4 The Robot

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This section of the *2013 FRC® Game Manual* presents legislation relevant to the construction of a 2013 *FIRST*® 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 *2013 FRC Game Manual*.

4.1 ROBOT Rules

The rules listed below explicitly address what and how parts and materials may be used on a 2013 FRC 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), 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.

Teams may be asked to provide documentation proving legality of non-2013 KOP items during Inspection where a Rule specifies limits for a legal part (e.g. pneumatic components, 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@usfirst.org for an official ruling. To seek approval for alternate devices for inclusion in future FRC seasons, please contact frcparts@usfirst.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 logos (or the name of the supporting youth organization, if appropriate).

4.1.1 General ROBOT Design

4.1.1.1 R01

Each registered FRC team may enter only one (1) ROBOT into the 2013 FRC. The ROBOT must be built by the FRC Team to perform specific tasks when competing in ULTIMATE ASCENT. 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 ULTIMATE ASCENT (e.g. a box of unassembled parts placed on the FIELD, or a ROBOT designed to play a different game would not satisfy this definition).

4.1.1.2 R02

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 R25. 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.

4.1.1.3 R03

The ROBOT must satisfy the following size constraints:

A. total length of the FRAME PERIMETER sides may not exceed 112 in. (see Figure 4-1 for examples),
B. PLAYING CONFIGURATION horizontal dimensions may never exceed a 54 in. diameter cylinder (see G23 and G23-1), and
C. height may never exceed 84 in. tall.

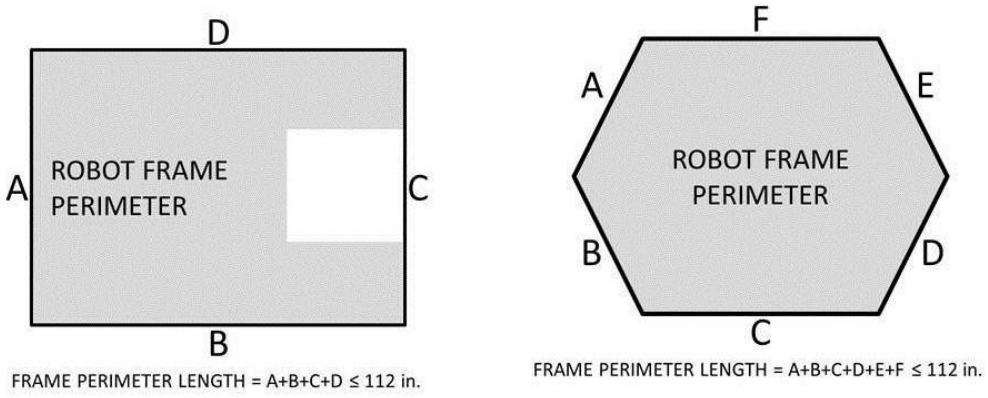

Figure 4-1: FRAME PERIMETER Length Calculations

Consider G22 restricting ROBOT height on various parts of the FIELD during the MATCH when designing and building the ROBOT.

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.

4.1.1.4 R04

In the STARTING CONFIGURATION, no part of the ROBOT may 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 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.

4.1.1.5 R05

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 limitations, the items listed below are not included in the weight assessment:

A. the 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) and
B. BUMPERS (including BUMPER covers, if appropriate).

4.1.1.6 R06

Traction devices may not have surface features such as metal, sandpaper, hard plastic studs, cleats, or similar attachments. 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.

4.1.1.7 R07

ROBOTS must allow removal of DISCS 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 DISCS and ROBOTS can quickly, simply, and safely be removed. Teams may be asked to demonstrate this during Inspection.

4.1.2 Safety & Damage Prevention

4.1.2.1 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 R08 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 VISION TARGET)

D. Exposed lasers other than Class I.

E. Flammable gasses

F. Any device intended to produce flames or pyrotechnics

G. Hydraulic fluids or hydraulic components

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

4.1.2.2 R09

Protrusions from the ROBOT and exposed surfaces on the ROBOT shall not pose hazards to the ARENA elements 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.

4.1.2.3 R10

Teams must supply at least two (2) attachment points for the belaying device (see Section 2.2.5) to mount to their ROBOTS. Attachment points must be:

A. easily accessible after the ROBOT has CLIMBED the PYRAMID,
B. on opposite sides of the ROBOT,
C. located near the ROBOT'S balance point, and
D. made from exposed structural members that will allow a rope to be wrapped around it or two eyelets (McMaster PN3014T45 or similar) mounted to the frame. Opening of the eyelets must be at least ¾ in. in diameter.

4.1.3 Budget Constraints

4.1.3.1 R11

The total cost of all items on the ROBOT shall not exceed $4000 USD. All costs are to be determined as explained in *Section 4.1.3: Budget Constraints*. Exceptions are as follows:

A. individual fasteners, adhesives, and lubricants, that are less than $1 each and
B. Kit of Parts (KOP) items

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

Per T7, teams must be prepared to display a Bill of Materials (BOM) to Inspectors during Inspection. The BOM may be displayed in either printed or electronic form.

4.1.3.2 R12

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

4.1.3.3 R13

Individual COMPONENTS or MECHANISMS, not excluded in R11, that are retrieved from previous ROBOTS and used on 2013 ROBOTS must have their undepreciated cost included in the 2013 ROBOT BOM and applied to the overall cost assessment.

4.1.3.4 R14

The BOM 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 other FRC 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: A Team purchases steel bar stock for $10 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.

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

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.

4.1.3.5 R15

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 R12.

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 R12.

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 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 BOM 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

4.1.4.1 R16

ROBOT elements, including software, that are designed or created before Kickoff are not permitted, unless they are publicly available prior to Kickoff.

