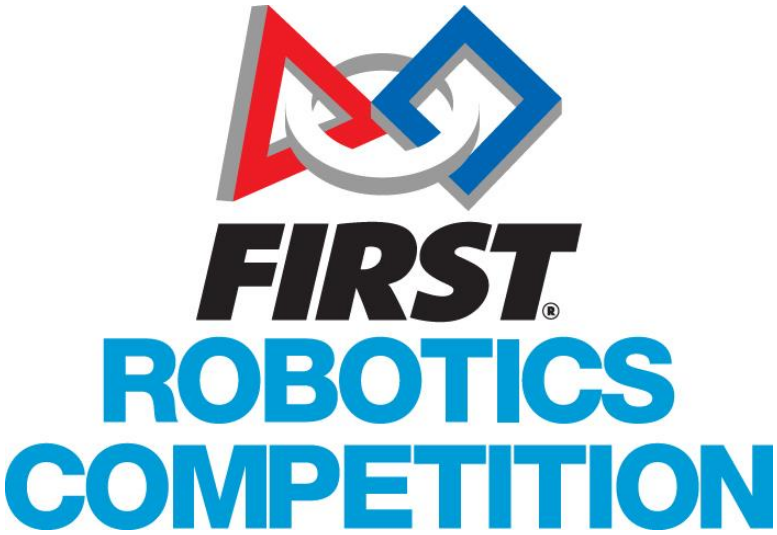


FIRST Robotics Competition Pneumatics Manual

The *FIRST* Robotics Competition (FRC) pneumatic components are outlined in this document. It is being provided as a courtesy, and therefore does not supersede any information or rules provided in the *FIRST* Robotics Competition Manual. For official questions, please go to the *FIRST* Forums at http://forums.usfirst.org.

Contents

Pneumatic Advantages

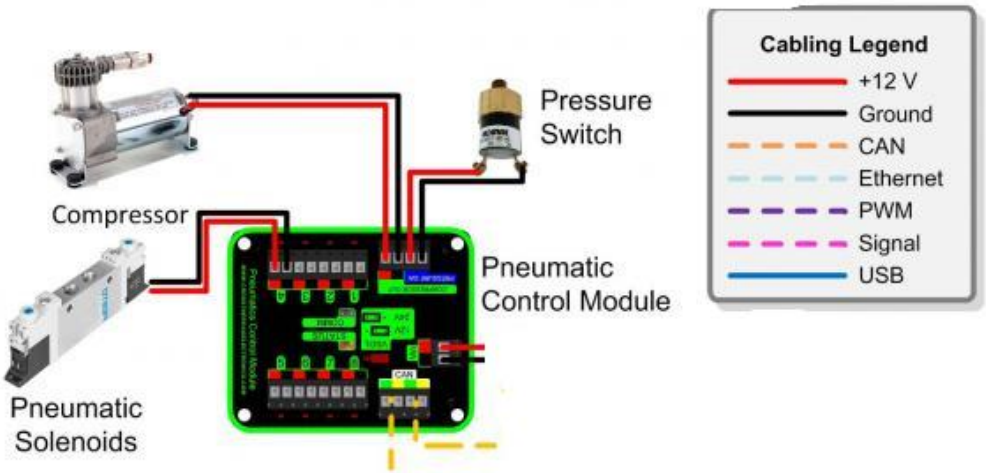
Fluid power technology encompasses both hydraulics and pneumatics. Hydraulic applications use pressurized fluids, mostly oil, while pneumatic applications use pressurized gases, mostly air. Mobile construction equipment uses a hydraulic pump mounted on the engine. The outlet of the pump is plumbed to a set of valves. Each valve is then plumbed to a cylinder. This allows you to distribute power from the engine all around the equipment. The same is true for an FRC robot. Once you install the compressor operating one valve and cylinder combination, you've done most of the work. To add an additional valve and cylinder combination, you just tee into the pressure line, add in the additional circuit, and update your code.

- Weight - Compare the weight of several valves and cylinders to that of the motors, gears, belts, and chains used on some lift mechanisms and you will find the weight comparable, if not much lighter.
- Simple to Design - Using pneumatics is much easier than building a motor; gear, chain and sprocket lift mechanism. Once you have reviewed the layout in Appendix A, you will find it very easy to build a circuit.
- Adjustable Force - To adjust the force of the cylinder, all you have to do is adjust the regulator in front of it. The force is equal to the area of the cylinder piston times the pressure. Remember that the valves need a minimum of 15 – 30 psi to work properly.
- Durable - All of us have problems burning up motors from time to time. You can stall an air cylinder against a load indefinitely and turn off the compressor. The materials provided are industrial grade products.
- Strong - Teams have the option of using a small 0.75" bore cylinder at 20psi, a medium cylinder at 1.5", or a large 2" cylinder. By varying the pressure to the cylinders, you can produce a force from 9 pounds up to 180 pounds, depending on your needs.
- Custom Cylinders and a Rotary Actuator - You can order the cylinder you need for the job, listed in Appendix C.
- Last Minute Additions - At the last minute, you can add a cylinder and valve very quickly.

Pneumatic Components

Below are the components needed to set up an FRC pneumatics system.

Pneumatics Control Module



Cross the Road Electronics' Pneumatics Control Module (PCM) is in each Rookie Kit. The PCM is used to control the compressor, solenoids, and pressure switch. The pressure switch should be wired into the 2 Weidmuller ports labeled "PRESSURE SW", while the compressor's red and black wires should go directly into the red and black "COMPRESSOR OUT" Weidmuller connectors.

