



# The Robot

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# 4 THE ROBOT

This section of the *2012 FRC Game Manual* presents legislation relevant to the construction of a 2012 *FIRST*<sup>®</sup> Robotics Competition (FRC) Robot. Robots will be Inspected at each FRC event to confirm compliance before being allowed to compete, per *Section 5.5.2 in The Tournament, Eligibility and Inspection of the 2012 FRC Game Manual*.

## 4.1 ROBOT RULES

Many of the rules listed below explicitly address what and how parts and materials may be used. There are many reasons for the structure of the rules, including safety, reliability, parity, creation of a reasonable design challenge, adherence to professional standards, impact on the competition, compatibility with the KOP, etc. When reading these rules, please use technical common sense (engineering thinking) rather than “lawyering” the interpretation and splitting hairs over the precise wording in an attempt to find loopholes. Try to understand the reasoning behind a rule.

In addition, another intent of these rules is to have all energy sources and active actuation systems on the Robot (e.g. batteries, compressors, motors, servos, cylinders, 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 to ensure that the Inspectors are able to accurately assess the legality of a given part.

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 [frcparts@usfirst.org](mailto:frcparts@usfirst.org) for an official ruling.

### 4.1.1 General Robot Design

**[R01]** Each registered FRC team may enter one Robot into the 2012 FRC. The Robot must be built by the FRC team to perform specific tasks when competing in *Rebound Rumble*. The Robot must include all of the basic systems required to be an active participant in the game – power, communications, control, mobility, and actuation. The Robot implementation must obviously follow a design approach intended to play the 2012 FRC game (e.g. a box of unassembled parts placed on the Court, or a Robot designed to play a different game would not satisfy this definition).

The Robot must have a Frame Perimeter that is comprised of fixed, non-articulated structural elements of the Robot. The Frame Perimeter of a Robot is defined by the outer-most set of exterior vertices on the Robot that are within the Bumper Zone, which is between 2 and 10 in. from the floor. Minor protrusions no greater than ¼ in. such as bolt heads, fastener ends, and rivets are not considered part of the Frame Perimeter.

To determine the Frame Perimeter, wrap a piece of string around the Robot at the level described in [R02]. The string describes this polygon.

Note: to permit a simplified definition of the Frame Perimeter and encourage a tight, robust connection between the Bumpers and the Frame Perimeter, minor protrusions such as bolt heads, fastener ends, rivets, etc are excluded from the determination of the Frame Perimeter.

**[R02]** The Robot must satisfy the following size constraints:

- A. horizontal dimensions must not exceed 28 by 38 in.,
- B. the absolute height must not exceed 84 in.,
- C. the height of the Robot at the start of the match must not exceed 60 in.,
- D. any appendage may not extend more than 14 in. beyond the frame perimeter, and
- E. no other part of the Robot may extend beyond the vertical projection of the Frame Perimeter (with the exception of minor protrusions permitted per 0).

Expect to demonstrate the Robot's ability to constrain itself to the envelope defined in Rule 0 to Inspectors.

Please refer to *Section 3: The Game* for Robot specific dimension constraints during the Match.

If a Robot is designed as intended and pushed up against a vertical wall (with Bumpers removed and appendages retracted), only the Frame Perimeter (or its minor protrusions) will be in contact with the wall.

**[R03]** The Robot weight may not exceed 120 lbs. When determining weight, the basic Robot structure and all elements of all additional Mechanisms that might be used in different configurations of the Robot shall be weighed together.

For the purposes of determining compliance with the weight and volume limitations, the items listed below are not included in the weight assessment:

- A. the 12V battery and its associated half of the Anderson cable quick connect/disconnect pair (including no more than 12 in. of cable per leg, the associated cable lugs, connecting bolts, and insulation) and
- B. Bumpers (including Bumper covers, if appropriate).

**[R04]** Robots shall display their school name (or the name of the supporting youth organization, if appropriate), and primary sponsor name and/or logo whenever the Robot is competing.

The support provided by the corporate sponsors and mentors on your team is important, and is to be acknowledged with the appropriate display of their names/logos on the exterior of the Robot.

**[R05]** Any non-functional decorations included on the Robot must not affect the outcome of the match and must be in the spirit of Gracious Professionalism.

**[R06]** Traction devices may not have surface features such as metal, sandpaper, hard plastic studs, cleats, or other attachments. Traction devices include all parts of the Robot that are designed to transmit any propulsive and/or braking forces between the Robot and the Court.

**[R07]** Robots shall not be re-enabled after the Match and must allow removal of Basketballs from the Robot and the Robot from the Court while disabled or powered off.

#### 4.1.2 Safety & Damage Prevention

**[R08]** Robot parts shall not be made from hazardous materials, be unsafe, cause an unsafe condition, or interfere with the operation 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 designed or used to obstruct or limit the vision of any drivers and/or coaches 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, infra-red proximity detectors, etc.(e.g. including imagery on your Robot that, to a reasonably astute observer, mimics the Vision Target)

D. Exposed lasers other than Class I.

E. COTS devices with completely enclosed integral lasers, such as a laser ring gyro, are permitted.

F. Flammable gasses

G. Any devices intended to produce flames or pyrotechnicsHydraulic fluids or hydraulic components

Teams should provide MSD Sheets for any materials they use that might be considered questionable during Robot Inspection.

**[R09]** Protrusions from the Robot and exposed surfaces on the Robot shall not pose hazards to the Arena, Basketballs or people.

If the Robot includes protrusions that form the “leading edge” of the Robot as it drives and are less than 1 in.<sup>2</sup> in surface area, it will invite detailed Inspection. For example, forklifts, lifting arms, or grapplers. may be carefully Inspected for these hazards.

All points and corners that would be commonly expected to contact a Basketball should have a minimum radius of 0.125 in. to avoid becoming a snag, abrasion, or puncture hazard. All edges that would be commonly expected to contact a Basketball should have a minimum radius of 0.030 in.

### 4.1.3 Budget Constraints

**[R10]** The Kit of Parts (KOP) is the collection of items obtained via any of the following KOP channels:

- Via the Kickoff Kit (items are listed in the [2012 Kickoff Kit Checklist](#)),
- Via the Virtual Kit (details on the [Kit of Parts website](#)),
- and via [FIRST Choice](#).

**[R11]** 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.

**[R12]** A Mechanism is a COTS or custom 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.

**[R13]** The total cost of all non-KOP items shall not exceed \$3,500.00 USD. All costs are to be determined as explained in *Section 4.1.3 : Budget Constraints*.

The following items are excluded from the total cost calculation:

- A. items listed on any KOP Checklist (qty is limited to the total listed in the most recent checklist),
- B. items obtained via a Product Donation Voucher included in the KOP,
- C. items ever distributed to the team via *FIRST Choice*,
- D. any non-functional decorations,
- E. individual fasteners, adhesives, or lubricants that are less than \$1.00 each,
- F. spare parts, and
- G. parts of the Operator Console.

**[R14]** No individual item shall have a value that exceeds \$400.00. The total cost of Components purchased in bulk may exceed \$400.00 USD as long as the cost of an individual Component does not exceed \$400.00.

Teams should be prepared to prove to Inspectors the cost of any non-KOP item and the total cost of the Robot.

Per *Section 5, The Tournament*, teams should be prepared to display a BOM to Inspectors during Inspection. The BOM may be displayed in either printed or electronic form.

**[R15]** Individual Components or Mechanisms, not excluded in Rule [R10], that are retrieved from previous Robots and used on 2012 Robots must have their undepreciated cost included in the 2012 Robot cost accounting and applied to the overall cost limits.

**[R16]** The Bill of Materials cost of each non-KOP item must be calculated based on the unit fair market value for the material and/or labor, except for labor provided by team members (including sponsor employees who are members of the team) and shipping.

Example: A team orders a custom bracket made by a company to the team's specification. The company's material cost and normally charged labor rate apply.

Example: A team receives a donated sensor. The company would normally sell this item for \$52, which is therefore its fair market value.

Example: Special price discounts from National Instruments and Texas Instruments are being offered to all *FIRST* teams. The discounted purchase price of items from these sources would be used in the additional parts accounting calculations.

