4 Robot

4 ROBOT

This section of the 2016 *FIRST* Robotics Competition Game Manual presents legislation relevant to the construction of a 2016 *FIRST* Robotics Competition ROBOT. ROBOTS will be Inspected at each *FIRST* Robotics Competition event to confirm compliance before being allowed to compete, per Section 5 (5.5.2 Eligibility and Inspection).

4.1 Overview

The rules listed below explicitly address what and how parts and materials may be used on a 2016 *FIRST* Robotics Competition ROBOT. 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 Kit of Parts (KOP), which is the collection of items listed on any Kickoff Kit Checklists, distributed via *FIRST* Choice, or obtained via a Product Donation Voucher (PDV), etc.

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 that the Inspectors are able to accurately assess the legality of a given part.

FIRST Robotics Competition 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 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.

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. 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 two (2) ROBOT grippers from RoboHands Corp. and receives both items. They put one in their storeroom and plan to use it later. Into the other, they drill “lightening holes” to reduce weight. The first gripper is still classified as a COTS item, but the second gripper 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 during the pre-season, and uses them to fabricate a gearbox for their ROBOT during the build period following Kickoff. 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 single-board processor version 1.0, which can no longer be purchased. Only the COTS single-board processor version 2.0 may be purchased. If the COTS single-board processor version 1.0 is functionally equivalent to its original condition, it may be used.

Example 6: 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 of 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 an *FIRST* Robotics Competition Team or collection of *FIRST* Robotics Competition Teams. While there may be some individuals affiliated with both an *FIRST* Robotics Competition Team and the VENDOR, the business and activities of the Team and VENDOR must be completely separable.

C. 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.

D. should maintain sufficient stock or production capability to fill Teams' orders within a reasonable period during the 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.)

E. makes their products available to all *FIRST* Robotics Competition Teams. VENDOR must not limit supply or make a product available to just a limited number of *FIRST* Robotics Competition Teams.

> The intent of this definition it 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 *FIRST* Robotics Competition 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, *FIRST* Robotics Competition events are not always near home – when parts fail, local access to replacement materials is often critical.

A FABRCATED 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. length of aluminum which has been cut into 5ft. pieces for transport is neither COTS (it's not in the state received from the VENDOR), nor a FABRICATED ITEM (the cuts were not made to advance the part towards it's final form on the ROBOT).

Teams may be asked to provide documentation proving legality of non-2016 KOP items during Inspection where a Rule specifies limits for a legal part (e.g. pneumatic items, current limits, COTS electronics, etc.).

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@firstinspires.org for an official ruling. To seek approval for alternate devices for inclusion in future *FIRST* Robotics Competition seasons, please contact frcparts@firstinspires.org with item specifications.

Teams should acknowledge the support provided by the corporate Sponsors and Mentors with an appropriate display of their school and Sponsors names and/or logos (or the name of the supporting youth organization, if appropriate).

FIRST Robotics Competition can be a full-contact ROBOT competition and may include rigorous game play. While Game and ROBOT Rules limit severe damage to ROBOTS, Teams should design their ROBOTS to be robust.

4.2 General ROBOT Design

R1 A Team must submit their ROBOT for Inspection. The ROBOT must be an electromechanical assembly built by the *FIRST* Robotics Competition Team to perform specific tasks when competing in *FIRST* STRONGHOLD. The ROBOT must include all of the basic systems required to be an active participant in the game – power, communications, control, and movement. The ROBOT implementation must obviously follow a design approach intended to play *FIRST* STRONGHOLD (e.g. a box of unassembled parts placed on the FIELD, or a ROBOT designed to play a different game does not satisfy this definition).

> R1 requires that the ROBOT a Team uses in competition was built by that Team, but isn't intended to prohibit assistance from other Teams (e.g. fabricating elements, supporting construction, writing software, developing game strategy, contributing COMPONENTS and/or MECHANISMS, etc.).

R2 The ROBOT must have a FRAME PERIMETER, contained within the BUMPER ZONE, that is comprised of fixed, non-articulated structural elements of the ROBOT. 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 BUMPER ZONE described in R22. 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.

R3 The ROBOT must satisfy the following size constraints:

A. total length of the FRAME PERIMETER sides must not exceed 120 in. (see Figure 4-1 for examples),

B. must not extend greater than 15 in. beyond the FRAME PERIMETER (see Figure 4-2 for examples) (see G18), and

C. ROBOT STARTING CONFIGURATION height must not exceed 54 in. (note that ROBOT height may exceed this limit in-MATCH as allowed by G17).

Figure 4-1: FRAME PERIMETER Length Calculations

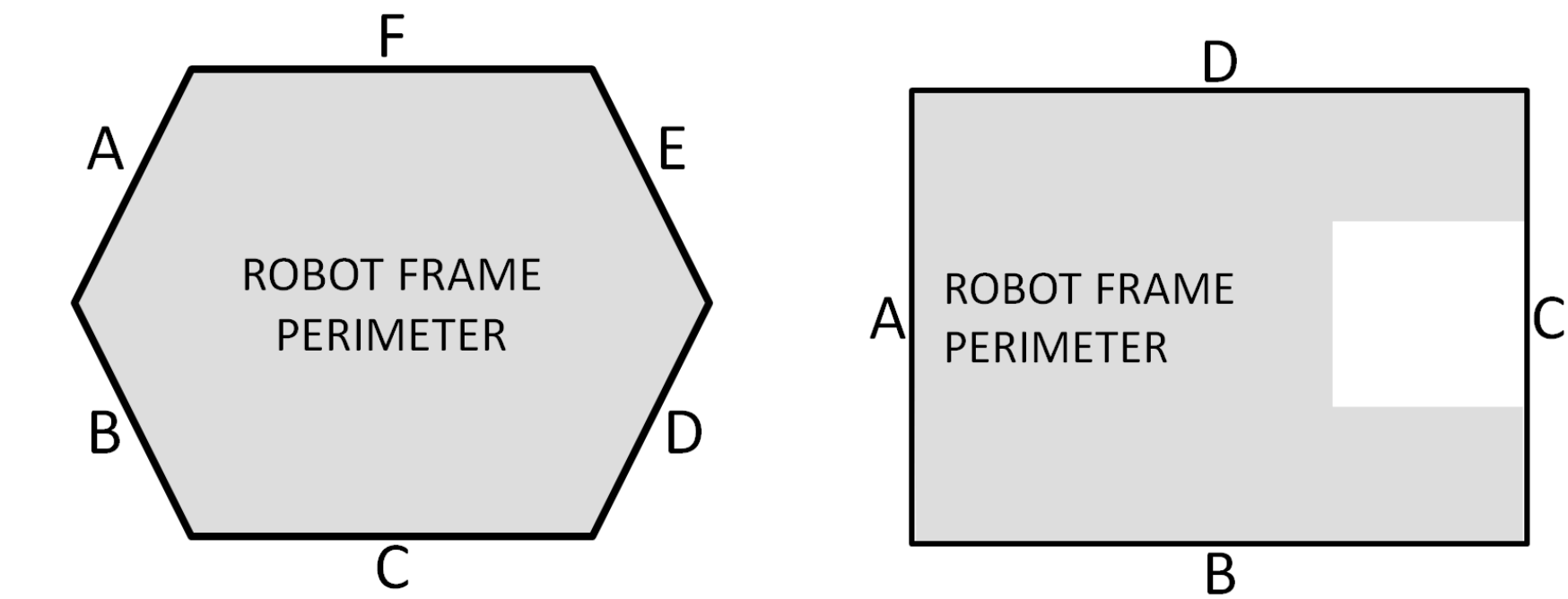
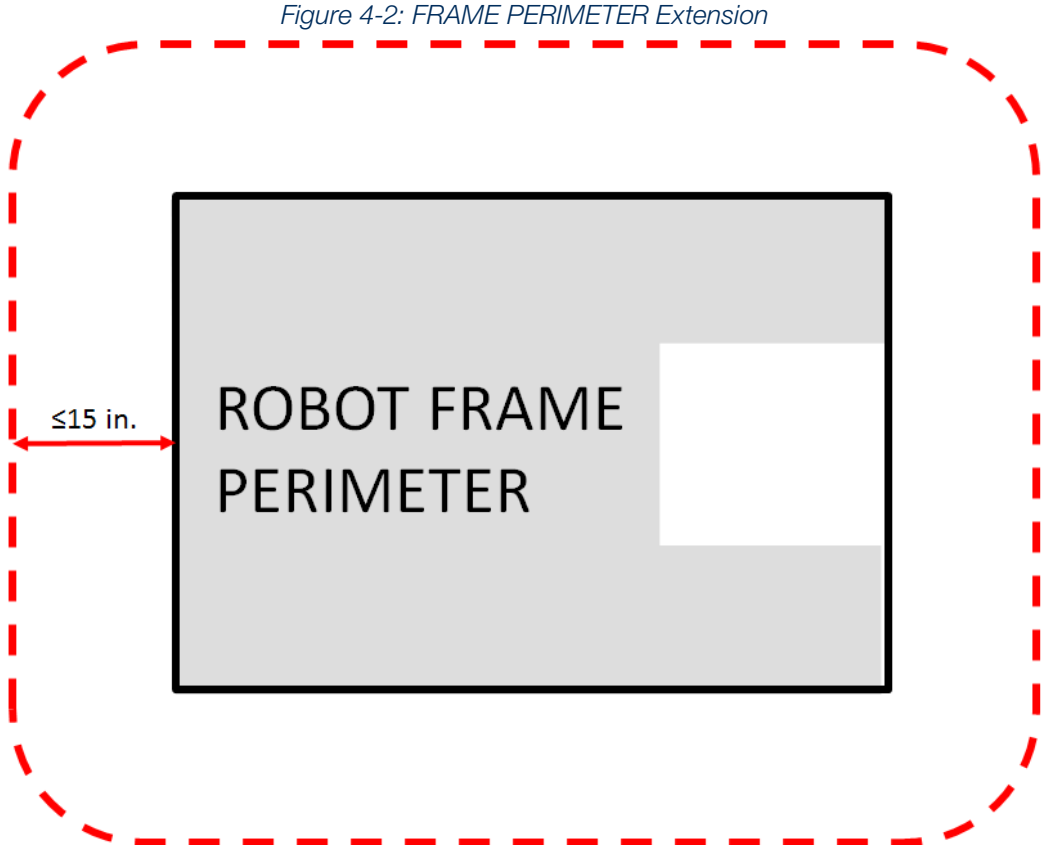


Figure 4-2: FRAME PERIMETER Extension



Expect to have to demonstrate a ROBOT'S ability to constrain itself per B above during Inspection. PLAYING CONFIGURATION constraints may be implemented with either hardware or software.

Teams should think carefully about how they will transfer their ROBOTS from place to place during the events. Many *FIRST* Robotics Competitions take place in venues with standard sized doors. Be sure to consider the size of the ROBOT on its cart to make sure it will fit through doors. Also consider the size of the ROBOT to ensure that it will fit into a shipping crate, bag, vehicle, etc.

R4 In the STARTING CONFIGURATION (the physical configuration in which a ROBOT starts a MATCH), no part of the ROBOT shall extend outside the vertical projection of the FRAME PERIMETER, with the exception of minor protrusions such as bolt heads, fastener ends, rivets, etc.

If a ROBOT is designed as intended and each side is pushed up against a vertical wall (in STARTING CONFIGURATION and with BUMPERS removed), only the FRAME PERIMETER (or minor protrusions) will be in contact with the wall.

R5 The ROBOT weight must 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 limitations, the ROBOT BUMPERS and ROBOT 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) are excluded.