The PCM can control 8 single solenoid valves or 4 double solenoid valves. It also supports both 12 and 24 volt solenoids however, only one voltage may be used at a time. This 12 or 24 volt selection is done by relocating the jumper in the "VSOL" slot. The solenoids provide in the Rookie Kit and via *FIRST* Choice is 24 volt so make sure the jumper is in the correct location before turning on. Finally the PCM receives power from the PDP via the 2 "Vin" connectors and signal from the 4 "CAN" connectors. The PCM will handle turning the compressor on and off based on the state of the pressure switch and the Enable state of the robot. If any Solenoid Valve object is opened (LabVIEW) or constructed (C++/Java) in your code, the PCM compressor control will be automatically enabled.

Compressor

Compressors are in each rookie team's Kickoff Kit and available through *FIRST* Choice for 2015. The compressor is a Viair 090C Air Compressor. It will put out approximately 120psi before the relief valve opens. Because the compressor can produce a significant amount of vibration, we recommend that you use vibration isolation mounts that come preinstalled on the compressor. In order for these to isolate the vibration, they need to be mounted to a stiff piece of material, such as a 1/4" aluminum plate. The compressor can also get very hot and should not be in direct contact with anything else. The compressor should be wired directly to the "COMPRESSOR OUT" Weidmuller connectors on the pneumatic control module (PCM). Do not reverse the compressor!

The compressor can be mounted on or off-board the robot. Please read *Game & Season Manual Section 8 Robot Rules* for all of the rules associated with this.

Pressure Relief Valve

IMI Precision Engineering (formerly known as Norgren) has supplied the 120 PSI pressure relief valve in each rookie Kickoff Kit as well as *FIRST* Choice. The pressure relief valve needs to be connected to compressor via hard fittings. If a team is using an off board compressor, then 2 pressure relief valves will be necessary, one on the robot and one on the compressor. It is up to the teams to properly install the relief valve as shown in the instructions below. This is a safety measure meant to ensure proper operation of the pneumatic system.

Pressure Switch

We have included a pressure switch manufactured by Nason in *FIRST* Choice and the rookie Kickoff Kit for 2015. This switch is normally closed. The switches will open at approximately 115 psi and will not close again until the pressure drops to approximately 95 psi. This will allow you to turn off the compressor once you are up to 115psi, saving power in the battery. It must be wired directly to the "PRESSURE SW" Weidmuller connectors. The PCM will handle turning the compressor on and off based on the state of the pressure switch and the Enable state of the robot. If any Solenoid Valve object is opened (LabVIEW) or constructed (C++/Java) in your code, the PCM compressor control will be automatically enabled.

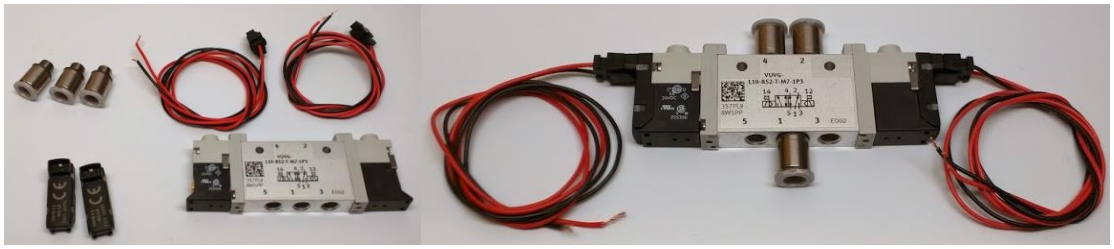
Air Tank

A plastic air tank is available in *FIRST* Choice and the rookie Kickoff Kit from Clippard Instruments. The tank is designed to withstand up to 125 psi and temperatures from 35F to 100F. It should also be installed such that it is protected from impact to reduce the risk of rupturing. When securing the tank ensure that fasteners do not get over tightened or apply pressure to the tank.

Regulators

IMI Precision Engineering has supplied the primary pressure regulator. This is a relieving regulator. This means that it will limit the downstream system pressure and can relieve excess pressure if something in the downstream system causes the pressure to increase. This regulator has a maximum output pressure of 60 psi and must be placed before any working components. The pressure is adjustable and may be reduced for use on your robot at your discretion. On the top of the regulator, you will note that one port extends out a little bit more than the others and has an arrow on it. This arrow is to denote the outlet of the regulator. The opposite port is the inlet. A pressure gauge may be placed in either of the other ports if desired, and you will have to plug the other port with one of the enclosed hex plugs.

Electric Valves



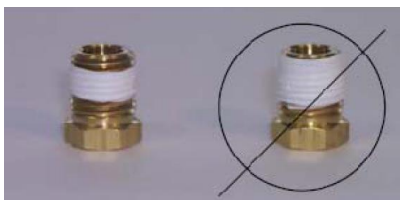
FESTO has supplied one complete double solenoid valve kit. The packaging will contain one two way valve, two plug socket wire, and three fittings. The pictures above are similar to what you will receive in the rookie kit, except the rookie kit solenoid comes with the electrical base pre-installed. The pneumatic tube fittings are the “push to connect” type so all you have to do is push in the tubing and then pull back slightly to ensure a snug fit. The valve is a 24V valve, thus the jumper on the PCM must be in the 24V output position.