Example: A team purchases steel bar stock for \$10.00 and has it machined by a local machine shop. The machine shop is not considered a team sponsor, but donates two hours of expended labor anyway. The team must include the estimated normal cost of the labor as if it were paid to the machine shop, and add it to the \$10.00.

Example: A team purchases steel bar stock for \$10.00 and has it machined by a local machine shop that is a recognized sponsor of the team. If the machinists are considered members of the team, their labor costs do not apply. The total applicable cost for the part would be \$10.00.

It is in the best interests of the teams and *FIRST* to form relationships with as many organizations as possible. Teams are encouraged to be expansive in recruiting and including organizations in their team, as that exposes more people and organizations to *FIRST*. Recognizing supporting companies as sponsors of, and members in, the team is encouraged - even if the involvement of the sponsor is solely through the donation of fabrication labor.

Example: A team purchases a 4 by 4 ft sheet of aluminum, but only uses a piece 10 by 10 in. on their Robot. The team identifies a source that sells aluminum sheet in 1 by 1 ft pieces. The team may cost their part on the basis of a 1 by 1 ft piece, even though they cut the piece from a larger bulk purchase. They do not have to account for the entire 4 by 4 ft bulk purchase item.

**[R17]** If the item is part of a modular system that can be assembled in several possible configurations, then each individual module must fit within the price constraints defined in Rule [R14].

If the modules are designed to assemble into a single configuration, and the assembly is functional in only that configuration, then the total cost of the complete assembly including all modules must fit within the price constraints defined in Rule [R14].

In summary, if a Vendor sells a system or a kit, a team must use the entire system/kit Fair Market Value and not the value of its Component pieces.

Example1: Vendor A sells a gearbox that can be used with a number of different gearsets, and can mate with two different motors they sell. A team purchases the gearbox, a gearsset, and a motor (which are not offered together as an assembly or kit), then assembles them together. Each part is treated separately for the purpose of Bill of Materials costing, since the purchased pieces can each be used in various configurations.

Example2: Vendor B sells a robotic arm assembly that the team wants to use. However, it costs \$700, so they cannot use it. The Vendor sells the "hand", "wrist" and "arm" as

separate assemblies, for \$200 each. A team wishes to purchase the three components separately, then reassemble them. This would not be legal, as they are really buying and using the entire assembly, which has a Fair Market Value of \$700.

#### 4.1.4 Fabrication Schedule

**[R18]** Robot elements designed or created before the Kickoff presentation, including software, are not permitted.

Please note that this means that Fabricated items from Robots entered in previous *FIRST* competitions may not be used on Robots in the 2012 FRC. Before the formal start of the Robot Build Season, teams are encouraged to think as much as they please about their Robots. They may develop prototypes, create proof-of-concept models, and conduct design exercises. Teams may gather all the raw stock materials and COTS Components they want.

Example: A team designs and builds a two-speed shifting transmission during the fall as a training exercise. When designing their competition Robot, they utilize all the design principles they learned. To optimize the transmission design for their Robot, they improve the transmission gear ratios and reduce the size, and build two new transmissions, and place them on the Robot. All parts of this process are permitted activities.

Example: The same team realizes that the transmission designed and built in the fall perfectly fits their need for a transmission to drive the Robot arm. They build an exact copy of the transmission from the original design plans, and bolt it to the Robot. This would be prohibited, as the transmission – although fabricated during the competition season – was built from detailed designs developed prior to Kick-off.

Example: A team developed an omni-directional drive system for the 2011 competition. Over the summer of 2011 they refined and improved the control software (written in C) to add more precision and capabilities. They decided to use a similar system for the 2012 competition. They copied large sections of unmodified code over into the control software of the new Robot (also written in C). This would be a violation of the schedule constraint, and would not be allowed.

Example: The same team decides to use the LabVIEW as their software environment for 2012. Following kickoff, they use the previously-developed C code as a reference for the algorithms and calculations required to implement their omni-directional control solution. Because they developed new LabView code as they ported over their algorithms, this would be permitted.

Example: A different team develops a similar solution during the fall, and plans to use the developed software on their competition Robot. After completing the software, they post it in a generally accessible public forum and make the code available to all teams. Because they have made their software generally available (per the definition of COTS, it is considered COTS software and they can use it on their Robot).

- [R19]** The Robot (including items intended for use during the competition in alternative configurations of the Robot, excluding items permitted per Rule [R26]) must be bagged or crated (as appropriate for your event), and out of team hands by the shipment deadline specified in the [FRC Administrative Manual, Section 5](#).
- [R20]** Teams must stay “hands-off” their Robot from Stop Build Day until their first competition, during the period(s) between their competitions, and outside of pit hours while attending competitions; there are no restrictions on when software may be developed. Specific exceptions are as follows:
- On days a team is not attending an event, they may continue development of any items permitted per Rule [R25], but must do so without interfacing with the Robot.
  - Teams attending 2-day events may access their Robots per the rules defined in the *Administrative Manual, Section 5.7, Robot Access Period - for Teams Attending 2-Day Events*.
- [R21]** At competitions, teams may only produce Fabricated Items in the pits or competition-provided machine shops, as defined in the *Administrative Manual, Section 4.8, The Pit*.

#### **4.1.5 Material Utilization**

- [R22]** A Commercial, Off-The-Shelf (COTS) item is defined as a part in its unaltered, unmodified state. A COTS item is a standard (i.e. not custom order) part that is or at one time been commonly available from a Vendor. Once a COTS item is modified in any way, it becomes a Fabricated Item.
- [R23]** A Vendor is a legitimate business source for COTS items that satisfies all of the following criteria:
- The Vendor must have 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.
  - The Vendor shall not be a “wholly owned subsidiary” of an FRC team or collection of FRC teams. While there may be some individuals affiliated with both an FRC team and the Vendor, the business and activities of the team and Vendor must be completely separable.
  - The Vendor must be able to ship any general (i.e., non-*FIRST* unique) product within five business days of receiving a valid purchase request. It is recognized that certain unusual circumstances (such as 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.
  - The Vendor should maintain sufficient stock or production capability to fill teams’ orders within a reasonable period during the build season (less than 1 week). (Note that 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 two weeks. This would be considered a Fabricated Item, and the two weeks 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 five business days and leave the welding of the cuts to the team.)
  - The Vendor makes their products available to all FRC teams. Vendor must not limit supply or make a product available to just a limited number of FRC 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 the 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 FRC 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 national distributors (e.g. Home Depot, Lowes, MSC, Radio Shack, McMaster-Carr, etc.). Remember, FRC events are not usually near home – when parts fail, local access to replacement materials is often critical.

- [R24] COTS items from Robots entered in previous FRC competitions or COTS items that are no longer commercially available may be used only if they are functionally equivalent to the original condition as delivered from the Vendor (e.g. a part that has non-functional label markings added would be permitted, but a part that has device-specific mounting holes added would be prohibited).
- [R25] Lubricants may be used only to reduce friction within the Robot. Lubricants shall not be allowed to contaminate the Court or other Robots.
- [R26] Teams may bring a maximum of 30 lbs of Fabricated Items to each competition event to be used to repair and/or upgrade their Robot at the competition site. The Operator Console and any battery assemblies (see [R03]-A) are not applicable.

#### 4.1.6 Bumper Rules

- [R27] Robots are required to use Bumpers to protect all exterior vertices of the Frame Perimeter. For adequate protection, at least 8 in. of Bumper must be placed on each side of each exterior vertex (see Figure 4-1, Figure 4-2, and Figure 4-3).

