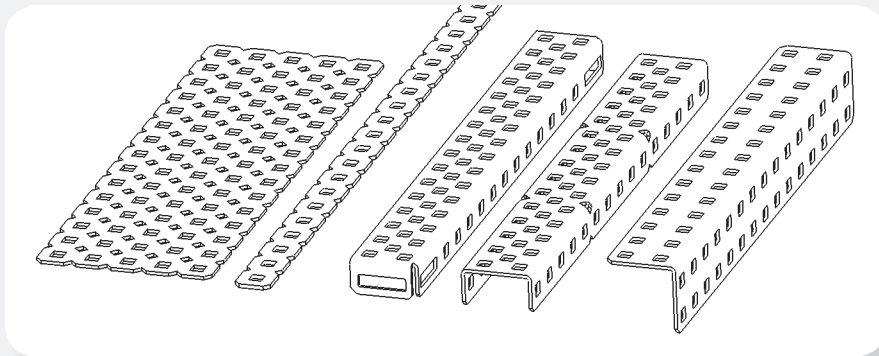


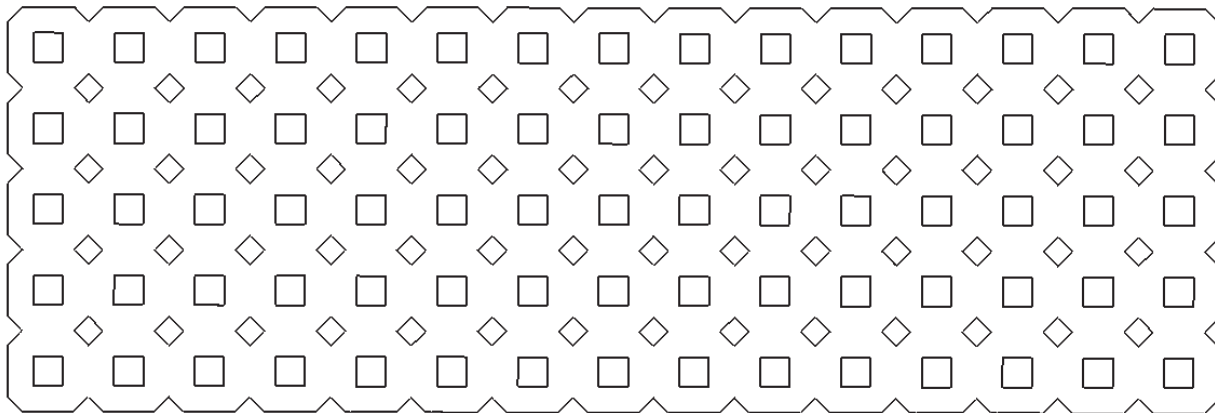
Introduction to the Structure Subsystem

The parts in the VEX Structure Subsystem form the base of every robot. These parts are the “skeleton” of the robot to which all other parts are attached. This subsystem consists of all the main structural components in the VEX Design System including all the metal components and hardware pieces. These pieces connect together to form the “skeleton” or frame of the robot.

In the VEX Robotics Design System the majority of the components in the Structure Subsystem are made from bent sheet-metal. These pieces (either aluminum or steel) come in a variety of shapes and sizes and are suited to different functions on a robot. Different types of parts are designed for different applications.

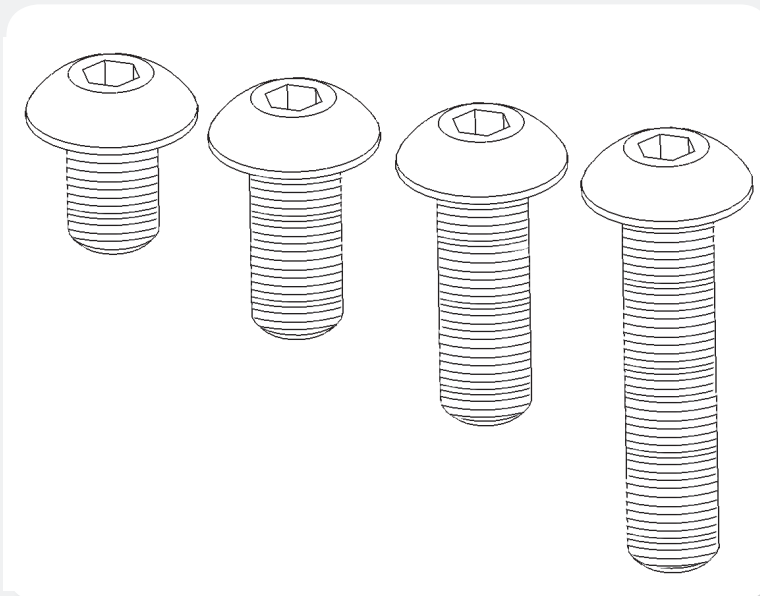
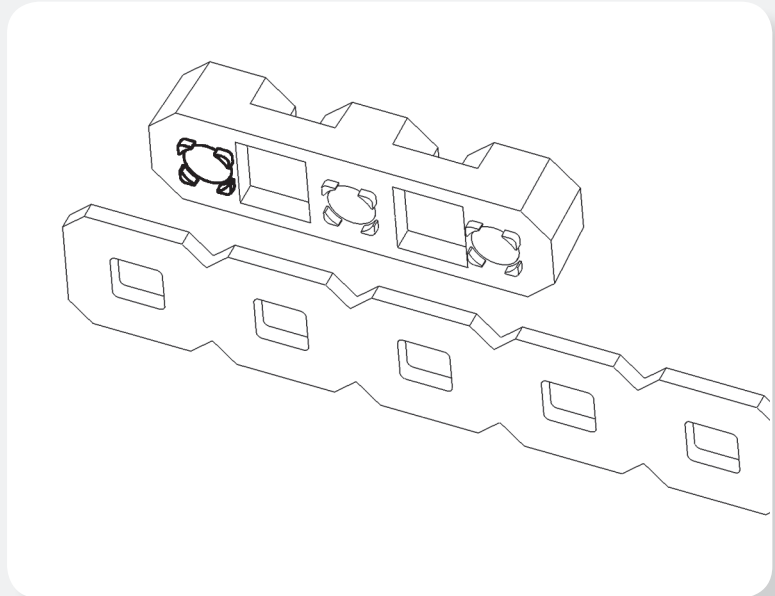


