This section of the 2021 FIRST® Robotics Competition Game Manual presents rules relevant to the construction of a 2021 FIRST Robotics Competition ROBOT. ROBOTS must pass Inspection at each FIRST Robotics Competition event to confirm compliance before being allowed to compete in a Qualification or Playoff MATCH, per Inspection & Eligibility Rules.

9.1 Overview

The rules listed below explicitly address legal parts and materials and how those parts and materials may be used on a 2021 ROBOT. A ROBOT is an electromechanical assembly built by the FIRST Robotics Competition team to play the current season’s game and includes all the basic systems required to be an active participant in the game –power, communications, control, BUMPERS, and movement about the FIELD.

There are many reasons for the structure of the rules, including safety, reliability, parity, creation of a reasonable design challenge, adherence to professional standards, impact on the competition, and compatibility with the Kit of Parts (KOP). The KOP is the collection of items listed on the 2020 and 2021 Kickoff Kit checklists, distributed to the team via FIRST Choice in the 2020 and/or 2021 season, or paid for completely (except shipping) with a Product Donation Voucher (PDV) from the 2020 and/or 2021 season.

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 and efficiently assess the legality of a given part.

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 (with the exception of installation or modification of any software). Items that are no longer commercially available but are functionally equivalent to the original condition as delivered from the VENDOR are considered COTS and may be used.

Example 1: A team orders 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.
FIRST desires to permit teams to have the broadest choice of legitimate sources possible, and to obtain COTS items from the sources that provide them with the best prices and level of service available. Teams also need to protect against long delays in availability of parts that will impact their ability to complete their ROBOT. The build season is brief, so the VENDOR must be able to get their product, particularly FIRST unique items, to a team in a timely manner.

Ideally, chosen VENDORS should have national distributors (e.g. Home Depot, Lowes, MSC, 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 FABRICATED ITEM is any COMPONENT or MECHANISM that has been altered, built, cast, constructed, concocted, created, cut, heat treated, machined, manufactured, modified, painted, produced, surface coated, or conjured partially or completely into the final form in which it will be used on the ROBOT.

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

Teams may be asked to provide documentation proving legality of non-2020 or 2021 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 competition and may include rigorous game play. While the rules aim to limit severe damage to ROBOTS, teams should design their ROBOTS to be robust.

9.2 General ROBOT Design

R1. The ROBOT (excluding BUMPERS) must have a FRAME PERIMETER, contained within the BUMPER ZONE and established while in the ROBOT’S STARTING CONFIGURATION, that is comprised of fixed, non-articulated structural elements of the ROBOT. Minor protrusions no greater than ¼ in. (~6 mm) such as bolt heads, fastener ends, weld beads, and rivets are not considered part of the FRAME PERIMETER.

To determine the FRAME PERIMETER, wrap a piece of string around the ROBOT (excluding BUMPERS) at the BUMPER ZONE described in R18 and pull it taut. The string outlines the FRAME PERIMETER.

Example: A ROBOT’S chassis is shaped like the letter ‘V’, with a large gap between chassis elements on the front of the ROBOT. When wrapping a taut string around this
See Game Rules: ROBOTS for height and extension restrictions for various areas of the FIELD.

R5. The ROBOT weight must not exceed 125 lbs. (~56 kg). When determining weight, the basic ROBOT structure and all elements of all additional MECHANISMS that might be used in a single configuration of the ROBOT shall be weighed together (see I3).

For the purposes of determining compliance with the weight limitations, the following items are excluded:

A. ROBOT BUMPERS
B. ROBOT battery and its associated half of the Anderson cable quick connect/disconnect pair (including no more than 12 in. (~30 cm) of cable per leg, the associated cable lugs, connecting bolts, and insulation)
C. tags used for location detection systems if provided by the event

9.3 ROBOT Safety & Damage Prevention

R6. Traction devices must not have surface features that could damage the ARENA (e.g. metal, sandpaper, hard plastic studs, cleats, hook-loop fasteners 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.

R7. Protrusions from the ROBOT and exposed surfaces on the ROBOT shall not pose hazards to the ARENA elements (including the POWER CELLS) or people.

R8. 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 R8 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 vision targets described in Vision Targets)
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 24 Volts
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.
l. Tire sealant
m. High intensity light sources used on the ROBOT (e.g. super bright LED sources marketed as 'military grade' or 'self-defense') may only be illuminated for a brief time while targeting and may need to be shrouded to prevent any exposure to participants. Complaints about the use of such light sources will be followed by re-inspection and possible disablement of the device. Teams should provide MSD Sheets for any materials they use that might be considered questionable during ROBOT Inspection.