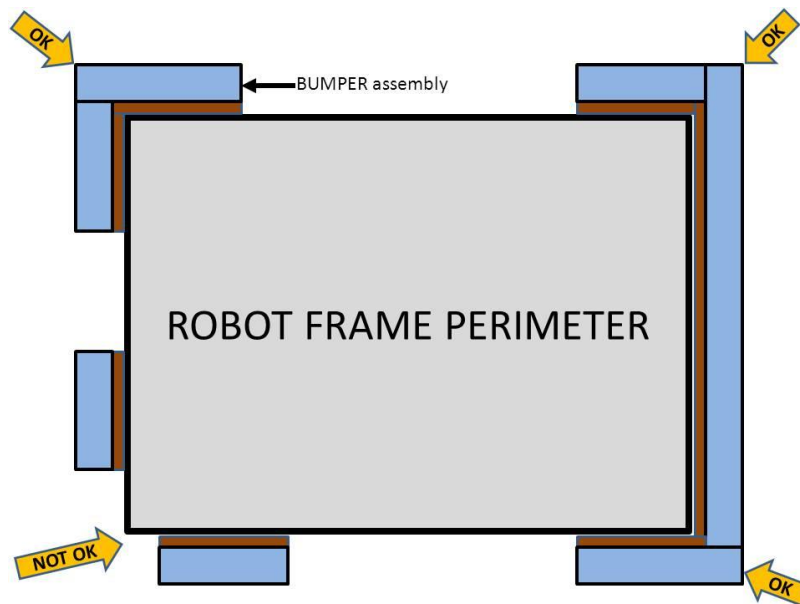


Figure 4-1

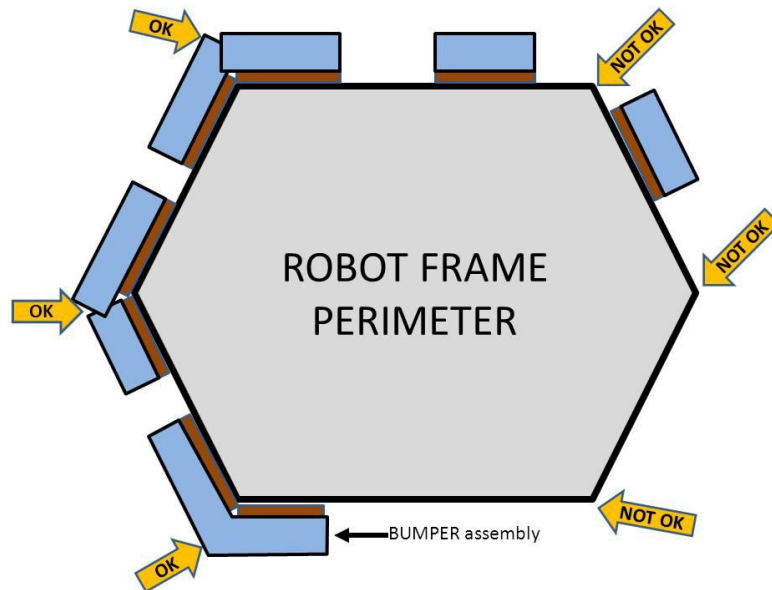


Figure 4-2

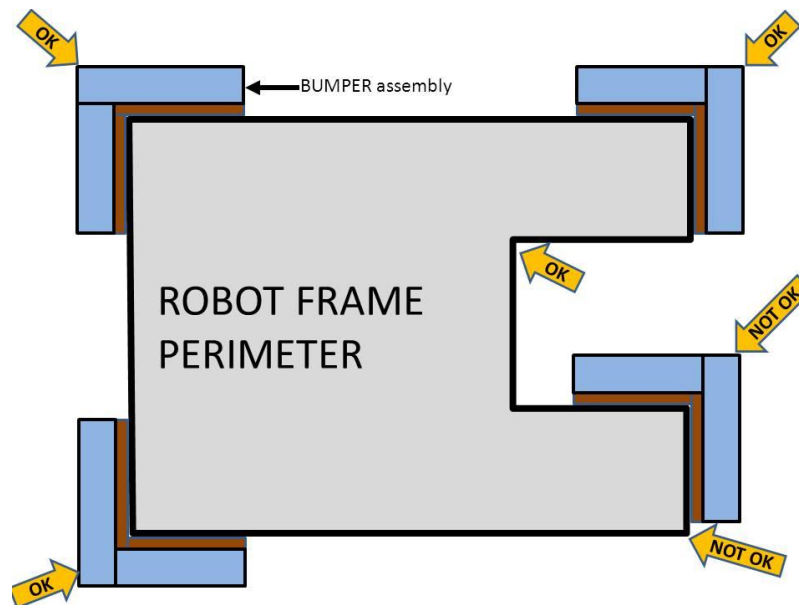


Figure 4-3

[R28] Bumpers must be constructed as follows (see Figure 4-4):

- be backed by  $\frac{3}{4}$  in. (nominal) thick by 5 in. tall plywood.
- hard Bumper parts (e.g. plywood, fasteners, etc) may not extend more than 1 in. beyond the end of the Frame Perimeter(see Figure 4-4).

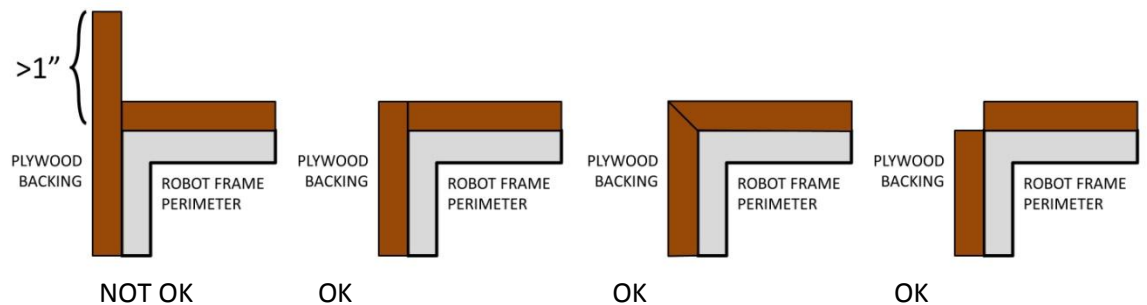


Figure 4-4

- c. use a stacked pair of 2-½ in. “pool noodles” as the bumper cushion material which completely covers the plywood. Cushion material may extend up to 2-½ in. beyond the end of the plywood.
- d. be covered with a rugged, smooth cloth. The cloth must completely enclose all exposed surfaces of the plywood and pool noodle material. The fabric covering the Bumpers must be a solid red or blue in color. Visually, the red or blue must be as close to the corresponding color in the *FIRST* logo as reasonable (i.e. to a reasonably astute observer, they appear similar). The only markings permitted on the Bumper fabric cover are the team number (see Rule [R35]).
- e. must attach to the Frame Perimeter of the Robot with a rigid fastening system to form a tight, robust connection to the main structure/frame (e.g. not attached with Velcro). The attachment system must be designed to withstand vigorous game play. All removable fasteners (e.g. bolts, locking pins, pip-pins, etc.) will be considered part of the Bumpers.
- f. Each set of Bumpers (including any fasteners and/or structures that attach them to the Robot) must weigh no more than 20 lbs.

If a multi-part attachment system is utilized (e.g. interlocking brackets on the Robot and the Bumper), then the elements permanently attached to the Robot will be considered part of the Robot, and the elements attached to the Bumpers will be considered part of the Bumper. Each element must satisfy all applicable rules for the relevant system.

