12 ROBOT Construction Rules (R)

The rules listed below explicitly address legal parts and materials and how those parts and materials may be used on a ROBOT. A ROBOT is an electromechanical assembly built by the *FIRST* Tech Challenge team to play the current season's game and includes all the basic systems required to be an active participant in the game –power, communications, control, and movement about the FIELD.

There are many reasons for the structure of the rules, including safety, reliability, parity, creation of a reasonable design challenge, adherence to professional standards, and impact on the competition.

Another intent of these rules is to have all energy sources and active actuation systems on the ROBOT (e.g., batteries, motors, servos, and their controllers) drawn from a well-defined set of options. This is to ensure that all teams have access to the same actuation resources and that the INSPECTORS can accurately and efficiently assess the legality of a given part.

> ROBOT construction rules in this section only apply to the construction of your ROBOT as it might be inspected. MATCH play rules and consequences for violating rules during MATCH play are outlined in section 11 Game Rules (G).

ROBOTS are made up of COMPONENTS and MECHANISMS. A COMPONENT is any part in its most basic configuration, which cannot be disassembled without damaging or destroying the part or altering its fundamental function. A MECHANISM is an assembly of COMPONENTS that provide specific functionality on the ROBOT. A MECHANISM can be disassembled (and then reassembled) into individual COMPONENTS without damage to the parts.

Many rules in this section reference Commercial-Off-The-Shelf (COTS) items. A COTS item must be a standard (i.e., not custom order) part commonly available from a VENDOR for all teams for purchase. To be a COTS item, the COMPONENT or MECHANISM must be in an unaltered, unmodified state (with the exception of installation or modification of any software). Items that are no longer commercially available but are functionally equivalent to the original condition as delivered from the VENDOR are considered COTS and may be used.

> Example 1: A team orders 2 ROBOT panels from RoboPanels Corp. and receives both items. They put 1 in their storeroom and plan to use it later. Into the other, they drill "lightening holes" to reduce weight. The first panel is still classified as a COTS item, but the second panel is now a FABRICATED ITEM, as it has been modified.
>
> Example 2: A team obtains openly available blueprints of a drive module commonly available from Wheels-R-Us Inc. and has local machine shop "We-Make-It, Inc." manufacture a copy of the part for them. The produced part is not a COTS item, because it is not commonly carried as part of the standard stock of We-Make-It, Inc.
>
> Example 3: A team obtains openly available design drawings from a professional publication and uses them to fabricate a gearbox for their ROBOT. The design drawings are considered a COTS item and may be used as "raw material" to fabricate the gearbox. The finished gearbox itself would be a FABRICATED ITEM, and not a COTS item.

Example 4: A COTS part that has non-functional label markings added would still be considered a COTS part, but a COTS part that has device-specific mounting holes added is a FABRICATED ITEM.

Example 5: A team has a COTS gearbox which has been discontinued. If the COTS gearbox is functionally equivalent to its original condition, it may be used.

A VENDOR is a legitimate business source for COTS items that satisfies all the following criteria:

A. has a Federal Tax Identification number. In cases where the VENDOR is outside of the United States, they must possess an equivalent form of registration or license with the government of their home nation that establishes and validates their status as a legitimate business licensed to operate within that country.
B. is not a "wholly owned subsidiary" of a *FIRST* team or collection of teams. While there may be some individuals affiliated with both a team and the VENDOR, the business and activities of the team and VENDOR must be completely separable.
C. should maintain sufficient stock or production capability so they are able to ship any general (i.e., non-*FIRST* unique) product within a timely manner. It is recognized that certain unusual circumstances (such as a global supply chain disruption and/or 1,000 *FIRST* teams all ordering the same part at once from the same VENDOR) may cause atypical delays in shipping due to backorders for even the largest VENDORS. Such delays due to higher-than-normal order rates are excused. This criterion may not apply to custom-built items from a source that is both a VENDOR and a fabricator.

For example, a VENDOR may sell flexible belting that the team wishes to procure to use as treads on their drive system. The VENDOR cuts the belting to a custom length from standard shelf stock that is typically available, welds it into a loop to make a tread, and ships it to a team. The fabrication of the tread takes the VENDOR 2 weeks. This would be considered a FABRICATED ITEM, and the 2-week ship time is acceptable. Alternately, the team may decide to fabricate the treads themselves. To satisfy this criterion, the VENDOR would just have to ship a length of belting from shelf stock (i.e., a COTS item) to the team within 5 business days and leave the welding of the cuts to the team.

D. makes their products available to all *FIRST* Tech Challenge teams. A VENDOR must not limit supply or make a product available to just a limited number of *FIRST* Tech Challenge teams.

The intent of this definition is to be as inclusive as possible to permit access to all legitimate sources, while preventing ad hoc organizations from providing special-purpose products to a limited subset of teams in an attempt to circumvent any applicable cost accounting rules.

FIRST desires to permit teams to have the broadest choice of legitimate sources possible, and to obtain COTS items from the sources that provide them with the best prices and level of service available. Teams also need to protect against long delays in availability of parts that will impact their ability to complete their ROBOT. The build season is brief, so the VENDOR must be able to get their product, particularly *FIRST* unique items, to a team in a timely manner.

> Ideally, chosen VENDORS should have effective distribution channels. Remember, *FIRST* Tech Challenge events are not always near home – when parts fail, local access to replacement materials is often critical.

A FABRICATED ITEM is any COMPONENT or MECHANISM that has been altered, built, cast, constructed, concocted, created, cut, heat treated, machined, manufactured, modified, painted, produced, surface coated, or conjured partially or completely into the final form in which it will be used on the ROBOT.

> Note that it is possible for an item (typically raw materials) to be neither COTS nor a FABRICATED ITEM. For example, a 20 ft. (~610 cm) length of aluminum which has been cut into 5 ft. (~152 cm) pieces by the team for storage or transport is neither COTS (it is not in the state received from the VENDOR), nor a FABRICATED ITEM (the cuts were not made to advance the part towards its final form on the ROBOT).

Teams may be asked to provide documentation (i.e., reference the relevant rule in this manual) proving the legality of items during inspection where a rule specifies limits for a legal part (e.g., motors, servos, current limits, COTS electronics).

Some of these rules make use of English unit requirements for parts. If your team has a question about a metric-equivalent part's legality, please e-mail your question to the *FIRST* Tech Challenge at firsttechchallenge@firstinspires.org for an official ruling. To seek approval for alternate parts/devices for inclusion in future *FIRST* Tech Challenge seasons, please use the Part Suggestion Form.

FIRST Tech Challenge can be a high-contact competition and may include rigorous gameplay. While the rules aim to limit severe damage to ROBOTS, teams should design their ROBOTS to be robust.

12.1 General ROBOT Design

R101 ***STARTING CONFIGURATION is limited to an 18-inch Cube.** In the STARTING CONFIGURATION (the physical configuration in which a ROBOT starts a MATCH), the ROBOT must be fully self-contained within an 18-inch wide, by 18-inch long, by 18-inch-high volume. The only exceptions are:

A. preloaded SCORING ELEMENTS may extend outside the starting size constraint.
B. minor protrusions up to 0.25 inches (6.4 mm) by flexible materials (e.g., zip tie, surgical tube, string) may extend beyond the 18-inch (45.7 cm) size constraint.

> If a ROBOT uses interchangeable MECHANISMS per I303, teams should be prepared to show compliance with this rule and R104 in all configurations.

R102 ***ROBOTS may assist in holding the STARTING CONFIGURATION.** In the STARTING CONFIGURATION, ROBOTS must be fully self-supported (i.e., does not exert force on the sides or top of a sizing tool). ROBOTS may accomplish this using any combination of:

A. mechanical means while powered-off, and/or
B. initializing an OpMode that pre-positions servos and motors to a desired stationary position. OpMode may control motors and servos to hold their position to maintain the STARTING CONFIGURATION.

> ROBOTS holding STARTING CONFIGURATION during inspection or waiting for a MATCH to start may have to do so for several minutes and should limit the possibility of thermal failure (e.g., not having motors stalled against a hard stop).

Teams must also be especially cautious when operating a running ROBOT during inspection, notifying the INSPECTOR that the ROBOT is live and taking every precaution to ensure the process is carried out safely.

R103 ***There is no ROBOT weight limit.** There is no explicit weight limit for *FIRST* Tech Challenge ROBOTS.