The VEX structural pieces all contain square holes (0.182" sq) on a standardized 1/2" grid. This standardized hole-spacing allows for VEX parts to be connected in almost any configuration. The smaller diamond holes are there to help users cut pieces using tin-snips or fine-toothed hacksaws without leaving sharp corners.



Introduction to the Structure Subsystem, continued

VEX square holes are also used as “alignment features” on some components. These pieces will “snap” in place into these square holes. For example, when mounting a VEX Bearing Flat there are small tabs which will stick through the square hole and hold it perfectly in alignment. This allows for good placement of components with key alignment requirements. (It would be bad if a bearing slipped out of place!) Note that hardware is still required to hold the Bearing Flat onto a structural piece.



Hardware is an important part of the Structure Subsystem. Metal components can be directly attached together using the 8-32 screws and nuts which are standard in the VEX kit. The 8-32 screws fit through the standard VEX square holes. These screws come in a variety of lengths and can be used to attach multiple thicknesses of metal together, or to mount other components onto the VEX structural pieces.

Allen wrenches and other tools are used to tighten or loosen the hardware.

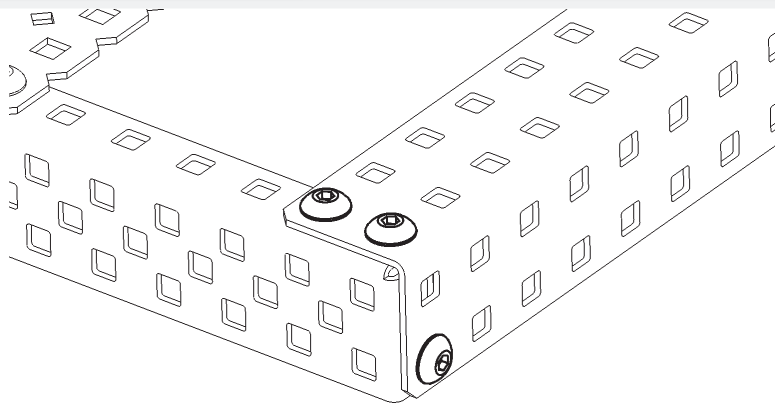
Note: There are two types of screws that are part of the VEX Robotics Design System.

- Size 8-32 screws are the primary screws used to build robot structure.
- Size 6-32 screws are smaller screws which are used for specialty applications like mounting the VEX Motors and Servos.

Introduction to the Structure Subsystem, continued

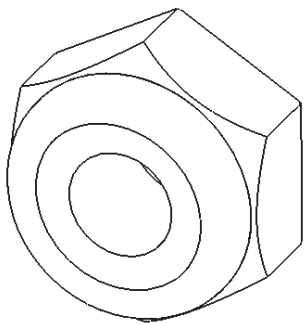
HINT:

Attach components together with multiple screws from different directions to keep structural members aligned correctly and for maximum strength!

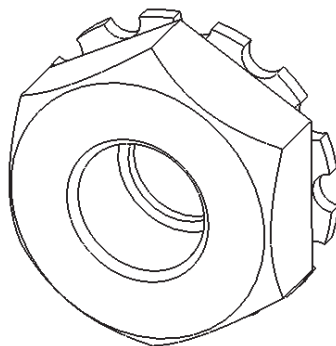


When using screws to attach things together, there are three types of nuts which can be used.

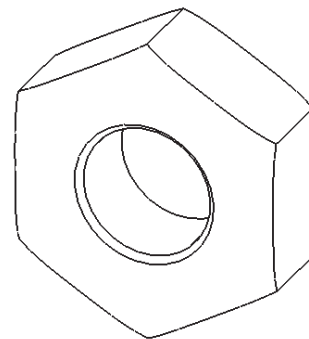
- Nylock nuts have a plastic insert in them which will prevent them from unscrewing. These are harder to install, as you need to use an open-ended wrench to tighten them up. These nuts will not come off due to vibration or movement.
- KEPS nuts have a ring of “teeth” on one side of them. These teeth will grip the piece they are being installed on. This means you do not NEED to use an open-ended wrench to tighten them (but it is still recommended). These nuts are installed with the teeth facing the structure. These nuts can loosen up over time if not properly tightened; however they will work great in most applications.
- Regular nuts have no locking feature. These basic hex nuts require a wrench to install and may loosen up over time, especially when under vibration or movement. They are very thin and can be used in some locations where it is not practical to use a Nylock or KEPS nut.