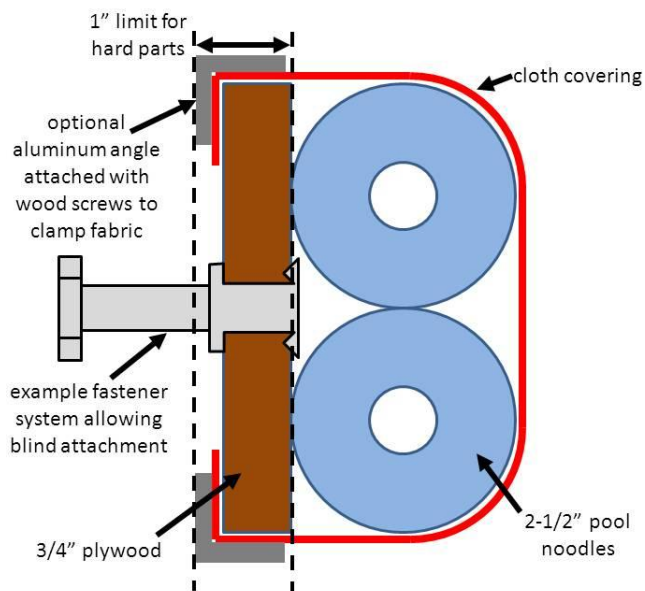
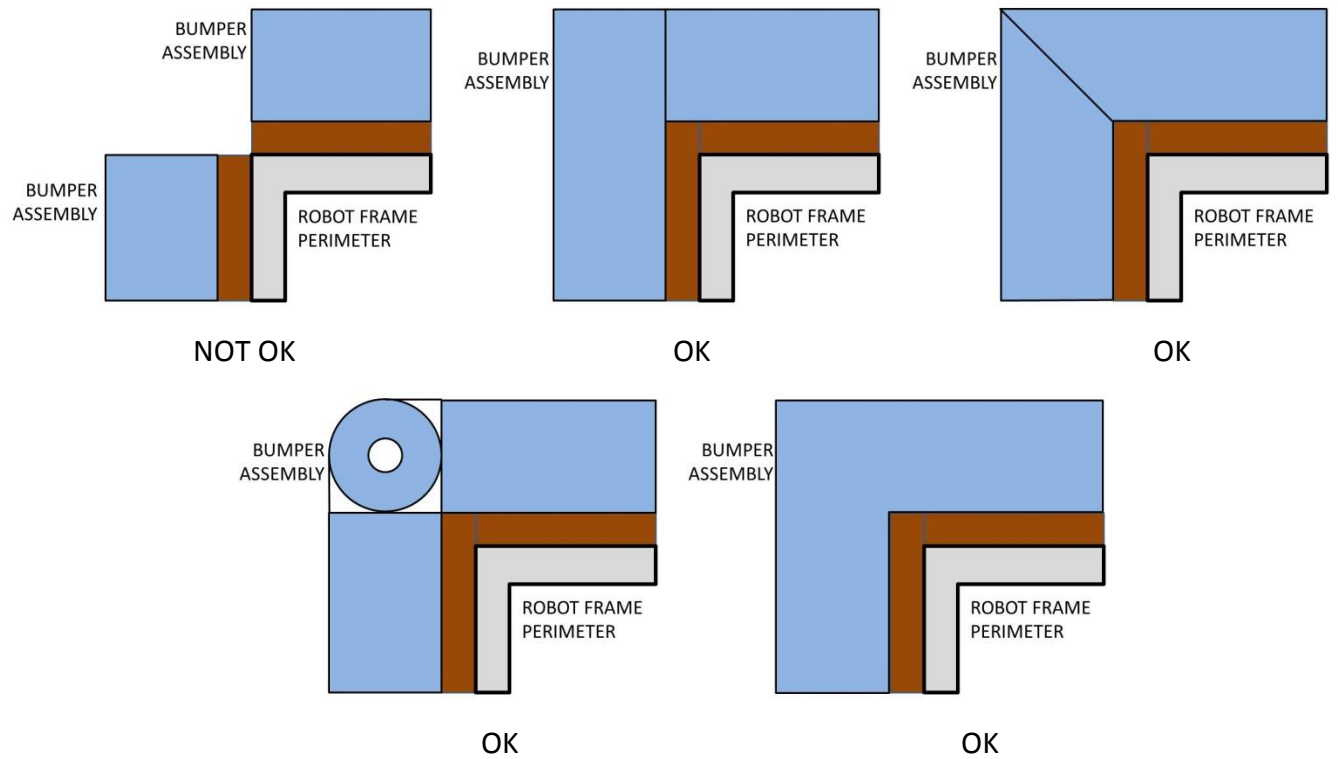


Figure 4-5

- [R29] Bumpers must be located entirely within the Bumper Zone when the Robot is standing normally on a flat floor.
- [R30] Bumpers may not be articulated.
- [R31] Joints between Bumpers and the radial projections of corners must be filled with pool noodle material. Examples of implementation are shown in Figure 4-6.



**Figure 4-6**

**[R32]** Bumpers must be designed for quick and easy installation and removal to aid in weighing and inspection.

As a guideline, Bumpers should be removable by one person in less than 10 minutes.

- [R33] Bumpers must be supported by the structure/frame of the Robot (i.e. the gap between the backing material and the frame must not be greater than  $\frac{1}{4}$  in. and no section of Bumper greater than 8 in. may be unsupported). See Figure 4-7.

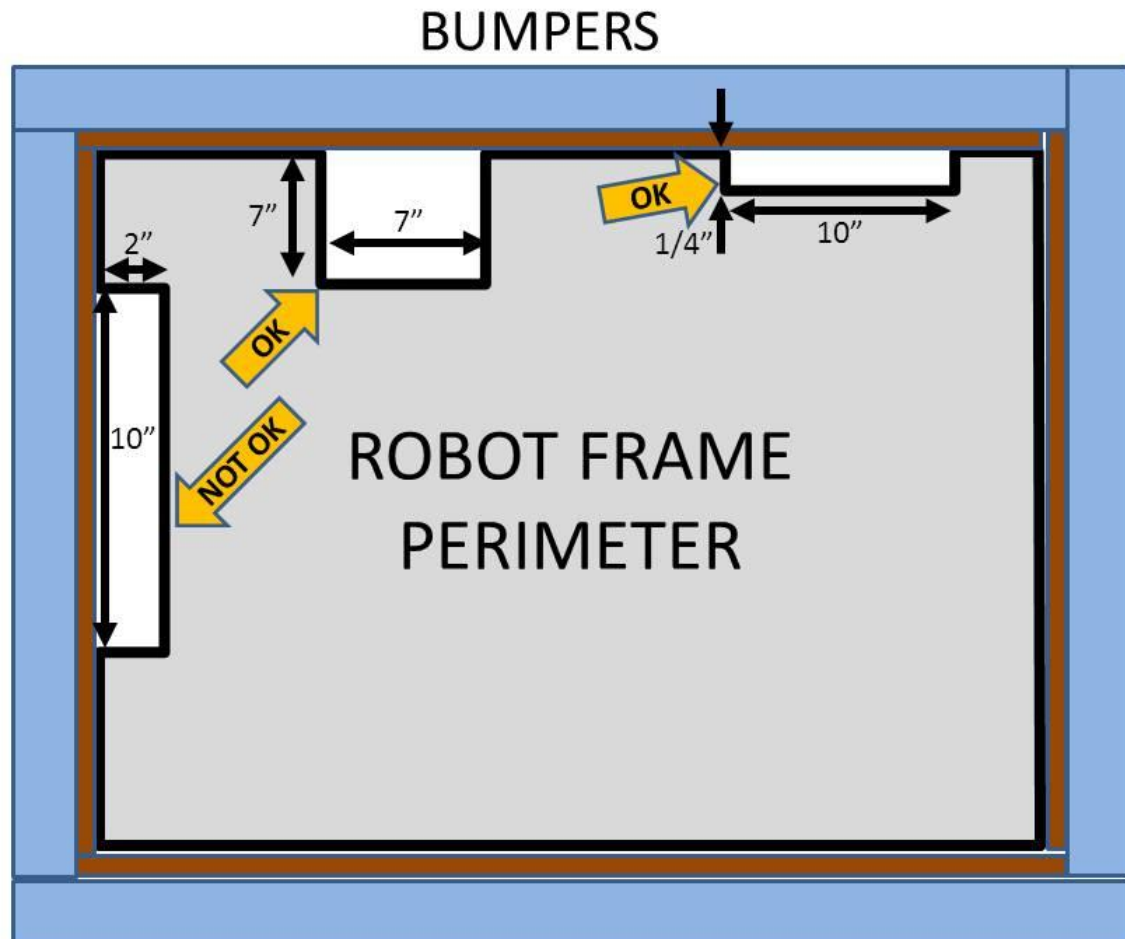


Figure 4-7

- [R34] Each Robot must be able to display red or blue Bumpers to match their alliance color.
- [R35] Teams shall display their team number on the Bumpers in four locations at approximately 90° intervals around the perimeter of the Robot. The numerals must be at least 4 in. high, at least  $\frac{3}{4}$  in. in stroke width, and be either white in color or outlined in white. Team numbers must be clearly visible from a distance of not less than 100 ft, so that judges, referees, and announcers can easily identify competing Robots.