While there is no official weight limit, teams should still consider the impact of a ROBOT'S weight on various factors, including but not limited to:

- FIELD TILE damage
- battery consumption
- ROBOT transportation
- total ROBOT performance

R104 **There is a horizontal expansion limit.** After the MATCH has started, ROBOTS may expand beyond the STARTING CONFIGURATION but are still subject to sizing constraints. The sizing constraints are:

A. there is no vertical height limit relative to the TILE floor for ROBOT extensions,
B. the horizontal size boundary is a 20 in. x 42 in. (50.8 cm x 106.7 cm) rectangle measured parallel (coplanar) to the TILE floor,
C. the horizontal size boundary translates and rotates with the overall configuration of the CHASSIS of the ROBOT, which is the structural frame or base of a ROBOT that allows it to move and maneuver.
D. the maximum extent of all extensions of the ROBOT must be confined to the horizontal size boundary, with the ROBOT chassis remaining in the same relative location within the horizontal size boundary at all times (the location and orientation of the chassis within the horizontal size boundary is determined by the team), and
E. the horizontal size boundary as described in B is always parallel (coplanar) to the TILES, so ROBOTS which change orientation (drive, tip, roll, etc.) during the MATCH are still subject to the horizontal expansion limit measured parallel (coplanar) to the TILES.

This rule is intended to limit the amount of floor area each ROBOT can cover with the maximum range of motion of all extensions (extensions may be software or hardware limited). All possible movement of extensions outside the STARTING CONFIGURATION must be constrained within the horizontal size boundary.

Teams should be prepared to show compliance with this rule and demonstrate their ROBOT expansions during the inspection process. During inspection each ROBOT will be placed completely within a 20 in. x 42 in. taped box, with the position and orientation within the box chosen by the team. While keeping the ROBOT chassis stationary, the ROBOT must demonstrate that the full range of motion of all extensions outside of STARTING CONFIGURATION remain contained within the fixed 20 in. x 42 in. working area.

Teams are subject to penalties listed in G418 for any violations during the MATCH.

Figure 12-1: Expansion Limits

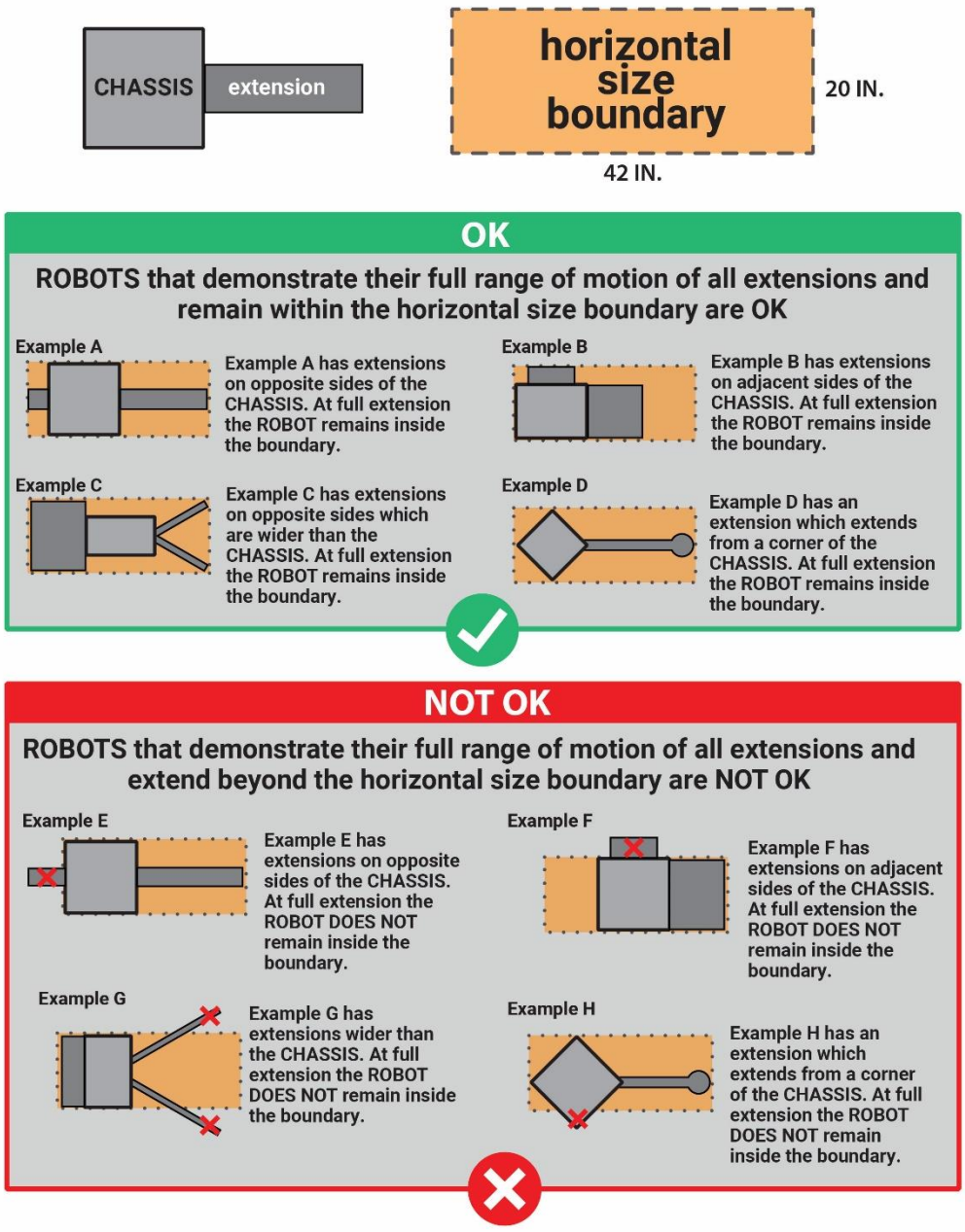
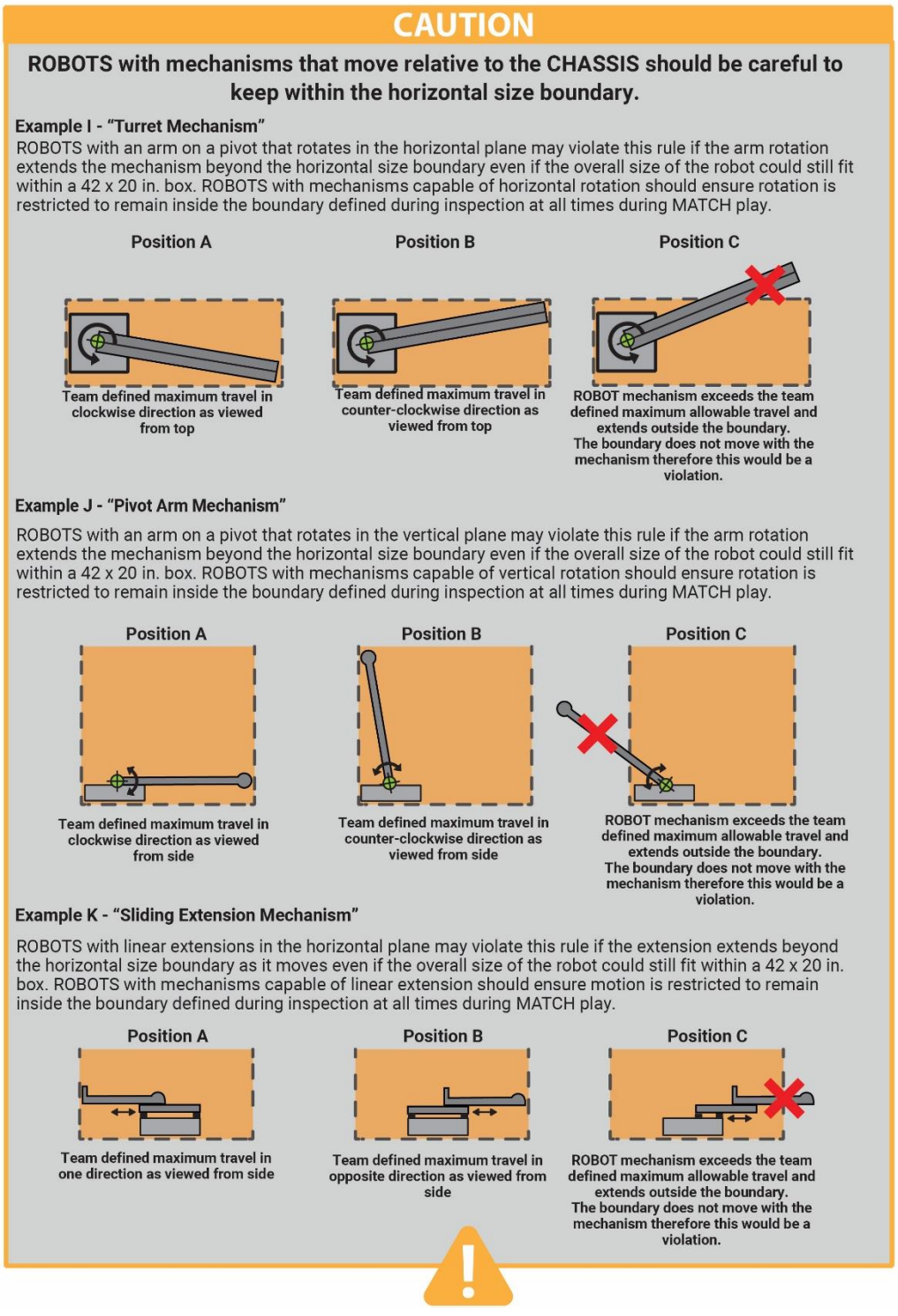


Figure 12-2: Expansion Limit Examples



12.2 ROBOT Safety & Damage Prevention

R201 ***Do not damage the TILE floor.** Traction devices must not have surface features which could damage the TILE floor. Traction devices are all parts of the ROBOT that are designed to transmit any propulsive and/or braking forces between the ROBOT and the FIELD.

