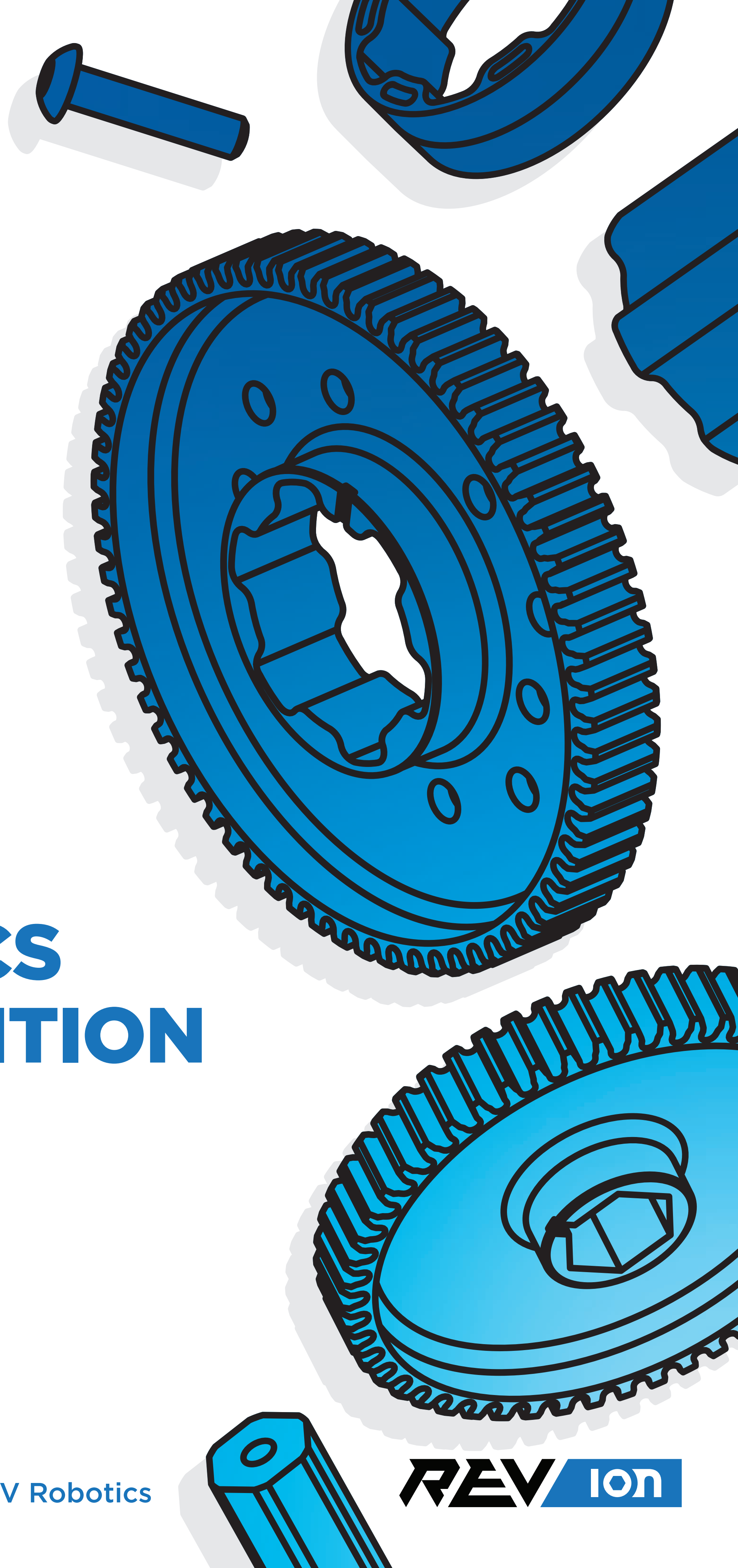
FIRST® ROBOTICS COMPETITION ROBOT BASICS



A Guide Presented by REV Robotics

WELCOME!

Welcome to the *FIRST* ® community! You are joining a great group of people who are all working to promote and become the next generation of STEM professionals.

We founded REV in 2014 to bring new, innovative products to the educational robotics community and to promote the next generation of STEM professionals. When designing products for teams, these experiences are at the forefront of our minds. REV Robotics is always working to create products that help more teams innovate, compete, and achieve their goals.

Regardless of if your team is a brand-new rookie *FIRST* ® Robotics Competition team or a veteran team with more than a decade of experience, the season kickoff brings new and unique challenges every year. Here at REV Robotics, we understand that adapting to game challenges requires rapid iteration. We created REV ION to allow for complex robot designs without large budgets or extensive manufacturing equipment, using many of the basic tools that teams are already using for their build season. We use REV ION parts to present engineering concepts within this document, regardless of the specific build system your team chooses.

We hope this guide introduces you to some of the basic components and techniques used within the *FIRST* Robotics Competition and serves as a great starting point as you begin to build your robot. For more information or technical assistance, visit our website at www.revrobotics.com or reach out to us via email at support@revrobotics.com

Good luck this season and see you at the competition!

Greg Needel and David Yanoshak
Co-Founders of REV Robotics

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Categories of Robot Parts

A robot is built from many varying types of parts. All the parts on a robot can be broken down into the following categories. This guide will explain each category, as well as provide some suggestions for building.

Hardware and Tools

Hardware refers to the fasteners used to hold the structure together, such as screws, bolts, nuts, rivets, etc.

Structure

These parts are the framework to which all other parts are attached.

Transmitting and Transforming Motion

Sprockets, chain, belts, pulleys, and gears are used to transfer motion on the robot. Differences in the sizes of gears and sprockets allow for changes to speed and torque.

Supporting and Constraining Motion

Parts, such as shaft collars and spacers, help restrict or constrain motion to the intended direction. Unwanted motion hurts the accuracy and repeatability of the robot's actions.

Drivetrains

Drivetrains are the base of most *FIRST* Robotics Competition robots. They are generally made of wheels, gearboxes, motors, and structure. There are many different styles of drivetrains featuring different components that will affect the maneuverability of the robot.

Actuators

Actuators, like motors and servos, create motion on the robot.

There are other types of parts that go into creating a robot that won't be discussed in this guide. For more information on those, please see the "What's Next" section at the end of this guide.

Hardware and Tools

Teams in *FIRST* Robotics Competition use hardware to connect, or fasten, brackets and structure together on a robot. Different applications require different lengths and/or profiles of screws. When attaching a bracket to aluminum extrusion, shorter screws with a low-profile head, like a button head screw, are generally required. Longer screws are used to connect Control System components and other thicker materials. Locking nyloc nuts are suggested to prevent the screws from loosening due to vibrations as the robot moves.

Many different build systems, such as the REV ION Build System, have standardized hardware sizes in order to cut down on the amount of hardware and tools teams need to keep on hand. Consider picking a standard for your team, like #10-32, and using it throughout your robot.

See the "Structure Application Examples" section on pages 9-10 of this guide to find some 'best practice' tips for working with hardware.

We recommend these tools to start building your team's toolbox:

- Nut Driver Set
- Drill Bit Set
- Hack Saw
- Hex Key Set
- Tap and Drill Set
- Metal Files
- Combination Wrenches
- Ratcheting Wrenches
- Screw Drivers
- Chain Tool
- Pop Rivets and Riveter

For more information on recommended tools, check out the *Suggested Tools for FIRST Robotics Competition Teams Guide*, which can be found on the technical resources web page:
www.firstinspires.org/resource-library/frc/technical-resources

Structure

This section goes over all of the basic structure elements used in *FIRST* Robotics Competition. Here, we give a comparison between T-Slot Extrusion and Patterned Extrusions, as well as a few tips and tricks for anyone choosing to build with REV ION.

The majority of a robot's structural elements can be divided into two main categories:

- **Extrusion**
  - Patterned
  - T-Slot
  - Plain Stock
- **Brackets**
  - Motion
  - Structure

Extrusion

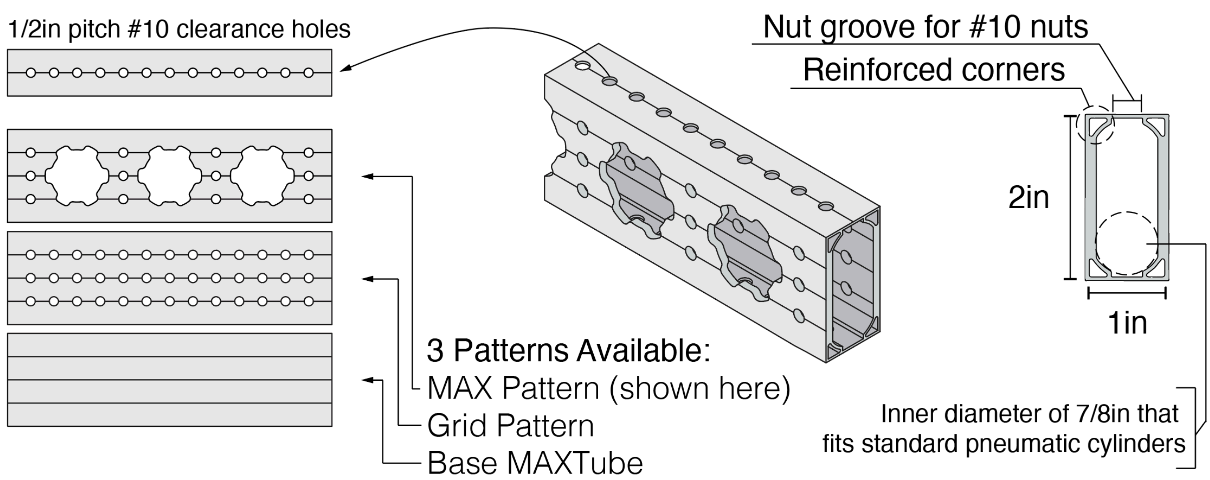
There are three primary types of structure pieces used when building a robot: T-Slot Extrusion, Patterned Extrusion, and Plain Extrusion Stock. While they all have a few similar features, they each have applications best suited for them.

