Pneumatics Step-by-Step
(For the roboRIO Controller)

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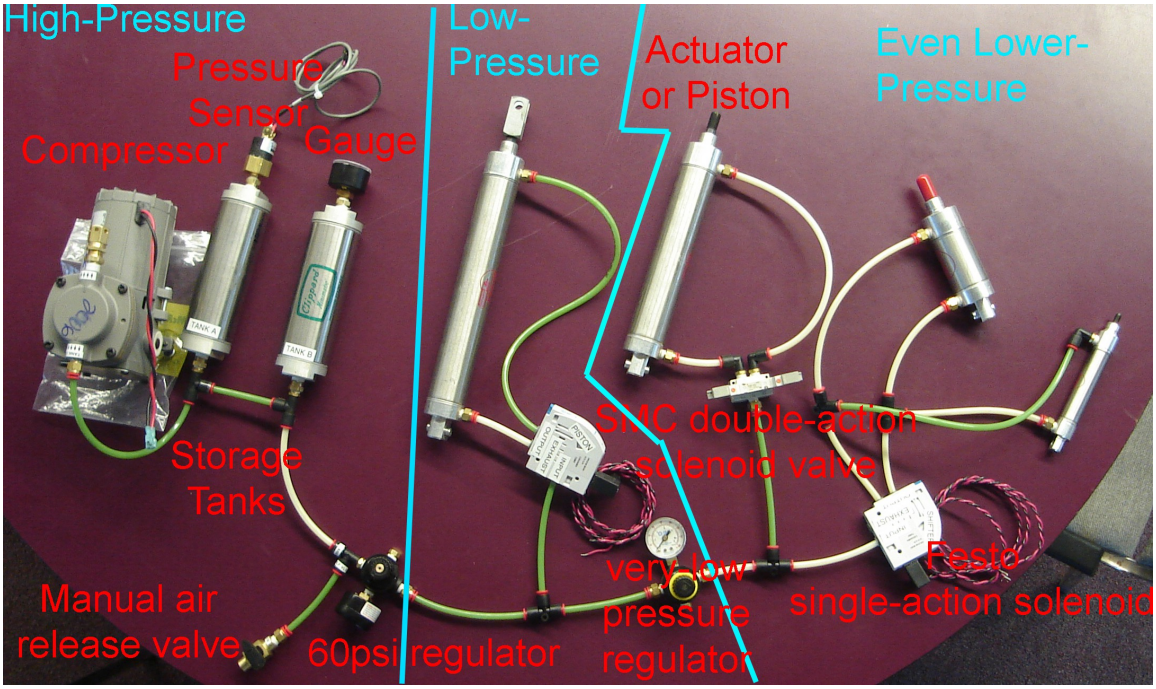
How to Assemble Your Pneumatics

It's a good idea to plan ahead and layout all your parts on a big table or the floor before you begin connecting things, and of course a layout design is always helpful. For help with designing pneumatics circuits see: http://team358.org/files/pneumatic/PneumaticsForNewbies.pdf.
This Step-by-Step goes through all the mechanical connections and pneumatic system testing, before adding in the electronic side that powers it, and finally the computer controls, but we begin right away with running the compressor with a battery to test for air leaks as each circuit stage is completed.



Compressor

Parts needed: compressor, emergency relief valve, brass fittings, Teflon tape

1. Use brass fittings at the compressed air output. This will get hot, so the initial fittings must be brass to distribute the heat before it gets close to plastic tubing.
2. Attach the pressure safety valve to the compressor via a brass T-fitting. Some models have an extra port that can be used directly. (use Teflon tape as a seal)
3. Other brass fittings can be used to connect the gauge/pressure switch if desired.
4. Finish up with a push-to-connect fitting. (use Teflon tape as a seal)
5. Mount the compressor using the vibration dampers (otherwise known as rubber feet) to minimize rattling everything else on your robot loose.