> Examples of traction devices known to cause damage when used directly on TILE floors are high traction wheels (for example, AndyMark am-2256) and high grip tread (for example, Roughtop, AndyMark am-3309). While these (and other) COMPONENTS are not outright prohibited, e.g., used as part of an intake, MECHANISMS that involve these COMPONENTS contacting the TILE floor are not allowed.

R202 ***No exposed sharp edges.** Protrusions from the ROBOT and exposed surfaces on the ROBOT shall not pose hazards to the ARENA elements (including SCORING ELEMENTS) or people.

R203 ***Design ROBOTS for safety.** ROBOT parts shall not be made from hazardous materials, be unsafe, cause an unsafe condition, or interfere with the operations of other ROBOTS. Examples of items that will violate this rule include (but are not limited to):

A. shields, curtains, or any other devices or materials solely designed or used to obstruct or limit the vision of any DRIVE TEAM members and/or interfere with their ability to safely control their ROBOT,
B. speakers, sirens, air horns, or other audio devices that generate sound at a level sufficient to be a distraction,
C. any devices or decorations specifically intended to jam or interfere with the remote sensing capabilities of another ROBOT, including vision systems, acoustic range finders, sonars, infrared proximity detectors, etc. This includes imagery on your ROBOT that utilizes or closely mimics 36h11 AprilTags,
D. flammable gasses,
E. any device intended to produce flames or pyrotechnics,
F. hydraulic fluids or hydraulic items,
G. switches or contacts containing liquid mercury,
H. exposed, untreated hazardous materials (e.g., lead weights) used on the ROBOT. These materials may be permitted if painted, encapsulated, or otherwise sealed to prevent contact. These materials may not be machined in any way at an event.
I. high intensity light sources used on the ROBOT may only be illuminated for a brief time while targeting and may need to be shrouded to prevent any exposure to participants. Complaints about the use of such light sources will be followed by re-inspection and possible disablement of the device,
J. animal based materials,
K. any device designed to damage or flip competing ROBOTS,
L. devices or conditions that pose an unnecessary risk of entanglement
M. materials that would cause an unsafe condition if released (loose ball bearings, coffee beans, etc.).

> Flashing lights can be particularly distracting and can cause harm to some individuals. Decorative or functional lighting which flashes at greater than 2Hz will invite additional scrutiny and teams may be asked to disable or modify their lighting at the discretion of the head REFEREE and/or LRI.

R204 ***SCORING ELEMENTS stay with the FIELD.** ROBOTS must allow removal of SCORING ELEMENTS from the ROBOT and the ROBOT from FIELD elements while powered off.

> Teams must make sure that SCORING ELEMENTS and ROBOTS can be quickly, simply, and safely removed.
>
> Teams are encouraged to consider G501 when developing their ROBOTS.

R205 ***Do not contaminate the FIELD.** ROBOTS may not contain any materials which if unintentionally released would damage the FIELD, other ROBOTS or delay the start of a MATCH due to required decontamination. Lubricants may be used only to reduce friction within the ROBOT. Lubricants must not contaminate the FIELD or other ROBOTS.

> Lubricants used on the ROBOT must not be excessively applied such that they spin off or drip off during normal ROBOT operations on the FIELD.
>
> Additional examples of items that will violate this rule include (but are not limited to):
>
> – any ballast not secured sufficiently, including loose ballast such as sand or ball bearings, such that it may be released on the FIELD during a MATCH
> – liquid or gel materials
> – tire sealant, and
> – other lubricants

R206 ***Do not damage SCORING ELEMENTS.** ROBOT elements likely to contact SCORING ELEMENTS shall not pose a significant hazard to the SCORING ELEMENT.

> SCORING ELEMENTS are expected to undergo a reasonable amount of wear and tear as they are handled by ROBOTS, such as scratching or marking. Gouging, tearing off pieces, or routinely marking SCORING ELEMENTS are violations of this rule.

R207 ***No air power on the ROBOT.** ROBOTS may not use any closed air devices such as but not limited to pneumatic solenoids or cylinders, gas storage vessels, gas springs, compressors, or vacuum generating devices. Air-filled (pneumatic) wheels are exempt from this rule.

12.3 Fabrication

R301 ***Legal COTS parts and raw materials can be modified.** Allowed raw materials and legal COTS parts can be modified (drilled, cut, painted, etc.) as long as no other rules are violated.

> Raw materials refers to unfinished building stock such as but not limited to:
>
> – sheet stock
> – extruded shapes
> – metals, plastic, rubber, and wood
> – magnets

R302 ***Custom parts can be reused year to year.** FABRICATED ITEMS created before Kickoff are permitted.

R303 ***Custom designs and software can be reused year to year.** ROBOT software and designs created before Kickoff are permitted.

R304 ***SCORING ELEMENTS are not allowed for ROBOT construction.** Current season SCORING ELEMENTS or replicas of SCORING ELEMENTS are not allowed to be used as part of ROBOT construction or for any other team supplied SCORING ELEMENTS.

R305 ***During an event, work can occur outside of pit hours.** During an event a team is attending (regardless of whether the team is physically at the event location), the team may work on or practice with their ROBOT or ROBOT elements outside of the hours that pits are open.

> For teams who chose to work offsite during an event please work smart and safely. Ensure team members get adequate rest and have sufficient adult supervision during afterhours and off-site work.
>
> Note that E107 and E108 impose additional restrictions on work done on the ROBOT or ROBOT materials while attending an event.

R306 ***COTS MECHANISMS have limits.** COTS MAJOR MECHANISMS (as defined in I301) purposefully designed to complete a game task are prohibited.

Allowed exceptions to this rule are:

A. COTS drive chassis, provided none of the individual parts violate any other rules.

> COTS parts are intended to help teams design and build ROBOT MECHANISMS to complete game tasks and solve challenges but are not intended to be purpose-built complete bolt-on out-of-the-box solution to complete game objectives.

R307 ***COTS must be single DoF.** COTS COMPONENTS and MECHANISMS must not exceed a single degree of mechanical freedom (DoF). Examples of allowed COTS single degree of freedom MECHANISMS and COMPONENTS are as follows:

A. linear slide kit,
B. linear actuator kit,
C. single speed (non-shifting) gearboxes,
D. pulley,
E. turntable,
F. lead screw, and
G. single DoF gripper.

Allowed exceptions to this rule are:

H. ratcheting devices (wrenches, bearings, etc.),
I. holonomic wheels (omni or mecanum), and
J. dead-wheel odometry kits.

> The general test for a single degree of freedom MECHANISM is whether the orientation and position of each COMPONENT in the MECHANISM can be generally predicted based on the orientation and position of a single COMPONENT (such as the input) of the system.
>
> Example 1: A mecanum drivetrain is made up of four independent drive modules, each with a single DoF (ignoring the DoF of the mecanum wheels as allowed by

this rule), attached to a common structure (e.g., chassis). The overall MECHANISM is still a single DoF.

Example 2: Dead wheel odometry modules, allowed by this rule, are typically composed of a 1 DoF wheel (ignoring the effect of the holonomic wheel) providing forward/backwards motion and a spring force providing an additional unique rotational or vertical motion, creating a two DoF system.

Example 3: Simple gripper claws, comprised of a single actuator moving two gripper jaws simultaneously or double actuators each controlling an independent gripper jaw, are by and large a single DoF. However, grippers that incorporate additional actuators providing additional twisting and/or bending actions (like a wrist) add degrees of freedom that are prohibited in COTS MECHANISMS.

