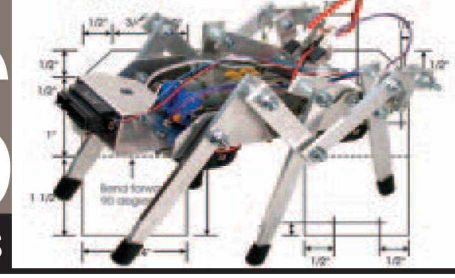


■ BY VERN GRANER

PNEUMATICS IN ROBOTICS

THE PRESSURE'S ON!

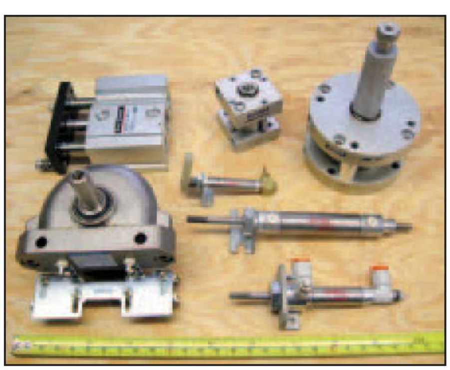
In taking some of my own advice from last month's Robo Resolutions article, this month we're going to try something new! Let's dip our toe into some possibly unfamiliar waters as we explore the world of electronically controlled pneumatic actuators for hobby robotic and animatronic mechanisms.

PLUMBING THE DEPTHS OF PNEUMATICS

In the world of experimental and hobby robotics, servo motors and solenoids tend to dominate the landscape. This is most likely due to the simplicity of using a single power source for all the functions (movement, computing, sensors, etc.).

However, in commercial automation and industrial assembly lines, many of the moving systems rely on compressed air and air-powered actuators of various types (**Figure 1**) to do the work. One of the interesting things you'll discover when you start to play with the components of a pneumatic system is that what you're actually doing is *plumbing*! Subsequently, you get to explore a whole new set of schematic symbols and terminology. To help you get started, I've included a link to some common pneumatic symbology in the Resources section.

■ Figure 1. Examples of typical pneumatic actuators.



THE BASIC PARTS OF A PNEUMATIC SYSTEM

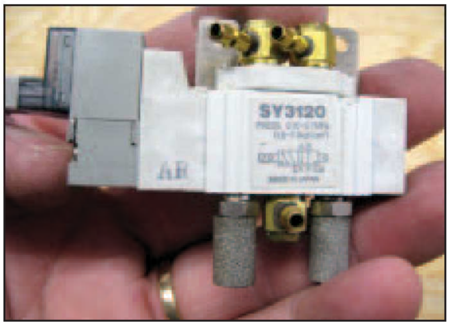
Since there are plenty of great resources on the Internet to get you going with pneumatics, in this article I'm only going to give a quick overview of the basic parts you will need in order to start experimenting with pneumatics for your next robotic project.

■ Figure 2. A 1.5 gallon workbench portable air compressor. This unit features much quieter operation than most typical "pancake" type compressors.

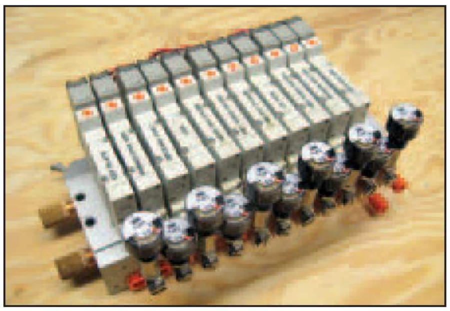
Compressor: (**Figure 2**) When using pneumatics, you need a ready supply of compressed gas. This is typically provided by an air compressor. Though many of the pneumatic systems incorporated into "battling" robots use high-pressure CO_2 systems (for both strength and portability), I wanted to have a non-exhaustible air source that didn't require me to get tanks refilled. For my experimentation, I purchased a 1.5 gallon, 150 psi

■ Figure 3. An air pressure regulator. PLEASE NOTE: A *flow* regulator is not the same thing as a *pressure* regulator! A flow regulator simply limits the speed the air may pass through the device and does NOT limit pressure! Be sure to read the description carefully before making a purchase so you don't end up with the wrong part!

