

Pneumatics Step-by-Step

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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, (1) tube fitting, Teflon tape

1. Attach the pressure safety valve to the compressor (must use Teflon tape as a seal)
2. Add a tube fitting to the output port using Teflon tape
3. Test the compressor by connecting the wires directly to a 12v source briefly

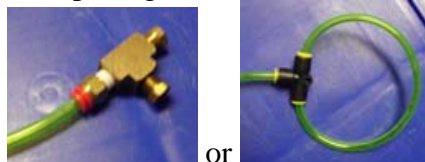


High-Pressure Circuit

Parts needed: storage tank(s), pressure sensor, manual relief valve, gauge, multiple tube fittings, tubing, Teflon tape.

Most common mistake: not sealing *everything* with Teflon tape and not checking for leaks section by section as you go.

1. Add fittings to one or more storage tanks using Teflon tape
2. Add pressure sensor using Teflon tape
3. Add manual relief valve using Teflon tape
4. Add pressure gauge using Teflon tape
5. Leave tail to add 60psi regulator later, but plug it temporarily, e.g.,



or



6. Connect all tubing
7. Test again by connecting the compressor to a 12v source and watch the gauge climb. The sensor is not yet hooked up, so it will not automatically stop yet.
8. Check for leaks when you stop the compressor and correct any you find

Low-Pressure Circuit

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

1. Assemble the all-black regulator using Teflon tape
 - a. The low-pressure port *indicated by an arrow* gets a tube fitting using Teflon tape
 - b. The port opposite the low-pressure outlet is for the high-pressure input. Add a tube fitting for high-pressure air using Teflon tape
 - c. Add a pressure gauge to either of the remaining two ports using Teflon tape
 - d. Add the plug packed with the regulator to the final unused port using Teflon tape

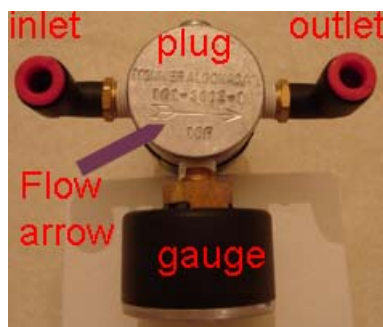


2. Add the 60psi (all black) regulator to a tube from the tail-end of the High-Pressure Circuit.
3. Assemble SMC solenoid if used or use the pre-assembled Festo or Bosch-Roxroth
 - a. Swap out any 24VDC ends for 12VDC replacements on the main body



- b. Add the separate ports to the main body careful to use the rubber seal
 - c. Add tube fittings to the input and output ports using Teflon tape
4. Connect regulator via tubing to one or more solenoids
 5. Add tube fittings to cylinders using Teflon tape
 6. Connect the solenoid(s) to cylinders with tubing
 7. If you will have an even lower-pressure circuit, then leave a tail plugged for testing
 8. Run the compressor as before to see if the circuit holds air. The solenoids cannot be tested yet.
Adjust the regulator to the low-pressure you want, e.g., 60-30psi.

For additional lower pressure circuits repeat as for the Low-Pressure Circuit above, but using the regulator with the yellow ring.





Tubing Solenoid Valves

- Festo (single solenoid)
 - Fully assembled, simply push the tubing into the ports.
 - Port 1 - pressure input – minimum of ~35psi for the valve to work
 - Port 2 – output to cylinder. relay1_fwd=0; means pressure is coming out (default position)
 - Port 3 - exhaust for excess air leaving cylinder
 - Port 4 – output to other end of cylinder. relay1_fwd=1; means pressure is coming out
- SMC (single & double solenoids)
 - This has to be assembled from several parts. 1) the main body, 2) the ports/gaskets, 3) screw SMC fittings. You'll need a miniature screwdriver, such as those used to fix eyeglasses. Then the tubing is pushed into the fittings.
 - – minimum of ~20psi for the valve to work
 - "X" and "PE" are not used.
 - "EA" and "EB" are the exhaust for the "A" and "B" ports.
 - "A" & "B" go to the two ends of a cylinder
- Bosch-Rexroth (single solenoid)
 - Fully assembled, remove the grey nut and slide it onto the tubing, push the tubes onto the port, tighten the grey nut to secure it.
 - "P" – pressure input
 - "B" - output to cylinder. relay1_fwd=0; means pressure is coming out (default position)
 - "A" - output to other end of cylinder. relay1_fwd=1; means pressure is coming out
 - "R" – exhaust port

Wiring

Parts needed: black/red wire, female spade connectors, breaker panel, 20a snap-action breaker for each Spike used plus an extra one for the compressor's Spike, one Spike for each solenoid and one for the compressor, 12v battery, (2) Anderson connectors, 12v on/off switch.