12.4 ROBOT SIGN Rules

A ROBOT SIGN is a required assembly which attaches to the ROBOT. A ROBOT SIGN simultaneously identifies a ROBOT'S team number as well as its ALLIANCE affiliation for FIELD STAFF. Criteria used in writing these rules include the following:

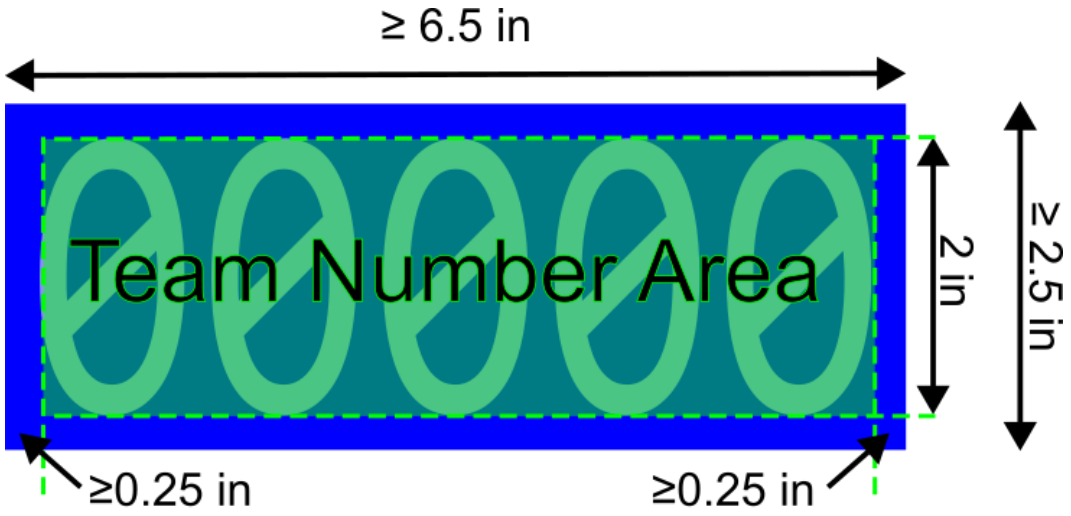
- Maximize FIELD STAFF'S ability to determine team number and ALLIANCE of a ROBOT,
- Minimize the amount of design challenge in creating ROBOT SIGNS, and
- Increase consistency in displaying ROBOT identification.

R401 ***Two ROBOT SIGNS per ROBOT.** ROBOT SIGNS must be placed in at least two separate locations on the ROBOT. These locations must be on opposite or adjacent surfaces of the ROBOT, ≥90 degrees apart. All ROBOT surfaces visible to FIELD STAFF can be used for placing ROBOT SIGNS including the top of the ROBOT. The intent of this rule is for FIELD STAFF to easily view ROBOT SIGNS from at least 12 feet (3.66 meters) away before, during, and after the MATCH. ROBOT SIGNS must meet the following criteria:

A. be made of a robust material,
B. minimally be 6.5 inches (16.5 cm) wide (Figure 12-3),
C. minimally be 2.5 inches (6.4 cm) tall (Figure 12-3), and
D. be supported by the structure/frame of the ROBOT.

Examples of robust materials that satisfy this rule include, but are not limited to, acrylic, plastic laminated paper, wood, and metal. ROBOT SIGNS must be designed to withstand vigorous game play.

Figure 12-3: Team Number ROBOT SIGN Sizing



R402 ***ROBOT SIGNS indicate your ALLIANCE.** Each ROBOT SIGN must contain a 6.5 in. by 2.5 in. (16.5 cm by 6.4 cm) rectangle with a solid red or blue opaque background to indicate their ALLIANCE color (Figure 12-4), as assigned in the MATCH schedule at the event. Visible markings on ROBOT SIGNS when installed on the ROBOT, other than the following, are prohibited:

A. those required per R403,
B. solid white *FIRST* logos no larger than 1.5 in. (3.8 cm) in height (Figure 12-5),
C. small amounts of hook-and-loop tape, hard fasteners, or functional equivalents,
D. narrow areas of differing colors exposed at corners, folds, or cutouts,
E. dark narrow markings on background solely for template purposes,
F. cannot be powered or rely on power from any sources to illuminate/reveal ALLIANCE color

ROBOT SIGNS that are reversible or configurable must not allow the opposite ALLIANCE color to be visible to FIELD STAFF, except where permitted by this rule.

Figure 12-4: Minimum sized ALLIANCE rectangle

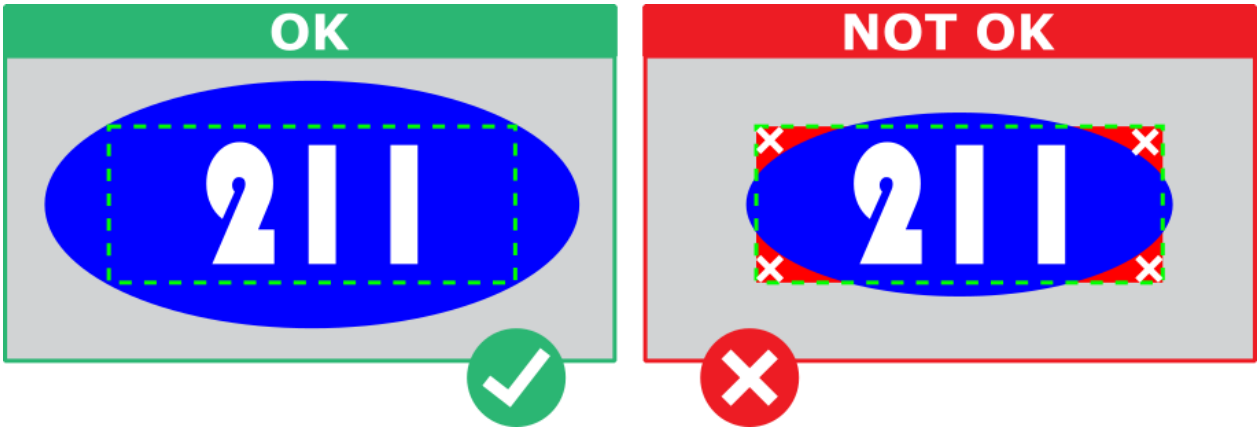


Figure 12-5: Legal team number display for team 117 playing on the red ALLIANCE

R403 ***Team number on ROBOT SIGNS.** Team numbers must be displayed and positioned on the ROBOT SIGN as shown in Figure 12-3, Figure 12-6, and, Figure 12-7 and meet the following additional criteria:

A. consist of solid opaque white Arabic numbers (e.g., 1,2,3,4) nominally 2 inches (5.1 cm) tall,
B. there must be a minimum of 1/4" inches (6.4 mm) of background surrounding the numbers,
C. numbers may not be vertically stacked (Figure 12-7)
D. be made of robust materials
E. cannot be powered or rely on power from any sources to illuminate/reveal numbers

Figure 12-6: Legal number for team 21001 playing on the blue ALLIANCE

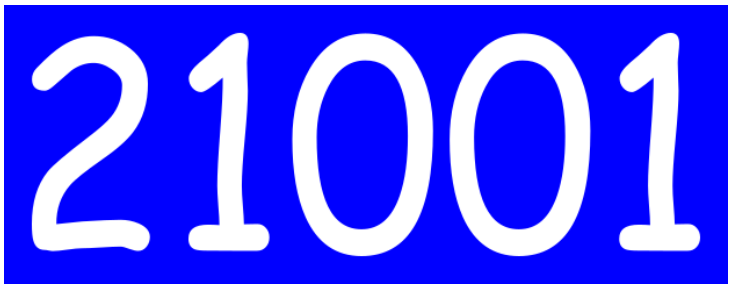


Figure 12-7: Team number orientation examples for team 1355 playing on the blue ALLIANCE

If a team at an event does not have completely legal ROBOT SIGNS, and there is no color printer or other means available at the event to create a legal ROBOT SIGN, the head REFEREE may approve an alternate substitute for use at the event.

Nominal measurements for team numbers provide for a tolerance of +/- ¼" to the number height to allow for purchased numbers that are nominally 2" tall.

Team numbers must be robust enough to withstand the rigors of MATCH play. Example robust materials include:

- self-adhesive numbers (mailbox or vinyl numbers)
- ink jet or laser printed numbers on paper and laminated or protected from ROBOT-to-ROBOT interaction.

Examples of prohibited team numbers on ROBOT SIGNS include but are not limited to:

- team numbers only visible by edge lit engraved plastic
- LED Display numbers

12.5 Motors & Actuators

R501 ***Allowable motors.** The only allowed motor actuators are:

Table 12-1: Motor allowances

Motor Name	Part Numbers Available	Notes
AndyMark NeveRest 12V DC	am-3104, am-3104b	
AndyMark NeveRest Hex 12V DC	am-3104c	
goBILDA Yellow Jacket 520x Series 12V DC	5201-0002-0026, etc.	5201, 5202, 5203, and 5204 series
Modern Robotics / MATRIX 12V DC	5000-0002-0001	
REV Robotics HD Hex 12V DC	REV-41-1291	
REV Robotics Core Hex 12V DC	REV-41-1300	
Studica Robotics Maverick 12V DC	75001	
TETRIX MAX 12V DC	739530	Discontinued
TETRIX MAX TorqueNADO 12V DC	W44260	
VEX EDR 393	276-2177	Counts as a servo for R503
Factory installed vibration and autofocus motors resident in COTS computing devices (e.g., rumble motor in a smartphone). Can only be used as part of the device, cannot be removed and/or repurposed. These motors do not count toward the limit in R503.		
Motors integral to a COTS sensor (e.g., LIDAR, scanning sonar), provided the device is not modified except to facilitate mounting. These motors do not count toward the limit in R503.		

Many legal gearmotors are sold with labeling based on the entire assembly. These motors may be used with or without the provided gearbox.

R502 ***Allowable servos**. Servo actuators must meet the requirements below. Servos must be compatible with the power regulation devices they are ultimately used with (per R505) and may include additional servo position output interfaces (e.g., 4th Wire Position Feedback).