Please note that this means that FABRICATED ITEMS from ROBOTS entered in previous *FIRST* competitions may not be used on ROBOTS in the 2013 FRC. Before the formal start of the FRC 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: 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 Kickoff.

Example 3: 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 2013 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 4: The same Team decides to use LabVIEW as their software environment for 2013. 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 5: 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.

4.1.4.2 R17

The ROBOT (including items intended for use during the competition in alternative configurations of the ROBOT, excluding items permitted per R21) must be bagged or crated (as appropriate for your event), and out of Team hands by Stop Build Day, February 19, 2013 (refer to the *FRC Administrative Manual, Section 5* for more details).

4.1.4.3 R18

Teams must stay “hands-off” their ROBOT during the following time periods:

A. from Stop Build Day until their first event,
B. during the period(s) between their events, and
C. outside of Pit hours while attending events.

Additional time is allowed as follows:

D. 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 R21, 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 5.6, ROBOT Access Period - for Teams Attending 2-Day Events*.

4.1.5 Material Utilization

4.1.5.1 R19

COTS items from ROBOTS entered in previous FRC competitions that are no longer commercially available may be used only if they are functionally equivalent to the original condition as delivered from the VENDOR.

For example, 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.

4.1.5.2 R20

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

4.1.5.3 R21

Teams may bring a maximum of 30 lbs of FABRICATED ITEMS to each event to be used to repair and/or upgrade their ROBOT. The OPERATOR CONSOLE, BUMPERS, and any ROBOT battery assemblies (as described in R5-A) are exempt from this limit.

4.1.6 BUMPER Rules

4.1.6.1 R22

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 4-2).

The dimension defined in R22 is measured along the FRAME PERIMETER. The portion of the BUMPER that extends into the corner is not included in the 8 in. requirement.

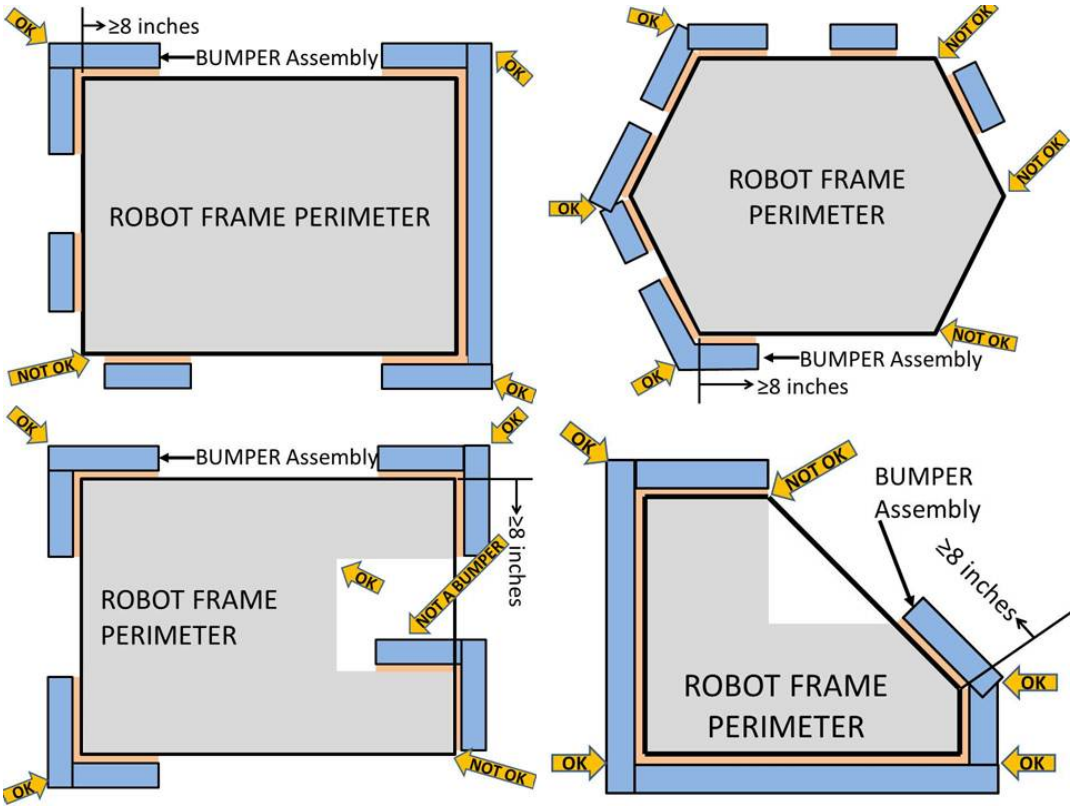

Figure 4-2: BUMPER Corner Examples

4.1.6.2 R23

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.

4.1.6.3 R24

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

A. be backed by ¾ in. (nominal) thick by 5 in. (± ½ in) tall plywood or solid, robust wood.

Particle board or chipboard is not likely to survive the rigors of FRC gameplay and thus not compliant with R24-A.