Nylock Nut



KEPS Nut



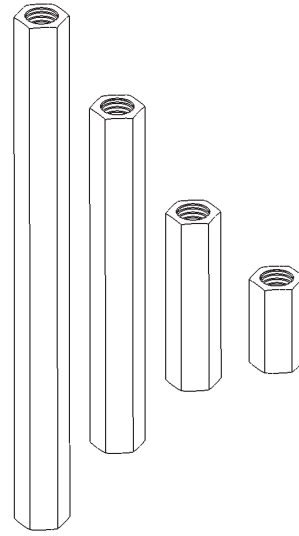
Regular (Hex) Nut

WARNING: It is important to be careful when tightening screws. The allen wrenches may round or “strip out” the socket on the head of the screw if they are not fully inserted into the socket.

Use care when tightening screws to prevent stripping out the head of the screw!

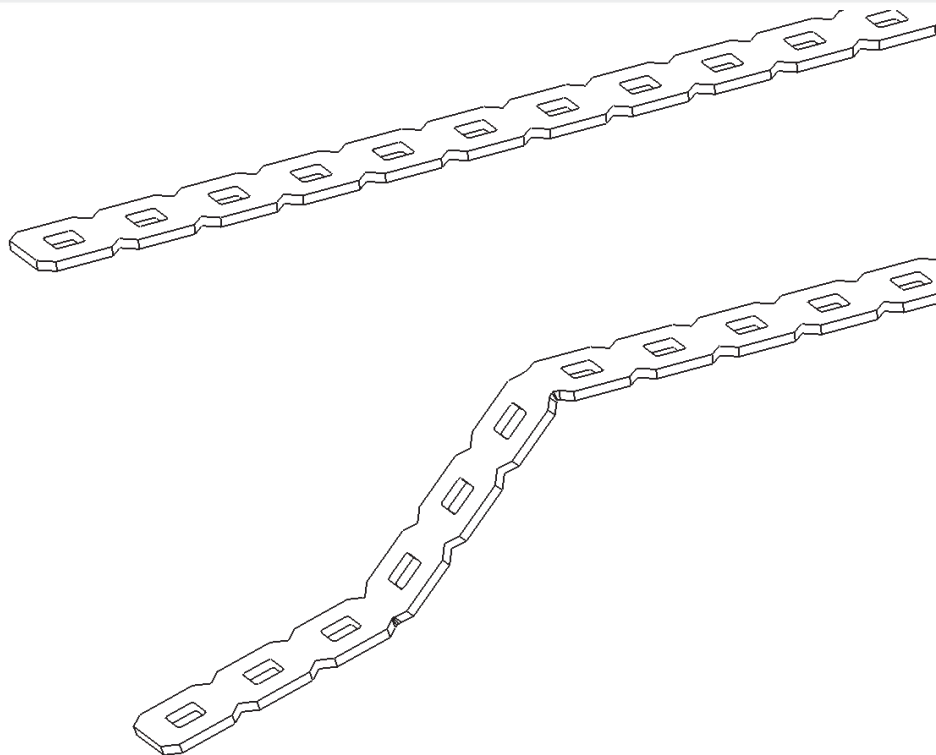
Introduction to the Structure Subsystem, continued

Components can also be offset from each other using 8-32 threaded standoffs; these standoffs come in a variety of lengths and add great versatility to the VEX kit. These standoffs work great for mounting components in the VEX system as well as for creating structural beams of great strength.



One of the key features of many VEX structural parts is their “bend-able” and “cut-able” nature. Users can easily modify many of these structural parts into new configurations better suited for their current needs. Flat plates can be bent into brackets. Many metal components can be cut to custom lengths. These parts were **DESIGNED** to be modified.

Note: It is almost impossible to fully flatten a piece once it has been bent.

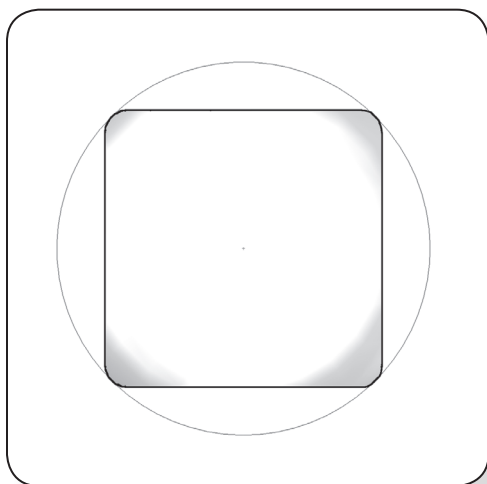
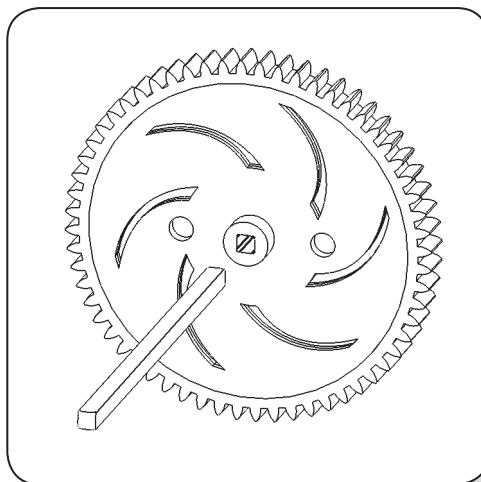


Introduction to the Motion Subsystem

The Motion Subsystem comprises all the components in the VEX Robotics Design System which make a robot move. These components are critical to every robot. The Motion Subsystem is tightly integrated with the components of the Structure Subsystem in almost all robot designs.