R9. ROBOTS must allow removal of game pieces 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 game pieces and ROBOTS can be quickly, simply, and safely removed.

Teams are encouraged to consider rule C7 when developing their ROBOTS.

R10. Lubricants may be used only to reduce friction within the ROBOT. Lubricants must not contaminate the FIELD or other ROBOTS.

9.4 Budget Constraints & Fabrication Schedule

R11. This rule has been removed for the 2021 season.

R12. No individual, non-KOP item or software used on the ROBOT shall have a Fair Market Value that exceeds $500 USD. The total cost of COMPONENTS purchased in bulk may exceed $500 USD as long as the cost of an individual COMPONENT does not exceed $500 USD.

Teams should be ready to show inspectors documentation of Fair Market Value (FMV) for any COMPONENTS that appear to be in the range of the $500 USD limit.

The Analog Devices ADIS16448 IMU MXP Breakout Board does not have a published FMV. This device is considered to comply with R12 regardless of its true FMV.

The FMV of a COTS item is its price defined by a VENDOR for the part or an identical functional replacement. This price must be generally available to all FIRST Robotics Competition teams throughout the build and competition season (i.e. short-term sale prices or coupons do not reflect FMV), however teams are only expected to make a good faith effort at determining the item price and are not expected to monitor prices of ROBOT items throughout the season. The FMV is the cost of the item itself and does not include any duties, taxes, tariffs, shipping, or other costs that may vary by locality.

The FMV of COTS software is the price, set by the VENDOR, to license the software (or component of the software) that runs on the ROBOT for the period from Kickoff to the end of the FIRST Championship. The FMV of software licensed free-of-cost, including through the Virtual KOP, for use on the ROBOT is $0.

The FMV of FABRICATED parts is the value of 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, and/or event provided Machine Shops. Material costs are accounted for as the cost of any purchasable quantity that can be used to make the individual part (i.e. the purchasable raw material is larger than the FABRICATED part).

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.
R14. This rule has been removed for the 2021 season.

R15. This rule has been removed for the 2021 season.

R16. During an event a team is attending (regardless of whether the team is physically at the event location), the team may neither work on nor practice with their ROBOT or ROBOT elements outside of the hours that pits are open, with the following exceptions:

A. OPERATOR CONSOLE,
B. BUMPERS (a protective assembly designed to attach to the exterior of the ROBOT and constructed as specified in BUMPER Rules),
C. battery assemblies as described in R5-B,
D. FABRICATED ITEMS consisting of one COTS electrical device (e.g. a motor or motor controller) and attached COMPONENTS associated with any of the following modifications:
   i. wires modified to facilitate connection to a ROBOT (including removal of existing connectors)
   ii. connectors and any materials to secure and insulate those connectors added (Note: passive PCBs such as those used to adapt motor terminals to connectors are considered connectors)
   iii. motor shafts modified and/or gears, pulleys, or sprockets added
   iv. motors modified with a filtering capacitor as described in the Blue Box below R56
E. COTS items with any of the following modifications:
   i. Non-functional decoration or labeling
   ii. Assembly of COTS items per manufacturer specs, unless the result constitutes a MAJOR MECHANISM as defined in I1
F. Software development
G. Batteries may be charged during the designated Load-in time

For the purposes of this rule, official events begin at the start of the first designated Load-in period, according to the Public Schedule. If the Public Schedule is not available or the Public Schedule does not include a Load-in period, the event begins at 6 AM local time. Examples of activity prohibited by R16 include:

a. Working on the ROBOT at the team’s shop after Load-in for the event has begun
b. Working on ROBOT parts at night at the team’s hotel.

Note that E8 and E20 impose additional restrictions on work done on the ROBOT or ROBOT materials while attending an event.

One purpose of R16 is to increase equity between teams with significant travel to an event and those nearby (close teams would otherwise have an advantage by being able to work on their ROBOT, in their shop, until it’s time to go to the event).