Most common mistakes: Not using color coded red/black wire making it easy to mis-wire, and not recognizing the difference between:

- RC PWM outputs (not used in pneumatics)
- Digital Inputs/Outputs(inputs used for Pressure Switch & Reed switches)
- Relay Outputs (used for spikes controlling solenoids and the compressor)
- Analog Inputs (not used in pneumatics)

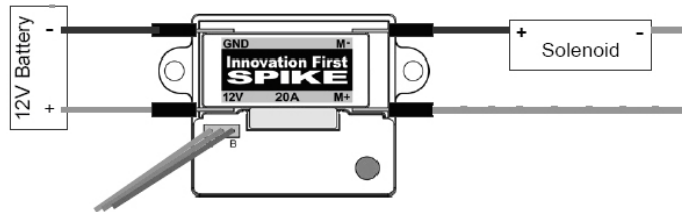
Compressor First

Most common mistake: wiring the compressor backwards (no it will not suck air out).

1. Wire the compressor to a Spike using female spade connectors
2. Replace the Spike fuse with a 20a snap-action breaker
3. Wire the Spike to the breaker panel using more female spade connectors
4. Add the 20a snap-action breaker
5. Wire the red (positive) side of the breaker panel to a 12v on/off switch
6. Wire the breaker panel black (ground) to an Anderson connector
7. Wire the on/off switch to the Anderson connector
8. Connect a 12v battery with a matching Anderson connector
9. Flip the on switch and see if the compressor runs
10. Note: The compressor will run in reverse, just less efficiently, so make sure red goes to M+.

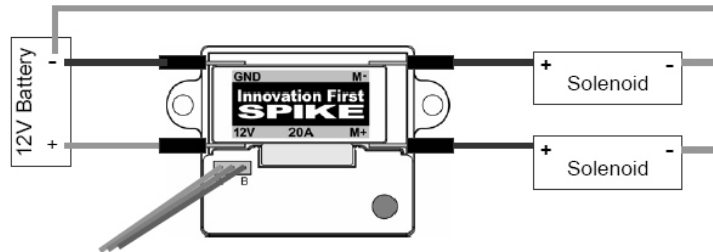
Solenoids Second

1. Add wires to the solenoid(s) connectors if necessary
 - a. Festo - Slide the gray connector from the black housing (can be pushed out from top with supplied screw), and wire 1 – Negative, 2 – Positive.
 - b. Bosch-Roxroth - Two connectors are included, crimp and wire onto the connectors and then just push one over each spade.
2. Wire the solenoid to a Spike using female spade connectors
 - a. Single-action solenoid (Festo, Bosch-Roxroth and some SMCs) just wire black to M- and red to M+



Spike Wiring for One Solenoid

- b. Double-action solenoid (some SMCs) has 4 wires. The two reds go to M+ and M- respectively, while the two blacks join and go to the breaker panel. See the diagram.

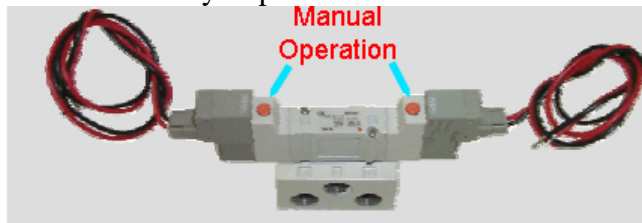


Spike Alternate Wiring for Two Solenoids

3. Wire the Spike to the breaker panel using female spade connectors
4. Add a 20a snap-action breaker for each solenoid
5. Flip the on switch and quickly, as the compressor runs, manually test each solenoid. Indicator lights on the Spikes should all be on and solenoid indicator lights will go on as they are operated. Your cylinders should be moving in and out as you manually operate the solenoids.
 - a. Festo - moving the blue switch (bottom left in image) in the direction of the arrow will shift the valve



- b. 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.