B. 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?3and Figure 4?4).

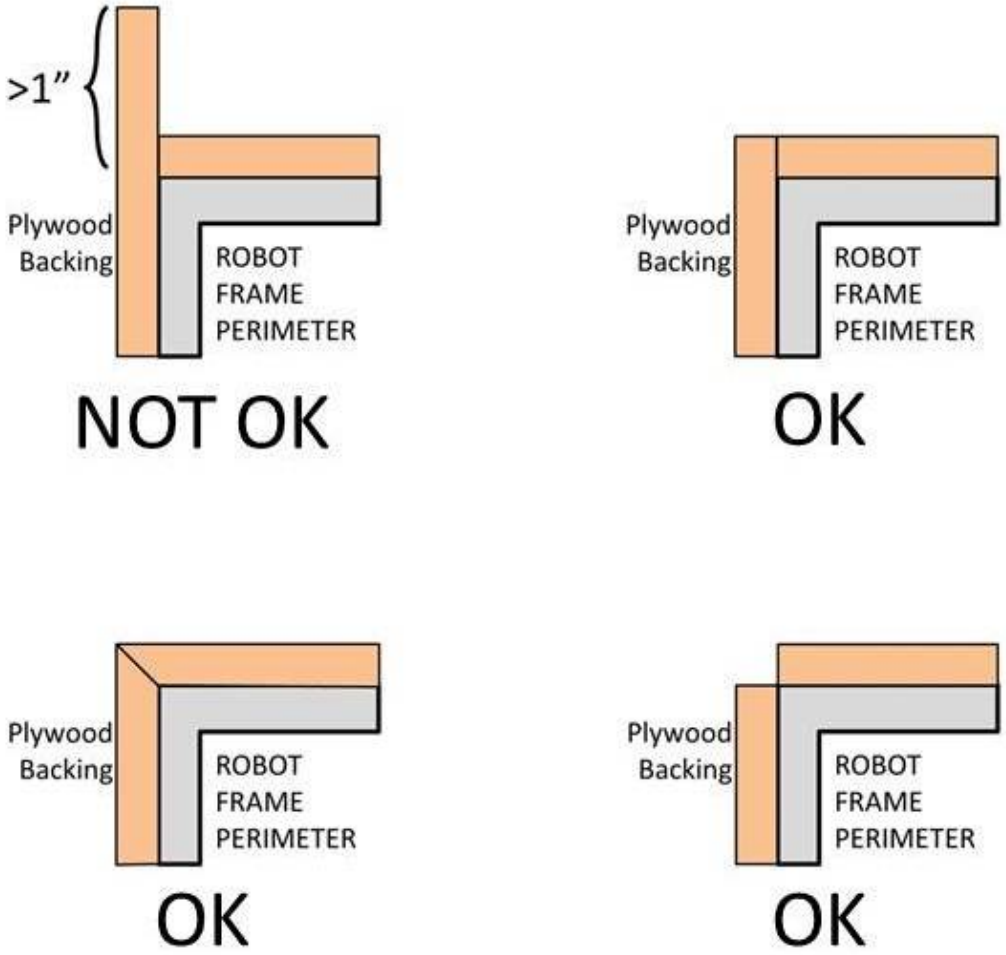

Figure 4-3: Hard Parts of BUMPER Corners

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 4-4). Cushion material may extend up to 2 ½ in. beyond the end of the plywood (see Figure 4-2).
D. be covered with a rugged, smooth cloth.

Silk or bedding are not considered rugged materials. 1000D Cordura is recommended.

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 Rule R31).

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. 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 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.

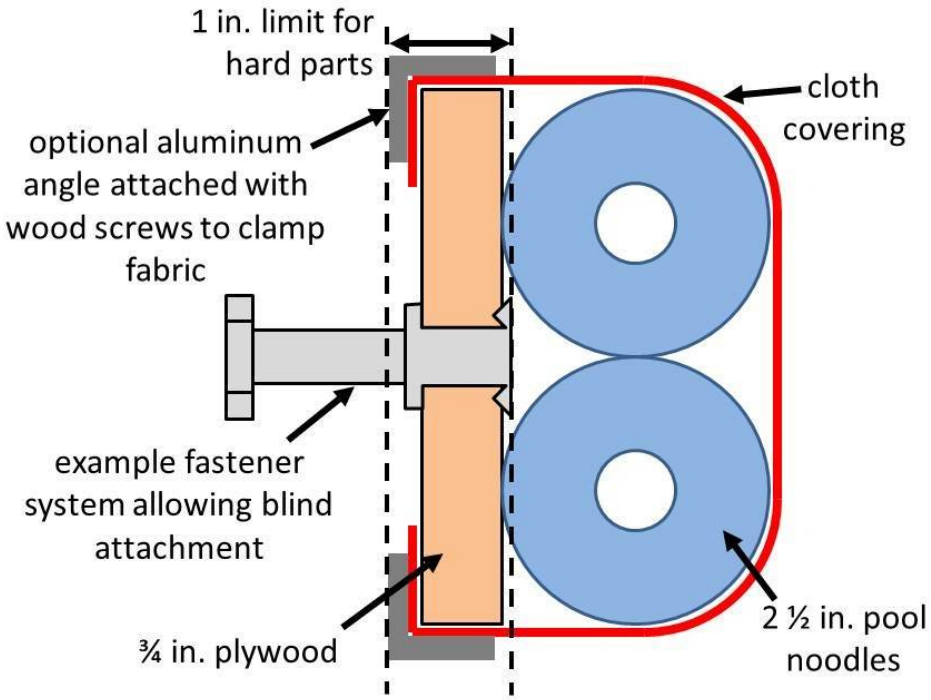

Figure 4-4: BUMPER Cross Section

4.1.6.4 R25

BUMPERS must be located entirely within the BUMPER ZONE, which is between 2 and 10 in. from the floor, in reference to the ROBOT standing normally on a flat floor.

4.1.6.5 R26

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

4.1.6.6 R27

Corner joints between BUMPERS must be filled with pool noodle material. Examples of implementation are shown in Figure 4-5.