High-Pressure Circuit

Parts needed: storage tank(s), pressure sensor, manual relief valve, gauge, push-to-connect tube fittings, brass fittings, tubing, Teflon tape. Lots of plumbing setup variations are possible here.
Most common mistakes: not sealing *everything* with Teflon tape, not checking for leaks section by section as you go, not making all tubing cuts as <u>square</u> as possible.

1. Add fittings to one or more storage tanks using Teflon tape, note some tanks, e.g., black Clippard, come with built-in push-to-connect fittings.
2. Add pressure sensor using Teflon tape to a brass fitting or a storage tank that accepts screw fittings. Brass fittings then can connect directly to the compressor or add push-to-connect fittings to connect to plastic tubing.
3. Add a push-to-connect fitting to the manual relief valve using Teflon tape
4. Add pressure gauge using Teflon tape to brass/push-to-connect fittings or a storage tank that accepts screw fittings.
5. Add manual relief valve via a push-to-connect fitting. This lets you release pressure when you are one.
6. Leave tail to add 60psi regulator later, but plug it temporarily, e.g.,

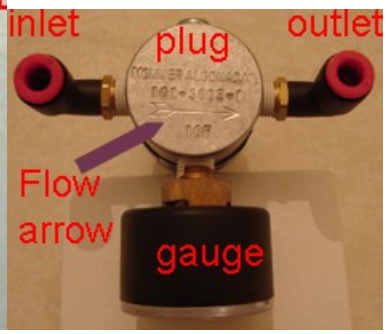
 or 

7. Connect all tubing
8. **Test** by connecting the compressor directly to a 12v source and watch the gauge climb to about 60psi and disconnect. The compressor is not yet controlled, so it will not automatically stop yet.
9. Check for leaks and correct any you find. Get it to sit for 10 minutes without any leaking.
10. Adjust the pressure safety valve to 125psi. Do so by running the pressure up to 130psi, loosen the lock nut in the center and twist the knob until pressure drops to 125psi, then retighten the lock nut. This valve is intended to bleed air if pressure ever gets above the limit setting.

Low-Pressure Circuit

Parts needed: regulator, solenoid(s), cylinder(s), multiple push-to-connect tube fittings, brass fittings, tubing, Teflon tape.
Most common mistakes: incorrect assembly of the regulator by not recognizing the high-pressure port. Not using the correct solenoid ports.

1. Assemble the regulator using Teflon tape
    a. The regulator typically has 4 openings. Only ONE of these is for the high-pressure input tube, the other 3 are all low-pressure outputs.
    b. The low-pressure port *indicated by the point of an arrow* gets a push-to-connect tube fitting using Teflon tape
    c. The ONE port is at the tail of the arrow, opposite the low-pressure outlet, is for the high-pressure input. Add a tube fitting for high-pressure air using Teflon tape. All other outputs are low pressure and if unused should be plugged.
    d. Add a pressure gauge to either of the remaining two ports using Teflon tape
    e. The last port can also have a push-to-connect fitting or use the plug packed with the regulator to seal unused ports using Teflon tape.

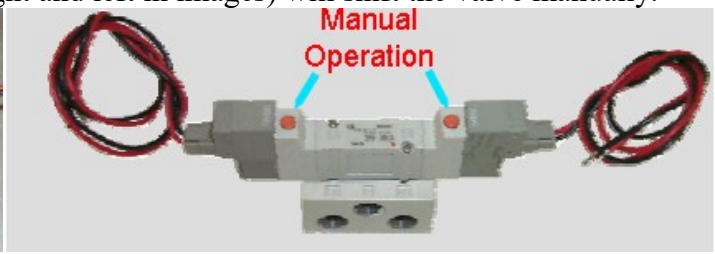


2. Add the 60psi regulator to a tube from the tail-end of the High-Pressure Circuit.
3. **Test:** Plug the low pressure regulator outputs temporarily with a loop back as we did before for the high-pressure test and do another pressure test up to 115psi. If the high pressure line is in the wrong regulator port, then the high pressure gauge at the compressor will not be able to rise above 60psi. The gauge on the low-pressure port of the regulator should read no more than 60psi. Adjust the regulator to the low-pressure you want, e.g., 60-30psi. The regulator has a lock ring that gets pulled straight out, then the big knob can adjust the low-pressure. Relock when finished. Correct any leaks before proceeding.
4. Assemble solenoids if required, following the manufacturer's instructions. In general:
    a. Check the solenoid to see if it is 24VDC or 12VDC, and be sure you have the right one for the voltage you have chosen to use. Voltages cannot be mixed on a single PCM.