R6 Traction devices must not have surface features such as metal, sandpaper, hard plastic studs, cleats, hook-loop fasteners or similar attachments that could damage the ARENA. Traction devices include all parts of the ROBOT that are designed to transmit any propulsive and/or braking forces between the ROBOT and FIELD carpet.

R7 ROBOTS must allow removal of BOULDERS from the ROBOT and the ROBOT from FIELD elements while DISABLED and powered off.

ROBOTS will not be re-enabled after the MATCH, so Teams must be sure that BOULDERS and ROBOTS can be quickly, simply, and safely removed.

4.3 Safety & Damage Prevention

R8 Protrusions from the ROBOT and exposed surfaces on the ROBOT shall not pose hazards to the ARENA elements (including the BOULDERS) or people.

If the ROBOT includes protrusions that form the "leading edge" of the ROBOT as it drives and have a surface area of less than 1 $in.^2$, it will invite detailed Inspection. For example, forklifts, lifting arms, or grapplers may be carefully Inspected for these hazards.

R9 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 R9 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, infrared proximity detectors, etc. (e.g. including imagery on your ROBOT that, to a reasonably astute observer, mimics the retro-reflective features of the TOWER described in Section 2.3.1.3 TOWER)

D. Exposed lasers other than Class I.

E. Flammable gasses

F. Any device intended to produce flames or pyrotechnics

G. Hydraulic fluids or hydraulic items

H. Switches or contacts containing liquid mercury

I. Circuitry used to create voltages in excess of 24V

J. Any ballast not secured sufficiently, including loose ballast e.g. sand, ball bearings, etc., such that it may become loose during a MATCH.

K. 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.

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

4.4 Budget Constraints

R10 The total cost of all items on the ROBOT shall not exceed $4000 USD. All costs are to be determined as explained in Section 4.4 Budget Constraints. Exceptions are as follows:

A. individual COTS items that are less than $5 USD each and

B. KOP items

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

There is no quantity limit on KOP items in regards to R10. If the item is a KOP item, it does not require an associated cost on the Cost Accounting Worksheet (CAW).

Per T11, Teams must be prepared to display a CAW to Inspectors during Inspection. The CAW may be displayed in either printed or electronic form.

Individual COMPONENTS or MECHANISMS, not excluded in R10, that are retrieved from previous ROBOTS and used on 2016 ROBOTS must have their undepreciated cost included in the 2016 CAW and applied to the overall cost assessment.

R11 No individual, non-KOP item shall have a value that exceeds $400 USD. The total cost of COMPONENTS purchased in bulk may exceed $400 USD as long as the cost of an individual COMPONENT does not exceed $400 USD.

If a COTS 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 R11.

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 R11.

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.

Example 1: VENDOR A sells a gearbox that can be used with a number of different gear sets, and can mate with two different motors they sell. A team purchases the gearbox, a gear set, 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 CAW costing, since the purchased pieces can each be used in various configurations.

Example 2: VENDOR B sells a robotic arm assembly that the team wants to use. However, it costs $700 USD, so they cannot use it. The VENDOR sells the “hand”, “wrist”, and “arm” as separate assemblies, for $200 USD each. A team wishes to purchase the three items 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 USD.

Example 3: VENDOR C sells a set of wheels or wheel modules that are often used in groups of four. The wheels or modules can be used in other quantities or configurations. A team purchases four and uses them in the most common configuration. Each part is treated separately for the purpose of CAW costing, since the purchased pieces can be used in various configurations.

R12 The CAW 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), members of other Teams, event provided Machine Shops and shipping.

Example 1: 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 2: A Team receives a donated sensor. The company would normally sell this item for $52 USD, which is therefore its fair market value.

Example 3: Special price discounts from National Instruments and other *FIRST* Robotics Competition Suppliers are being offered to all *FIRST* Teams. The discounted purchase price of items from these sources may be used in the additional parts accounting calculations.

Example 4: A Team purchases steel bar stock for $10 USD and has it machined by a local machine shop. The machine shop is not considered a team Sponsor, but donates two (2) 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 USD.

Example 5: A Team purchases steel bar stock for $10 USD 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 USD.

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 6: A Team purchases steel bar stock for $10 USD and has it machined by another Team. The total applicable cost for the part would be $10 USD.

Example 7: 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.

4.5 Fabrication Schedule

R13 Physical ROBOT elements created before Kickoff are not permitted. Exceptions are:

A. OPERATOR CONSOLE,

B. BUMPERS (a protective assembly designed to attach to the exterior of the ROBOT and constructed as specified in Section 4.7 BUMPER Rules),

C. battery assemblies per R5,

D. FABRICATED ITEMS consisting of one COTS electrical device (e.g. a motor or motor controller), connectors, and any materials used to secure and insulate those connectors

> Please note that this means that FABRICATED ITEMS from ROBOTS entered in previous *FIRST* competitions may not be used on ROBOTS in the 2016 *FIRST* Robotics Competition (other than those allowed per R13-C and R13-D). Before the formal start of the *FIRST* Robotics Competition 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 1: A Team designs and builds a two-speed shifting transmission during the fall as a training exercise. After Kickoff, they utilize all the design principles they learned in the fall to design their ROBOT. 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 2: A Team re-uses a 2016-legal motor from a previous Robot which has had connectors added to the wires. This is permitted, per exception C, because the motor is a COTS electrical COMPONENT.

R14 Software and mechanical/electrical designs created before Kickoff are only permitted if the source files (complete information sufficient to produce the design) are available publicly prior to Kickoff.

Example 1: A 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 made during the competition season – was built from detailed designs developed prior to Kickoff.

Example 2: 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 2016 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 3: The same Team decides to use LabVIEW as their software environment for 2016. 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 4: 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 publicly available before Kickoff, they can use it on their ROBOT.

Example 5: A Team develops a transmission during the fall. After completing the project, they publish the CAD files on a generally accessible public forum and make them available to all Teams. Because they have made the design publicly available before Kickoff, they can use the design to create an identical transmission, fabricated after Kickoff, for use on their 2016 ROBOT.

R15 All ROBOT elements (including items intended for use during the competition in alternative configurations of the ROBOT), with the exception of the WITHHOLDING ALLOWANCE per R18, BUMPERS, and COTS items, must be bagged and sealed, by 11:59PM local time on Stop Build Day, February 23, 2016 (refer to the *Admin Manual* Section 5 (5.3 Instructions for "Bag and Tag")).

R16 Teams must stay "hands-off" their bagged ROBOT elements during the following time periods:

A. between Stop Build Day and their first event,

B. during the period(s) between their events, and

C. outside of Pit hours while attending events.

Modifying parts at night offsite (e.g. pits have closed and you bring a MECHANISM back to the hotel to fix it) is a violation of R16-C.

Additional time is allowed as follows:

D. After Kickoff, there are no restrictions on when software may be developed.

E. On days a team is not attending an event, they may continue development of any items permitted per R18, including items listed as exempt from R18, but must do so without interfacing with the ROBOT.

F. Teams attending 2-day events may access their ROBOTS per the rules defined in the *Admin Manual* Section 5 (5.6 "ROBOT ACCESS PERIOD" – For Teams Attending District Events)

G. ROBOTS may be exhibited per *Admin Manual* Section 5 (5.4.3 Robot Displays).

4.6 Material Utilization

R17 Lubricants may be used only to reduce friction within the ROBOT. Lubricants must not contaminate the ARENA or other ROBOTS.

R18 At an Event, Teams may have access to a WITHHOLDING ALLOWANCE of FABRICATED ITEMS, not bagged per R15, to be used to repair and/or upgrade their ROBOT. The WITHHOLDING ALLOWANCE is a static set of items that shall not exceed 30 lbs. With permission from another Team, Teams may also have access to FABRCATED ITEMS that are part of that other Team's WITHOLDING ALLOWANCE to repair and/or upgrade their ROBOT. The WITHHOLDING ALLOWANCE may only be brought into the Venue when the Team initially loads in at the Event. Items made at an Event do not count towards this weight limit.

> Teams should be prepared to show their WITHOLDING ALLOWANCE items, and potentially have them weighed, during load-in.
>
> This means teams may not store FABRICATED ITEMS outside the pits to be brought to the event at a later time. This set may be changed between events (i.e. a Team may leave a different set of items out of the bag and/or fabricate new items to bring to their next event) provided the total weight of FABRICATED ITEMS brought to the next event does not exceed thirty (30) lbs.
>
> There is no restriction on the quantity of COTS items or items which do not meet the definitions of COTS or FABRICATED ITEMS (e.g. raw materials) that may be accessed by a Team at an Event.

For Teams attending 2-Day Events, these FABRICATED ITEMS may be used during the Robot Access Period and/or brought to the Event, but the total weight may not exceed 30 lbs. FABRICATED ITEMS constructed during the Robot Access Period and bagged with the ROBOT are exempt from this limit.

Example 1: A team creates 10 lbs of FABRICATED ITEMS after Stop Build Day. During their first Robot Access Period before their first event, they install these items on the ROBOT and bag them with the ROBOT. The team may bring up to 20 lbs. of FABRICATED ITEMS (which may be items removed from the ROBOT before bagging at the end of the Robot Access Period) with them to the event.

Example 2: A team creates 30 lbs of FABRICATED ITEMS after Stop Build Day. During their first Robot Access Period before their first event, they install these items on the ROBOT and bag them with the ROBOT. The team may not bring any FABRICATED ITEMS (including any initially bagged on Stop Build Day and removed during the Robot Access Period) with them to the event.

Items exempt from this limit are:

A. the OPERATOR CONSOLE,

B. any ROBOT battery assemblies (as described in R5).

4.7 BUMPER Rules

R19 ROBOTS are required to use BUMPERS to protect all outside corners of the FRAME PERIMETER. For adequate protection, at least 8 in. of BUMPER must be placed on each side of each outside corner (see Figure 4-3). If a side is shorter than 8 in., the entire side must be protected by BUMPER (see Figure 4-4). A round or circular FRAME PERIMETER, or segment of the frame perimeter, is considered to have an infinite number of corners.

The dimension defined in R19 is measured along the FRAME PERIMETER. The portion of the BUMPER that extends into the corner is not included in the 8 in. requirement.

