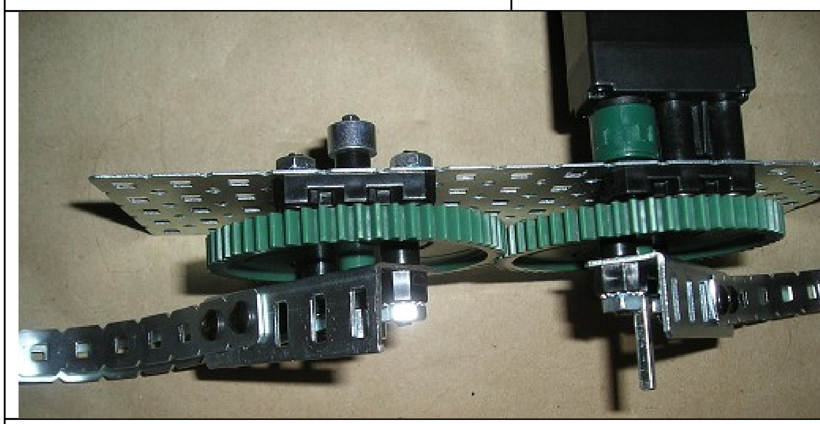




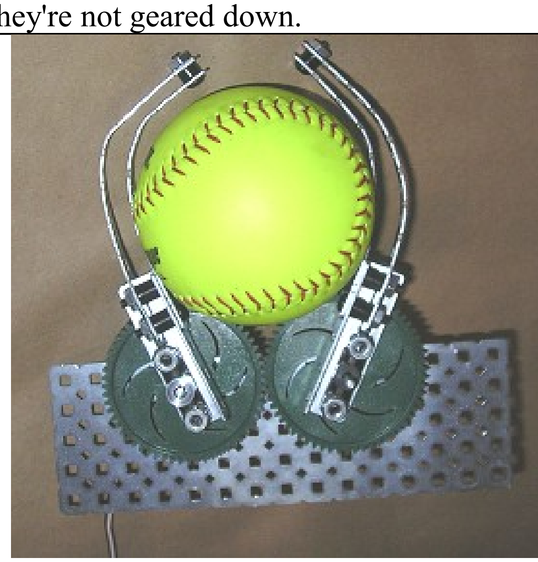
Attach bearing blocks, motor, and "fingers." Nest gears so that the "fingertips" are more or less symmetrically placed. Note that it's useless to attach a collar to the motor axle, as this does not prevent the axle from falling out.







Attach motor to a microcontroller, battery pack, and RF module. You can now open and close the pinchers. They move fast, because they're not geared down.



Project Notes and Engineering Principles:

You may have seen machines where (for a "modest" fee), a claw will swoop down and attempt to grab and lift a stuffed animal from a pile. Unfortunately, there is strong motivation to use a poor design -- the worse the claw works, the more money it makes for the vendor! In this project, you will build a device capable of lifting a small stuffed animal. Because of its complexity, this project is divided into 2 parts: the gripper, and the lift.

Grippers (One-Axis Linear Grip)

Imagine grabbing an object, like a soda can, with only your thumb and forefinger. You would probably attempt to grab the can by either 1) pinching it with the tips of your fingers or 2) encircling it with the entire length of the arc formed by your thumb and forefinger. In the same way, a linear one-axis grip holds an object with either the tips of its arms or by encircling it with its arms, the way you would hold onto a very large beach ball. For round objects, the second method requires less force to hold an object, as the greater contact surface provides more friction. The first method also requires that the "finger tips" be positioned very precisely, but is better for picking up small, light objects of irregular shape.

To keep hold of the object, you have to continually keep the motor powered to apply continuous pressure, or the pinchers will "let go", even if they remain closed. For this reason, a continuous motor, rather than a servo (with motion limited to 120^{o} of rotation) is used, as a servo is capable of closing on the object but unable to move beyond a certain point to apply the needed pressure. There are other gripper designs that keep holding on without continual powering from the motor. These include *bi-stable* designs (having 2 stable positions: open and closed) such as those activated by rubber bands or pneumatics, 2-axis grips, and roller grips.