Patterned	T-Slot	Plain Stock
• A fixed pattern of mounting holes • Locations for mounting structure, gears, sprockets, bearings, shafts, motors, and servos • Good for a robot drivetrain • MAXTube accepts standard #10-32 Hardware on 1/2in pitch	• Slots allow for brackets to be placed anywhere • Adjust design with ease • Good for linear motion • REV ION 1in T-Slot Extrusion accepts standard #10 Nuts and #10 Low-Profile Nyloc Nuts	• Available in many profiles including square/ rectangular tube, and C-channel • Ultimate choice for customization, but it requires precise machining

Patterned Extrusions

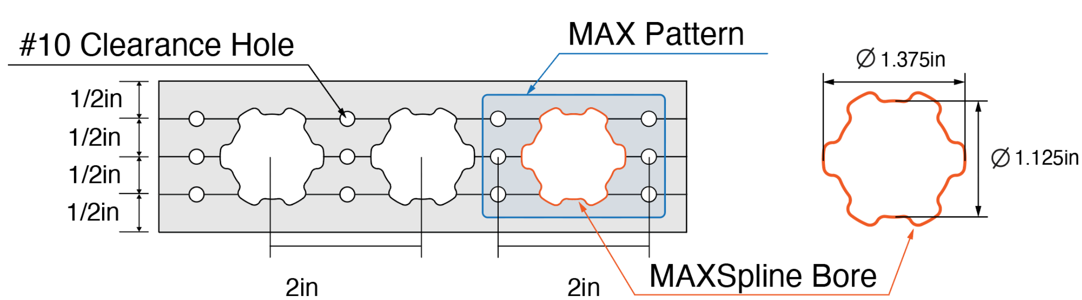
Using patterned extrusion to build a sturdy drivetrain is a great start to a robot.
Pre-drilled holes, often in a grid pattern, allow for the rapid iteration of a design without needing to machine a new part. A wide variety of different patterns exist, each one with its own set of standards. REV Robotics is just one of many manufacturers of patterned extrusion. Each team should evaluate the different patterns available and decide which design best suits their robot based on the desired features. Making sure that any patterned extrusions your team uses are compatible with each other will save you time in the long run.

REV ION has three options for patterned extrusions within the MAXTube line: Base MAXTube, MAXTube with Grid Pattern, and MAXTube with MAX Pattern. All 1in sides of the MAXTube extrusion have a nut groove inside to fit #10 nuts, making assembly easier by helping to retain nuts where a wrench can't reach.

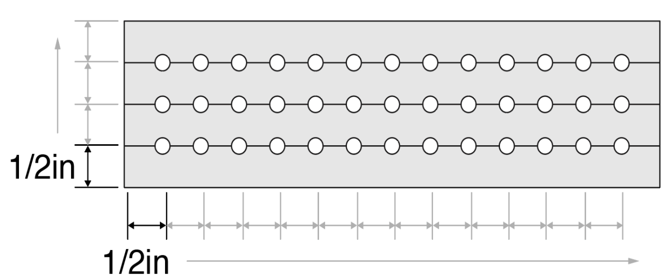


MAXTube with MAX Pattern features a combination of #10 clearance holes and a MAXSpline bore patterned every 2in. The #10 clearance holes are arranged on a common 1/2in pitch grid. MAX Pattern frees teams from cutting and drilling, with easy installation of bearings for different live axle applications, as well as correct center-to-center distances for simple 1:1 power transmission with #25 chain or RT25 belts.

MAXSpline is a shape unique to REV ION. Learn more about power transmission with MAXSpline in the motion section of this guide.



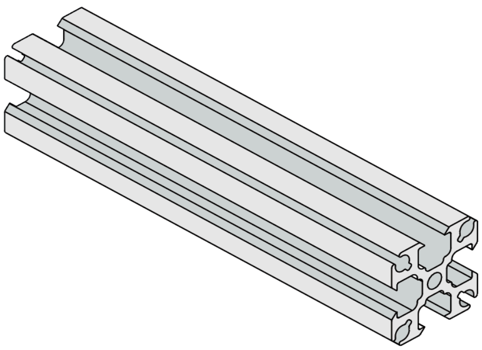
MAXTube's Grid Pattern is featured on two sizes of MAXTube: 1x1 and 2x1. A grid of #10 clearance holes are spaced along each side of the MAXTube on a 1/2in pitch.

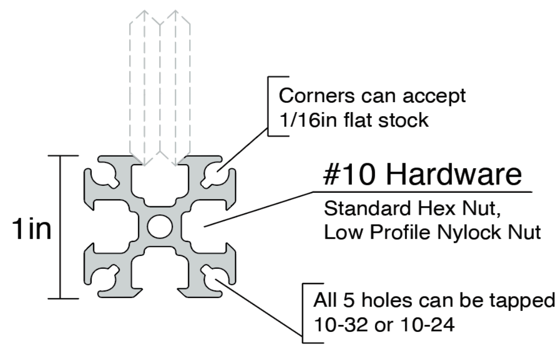


T-Slot Extrusions

The flexibility of T-Slot Extrusion makes using it a great option for builds that won't fit on the pattern of your patterned extrusion. Teams are not locked into a pitch, so there are virtually infinite options for mounting other components. T-Slot Extrusion is also a great option for adding linear motion to your robot. T-Slot Extrusion is available in many sizes from different manufactures, including REV Robotics, 80/20, and Bosch. Each brand of T-Slot Extrusion has different features, including compatible hardware sizes and extrusion profiles.

When using REV ION T-Slot Extrusion, standard #10 Hex Nuts or #10 Low-Profile Nyloc Nuts will fit in the slots, allowing teams to use a more commonly available option than specialized T-nuts.





Brackets

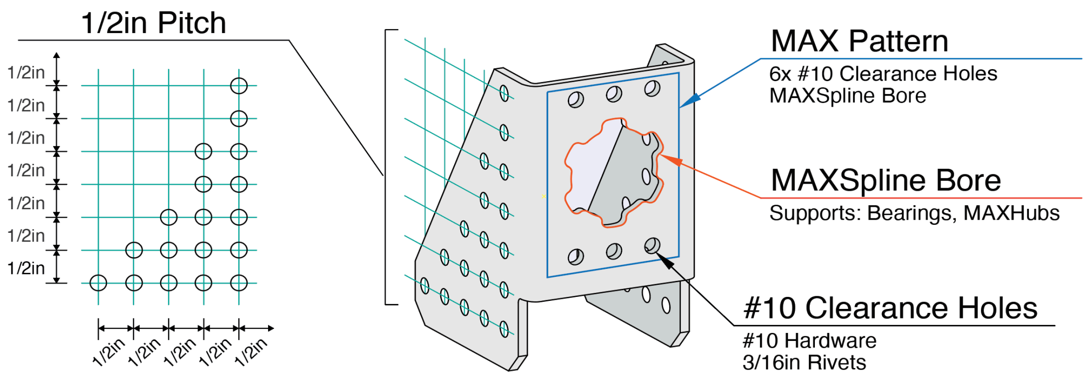
Brackets are used to join different parts of the robot together. Most brackets can be divided into two categories: **Motion** and **Structure**. Motion brackets help create strong attachment points for your motion components and any parts of your robot that move. Structure brackets are designed to hold pieces of extrusion together.

Motion Brackets

Most available motion brackets are very specific to the components that they are designed to work with, and they often include special hole patterns for motors or different bores. The motion brackets you use will heavily depend on the motion components you design into your robot. Be sure to check the compatibility of your brackets with any other structure or components you are using on your robot.

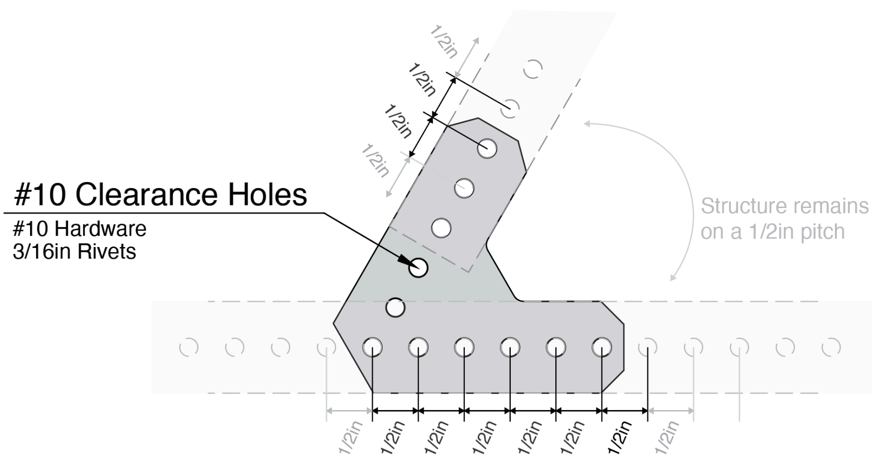
In the REV ION Build System, motion brackets are referred to as MAXSpline Brackets because within the ION System, the MAXSpline shape is the core to transmitting motion. The major distinguishing feature of MAXSpline brackets are a MAXSpline bore, or a full MAX Pattern to support bearings and MAXHubs.

MAXSpline Brackets that feature the MAX Pattern are designed to keep the pattern on pitch.

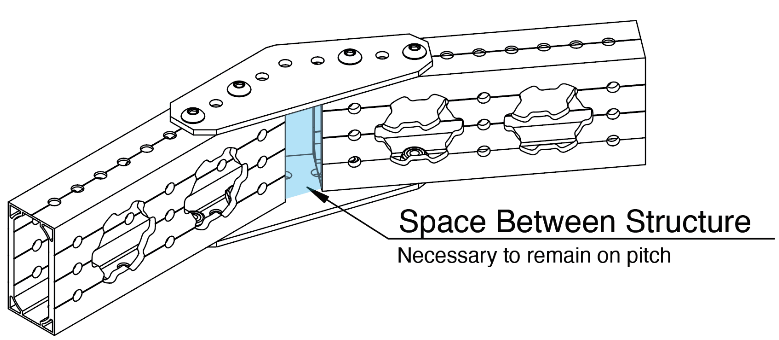


Structure Brackets

Structure brackets are designed to secure pieces of structure together at varying angles. There are different hole patterns available to accommodate the different extrusion types and patterns. In the REV ION Build System, structure brackets are any bracket that does not have a MAXSpline Bore.



ION 1in Brackets are hole-aligned to maintain the pitch grid between your MAXTubes. When building a robot with hole-aligned brackets, you will likely notice an open space between the structure ends, where they do not touch at the corner. This is expected and will not affect the strength of your joint.