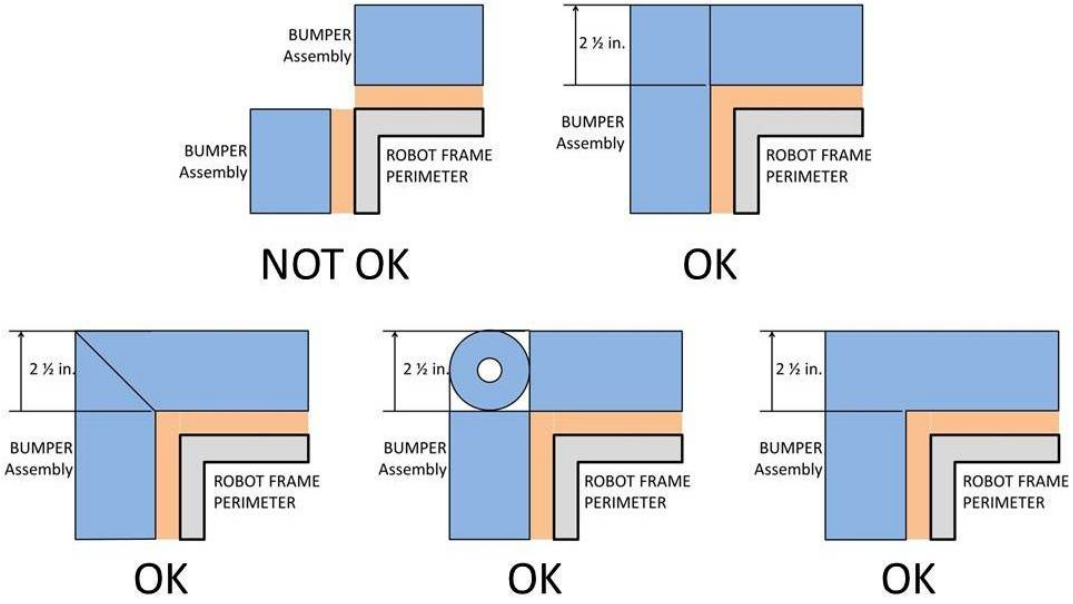

Figure 4-5: Soft Parts of BUMPER Corners

4.1.6.7 R28

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

As a guideline, BUMPERS should be removable by two (2) people in fewer than five (5) minutes.

4.1.6.8 R29

BUMPERS must be supported by the structure/frame of the ROBOT (see Figure 4-6). To be considered supported:

A. a minimum of 1 in. at each end of the BUMPER must be backed by the FRAME PERIMETER,
B. the gap between the backing material and the frame must not be greater than ¼ in., and
C. no section of BUMPER greater than 8 in. may be unsupported.

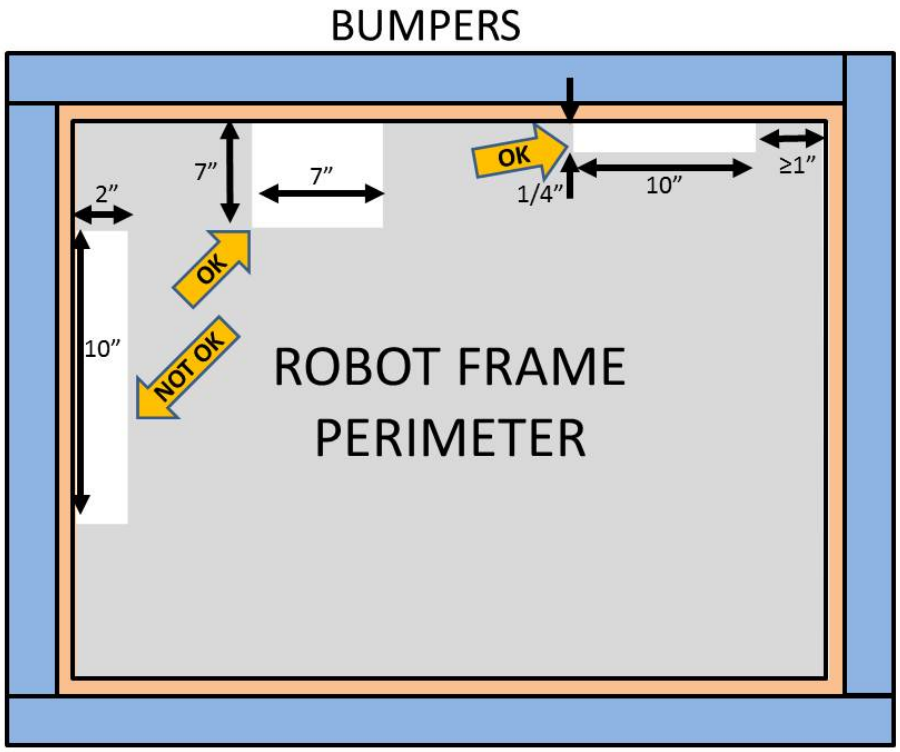

Figure 4-6: BUMPER Support Examples

4.1.6.9 R30

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 5.3.2).

4.1.6.10 R31

Team numbers must be displayed on the BUMPERS and meet the following 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. may not wrap around a corner of the FRAME PERIMETER
C. be positioned around the ROBOT such that an observer walking around the perimeter of the ROBOT can unambiguously tell the Team’s number from any point of view.

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.

4.1.7 Motors & Actuators

4.1.7.1 R32

The only motors and actuators permitted on 2013 FRC 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-RS775-12 M7-RS775-18 M5-RS550-12 M5-RS550-12-B M5-RS545-12 M5-RS540-12 M3-RS395-12 M3-RS390-12	4
AndyMark 9015	am-0912	4
Denso Throttle Control	AE235100-0160	4
VEX BAG and/or mini-CIM	217-3351 217-3371	4
AndyMark PG	am-2161 am-2194	3
Window Motors	262100-3030	2

	262100-3040 Various from *FIRST*® Choice	
VEX 2-wire Motor 393	276-2177	2
Snow Blower Motor	am-2235	1
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)		Unlimited
Drive motors or fans that are part of a motor controller or COTS computing device		Unlimited
Fans included in the 2013 Kickoff Kit, *FIRST*® Choice, or as a Talon motor controller accessory		Unlimited
COTS servos with a maximum power rating of 4W each at 6VDC Per the Servo Industry, Servo Max Power Rating = (Stall Torque) X (No Load Speed)		Unlimited

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. Stalling many motors at the same time could lead to drops in ROBOT battery voltage that will result in loss of power to core Control System components.