Gauges

IMI Precision Engineering has supplied gauges for 2015. These gauges should be installed in the system to show stored and working pressure, meaning that two are usually required. The gauges read from 0-160 psi, 0-11 bar, and 0-1.1 MPa. One gauge must be installed on the regulator which will display the working pressure, which may not exceed 60 psi. The stored pressure gauge can be installed anywhere upstream of the working pressure regulator.

Parker Fittings

Parker Hannifin donated the plug valve, shown in the bottom left figure above. This valve can be used to release all of the air in the system. This valve must be installed in a location that will release all system pressure when opened. The valve should be placed in an easy-to-get-to location on the robot. Parker Hannifin also donated all the other fittings in the image above as well as the other items in the Rookie Kit and *FIRST* Choice. Many of these components are necessary to build a legal pneumatic system and their usage will be shown in the setup instructions below. It is important to note that all male threads require Teflon tape to seal properly. To install, wrap the tape around the threads of the fitting. The best method of wrapping tape is to roll the tape in a direction to match the threads. The recommendation to leave the first two threads open is to avoid tape coming loose from the first thread that can block one of the valves.



Tubing

Freelin-Wade has donated the pneumatic tubing this year. The tubing has an outside diameter of 0.25" and an inside diameter of 0.160". The tubing provided in the rookie Kickoff Kits is black while *FIRST* Choice has an assortment of colors. Be careful when cutting tubing as angled cuts can result in leaks.

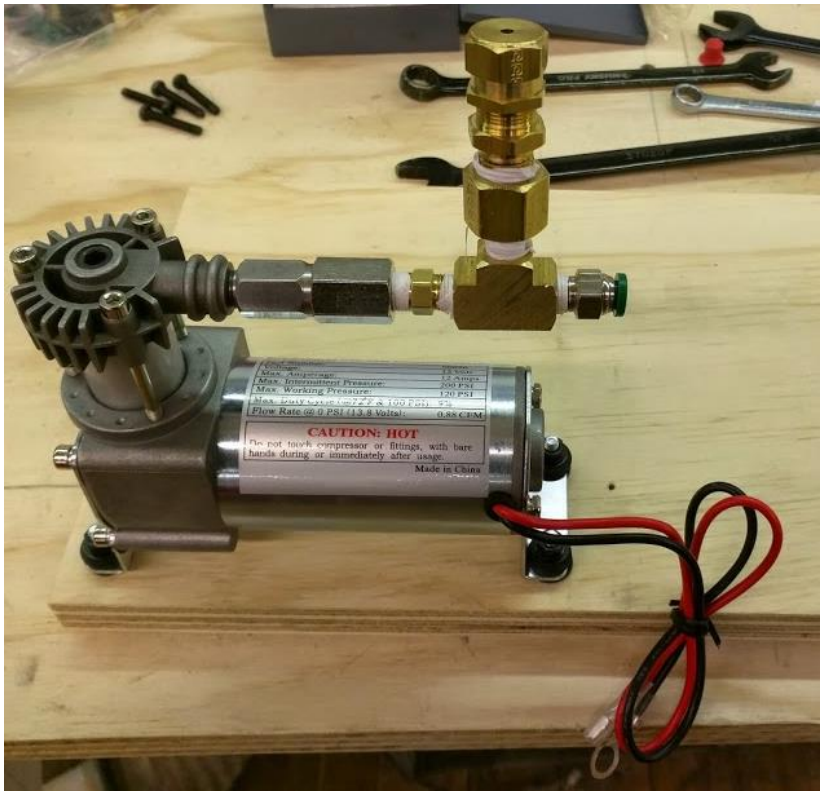
Custom Bimba Cylinders

You will be able to order custom cylinders for your robot again this year. You have a choice of bore (diameter) sizes. You can order the stroke (length of extension) you require. This flexibility will significantly increase your ability to design pneumatics into robot. Most of the bore and stroke options are in stock and Bimba is ready to ship directly to your team. All the actuators can be ordered with a magnetic piston and two magnetically operated reed switches. These switches will "close" when the piston is underneath them. It is not recommended to try to sense a mid-stroke position with these switches. Please follow the link posted in the Virtual Kit section of the Kit of Parts website (http://www.firstinspires.org/robotics/frc/kit-of-parts) for custom order information.

Pneumatics Setup

For the purpose of this setup documentation, all components are mounted to a bench top board.