    b. If the manifold with the ports comes separately, then add it to the main body being careful to use the rubber seal
    c. Add tube fittings to the input and output ports using Teflon tape.
    d. For each output (1 for a single solenoid, 2 for a double) there will be a corresponding exhaust port. Don't use fittings on the exhaust ports-leave them open.
5. Connect regulator via tubing to one solenoid at a time, so you can pressure test each new addition
6. Add tube fittings to cylinder(s) using Teflon tape
7. Connect the solenoid(s) to cylinders with tubing
8. If you will have an even lower-pressure circuit, or other solenoids to come, then leave a tail plugged for testing
9. **Test**: Run the compressor as before to see if the circuit holds air. The solenoids can be tested manually using little press buttons on each. you may have to use a pen to push them. Correct any leaks before proceeding.

    Note: the single solenoids will revert to the default position when the override button is released, but the double solenoid will stay in position. Some solenoid models allow a twist that locks the button in position. Be careful <u>not</u> to lock the buttons.

Pushing the blue or orange buttons (on the right and left in images) will shift the valve manually.



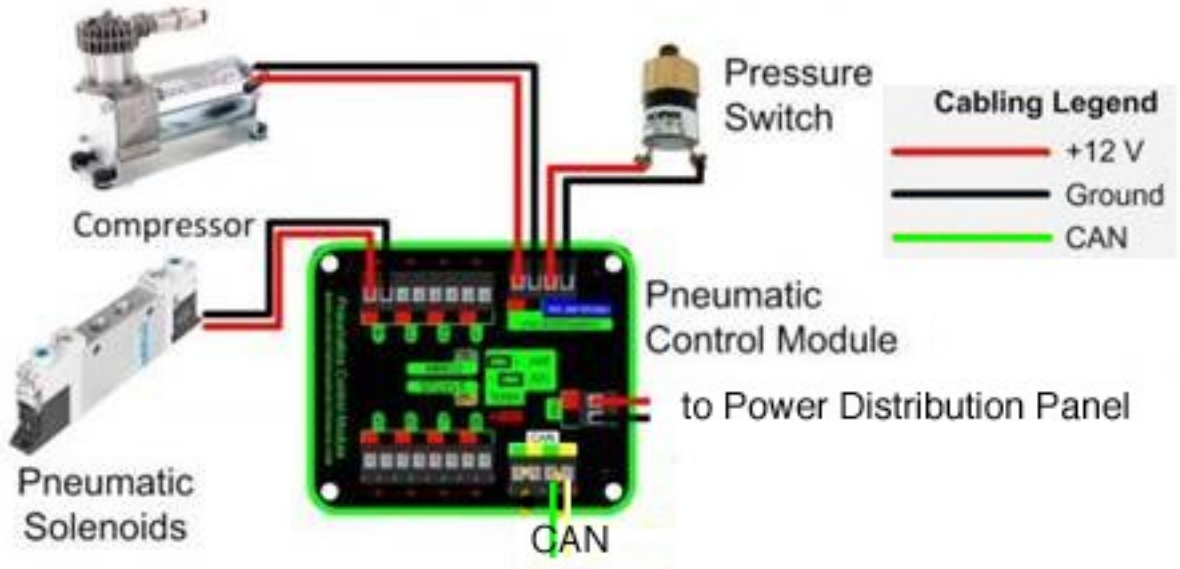
Multiple Low-Pressure Circuits

If you need to operate cylinders at two different pressures, e.g., one at 60psi and another at 30psi, then just add additional regulators as necessary. Subsequent regulators will not be able to set a pressure higher than the previous low-pressure system it connects to.