4.1.7.2 R33

The integral mechanical and electrical system of any motor may 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.
C. The locking pins on the window motors (P/N: 262100-3030 and 262100-3040) may be removed.
D. The connector housings on the window motors (P/N: 262100-3030 and 262100-3040) may be modified to facilitate lead connections.
E. The Integrated Encoder Module (P/N: 276-1321) may be installed on the VEX 2-wire Motor 393 (P/N 276-2177).
F. The VEX 2-wire Motor 393 (P/N: 276-2177) gears may be changed or replaced per the Supplier instructions.

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, the gearbox is considered integral to the motor, thus the motor may not be used without the gearbox.

4.1.8 Power Distribution

4.1.8.1 R34

The only legal source of electrical energy for the ROBOT during the competition, the ROBOT battery, is one of the following 12VDC non-spillable lead acid batteries:

A. MK Battery (P/N: ES17-12) or
B. EnerSys (P/N: NP 18-12)

Exception: Batteries integral to and part of a COTS computing device or self-contained camera are also permitted (e.g. laptop batteries), 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 must be securely fastened to the ROBOT.

4.1.8.2 R35

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

4.1.8.3 R36

Each electrical terminal on the ROBOT battery and its connection (lugs, stripped wire ends, etc.) to the 6AWG wire must be fully insulated.

4.1.8.4 R37

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,
B. a change in the altitude of the ROBOT center of gravity, and
C. storage achieved by deformation of ROBOT parts.

4.1.8.5 R38

The ROBOT battery, the main 120-amp (120A) circuit breaker (Cooper Bussman P/N: CB185-120), and the Power

Distribution (PD) Board shall be connected as shown in Figure 4-7.

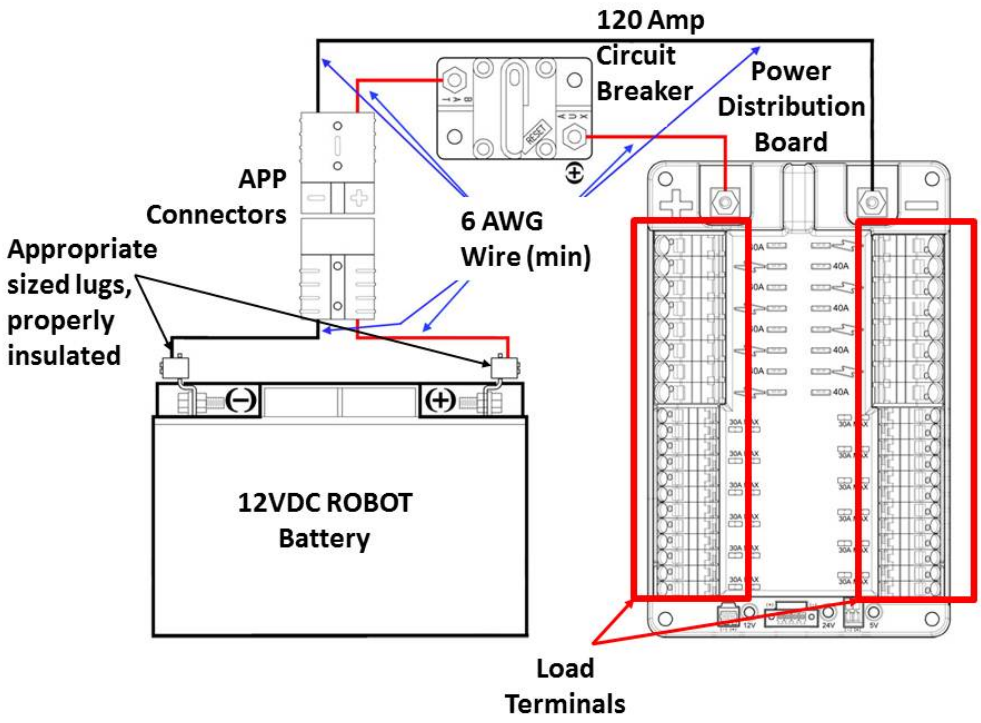

Figure 4-7: Main Power Distribution

4.1.8.6 R39

All circuits, with the exceptions of those listed in R43 and R44, must connect to, and have power sourced solely by, a single protected 12VDC WAGO connector pair (the Load Terminals) or the 5VDC supply on the PD Board (not the M6 shanks) as shown in Figure 4-8.

4.1.8.7 R40

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.

R40 is checked by observing a >10k? resistance either the (+) or (-) post within the APP connector that is attached to the PD Board and any point on the ROBOT.

The chassis for the cRIO and the Axis 206 camera have grounded enclosures. Under R40 (and for their protection), it is required that they be electrically isolated from the ROBOT frame when installed on the ROBOT.

4.1.8.8 R41

The 120A circuit breaker must be quickly accessible from the exterior of the ROBOT.

It is recommended that the 120A circuit breaker location be clearly and obviously labeled so it can be easily found by ARENA staff during a MATCH. Considering the ROBOT will also have to be powered off before being removed from the PYRAMID, Teams are encouraged to give extra consideration to the placement of the main breaker.

4.1.8.9 R42

The PD Board and all circuit breakers must be easily visible for Inspection.

4.1.8.10 R43

The cRIO power input must be connected to the 24VDC supply terminals on the PD Board shown in Figure 4-8. With the exception of one Solenoid Breakout Board, no other electrical load can be connected to these terminals.

Please note per R70 that, for an 8-slot cRIO, the power drawn by the Solenoid Breakout Board may not exceed 16W. For a 4-slot cRIO, it may not exceed 21W.