Structure Application Examples

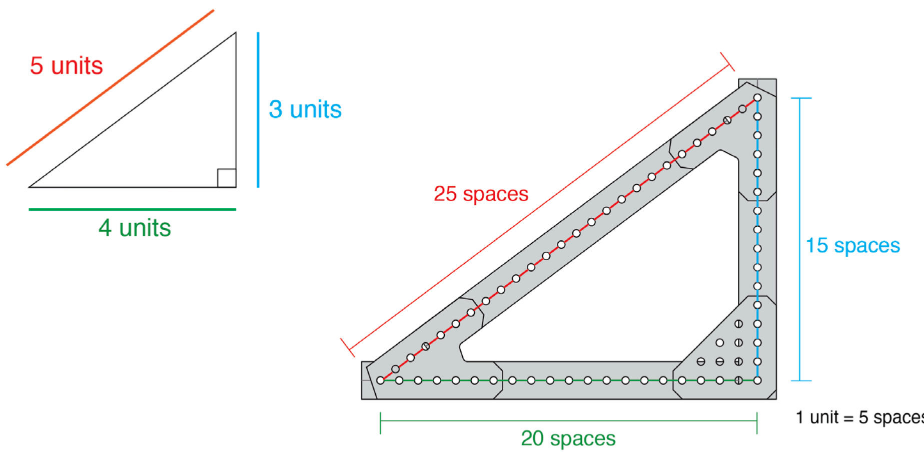
Check out the following tips and tricks, so you can quickly become a master robot builder.

3-4-5 Brackets

Triangles are a sturdy structural shape, commonly used on robots to support many types of mechanisms. Vertical structures are very common and can be supported with a 90 degree, or "right" triangle.

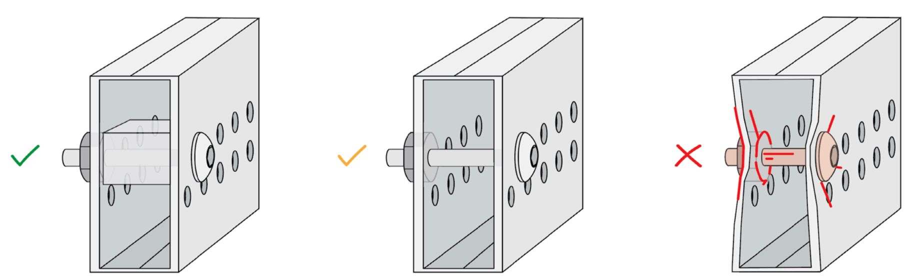
Building a triangle out of patterned extrusion with a fixed pitch hole pattern can be a little difficult when trying to ensure the holes line up across all sides and all angled brackets. For example, a simple right triangle can be made with a set of 45, 45, and 90 degree brackets. Unfortunately, the required lengths of structure to form the triangle sides end up being irrational numbers, and therefore, won't line up with the holes along the hypotenuse.

REV ION features 3-4-5 brackets specifically designed to have the exact angles that make up a triangle with sides that are multiples of 3, 4, and 5 length units. In other words, the holes on all sides of a triangle built with 3-4-5 brackets will line up on pitch. Count the number of spaces between holes for each side of the triangle, and roughly cut the structure to length. In the example below, each side is a multiple of five spaces (1 unit), but that base unit will depend on the overall desired dimensions of the triangle.



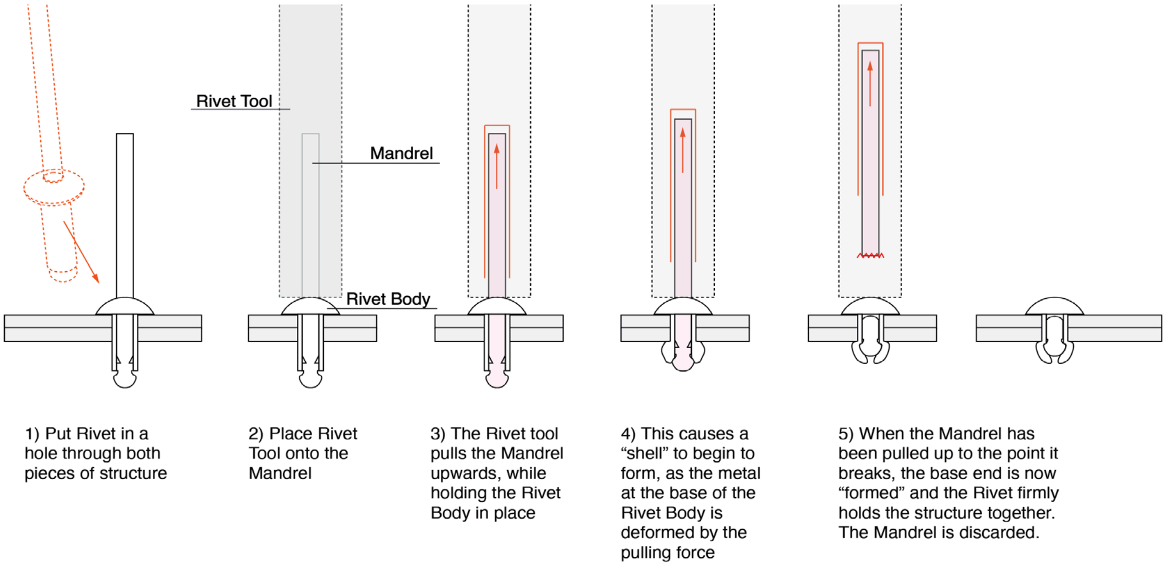
How to Bolt Through a Tube

When bolting through a tube, be careful not to over-tighten the bolt. Doing so can cause the tube to crush or deform. If you need to tighten the bolt for heavy-duty applications, be sure to support the tube from the inside.



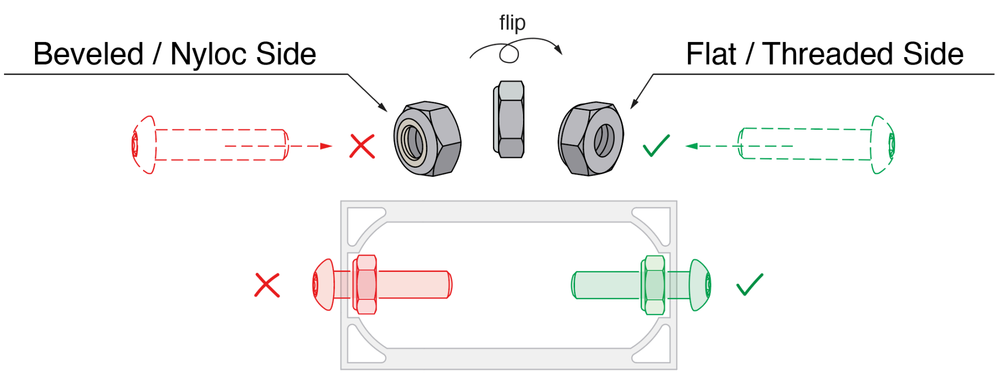
Rivets

Rivets are a popular alternative to nuts and bolts. By using a specialized tool, you can secure brackets and other components to a robot with one item.



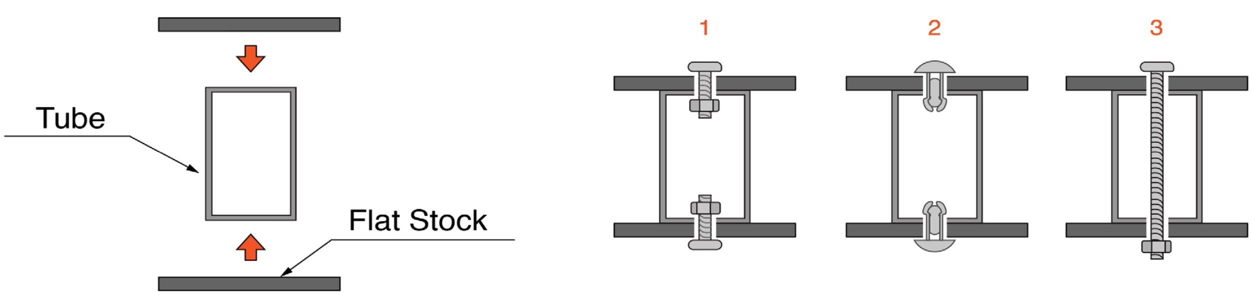
Nut Direction Matters

Nyloc nuts have a built-in nylon collar that secures a screw with friction. As the nut is tightened, the nylon collar deforms around the threads, creating a lock that is vibration-resistant. When using nyloc nuts, make sure to thread the screw through the flat, threaded side first. This ensures that the nylon collar of the nyloc nut will engage with the threads properly.



Joining Flat Stock or Brackets to Tube

There are three ways to attach flat stock or brackets to tube: bolting through each wall of the tube separately, using rivets to attach each piece to the tube, and using one bolt to attach all pieces.



Motion

Transmitting Motion is the act of getting motion from one part of the robot to another using shafts, sprockets, gears, belts, pulleys, etc.

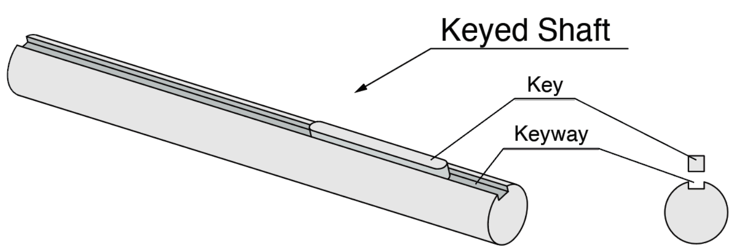
Transforming Motion is the act of changing the turning force (torque) and speed. Torque and speed are inverse to each other, meaning when one increases, the other decreases. Several of the same components that *transmit* motion are also used to *transform* motion (sprockets and chain, belts and pulleys, and gears).

The core component to transmitting motion on a robot is a shaft. They come in many shapes and styles, but the goal of each shaft is to transmit motion to other components.