For additional lower pressure circuits repeat as for the Low-Pressure Circuit above with an additional regulator attached to the previous low-pressure setup.

roboRIO Wiring

We'll assume the rest of your roboRIO control system is already setup properly. Parts needed: black/red wire, green/yellow wire, roboRIO, Power Distribution Panel, Pneumatics Control Module.
Most common mistakes: Not using color coded, e.g., red/black wire, making it easy to mis-wire.



CAN

In the roboRIO control system pneumatics are entirely handled by the Pneumatics Control Module (PCM) and controlled via the CAN bus from the roboRIO. This means that green/white wires must connect the two

together. Connect the CAN terminals on the roboRIO to one of the sets of CAN terminals on the PCM (either of the two sets of CAN terminals on the PCM will do**).**

Next, the PCM should have a CAN address of "0" for the first one and any other unique CAN numbers if more PCM's are used. Several PCM's can be used if you need to control more solenoids, but the PCM at CAN ID "0" should be used to control the single compressor we are allowed in FRC.
To check or set the PCM CAN ID connect a laptop to the roboRIO and use a browser to browse to roboRIO-TEAM.local, where TEAM is your team number (no leading zeros).
If powered and CAN is wired correctly, the PCM will be listed on the left of the screen. Click on it and set the CAN ID to zero if necessary.

Compressor

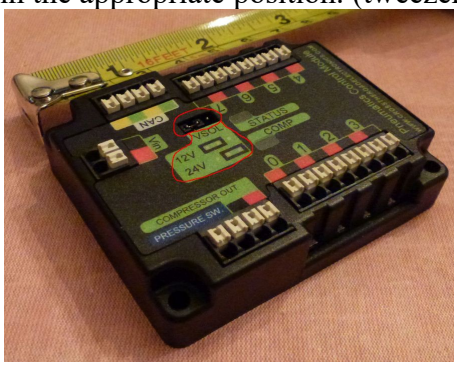
Wire the compressor directly to the PCM terminals marked "compressor out". This may be difficult because the wires and insulation are large. Strip the wire 8-10mm and give it a test tug to make sure they are secure. If these give you too much trouble the larger wires can be soldered to a short piece of slightly smaller gauge wire to make the connection.

Pressure Switch

1. Use only signal & ground from a PWM-style cable– the two outside pwm-cable wires, NOT power
2. Connects to the PCM terminals marked "pressure sw." Polarity doesn't matter.

Pneumatic Control Module (PCM)

1. The PCM power must be wired back to the Power Distribution Panel.
2. The CAN terminals must be wired to the roboRIO CAN terminals.
3. The PCM has a small jumper to specify the voltage required by all the attached solenoids, 12 or 24v.
   - Place the PCM jumper in the appropriate position. (tweezers may be required)



In general 24v solenoids are safer to use, because the PCM regulates the 24v output down to a very low robot battery voltage, while the 12v outputs simply follow the battery voltage down, threatening to brown-out the 12v solenoids.

Wiring Solenoid Valves

1. Wire the solenoid directly to the PCM:

a. A double solenoid has two sets of wires (a pair from each end) which are connected to individual solenoid terminals on the PCM.

b. A single solenoid has one set of wires (from only one end) which are also connected to solenoid terminals on the PCM.

c. This means a PCM has room for 8 single solenoids or 4 double solenoids, or some combination of the two types.

d. When a solenoid is activated by user code the PCM lights up a red indicator. See earlier PCM picture where 4 red solenoid indicators are activated.

Test Again!

Now that the compressor and pressure switch are wired up it is time to write code and test the automatic system.

1. Download code (whatever language) to the roboRIO that has defined at least one solenoid. That's all it takes to get everything running.
2. Enable from the Driver Station
3. The compressor should now run up to ~115psi and stop. After it stops bleed a little air from the manual relief valve and reseal to test that the compressor starts again when pressure drops below 95psi. If it doesn't pass any of these tests then check the wiring or the other settings and plumbings as called for.
4. On the PCM the Status light should blink green and the compressor light should be green only while the compressor is running.
5. The solenoids can be manually tested at this point if your code isn't ready to direct the solenoids.
6. When solenoid code logic is ready, test again.

