EBOT Workshop #1
Basic Mechanical Design

Part 1: What’s in the Kit?

Bars and Plates

Bars and plates are two of the most useful pieces in the Robovation kit. Most structures will be built using these two pieces. The notches along the sides of both pieces (as well as the small holes in the plates) indicate the best places for cutting and bending.

If you do bend one of these pieces, never bend it over a sharp corner such as the edge of a table. Creating a sharp bend can weaken the piece and make it hard to unbend in the future. In our experience, it is best to just bend these pieces in your hands.

Angle Bars

Although the obvious use of angle bars is for building corners, they are very useful in a variety of situations. Unlike the regular bars, the angle bars will not bend and flex, and therefore are highly recommended for building rigid structure such as your chassis.

The notches in the angle bars divide them into three sections: one 5 holes long, one 10 holes long, and one 15 holes long. By cutting in various places, you can produce pieces that are 5, 10, 15, 20, 25, or 30 holes long.

The slots in the side of the angle bars are also very useful, as they allow you to attach an item in between two holes, or to make a sliding joint. We will talk more about that when we get to motor mounting.

Gussets

Gussets are used whenever two plates or bars need to join at an angle.
Plus gussets are used any time two pieces need to be joined in a plus shape (trying to attach two bars into a T shape with a single nut and bolt where they join will not be sturdy at all). Sandwich the plus gusset in between the two plates you want to join – don’t try to put both on one side.

Angle gussets are used for going around corners. They can be much more useful than a short angle bar because they have a longer reach, and because of the long slot which is oriented perpendicular to the angled side. They are very useful for mounting things off the bottom of your chassis whose height needs to be precisely adjusted (such as sensors or skids).

The pivot gusset is used whenever you need an angle other than 90 degrees. Simply put one bolt though the hole in the corner and the other bolt in the slot. You can use a lock washer (see below) for a rigid joint or a Nylock (see below) for a pivoting joint. If you need a 45 degree angle, you can use the 45 degree hole instead of the slot.

### Nuts and Bolts

| Bolt | Motor Screw | Lock Nut | Nylock | Steel Washer | Teflon Washer | Shaft Collar |

There are many types of small pieces like nuts and bolts, and it is important to understand the function of each one.

Bolts are used for fastening most pieces together. They fit through the large holes in the plates, bars, and gussets, and thread into either nut.

The motor screws are only used for attaching motors and limit switches. They thread directly into the plastic of those pieces. See the motor mounting section for important cautions.

The lock nuts are the most common type of nut used. When tightened down all the way, the spiky spring creates enough pressure on the threads to prevent the nut from coming loose. However, if they are not tightened down, or are tightened against a surface that rotates, there is a good chance that they will fall off. Make sure that when you install them, the spiky side is facing the plate or bar you are attaching to.

The Nylock nut has a nylon insert that prevents it from coming loose. It is much harder to use than the lock nut (you will probably need a wrench or a pair of pliers), but has the advantage that it does not need to be tightened all the way and can be used against rotating faces. You will need to use a Nylock for any joint that is held together with a bolt.
The washers are used between any two surfaces that rotate against each other. The use of washers is covered in Part 2, but the important thing to note here is that the Teflon washers are white plastic while the steel washers are metal. Also note that the Teflon washers are much more expensive than the steel ones, so try not to lose them.

The shaft collar is used for securing shafts in place (see below). To attach them to a shaft, loosen the black set screw with the smaller of the two Allen wrenches in the kit, slide the collar into place, align the set screw over one of the flat faces, and tighten the set screw.

**Shafts and Shaft Collars**

The shafts in this kit are somewhat unique in that they are square and not round. The square shape makes it easy to attach things to a shaft, such as a wheel or sprocket, that you want to rotate with the shaft. However, because of the square shape, it is important to always use some type of bearing (see below).

Shaft collars are used to prevent a shaft from sliding out of place. It is a good idea to have at least one shaft collar on every shaft. If you don’t tighten the set screw, the shaft collar can be used as a spacer, but there is usually no good reason not to tighten them.

**Locking Bars, Bearing Bars, and Delrin Bearings**

Locking bars and bearing bars are easily confused, but serve very different purposes.

Locking bars (with square holes), are used for fixing structures such as arms or other mechanisms to a shaft to that they will rotate with the shaft. A sample installation is shown below for fixing a short bar to a shaft.
Bearings are used any time a shaft passes through a bar, plate or gusset, and you don’t want it to rotate with the shaft.