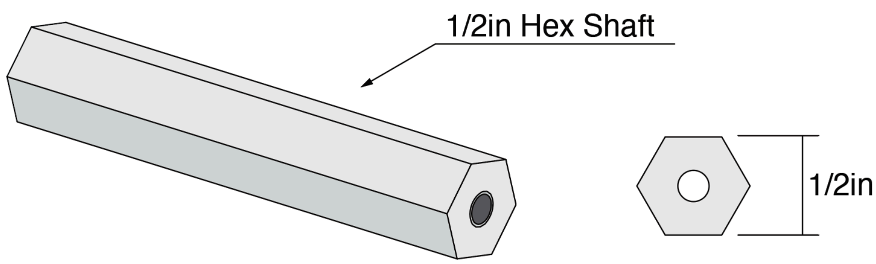
Shafts

One of the oldest and least used shaft types is a D-shaft - a round shaft with one flat side that makes a D shape. To transmit motion with a D-shaft, shaft collars and motion components are secured to the flat side of the shaft using a set screw. Transferring torque through a set screw can cause failure in high-torque applications, and the set screws require re-tightening under the best of circumstances, so this method is generally not recommended.

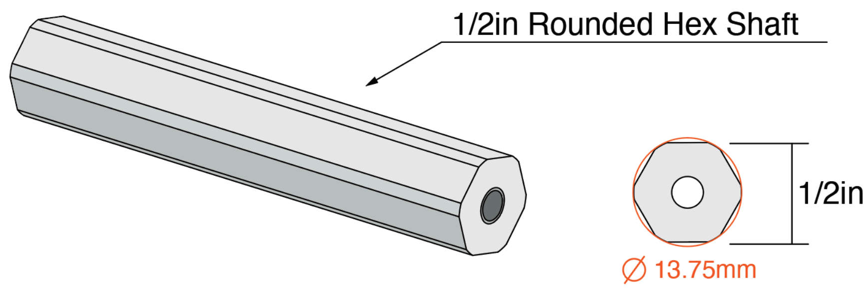
Another shaft type commonly found on motors and gearboxes are Keyed Shafts. These consist of two parts: a round shaft with a groove called a keyway, and a key that fits into that groove. Components attached to keyed shafts will also have a keyway, as the key is how torque is transferred from the shaft.



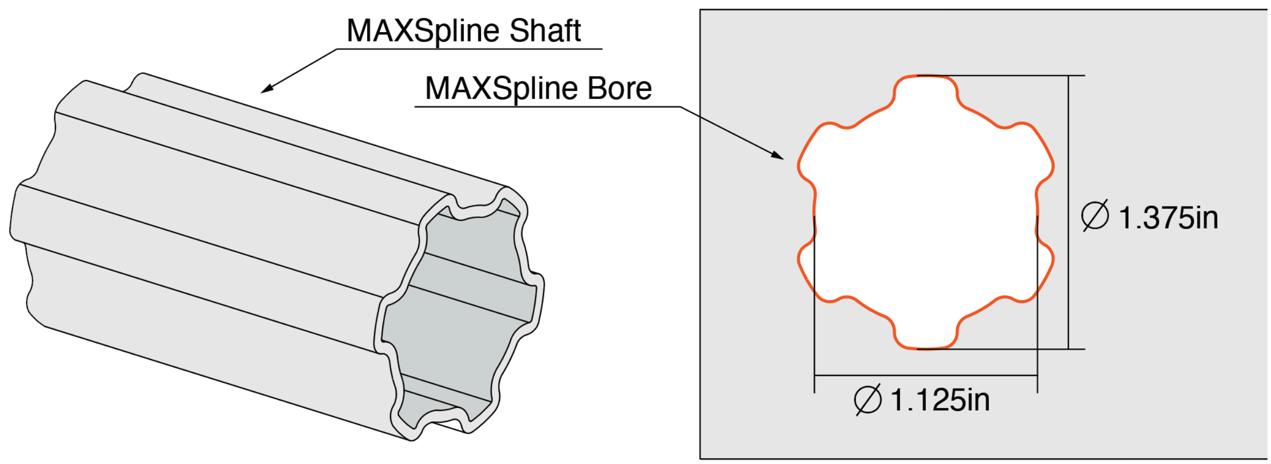
A 1/2in Hex Shaft is the most common way to transmit motion in *FIRST* Robotics Competition. The six-sided shape provides reliable torque transfer and is commonly used in wheels, gears, sprockets, and more.



Sometimes when building with 1/2in hex shaft, it can be difficult to line up the shape within hex bore elements because the corners must be perfectly aligned. 1/2in Rounded Hex Shaft is a popular variation of 1/2in hex shaft. With the corners rounded to form a 13.75mm circle, 1/2in Rounded Hex Shaft pilots smoothly inside 1/2in hex bore components as well as standard 1.125in flanged bearings for an easy assembly experience.

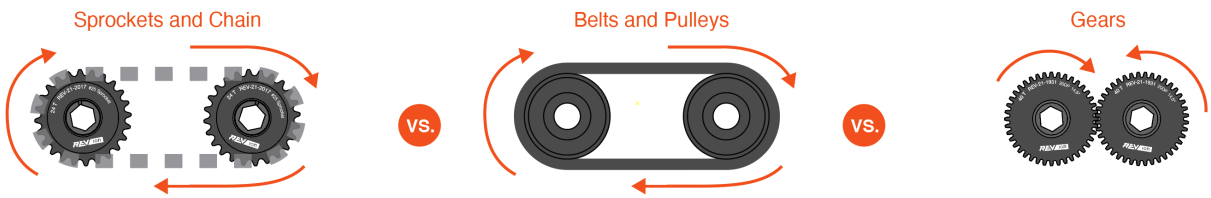


The last common style of shaft is the spline shaft. Spline shafts are identified by their grooves or teeth that run down the length of the shaft and interlock with other motion pieces. An example of a spline is the MAXSpline from the REV ION Build System. This hex-like spline is incorporated into the other main motion components (sprockets, gears, wheels, and shafts). This unique shape allows us to do things like combine a bearing support with a torque transfer feature for added configurability of motion components.



Motion Transmission Systems

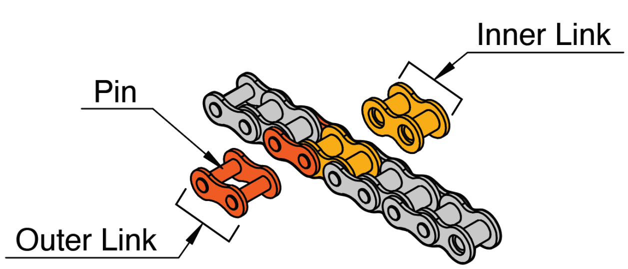
The three primary systems used to transmit motion are: sprockets and chain, belts and pulleys, and gears.

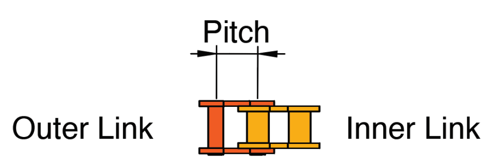


Sprockets and Chain	Belts and Pulleys	Gears
• Good for transmitting motion over long distances • Changing sprocket sizes requires changing the chain length and/or spacing • Chain is forgiving in construction accuracy • Chain tension and wrap are important	• Smooth and efficient • Can be lighter than gears or sprockets that are traditionally made of metal • Changing pulley size and/or spacing needs a new belt length • Belt tension and wrap are important	• Can be used for changing rotation direction • Compact • Flexible in adjusting speed and torque • Gear spacing is important

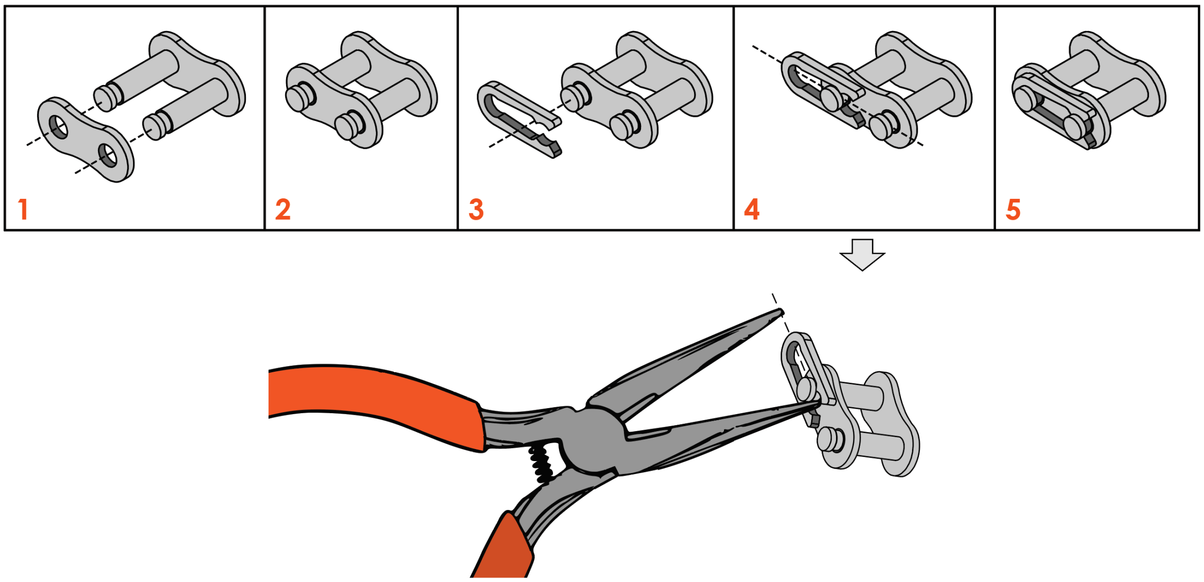
Sprockets and Chain

Sprockets and Chain are ideal for transmitting motion over long distances. A chain consists of a continuous set of links that ride on the sprockets to transmit motion. The two most commonly used sizes of chain in *FIRST* Robotics Competition are #25 and #35. When choosing between chain sizes, it is important to consider the pitch of the chain and the weight and forces that your mechanism will be experiencing. The REV ION Build System is designed around #25 chain using compatible #25 sprockets.