#### 4.1.7 Power Distribution

- [R36] The only legal source of electrical energy for the Robot during the competition is one MK ES17-12 12VDC non-spillable lead acid battery, or one EnerSys NP 18-12 battery, as provided in the 2012 KOP. This is the only battery allowed on the Robot.

Batteries integral to and part of a COTS computing device are also permitted (i.e. laptop batteries), provided they're only used to power the COTS computing device.

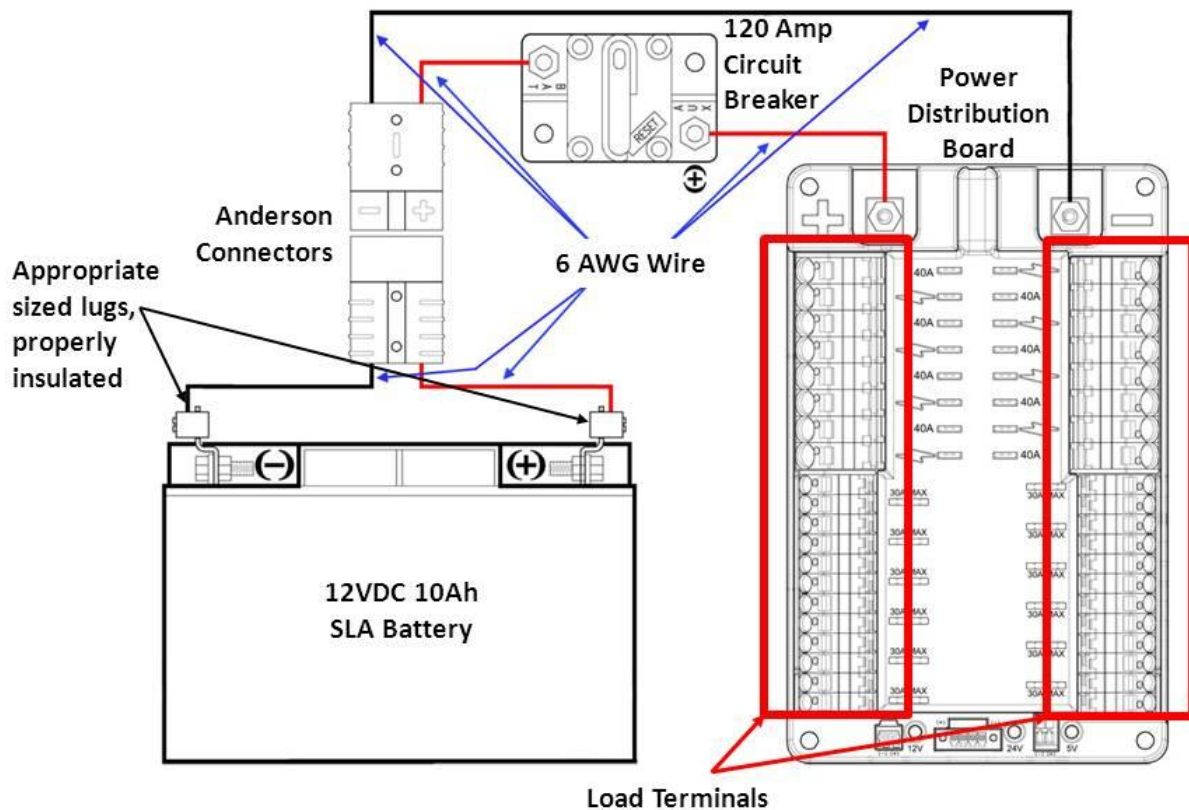
- [R37] Items specifically *prohibited* from use on the Robot include:

- A. circuit breakers used on the Power Distribution (PD) Board that are different from the Snap Action breakers provided in the KOP,
- B. PD Boards and/or fuse panels other than the single PD Board provided in the KOP since 2009, and

**[R38]** All wiring and electrical devices, including all control system components, shall be electrically isolated from the Robot frame. The Robot frame must not be used to carry electrical current.

The chassis for the cRIO and the supplied KOP camera have grounded enclosures. Under this rule (and for their protection), it is required that they be electrically isolated from the Robot frame when installed on the Robot.

**[R39]** The 12V battery, the main 120-amp circuit breaker, and the PD Board shall be connected as shown in Figure 4-8.



**Figure 4-8**

**[R40]** The 120-amp circuit breaker must be quickly accessible from the exterior of the Robot.

It is recommended that the 120-amp circuit breaker location be clearly and obviously labeled to permit it to be easily found by Arena staff during a match.

**[R41]** The PD Board and all circuit breakers must be easily visible for Inspection.

- [R42]** All electric power utilized by the Robot shall be distributed from the load terminals of the PD Board (not the M6 shanks).
- A. The cRIO power input must be connected to the 24 Vdc supply terminals on the PD Board. With the exception of one Solenoid Breakout Board, no other electrical load can be connected to these terminals.
  - B. The wireless bridge power feed must be supplied by the 5V converter (model # TBJ12DK025Z) connected to the marked 12 Vdc supply terminals located at the end of the PD Board (i.e. the terminals located between the indicator LEDs, and not the main WAGO connectors along the sides of the PD Board). No other electrical load can be connected to these terminals (please reference any *2012 Robot Power Distribution Diagram* posted on the [Kit of Parts site](#) for wireless bridge wiring information).
  - C. All other branch circuits must connect to, and have power sourced solely by, a protected 12 Vdc WAGO connector pair or the 5V supply on the PD Board.
  - D. Only one wire shall be connected to each WAGO connector on the PD Board. If multi-point distribution of circuit power is required (e.g. to provide power to the three KOP breakout boards via one 20-amp circuit), then all incoming wires must be appropriately spliced into the main lead, and only one lead inserted into the WAGO connector to connect the circuit.
- [R43]** All active PD Board branch circuits shall be protected from overload with an appropriate value auto resetting Snap Action circuit breaker. Specifically,
- A. Each speed controller branch circuit must be protected by one and only one 20-amp, 30-amp, or 40-amp circuit breaker on the PD Board (from the KOP or identical equivalent). No other electrical load can be connected to the breaker supplying this circuit.
  - B. Each relay module branch circuit must be protected with one and only one 20-amp circuit breaker on the PD Board (from the KOP or identical equivalent). No other electrical load can be connected to the breaker supplying this circuit.
  - C. Each Digital Sidecar branch circuit must be protected with one and only one 20-amp circuit breaker on the PD Board (from the KOP or identical equivalent). No other electrical load can be connected to the breaker supplying this circuit.
  - D. If a compressor is used, the relay module branch circuit supplying the compressor must be protected with a 20-amp circuit breaker (from the KOP or identical equivalent). No other electrical load can be connected to the breaker supplying this circuit.
  - E. A single branch supply circuit may be spliced to supply power to one, two or three of the Analog/Solenoid Breakout Boards. This circuit must be protected with one and only one 20-amp circuit breaker on the PD Board (from the KOP or identical equivalent). No other electrical load can be connected to the breaker supplying this circuit.

Please note, per [R64], that for an 8-slot cRIO, the circuit may not exceed 16W. For a 4-slot cRIO, the circuit may not exceed 21W.

Smaller value Snap Action auto resetting breakers may be used on the PD Board for circuitry not defined above.

In addition to the required branch power circuit breakers, smaller value fuses or breakers may be incorporated into custom circuits for additional protection.

**[R44]** All active circuits shall be wired with appropriately sized wire:

Application	Minimum wire size
40A circuit	12 AWG (2.052mm)
30A circuit	14 AWG (1.628mm)
20A circuit	18 AWG (1.024mm)
between the PD Board and the Analog and/or Solenoid Breakouts if a common power feed is used	
between the PD Board and the Analog and/or Solenoid Breakouts if individual power feeds are used	20 AWG (0.8128mm)
between the PD Board and the cRIO	
between the PD Board and the wireless bridge between the PD board and 5A custom circuits	
pneumatic valves	24 AWG (0.5106mm)

The branch circuit may include intermediate elements such as COTS connectors, splices, COTS flexible/rolling/sliding contacts, and COTS slip rings, as long as the entire electrical pathway is via appropriately gauged conductors.