Table 12-2: Servo Requirements at 6V

Actuator Class	Mechanical Output Power	Stall Current	Example Servos (including, but not limited to) NOT COMPLETE LIST
Servo	≤ 8 watts @6V	≤ 4 amps @6V	AndyMark High-Torque Servos (am-4954)
			Axon MAX+ Servo (Axon MAX+)
			DSSERVO 35KG Coreless (DS3235MG)
			FEETECH Digital Servo (FT5335M-FB)
			goBILDA Dual Mode Servo (2000-0025-0003)
			REV Robotics Smart Servo (REV-41-1097)
			Studica Multi-Mode Smart Servo (75002)
Linear Servo	N/A	≤ 1 amps @6V	Actuonix Micro Linear Servo (P8-100-252-12-R)
			Hitec Linear Servo (HLS12-3050-6V)
			Studica Linear Servo RC Actuator (75014)

Servo mechanical output power is approximated by the following formula (using 6V data reported by manufacturer):

- **Mechanical Output Power** = **0.25** x (**Stall Torque** in *N-m*) x (**No Load Speed** in *rad/s*)

Servos must meet both requirements to be legal for use. Refer to the Legal and Illegal Parts List for a list of servos that are pre-approved, otherwise teams must be able to provide documentation verifying servo specifications. Use the online calculator to verify output power compliance.

If a manufacturer does not provide 6V specs, any specs for voltages that exceed 6V are allowed to be used.

Stall current is the maximum stall current possible for the device at the specified voltage, regardless of any user or VENDOR adjustable software limits that may be available within the servo.

It is important to ensure the voltage provided by the intended power regulation device is within the operating voltage range of the desired servo. The REV Control Hub and REV Expansion Hub provide 5V to servos, and the REV Servo Power Module, Studica Servo Power Block, and REV Servo Hub provide 6V to servos. While virtually all servos are compatible with 6V, servos with an operating voltage range of 6-8.4 DCV, for example, may not work properly when only provided 5V.

R503 ***ROBOTS are limited to a total of 8 motors and 12 servos.** A ROBOT may not have more than 8 motors and 12 servos from the allowable actuator lists per R501 and R502 for all MECHANISMS used in all configurations, with the following exceptions:

A. The VEX EDR 393 (276-2177) motor is counted as a servo instead of a motor.

> If a ROBOT has multiple configurations used at a single event which use different MECHANISMS, the sum total of all motors and servos must be less than or equal to the limit set in this rule.
>
> For servos, note that each REV Expansion Hub and REV Control Hub provide 5V and are limited to a max current output of 5A total shared across all servo ports and the +5V auxiliary power port, with a 2A maximum limit across paired servo ports (10W of maximum electrical output power per port pair, 25W total). Teams should make sure that their total servo power usage always remains below this limit.
>
> Given the extensive number of motors and servos allowed on the ROBOT, teams are encouraged to consider the total power available from the ROBOT battery during the design and build of the ROBOT. Drawing large amounts of current from many motors and/or servos at the same time could lead to drops in ROBOT battery voltage that may result in exceeding the battery fuse limits or browning out the control system leading to power loss or communications loss.

R504 ***Do not modify actuators unless explicitly allowed.** The integral mechanical and electrical system of any motor or servo must not be modified. Motors and servos used on the ROBOT shall not be modified in any way, except as follows:

A. the mounting brackets and/or output shaft/interface may be modified to facilitate the physical connection of the motor to the ROBOT and actuated part,
B. the electrical leads may be trimmed to length as necessary and connectors or splices to additional wiring may be added, and purely electrical enclosures can be substituted with functionally equivalent replacements,
C. servos may be modified as specified by the manufacturer (e.g., re-programming or modification for continuous rotation),
D. minimal labeling may be applied to indicate device purpose, connectivity, functional performance, etc. as long as the team applied label does not obstruct the markings used to identify the device,
E. insulation may be applied to electrical terminals,
F. repairs, provided the original performance and specifications are unchanged, and
G. maintenance recommended by the manufacturer.

R505 ***All actuators must be powered from approved devices.** With the exception of servos, fans, or motors integral to sensors of COTS computing devices permitted in R501, each actuator must be controlled by a power regulating device. The only power regulating devices for actuators permitted on the ROBOT are:

Table 12-3: Power Regulators and Limits

Power Regulating Device	Part Number	Load Limit per Device
REV Control Hub or Expansion Hub Motor Ports	REV-31-1153 / REV-31-1595	2 Motors per Port
REV Control Hub or Expansion Hub Servo Ports	REV-31-1153 / REV-31-1595	2 Servos per Port
REV Servo Power Module	REV-11-1144	2 Servos per Port OR 2 VEX Motor Controller 29 (one per port)
REV Robotics Servo Hub	REV-11-1855	2 Servos per Port
REV SPARKmini	REV-31-1230	2 Motors per Device
Studica Servo Power Block	75005	2 Servos per Port
VEX Motor Controller 29	276-2193	1 VEX EDR 323 Motor (Counts as a Servo per R503)

R506 ***No relays or alternative electrical actuation.** The application of electromechanical actuation through the use of additional relays, electromagnets, electrical solenoid actuators, or related systems is prohibited. In addition, the use of relays and electromagnets is also prohibited.

12.6 Power Distribution

In order to maintain safety, the rules in this section apply at all times while at the event, not just while the ROBOT is on the FIELD for MATCHES.

R601 ***Battery limit – everyone has the same main ROBOT power.** The only legal source of electrical energy for the ROBOT control system and actuation during the competition, the ROBOT battery, must be 1 and only 1 approved 12V NiMH main battery. The ROBOT main battery must have a COTS equivalent in-line 20A ATM mini blade fuse installed. Installed connectors may be replaced with other popular connectors such as Anderson Powerpole, XT30, or any connector with a comparable power rating. The only allowed ROBOT main power battery packs are:

Table 12-4: Legal ROBOT Main Power Battery Packs

Battery Pack	Part Number	Notes
AndyMark Flat Pack Battery DC 12V	am-5290	
goBILDA 12V NiMH Nested Battery	3100-0012-0020	
Matrix 12V 3000mAh NiMH	14-0014	
REV 12V Slim Battery	REV-31-1302	
Studica 12V 3000mAh NiMH	70025	
TETRIX MAX 12V 3000mAh NiMH	W39057	Formerly 739023

There are many other similar style batteries available from multiple VENDORS, but only the listed manufactures and part numbers are legal for use at *FIRST* Tech Challenge Events.

Batteries should be charged in accordance with manufacturer's specification. (Please see the *FIRST* Safety Manual for additional information.)

R602 ***Other batteries are only allowed for peripheral devices and LEDs only.** COTS USB battery packs with a capacity of 100Wh or less (27,000mAh at 3.7V), with 5V/5A max output or 12V/5A max output using USB-PD per port, and batteries integral to a self-contained camera (e.g., GoPro style camera) may be used provided they are:

A. connected only using unmodified COTS cables,
B. charged according to manufacturer recommendations,
C. securely fastened to the ROBOT,
D. not supplement power to any of the ROBOT actuators, and
E. not used by any devices receiving control signals from the ROBOT control system (i.e., COTS USB battery packs must remain electrically isolated from the ROBOT power systems.) Exceptions to part E of this rule are:
   i. powered USB Hubs, and
   ii. ROBOT CONTROLLER smartphones

For example, a REV Blinkin powered by a COTS USB battery pack cannot be controlled by signals from a REV Control or Expansion Hub. Any device receiving signals from a REV Control or Expansion Hub must be powered by the main ROBOT battery.

R603 ***Charge batteries with safe connectors.** Any battery charger used to charge a ROBOT battery must have a corresponding polarized connector installed.

Batteries must never be charged using alligator clips or similar.

R604 ***Charge batteries at a safe rate.** Any battery charger used to charge a ROBOT battery may not be used such that it exceeds a 3-amp average charge current. Follow all manufacturer recommendations when charging batteries.

R605 ***Batteries are not ballast.** No batteries other than those allowed per R601 and R602 are allowed on the ROBOT, whether or not they are being used to supply power.

For example, teams may not use additional batteries as extra weight on their ROBOTS.

R606 ***Batteries should be securely mounted.** The ROBOT battery must be secured such that it will not dislodge during vigorous ROBOT interaction including if the ROBOT is turned over or placed in any arbitrary orientation. Batteries must be mounted such that they are protected from direct contact with other ROBOTS or any sharp edges.

R607 ***Electrical connections should be robust and must be insulated.** All electrical paths may include intermediate elements such as COTS connectors (Anderson Powerpole, XT30, and similar crimp or quick-connect style connectors), splices, COTS flexible/rolling/sliding contacts, and COTS slip rings, as long as the entire electrical pathway is via appropriately gauged/rated elements and all connections are protected from accidental electrical shorts

Teams are strongly encouraged to insulate all exposed electrical terminations or provide physical barricades to protect from accidental electrical shorts.