4.1.8.11 R44

The wireless bridge power feed must be supplied by the 12VDC-to-5VDC converter (P/N: CLL25-24S05) connected to the marked 12VDC supply terminals 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) shown in Figure 4?8. No other electrical load may be connected to these terminals.

Please reference the 2013 ROBOT Power Distribution Diagram posted on the Kit of Parts site for wireless bridge wiring information.

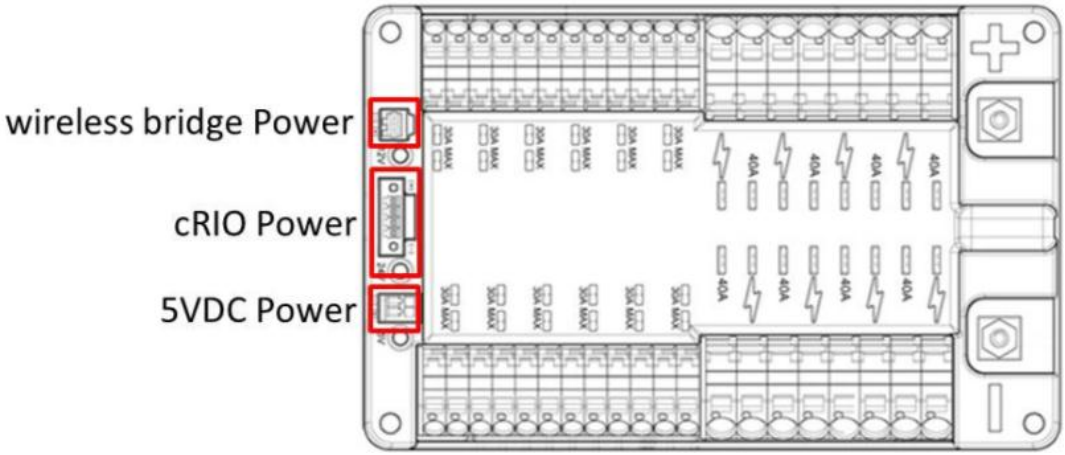

Figure 4-8: Wireless Bridge, cRIO, and 5VDC Power Connections

4.1.8.12 R45

Only one wire may be connected to each WAGO connector on the PD Board.

If multi-point distribution of circuit power is needed (e.g. to provide power to three (3) KOP breakout boards via one 20A circuit), then all incoming wires may be appropriately spliced into the main lead, and only one lead inserted into the WAGO connector to connect the circuit.

4.1.8.13 R46

The only circuit breakers permitted for use in the PD Board are:

A. Snap Action VB3-A Series, terminal style F57
B. Snap Action MX5-A40

4.1.8.14 R47

Each branch circuit must be protected by one and only one circuit breaker on the PD Board 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
Relay Module	Up to 20A	1
Digital Sidecar	20A	1
Analog/Solenoid	20A	3

Breakout Board		

R47 does not prohibit the use of smaller value fuses within custom circuits for additional protection.

4.1.8.15 R48

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

Table 4-3: Legal Wire Size

Application	Minimum Wire Size
30 – 40A circuit	12 AWG (2.052mm)
20 – 30A circuit	14 AWG (1.628mm)
5 – 20A circuit	18 AWG (1.024mm)
Between the PD Board and the Analog and/or Solenoid Breakout Boards (even though they are protected by a 20A circuit breaker per R47)	
Between the PD Board and the cRIO	20 AWG (0.8128mm)
Between the PD Board and the wireless bridge	
?5A circuit	
Pneumatic valves	24 AWG (0.5106mm)

Wires that are originally attached to legal devices are part of the device and by default legal as supplies. Such wires are exempt from R48.

4.1.8.16 R49

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.

4.1.8.17 R50

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

A. Red, white, brown, or black-with-stripe on the +24VDC, +12VDC, and +5VDC connections
B. Black or blue for the common or negative side (-) of the connections.

4.1.8.18 R51

The only power regulating devices for actuators permitted on the ROBOT include:

A. Jaguar motor controller (P/N: MDL-BDC, MDL-BDC24, and 217-3367),
B. Victor 884 motor controller (P/N: VICTOR-884-12/12),
C. Victor 888 motor controller (P/N: 217-2769),
D. Talon motor controller (P/N: CTRE_Talon and am-2195),
E. VEX motor controller (P/N: 276-2193) for controlling VEX 2-wire Motor 393 (P/N: 276-2177) only, and
F. Spike H-Bridge Relay (P/N: 217-0220).

4.1.8.19 R52

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

Table 4-4: Legal Power Regulating Device Use

Electrical Load	Jaguar, Victor, or Talon motor controller	Spike H-Bridge Relay	VEX motor controller	Solenoid Breakout
am PG motor M3-RS390-12 M3-RS395-12 M5-RS545-12 M5-RS555-12 M7-RS775-12 262100-3030 262100-3040 ARA Window motors AE235100-0610	Yes Up to 2 per controller	Yes	No	No
CIM am-0912 M5-RS540-12 M5-RS550-12 M5-RS550-12-B M7-RS775-18 217-3351 217-3371	Yes	No	No	No
276-2177	Yes Up to 2 per controller	Yes	Yes	No
Compressor	No	Yes	No	No

Pneumatic Solenoids	No	Yes*	No	Yes
Electric Solenoids	No	Yes	No	Yes

*Multiple low-load, pneumatic solenoid valves or lights may be connected to a single relay module. This would allow one (1) 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.

4.1.8.20 R53

Servos must be directly connected to the PWM ports on the Digital Sidecar. They must not be connected to motor controllers or relay modules.

4.1.8.21 R54

Custom circuits shall not directly alter the power pathways between the ROBOT battery, PD Board, motor 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.

4.1.9 Control, Command, & Signals System

4.1.9.1 R55

ROBOTS must be controlled via one (1) programmable National Instruments cRIO (P/N: cRIO-FRC or cRIO-FRCII), with image version FRC_2013_v47.