Wires that are originally attached to legal devices are part of the device and by default legal as supplied. Such wires are exempt from Rule [R44].

**[R45]** All active circuit wiring with a constant polarity (i.e., except for outputs of relay modules, speed controllers, or sensor outputs) shall be color-coded as follows:

- A. Use red, white, brown, or black with stripe wire on the +24 Vdc, +12 Vdc and +5 Vdc connections.
- B. Use black or blue wire for the common or negative side of the (-) connections.

**[R46]** Each power-regulating device (speed controller or relay module) shall control one and only one electrical load (motor, actuator, electric solenoid, or compressor).

Exception: Multiple low-load, pneumatic solenoid valves or lights may be connected to a single relay module. This would allow one relay module to drive multiple pneumatic actions or multiple lights. No other electrical load can be connected to a relay module used in this manner.

**[R47]** Custom circuits shall not directly alter the power pathways between the battery, PD Board, speed controllers, relays, motors, or other elements of the Robot control system (including the power pathways to other sensors or circuits). Custom high impedance voltage monitoring or low impedance current monitoring circuitry connected to the Robot's electrical system is acceptable, if the effect on the Robot outputs is inconsequential.

#### 4.1.8 Motors & Actuators

**[R48]** The only motors and actuators permitted on 2012 FRC Robots include:

- A. up to 4 CIM motors (part #FR801-001, M4-R0062-12, AM802-001A, or PMR25R-45F-1003),
- B. up to 4, in any combination, of the BaneBots motors provided in the KOP (acceptable part numbers are M7-RS775-12, M7-RS775-18, M5-RS550-12, M5-RS550-12-B, and M3-RS395-12),
- C. up to 2 window motors (acceptable part #s are 262100-3030 and 262100-3040),



- D. up to 2 FisherPrice motors (acceptable part #s are 00968-2719, 00801-0673, and 00968-9015),
- E. up to 2 AndyMark motors (acceptable part # is am-9012),
- F. up to 2 AndyMark gearmotors (acceptable part # is am-9014),
- G. up to 2 Denso throttle control motors (acceptable part # AE2351000)
- H. up to 2 Vex motors (acceptable part # 276-2177)
- I. up to 2 window lift, seat, windshield wiper or door motors obtained through either the *FIRST*-Automotive Recyclers Association partnership or from a prior years' KOP.

Note: It will be up to the teams to show that the motors used on the Robot are legal by providing paperwork showing the motor's original use, i.e. if it's called a "seat motor" on the ARA receipt, it is a seat motor.

- J. electrical solenoid actuators, no greater than 1 in. stroke and no greater than 10 watts continuous duty,
- K. drive motors or fans that are part of a speed controller or COTS computing device
- L. an unlimited number of COTS servos with a maximum power rating of 4W each

Servo Max Power Rating = (Stall Torque) X (No Load Speed)

**[R49]** Motors, servos, and electric solenoids 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 input leads may be trimmed to length as necessary.
- C. The locking pins on the window motors (PN 262100-3030 and 262100-3040) may be removed.
- D. The connector housings on the window motors (PN 262100-3030 and 262100-3040) may be modified to facilitate lead connections.

The intent of this rule is to maintain the maximum power level for each Robot, yet still allow teams to modify mounting tabs and the like, not to gain a weight reduction by potentially compromising the structural integrity of any motor. The integral mechanical and electrical system of the motor is not to be modified.

Note that for the Window motors and the AndyMark gearmotor, the gearboxes are considered integral to the motor, thus the motor may not be used without the gearbox.

**[R50]** All electrical loads (motors, actuators, compressors, electric solenoids) must be supplied by an approved power regulating device (speed controller, relay module, or Digital Sidecar PWM port) that is controlled by the cRIO on the Robot.

- a. Each CIM motor and Fisher-Price motor must be connected to one and only one approved speed controller. These motors must not be connected to relay modules.
- b. Servos must be directly connected to the PWM ports on the Digital Sidecar. They must not be connected to speed controllers or relay modules.
- c. If used, the compressor must be connected to one and only one approved relay module.
- d. Each other electrical load (motor or actuator) must be supplied by one and only one approved speed controller, or one and only one relay module.

- e. Electric solenoids may alternatively be supplied by the Solenoid Breakout Board connected to the NI 9472 cRIO module.

**[R51]** The only power regulating devices for actuators permitted on 2012 FRC Robots include:

- A. Jaguar motor controller (PNs MDL-BDC and MDL-BDC24),
- B. Victor motor controller (PN FR-VIC884)
- C. Vex motor controller (PN 276-2193)
- D. Spike Relay module (PN SPIKE-RELAY-H)

To seek approval for alternate devices for inclusion in future FRC seasons, please contact [frcparts@usfirst.org](mailto:frcparts@usfirst.org) with the item specifications.

#### 4.1.9 Control, Command & Signals System

**[R52]** Robots must be controlled via one programmable National Instruments cRIO (part # cRIO-FRC or cRIO-FRCII), with image version FRC\_2012\_v43. Other controllers shall not be used.

As long as the CAN bus is wired legally so that the heartbeat from the cRIO is maintained, all closed loop control features of the Jaguar motor controller may be used. (That is, commands originating from the cRIO to configure, enable, and specify an operating point for all Jaguar closed loop modes fit the intent of [R53].)

**[R53]** Connections to the cRIO Ethernet ports must be compliant with the following parameters:

- A. The DAP-1522 wireless bridge is connected to the cRIO Ethernet port 1 (either directly or via a CAT5 Ethernet pigtail).
- B. Ethernet-connected COTS devices or custom circuits may connect to any remaining Ethernet ports; however, these devices may not transmit or receive UDP packets using ports 1100-1200 except for ports 1130 and 1140.

**[R54]** The cRIO, Driver Station software, and wireless bridge must be configured to correspond to the correct team number (assigned to the team by *FIRST*), per the procedures defined in the FRC control system documentation

**[R55]** One D-Link DAP-1522 is the only permitted device for communicating to and from the Robot during the match. All signals must originate from the Operator Console and be transmitted to the Robot via the official Arena hardware. No other form of wireless communications shall be used to communicate to, from or within the Robot (e.g. radio modems from previous *FIRST* competitions and Bluetooth devices are not permitted on the Robot during competition).

Teams are encouraged to mount the wireless bridge away from noise generating devices such as the CIM motors. By making the diagnostic lights visible, Arena personnel are in a better position to assist teams.

**[R56]** The DAP-1522 wireless bridge must be mounted on the Robot such that the diagnostic lights are visible to Arena personnel.

- [R57]** Robots shall use the diagnostic Robot Signal Light (RSL) provided in the KOP. It must be mounted on the Robot such that it is easily visible while standing three feet in front of the Robot.
- A. The RSL must be connected to the “RSL” supply terminals on a Digital Sidecar

See the 2012 Robot Data Diagram on the KOP website and the item bulletin online here for connection details.

- B. The Digital Sidecar must be connected to a NI 9403 module in Slot 2 of the cRIO.
- C. The RSL must be wired for “solid light” operation, by placing a jumper between the La and Lb terminals on the light per Figure 4-9.