- c. Bosch-Rexroth - The yellow arm on the opposite side of the valve is the manual override. On this valve you can turn the override on and leave it in that position.

Pressure Switch

1. Use only signal & ground – the outside pwm-cable wires, NOT power
2. Connects to an RC Digital Input (default code expects Digital Input 18)

Special Parts

Actuator magnetic reed switches use just the signal and ground wires for a pwm-style cable. The pwm cable then connects to a Digital Input.

Controls

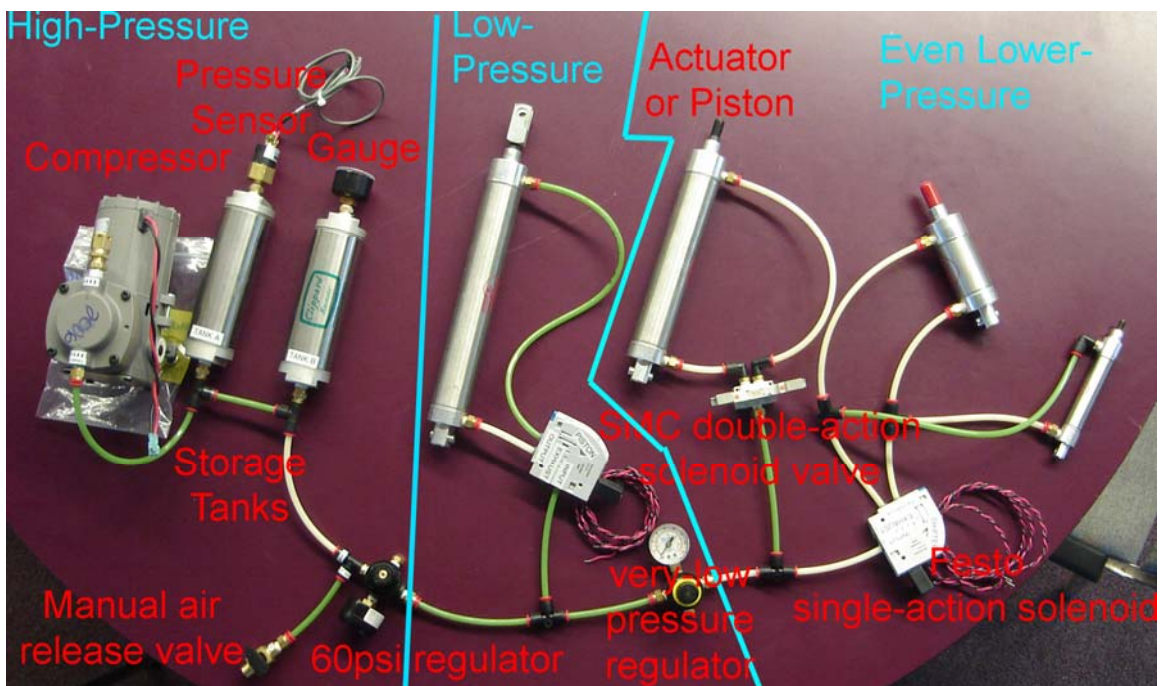
Parts needed: Robot Controller/Operator Interface, pwm cables, female spade and open-end connectors, tether cable, 20a snap-action breaker, red/black wires, joystick. Assumes the Default code is already loaded in the RC (as it comes delivered in the KOP).

Most common mistake: not hooking Spikes to RC **Relay** outputs

1. Connect the compressor Spike to **Relay 8** output on the Robot Controller using a pwm-style cable
2. Connect each of the solenoid Spikes to any available **Relay** outputs on the Robot Controller using pwm-style cables
3. Connect the Pressure switch to **Digital Input 18** using a pwm-style cable. The power or center wire is NOT used. Only connect the two outermost wires, signal and ground.
4. Connect the Robot Controller to the breaker panel using female spade and open-end connectors, then add a 20a snap-action breaker for it.
5. Tether the Operator Interface to the Robot Controller, add a joystick or other control you'll use for testing the solenoids to one of the OI joystick ports.
6. Flip the on switch and the compressor should start up
7. The compressor should automatically turn off when 120psi is reached on the High-Pressure Circuit gauge. Watch the gauge and wait for it. Troubleshoot.
8. The compressor will be turned on again when the high-pressure drops below 95psi.
9. Test the operation of each solenoid by a joystick attached to the OI ports

Controls described assuming a standard KOP joystick:

- Joystick port 1 trigger and thumb buttons control relay 1
- Port 1 buttons on the face to either side of the hat button controls relay 5
- Port 2 trigger and thumb buttons control relay 2
- Port 3 trigger and thumb buttons control relay 3
- Port 3 buttons on the face to either side of the hat button controls relay 6
- Port 4 trigger and thumb buttons control relay 4
- Port 4 buttons on the face to either side of the hat button controls relay 7



Programming Beyond the Default Code...