Animal Grabber – Part 2: The Lift

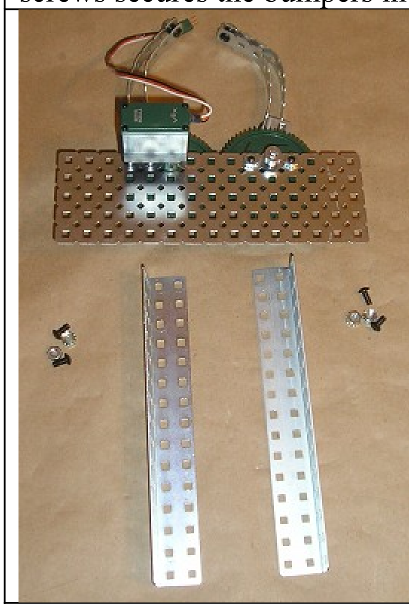
Kits needed: See Part 1

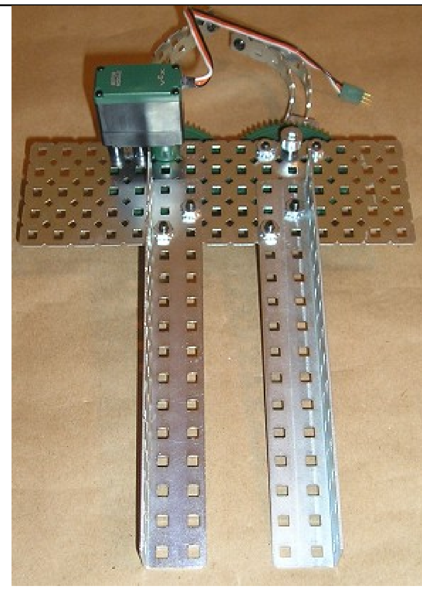
Pieces to cut: See Part 1

Bill of Materials: See Part 1

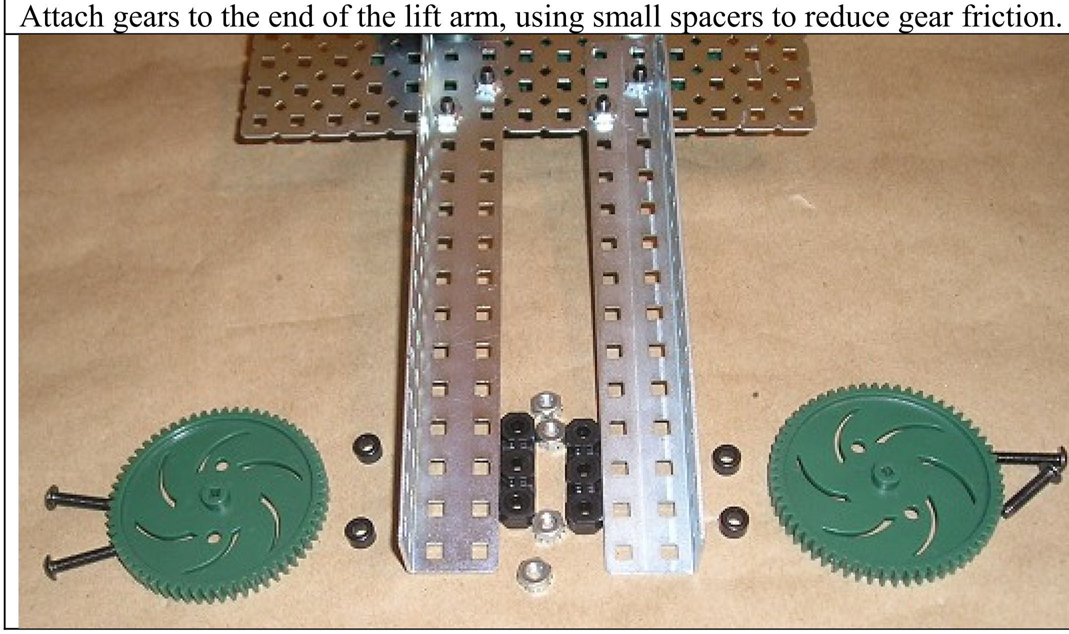
Build Sequence:

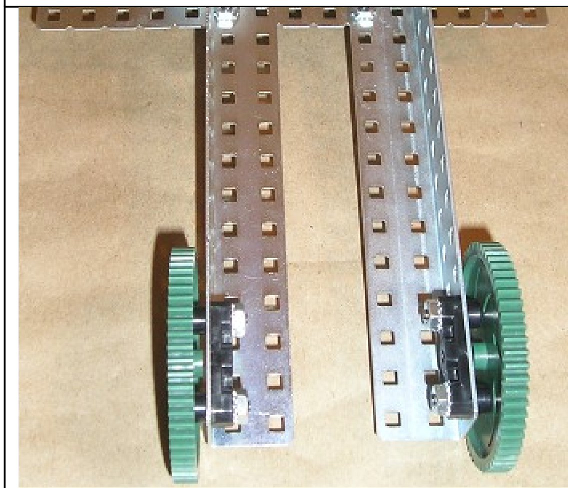
Attach chassis bumpers for lift arms to the metal plate. Note that diagonal placement of the screws secures the bumpers in 2 dimensions with a minimum of 2 screws.

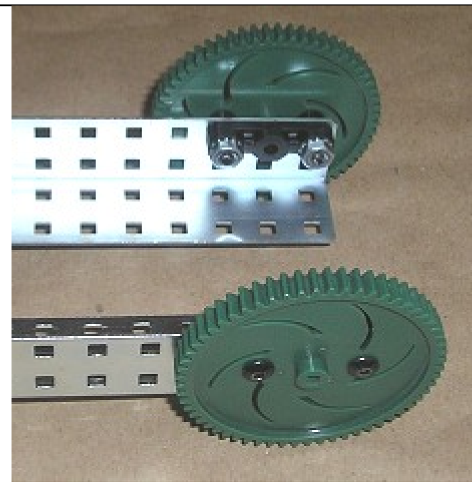




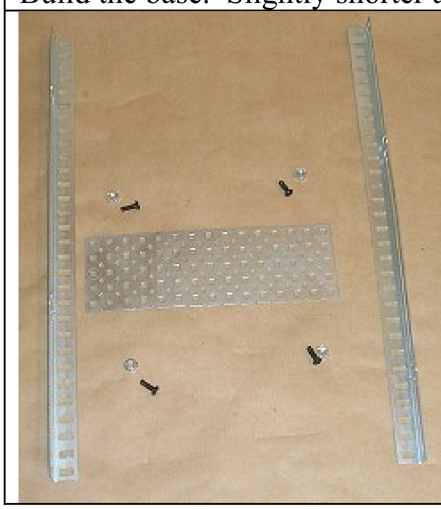
Attach gears to the end of the lift arm, using small spacers to reduce gear friction.

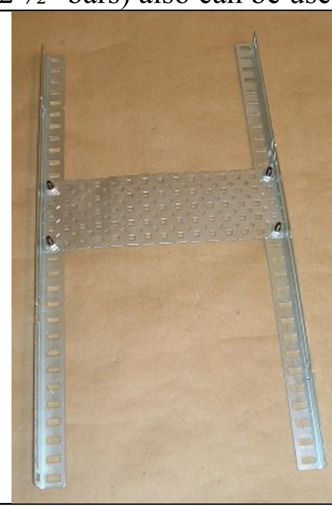




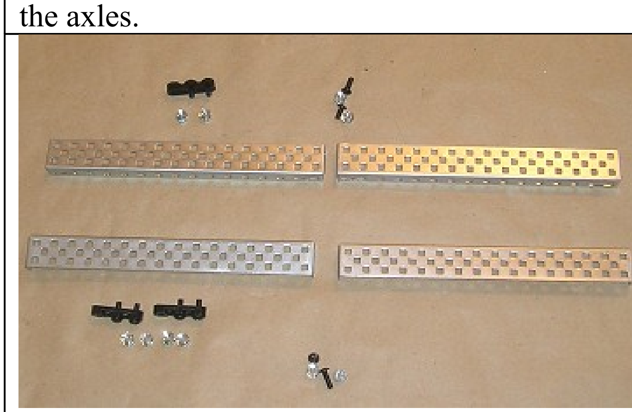


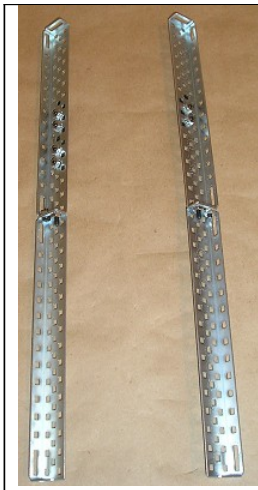
Build the base. Slightly shorter angle bars (e.g. 12 ½" bars) also can be used for the base.