9.5 BUMPER Rules

A BUMPER is a required assembly which attaches to the ROBOT frame. BUMPERS protect ROBOTS from damaging/being damaged by other ROBOTS and FIELD elements. Criteria used in writing these rules includes the following:

- Minimize variety of BUMPERS so teams can expect consistency
- Minimize the amount of design challenge in creating BUMPERS
- Minimize cost of BUMPER materials
- Maximize use of relatively ubiquitous materials
9.6 Motors & Actuators

R27. The only motors and actuators permitted on 2021 ROBOTS include the following (in any quantity):

Table 9-1 Motor allowances

<table>
<thead>
<tr>
<th>Motor Name</th>
<th>Part Numbers Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>AndyMark 9015</td>
<td>am-0912, am-3104</td>
</tr>
<tr>
<td>AndyMark NeveRest</td>
<td>am-2161 (alt. PN am-2765), am-2194 (alt. PN am-2766)</td>
</tr>
<tr>
<td>AndyMark PG</td>
<td>am-2161 (alt. PN am-2765), am-2194 (alt. PN am-2766)</td>
</tr>
<tr>
<td>AndyMark RedLine Motor</td>
<td>am-3775, am-3775a</td>
</tr>
<tr>
<td>AndyMark Snow Blower Motor</td>
<td>am-2235, am-2235a</td>
</tr>
<tr>
<td>Banebots</td>
<td>am-3830, M7-RS775-18</td>
</tr>
<tr>
<td></td>
<td>RS775WC-8514</td>
</tr>
<tr>
<td>CIM</td>
<td>FR801-001, M4-R0062-12, AM802-001A</td>
</tr>
<tr>
<td></td>
<td>217-2000, PM25R-44F-1005</td>
</tr>
<tr>
<td></td>
<td>M5 – RS550-12, RS550VC-7527, RS550</td>
</tr>
<tr>
<td>CTR Electronics/VEX Robotics Falcon 500</td>
<td>217-6515, am-6515</td>
</tr>
<tr>
<td></td>
<td>19-70850, am-6515 Short</td>
</tr>
<tr>
<td>Current/former KOP Automotive motors</td>
<td>Denso AE235100-0160</td>
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<tr>
<td></td>
<td>Denso 5-163800-RC1</td>
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<tr>
<td></td>
<td>Denso 262100-3030</td>
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<tr>
<td></td>
<td>Denso 262100-3040</td>
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<tr>
<td></td>
<td>Bosch 6 004 RA3 194-06, Johnson Electric JE-PLG-149</td>
</tr>
<tr>
<td>Nidec Dynamo BLDC Motor</td>
<td>am-3740, DM3012-1063</td>
</tr>
<tr>
<td>Playing with Fusion Venom</td>
<td>BDC-10001</td>
</tr>
<tr>
<td>REV Robotics HD Hex Motor</td>
<td>REV-41-1291</td>
</tr>
<tr>
<td>REV Robotics NEO Brushless</td>
<td>REV-21-1650</td>
</tr>
<tr>
<td>REV Robotics NEO 550</td>
<td>REV-21-1651</td>
</tr>
<tr>
<td>VEX BAG</td>
<td>217-3351</td>
</tr>
<tr>
<td>VEX Mini-CIM</td>
<td>217-3371</td>
</tr>
<tr>
<td>West Coast Products RS775 Pro</td>
<td>217-4347</td>
</tr>
<tr>
<td>Electrical solenoid actuators, no greater than 1 in. (nominal) stroke and rated electrical input power no greater than 10 watts (W) continuous duty at 12 volts (VDC)</td>
<td></td>
</tr>
<tr>
<td>Fans, no greater than 120mm (nominal) size and rated electrical input power no greater than 10 watts (W) continuous duty at 12 volts (VDC)</td>
<td></td>
</tr>
<tr>
<td>Hard drive motors part of a legal COTS computing device</td>
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<tr>
<td>Factory installed vibration and autofocus motors resident in COTS computing devices (e.g. rumble motor in a smartphone).</td>
<td></td>
</tr>
<tr>
<td>PWM COTS servos with a retail cost &lt; $75.</td>
<td></td>
</tr>
<tr>
<td>Motors integral to a COTS sensor (e.g. LIDAR, scanning sonar, etc.), provided the device is not modified except to facilitate mounting</td>
<td></td>
</tr>
<tr>
<td>One (1) compressor compliant with R79 and used to compress air for the ROBOT’S pneumatic system</td>
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</tbody>
</table>

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.

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

2 A CUSTOM CIRCUIT is any electrical COMPONENT of the ROBOT other than motors, pneumatic solenoids, roboRIO, PDP, PCM, VRM, RSL, 120A breaker, motor controllers, relay modules (per R29-B), wireless bridge, electrical solenoid actuators, or batteries.