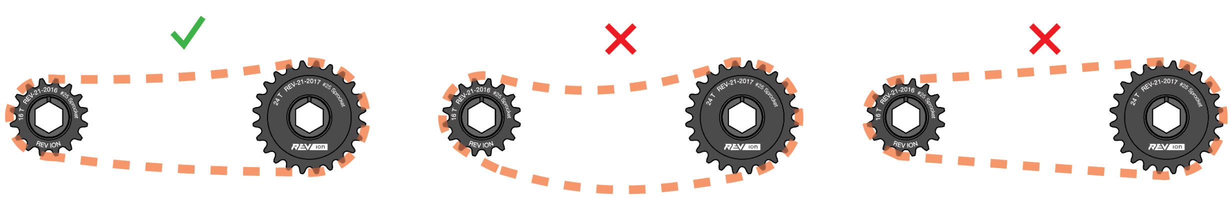


Creating a loop of chain requires breaking off the correct number of links by removing a specific chain pin and joining the ends together. Chain can be broken using many methods, including a Chain Tool or various steel cutting blades, like a dremel. Once you have counted the number of links necessary for your application, the chain can be joined using a master link or by replacing a pin. The diagram below shows how a master link is assembled to replace an outer link.

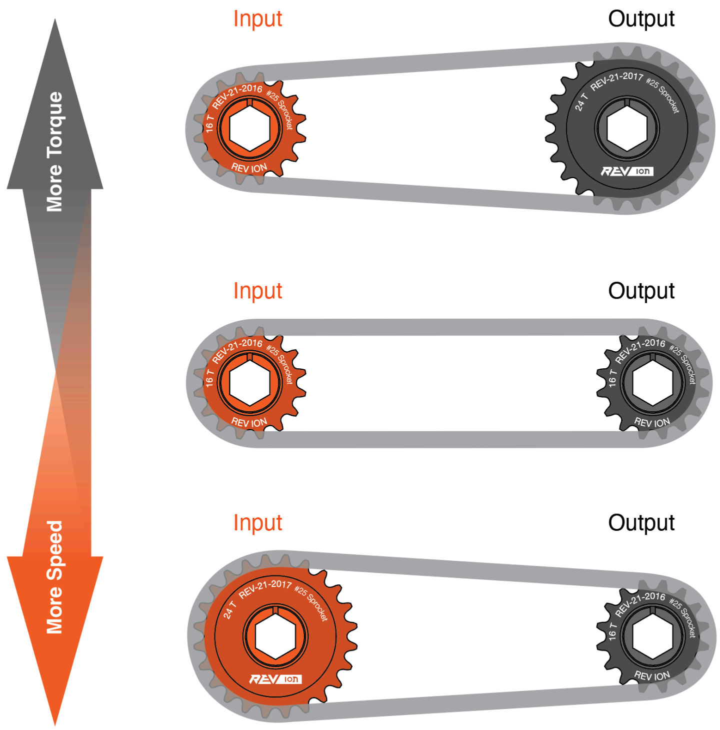


Instead of using a master link, REV's #25 Chain Tool can be used to push out a pin and then push the pin back in once the link has been formed for a stronger, but more difficult, joining method. For instructions on how to break and reassemble the chain using this method, see the *Chain Tool User's Manual* and 'How-To' video found on its product page on our website.

When creating your loop of chain, remember that properly tensioned chains should not be tight. If the chain is too tight on your sprockets, it can waste energy, making your actuators work harder while causing premature wear and damage. If the chain is too loose, it can slip off or skip teeth on the sprockets.



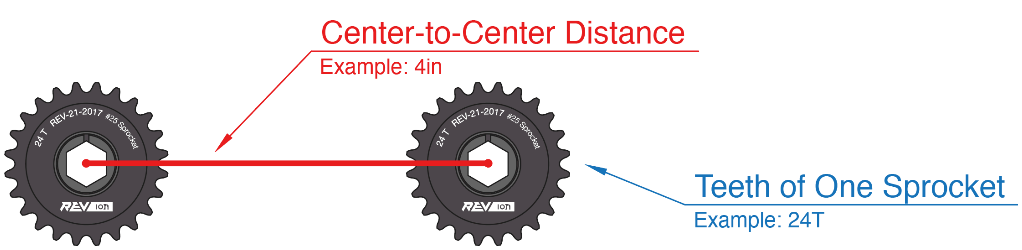
Transforming the torque and speed of motion with sprockets and chain is accomplished by changing the size of the sprockets.



Chain Loops can be used with ION Sprockets and structure featuring the MAX Pattern. Any 1:1 ratio will have the correct center-to-center distance for a properly tensioned chain, without the need for tensioning bushings. To calculate how many links you will need, multiply the center-to-center distance by eight, and add the number of teeth on one sprocket.

Links of #25 chain = (Center-to-center Distance x 8) + Teeth in one sprocket

(Center-to-Center Distance x 8) + ___T = Links of #25 Chain



(4in x 8) + 24T = 56 Links of #25 Chain

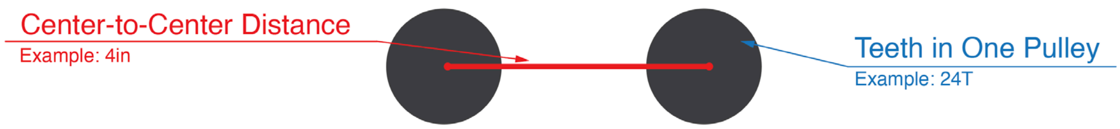
If a ratio other than 1:1 is needed when using the REV ION Build System, use our Ratio Plates to accommodate for the change in center-to-center distance. An ION Ratio Plate provides an offset from the standard MAX Pattern pitch that creates the center-to-center distance.

Belts and Pulleys

Belts and pulleys are a great, lightweight option for building a smooth-running mechanism. They are very similar to chain and sprockets, with the belt replacing chain and pulleys replacing sprockets.

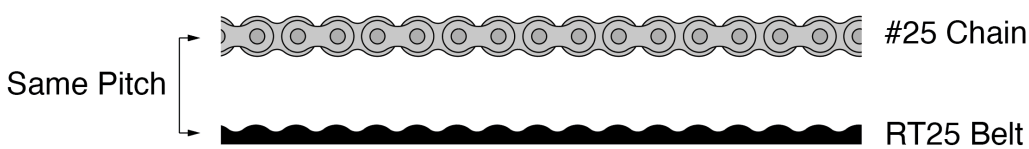
The biggest difference is that belts are a set size and can not be adjusted, so you lose some flexibility in spacing options. If you want to change the spacing of your pulleys or use a different size pulley to increase speed, you will likely need a different sized belt.

(Center-to-Center Distance x 8) + Teeth in One Pulley = Belt Size of an RT25 Belt



(4in x 8) + 24T = 56 Tooth RT25 Belt

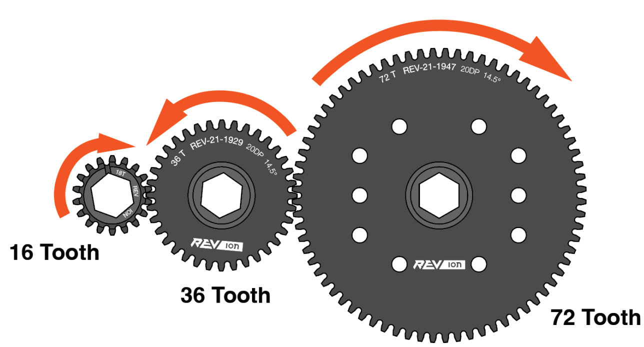
In the REV ION Build System, we created a new standard of belt called RT25. Unlike many common metric belt standards, RT25 Belts haves a 1/4in pitch just like #25 chain. With this pitch, both RT25 belts and #25 chain work natively within the ION build system. Since they are both on a 1/4in pitch, they can be swapped out 1:1 for rapid prototyping and iteration of designs. The pitch compatibility with MAX Pattern also makes it easier to swap in different belt lengths when you want to make changes. These belts are comparable in strength to the belts that teams are accustomed to using while working on the same pitch as the ION Build System.



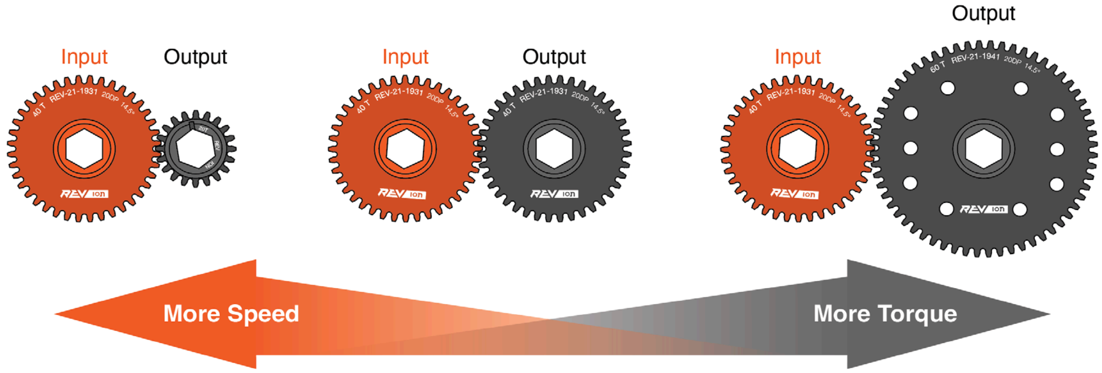
Gears

Gears have teeth that mesh with other gears in order to transmit motion. Gears offer more flexibility in transforming motion than sprockets and chain or pulleys and belts because there are a larger variety of gear sizes available.

Gears are ideal for use in more compact spaces and are also used for changing the direction of rotation.



Transforming the torque and speed of motion can be accomplished by changing the size of the gears.



To ensure that you have a proper amount of gear teeth mesh, it is important to calculate the center-to-center distance in between your gears. You can do this by first calculating the pitch diameter (PD) of each gear using some combination of module (M), number of teeth (N), or outside diameter (OD).