Figure 4-3: BUMPER Corner Examples

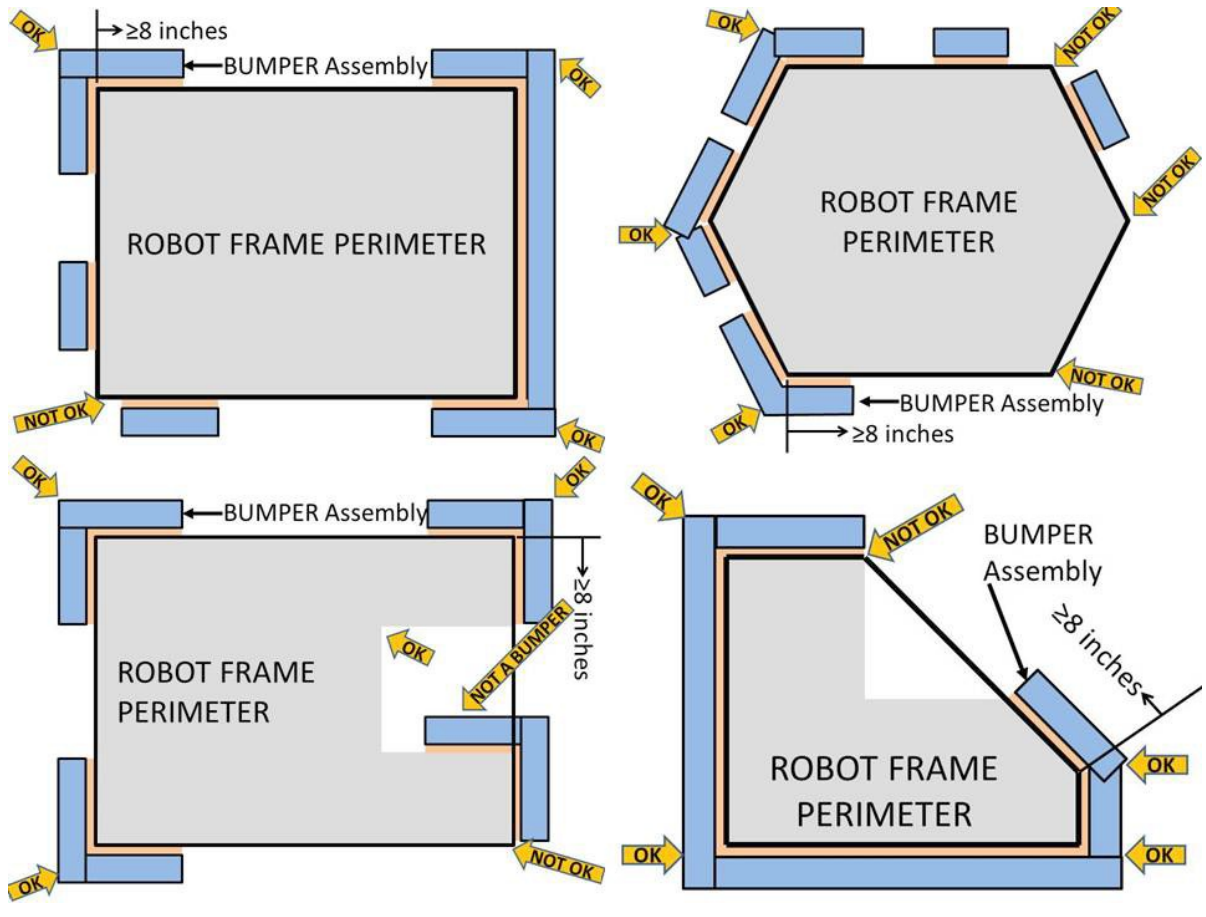
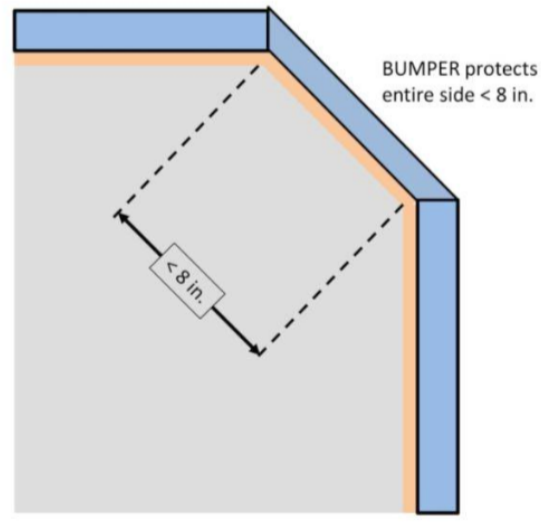


Figure 4-4: BUMPER Side Less Than 8 in.



R20 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.

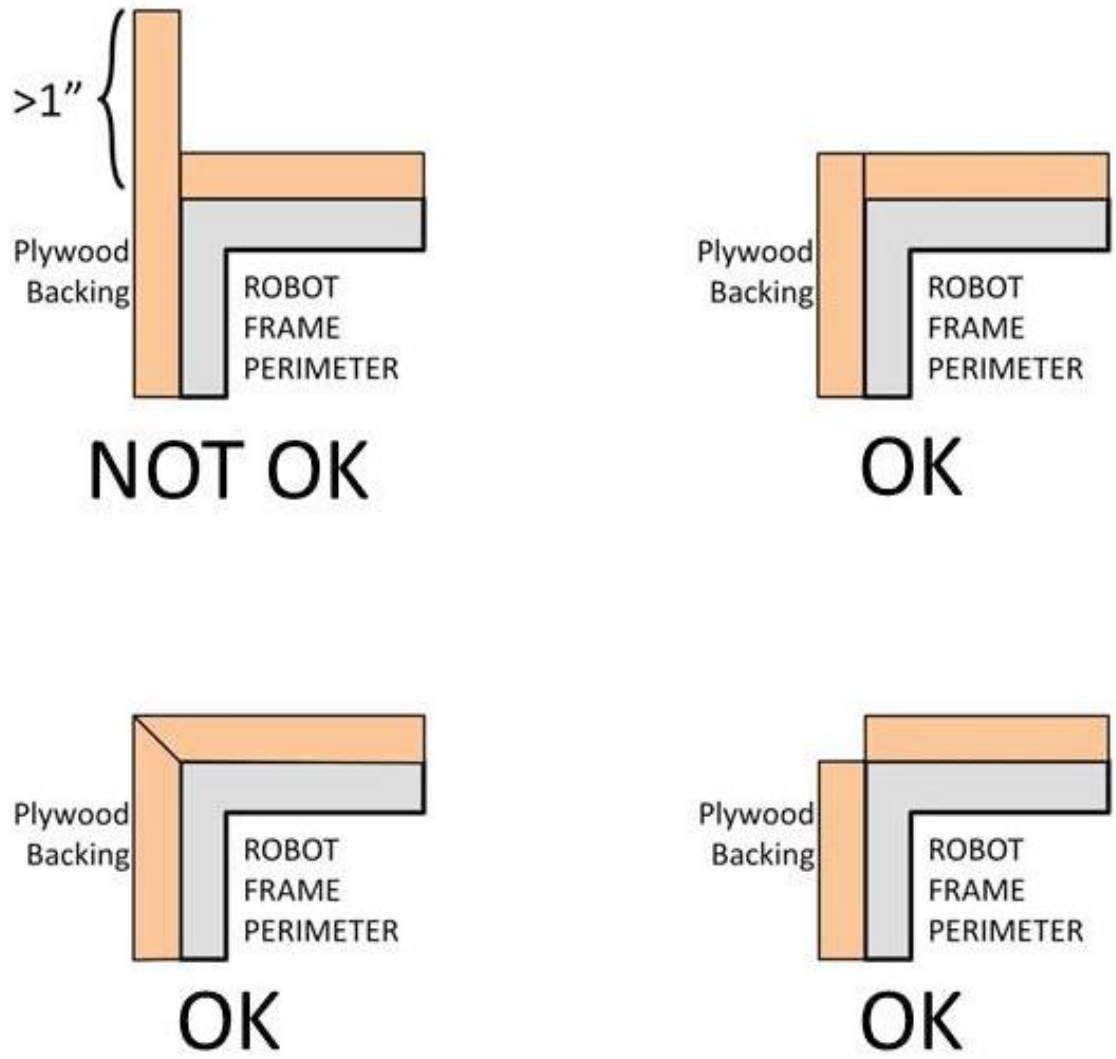
R21 BUMPERS must be constructed as follows (see Figure 4-7):

A. be backed by ¾ in. (nominal) thick by 5 in. (± ½ in) tall plywood or solid, robust wood. Small clearance pockets and/or access holes in the plywood backing are permitted, as long as they do not significantly affect the structural integrity of the BUMPER.

> Particle board or chipboard is not likely to survive the rigors of *FIRST* Robotics Competition gameplay and thus not compliant with R21-A.

B. hard BUMPER parts allowed per R21-A, R21-E, R21-F, and R21-G must not extend more than 1 in. beyond the FRAME PERIMETER with the exception of minor protrusions such as bolt heads, fastener ends, rivets, etc (Figure 4-5 and Figure 4-7).

Figure 4-5: Hard Parts of BUMPER Corners



C. use a stacked pair of approximately 2 ½ in. round, petal, or hex “pool noodles” (solid or hollow) as the BUMPER cushion material (see Figure 4-7). All pool noodles used on a ROBOT must be the same diameter, cross-section, and density (e.g. all round hollow or all hex solid). Cushion material may extend up to 2 ½ in. beyond the end of the plywood (see Figure 4-8). To assist in applying the fabric covering, soft fasteners may be used to attach the pool noodles to the wood backing, so long as the cross section in Figure 4-7 is not significantly altered (e.g. tape compressing the pool noodles)

> All pool noodles used on a ROBOT must be the same in order to maintain the desired interaction between ROBOTs in the cases of BUMPER-to-BUMPER contact. BUMPERS containing pool noodles of vastly different construction may cause a “ramp” effect when interacting with other BUMPERS.

D. be covered with a rugged, smooth cloth. (multiple layers of cloth and seams are permitted if needed to accommodate R27, provided the cross section in Figure 4-7 is not significantly altered).

> Silk or bedding are not considered rugged materials, however 1000D Cordura is. Tape (e.g. gaffer’s tape) matching the BUMPER color is allowed to patch small holes on a temporary basis.

The cloth must completely enclose all exterior surfaces of the wood and pool noodle material when the BUMPER is installed on the ROBOT. The fabric covering the BUMPERS must be a

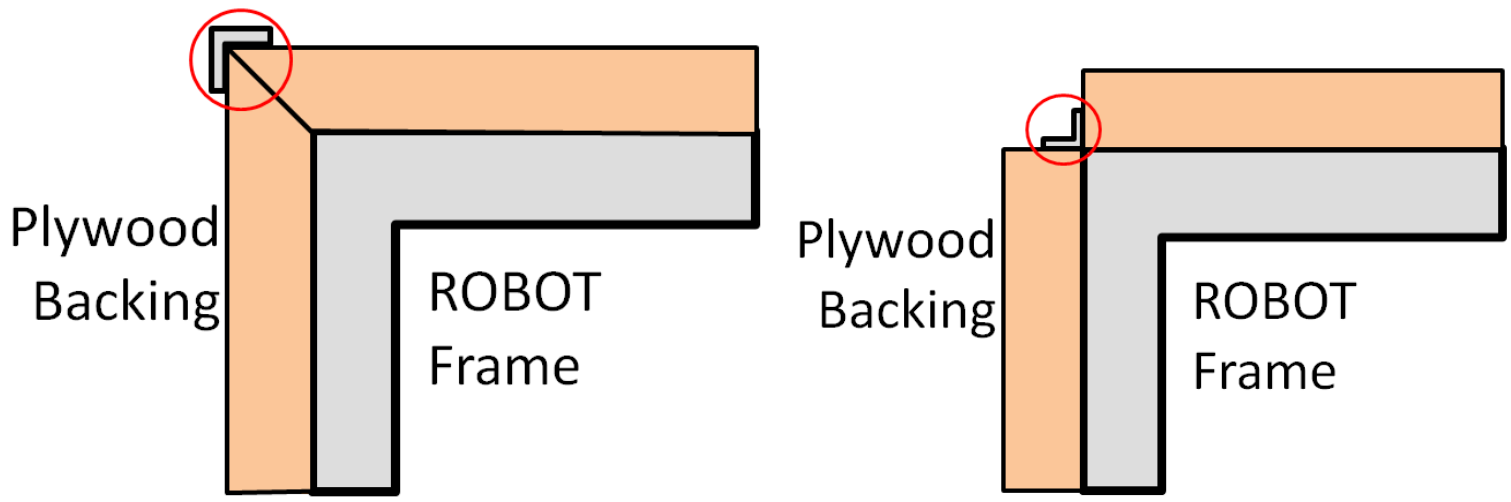
solid Red or Blue in color. The only markings permitted on the BUMPER fabric cover are the Team number (see R28).

> 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).