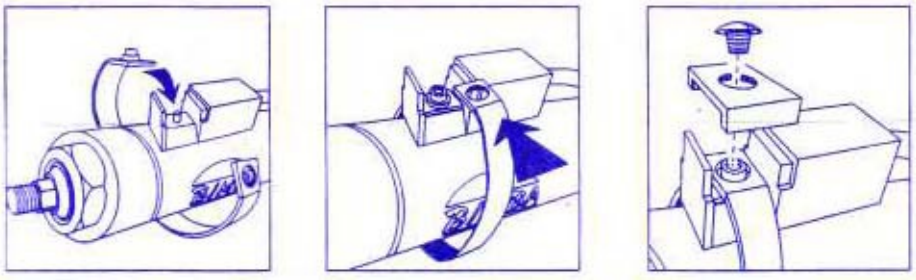
Special Parts

Flow control fittings

The cylinders normally operate as fast as the pressure allows, which can make for very quick and violent slamming. The reaction of a cylinder can be slowed down and softened by special adjustable flow control fittings that screw right into the cylinder ports. These types of fittings usually restrict the air flow in one direction only and are marked on the side with flow arrows (see photo) showing the direction restricted/unrestricted air flow. The large arrow is the unrestricted flow direction while the small arrow is the direction of air flow metered by the adjustable thumb dial. The thumb dial also has a locking nut underneath it to keep the setting from drifting during use.

Actuator magnetic reed switches/Magnetic cylinders:

These reed switches physically mount by clamps directly onto a special magnetic cylinder. They can be positioned anywhere along the cylinder to tell your code when a cylinder is open/closed or three-quarters open, for instance. Usually, a pair of reed switches will come with a magnetic cylinder order.
To hook these switches up to the control system, use just the signal and ground wires for a pwm-style cable. The pwm cable then connects to a Digital Input on the roboRIO.



Assembling Regulators (Revisited)

There is a definite right way to assemble these. Some styles have a large arrow on the back. You will note on some types that one port extends out a little bit more than the others. It may have the flow direction arrow on it to denote the low-pressure outlet of the regulator. The opposite port at the tail of the arrow is the high-pressure inlet. All other ports are low-pressure. A pressure gauge may be placed in any of the low-pressure ports. You will have to plug any unused ports with the enclosed hex plug(s). Seal all threads with Teflon tape.