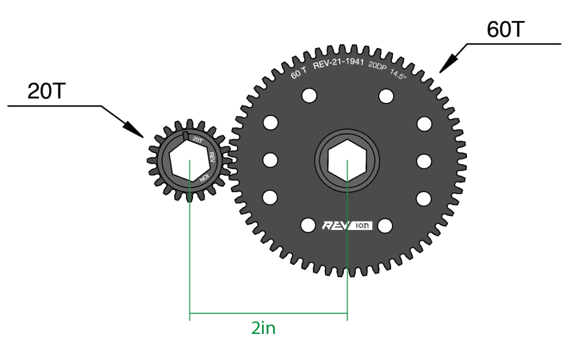
- $PD = M \times N$
- $PD = (OD \times N) / (N + 2)$
- $PD = OD - (2 \times M)$

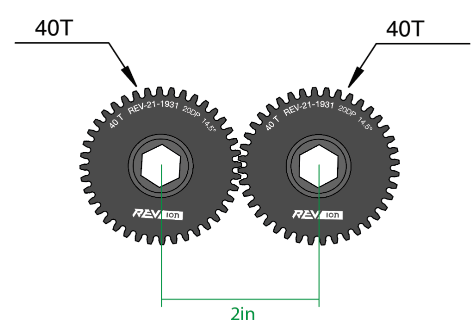
Then, use the pitch diameters to calculate the center-to-center distance (CCD)

- $CCD = ((PD1) / 2) + ((PD2) / 2)$

Any two REV ION gears that add up to 80 teeth will fit center-to-center on structure elements featuring the MAX Pattern and have a center-to-center distance of 2in.

___T + ___T = 80





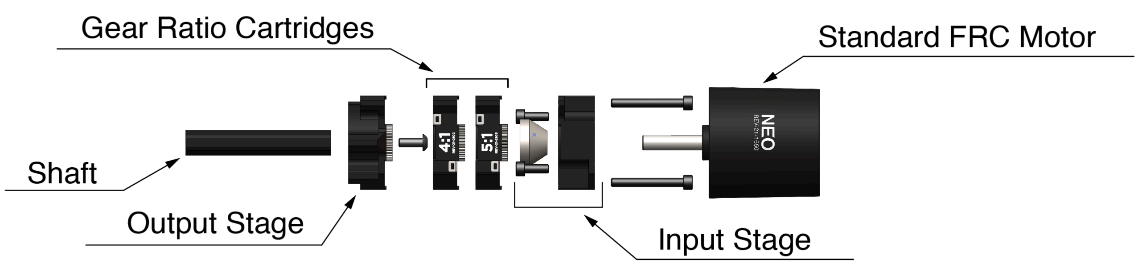
20 T + 60 T = 80

40 T + 40 T = 80

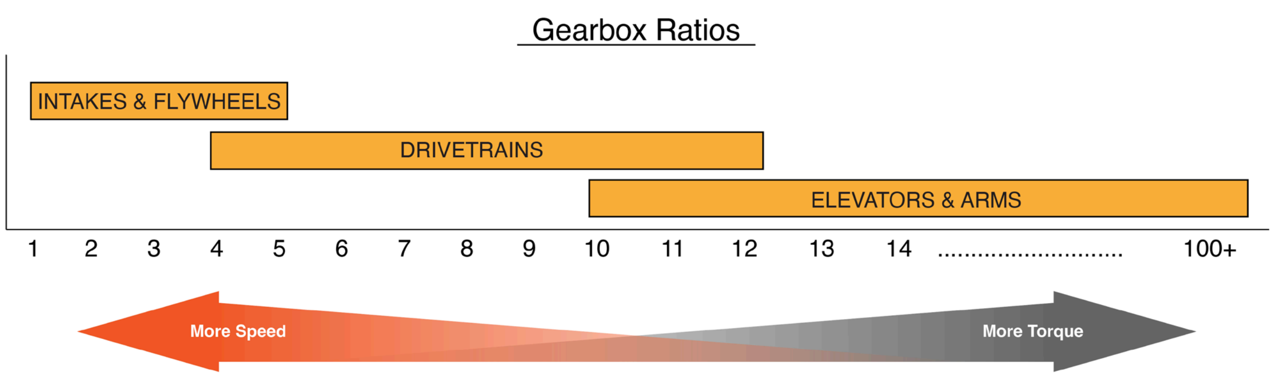
Gearboxes

Gearboxes are a very common way to transform motion in *FIRST* Robotics Competition. They are generally compact and modular, able to be mounted on your robot wherever they're needed. Some have fixed gear ratios, and some can be easily changed for the needed application. A popular style of gearbox is the adjustable, modular, planetary gearbox. In this kind of planetary gearbox, cartridges of different gear ratios are stacked to create an overall reduction. This is a fantastic option for teams to prototype with because they can quickly change the gear ratio without needing to redesign the entire mechanism.

One example of this kind of planetary gearbox is the ION MAXPlanetary Gearbox. The MAXPlanetary system consists of pre-assembled and lubricated gear cartridges, available in 3:1, 4:1, and 5:1 gear ratios. Teams can easily adjust torque and speed for different applications by configuring different combinations of cartridges. When assembling the MAXPlanetary Gearbox or any other planetary gearbox, it is important to place the highest gear ratio cartridge next to the motor. Additional cartridges should then be mounted in descending order.



A wide range of gear ratios are possible with the three available cartridges. When combining up to three cartridges, just multiply each cartridge gear ratio to find the overall gear ratio. For example, a combination of the 4:1 and 5:1 cartridges make a 20:1 overall gear ratio. The table below shows the common use cases for all possible ratios that can be created with the MAXPlanetary Gearbox.



While this table is a good starting point, please take a look at the *MAXPlanetary Gearbox User's Manual* on our website before configuring the gearbox. The guide contains detailed information about the system features and limitations that are very useful when designing a robot. The online documentation also has information about how the type of motor used will affect what ratios are effective for different mechanisms.

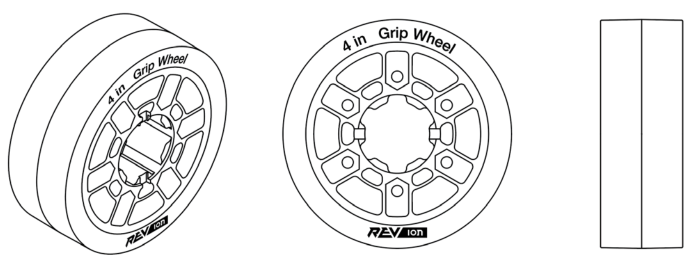
Wheels

Most wheels used in *FIRST* Robotics Competition can be divided into four categories; Standard, Omni, Mecanum, and Compliant. Each manufacturer makes slightly different wheels, with varying materials, sizes, durometers, and colors. One element to consider when choosing a wheel is the bore size, and if you will need any additional hubs to convert your wheel to the needed input or output.

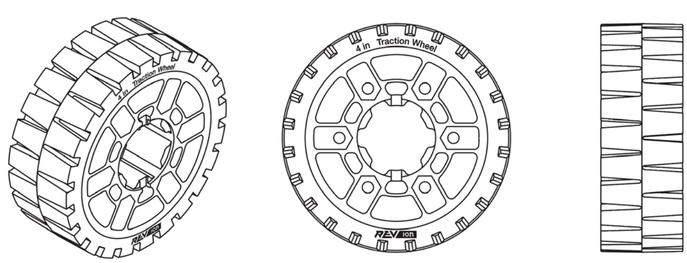
Most sizes of ION wheels feature a MAXSpline bore that can fit standard 1.125in OD bearings or easily be adapted to other bores using MAXHubs. Smaller wheels feature 1/2in hex bore. Larger sizes of ION Traction, Grip, and Omni Wheels have spokes with a bolt circle of #10 clearance holes patterned outward at 1/2in pitch. They also have a 3/8in-wide nut groove that eliminates the need for a wrench when utilizing the holes on the spokes.

Standard Wheels

Standard wheels include wheels with smooth or grip-textured tread. These wheels are versatile, being a great option for drivetrains, as well as intakes or flywheels. Standard wheels without a tread pattern are designed for optimal grip in situations where the material the wheel is interacting with is compliant, like carpet or foam.

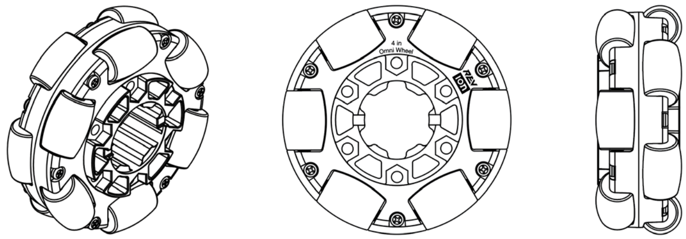


Standard wheels that have a tread pattern are designed for increased traction. They are good for drivetrains when you need a lot of pushing force.



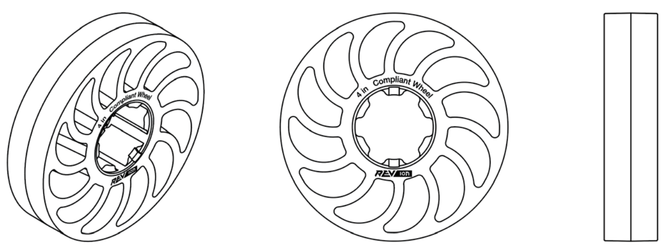
Omni Wheels

Omni wheels have smaller rollers around the circumference of the wheel. These rollers can passively roll perpendicularly to the direction the wheel is driven. Using omni wheels in conjunction with each other can create more maneuverable robots in advanced drivetrain applications. This wheel makes it easier for a robot with a differential drivetrain to turn.



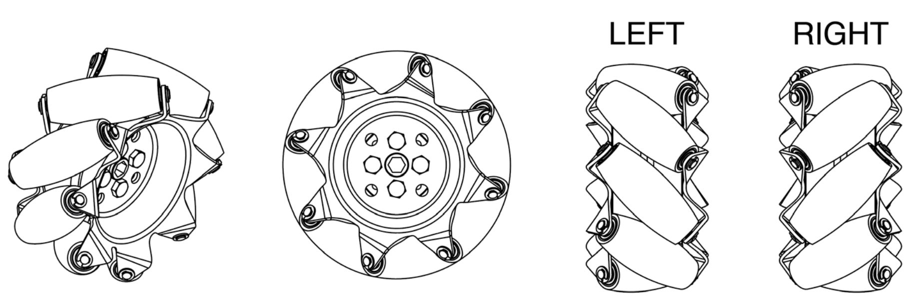
Compliant Wheels

Compliant wheels are ideal for intakes and conveyor systems where a bit of “give” is needed. These wheels come in many sizes and are available in multiple durometers. As the tread durometer increases, the compliant wheel gets harder, which will change the wheels’ traction, wear, and compliance. Many compliant wheels feature “hurricane” or other shaped cutouts to ensure even compliance across the rotation of the wheel.