E. optionally use aluminum angle, as shown in Figure 4-6 or other fasteners (e.g. staples, screws, etc.) to clamp cloth.

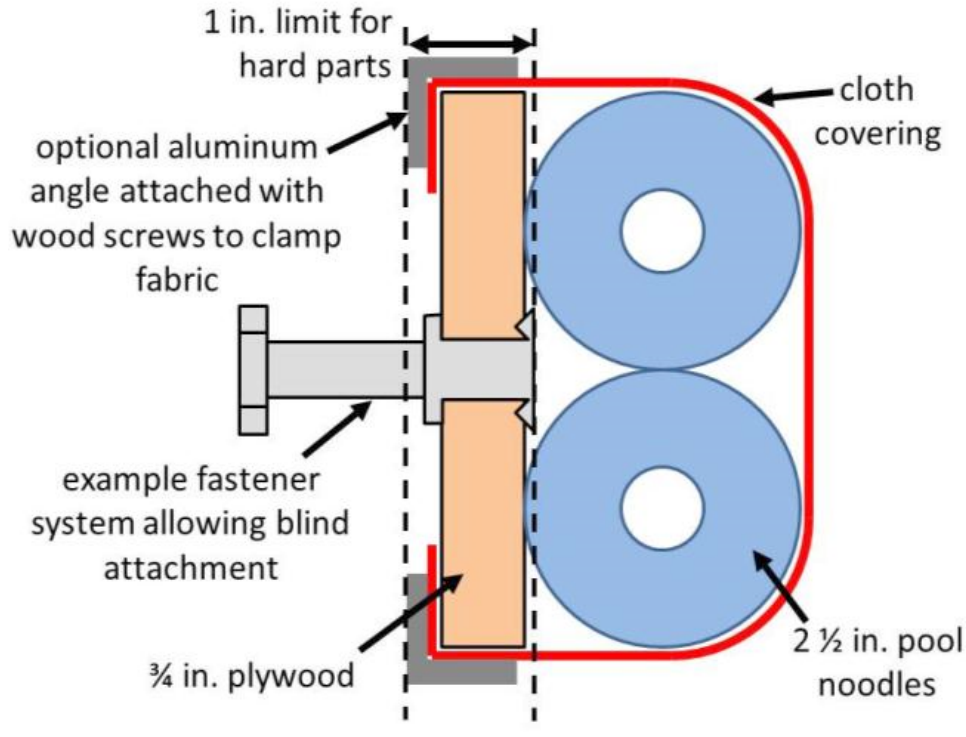
F. Optionally use aluminum brackets (i.e. angle or sheet metal) to attach BUMPER segments to each other (see Figure 4-6).

Figure 4-6: Hard Parts of BUMPER Corners



G. 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 hook-and-loop, tape, or tie-wraps). 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.

Figure 4-7: BUMPER Vertical Cross Section



R22 BUMPERS must be located entirely within the BUMPER ZONE, which is the volume contained between two virtual horizontal planes, 4 in. above the floor and 12 in. above the floor, in reference to the ROBOT standing normally on a flat floor. BUMPERS do not have to be parallel to the floor.

This measurement is intended to be made as if the ROBOT is resting on a flat floor (without changing the ROBOT configuration), not relative to the height of the ROBOT from the FIELD carpet.

Examples include:

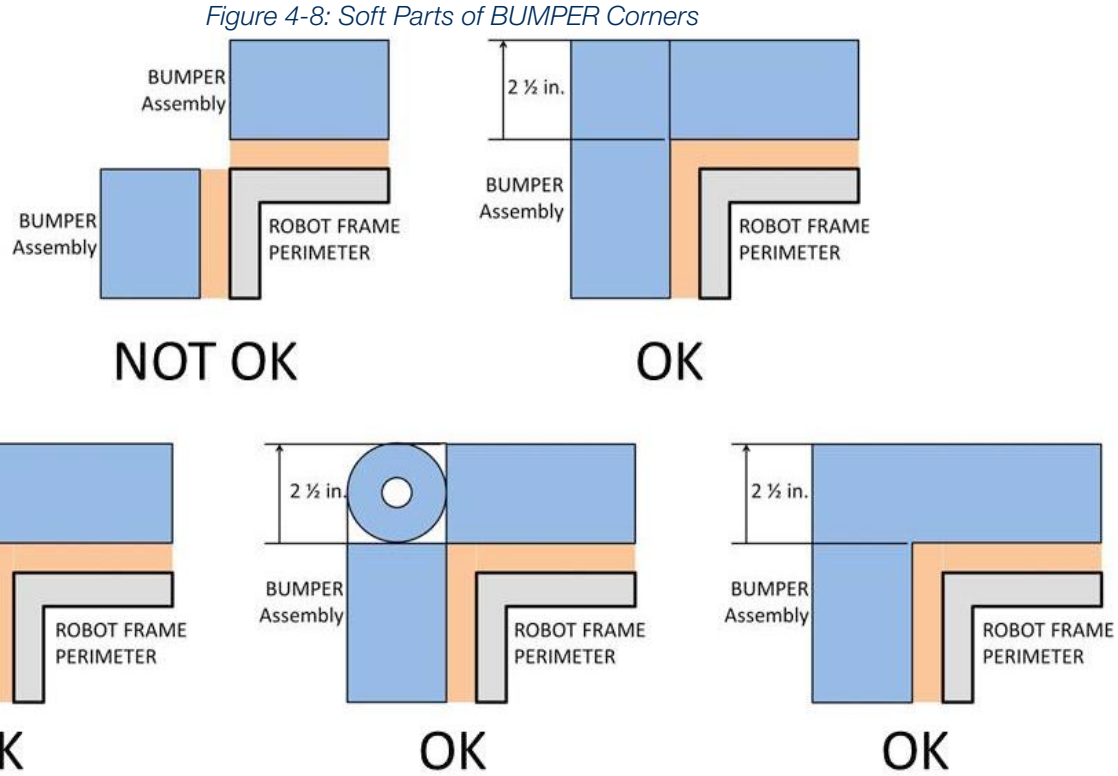
A. A ROBOT that is at an angle while traversing a DEFENSE has its BUMPERS outside the BUMPER ZONE. If this ROBOT were virtually transposed onto a flat floor, and its BUMPERS are in the BUMPER ZONE, it meets the requirements of R22.

B. A ROBOT deploys a MECHANISM which lifts the BUMPERS outside the BUMPER ZONE (when virtually transposed onto a flat floor). This violates R22.

R23 BUMPERS must not be articulated (relative to the FRAME PERIMETER).

R24 Corner joints between BUMPERS must be filled with pool noodle material. Examples of implementation are shown in Figure 4-8.

Figure 4-8: Soft Parts of BUMPER Corners



R25 BUMPERS (the entire BUMPER, not just the cover) must be designed for quick and easy installation and removal to facilitate inspection and weighing.

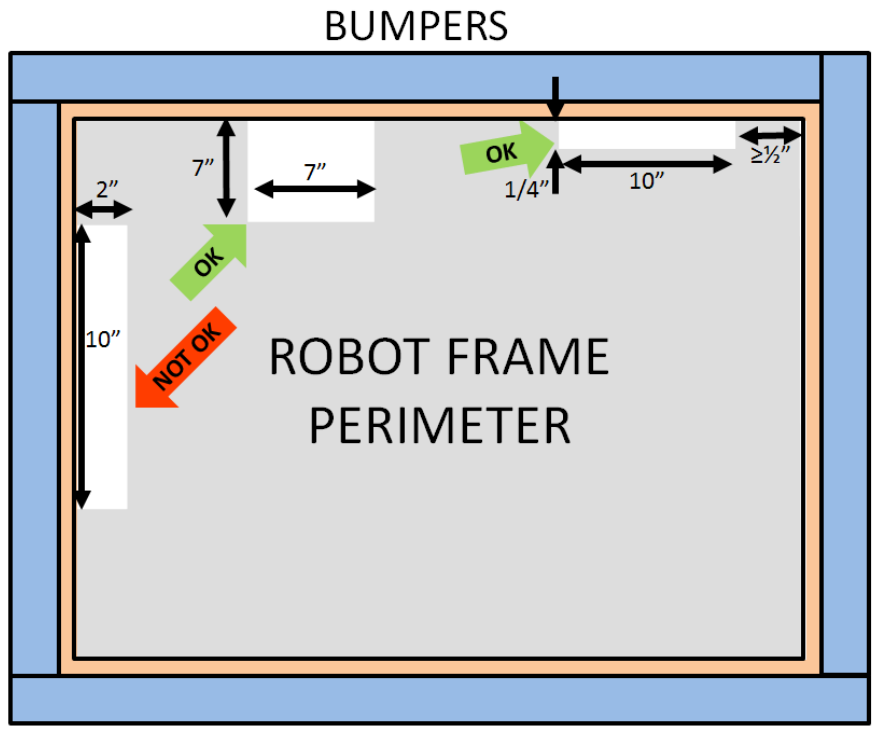
> As a guideline, BUMPERS should be able to be installed or removed by two (2) people in fewer than five (5) minutes.

R26 BUMPERS must be supported by the structure/frame of the ROBOT (see Figure 4-9). To be considered supported, a minimum of ½ in. at each end of the BUMPER must be backed by the FRAME PERMIETER. Additionally, any gap between the backing material and the frame:

A. must not be greater than ¼" deep, or

B. not more than 8 in. wide

Figure 4-9: BUMPER Support Examples



R27 Each ROBOT must be able to display Red or Blue BUMPERS to match their ALLIANCE color, as assigned in the MATCH schedule distributed at the event (reference Section 5 (5.1.1 MATCH Schedules)). BUMPER Markings visible when installed on the ROBOT, other than those explicitly required per R28, are prohibited.

R28 Team numbers must be displayed and positioned on the BUMPERS such that an observer walking around the perimeter of the ROBOT can unambiguously tell the Team's number from any point of view and meet the following additional criteria:

A. consist of numerals at least 4 in. high, at least ½ in. in stroke width, and be either white in color or outlined in white

B. must not wrap around sharp corners (less than 160 degrees) of the FRAME PERIMETER

> There is no prohibition against splitting Team numbers onto different sections of BUMPER. The intent is that the Team's number is clearly visible and unambiguous so that Judges, Referees, Announcers, and other Teams can easily identify competing ROBOTS.

4.8 Motors & Actuators

R29 The only motors and actuators permitted on 2016 *FIRST* Robotics Competition ROBOTS include the following:

Table 4-1: Legal Motors

Motor Name	Part Numbers Available	Max Qty Allowed
CIM	FR801-001 M4-R0062-12 AM802-001A 217-2000 PM25R-44F-1005 PM25R-45F-1004 PM25R-45F-1003 PMR25R-45F-1003 PMR25R-44F-1005	6
BaneBots	M7-RS775-18 / RS775WC-8514 M5-RS550-12 / RS550VC-7527 / RS550	Unlimited
West Coast Products RS775 Pro	217-4347	
AndyMark 9015	am-0912	
VEX BAG	217-3351	
VEX mini-CIM	217-3371	
AndyMark PG	am-2161 (alt. PN am-2765) am-2194 (alt. PN am-2766)	
Automotive Motors (Window, Door, Windshield Wiper, Seat, Throttle)	Various	
Snow Blower Motor	am-2235	
Electrical solenoid actuators, no greater than 1 in. stroke and rated electrical input power no greater than 10 watts (W) continuous duty at 12 volts (VDC)		
Hard drive motors or fans included in any Kickoff Kit, distributed via *FIRST* Choice, or that are a part of a legal motor controller (including manufacturer provided accessories) or COTS computing device		
PWM COTS servos		

For servos, note that the roboRIO is limited to a max current output of 2.2A on the 6V rail (12.4W of electrical input power). Teams should make sure that their total servo power usage remains below this limit at all times.