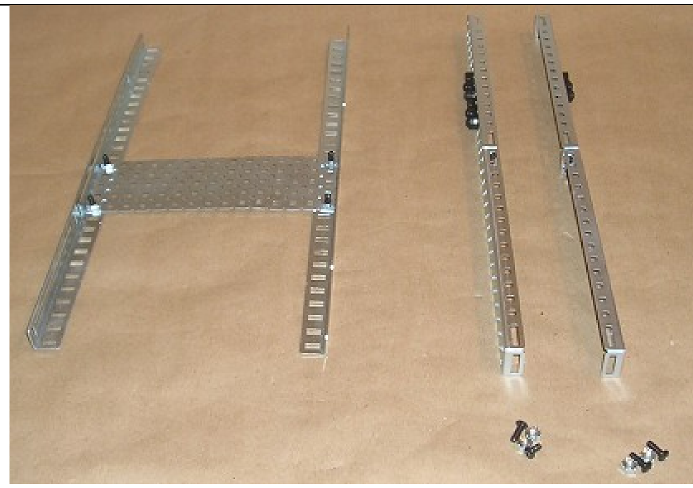




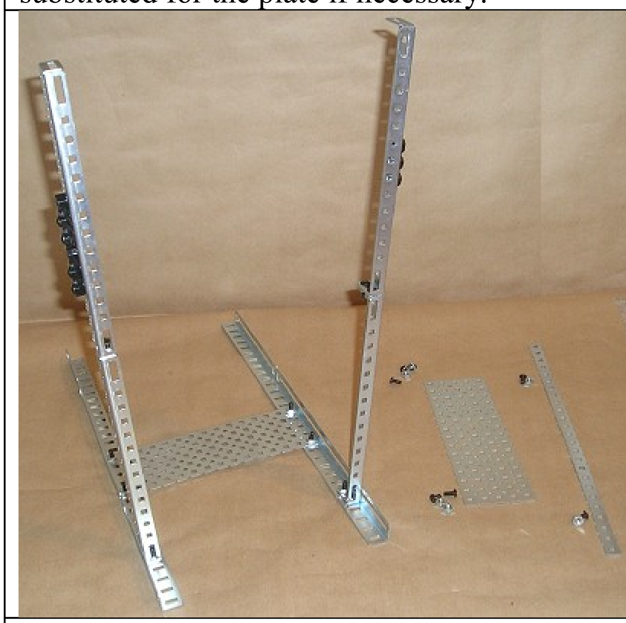
Assemble side supports, joining 2 chassis rails, and attaching bearing blocks that will support the axles.