Programming

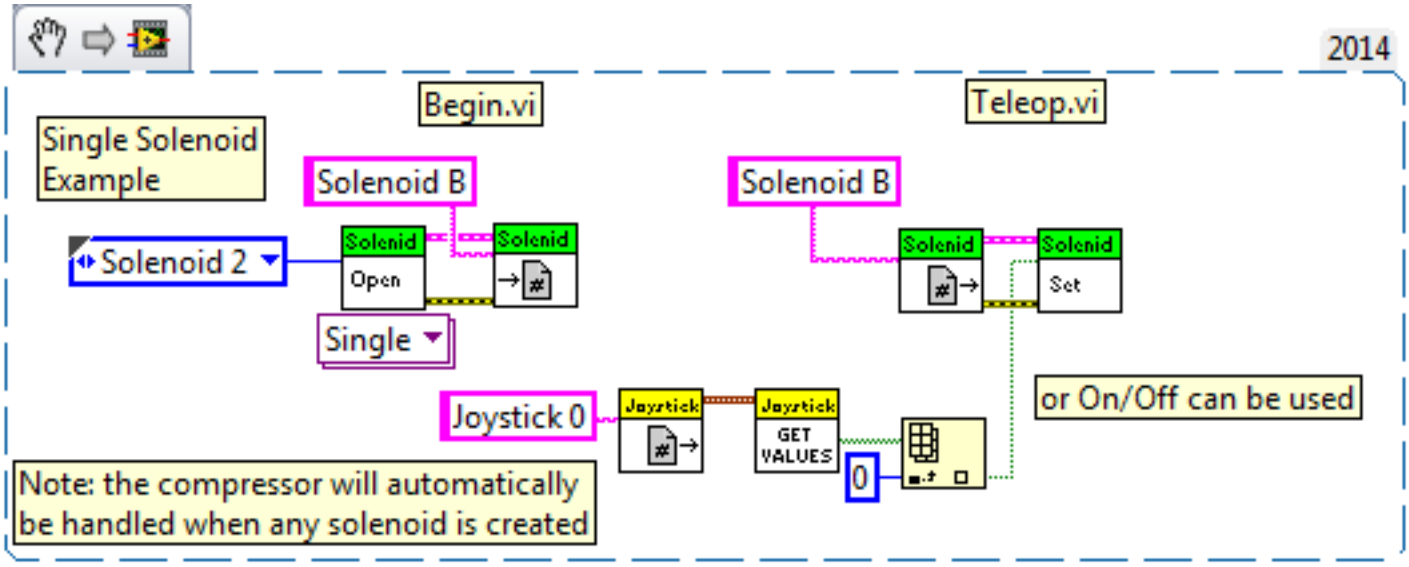
LabVIEW

The compressor is handled automatically when a solenoid is created, so no coding is required for that.
It is possible to force stop the compressor from automatically running, and in that case you will need to create a compressor in Begin.vi and give it a name , then elsewhere in the code add Start/Stop logic as desired.

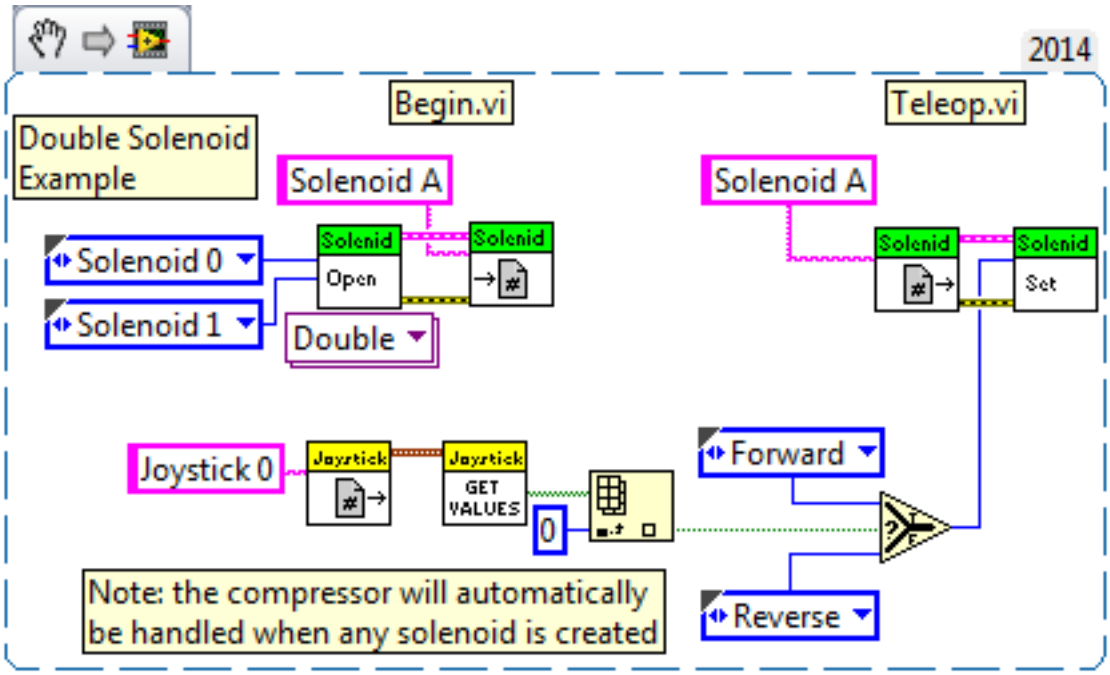
Solenoid

In these examples the trigger on joystick 2 controls the solenoid. The PCM also has status lights down on the side for each set of solenoid outputs that indicate (red light) when it is activated.