Mecanum Wheels

Mecanum wheels, when properly setup on a drivetrain, allow for omni-directional movement. A set of mecanum wheels used in a drivetrain include two left wheels and two right wheels each made up of rollers that are angled at 45 degrees. Mecanum wheels can also be used to create vectored intakes. By using the 45-degree angle of the rollers to your advantage, you can funnel game pieces towards a specific point on your robot, such as the opening of a conveyor.

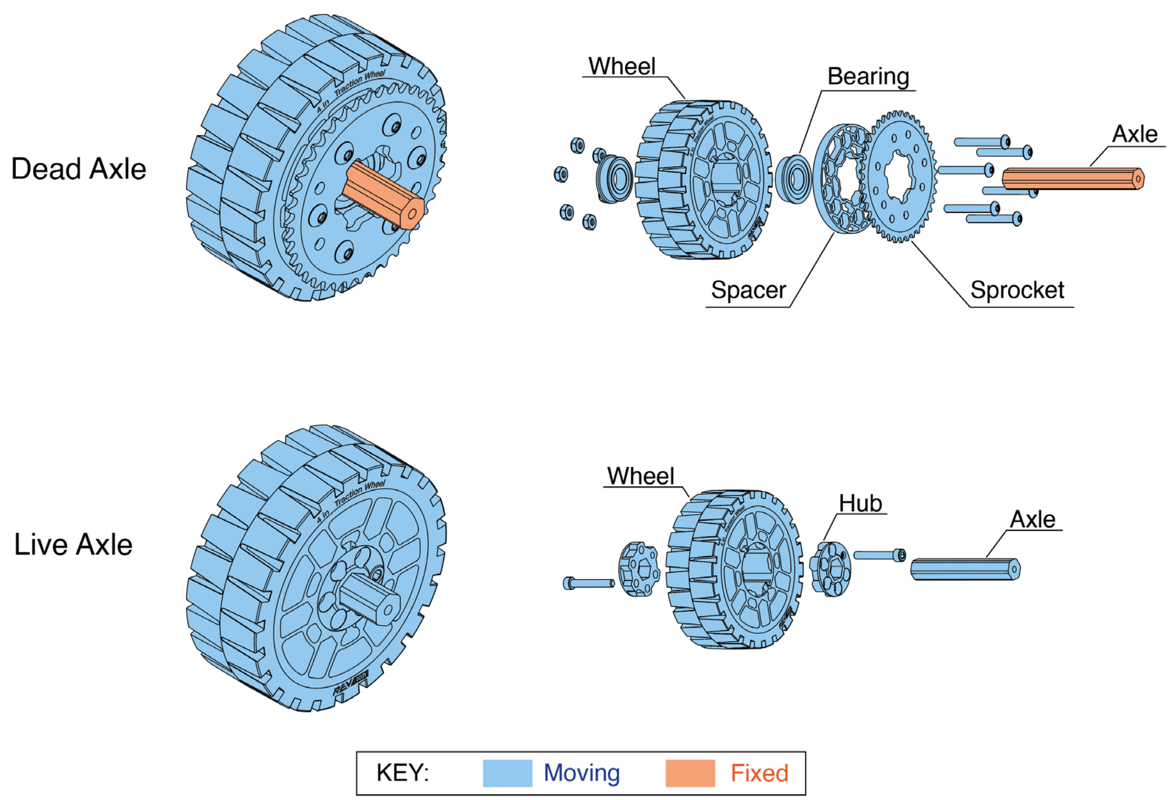


Mounting Wheels

The two main methods of attaching wheels to a robot are to create Live and Dead Axles.

A *Live Axle* is an axle that transmits torque to a wheel. This can be done through a 1/2in hex hub, gear, pulley, or sprocket. In a live axle assembly, the axle will rotate along with the wheel. Live axles are commonly used in drivetrains or as a flywheel.

A *Dead Axle* is an axle that only supports the wheels and does not move. Generally, bearings are used to support the wheel on the dead axle so it can spin freely. Dead axles remain stationary while the supported wheel is in motion. Some applications include free-spinning intake rollers and non-powered drivetrain wheels.



In the REV ION Build System, MAXHubs provide a way to transfer torque to a MAXSpline Bore from shafts of various shapes and sizes. MAXHub variants allow for other bores or mount holes to populate within an existing MAXSpline.

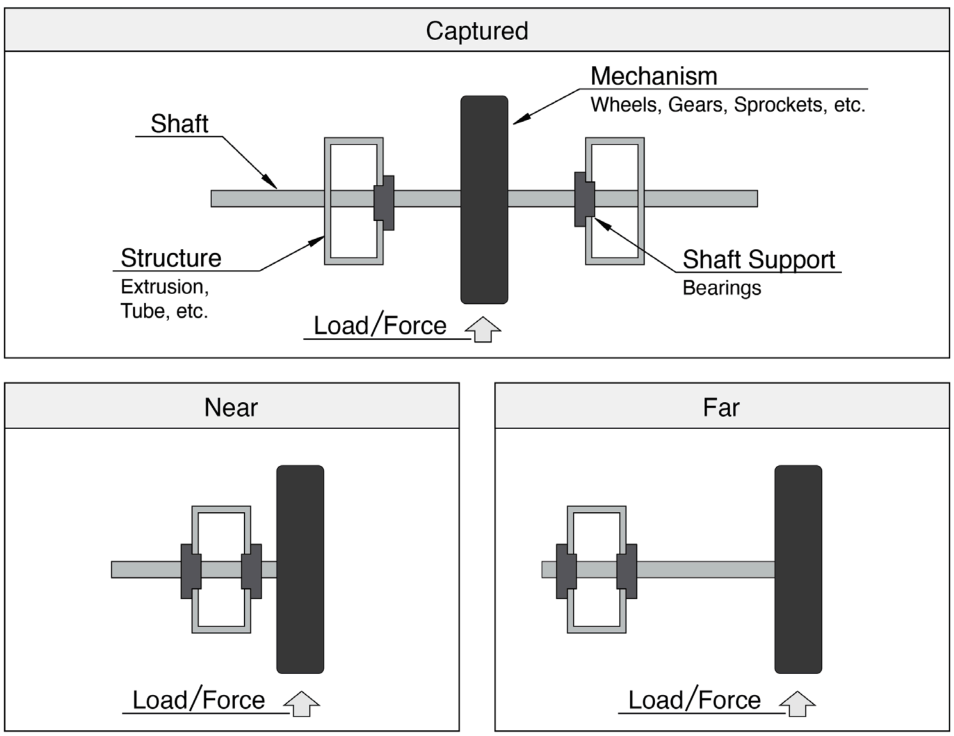
The MAXSpline Bore can also accept standard 1.125in bearings directly. This allows teams to quickly switch between live and dead axles while prototyping.

Supporting Motion

Supporting the mechanisms that move on the robot is very important. Without planning proper supports, shafts may not be able to spin and your mechanisms and actuators could be damaged.

Forces, or “loads”, that are at a right angle, or “normal” to the shaft, are the most important forces to counteract. The floor pushing on a wheel or two gears pushing against each other are two examples of normal forces.

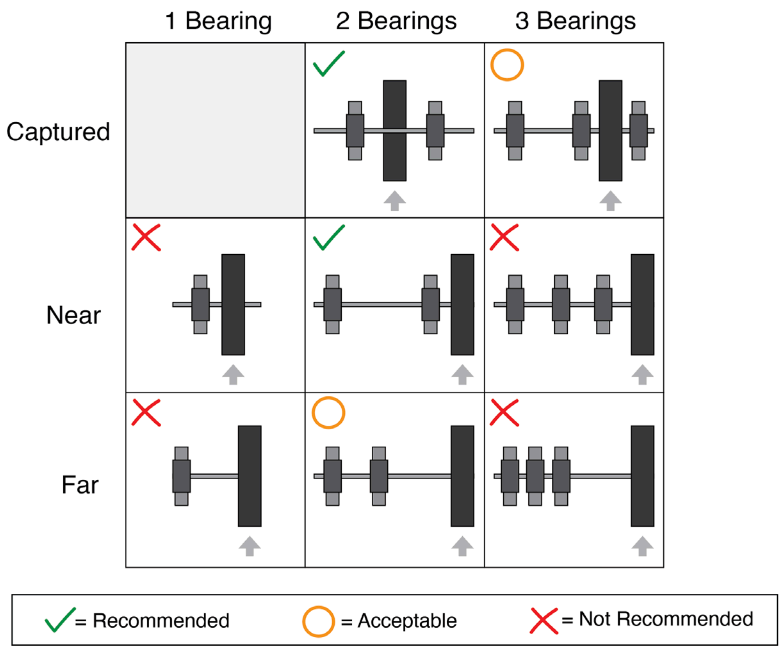
A shaft should be supported with two points of contact. Without two support points, the shaft can pivot in the direction of the force. Ideally, those two points of contact should “capture” the mechanism under load. In other words, the support points are on either side of the mechanism. If a mechanism can’t be captured, it is important to keep the load as close to the two support points as possible.
Below are some examples of the three major supported load configurations: Captured, Near, and Far.



Additionally, the further apart the two support points are from each other, the better it can resist effects of a normal force. As the supports move closer together, they begin to act more like a single support.

Supporting a shaft is important, but adding more than two support points can have diminishing returns. Each bearing that the shaft passes through adds a constraint to that shaft. You need to balance having the appropriate amount of constraints to keep the shaft from moving due to normal forces, but not too many that the shaft becomes “overconstrained.” Overconstrained mechanisms can bind and make rotation difficult, causing stress on the actuators and even damaging components of your robot.

The diagram below gives an overview of how bearing quantity and arrangement can impact the stability of load configuration (Captured, Near, and Far).