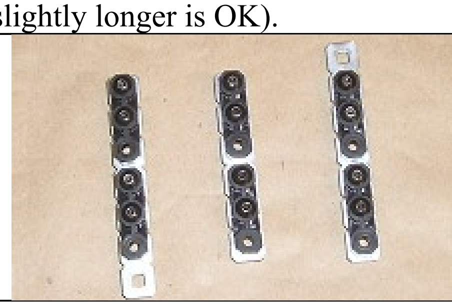




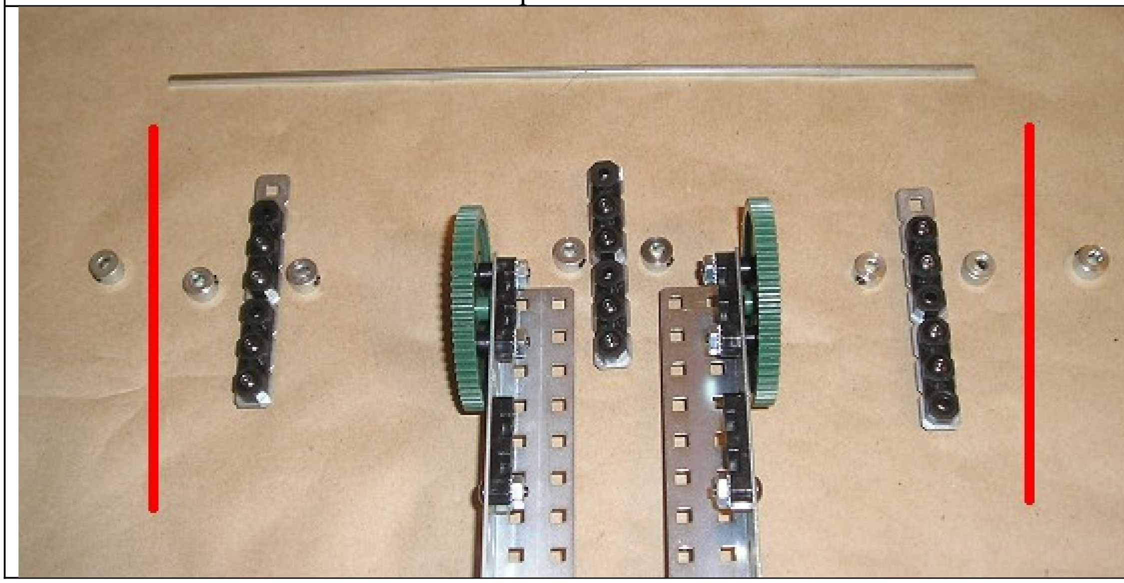
Attach supports across the top and back, a minimum of 15 holes. A long bar (or bars) can be substituted for the plate if necessary.

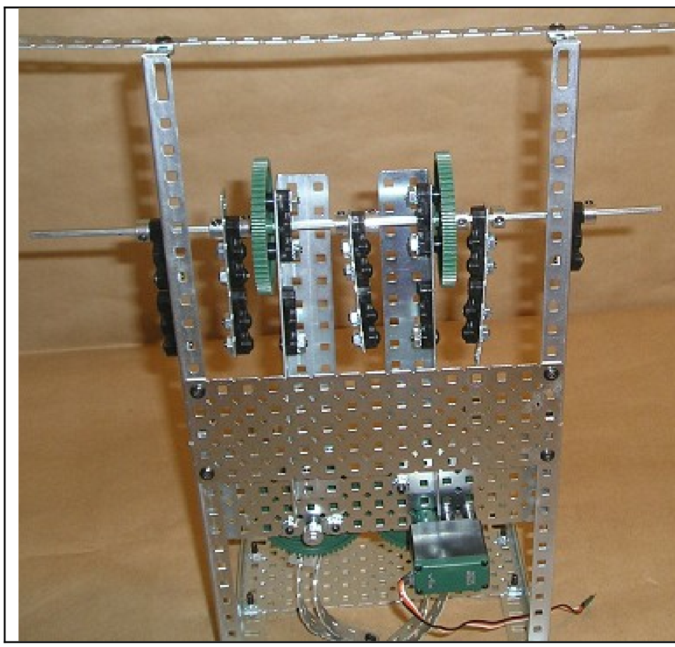


Assemble axle supports (ideally 6-hole bars, but slightly longer is OK).

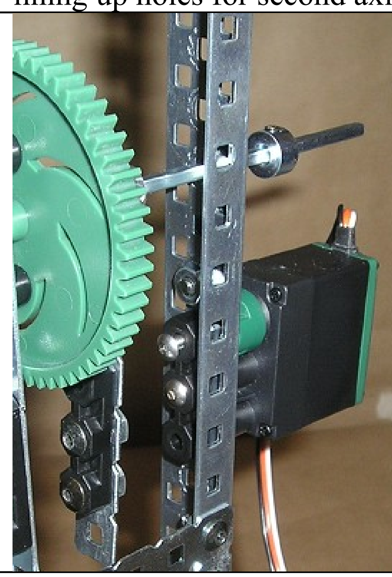


Attach the lift arm to the frame, inserting the 12" axle through the collars, supports, and gears in the order shown. Red lines indicate position of the frame.