Compressor and Relief Valve



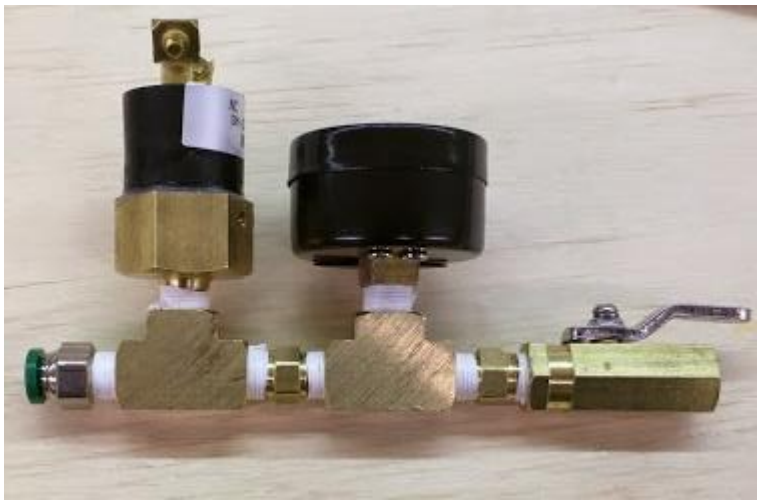
Steps

1. Install Hex Nipple 1/8” (216P-2) to VIAIR Compressor (00090) output port
2. Connect Union Tee (2203P-2) to Hex Nipple 1/8” (216P-2)
3. Connect Adapter 1/4” to 1/8” F/M (229-4-2) to Union Tee (2203P-2)
4. Install Pressure Relief Valve (16-004-011) to the Adapter 1/4" to 1/8” F/M (229-4-2)
5. Connect Male Connector (W68PLP-4-2) to the final slot on the Union Tee (2203P-2)

Notes:

- Secure all connection points with wrenches
- Use PTFE tape on all threaded connections
- The final product should look like the image above
- The Pressure Relief Valve needs to be calibrated

Pressure Switch, Gauge, and Plug Valve



Steps:

1. Attach Male Connector (W68PLP-4-2) to a slot on the Union Tee (2203P-2)
2. Install Pressure Switch (SM-2B-115R/443) into the middle slot of the Union Tee (2203P-2)
3. Connect Hex Nipple 1/8” (216P-2) to remaining port on Union Tee (2203P-2)
4. Connect a different Union Tee (2203P-2) to Hex Nipple 1/8” (216P-2)
5. Attach Pressure Gauge (18-013-212) to middle port of Union Tee (2203P-2)
6. Connect Hex Nipple 1/8” (216P-2) to remaining port on Union Tee (2203P-2)
7. Attach Micro Valve (MV709-2) to the open threads on the Hex Nipple (216P-2)

Notes:

- Secure all connection points with wrenches
- Use PTFE tape on all threaded connections
- The final product should look like the image above

Regulator and Gauge

Steps:

1. Install one Male Connector (W68PLP-4-2) into the outlet pressure port of the Pressure Regulator (R07-100RNEA) (designated by a larger port with an arrow pointing away from the regulator)
2. Install another Male Connector (W68PLP-4-2) into the inlet port of the Pressure Regulator (R07-100RNEA) (this is the opposite port from the outlet where the other male connector was just installed)
3. Attach Pressure Gauge (18-013-212) to an open port on the Pressure Regulator (R07-100RNEA)
4. Plug the remaining port of the Pressure Regulator (R07-100RNEA with the plugs provided or the 1/8” Plug (218P-2) provide in the KOP
5. The regulator should be mounted using the provided bracket and nut kit

Notes:

- Secure all connection points with wrenches
- Use PTFE tape on all threaded connections
- The final product should look like the third image above
- The regulator needs to be adjusted for a specific pressure by rotating the knob

Actuation

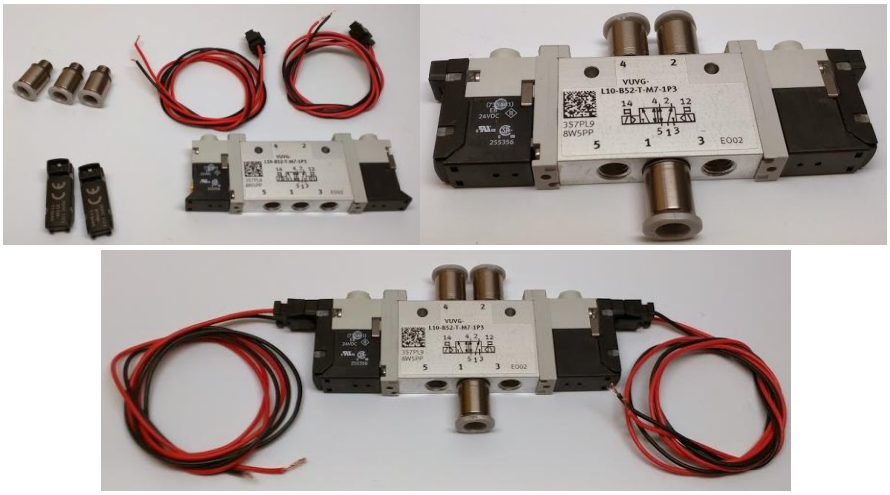
Steps:

1. Attach Elbow Push to Connect fittings (W369PLP-4-2) to both the inlet and outlet pressure port of the actuator

Notes:

- Secure all connection points with wrenches
- Use PTFE tape on all threaded connections

Electrical Valve



Steps:

1. Screw in all three push to connect fittings into ports 1, 2 and 4 of the Solenoid Valve (566475)
2. Connect both wires (566654) to the Electrical Sub Bases (566716)

Notes:

- The final product should look like the bottom image above but not exactly the same
- This valve pictured above is a 24 volt solenoid, the same as the one provided in the KOP

Air Tank

Notes:

- The air tank in the KOP uses two push to connect fittings to make attachment easier
- NEVER use the air tank outside of operating conditions
- Install the air tank on the robot such that it is shielded from impact from other robots
- When fastening tank do not over tighten or cause pressure to the outside of the tank

Plumbing

Steps:

1. Cut a piece of Pneumatic Tubing (1A-151-01) and connect it to the Male Fitting (W68PLP-4-2) directly off the compressor
2. Connect a Push to Connect Union Tee (364PLP-4) to the other end of the Pneumatic Tubing (1A-151-01)
3. Cut another piece of Pneumatic Tubing (1A-151-01) and connect it between the Union Tee (364PLP-4) and the Air Tank (AVT-PP-35)
4. Cut a piece of Pneumatic Tubing (1A-151-01) to go between the open slot on the Air Tank (AVT-PP-35) and the inlet pressure port on the Regulator (R01-100RNEA)
5. Next cut a piece of Pneumatic Tubing (1A-151-01) to go between the outlet pressure port of the Regulator (R01-100RNEA) and the inlet pressure port (1) of the Electrical Valve
6. Cut two more pieces of Pneumatic Tubing (1A-151-01) to go from the push to connect fittings on the Electrical valve in ports 2 and 4 to the inlet and outlet ports on the actuator

Notes

- Tubing should be cut in a straight line and not at an angle to ensure proper connection

Wiring

Notes

- To wire the pneumatic system please refer to the “Wiring Pneumatics” document located here.

Setup

Notes

- To setup the pneumatic system please refer to the “Updating and Configuring Pneumatics Control Module and Power Distribution Panel” document located here.

Calibration of Relief Valve

Steps

1. Loosen the locknut on the relief valve
2. Jumper the bypass of the Pressure Switch so that the compressor runs continuously
3. When pressure gets to 125psi remove the jumper
4. Rotate cap until air escapes and the pressure remains in the 120-125psi range
5. Finger tighten the locknut
6. Dump air from system then refill with the jumper on the compressor
7. If the system stabilizes somewhere between 120-125psi range further tighten down the locknut, if it does not adjust the cap again and repeat the process

Resources

WPI has saved presentations given on many topics by FRC mentors at The *FIRST* Championship Forums in the past. Presentations geared towards pneumatics can be found here:

http://first.wpi.edu/FRC/frc-mechanical.html

Appendix C describes the cylinders available to FRC teams as part of the Bimba donation. These items can be requested online. Please go to www.bimba.com and click on the *FIRST* link and follow the instructions. Quantities of no charge custom cylinders will be limited to 2 per team.

Cylinder Length Example

Look at the drawing of the 1-1/2” bore cylinder in Appendix B. You will notice that the cylinder pivots about a pivot pin located in the rear of the cylinder. There is a dimension on the drawing from that pin to the back of the thread on the rod end. That dimension is “4.38 + Stroke”. We will use this later.

Look at the drawing of the rod clevis. There is a locking nut shown on the drawing. If you look, there is a dimension of the width that is 0.25”. The locking nut threads on the rod first and is used to keep the clevis in place. Lastly, look at the dimension 1.31” on the rod clevis. Therefore, if you thread the locking nut on the rod thread all the way to the bottom of the thread and then tighten the clevis against it, you can calculate the distance from the rear pin to the clevis pin. This is called the pin to pin distance. Assume you want to move something 8 inches. You will need to order an 8” stroke cylinder.

To find the retracting pin-to-pin dimension, add the following lengths:

Base dimension = 4.38”
Stroke = 8.00”
Locking nut width = 0.25”
Clevis dimension = 1.31”
Pin-to-Pin Retraction = 13.94”

To find the extended pin-to-pin dimension, just add the stroke:

Pin-to-Pin retracted = 13.94”
Stroke = 8.00”
Pin-to-Pin Extended = 21.94”

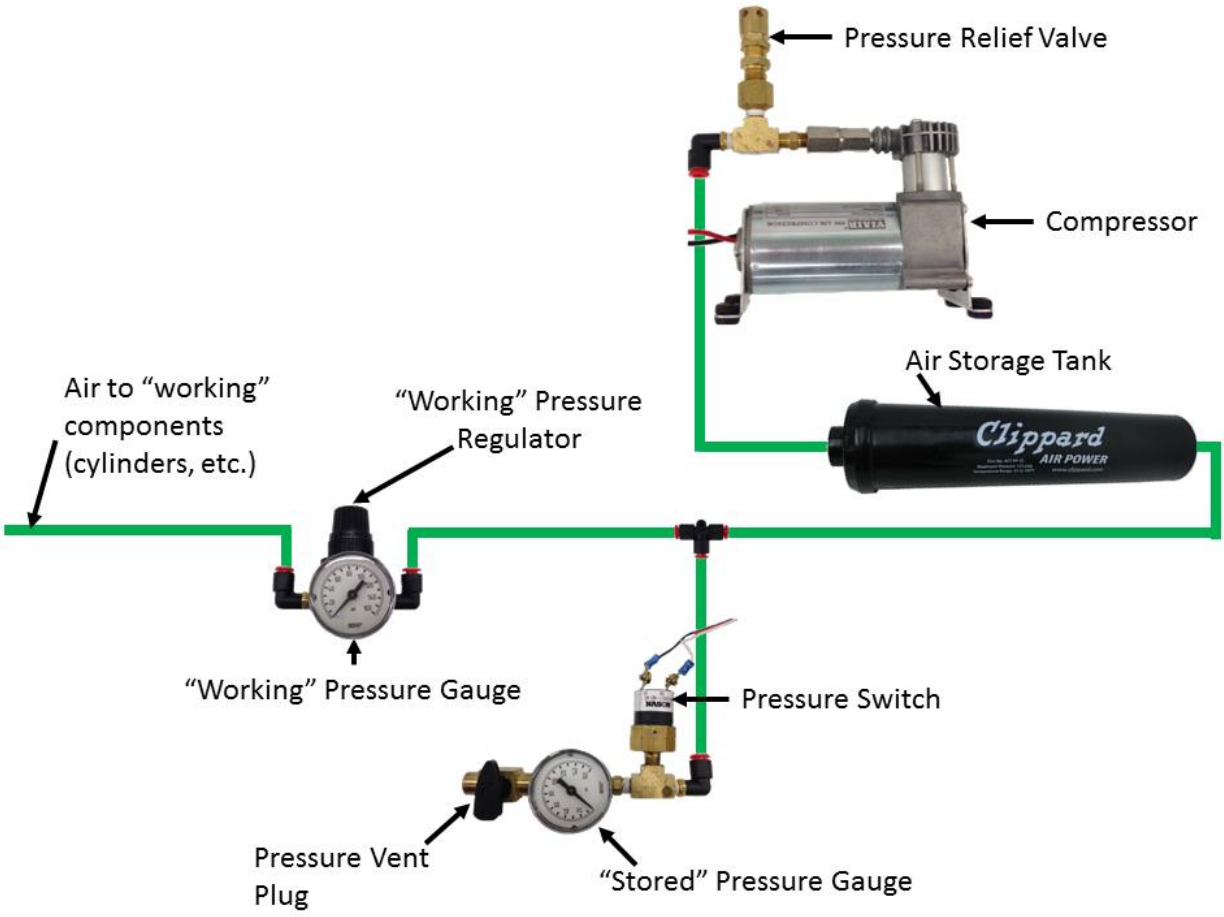
Note: The retracted length may be somewhat longer by not tightening the clevis all the way to the end of the thread.