R31. Servos must be connected to, and only to, one of the following:

A. PWM PORTS on the roboRIO
B. PWM PORTS on a WCP Spartan Sensor Board (P/N: WCP-0045)
C. REV Robotics Servo Power Module (P/N: REV-11-1144)

9.7 Power Distribution

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

R32. The only legal source of electrical energy for the ROBOT during the competition, the ROBOT battery, must be one and only one 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 3 in. x 6.6 in., +/- .1 in. for each dimension (~ 180 mm x 76mm x 168 mm, +/- 2.5 mm for each dimension)
E. Nominal weight: 11lbs. to 14.5 lbs. (~5 kg to 6.5 kg.)
F. Terminals: Nut and bolt style

Examples of batteries which meet these criteria include:

a. Enersys (P/N: NP18-12, NP18-12B, NP18-12BFR)
b. MK Battery (P/N: ES17-12)
c. Battery Mart (P/N: SLA-12V18)
d. Sigma (P/N: SP12-18)
e. Universal Battery (P/N: UB12180)
f. Power Patrol (P/N: SLA1116)
g. Werker Battery (P/N: WKA12-18NB)
h. Power Sonic (P/N: PS-12180NB)
i. Yuasa (P/N: NP18-12B)
j. Panasonic (P/N: LC-RD-1217)
k. Interstate Batteries (P/N: BSL1116)
l. Duracell Ultra Battery (P/N: DURA12-18NB)

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. (Please see the FIRST Safety Manual for additional information.)

R33. COTS USB battery packs with a capacity of 100Wh or less (20000mAh at 5V) and 2.5 Amp max output per port, or batteries integral to and part of a COTS computing device or self-contained
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 R53.

In order to show compliance with these rules, teams should use wire with clearly labeled sizes if possible. If unlabeled wiring is used, teams should be prepared to demonstrate that the wire used meets the requirements of R53 (e.g. wire samples and evidence that they are the required size).

R54. 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.

Slip rings containing mercury are prohibited per R8.

R55. 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.

Exceptions to this rule include:

C. Wires that are originally attached to legal devices and any extensions to these wires using the same color as the manufacturer.
D. Ethernet cable used in POE cables.

R56. CUSTOM CIRCUITS shall not directly alter the power pathways between the ROBOT battery, PDP, motor controllers, relays (per R29-B), motors and actuators (per R27), 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 R56 or R73.

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

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

9.8 Control, Command & Signals System

R57. ROBOTS must be controlled via one (1) programmable National Instruments roboRIO (P/N: am3000), with image version FRC_roboRIO_2020_v10 or later.

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

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 CAN motor controller may be used. (That is, commands originating from the roboRIO to configure, enable, and specify an operating point for all CAN motor controller closed loop modes fit the intent of R57).

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).

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).

For documentation on how to wire the CAN-bus connections of the PDP see How to Wire an FRC Robot.

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 PDP, PCMs, and/or CAN Motor Controllers 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 How to Wire an FRC Robot.

### 9.9 Pneumatic System

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

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

R75. All pneumatic items must be COTS pneumatic devices and either:

A. rated by their manufacturers for pressure of at least 125psi (~862 kPa), or
R86. 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.

R87. The outputs from multiple solenoid valves must not be plumbed together.

9.10 OPERATOR CONSOLE

R88. The Driver Station software provided by National Instruments (install instructions found here) is the only application permitted to specify and communicate the operating mode (i.e. Autonomous/Teleoperated) and operating state (Enable/Disable) to the ROBOT. The Driver Station software must be revision 21.0 or newer.

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

R89. 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 diagnostic information. It must be positioned within the OPERATOR CONSOLE so that the screen display can be clearly seen during Inspection and in a MATCH.

R90. 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 FMS 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.

R91. The OPERATOR CONSOLE must not
   A. be longer than 60 in. (~152 cm)
   B. be deeper than 14 in. (~35 cm) (excluding any items that are held or worn by the DRIVERS during the MATCH)
   C. extend more than 6 ft. 6 in. (~198 cm) above the floor
   D. attach to the FIELD (except as permitted by G26)

   There is a 54 in. (~137 cm) long by 2 in. (nominal) wide strip of hook-and-loop tape (“loop” side) along the center of the PLAYER STATION support shelf that should be used to secure the OPERATOR CONSOLE to the shelf, per G26. See PLAYER STATION for details.

   Please note that while there is no hard weight limit, OPERATOR CONSOLES that weigh more than 30 lbs. (~13 kg.) will invite extra scrutiny as they are likely to present unsafe circumstances.