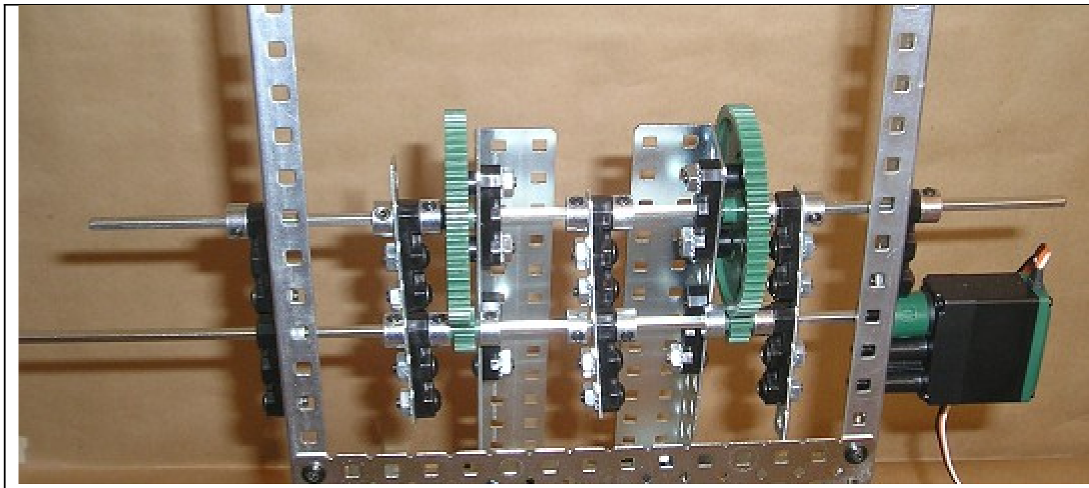




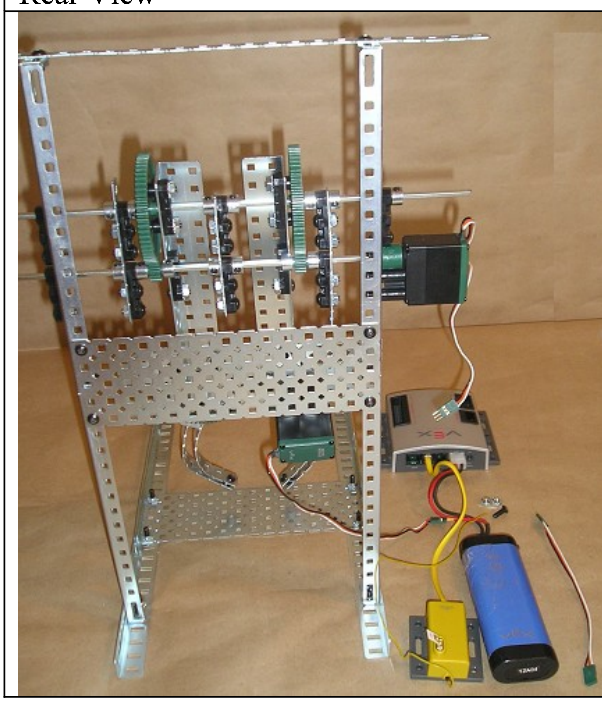
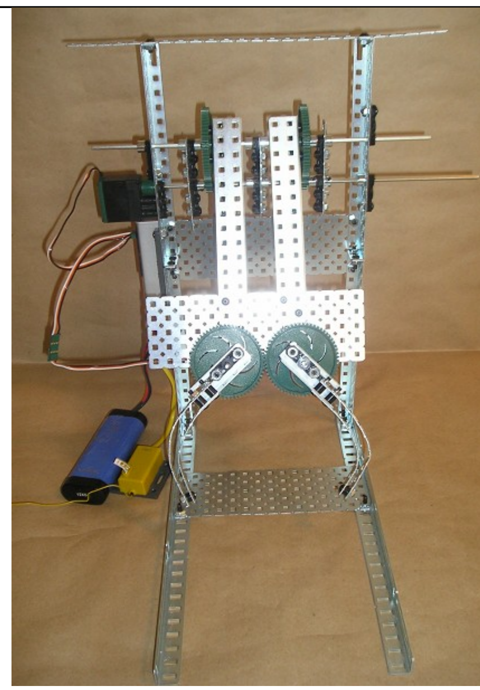
Attach motor below first axle, lining up holes for second axle.