Many thanks to the following FRC Suppliers who provided pneumatic components for the 2015 Kit of Parts:

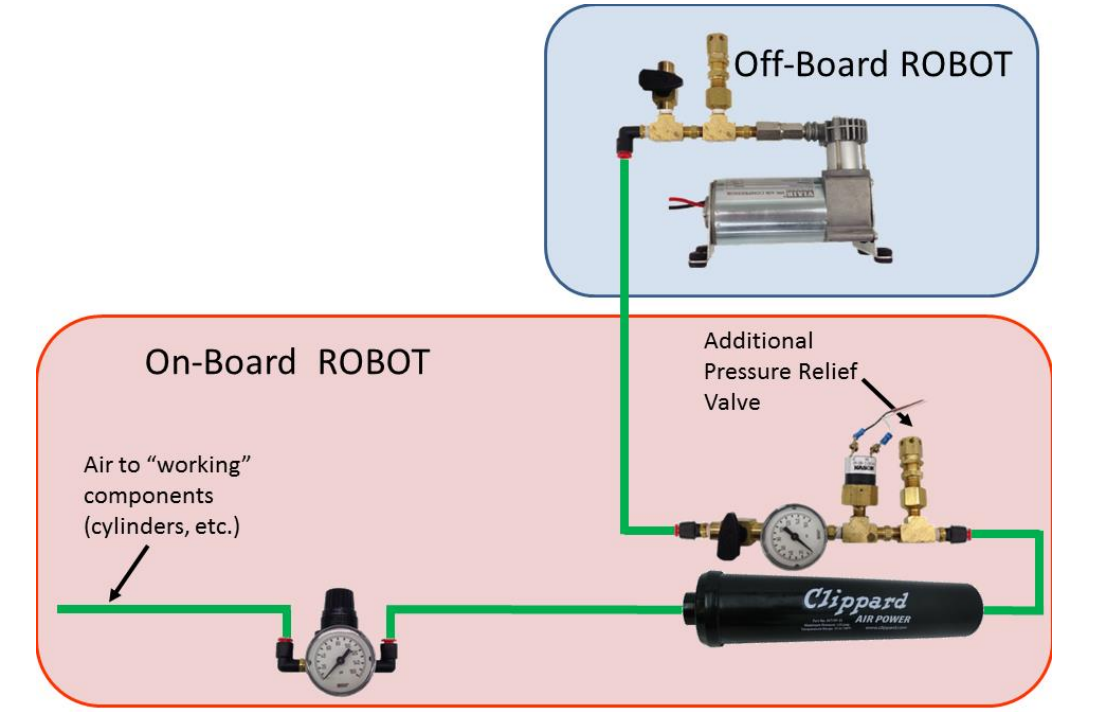
Bimba Manufacturing (http://www.bimba.com)
Clippard Instrument Laboratory, Inc. (http://www.clippard.com)
Festo Corporation (http://www.festo.com)
Freelin-Wade (http://www.freelin-wade.com)
HPE Automation (http://www.hpeco.com)
IMI Precision Engineering (formerly Norgren (http://www.norgren.com)
Nason Corporation (http://www.nasonptc.com)
Parker Hannifin, Inc. (http://www.parker.com)