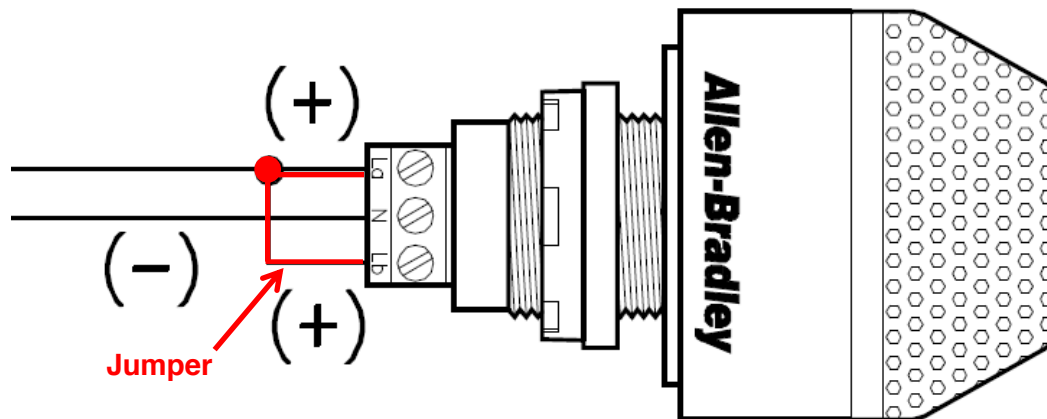


Figure 4-9

- [R58]** The control system is designed to allow wireless control of the Robots. The Driver Station software, FirstTouch I/O module, cRIO, speed controllers, relay modules, wireless bridge, and batteries shall not be tampered with, modified, or adjusted in any way (tampering includes drilling, cutting, machining, gluing, rewiring, disassembling, etc.), with the following exceptions:
- A. User programmable code in the cRIO may be customized.
- B. Dip switches on the cRIO may be set.
- C. Speed controllers may be calibrated as described in owner's manuals.
- D. The supplied fans attached to speed controllers may be powered from the power input terminals.
- E. The fuse on a relay feeding the compressor may be replaced with a 20 Amp Snap-Action circuit breaker (recommended).
- F. Wires, cables, and signal lines may be connected via the standard connection points provided on the devices.
- G. Fasteners may be used to attach the device to the Operator Console or Robot.
- H. Labeling may be applied to indicate device purpose, connectivity, functional performance, etc.
- I. Brake/Coast jumpers on speed controllers may be changed from their default location.
- J. Limit switch jumpers may be removed from a Jaguar speed controller and a custom limit switch circuit may be substituted.

- K. If CAN-bus functionality is used, the Jaguar firmware may (must) be updated as required by *FIRST* (see Rule [R61]-D).
- L. The First Touch I/O module's firmware may be modified.
- M. Devices may be repaired, provided the performance and specifications of the component after the repair are identical to those before the repair.

Please note that the Driver Station application is a separate application from the Dashboard. The Driver Station software may not be modified, while teams are expected to customize their Dashboard code.

Note that if you are using the FirstTouch I/O module as part of the Operator Console, you should not update the firmware if the manufacturer releases a new version. The new version will wipe out the *FIRST* custom firmware and your FirstTouch I/O module will no longer function with the Driver Station software. If a team does wipe out the *FIRST* custom firmware, it can be restored via the most recent Driver Station update.

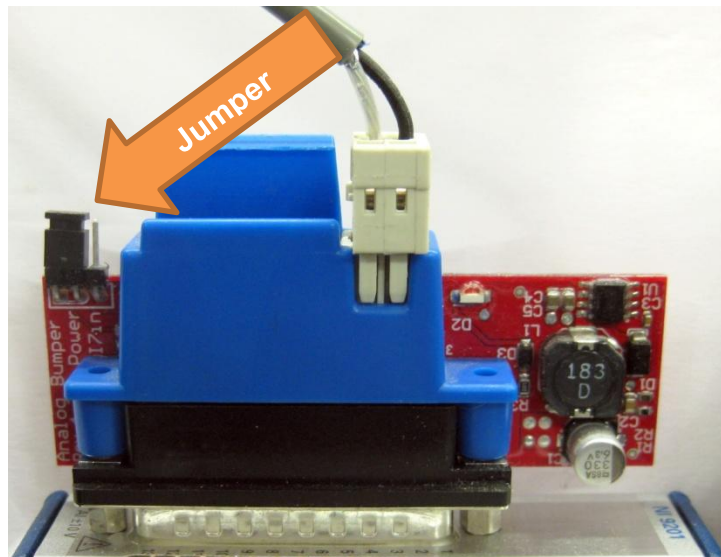
Please note that while repairs are permitted per the FRC Game Manual, the allowance is independent of any manufacturer's warranty. Teams make repairs at their own risk and should assume that any warranty or RMA options are forfeited. Be aware that diagnosing and repairing components such as these can be difficult.

- [R59]** Neither 12Vdc power nor relay module, speed controller, or PWM outputs may be connected to the analog/solenoid breakout boards or the Digital Sidecar (with the exception of the designated 12Vdc input terminals).
- [R60]** Every relay module, servo, and PWM speed controller shall be connected via PWM cable to the Digital Sidecar and be controlled by signals provided from the cRIO via the Digital Sidecar. They shall not be controlled by signals from any other source.
- [R61]** Each Jaguar must be controlled with signal inputs sourced from the cRIO and passed via either a connected PWM cable or a CAN-bus connection.
  - A. The Jaguar must receive signals via either a PWM cable -OR- a CAN-bus connection. Both may not be used simultaneously.
  - B. PWM configuration: If the Jaguar speed controller is controlled via PWM communications, the PWM port on the Jaguar speed controller must be connected directly to a PWM port on the Digital Sidecar with a PWM cable. No other devices may be connected to these PWM ports. No other devices may be connected to any other ports on the Jaguar speed controller with the exception of connection to the coast/brake port.
  - C. CAN-bus configuration: If the Jaguar speed controller is controlled via CAN-bus communications, then each Jaguar speed controller must be connected to either the cRIO or another CAN-bus device with a CAN-bus cable.
  - D. If the CAN-bus configuration is used, the firmware on all Jaguar speed controllers must be updated to at least Version 94 of the official *FIRST* firmware.
- [R62]** If CAN-bus communications are used, the CAN-bus must be connected to the cRIO through either the Ethernet network connected to Port 1, Port 2, or the DB-9 RS-232 port connection.

- A. Ethernet-to-CAN bridges or RS-232-to-CAN bridges (including the “black” Jaguars, MDL-BDC24) may be used to connect the CAN-bus to the cRIO.
- B. Additional switches, sensor modules, custom circuits, third-party modules, etc. may also be placed on the CAN-bus.
- C. No device that interferes with, alters, or blocks communications between the cRIO and the Jaguars will be permitted (tunneling packets for the purposes of passing them through an Ethernet-to-CAN bridge is acceptable as the commands are not altered).

**[R63]** Outputs from each Solenoid Breakout shall not cumulatively exceed 16W for the cRIO-FRC (8-slot) and 21W for the cRIO-FRC II (4-slot).

**[R64]** A National Instruments 9201 module must be installed in slot 1 of the cRIO . An analog breakout must be connected to this module. A jumper must be installed in the “Power” position (two outer pins) on the analog breakout (see Figure 4-10). The analog breakout must be powered from the PD Panel.



**Figure 4-10**

These connections enable monitoring of the battery voltage by the Driver Station and the Field Management System.

- [R65]** All outputs from sensors, custom circuits and additional electronics shall connect to only the following:
- A. other custom circuits,
  - B. additional COTS electronics,
  - C. input ports on the Digital Sidecar,
  - D. input ports on the Analog Breakout,
  - E. the RS-232 DB-9 RS-232 port on the cRIO,
  - F. the Ethernet network connected to either Port 1 or Port 2 of the cRIO,
  - G. the CAN-bus if and only if all Jaguar speed controllers on the CAN-bus are wired in full compliance with Rules [R61] and [R62], or
  - H. the sensor inputs on the Jaguar speed controller.

Custom circuits and additional electronics are allowed to utilize the Port 2 Ethernet bus on the cRIO-FRC and/or the CAN-bus to communicate between devices. Note however, that the Robot must be controlled by the cRIO (see Rule [R52]). Thus, any additional devices on the Ethernet or CAN-bus must not provide command signals that do not originate from the cRIO. It is our intent to incrementally open access to the full control system technologies in a controlled manner that reduces the risk of “unanticipated surprises” as we gain experience with the system.

- [R66]** A noise filter may be wired across motor leads or PWM leads. For the purposes of Inspection and rules compliance, such filters will not be considered custom circuits, and will not be considered a violation of Rule [R49] or Rule [R65]. Acceptable signal filters must be fully insulated and are:
- A one microfarad (1  $\mu$ F) or less non-polarized capacitor may be applied across the power leads of any motor on your Robot (as close to the actual motor leads as reasonably possible).
  - A resistor may be used as a shunt load for the PWM control signal feeding a servo.
- [R67]** Any decorations that involve broadcasting a signal to/from the Robot, such as remote cameras, must be approved by *FIRST* (via e-mail to [frcteams@usfirst.org](mailto:frcteams@usfirst.org)) prior to the event and tested for communications interference at the venue. Such devices, if reviewed and approved, are excluded from Rule [R55].