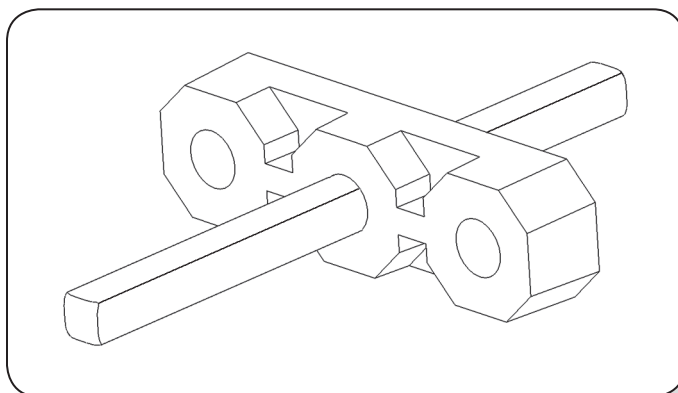
In the VEX Robotics Design System the motion components are all easily integrated together. This makes it simple to create very complex systems using the basic motion building blocks.

The most fundamental concept of the Motion Subsystem is the use of a square shaft. Most of the VEX motion components use a square hole in their hub which fits tightly on the square VEX shafts. This square hole – square shaft system transmits torque without using cumbersome collars or clamps to grip a round shaft.

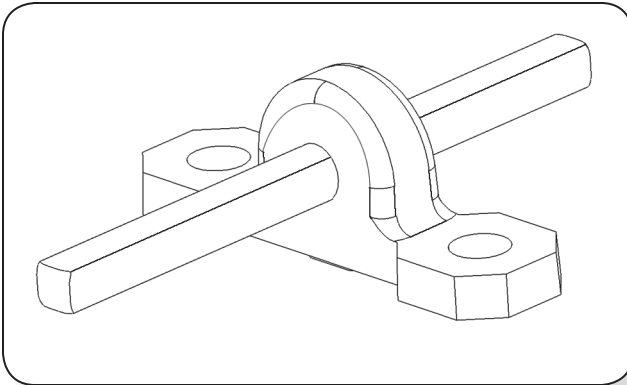


The square shaft has rounded corners which allow it to spin easily in a round hole. This allows the use of simple bearings made from Delrin (a slippery plastic). The Delrin bearing will provide a low-friction piece for the shafts to turn in.

These VEX Delrin bearings come in two types, the most common of which is a Bearing Flat. The Bearing Flat mounts directly on a piece of VEX structure and supports a shaft which runs perpendicular and directly through the structure.

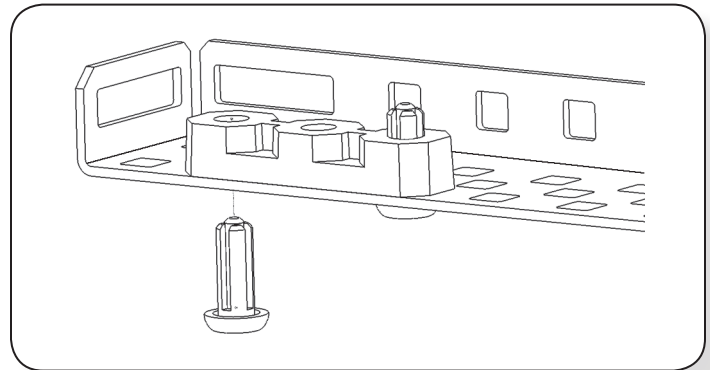


Introduction to the Motion Subsystem, continued



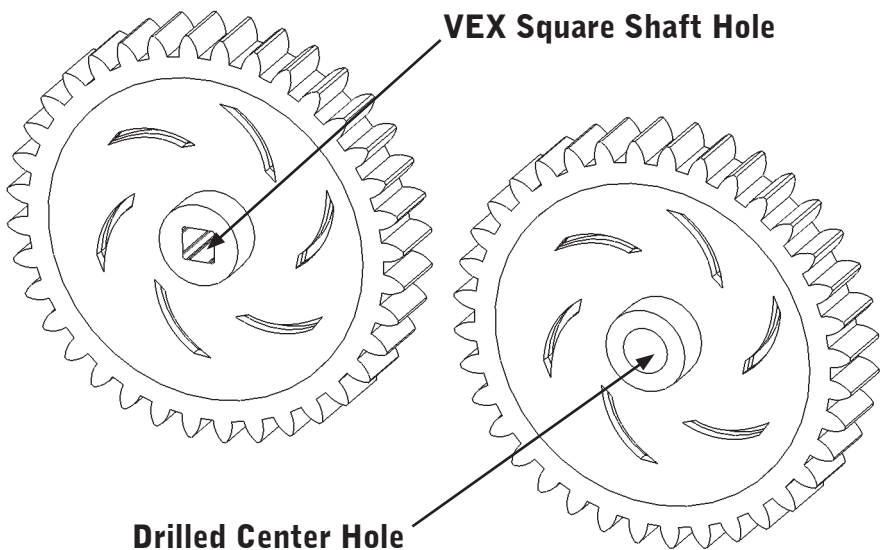
Another type of bearing used in the VEX Motion Subsystem is a Bearing Block; these are similar to the “pillow-blocks” used in industry. The Bearing Block mounts on a piece of structure and supports a shaft which is offset either above, below, or to the side of the structure.