This is the total number of each motor a Team may use on their ROBOT, not the quantity per part number. For example, each team may use up to six (6) CIM motors on their ROBOT, regardless of the quantity or combination of each individual part number used.

Given the extensive amount of motors 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 at the same time could lead to drops in ROBOT battery voltage that may result in tripping the main breaker or trigger the brownout protection of the roboRIO. For more information about the roboRIO brownout protection and measuring current draw using the PDP, see RoboRIO Brownout and Understanding Current Draw.

R30 The integral mechanical and electrical system of any motor must not be modified. 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 and connectors or splices to additional wiring may be added.

C. The locking pins on the window motors (P/N: 262100-3030 and 262100-3040) may be removed.

D. The connector housings on window, door, windshield wiper or seat motors and Bosch motors (P/N: 6004 RA3 353-01) may be modified to facilitate lead connections.

E. Servos may be modified as specified by the manufacturer (e.g. re-programming or modification for continuous rotation).

The intent of this rule is to 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 previous KOP Window motors and the Bosch motor, the gearbox is considered integral to the motor, thus the motor may not be used without the gearbox.

4.9 Power Distribution

R31 The only legal source of electrical energy for the ROBOT during the competition, the ROBOT battery, must be a non-spillable sealed lead acid (SLA) battery with the following specifications:

A. Nominal voltage: 12V

B. Nominal capacity at 20 hour discharge rate: minimum 17Ah, maximum 18.2Ah

C. Shape: Rectangular

D. Nominal Dimensions:7.1 in x 3in. x 6.6 in (+/- .1 in. for each dimension)

E. Nominal weight: 11lbs to 14.5 lbs

F. Terminals: Nut and bolt style

Examples of batteries which meet this criteria include:

- Enersys (P/N: NP18-12, NP18-12B, NP18-12BFR)
- MK Battery (P/N: ES17-12)
- Battery Mart (P/N: SLA-12V18)
- Sigma (P/N: SP12-18)
- Universal Battery (P/N: UB12180)
- Power Patrol (P/N: SLA1116)
- Werker Battery (P/N: WKA12-18NB)
- Power Sonic (P/N: PS-12180NB)
- Yuasa (P/N: NP18-12B)
- Panasonic (P/N: LC-RD-1217)
- Interstate Batteries (P/N: BSL1116)

Teams should be aware that they may be asked to provide documentation of the specifications of any battery not listed above.

Batteries should be charged in accordance with manufacturer's specification. The battery charger output should not exceed 6 amps and they must have the corresponding Anderson connector installed. (Please see the *FIRST* Safety Manual for additional information.)

Additionally, batteries integral to and part of a COTS computing device or self-contained camera are also permitted (e.g. laptop batteries, GoPro style camera, etc.), provided they're only used to power the COTS computing device and any peripheral COTS USB input devices connected to the COTS computing device and they are securely fastened to the ROBOT.

R32 No batteries other than those allowed per R31 are allowed on the ROBOT, whether or not they are being used to supply power.

This means teams may not use additional batteries as extra weight on their ROBOTS, for example.

R33 The ROBOT battery must be secured such that it will not dislodge should the ROBOT be turned over or placed in any arbitrary orientation.

R34 Each electrical terminal on the ROBOT battery, main breaker, and their connections (lugs, stripped wire ends, etc.) to the wire must be fully insulated at all times.

R35 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. compressed air stored in the pneumatic system that has been charged in compliance with R79 and R80,

B. a change in the altitude of the ROBOT center of gravity,

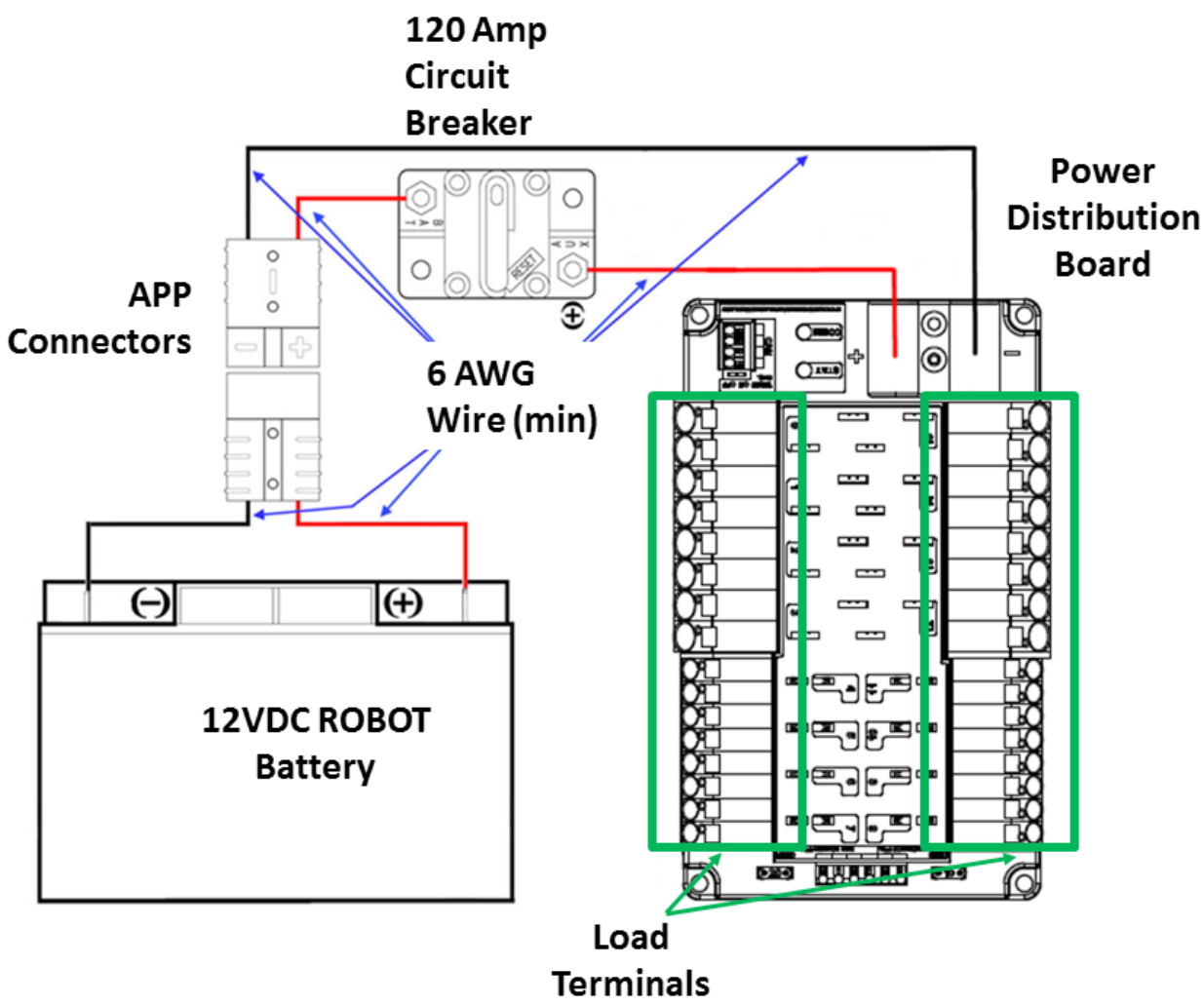
C. storage achieved by deformation of ROBOT parts,

D. closed-loop COTS pneumatic (gas) shocks, and

E. air-filled (pneumatic) wheels.

R36 The one (1) ROBOT battery, a single pair of Anderson Power Products (or APP) 2-pole SB type connectors, the one (1) main 120-amp (120A) circuit breaker (Cooper Bussman P/N: CB185-120), and the one (1) Cross The Road Electronics Power Distribution Panel (PDP, P/N: am-2856, 217-4244) shall be connected with 6 AWG wire or larger as shown in Figure 4-10.

Figure 4-10: Main Power Distribution



"SB type" refers to SB type only (e.g. SB-50, SB-120, etc.), not SBS or any other part type beginning with SB. All batteries supplied by *FIRST* (such as Spare Parts and international batteries) will have a Red or Pink SB50 connector installed which may not be removed.

The pink connectors included in the 2016 KOP mate with the Red SB50 connector.

R37 All circuits, with the exceptions of those listed in R42 and R44, must connect to, and have power sourced solely by, a single protected 12VDC WAGO connector pair (i.e. the Load Terminals, as shown in Figure 4-10) not the M6 cap screws.

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.

R38 is checked by observing a >3kΩ resistance between either the (+) or (-) post within the APP connector that is attached to the PDP and any point on the ROBOT.

The Victor-SP and Talon-SRX motor controller cases are electrically isolated. They may be mounted directly to ROBOT frame components.

The Axis 206 camera has a grounded enclosure. Under R38 (and for their protection), it is required that they be electrically isolated from the ROBOT frame when installed on the ROBOT.

R39 The 120A circuit breaker must be quickly accessible from the exterior of the ROBOT. This is the only 120A circuit breaker allowed on the ROBOT.

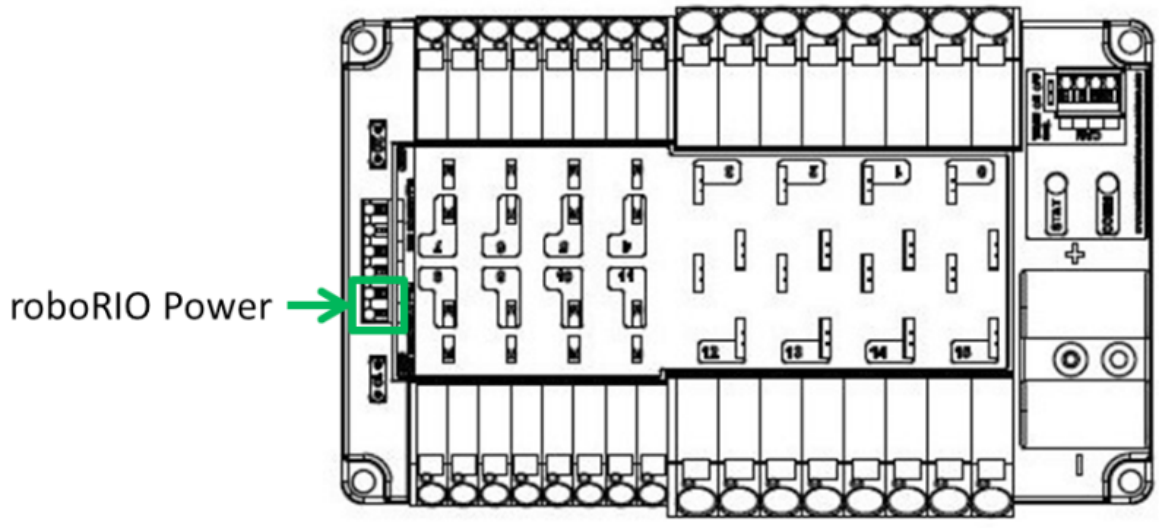
It is strongly recommended that the 120A circuit breaker location be clearly and obviously labeled so it can be easily found by FIELD staff during a MATCH.

R40 The PDP and all circuit breakers must be easily visible for Inspection.

R41 Any active electrical item that is not an actuator (specified in R29) or core Control System item (specified in R66) is considered a CUSTOM CIRCUIT. CUSTOM CIRCUITS shall not produce voltages exceeding 24V.