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

4.1.9.2 R56

One (1) D-Link wireless bridge (P/N: DAP-1522), hardware revision B, is the only permitted device for communicating to and from the ROBOT during the MATCH.

Hardware revision A, distributed in 2011 and 2012, is not legal for 2013. Teams participating in the Irael Regional may use hardware version Rev A or Rev B.

4.1.9.3 R57

The DAP-1522 wireless bridge must be connected to the cRIO Ethernet port 1 (either directly or via a CAT5 Ethernet pigtail).

4.1.9.4 R58

Ethernet-connected COTS devices or custom circuits may connect to any remaining Ethernet port but must not transmit or receive UDP packets using ports 1100-1200 with the exception of ports 1130 and 1140.

4.1.9.5 R59

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

A. Network Ports:
   A. TCP 1180: This port is typically used for camera data from the cRIO to the Driver Station (DS) when the camera is connected to port 2 on the 8-slot cRIO (P/N: cRIO-FRC). This port is bidirectional.
   B. TCP 1735: SmartDashboard, bidirectional
   C. UDP 1130: Dashboard-to-ROBOT control data, directional
   D. UDP 1140: ROBOT-to-Dashboard status data, directional
   E. HTTP 80: Camera connected via switch on the ROBOT, bidirectional
   F. HTTP 443: Camera connected via switch on the ROBOT, bidirectional

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 port 2).

B. Bandwidth: 7 Mbits/second

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

4.1.9.6 R60

The cRIO, 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 FRC Control System.

4.1.9.7 R61

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

4.1.9.8 R62

No form of wireless communication shall be used to communicate to, from, or within the ROBOT, except those required per R56 and R61 (e.g. radio modems from previous *FIRST* competitions and Bluetooth devices are not permitted on the ROBOT during competition).

4.1.9.9 R63

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.

4.1.9.10 R64

ROBOTS must use at least one (1) diagnostic ROBOT Signal Light (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 a Digital Sidecar that is connected to an NI 9403 module in Slot 2 of the cRIO, and
C. wired for solid light operation, by placing a jumper between the “La” and “Lb” terminals on the light per Figure 4-9.

See the 2013 ROBOT Data Diagram on the KOP website and the item bulletin for connection details.

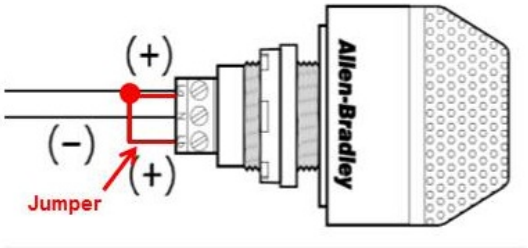

Figure 4-9: Jumper on RSL

4.1.9.11 R65

The Driver Station software, cRIO, motor 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:

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 cRIO may be customized.
B. Dip switches on the cRIO may be set (applies to cRIO-FRC only).
C. Motor controllers may be calibrated as described in owner's manuals.
D. Fans may be attached to motor controllers and may be powered from the power input terminals.
E. If powering the compressor, the fuse on a Spike H-Bridge Relay may be replaced with a 20A Snap-Action circuit breaker.
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 motor controllers 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. If CAN-bus functionality is used, the Jaguar firmware must be updated as required by *FIRST* (see Rule R68-D).
L. The First Touch I/O module's firmware may be modified.

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.

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 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.

4.1.9.12 R66

Neither 12VDC power nor relay module or motor controller outputs may be connected to the Analog/Solenoid Breakout Boards or the Digital Sidecar (with the exception of the designated 12VDC input terminals).

4.1.9.13 R67

Every relay module, servo, and PWM motor 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.

4.1.9.14 R68

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.

1. The Jaguar must receive signals via either a PWM cable or a CAN-bus connection. Both may not be used simultaneously.
2. PWM configuration: If the Jaguar motor controller is controlled via PWM communications, the PWM port on the Jaguar motor controller must be connected directly to a PWM port on the Digital Sidecar with a PWM cable. No other device may be connected to these PWM ports. No other device may be connected to any other port on the Jaguar motor controller with the exception of connection to the coast/brake port or the limit switch ports.
3. CAN-bus configuration: If the Jaguar motor controller is controlled via CAN-bus communications, each Jaguar motor controller must be connected to either the cRIO or another CAN-bus device with a CAN-bus cable.
4. If the CAN-bus configuration is used, the firmware on gray Jaguar motor controllers must be updated to at least Version 101 of the official *FIRST* firmware and Version 107 for black Jaguars.

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 R55.)

4.1.9.15 R69

If CAN-bus communication is 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) 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).

4.1.9.16 R70

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).

4.1.9.17 R71

Control components must be configured to report the ROBOT'S battery voltage. Specifically:

A. A National Instruments 9201 analog module must be installed in slot 1 of the cRIO.
B. An Analog Breakout Board must be connected to this module.
C. A jumper must be installed in the "Power" position (two outer pins) on the Analog Breakout Board (see Figure 4-10).
D. The Analog Breakout Board must be powered from the PD Board.

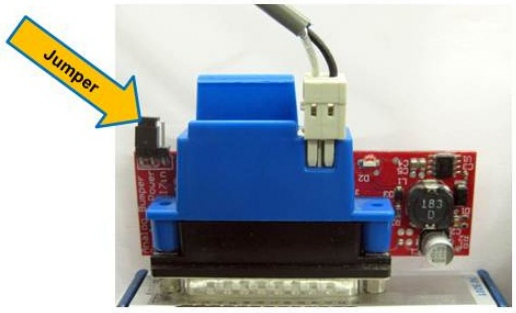

Figure 4-10: Jumper for Battery Voltage Reading

4.1.9.18 R72

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 Board,
E. the 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 motor controllers on the CAN-bus are wired in full compliance with R68 and R69, or
H. the sensor inputs on the Jaguar motor 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 R55). Thus, any additional devices on the Ethernet or CAN-bus must not provide command signals that do not originate from the cRIO.