- Compressor
 - rc_dig_in18 = 0 when the sensor wants the compressor to run and =1 when the compressor should be off.
- Single-action solenoid valve
 - relay1_fwd = 0; relay1_rev=0; -one direction
 - relay1_fwd = 1; relay1_rev=0; -the opposite direction (rev is used for ground in both cases)
 - Takes <15ms to react
- Double-action solenoid valve
 - relay1_fwd = 0; relay1_rev=1; -one direction
 - relay1_fwd = 1; relay1_rev=0; -the other direction
 - Takes <15ms to react
- Actuator magnetic reed switches – Are read by the RC as any other switch through any Digital Input
- Click & release vs. click & hold

Assembling Regulators (Revisited)

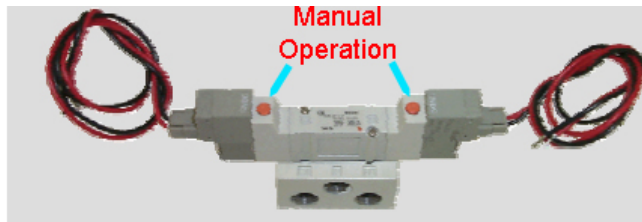
There is a definite right way to assemble these. You will note that one port extends out a little bit more than the others. It also has an arrow on it to denote the low-pressure outlet of the regulator. The opposite port is the high-pressure inlet. A pressure gauge may be placed in either of the other ports. You will have to plug the other gauge port with the enclosed hex plug. Seal all threads with Teflon tape.

The all-black regulator must be used for stepping down the high-pressure, but the regulator with the yellow ring can be used between your low-pressure circuit and an even lower pressure sub-circuit.

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
 - Sensor or compressor controlling pwm-cables not hooked to the correct Digital Input or Relay Output. If the sensor is not connected right, then typically Digital Inputs by default read like the compressor should be running.
 - Test the sensor output with a multi-meter (ohm setting)
- Compressor won't run
 - Compressor not wired to the spike to the breaker panel correctly
 - Missing spike breaker
 - Pressure sensor mis-wired or not connected to the right Digital Input
 - Fuse blown in the compressor spike
 - Sensor or compressor controlling pwm-cables not hooked to the correct Digital Input or Relay Output
- Pressure too high or too low (see testing for air leaks below)
 - Kinked or pinched tubing
 - High-Pressure side
 - An uncommon reason can be the automatic release valve you added to the compressor. It comes pre-set for 125psi and shouldn't be tampered with, but it can be knocked out of adjustment if the wrong piece was twisted by an inexperienced student. It does not let the high pressure get above 125psi no matter how much the compressor runs. It uses a double-nut to keep it secure, so with NO pressure in the system release the thin inner lock nut and tighten the larger, outer cap to increase the release pressure.
 - Low-Pressure side
 - Almost always due to the regulator,
 - Check that the low-pressure output port was used.
 - 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/spike not wired correctly
 - Spikes are controlled by RC Relay outputs. Make sure the spike pwm-style cable is hooked to a Relay.
 - Software incorrect
 - Test solenoid manual override to see if it's a pressure or an electrical problem.
 - Festo - moving the blue switch in the direction of the arrow 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.



- Bosch-Rexroth - The yellow arm on the opposite side of the valve is the manual override. On this valve you can turn the override on and leave it in that 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 loopback T-fitting to isolate sections that are leaking. Isolate leaking pressure sections one by one, disconnecting later sections so you can concentrate on controlling leaks in one section at 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 or nicked 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.

- Rarely, 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 (20psi for SMC & Bosch-Roxroth, 30psi for Festo). The running compressor provides .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. 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