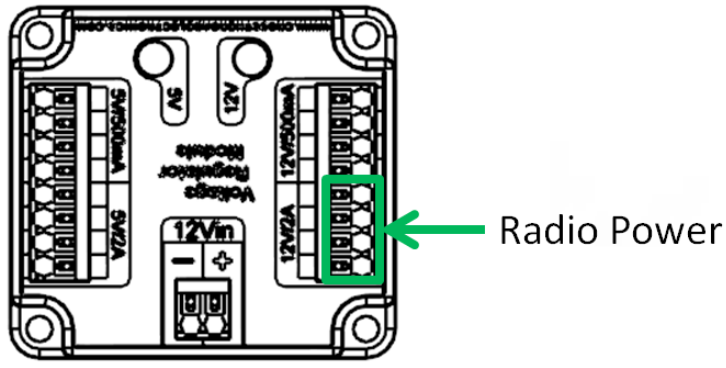
R42 The roboRIO power input must be connected to the dedicated supply terminals on the PDP shown in Figure 4-11. No other electrical load shall be connected to these terminals.

Figure 4-11: roboRIO Power Connections



R43 The Wireless Bridge power must be supplied directly by the 12V 2A output of a Cross the Road Electronics Voltage Regulator Module (VRM) (P/N: am-2857, 217-4245) and must be the only load connected to those terminals.

Figure 4-12: Radio Power Connection

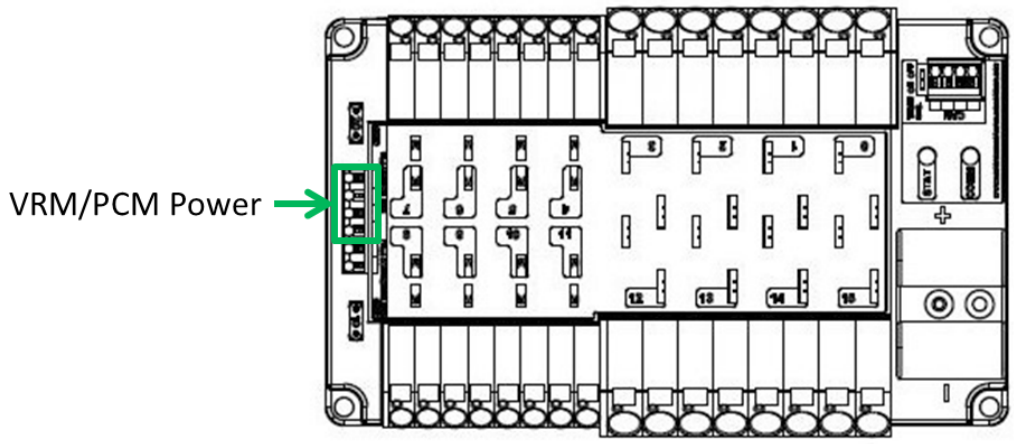


Note that this wiring is different from the wiring for the radio used in 2015. When using a 2015 VRM with the OM5P-AN radio, the radio should be connected as described above, not to the terminals labeled “Radio”.

Note that this prohibits using any POE Injector device to power the radio, but does not prohibit using any PASSIVE CONDUCTORS to inject the VRM power into an Ethernet cable plugged into the radio port labeled “18-24v POE”.

R44 The VRM supplying power to the Wireless Bridge per R43 must be connected to the designated supply terminals at the end of the PDP, and not the main WAGO connectors along the sides of the PDP as shown in Figure 4-13. With the exception of a single Cross the Road Electronics Pneumatics Control Module (PCM, P/N: am-2858), no other electrical load shall be connected to these PDP terminals.

Figure 4-13: VRM/PCM Power Connection



> Please reference Wiring the 2016 FRC Control System for Wireless Bridge wiring information.

R45 Only one wire shall be connected to each WAGO connector on the PDP.

> If multi-point distribution of circuit power is needed (e.g. to provide power to multiple PCMs and/or VRMs from one 20A circuit), then all incoming wires may be appropriately spliced into the main lead (e.g. using an insulated terminal block, crimped splice or soldered wire splice), and the single main lead inserted into the WAGO connector to power the circuit.

R46 The only circuit breakers permitted for use in the PDP are:

A. Snap Action VB3-A Series, terminal style F57

B. Snap Action MX5-A40

R47 The fuses in the PDP shall only be replaced with functionally identical fuses (mini automotive blade fuses with values matching those printed on the PDP)

R48 Each branch circuit must be protected by one and only one circuit breaker on the PDP per Table 4-2. No other electrical load can be connected to the breaker supplying this circuit.

Table 4-2: Branch Circuit Protection

Branch Circuit	Circuit Breaker Value	Quantity Allowed Per Breaker
Motor Controller	Up to 40A	1
CUSTOM CIRCUIT	Up to 40A	1
Fans permitted per Table 4-1 and not already part of COTS computing devices	Up to 20A	No limit
Relay Module	Up to 20A	1
PCM – with compressor	20A	1
Additional VRM (non-radio) Additional PCM (non-compressor)	20A	3 total

R48 does not prohibit the use of smaller value breakers in the PDP or any fuses or breakers within CUSTOM CIRCUITS for additional protection.

R49 All circuits shall be wired with appropriately sized insulated wire:

Table 4-3: Legal Wire Size

Application	Minimum Wire Size
31 – 40A protected circuit	12 AWG (2.052mm)
21 – 30A protected circuit	14 AWG (1.628mm)
6 – 20A protected circuit	18 AWG (1.024mm)
Between the PDP dedicated terminals and the VRM or PCM	
Compressor outputs from the PCM	
Between the PDP and the roboRIO	22 AWG (0.645mm)
VRM 2A circuits	
≤5A protected circuit	
roboRIO PWM port outputs	26 AWG (0.404mm)
SIGNAL LEVEL circuits (i.e. circuits which draw ≤1A continuous and have a source incapable of delivering >1A, including but not limited to roboRIO non-PWM outputs, CAN signals, PCM Solenoid outputs, VRM 500mA outputs and Arduino outputs)	28 AWG (0.321mm)

Wires that are recommended by the device manufacturer or originally attached to legal devices are considered part of the device and by default legal. Such wires are exempt from R49.

R50 Branch circuits 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/rated elements.

R51 All non-SIGNAL LEVEL wiring with a constant polarity (i.e., except for outputs of relay modules, motor controllers, or sensors) shall be color-coded along their entire length from the manufacturer as follows:

A. Red, yellow, white, brown, or black-with-stripe on the positive (e.g. +24VDC, +12VDC, +5VDC, etc.) connections

B. Black or blue for the common or negative side (-) of the connections.

Wires that are originally attached to legal devices are considered part of the device and by default legal. Such wires are exempt from R51.

R52 With the exception of servos, fans, or hard drive motors permitted in R29, each actuator must be controlled by a power regulating device. The only power regulating devices for actuators permitted on the ROBOT include:

A. Motor Controllers

i. Jaguar Motor Controller (P/N: MDL-BDC, MDL-BDC24, and 217-3367)

ii. SD540 Motor Controller (P/N: SD540x1, SD540x2, SD540x4, SD540Bx1, SD540Bx2, SD540Bx4)

iii. Spark Motor Controller (P/N: REV-11-1200)

iv. Talon Motor Controller (P/N: CTRE_Talon, CTRE_Talon_SR, and am-2195)

v. Talon SRX Motor Controller (P/N: 217-8080), equipped with firmware version 0.28 or newer if using via PWM. See R59 if using via CAN.

vi. Victor 884 Motor Controller (P/N: VICTOR-884-12/12)

vii. Victor 888 Motor Controller (P/N: 217-2769)

viii. Victor SP Motor Controller (P/N: 217-9090)

B. Relay Modules

i. Spike H-Bridge Relay (P/N: 217-0220 and SPIKE-RELAY-H)

C. Pneumatics controllers

i. Pneumatics Control Module (P/N: am-2858, 217-4243)

> Please see the Talon User Guide for more information about the Talon SRX firmware update, determining the firmware on your Talon SRX, and instructions on how install.

R53 Each power regulating device may control electrical loads per Table 4-4. Unless otherwise noted, each power regulating device shall control one and only one electrical load.

Table 4-4: Legal Power Regulating Device Use

Electrical Load	Motor Controller	Relay Module	Pneumatics Controller
CIM **AndyMark 9015** **WCP RS775 Pro** **VEX BAG/MiniCIM** **BaneBots motors**	**Yes**	**No**	**No**
Automotive Window/Door/Windshield Wiper/Seat/Throttle Motors **AndyMark PG** **Snow-Blower Motor**	**Yes** **Up to 2 per controller**	**Yes**	**No**
Compressor	**No**	**Yes**	**Yes**
Pneumatic Solenoid Valves	**No**	**Yes***	**Yes (1 per channel)**
Electric Solenoids	**No**	**Yes***	**Yes (1 per channel)**
CUSTOM CIRCUITS	**Yes**	**Yes***	**Yes (1 per channel)**

*Multiple low-load, pneumatic solenoid valves, electric solenoids or CUSTOM CIRCUITS may be connected to a single relay module. This would allow one (1) relay module to drive multiple pneumatic actions or multiple CUSTOM CIRCUITS. No other electrical load can be connected to a relay module used in this manner.

R54 Servos must be connected to the PWM ports on the roboRIO, either directly or through the PWM ports on a WCP Spartan Sensor Board. They must not be connected to the MXP, motor controllers, or relay modules.

R55 CUSTOM CIRCUITS shall not directly alter the power pathways between the ROBOT battery, PDP, motor controllers, relays, motors and actuators (per R28), pneumatic solenoid valves, or other elements of the ROBOT control system (items explicitly mentioned in R66). 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.

A noise filter may be wired across motor leads or PWM leads. Such filters will not be considered CUSTOM CIRCUITS and will not be considered a violation of R55 or R73.

Acceptable signal filters must be fully insulated and must be one of the following:

A. A one microfarad (1 µF) 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).

B. A resistor may be used as a shunt load for the PWM control signal feeding a servo.

4.10 Control, Command & Signals System

R56 ROBOTS must be controlled via one (1) programmable National Instruments roboRIO (P/N: am3000), with image version FRC_2016_v19 and firmware v3.0.0.

> There are no rules that prohibit co-processors, provided commands originate from the roboRIO to configure, enable, and specify all operating points for all power regulating devices. This includes motor controllers legally wired to the CAN-bus.

R57 One (1) OpenMesh Wireless Bridge (P/N: OM5P-AN), that has been configured with the appropriate encryption key for your team number at each event, is the only permitted device for communicating to and from the ROBOT during the MATCH.

> The D-Link DAP1522 radio distributed from 2011-2015 is not legal for 2016 *FIRST* Robotics Competition Competition.

R58 The Wireless Bridge must be connected to the roboRIO Ethernet port (either directly or via a CAT5 Ethernet pigtail).

R59 Ethernet-connected COTS devices or CUSTOM CIRCUITS may connect to any remaining Ethernet port on the Wireless Bridge but must not transmit or receive UDP packets using ports 1100-1200 with the exception of ports 1130 and 1140.

R60 Communication between the ROBOT and the OPERATOR CONSOLE is restricted as follows:

A. Network Ports:

i. TCP 1180: Camera data from the roboRIO to the Driver Station (DS) when the camera is connected the roboRIO via USB, bi-directional.

ii. TCP 1735: SmartDashboard, bi-directional

iii. UDP 1130: Dashboard-to-ROBOT control data, uni-directional

iv. UDP 1140: ROBOT-to-Dashboard status data, uni-directional

v. HTTP 80: Camera connected via switch on the ROBOT, bi-directional

vi. HTTP 443: Camera connected via switch on the ROBOT, bi-directional

vii. UDP/TCP 554: Real-Time Streaming Protocol for h.264 camera streaming, bi-directional

viii. UDP/TCP 5800-5810: Team Use, bi-directional

Teams may use these ports as they wish if they do not employ them as outlined above (i.e. TCP 1180 can be used to pass data back and forth between the ROBOT and the DS if the Team chooses not to use the camera on USB).