R608 ***Limit non-battery energy.** Non-electrical sources of energy used by the ROBOT (i.e., stored at the start of a MATCH) shall come only from the following sources:

A. a change in the altitude of the ROBOT center of gravity, or
B. storage achieved by deformation of ROBOT parts including, but not limited to, springs, rubber bands, surgical tubing, etc.

R609 ***Connect the ROBOT battery safely though the Main Power Switch.** Exactly one main power switch must control all power provided by the ROBOT battery pack to all power regulating devices on the ROBOT such that all the following conditions are met:

A. must be one of the following approved power switches:

Table 12-5: Legal Power Switches

Power Switch	Part Number
AndyMark FTC Power Switch w/ Bracket	am-4969
REV Switch Cable and Bracket	REV-31-1387
Studica On/Off Power Switch Kit	70182
TETRIX R/C Switch Kit	W39129

B. must be mounted or located where it is accessible to the team and FIELD STAFF
C. a "Main Power Switch" label no smaller than 1 in. x 2.5 in. (2.5 cm x 6.4 cm) must be placed near the switch on a flat surface.

Figure 12-8: example Main Power Switch label

D. secondary power switches can be used on the 12V line downstream of the main power switch provided they are clearly labeled as "secondary switch" and must still be one of the approved switches.

There are no specific location requirements for the main power switch, but it should be located clear of any moving parts and other obstructions that would block its access during normal ROBOT operations.

Examples considered not "quickly and safely accessible" include main power switches covered by an access panel or door, or mounted on, underneath or immediately adjacent to moving COMPONENTS.

The main power switch should be mounted on the ROBOT, so it is protected from ROBOT-to-ROBOT contact to avoid inadvertent actuation or damage.

R610 ***Fuse ratings should not be altered.** Fuses must not be replaced with fuses of higher rating than originally installed or according to manufacturer's specifications; fuses may not be shorted out. Fuses must not exceed the rating of those closer to the battery. If necessary, a fuse may be replaced with a

smaller rating. Replaceable fuses must be single use only; self-resetting fuses (breakers) are not allowed.

R611 ***The ROBOT frame is not a wire.** All wiring and electrical devices shall be electrically isolated from the ROBOT frame. The ROBOT frame must not be used to carry electrical current. Electrically grounding the control system electronics to the frame of the ROBOT is only permitted such that all of the following conditions are met:

A. must use one of the following approved parts:

Table 12-6: Legal ROBOT Grounding Straps

Grounding Strap	Part Number
AndyMark Resistive Grounding Strap	am-4648a
REV Resistive Grounding Strap	REV-31-1269

B. the strap must directly connect to a fully COTS COMPONENT with an XT30 connector, and also must connect directly to the frame of the ROBOT.
C. no ROBOT COMPONENTS or MECHANISMS are designed to electrically ground the ROBOT frame to the FIELD.

Compliance with this rule can be checked by unplugging the battery from the ROBOT main power switch assembly and observing a >120Ω resistance between the (+ / red) input terminal of the ROBOT main power switch assembly in the "ON" position or the (- / black) input terminal of the ROBOT main power switch assembly and any electrically connected point on the ROBOT. Most aluminum has a clear anodizing layer or oxidation layer on it that acts as an insulator. In order to make a good electrical connection with the grounding strap to the frame, it may be necessary to scratch/file/remove the anodize/oxidation layer from the area of contact with the metal first.

Note that some cameras, decorative lights, and sensors (some encoders, some IR sensors, etc.) have grounded enclosures or are manufactured with conductive plastics. These devices must be electrically isolated from the ROBOT frame to ensure compliance with this rule.

Examples of devices with COTS XT30 connectors include but are not limited to the REV Control Hub (REV-31-1595), a COTS XT30 power distribution block (such as a REV-31-1293), or a COTS Anderson Powerpole to XT30 Adapter (such as REV-31-1385). For additional details on installation of the grounding strap, please see the ROBOT Wiring Guide.

R612 ***Electrical system must be inspectable.** All power regulating devices (per R505), associated wiring, and all fuses must be visible for inspection.

"Visible for inspection" does not require that the items be visible when the ROBOT is in STARTING CONFIGURATION, provided the team can make the items viewable during the inspection process.

R613 ***No high voltage allowed.** Any active electrical item that is not an actuator (specified in R501) or power regulation device (specified in R505) is considered a CUSTOM CIRCUIT. CUSTOM CIRCUITS shall not provide regulated output voltages exceeding 5V but may pass through unregulated battery voltage.

R614 ***Energize Power Regulating Devices as specified.** All power regulating devices (R505) must be powered per the manufacturer's instructions and the following table must be true:

Table 12-7: Power Regulation Device Power Requirements

Power Regulating Device	Part Number	Method of Powering
REV Control Hub / REV Expansion Hub	REV-31-1153 / REV-31-1595	Only powered using the XT30 connectors on the device by the ROBOT main battery
REV Servo Power Module	REV-11-1144	Only powered using the screw terminals and must only be powered by the ROBOT main battery
REV Robotics Servo Hub	REV-11-1855	Only powered using the power terminals and must only be powered by the ROBOT main battery
REV SPARKmini	REV-31-1230	Only powered by the Power input and must only be powered by the ROBOT main battery
Studica Servo Power Block	75005	Only powered by JST-VH power connector, and must only be powered by the ROBOT main battery
VEX Motor Controller 29	276-2193	Only powered via servo connector

R615 ***Use appropriately sized wire.** All circuits shall be wired with appropriately sized insulated copper wire (SIGNAL LEVEL cables do not have to be copper):

Table 12-8: Wire sizing requirements

Application	Minimum Wire Size
12V Main Battery Power	18 AWG (19 SWG or 1 mm^2)
Motor Power (unless otherwise listed)	
11-20A fuse protected circuit	
Motor Power - TETRIX MAX 12V DC Motors, REV Robotics Core Hex (REV-14-1300)	22 AWG (22 SWG or 0.5 mm^2)
PWM / Servo	
LEDs (5V / 12V)	
≤10A fuse protected circuit	
SIGNAL LEVEL circuits (i.e., circuits which draw ≤1A continuous and have a source incapable of delivering >1A, including but not limited to: I2C, DIO, Analog, encoder and RS485 connections)	28 AWG (29 SWG or .08 mm^2)

Integrated wires originally attached to legal COTS devices or wires included/sold by the manufacturer are considered part of the device and by default legal. Such wires are exempt from this rule.

In order to show compliance with these rules, teams should use wire with clearly labeled sizes if possible. If unlabeled wiring is used, teams should be prepared to demonstrate that the wire used meets the requirements of this rule (e.g., wire samples and evidence that they are the required size).

R616 ***Use specified wire colors.** All non-SIGNAL LEVEL wiring with a constant polarity (i.e., except for outputs of motor controllers, or sensors) must use consistent color-coding with different colors used for the positive (red, yellow, white, brown, or black with white stripe) and negative/common (black, blue) wires.

R617 ***Powered USB hubs must draw energy from approved sources.** Powered USB hubs used on the ROBOT can only be powered through one of the following ways:

A. an approved COTS USB battery Pack per R602, or
B. the 5V auxiliary power port on the REV Expansion Hub or REV Control Hub

R618 ***Do not modify critical power paths.** CUSTOM CIRCUITS shall not directly alter the power pathways between:

A. the ROBOT battery and main power switch,
B. the main power switch and a power regulating device (per R609),
C. any two power regulating devices (per R613), or
D. power regulating devices and actuators.

Custom high impedance voltage monitoring or low impedance current monitoring circuitry connected to the ROBOT'S electrical system is acceptable if the effect on power pathways is inconsequential.

Altering a power pathway includes, but is not limited to, altering the voltage of the power pathway using a boost (DC voltage step-up) or buck (DC voltage step-down) converter or otherwise altering the natural variable DC voltage provided by the ROBOT battery to create a constant DC voltage.

R619 ***Do not mix and match power on or between power regulation devices.** The following rules must be adhered to when using power on any power regulation device (per R505):

A. other than power used to energize the power regulation device (per R614) no power originating outside the power regulation device may be used on or with devices connected to the power regulation device. The only exceptions are connections intended for communication between devices (RS485/USB/PWM/etc.).

Example 1: The +5V port on a REV Expansion Hub cannot be used to power devices connected to a REV Control Hub's I2C ports.

Example 2: A regulated 5V output provided by a CUSTOM CIRCUIT cannot be used to power an I2C device connected to a REV Control Hub.

B. power originating from ports/connectors on power regulation devices may only be used for devices directly connected to that port/connector. The only exception to this is +5V power from the +5V power port on the REV Control Hub or REV Expansion Hub may be used in conjunction with any Analog, Digital, or I2C port on that device. In addition, the +5V power port may be used to power external devices.

Example 1: The power provided by Digital Port 0-1 on a REV Control Hub should not be used to power devices connected to I2C Port 0. However, power provided by Digital Port 0-1 can be used to power devices connected to both signal channels N and N+1 on Digital Port 0-1.