Single Solenoid example:



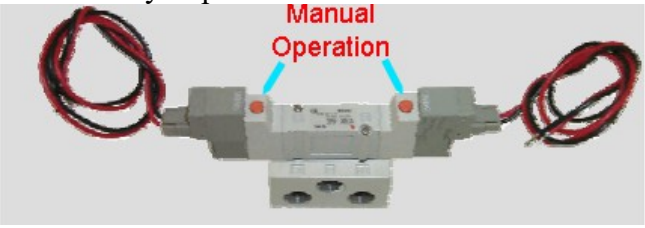
Double Solenoid example:



Troubleshooting

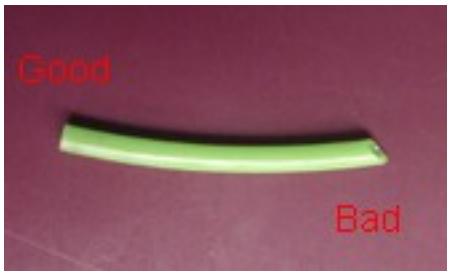
Sort of a checklist to evaluate problems, the key is patient and methodical checkout of the entire system.

- General layout
  - Parts in the wrong place
  - Pistons too large and powerful or too small and under powered.
  - Pressure too high or too low (<30psi). solenoids require 20-30psi to operate.
  - Piston moves too fast. Use flow valves fittings to slow down overly speedy pistons.
- Compressor won't shut off
  - Pressure sensor on the wrong side of the regulator
  - Regulator plumbed incorrectly (pressure won't rise above ~60psi)
  - Test the sensor output with a multi-meter (ohm setting)
- Compressor won't run
  - Compressor not wired to the PCM correctly
  - Sensor or compressor controlling pwm-cables not connected properly to the PCM terminals. If the sensor is not connected right, then by default read like the compressor is not running.
  - Pressure sensor mis-wired or not connected to the right PCM terminals
  - PCM has no power
- Pressure too high
  - Kinked or pinched tubing
  - High-Pressure side
    - The automatic release valve you added to the compressor my not be set correctly. If the high pressure ever gets above 125psi, then this is set incorrectly, no matter how much the compressor runs. It uses a double-nut to keep it secure, so make sure that's tight when you are done adjusting it.
  - Low-Pressure side
    - Almost always due to the regulator,
      - Check that the lone high-pressure output port on a regulator was used to connect to the compressor side.
      - The regulator may be set to a lower or higher pressure than you want. Adjust the regulator by loosening the locking ring and twisting the base ring while watching the attached gauge change.
- Pistons don't move
  - Solenoid tubed incorrectly
  - Solenoid/PCM not wired correctly
  - Software incorrect
  - Test solenoid manual override to see if it's a pressure or an electrical problem.
    - Festo - pressing the blue switch will shift the valve
    - SMC solenoids buttons are small, so you may have to use a pen to push them. Note: the single solenoids will revert to the default position when the override button is released, but the double solenoid will stay in position.



- Pistons moving in the wrong direction
  - Reverse the tubing going into the cylinder ends

- Regulator
  - Confusing the one low-pressure output port with the three high-pressure ports. On each regulator there is ONE port that is the low-pressure output, indicated by a directional arrow. The others are all high-pressure inputs/outputs.
  - Not dialing in the desired low-pressure.
  - Not tightening the adjustment dial lock.
- Air leaks
  - Use a dead-end tube into a plugged brass fitting or a T-fitting to isolate sections that are leaking. Isolate pressure sections one by one, disconnecting later so you can concentrate on controlling leaks in one a time.