B. Bandwidth: no more than 7 Mbits/second.

Note that, for 2016, the 7Mbit limit will be strictly enforced by the Wireless Bridge.

The FMS Whitepaper has more details on how to check and optimize bandwidth usage.

While *FIRST* makes every effort to provide a wireless environment that allows teams access to a full 7Mbits/second data rate (with about 100Kbit used for ROBOT control and status), at some events wireless conditions may not accommodate this.

R61 The roboRIO, Driver Station software, and Wireless Bridge must be configured to correspond to the correct Team number, per the procedures defined in Getting Started with the 2016 Control System.

R62 All signals must originate from the OPERATOR CONSOLE and be transmitted to the ROBOT via the ARENA Ethernet network.

R63 No form of wireless communication shall be used to communicate to, from, or within the ROBOT, except those required per R57 and R62 (e.g. radio modems from previous *FIRST* competitions and active Bluetooth devices are not permitted on the ROBOT during competition).

R64 The Wireless Bridge must be mounted on the ROBOT such that the diagnostic lights are visible to ARENA personnel.

Teams are encouraged to mount the wireless bridge away from noise generating devices such as motors, PCM(s), and VRM(s).

R65 ROBOTS must use at least one (1), but no more than two (2) diagnostic ROBOT Signal Lights (RSL) (P/N: 855PB-B12ME522).

Any RSL must be:

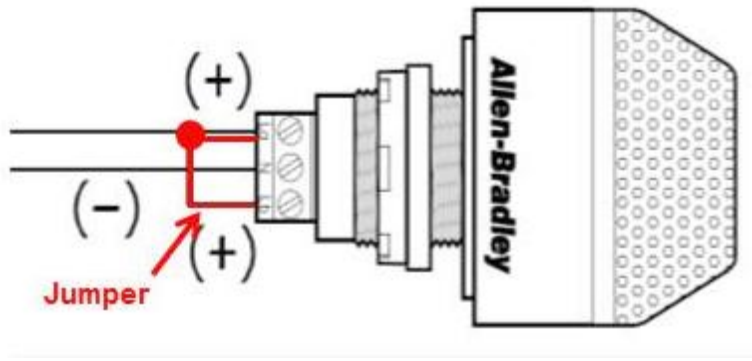
A. mounted on the ROBOT such that it is easily visible while standing three (3) ft in front of the ROBOT,

B. connected to the “RSL” supply terminals on the roboRIO,

C. wired for solid light operation, by placing a jumper between the “La” and “Lb” terminals on the light per Figure 4-14.

Please see Wiring the 2016 FRC Control System for connection details.

Figure 4-14: Jumper on RSL



R66 The Driver Station software, roboRIO, Power Distribution Panel, Pneumatics Control Modules, Voltage Regulator Modules, RSL, 120A breaker, motor controllers, relay modules, Wireless Bridge, and batteries shall not be tampered with, modified, or adjusted in any way (tampering includes drilling, cutting, machining, rewiring, disassembling, etc.), with the following exceptions:

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.

A. User programmable code in the roboRIO may be customized.

B. Motor controllers may be calibrated as described in owner's manuals.

C. Fans may be attached to motor controllers and may be powered from the power input terminals.

D. If powering the compressor, the fuse on a Spike H-Bridge Relay may be replaced with a 20A Snap-Action circuit breaker.

E. Wires, cables, and signal lines may be connected via the standard connection points provided on the devices.

F. Fasteners (including adhesives) may be used to attach the device to the OPERATOR CONSOLE or ROBOT or to secure cables to the device.

G. Thermal interface material may be used to improve heat conduction.

H. Labeling may be applied to indicate device purpose, connectivity, functional performance, etc.

I. Jumpers may be changed from their default location.

J. Limit switch jumpers may be removed from a Jaguar motor controller and a custom limit switch circuit may be substituted.

K. Device firmware may be updated with manufacturer supplied firmware.

L. Integral wires on the Victor SP or Talon SRX may be cut, stripped, and/or connectorized.

M. Devices may be repaired, provided the performance and specifications of the device after the repair are identical to those before the repair.

N. The cover may be removed from the Talon SRX data port.

Please note that while repairs are permitted per the *FIRST* Robotics Competition *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.

R67 Neither 12VDC power nor relay module or motor controller outputs shall be directly connected to the roboRIO (with the exception of the designated 12VDC input).

R68 Every relay module, servo, and PWM motor controller shall be connected to a corresponding port (relays to Relay ports, servos and PWM controllers to PWM ports) on the roboRIO (either directly or through a WCP Spartan Sensor Board) or via a legal MXP connection (per R69). They shall not be controlled by signals from any other source.

R69 If a motor is controlled via the MXP, its power regulating device must be connected by one of the following methods:

A. directly to any PWM pins,

B. via a network of PASSIVE CONDUCTORS used to extend the PWM pins, or

C. via one approved ACTIVE DEVICE:

i. Kauai Labs navX MXP

ii. RCAL MXP Daughterboard

iii. REV Robotics RIOduino

iv. REV Robotics Digit Board

v. WCP Spartan Sensor Board

> A PASSIVE CONDUCTOR is any device or circuit whose capability is limited to the conduction and/or static regulation of the electrical energy applied to it (e.g. wire, splices, connectors, printed wiring board, etc.).
>
> An ACTIVE DEVICE is any device capable of dynamically controlling and/or converting a source of electrical energy by the application of external electrical stimulus.
>
> The "network of PASSIVE CONDUCTORS" only applies to the pins being used for PWM output to motors or servos. This means that connecting an ACTIVE DEVICE, such as a sensor to one MXP pin does not prevent other MXP pins from being used in accordance with R69-B.

R70 Each Jaguar or Talon SRX must be controlled with signal inputs sourced from the roboRIO and passed via either a PWM (wired per R68) or CAN-bus (either directly or daisy-chained via another CAN-bus device) signal, but both shall not be wired simultaneously on the same device. If the CAN-bus configuration is used, the firmware on the device must be updated to at least the following versions:

A. Grey Jaguars – v109

B. Black Jaguars – v109

C. Talon SRX – v1.01. (no greater than 10.0)

> As long as the CAN bus is wired legally so that the heartbeat from the roboRIO is maintained, all closed loop control features of the Jaguar or Talon SRX motor controller may be used. (That is, commands originating from the roboRIO to configure, enable, and specify an operating point for all Jaguar or Talon SRX closed loop modes fit the intent of R56.)

R71 Each PCM must be controlled with signal inputs sourced from the roboRIO and passed via a CAN-bus connection from the roboRIO (either directly or daisy-chained via another CAN-bus device). The firmware on each PCM must be updated to at least version 1.62.

R72 The PDP CAN interface must be connected to the CAN-bus on the roboRIO (either directly or daisy-chained via another CAN-bus device). The firmware on the PDP must be updated to at least version 1.37.

> For documentation on how to wire the CAN-bus connections of the PDP see Wiring the 2016 FRC Control System.

R73 The CAN-bus must be connected to the roboRIO CAN port.

A. Additional switches, sensor modules, CUSTOM CIRCUITS, third-party modules, etc. may also be placed on the CAN-bus.

B. No device that interferes with, alters, or blocks communications among the roboRIO and the Jaguars, PDP, PCMs, and/or Talon-SRXs on the bus will be permitted.

Only one wire should be inserted into each Weidmuller CAN connector terminal. For documentation on how to wire the CAN-bus connections of the roboRIO, PCM, PDP and CAN motor controllers, see Wiring the 2016 FRC Control System.

4.11 Pneumatic System

R74 To satisfy multiple constraints associated with safety, consistency, Inspection, and constructive innovation, no pneumatic parts other than those explicitly permitted in Section 4.11 Pneumatic System shall be used on the ROBOT.

R75 All pneumatic items must be COTS pneumatic devices rated by their manufacturers for working pressure of at least 120psi (with the exception of R77-D).

R76 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, paint, file, machine, or abrasively remove any part of a pneumatic COMPONENT – this would cause the part to become a prohibited item. Consider pneumatic COMPONENTS sacred.

R77 The only pneumatic system items permitted on 2016 *FIRST* Robotics Competition ROBOTS include the items listed below.

A. Items available in the KOP (except as noted in R77-K),

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 1/8 in. NPT, BSPP, or BSPT port diameter,

D. Solenoid valves that are rated for a maximum working pressure that is less than 120 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 working 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,

F. Pressure transducers, pressure gauges, passive flow control valves (specifically “needle valve”), manifolds, and connecting fittings,

G. Check valves, provided that the requirements of R89 are still met.

H. Shutoff valves which relieve downstream pressure to atmosphere when closed (may also be known as 3-way or 3-way exhausting valves).

I. Pressure regulators with a maximum outlet pressure of no more than 60 psi,

J. Pneumatic cylinders, pneumatic linear, and rotary actuators,

K. Pneumatic storage tanks (with the exception of White Clippard tanks P/N: AVT-PP-41), and

L. Compressors compliant with R79.

> The following devices are not considered pneumatic devices and are not subject to pneumatic rules (though they must satisfy all other rules):
>
> A. a device that creates a vacuum
>
> B. closed-loop COTS pneumatic (gas) shocks
>
> C. air-filled (pneumatic) wheels

R78 If pneumatic COMPONENTS are used, the following items are required as part of the pneumatic circuit and must be used in accordance with this section, as illustrated in Figure 4-15.