#### **4.1.10 Pneumatic System**

- [R68]** To satisfy multiple constraints associated with safety, consistency, Robot Inspection, and constructive innovation, no pneumatic parts other than those explicitly permitted by the Pneumatic System Rules may be used on the Robot.
- [R69]** All pneumatic components must be COTS pneumatic devices rated by their manufacturers for working pressure of at least 125psi (with the exception of [R71]-D).
- [R70]** All pneumatic components must be used in their original, unaltered condition. Exceptions are as follows:
- A. tubing may be cut,
  - B. wiring for pneumatic devices may be modified to interface with the control system,
  - C. assembling and connecting pneumatic components using the pre-existing threads, mounting brackets, quick-connect fittings, etc.,
  - D. removing the mounting pin from a pneumatic cylinder, provided the cylinder itself is not modified,
  - E. labeling applied to indicate device purpose, connectivity, functional performance, etc.

Do not, for example, file, machine, or abrasively remove any part of a pneumatic cylinder – this would cause the part to become a prohibited item. Consider pneumatic components sacred.

**[R71]** The only pneumatic system items permitted on 2012 FRC Robots include the items listed below.

- A. Items listed in the *2012 KOP Checklist* or available via *FIRST Choice*.
- B. Pneumatic pressure vent plug valves functionally equivalent to those provided in the KOP.

Parker valves PV609-2 or MV709-2 are recommended.

- C. Solenoid valves with a maximum  $\frac{1}{8}$  in. NPT port diameter, and a maximum Cv of 0.32 (if non-KOP valves are used, the team will be required to provide part documentation validating that the valves meet these constraints).
- D. Solenoid valves that are rated for a maximum working pressure that is less than 125 psi rating mandated above are permitted, however if employed, an additional pressure relief valve must be added to the low pressure side of the main regulator. The additional relief valve must be set to a lower pressure than the maximum pressure rating for the solenoid valve.
- E. Additional pneumatic tubing, with a maximum 0.160 in inside diameter, functionally equivalent to that provided in the KOP, with the pressure rating clearly factory-printed on the exterior of the tubing or with supplier documentation showing the pressure rating.
- F. Pressure transducers, pressure gauges, and connecting fittings,
- G. Pressure regulators with a maximum bypass pressure of no more than 60 psi,
- H. Pneumatic cylinders,
- I. Pneumatic storage tanks, and
- J. Compressors compliant with Rule [R73].

For the purposes of the FRC, the following devices are not considered pneumatic devices and are not subject to pneumatic rules (though they must satisfy all other rules):

- a device that creates a vacuum
- closed-loop COTS pneumatic (gas) shocks
- air-filled (pneumatic) wheels

**[R72]** If pneumatic components are used on the Robot, the following items are required as part of the pneumatic system and must be connected in accordance with this section.

- A. Pressure gauges to display the “stored” and “working” air pressure (see Rule [R74]),
- B. A pressure relief valve, calibrated and set to release at 125 psi (see Rule [R75]),
- C. A pressure switch, calibrated and connected to the Robot control system (see Rule [R76]),
- D. An easily visible and accessible pressure vent plug valve to manually relieve the stored pressure (see Rule [R77]).

**[R73]** Compressed air on the Robot must be provided by one and only one compressor. Compressor specifications may not exceed nominal 12V, 1.05 cfm flow rate, 120 psi maximum working pressure. Off-board compressors must be controlled and powered by the Robot.

If an alternative compressor is used, the team may be required to provide documentation to show compliance with the performance specifications.

The only difference between an on- and off-board compressor is that the off-board compressor is physically removed from the Robot. The intent of this rule is to permit teams to take advantage of the weight savings associated with keeping the compressor off-board. However, using the compressor off-board of the Robot does NOT permit non-compliance with any other applicable rules.

The compressor may be mounted on the Robot, or it may be left off the Robot and used to pre-charge compressed air in the storage tanks prior to bringing the Robot onto the Court.

- [R74]** “Working” air pressure on the Robot must be no greater than 60 psi. All working air must be provided through one primary Norgren adjustable pressure regulator.
- A. All “working” pneumatic components (e.g. valves, cylinders, rotary actuators, etc.) must be downstream from this regulator.
  - B. Only the compressor, relief valve, pressure switch, pressure vent plug valve, pressure gauge, storage tanks, tubing, and connecting fittings may be in the high-pressure pneumatic circuit upstream from the regulator.
  - C. Pressure gauges must be placed in easily visible locations upstream and downstream of the regulator to display the “stored” and “working” pressures.
  - D. If the compressor is not included on the Robot (under the provisions of Rule [R73]), the regulator and high-pressure gauge may be located on-board or off-board, provided all other pneumatic rules are satisfied. Note that if the regulator is kept off-board the Robot with the compressor, then only low-pressure (60 psi or less) “working” air can be stored on the Robot.
- [R75]** The relief valve must be attached directly to the compressor or attached by suitable brass fittings connected to the compressor output port.

If necessary, teams are required to adjust the relief valve to release air at 125 psi. The valve may or may not have been calibrated prior to being supplied to teams.

- [R76]** The pressure switch must be connected to the high-pressure side of the pneumatic circuit (i.e. prior to the pressure regulator) to sense the “stored” pressure of the circuit. The two wires from the pressure switch must be connected directly to a digital input and ground port on the Digital Sidecar, and the cRIO must be programmed to sense the state of the switch and operate the relay module that powers the compressor to prevent over-pressuring the system.
- [R77]** The pressure vent plug valve must be connected to the pneumatic circuit such that, when manually operated, it will vent to the atmosphere to relieve all stored pressure. The valve must be placed on the Robot so that it is visible and easily accessible. If the compressor is not used on the Robot, then an additional vent valve must be obtained and connected to the high-pressure portion of the pneumatic circuit off board the Robot with the compressor (see Rule [R73]).
- [R78]** The outputs from multiple valves may not be plumbed together into the same input on a pneumatic cylinder.



### 4.1.11 Operator Console

- [R79] The Operator Console is the collection of the hardware used to run the Driver Station software and any associated equipment, control interfaces, display systems, structure, decorations, etc. used by the Drivers to operate the Robot.
- [R80] The Driver Station software provided on the [Kit of Parts website](#) is the only tool permitted to specify and communicate the operating mode (i.e. Autonomous/Teleop) and operating state (enable/disable) to the Robot. The Driver Station software must be revision 01.07.12.00 or newer.

Teams are permitted to use a portable computing device of their choice (laptop computer, PDAs, etc.) to host the Driver Station software while participating in competition Matches.

Please note that 19V DC, 2 amp power will be provided at the Player Station for Classmates provided in the KOPs via Classmate power adapters. The manufacturer has confirmed that the power supply provided at the Player Station is compatible with both E09 and E11 Classmate versions. No 120 V AC port will be available.

The FMS will verify that the Driver Station software is correct before it will permit a Robot to operate on the Court.

- [R81] Devices hosting the Driver Station software may only interface with the Field Management System (FMS) via the Ethernet cable provided at the Player Station. The Ethernet port on the Operator Console must be easily and quickly accessible.

Teams are strongly encouraged to use pigtailed on the Ethernet port used to connect to the FMS. Such pigtailed will reduce wear and tear on the port and, with proper strain relief employed, will protect the port from accidental jerks.

- [R82] The Operator Console must not exceed 48 in. long by 12 in. deep (excluding any items that are held or worn by the Drivers during the match).
- [R83] The Operator Console must include a graphic display to present the Driver Station diagnostic information. It must be positioned within the Operator Console so that the screen display can be clearly seen during Inspection and during operation in a match.
- [R84] Other than the system provided by the Arena, no other form of wireless communications shall be used to communicate to, from or within the Operator Console.

Examples of prohibited wireless systems include, but are not limited to, active wireless network cards and Bluetooth devices. For the case of FRC, a motion sensing input device (e.g. Microsoft Kinect) is not considered wireless communication and is allowed.

## 4.2 REVISION HISTORY

Revision	Release Date	Changes
-	1/3/12	Initial Release