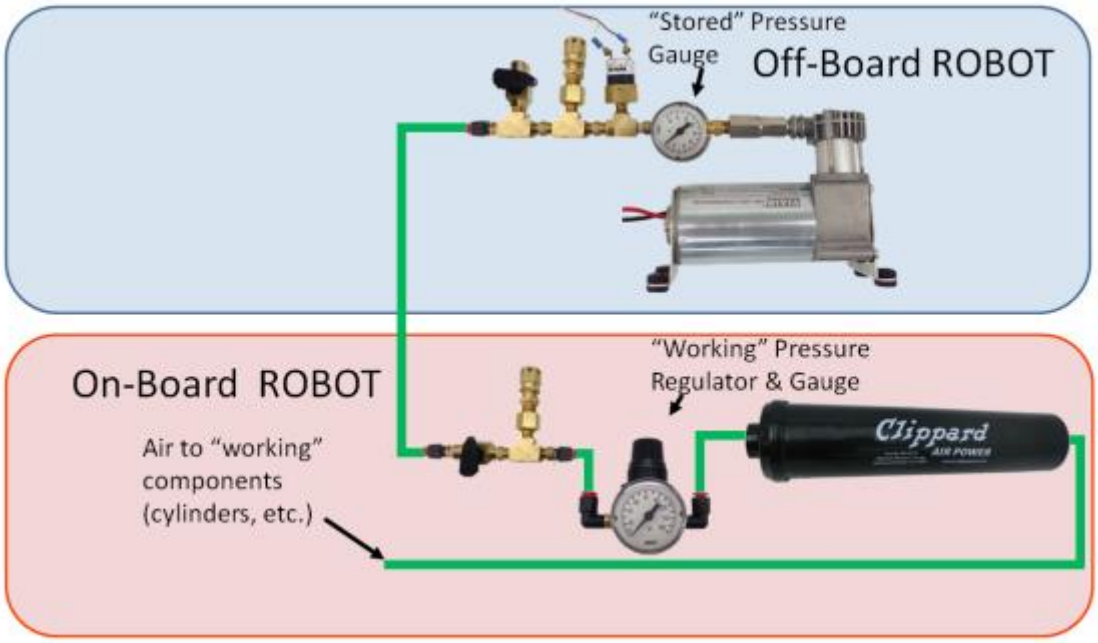
Appendix A

Example On Board Setups



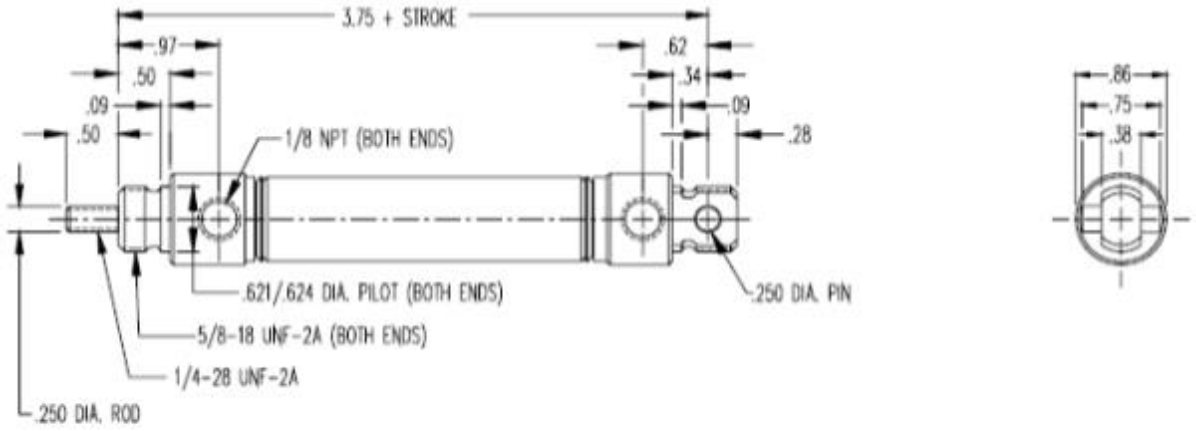
Example Off Board Setups

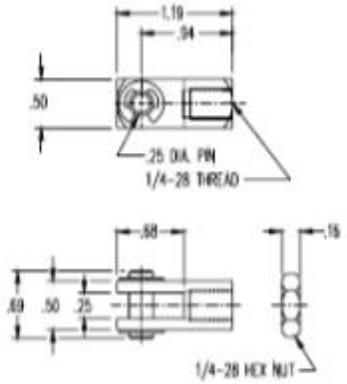




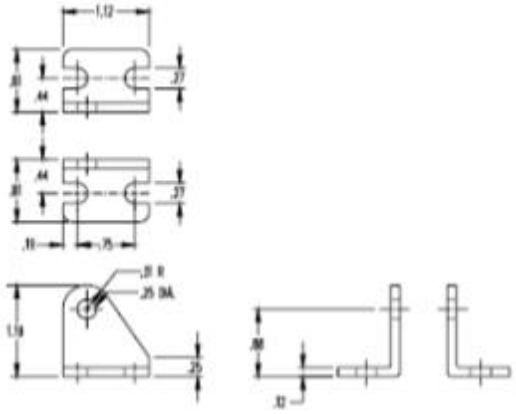
Appendix B

3/4" BORE





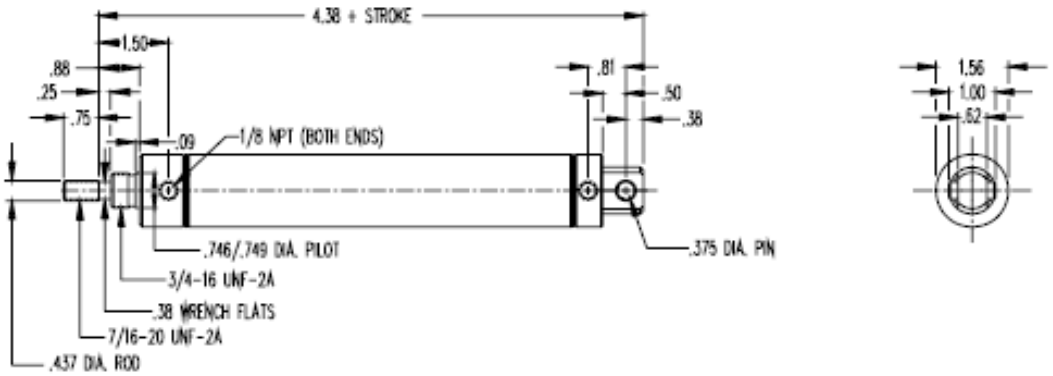
Rod Clevis
Bimba Part Number **D-166-3**

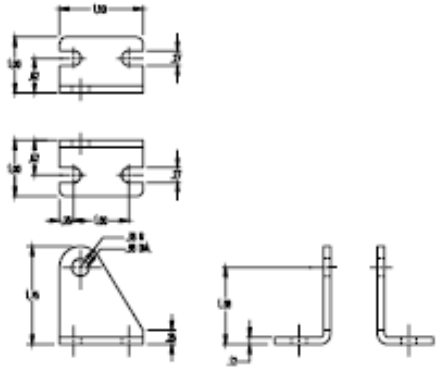


Rear Pivot Bracket
Bimba Part Number **D-167**

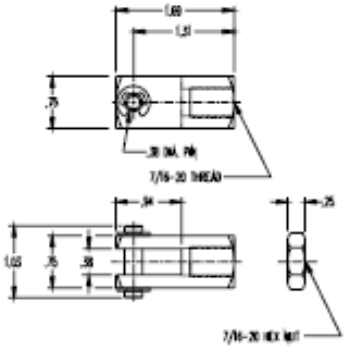
Appendix B

1-1/2" BORE





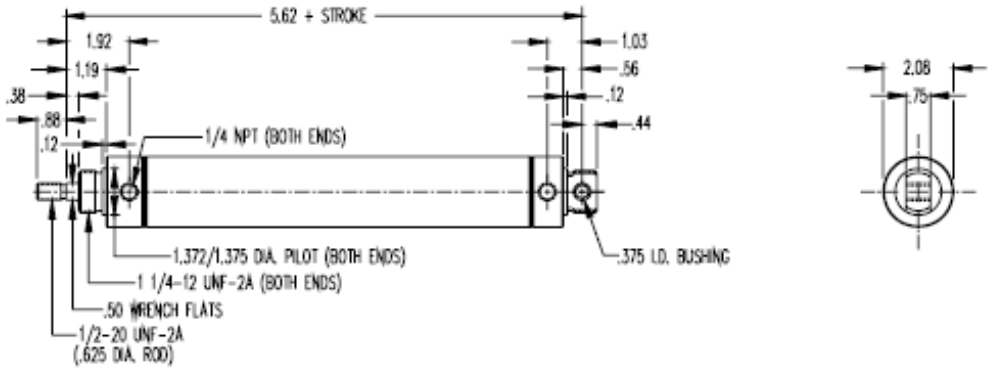
Rear Pivot Bracket
Bimba Part Number **D-229**

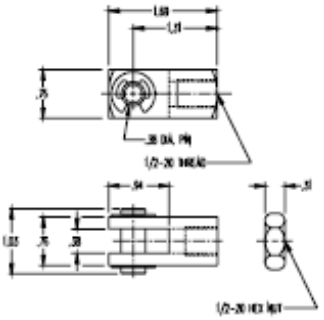


Rod Clevis
Bimba Part Number **D-231-1**

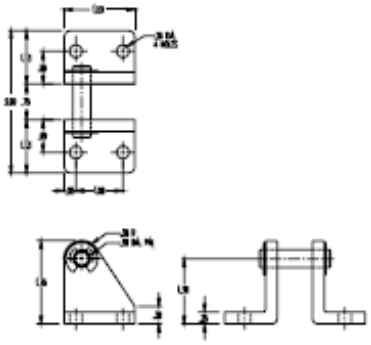
Appendix B

2" BORE





Rod Clevis
Bimba Part Number **D-231-3**



Rear Pivot Bracket
Bimba Part Number **D-620**

Appendix C

Extend and retract forces of all three bore sizes

	3/4" Bore	3/4" Bore
Pressure	Force Extended	Force Retracted
(pounds/sq. inch)	(pounds)	(pounds)
20	9	8
25	11	10
30	13	12
35	15	14
40	18	16
45	20	18
50	22	20
55	24	22
60	26	24
	1-1/2" Bore	1-1/2" Bore
Pressure	Force Extended	Force Retracted
pounds/sq. inch	(pounds)	(pounds)
20	35	32
25	44	40
30	53	48
35	62	57
40	71	65
45	79	73
50	88	81
55	97	89
60	106	97
	2" Bore	2" Bore
Pressure	Force Extended	Force Retracted
pounds/sq. inch	(pounds)	(pounds)
20	63	57
25	79	71
30	94	85
35	110	99
40	126	113
45	141	128
50	157	142
55	173	156
60	188	170