A. Compressor

B. Pressure relief valve connected via legal rigid fittings (e.g. brass, nylon, etc.)

C. Nason pressure switch, P/N SM-2B-115R/443

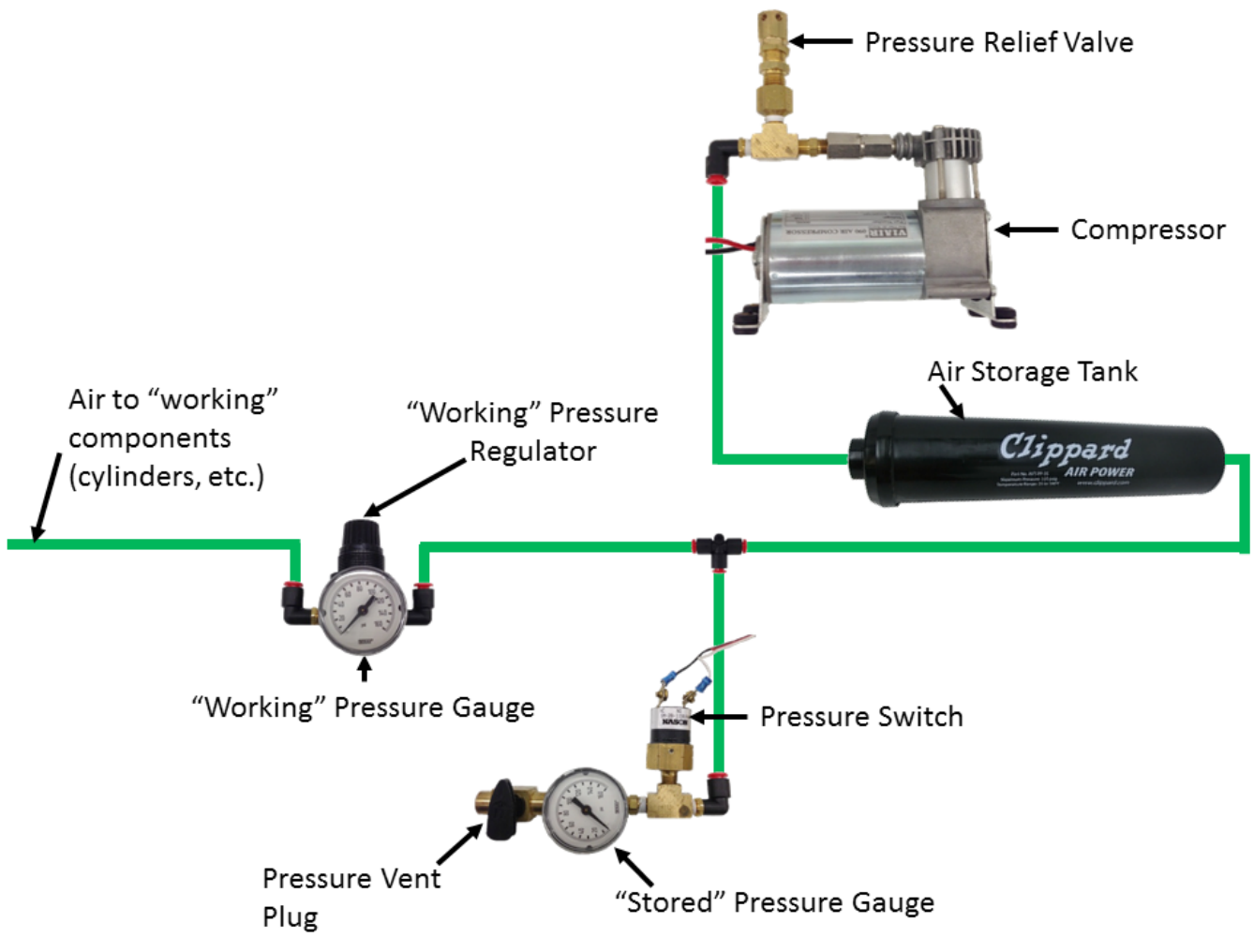
D. At least one Pressure vent plug

E. “Stored” pressure gauge (upstream from Primary Regulator)

F. “Working” pressure gauge (downstream from Primary Regulator)

G. “Working” pressure regulator

Figure 4-15: Pneumatic System Setup



R79 Compressed air on the ROBOT must be provided by one and only one compressor. Compressor specifications must not exceed nominal 1.10 cfm flow rate @ 12VDC.

R80 The compressor (permitted per R79) may be located off-board, however the compressor must still be controlled and powered by the ROBOT.

> The compressor may be mounted on the ROBOT, or it may be left off the ROBOT and used to pre-charge compressed air in storage tanks on the ROBOT provided the additional restrictions of R85 are met.
>
> 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.

R81 "Stored" air pressure on the ROBOT must be no greater than 120 psi. No stored air pressure intended for the ROBOT may be located off-board the ROBOT.

R82 "Working" air pressure on the ROBOT must be no greater than 60 psi and must be provided through a single primary adjustable, relieving, pressure regulator.

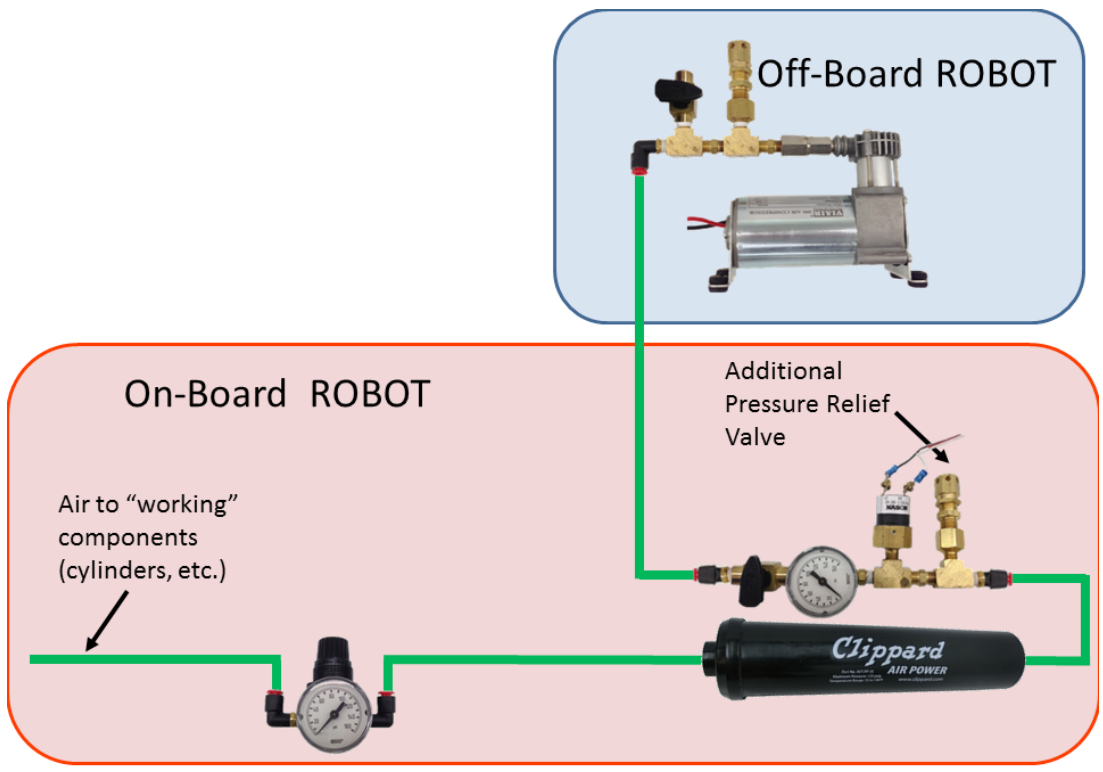
> Norgren regulator P/N: R07-100-RNEA or Monnier P/N: 101-3002-1 recommended.

R83 Only the compressor, relief valve (P/N: 16-004-011), pressure switch, pressure vent plug, pressure gauge, storage tanks, tubing, pressure transducers, and connecting fittings may be in the high-pressure pneumatic circuit upstream from the regulator.

R84 Pressure gauges must be placed in easily visible locations upstream and downstream of the regulator to display the "stored" and "working" pressures.

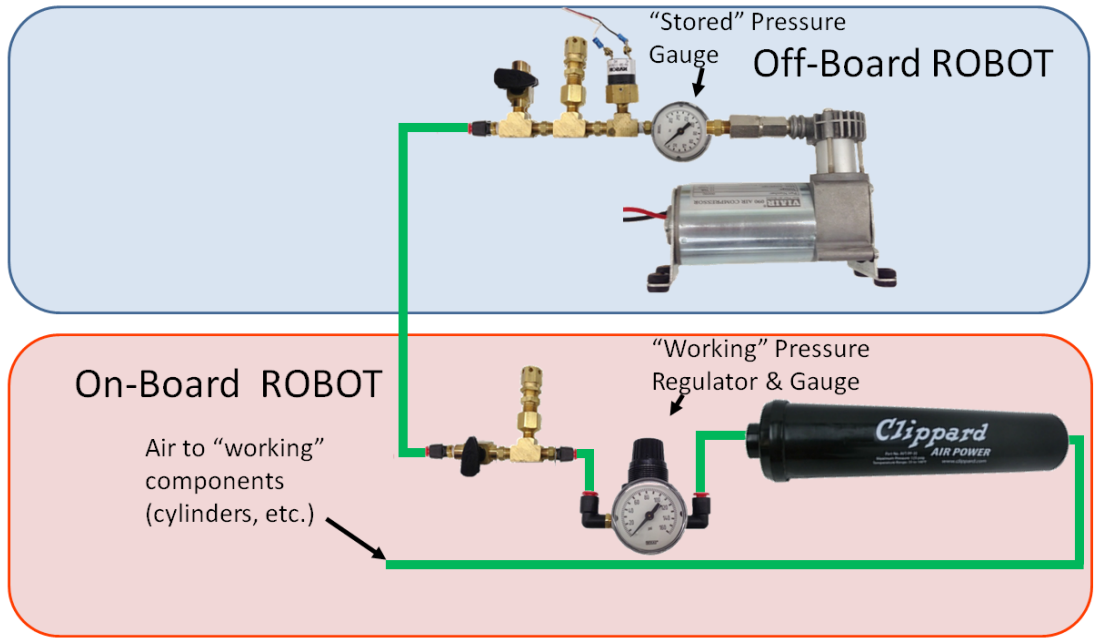
R85 If the compressor is not included on the ROBOT (under the provisions of R80) the "Stored" Pressure Gauge and pressure switch may be located on-board (Figure 4-16) or off-board (Figure 4-17) (but must be together), provided all other pneumatic rules are satisfied.

Figure 4-16: Off-Board Compressor with On-Board Switch and Gauge



R86 If the stored pressure gauge 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. The “working” pressure gauge must be installed on-board the ROBOT at all times (Figure 4-17).

Figure 4-17: Off-Board Compressor, Switch and Gauge with Additional On-Board Gauge



R87 The relief valve must be attached directly to the compressor or attached by legal hard fittings (e.g. brass, nylon, etc.) connected to the compressor output port. If using an off-board compressor, an additional relief valve must be included on the ROBOT.

> 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.

R88 The pressure switch requirements are:

A. It must be Nason P/N: SM-2B-115R/443

B. It 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.

C. The two wires from the pressure switch must be connected directly to the pressure switch input of the PCM controlling the compressor or, if controlled using the roboRIO and a Spike relay, to the roboRIO.

D. If connected to the roboRIO, the roboRIO 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.

R89 Any pressure vent plug must be:

A. connected to the pneumatic circuit such that, when manually operated, it will vent to the atmosphere to relieve all stored pressure in a reasonable amount of time, and

B. placed on the ROBOT so that it is visible and easily accessible.

If the compressor is not used on the ROBOT, then an additional pressure vent plug must be connected to the high-pressure portion of the pneumatic circuit off-board the ROBOT with the compressor (see R79).

R90 The outputs from multiple valves must not be plumbed together.

4.12 OPERATOR CONSOLE

R91 The Driver Station software provided on the National Instruments website is the only application 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 16.0.1 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.

R92 The OPERATOR CONSOLE, the set of COMPONENTS and MECHANISMS used by the DRIVERS and/or HUMAN PLAYER to relay commands to the ROBOT, must include a graphic display to present the Driver Station disgnostic information. It must be positioned within the OPERATOR CONSOLE so that the screen display can be clearly seen during Inspection and in a MATCH.

R93 Devices hosting the Driver Station software must only interface with the Field Management System (FMS) via the Ethernet cable provided at the PLAYER STATION (e.g. not through a switch). Teams may connect the FIELD Ethernet cable to their Driver Station device directly via an Ethernet pigtail, or with a single-port Ethernet converter (e.g. docking station, USB-Ethernet converter, Thunderbolt-Ethernet converter, etc.).The Ethernet port on the OPERATOR CONSOLE must be easily and quickly accessible.

> Teams are strongly encouraged to use pigtails on the Ethernet port used to connect to the FMS. Such pigtails will reduce wear and tear on the device's port and, with proper strain relief employed, will protect the port from accidental damage.

R94 The OPERATOR CONSOLE must not exceed 60 in. long by 14 in. deep (excluding any items that are held or worn by the DRIVERS during the MATCH).

> There is a 54 in. long by 2 in. wide strip of hook-and-loop tape ("loop" side) along the center of the PLAYER STATION support shelf that may be used to secure the OPERATOR CONSOLE to the shelf. See Section 2.3.1.1: PLAYER STATION for details.

R95 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 *FIRST* Robotics Competition, a motion sensing input device (e.g. Microsoft Kinect) is not considered wireless communication and is allowed.