Some bearings can be mounted to VEX structural components with Bearing Pop Rivets. These rivets are pressed into place for quick mounting. These Rivets are removable; pull out the center piece by pulling up on the head of the Rivet to get it to release.



HINT:

It is also possible to convert the square hole(s) in some Motion Subsystem Components to a round hole by using a drill (approximately 0.175” diameter) to create a round hole that replaces the part’s original square hole. A VEX square shaft can then spin freely in the newly created round hole. This is useful for some specialty applications.



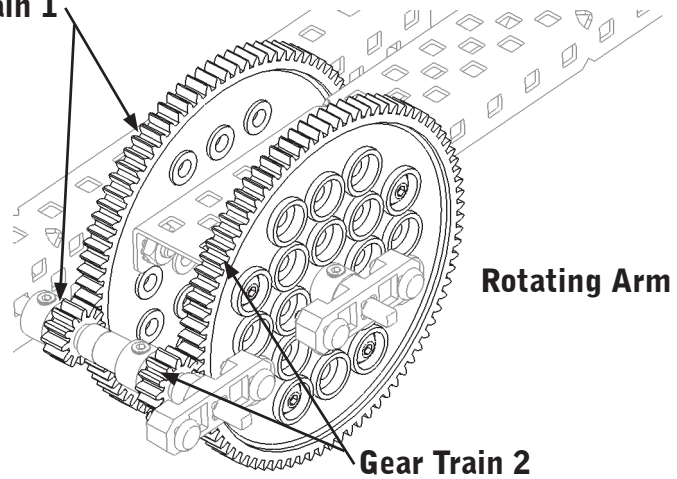
Introduction to the Motion Subsystem, continued

In some applications excessive loads can damage the components of the VEX Motion Subsystem. In these cases there are often ways to reinforce the system to reduce the load each individual component will experience, or so that the load is no longer concentrated at a single location on any given component.

EXAMPLE:

One example of a component failure is fracturing gear teeth. Another example is rounding out the square hole the shaft goes through. If either of these situations exists an easy way to fix it is to use multiple gears in parallel. Try using two gear trains next to each other to decrease the load on each individual gear.

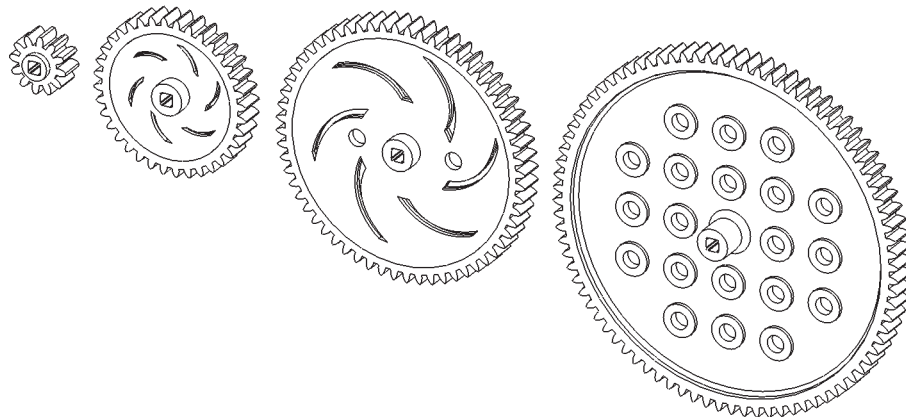
Gear Train 1



Rotating Arm

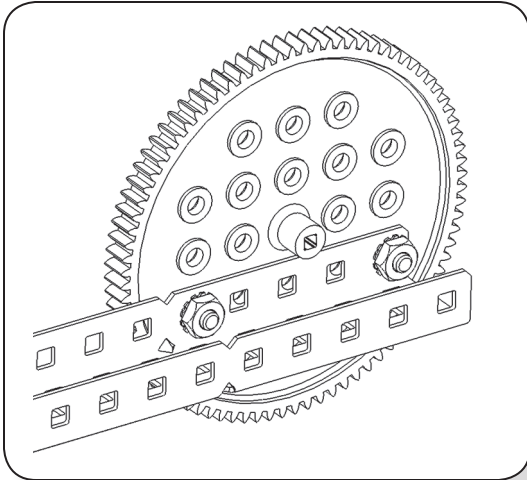
Gear Train 2

There are several ways to transfer motion in the VEX Robotics Design System. A number of Motion Subsystem accessory kits are available with a variety of advanced options. The primary way to transfer motion is through the use of spur gears. Spur gears transfer motion between parallel shafts, and can also be used to increase or decrease torque through the use of gear ratios.