Example 2: The +5V power can be used to power external devices such as externally powered USB hubs (per R617).

C. 6V power provided by the REV Servo Power Module, REV Robotics Servo Hub, or Studica Servo Power Block may only be used for powering servos.

6V power provided by the REV Servo Power Module, REV Robotics Servo Hub, or Studica Servo Power Block may only be used for powering servos.

12.7 Control, Command & Signals System

R701 ***Control the ROBOT with a single ROBOT CONTROLLER.** ROBOTS must be controlled via 1 programmable ROBOT CONTROLLER. The ROBOT CONTROLLER is the only source of control for the ROBOT actuators and must be comprised of:

A. REV Control Hub (REV-31-1595), or
B. an allowed smartphone Android device connected to a REV Expansion Hub (REV-31-1153)

In addition to A or B, a ROBOT may also contain:

C. no more than one additional REV Expansion Hub (REV-31-1153)

R702 ***Teams may not alter coprocessor software.** Modifying software on coprocessors, unless explicitly permitted in this rule or rule R703, is not allowed by teams. Firmware updates in binary form provided by the manufacturer may be applied as directed by the manufacturer.

The following are examples of allowed devices:

Example 1: The Adafruit BNO055 Absolute Orientation Sensor is an IMU package with an onboard ARM Cortex-M0 based coprocessor to crunch sensor data and produce composite output. Its coprocessor contains software that is not intended by the manufacturer to be modified by users.

Example 2: The SparkFun Optical Tracking Odometry Sensor is a laser and IMU tracking device that uses an onboard microcontroller to perform complex calculations and produce simplified results. SparkFun does provide the source code and toolchain for advanced users to modify/update the software, which is not permitted by this rule. Firmware updates provided by SparkFun are allowed to be applied to the device.

Example 3: The Digital Chicken Labs OctoQuad FTC Edition is an 8-channel encoder/PWM interface, utilizing a Raspberry Pi Pico coprocessor. Teams are not permitted to modify software running on the device, including replacing the software with their own. Updates provided in binary form by the manufacturer (Digital Chicken Labs) may be applied to the device.

R703 ***Some vision coprocessors can be programmed.** Programmable vision coprocessors that are natively supported by the FTC SDK may be programmed. The programmable vision coprocessors that are supported are:

Table 12-9: Supported programmable vision coprocessors

Device	Part Number
Limelight Vision Limelight 3A	LL_3A

Example 1: Optical Flow sensors are an example of a sensor that utilizes a vision coprocessor that is treated no differently than other coprocessors per R702.

Example 2: The DFRobot HuskyLens and the Charmed Labs Pixy2 are examples of vision coprocessors that are configurable but not programmable and are treated no differently than other coprocessors per R702.

Example 3: The OpenMV Cam, Luxonis OAK-1, and LimeLight Vision Limelight 3G are examples of programmable vision coprocessors that are prohibited.

See R715 for more information regarding vision coprocessor support.

R704 ***Use only legal Android smartphone devices.** Android smartphone devices, if used, must minimally be running the Android 7 (Nougat) operating system. The following table lists the legal Android smartphones:

Table 12-10: Legal Android Smartphones

Phone	Notes
Motorola Moto G4 Play	Sometimes noted as “4th Generation”
Motorola Moto G5	
Motorola Moto G5 Plus	
Motorola Moto E4	USA versions only, includes SKUs XT1765, XT1765PP, XT1766, and XT1767
Motorola Moto E5	XT1920
Motorola Moto E5 Play	XT1921

Some supported models still using Android 6.x (Marshmallow) might be updatable by the Motorola Rescue and Smart Assistance Tool.

Teams outside North America with extenuating circumstances (such as international purchasing limitations) are allowed to use alternate Android smartphones if necessary. Teams doing so are required to fill out this alternate Android Smartphone survey.

R705 ***Smartphone android devices used as a ROBOT CONTROLLER must connect to the REV Expansion Hub using USB.** If used as a ROBOT CONTROLLER, the smartphone android device must be connected via its integrated micro-USB port to a REV Expansion Hub either:

A. a mini-USB to OTG Micro Cable, or
B. any combination of Mini USB Cable, a USB Hub (powered or unpowered) and an OTG Micro adaptor (the hub can be integrated into the USB Hub).

R706 ***Bandwidth is restricted.** While in the ARENA and MATCH queue devices on the ROBOT network are limited to only the ROBOT CONTROLLER device and the DRIVER STATION device, and communication between the ROBOT CONTROLLER and the DRIVER STATION device is limited to ROBOT command data from the DRIVER STATION app, debugging data and telemetry from the ROBOT CONTROLLER app to the DRIVER STATION app, and single frame images used during ROBOT set-up pre-MATCH. When not in the ARENA or MATCH queue, additional devices (including, but not limited to, programming computers) may also communicate on the ROBOT network and teams must be careful to limit Wi-Fi streaming bandwidth between devices.

R707 ***Configure devices for your team number.** The ROBOT CONTROLLER, DRIVER STATION, and any spares used must be configured/named to correspond to the correct team number as follows:

A. ROBOT CONTROLLER should be named <team number>-RC (e.g., 12345-RC)
B. DRIVER STATION should be named <team number>-DS (e.g., 12345-DS)
C. If a spare ROBOT CONTROLLER or DRIVER STATION is configured, a letter designator may be added <team number>-<letter>-RC/DS (e.g., 12345-A-DS, 12345-B-DS)

> See the DRIVER STATION Instructions and ROBOT CONTROLLER Instructions for a detailed procedure for updating DRIVER STATION and ROBOT CONTROLLER "names."

R708 ***Do not interfere with the ROBOT networks.** During a MATCH, all communications signals must originate from only the ROBOT CONTROLLER device or the DRIVER STATION device using the ROBOT CONTROLLER Wi-Fi network. No other devices may attempt to connect to, interfere with, or alter the ROBOT CONTROLLER Wi-Fi network.

> Teams are allowed to connect programming laptops and other devices to the ROBOT CONTROLLER Wi-Fi network outside of a MATCH. These devices must be disconnected from the ROBOT CONTROLLER Wi-Fi network prior to and during a MATCH.

R709 ***No other wireless allowed.** No form of wireless communication shall be used to communicate to, from, or within the ROBOT, except those specified per R706 and R708.

> Devices that employ signals in the visual spectrum (e.g., cameras) and non-RF sensors that do not receive human-originated commands (e.g., "beam break" sensors or IR sensors on the ROBOT used to detect FIELD elements) are not wireless communication devices and thus this rule does not apply.

R710 ***Use assigned Wi-Fi bands and/or channels if requested.** Teams may be asked by the event director to use a specific Wi-Fi frequency band or channel on the day of competition. If requested, teams are required to do so. Teams may work with the FTA or wireless technical advisor (WTA) to find an alternate frequency band or channel if the suggested band/channel is deemed problematic by the FTA or WTA.

R711 ***ROBOT CONTROLLER must be visible for inspection.** The ROBOT CONTROLLER device must be mounted on the ROBOT such that the diagnostic lights, or device screen if applicable, can be visible for inspection.

"Visible for inspection" does not require that the items be visible when the ROBOT is in STARTING CONFIGURATION or normally during a MATCH, provided the team can make the items viewable during the inspection process if necessary.

Teams are strongly encouraged to make the diagnostic lights visible during normal MATCH play ROBOT configurations. If diagnostic LEDs are not visible during a MATCH, FIELD STAFF may not be able to provide comprehensive support to the team.

Teams are encouraged to mount the ROBOT CONTROLLER device away from noise generating devices such as motors and EMF shielding materials like sheets of metal.

R712 ***Only specified modifications to core control system devices permitted.** The DRIVER STATION device and software, Android-based ROBOT CONTROLLER device, main and secondary power switch(es), power regulation devices, fuses, and batteries shall not be tampered with, modified, or adjusted in any way (tampering includes drilling, cutting, machining, rewiring, disassembling, painting, removing enclosures and replacing with custom enclosures, etc.), with the following exceptions:

A. wires, cables, and signal lines may be connected via the standard connection points provided on the devices,
B. fasteners (including adhesives) may be used to attach devices to the OPERATOR CONSOLE or ROBOT or to secure cables to the device,
C. thermal interface material may be used to improve heat conduction,
D. labeling may be applied to indicate device identification, purpose, connectivity, functional performance, etc. as long as they do not cover labels or markings used to identify the product,
E. jumpers may be changed from their default location,
F. jumpers or switches may be moved to configure devices per the manufacturer's manual,
G. device firmware may be updated with manufacturer supplied firmware,
H. integral wires on motor controllers and batteries may be cut, stripped, and/or connectorized,
I. devices may be repaired, provided the performance and specifications of the device after the repair are identical to those before the repair,
J. add insulating material to exposed conductors, and
K. tape may be applied for debris protection.

Please note that while repairs are permitted, the allowance is independent of any manufacturer's warranty. Teams make repairs at their own risk and should assume that any warranty or return options are forfeited. Repairs must be functionally equivalent to original device condition.