4.1.9.19 R73

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 R54 or R72.

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.

4.1.9.20 R74

Any decorations that involve broadcasting a signal to/from the ROBOT, such as remote cameras, must be approved by *FIRST* (via e-mail to frcparts@usfirst.org) prior to the event and tested for communications interference at the venue. Such devices, if reviewed and approved, are excluded from R62.

4.1.10 Pneumatics System

4.1.10.1 R75

To satisfy multiple constraints associated with safety, consistency, Inspection, and constructive innovation, no pneumatic parts other than those explicitly permitted in Section 4.1.10 may be used on the ROBOT.

4.1.10.2 R76

All pneumatic components must be COTS pneumatic devices rated by their manufacturers for working pressure of at least 125psi (with the exception of R78-D).

4.1.10.3 R77

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.

4.1.10.4 R78

The only pneumatic system items permitted on 2013 FRC ROBOTS include the items listed below.

A. Items available in the 2013 KOP,
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 port diameter, and a maximum Cv of 0.32,
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,
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 R80.

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

4.1.10.5 R79

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 per Figure 4-11.

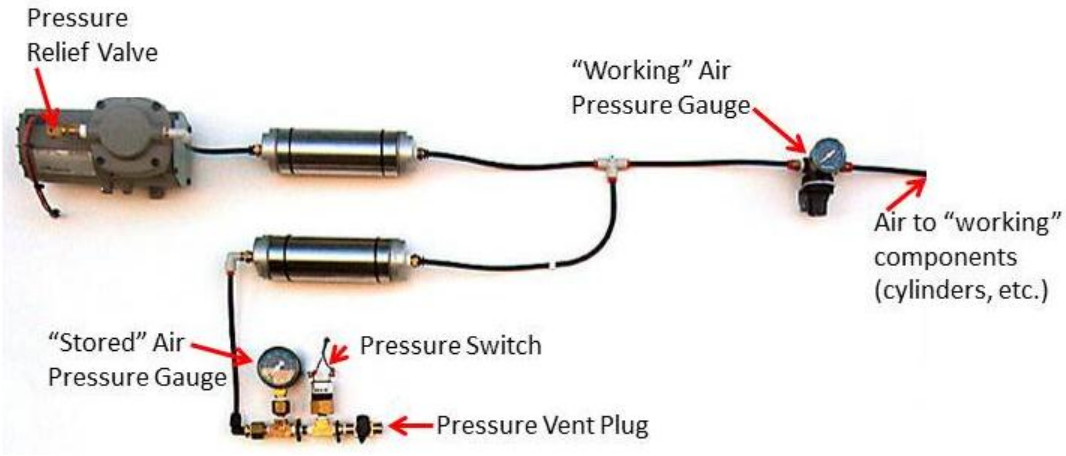

Figure 4-11: Pneumatic System Setup

4.1.10.6 R80

Compressed air on the ROBOT must be provided by one and only one compressor. Compressor specifications may not exceed nominal 12VDC, 1.05 cfm flow rate. Off-board compressors must be controlled and powered by 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 storage tanks on the ROBOT prior to bringing the ROBOT onto the FIELD.

4.1.10.7 R81

"Stored" air pressure on the ROBOT must be no greater than 120 psi. "Working" air pressure on the ROBOT must be no greater than 60 psi. All working air must be provided through one primary adjustable pressure regulator.

Norgren regulator P/N: R07-100-RNEA recommended.

4.1.10.8 R82

Only the compressor, relief valve (P/N: 16-004-011), 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.

4.1.10.9 R83

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

4.1.10.10 R84

If the compressor is not included on the ROBOT (under the provisions of Rule R80), the regulator and high-pressure gauge may be located on-board or off-board (but must be together), provided all other pneumatic rules are satisfied.

4.1.10.11 R85

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.

4.1.10.12 R86

The relief valve must be attached directly to the compressor or attached by legal fittings connected to the compressor output port. If using an off-board compressor, an additional relief valve must be included in the high pressure side of the pneumatic circuit 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.

4.1.10.13 R87

The pressure switch requirements are:

A. 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.
B. The two wires from the pressure switch must be connected directly to a digital input and ground pin on the Digital Sidecar.
C. 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.

4.1.10.14 R88

The pressure vent plug valve must be:

A. connected to the pneumatic circuit such that, when manually operated, it will vent to the atmosphere to relieve all stored pressure, 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 vent valve must be obtained and connected to the high-pressure portion of the pneumatic circuit off board the ROBOT with the compressor (see R80).

4.1.10.15 R89

The outputs from multiple valves may not be plumbed together.

4.1.11 OPERATOR CONSOLE

4.1.11.1 R90

The Driver Station software provided on the Kit of Parts 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 12.19.12.00 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.

4.1.11.2 R91

The OPERATOR CONSOLE 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.

4.1.11.3 R92

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 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 jerks.

4.1.11.4 R93

The OPERATOR CONSOLE must not exceed 60 in. long by 12 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 2.2.9 for details.

4.1.11.5 R94

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

Date	Section	Change
1/8/13	4.1.8	Updated Table 4-3 to allow up to 20A circuit to use 18 AWG wire
1/11/13	4.1.1	Removed "and volume" from second paragraph
1/11/13	4.1.10	Corrected part C to "1/8 in NPT port diameter"
1/15/13	4.1.1	Removed "vertical" and added reference to G23-1
1/15/13	4.1.6	Updated Figure 4-2
1/15/13	4.1.7	Added "PM25R-45F-1003" to legal CIM part numbers