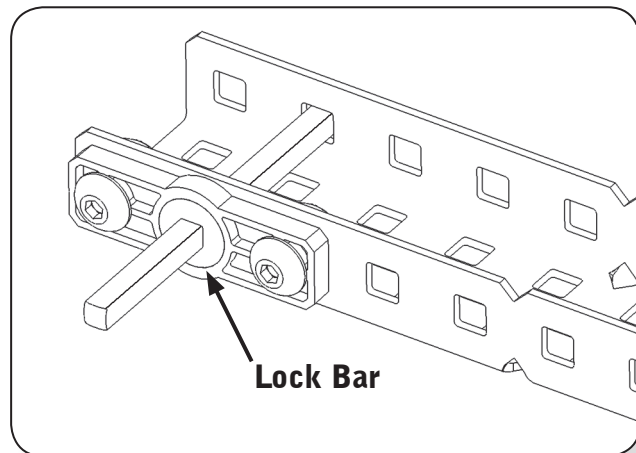
These gears can also be combined with sprocket & chain reductions, and also with advanced gear types to create even more complex mechanisms.

Introduction to the Motion Subsystem, *continued*



It is easy to drive components of the VEX Structure Subsystem using motion components in several different ways. Most of the VEX Gears have mounting holes in them on the standard VEX 1/2" hole spacing; it is simple to attach metal pieces to these mounting holes. One benefit of using this method is that in some configurations, the final gear train will transfer torque directly into the structural piece via a gear; this decreases the torque running through the shaft itself.

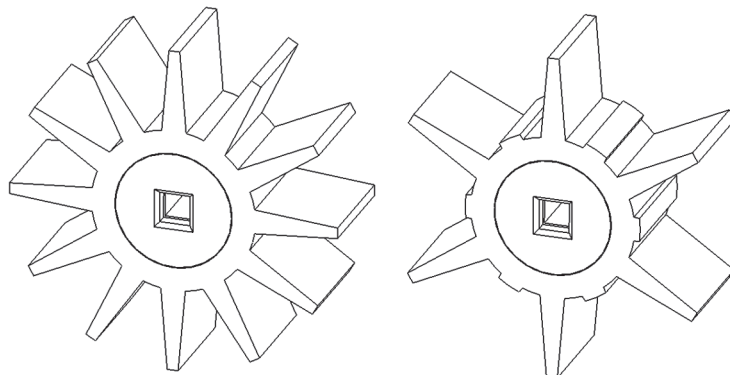
Another option to drive structural pieces using the Motion Subsystem is through a Lock Bar. These pieces are designed such that they can bolt onto any VEX structural component using the standard VEX 1/2" pitch. In the center of each piece there is a square hole which matches the VEX square shaft. As such, any VEX component can be "locked" to a shaft using the Lock Bar so that it will spin with the shaft. Note that the insert in each Lock Bar is removable and can be reinserted at any 15° increment.



Intake Rollers can be used in a variety of applications. These components were originally designed to be rollers in an intake or accumulator mechanism. The "fins" or "fingers" of the roller will flex when they contact an object; this will provide a gripping force which should pull on the object.

HINT:

Try cutting off some of the fins of an Intake Roller for better performance on some objects.



Concepts to Understand, continued

Speed vs. Torque

A motor can generate a set amount of power; that is, it can provide a specific amount of energy every second—this energy is most commonly used to make a wheel spin. Since there is only so much energy to go around, however, there is an inherent trade-off between **Torque**—the force with which the motor can turn the wheel—and **Speed**—the rate at which the motor can turn the wheel.

The exact configuration of torque and speed is usually set using gears. By putting different combinations of gears between the motor and the wheel, the speed-torque balance will shift.

Gears

Gear Ratio

You can think of gear ratio as a “multiplier” on torque and a “divider” on speed. If you have a gear ratio of 2:1, you have twice as much torque as you would if you had a gear ratio of 1:1, but only half as much speed.

Calculating the gear ratio between a pair of gears is simple. First, identify which gear is the “driving” gear, and which is the “driven” gear. The “driving” gear is the one that is providing force to turn the other one. Often, this gear is attached directly to the motor axle. The other gear, the one that the driving gear is turning, is called the “driven” gear.

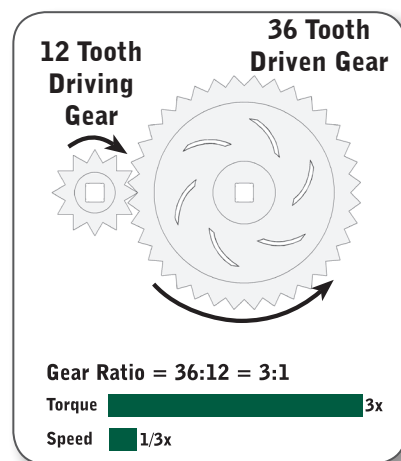
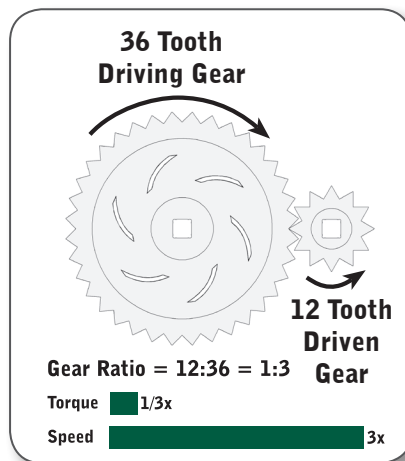
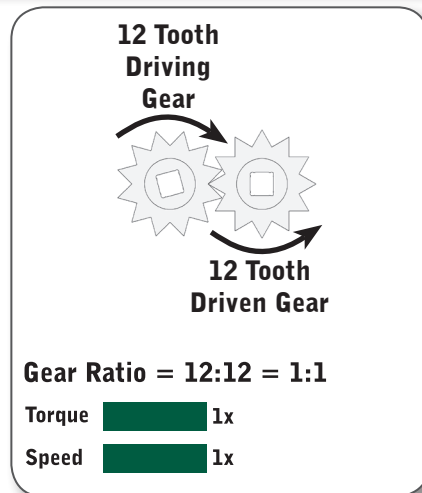
To find gear ratio, you just need to count the number of teeth on the “driven” gear, and divide it by the number of teeth on the “driving” gear.