Bearing bars are used with slow or non-continuous motion (such as a pivot) where little weight is being supported by the shaft. They are installed just like the locking bar, but you must make sure to align the round hole with the hole in your structure as shown below to prevent binding.

Delrin bearings are used with rapid or continuous motion (such as a shaft driven by a motor). They are made from a plastic called Delrin which is similar to Teflon, but much stronger. They are installed just like the locking and bearing bars, although you may need to use longer bolts due to the added thickness.

**Standoffs**

Standoffs are one of the most underutilized pieces in the kit. They are very useful for mounting anything a distance away from your structure and much easier to use than a box frame built from bars. A sample structure using standoffs is shown below. The structure built this way is much stronger than if it had been built by bending the bars.

It is also highly recommended that you mount your robot controller on short standoffs to that bolt-heads and nuts attached to your chassis don’t interfere.

**Sprockets and Chain**

Although the Robovation kit does not include gears, it does include sprockets and chains, which are similar (more on how sprockets and chains work is covered in Part 2). The
sprockets have square holes in them, and therefore will rotate with any shaft they are put on. The larger gears, which have spokes, are quite fragile, and should never be used to drive an arm or other mechanism that could easily get stuck against a field object unless they have been reinforced. If the large sprockets are being driven by the motor and not allowed to turn, it is very likely that the hub will break off of the spokes.

The chain is very similar to Lego chain, where all the links are identical (they are known as half-links). To attach links together, simply spread the two little fins apart on one link and place them over the two little bumps on the back of the link you are attaching it to. To separate them, carefully spread the find apart and pull. The process is hard to describe, but quite easy when you can actually see the chain.

Because your chains cannot have much slop in them, attaching the chain around two sprockets can be quite tricky. One trick is to wrap one end of the chain partially around one of your sprockets, so that the teeth will hold that end in place while you attach the other end to it.

**Wheels**

The wheels in the Robovation kit have soft foam tires and a plastic hub. The hub pulls apart into two pieces, and can be used separately as a winch. One side of the hub has a square hole, so when it will rotate with a shaft it is placed on.

Because of the softness of the foam tires, the robots should never be stored on their wheels. The foam will deform, and your wheels will end up with flat spots. Always store your robot upside-down or on top of a block of some sort with the wheels hanging over the edge.

Sometimes, the foam tires will come loose, and will spin independently of the hub. If this happens, you can drill a hole near the outside of the hub and drive a wood screw through it and into the tire.
Multi-Speed Motors

The multi-speed motors are actually a motors, gearbox, and speed controller built into one small unit. We’ll get more into motor speed and performance in Part 2.

The two round holes in the top of the motor are for the motor screws, and the square one is for the shaft you want to turn.

There are a couple of things you have to be careful of when installing the motors:

- Never back-drive the motors. Unless done very carefully, rotating a shaft by hand that is attached to a motor can damage the gears inside. You can replace the gears by unscrewing the small screws on the bottom of the motor, but it’s probably better to just be careful.

- Do not side-load the motors. Whenever you have a shaft going into the motor, you MUST have at least one Delrin bearing supporting the shaft. The motor is not designed to support any weight, and can be damaged easily. If you have a shaft going into the motor that is supporting weight (such as a shaft going to a wheel), it is best to use two Delrin bearings as shown below to prevent the shaft from “see-sawing” in the one bearing.

- Be careful when mounting. The motor screws tap directly into the plastic casing of the motor. Over-tightening them can strip the mounting holes or crack the casing. They should be finger-tightened only. We recommend that you use a socket from a socket wrench set without the handle for tightening the screws, and never use pliers or a wrench.
Robot Controller

The robot controller is covered more thoroughly covered in the programming workshops, but we will cover the basic mechanical parts here. The controller is mounted using the four holes in the corners. Make sure that you mount it in such a way that the program port is accessible – your programmers will thank you!

To turn the robot on, hold down the ON/OFF button for a few seconds. Press it again to turn the robot off.

The PWM cables from your radio receiver will connect to the ports labeled R/C PWM IN (channel 1 to port 1, channel 2 to port 2, etc.) Make sure that the black wire of the PWM cable goes to the side that says BLK.

The motors connect to the PWM OUT pins. Again, make sure that the black wire goes to the side that says BLK.

Sensors are wired to the DIGITAL IN/OUT – ANALOG IN pins. Details on that are covered in the programming workshop.

The battery connects to the white plastic connector. Because the connector is soldered directly onto the controller, it is easily damaged when trying to unplug the battery. We recommend that you construct a short battery extension cable that you leave plugged into the controller. This allows you to plug and unplug the battery from the cable, not the robot.