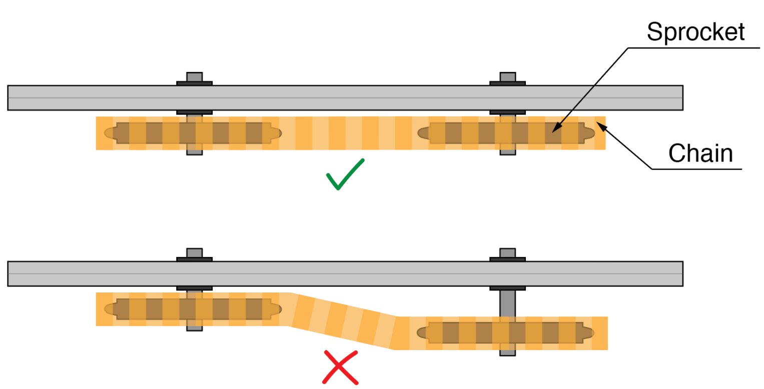


Constraining Motion

Robots need movement to accomplish goals; arms must pivot, wheels must turn, etc. However, movement that isn't directly related to those actions can affect the accuracy and precision of the robot mechanisms. This unintended motion must be properly restricted, or "constrained."

Long and thin structures can flex and deform, making it difficult to interact with objects and operate in a repeatable manner. Strengthen and constrain these structures by making use of brackets and extrusion.

Gears and sprockets must stay aligned, or they won't work properly. For example, if two sprockets are not perfectly aligned with each other, the chain between them will run off the sprockets. Keeping parts aligned on a shaft and keeping the shaft itself from sliding out is critical for reliably working robot mechanisms. Use a combination of spacers and shaft collars to align and constrain these parts into place.

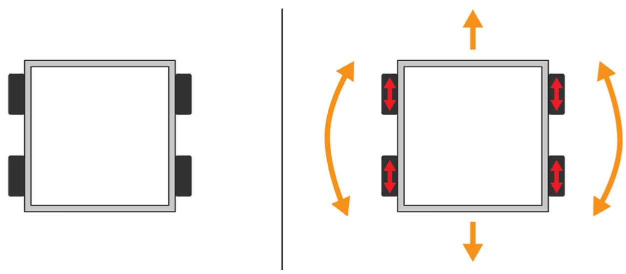


Drivetrains

One of the first considerations when designing a robot is identifying what kind of drivetrain will be built. A good starting point for most drivetrain styles is the AndyMark AM14U Drivetrain, available in the kit of parts. In this section, we will focus on drivetrain styles, not drivetrain kits.

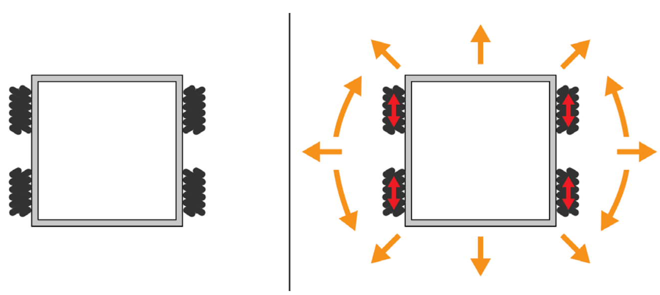
Differential Drivetrain

Differential drivetrains, also known as West Coast or Tank, control the left and right sides individually. This simple type of drivetrain is easy to design and build but can be less maneuverable than other types. To help improve maneuverability, omni wheels can be used on the front or back, so wheels slide across the floor while turning. When using six or more wheels, lowering the middle wheel of the drivetrain will cause less friction because not all wheels are touching the floor at one time.



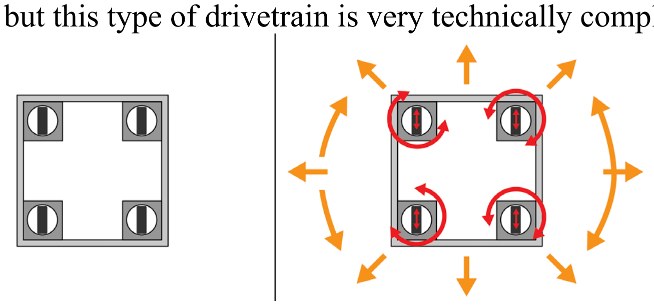
Mecanum Drivetrain

Mecanum drivetrains require four motors and a full set of mecanum wheels for operation. When the mecanum wheels are set up to create an "X" pattern from above, you can program the drivetrain to move side-to-side (strafe) or diagonally and drive like a differential drive would. This maneuverability is of great benefit to teams. However, because your wheels are made of rollers, your robot is more susceptible to being pushed.



Swerve Drivetrain

Swerve drivetrain uses standard wheels mounted on their own pivoting mechanisms. Most swerve drivetrains require two motors per wheel; one to rotate the wheel, and one to control the direction the wheel points. Your robot can move in any direction because the drive wheels pivot without changing the orientation of the drivetrain, but this type of drivetrain is very technically complex.



Actuators

Actuators, such as motors, servos, and pneumatic cylinders, are devices used to create movement on the robot. When designing a robot, selecting the correct actuator for the application is important.

DC Motors

DC Motors consist of two major parts, the part that rotates, or the “rotor”, and the part that is stationary, or the “stator”. A DC motor uses these parts to convert electrical energy into rotational mechanical energy using electricity and permanent magnets.

Two types of DC motors are used in *FIRST* Robotics Competition: Brushed DC Motors and Brushless DC motors. Both types are useful in various robot applications, and both have their trade-offs.

Brushed vs. Brushless

Operating a brushed DC motor is simple; provide DC electrical power and the motor spins. In a brushed motor, the rotor consists of electrical winding wires and the stator consists of permanent magnets. Since the electrical part is spinning, there needs to be a way to connect the external power wires to the spinning rotor. This is accomplished through conductive “brushes” that make contact with the stator, automatically sequencing the power to make the rotor spin. Brushes make it easy on us, but they produce extra friction which reduces the efficiency of the motor.

Brushless DC motors don’t have brushes. They still have both electrical winding wires and permanent magnets, but the locations are flipped. The stator now consists of the electrical parts, and the spinning rotor consists of the magnets. This means there is no more brush friction within the motor, making a brushless motor more power-efficient. However, you can’t just give it DC power and expect it to spin. Without the brushes doing the sequencing for us, you must use a specialized motor controller that is designed for brushless motors to properly sequence the power and get the rotor spinning.

Power Classes

Traditionally in *FIRST* Robotics Competition, there are two major power classes of motors: **Workhorse** and **Racehorse**.

Workhorse class motors are well-suited for applications that require a lot of torque or speed. They are not only high-power, but are resilient in high-load situations. This makes workhorse class motors ideal for drivetrains, flywheels, and arms. Common workhorse motors include the CIM, NEO, Falcon 500, and RS-775 style motors, but the available motors can change from season to season.

Racehorse class motors are generally smaller and more lightweight than workhorse class motors. Great for intakes, conveyors, and tight spaces, these motors are very versatile. Common racehorse class motors include the NEO 550, BAG Motor, RS-550 style motors, and several other lower power motors.

Be sure to check out the game manual for a list of legal motors this season!

Servo Motors

Servo Motors are a specialized kind of motor that can be controlled to move to a specific angle, instead of continuously rotating like a DC motor. Some servo motors can be programmed to run continuously as well, but not all servo motors have this function. Servos have an output spline and are often paired with servo horns to transmit motion to mechanisms like camera gimbals or small grippers.

Linear Actuators

There are two main types of linear actuators used in *FIRST* Robotics Competition: Motor Powered Linear Actuators and Pneumatic Cylinders.

Motion Powered Linear Actuators

Linear actuators that convert rotational motion into linear motion are generally known as Motor Powered Linear Actuators. These linear actuators come in many different sizes and often have DC motor and servo motor versions. Motor powered linear actuators are great for mechanisms where the linear motion needs to be varied, like raising or lowering the angle of a launcher.

Pneumatics

Pneumatic Cylinders are actuated by moving pressurized air through a closed system. They can either be retracted or extended- the output is binary with no in-between. These are ideal for when you need to extend part of your robot to the same length repeatedly, like deploying an intake.

For more information on Pneumatics, check out the *Pneumatics Manual* which can be found on *FIRST*'s technical resources webpage:
https://www.firstinspires.org/resource-library/frc/technical-resources.

What’s Next?

The methods outlined here in *FIRST Robotics Competition Robot Basics* are a great way to start building a robot that is ready to drive.

So, what’s next? Check out the following websites for information on how to get your robot moving by wiring and programming your control system.

FIRST Robotics Competition Resource Library

Technical resources to help with building, programming, and wiring a robot, as well as tips on running a *FIRST* Robotics Competition team.
www.firstinspires.org/resource-library/frc/technical-resources

Control System and Programming Documentation (WPILib)

Resources to help with wiring your control system and programming your robot.
docs.wpilib.org

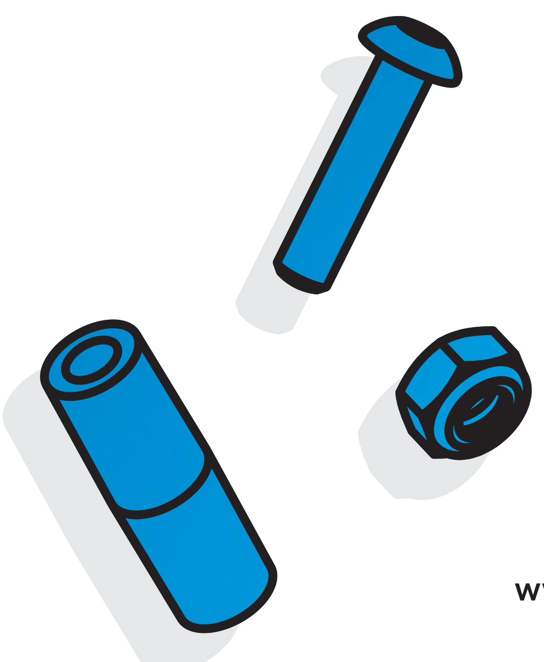
REV Robotics Documentation

Resources for help using REV products, including the REV Power Distribution Hub, SPARK MAX, NEO Brushless Motors, REV ION Build System, and more.
www.docs.revrobotics.com

Have a question for us?

The best way to get answers about REV Robotics products is to email us at:
support@revrobotics.com

For questions about *FIRST* Robotics Competition within your area visit:
www.firstinspires.org/find-local-support
Or, contact *FIRST* directly at:
FIRSTRoboticsCompetition@firstinspires.org



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