Mechanical Advantage –

The ratio of the force a machine can exert to the amount of force that is put in. Mechanical advantage can also be thought of as the “force multiplier” factor that a mechanical system provides.

If a vehicle has a gear train with a mechanical advantage of 2, for instance, it has twice as much force available to it, enabling it to go up hills that are twice as steep, or tow a load that is twice as heavy.

This additional force is never “free.” It always comes at the expense of something else, such as speed. Also note that mechanical advantages are frequently fractional, indicating that force is being sacrificed for speed or some other similar performance factor in a system.



Gears, continued

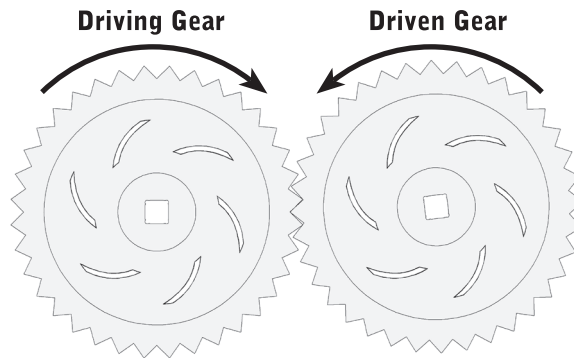
Idler Gears

Gears can be inserted between the driving and driven gears. These are called idler gears, and they have no effect on the robot's gear ratio because their gear ratio contributions always cancel themselves out (because they are a driven gear relative to the first gear, and a driving gear relative to the last gear—you would first multiply by the number of teeth on the idler gear and then divide by the same number, which always cancels out).

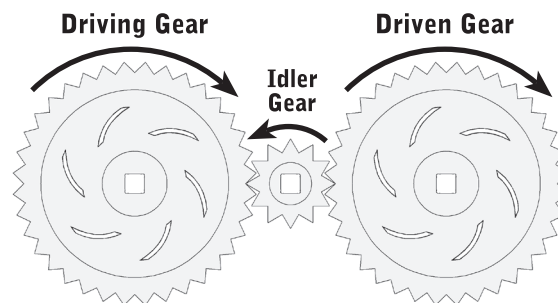
However, idler gears do reverse the direction of spin. Normally, the driving gear and the driven gear would turn in opposite directions. Adding an idler gear would make them turn in the same direction. Adding a second idler gear makes them turn in opposite directions again.

Idler gears are typically used either to reverse the direction of spin between two gears, or to transmit force from one gear to another gear far away (by using multiple idler gears to physically bridge the gap).