  - Look for the big leaks first by feel. Don't be fooled by air flowing from the Victor or other fans in your robot. When you get it down to tiny leaks then judicious use of soap blowing bubbles, soapy water, Windex can help locate problem joints.
  - Square cut tubing – tubing cut at any sort of angle rather than as square as possible will leak air from the system. The tube end needs to rest very flat inside the fittings to prevent air leaks.
  - Rough/scratched tubing ends also will not seal correctly
  - Failure to use Teflon tape to seal all screw thread fittings
  - Proper use of Teflon tape
    - Any Teflon that's been used once before should be replaced. Always use fresh Teflon and clean off all remnants. This means any on threads that have been screwed in once, then take off again need to have the Teflon replaced before screwing it on again.
    - Stop the Teflon several threads before the end to avoid scraps coming loose and clogging the solenoid valves.
    - Wrap Teflon in the opposite the direction you'll be screwing the threads in (clockwise as you look from the tip), so it pulls tighter rather than bunching up.
    - Make sure the wrap overlaps itself, but wrap it no more than twice around.
  - Cut, nicked, or worn tubing
  - Damaged fittings having either damaged threads through general abuse, cross threading, etc., or the seal on the push tube connection can be damaged from rough tubes, debris, or yanking the tube out too many times instead of releasing it properly.
  - Leaky regulator or other parts
  - Leaky solenoids
    - Large leaks could be caused by debris in the valve such as odd bits of Teflon tape or dirt. Try replacing the solenoid.
    - Most solenoid valves seem to suffer from slight leaks that slowly let air out of any system. No real solution to this problem other than for the SMC you can disassemble and rearrange the gaskets between parts. You can test if this is your problem by temporarily blocking or looping-back the exhaust ports.
    - Solenoids have a minimum pressure required to work. Make sure they are getting a minimum of between 20 & 30psi.
    - A valve can be stuck in an in-between state and you'll feel excess air escaping from one of the open exhaust ports. The valves only operate if they have some minimum air pressure to start with. To reset a stuck valve, force it up to minimum operating pressure by blocking the valve leaking exhaust vent with your finger, you can easily hold in the pressure, and the valve will self-reset at 20-30psi.
- Air used too quickly
  - Oversized actuators. Place your solenoid valves as close to the cylinders as possible to minimize that little bit of volume needed to fill the tubing.

    - Add more storage tanks
    - Too many actuators
    - Actuators used too often
    - Low pressure, 60psi or less, is too high, so too much stored air gets used too quickly.
    - Solenoids will stop operating when the system pressure drops too low (e.g., 20psi to 30psi). Most FRC running compressors provide ~0.4 cubic foot of air per minute.
- Mis-wiring
    - Sensor PWM-style cable uses only signal and ground, NOT power.
    - Solenoid
    - Sometimes the SMC solenoids come with 24volt coils that must be replaced with 12v coils. Check to see each coil is printed with "12vdc."

Parts is Parts

Parts photos to help you identify what's what are shown in the FIRST Pneumatics Manual:
http://www.team358.org/files/pneumatic/2017pneumatics-manual.pdf
The pneumatics system is divided into a high pressure circuit where pressure is stored at 120psi, and one or more low-pressure circuits at 60psi or less, known as working pressure.

High Pressure parts

Air compressor
Storage tank(s) - 18.85 cu-in per tank
Pressure release – you must be able to manually dump the pressurized air in your system
Pressure gauge – must read 120psi or less at all times
Pressure sensor – must help the Robot Controller (RC) turn off the compressor at ~120psi (and on at ~95psi)
Primary 60psi Regulator – takes tubing for high-side pressure, low-side exit, a pressure gauge, and a plug for the extra port. Pay particular attention to the flow arrow so you use the special low-pressure outlet.

Low Pressure parts

Pressure gauge – must read 60psi or less
Actuator(s) – pistons that push and pull
Actuator(s) with magnetic reed switches incorporated
Solenoid valve(s) –

- Single action solenoid – has a home position it returns to when power is cut off.
- Double action solenoid – keeps an actuator in whatever position it was last in when power is cut off.
- Assembling SMC solenoid valves

Vacuum system
Secondary <60psi regulator(s) – optional to step pressure down to a second even lower operating pressure. Takes tubing for 60psi side, low-side exit, a pressure gauge, and a plug for the extra port. Pay particular attention to the flow arrow so you use the special low-pressure outlet.

General parts

All Brass fittings – plugs, 3-way,
Brass/plastic hybrids – straight, right angle
All Plastic fittings – 3-way tube,
Tubing