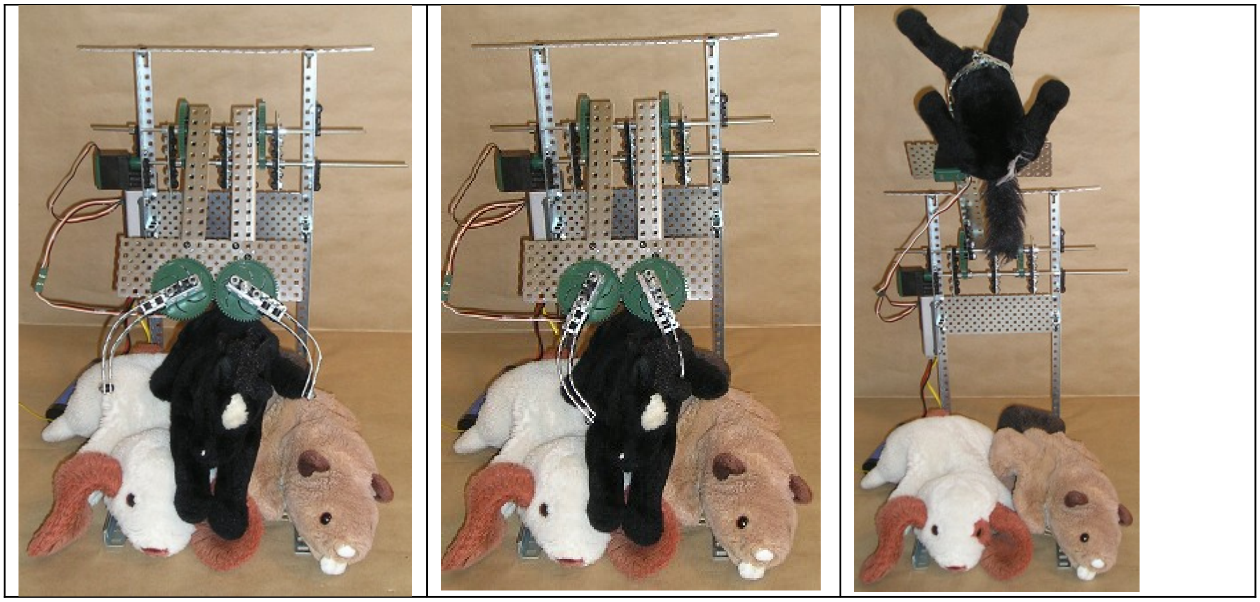


Insert the lower axle, attaching gears and collars in the order shown.



Plug the battery, RF module, and battery into the microcontroller. Because this model is non-mobile, placement is flexible. However, a PWM extension cable is needed for the gripper motor, as the motor wire is too short when the lift is fully extended.

Rear View	Front View
	



<u>Project Notes and Engineering Principles</u>

Lifts

One very important consideration in designing a lift is the amount of torque required, which depends on the weight lifted and the length of the arm. It is important to keep length of the lift arm to a minimum, as torque increases as you increase distance from the pivot point. Even so, most lifts (including this one) need to be geared down, trading speed for increased strength.

Bracing

Another consideration in this design is that the weighted long axle tends to bend downward, preventing the gears from fitting snugly together and causing them to slip. For this reason, 3 braces are inserted between axles, keeping the distance between the 2 axles constant. Had the 2 side supports been placed closer together, the axles would have less of a tendency to bend, making the braces unnecessary. However, this would produce a narrower base, and the structure would be more likely to tip over. Trade-offs like these often must be made.

Various long bars and plates are used to brace the frame. The size of these supports is flexible – pieces that hang over the edge are acceptable, even if they don't look pretty. This is a concession to minimize cutting. Too-large pieces can be reused in other projects that require larger pieces; once cut too small, they can't be increased in size.