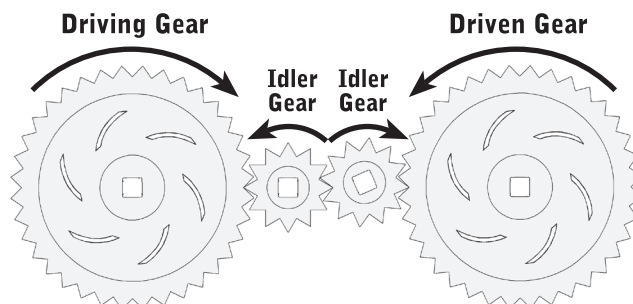
No Idler – Opposite Direction



One Idler – Same Direction



Two Idlers – Opposite Direction



Concepts to Understand, continued

Gears, continued

Compound Gear Ratio

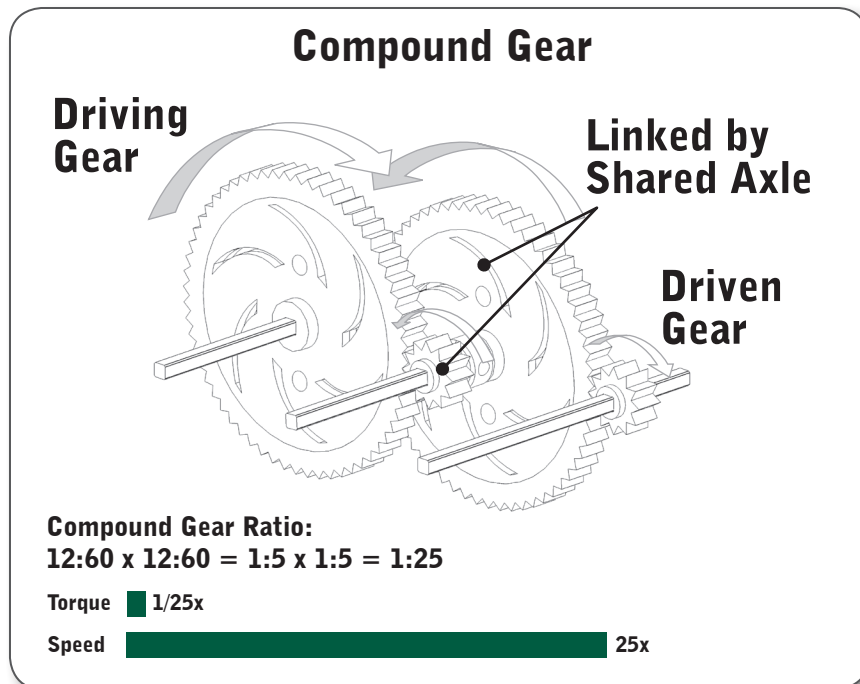
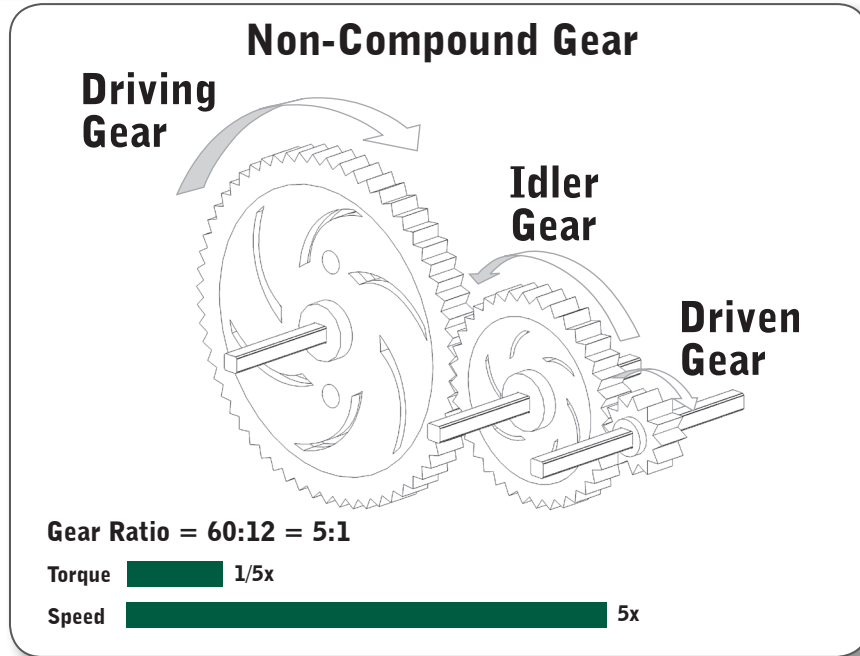
Compound gears are formed when you have more than one gear on the same axle. Compound gears are not to be confused with idler gears, as compound gears can affect the overall gear ratio of a system!

In a compound gear system, there are multiple gear pairs. Each pair has its own gear ratio, but the pairs are connected to each other by a shared axle.

The resulting compound gear system still has a driving gear and a driven gear, and still has a gear ratio (now called a "compound gear ratio").

The compound gear ratio between the driven and driving gears is then calculated by multiplying the gear ratios of each of the individual gear pairs.

Compound gears allow configurations with gear ratios that would not normally be achievable with the components available. In the example above, a compound gear ratio of 1:25 was achieved using only 12 and 60-tooth gears. This would give your robot the ability to turn an axle 25 times faster than normal (though it would only turn with 1/25th of the force)!



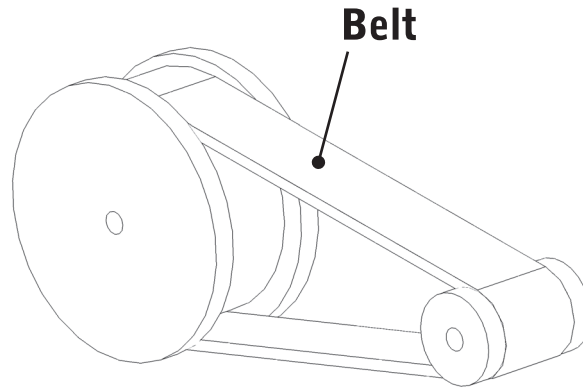
Gears, continued

Gear ratio with non-gear systems

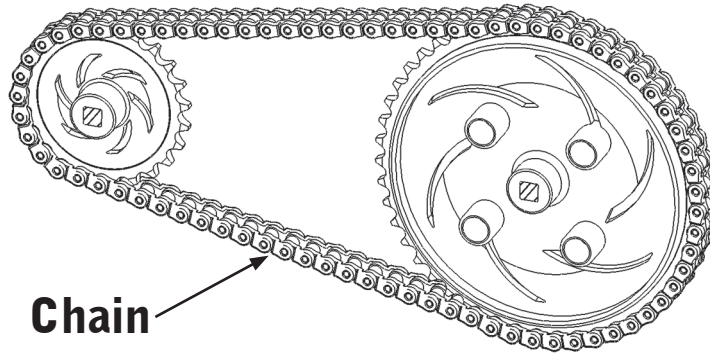
The real nature of gear ratios is a little more complex than just counting teeth on gears. Gear ratio is actually defined as the number of rotations that the driving axle needs to make in order to turn the driven axle around once. When dealing with toothed gears or sprockets, you can find the number of turns needed by counting teeth, as you have seen previously (see "Gear ratio").

With other types of systems, you can still find the "gear ratio" by measuring the number of rotations on the driven and driving axles. Some of these other drive types include belt-and-pulley drives and chain-and-sprocket drives.

Belt or chain drives are often preferred over gears when torque is needed to be transferred over long distances. Unlike spur gear reductions, Sprocket and Chain reductions do NOT reverse rotation.



Belt Drive



Chain Drive