Be aware that diagnosing and repairing COMPONENTS such as these can be difficult.

For example, "repairs" that change connector types, include device footprint modifications, or provide mechanical enhancements, are prohibited.

R713 ***Always keep control system device software up to date.** The following table lists the recommended software versions for each core control electronics module, and a link on how to update this software. Note that some devices have multiple pieces of software that may need to be updated each season,

and not all software is available prior to kickoff each season. Check the *FIRST* Tech Challenge Blog for release announcements.

Regardless of the versions selected, it is highly recommended that the installed ROBOT CONTROLLER App and DRIVER STATION App versions match major and minor values to ensure compatibility as not all software versions are compatible with each other.

Table 12-11: Recommended Software for Control System Devices

Device	Software and Minimum Recommended Versions	How to Update
REV Control Hub (REV-31-1595)	Control Hub OS Recommended: 1.1.2	Updating the Control Hub OS
REV Control Hub (REV-31-1595)	Hub Firmware Recommended: 1.8.2	Updating the Hub Firmware
REV Control Hub (REV-31-1595)	ROBOT CONTROLLER App Recommended: 10.0	Updating the ROBOT CONTROLLER App
REV Expansion Hub (REV-31-1153)	Hub Firmware Recommended: 1.8.2	Updating the Hub Firmware
Android Smartphone (ROBOT CONTROLLER device)	ROBOT CONTROLLER App Recommended: 10.0	Updating the ROBOT CONTROLLER App
Android Smartphone (DRIVER STATION device)	DRIVER STATION App Recommended: 10.0	Updating the DRIVER STATION App
REV Driver Hub (REV-31-1596)	Driver Hub OS Recommended: 1.2.0	Updating the Driver Hub OS
REV Driver Hub (REV-31-1596)	DRIVER STATION App Recommended: 10.0	Updating the DRIVER STATION App
REV Servo Hub (REV-11-1855)	REV Servo Hub Firmware Recommended: N/A	N/A

Software at or above the recommended versions have the latest bugfixes and updates. Teams are highly encouraged to update their software minimally to the recommended version. FIELD STAFF will not be able to provide comprehensive support to teams with software older than the recommended version.

Teams may choose to run older versions without affecting their ROBOT inspection status.

R714 ***USB is for vision.** Only the following devices may be connected to the ROBOT control system using USB:

A. webcams and optical vision sensors per R715,
B. USB hub, and
C. a REV Expansion Hub

R715 ***Use only supported USB vision.** Only single image sensor vision devices that are natively supported by the ROBOT CONTROLLER app are allowed to connect to USB (stereoscopic cameras are not allowed). This includes the following:

A. all UVC compatible USB webcams (Logitech C270, and related), and
B. Vision coprocessors allowed per R703.

To request support (or to provide sample drivers) for alternate USB vision devices for inclusion in future *FIRST* Tech Challenge seasons, please use the Part Suggestion Form.

UVC compatible USB webcams may only use the UVC provided stream / data. No other interfaces or data provided by the webcam may be used.

R716 ***Recording devices are okay.** Self-contained video recording devices (GoPro or similar) are allowed providing they are used only for non-functional post-MATCH viewing and the wireless capability is turned off.

R717 ***Lasers must be safe.** Lasers are not allowed unless they meet all of the following criteria:

A. must be part of a sensor,
B. must be rated as IEC/EN 60825-1" Class I" or IEC/EN 62471 "Exempt," and
C. non-visible spectrum

12.8 Pneumatic Systems

In order to maintain safety, the rules in this section apply at all times while at the event, not just while the ROBOT is on the FIELD for MATCHES.

R801 ***No Pneumatics.** No closed air systems are allowed on *FIRST* Tech Challenge ROBOTS except for those explicitly listed in R207.

12.9 OPERATOR CONSOLE

R901 ***Use only a specified DRIVER STATION device.** The OPERATOR CONSOLE may only have one approved android-based DRIVER STATION device connected and powered on. The OPERATOR CONSOLE must have at least one of the following:

A. REV Driver Hub (REV-31-1596) or
B. Approved Android Device from rule R704 with one OTG cable and COTS USB cable to connect the required gamepad controller(s).

> Teams who wish to have a spare DRIVER STATION device as part of their OPERATOR CONSOLE may do so as long as only one DRIVER STATION device is connected and powered on at a time.

R902 ***The OPERATOR CONSOLE must make the touch screen accessible.** The OPERATOR CONSOLE, the set of COMPONENTS and MECHANISMS used by the DRIVE TEAM to relay commands to the ROBOT, must make the touch screen of the DRIVER STATION device accessible. The DRIVER STATION device must be positioned within the OPERATOR CONSOLE so that the screen display can be clearly seen during inspection and in a MATCH. The DRIVER STATION device touch screen must be functional without the requirement of additional aides (e.g., mouse) in order to be used.

R903 ***Options for portable power to the DRIVER STATION device are limited.** The DRIVER STATION device can be charged onboard the OPERATOR CONSOLE using one (1) COTS USB external battery as long as the following requirements are met:

A. COTS USB battery adheres to capacity limits in R602 and usage in R602-A and R602-B
B. DRIVER STATION device is connected to the COTS USB external battery through the built-in USB-C port on the REV Driver Hub or through a USB Hub connected to the smartphone Android Device.

R904 ***Only limited gamepads are supported**. The OPERATOR CONSOLE may have no more than two (2) electrically unmodified gamepads in any combination from the following list connected to the DRIVER STATION at any time:

Table 12-12: Allowed Gamepads on OPERATOR CONSOLE

Gamepad	Part Number	Notes
Logitech F310 gamepad	940-00010	
Xbox 360 Controller for Windows	52A-00004	
Sony DualShock 4 Wireless Controller for PS4	N/A	

Gamepad	Part Number	Notes
Sony DualSense Wireless Controller for PS5	N/A	Operating in wired mode only (i.e., connected through USB cable without being Bluetooth paired to any device) This DOES NOT include the Sony DualSense Edge Wireless Controller in any configuration
Etpark Wired Controller for PS4	REV-39-1865	
REV Robotics USB PS4 Compatible Gamepad	REV-31-2983	
Quadstick game controller in Xbox 360 Emulation Mode	any model	

Enhancements to the gamepad that do not modify the electronics are legal. Different color gamepads are allowed provided they are the same model as the allowed gamepad.

Teams are strongly encouraged to use short USB cable extenders with the USB ports on the DRIVER STATION device. These extenders are used to reduce the wear and tear on the DRIVER STATION device ports from frequent plugging and unplugging – instead of plugging/unplugging directly into the DRIVER STATION device, gamepads are plugged and/or unplugged from the cable extenders. The extenders are intended to remain forever plugged into the DRIVER STATION device and, with proper strain relief employed, can protect the port from accidental damage.

Teams who wish to have spare gamepad(s) available as part of their OPERATOR CONSOLE may do so as long as no more than two gamepads are connected at any time.

R905 ***OPERATOR CONSOLE physical requirements.** The OPERATOR CONSOLE must not

A. include more than one (1) connected external USB hub,
B. contain any non-decorative electronics not otherwise required, or
C. exceed a volume of 3ft wide, 1ft deep and 2 ft tall (91.4cm by 30.5cm by 61.0 cm) excluding any items that are held or worn by the DRIVERS during the MATCH

Please note that while there is no hard weight limit, OPERATOR CONSOLES that weigh more than 20 lbs. (~9 kg.) will invite extra scrutiny as they are likely to present unsafe circumstances.

Teams who wish to have a spare external USB hub as part of the OPERATOR CONSOLE may do so as long as only one USB hub is connected at any time.

R906 ***ROBOT application wireless communication only.** Other than the connection controlled by the ROBOT CONTROLLER app running on the ROBOT and the DRIVER STATION app running on the DRIVER STATION device, no other form of wireless communications shall be used to communicate to, from, or within the OPERATOR CONSOLE during a MATCH.

Examples of prohibited wireless systems include, but are not limited to, active wireless network cards and Bluetooth devices.

Because this system uses a built-in wireless radio, teams are strongly encouraged to ensure there is no metal material blocking the line-of-sight between the DRIVER STATION device and the ROBOT CONTROLLER device which could impede the signal quality.

R907 ***No unsafe OPERATOR CONSOLES.** OPERATOR CONSOLES shall not be made using hazardous materials, be unsafe, cause damage, cause an unsafe condition, distract, or interfere with other DRIVE TEAMS or the operation of other ROBOTS.

DRIVER STATION sounds which are distracting or which mimic MATCH sounds are examples of disallowed OPERATOR CONSOLE features.

Sounds which are frequent or continuous which serve no apparent value to the MATCH play would likely be considered distracting.

The intent of this rule is to allow teams to use a container to store, organize, and transport the DRIVER STATION device and supporting electronics. The OPERATOR CONSOLE rules are not intended to allow systems that function as a ROBOT cart or replace a competition-provided OPERATOR CONSOLE stand, table, etc.