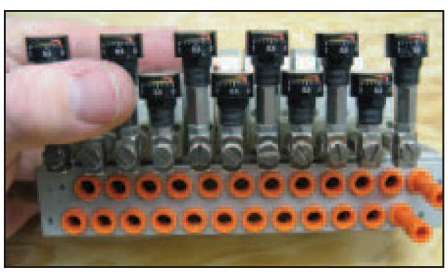
■ Figure 4. A 12 VDC five port, two position solenoid valve.



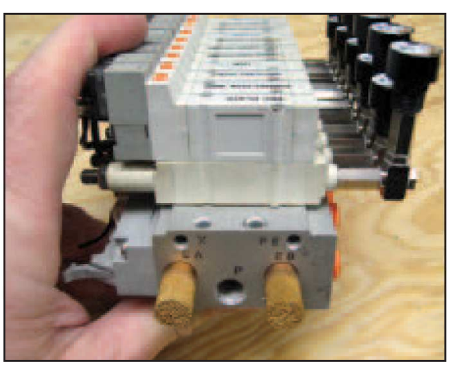
■ Figure 5. A 12 valve pneumatic manifold with eleven 24 VDC five port, two position valves installed.



■ Figure 6. The actuator connector section of the valve manifold. These are easy to use "press collar" type connectors making hook up and experimentation easy. The last two ports are blocked with plugs as the manifold only has 11 of the 12 sockets used.



■ Figure 7. Sideview of the manifold shows the Exhaust A and B mufflers in place and the connection point for air pressure (labeled P).



air compressor from Sears for about $125. I figured the compressor might come in handy as a workbench accessory, and boy was I right (see the compressor sidebar)!

Regulator: (**Figure 3**) Though most compressors come with a regulator built in to the unit itself, I found it's handy to be able to tailor the amount of air delivered to each pneumatic device. Also, in the event that you have multiple pneumatic devices being powered by a single air source, having a regulator at each device allows you to run your main air lines at a higher pressure and then adjust the pressure at each device to the minimum required to operate a given actuator.

For example, you could run your main air line at a pressure high enough to allow one device on your system to lift a heavy load, yet still allow another device on the same feed line to drop the pressure for a small cylinder performing more delicate work. It's a good rule of thumb to use only as much pressure as is necessary in order to get a given device to function. Having regulators on each device allows you to avoid having the highest pressure requirements dictate pressure for all devices on the same air feed.

Solenoid Valve: (**Figure 4**) In order to operate a pneumatic actuator, you need to be able to control where and when the air flows to the device. A solenoid valve allows you to use the presence or absence of power to route air pressure. Typical industrial solenoid valves use 24 volts to operate (though 12 volt and 110 VAC solenoid valves are available) and come in many different configurations. My preferred solenoid valve is a five port, two way solenoid valve such as those available from Burden's Surplus Center (**www.surpluscenter.com**).

This type of valve has a port for pressure (labeled P) and then has two ports for a dual-acting cylinder labeled A and B. When pressure is applied to the P port, it is sent to the A port and the B port is routed to the exhaust port EB. When power is applied to the solenoid, pressure is re-routed to the B port while the A port is then routed to the exhaust EA port.

A five port, two position valve — when combined with a dual-acting cylinder — provides a positive return, i.e., it doesn't rely on a spring or gravity to return the cylinder to its start position. It's also very efficient as it only uses the amount of air held in the air cylinder's interior for each activation. Using less air reduces the compressor requirements and will also reduce the number of cycles your compressor will need to run to keep sufficient air available as the pneumatic actuator is operated.

Sometimes a group of valves are placed on a manifold so that you only need to provide one source for air pressure to serve multiple pneumatic actuators (**Figure 5**). From my contacts through The Robot Group here in Austin, I was lucky enough to end up with a couple of these manifolds that were removed from a large industrial test machine. The manifolds hold multiple five port, two way valves with press-fit connectors for the A and B ports (**Figure 6**).

In addition, all exhaust ports are ganged so you only have two exhaust vents to deal with. Depending on the pressure, the exhausting air can be fairly loud. Many systems use air baffles or mufflers in order to reduce the noise levels (i.e., the hiss of the exhaust). In the manifold I have, all the valve exhausts are sent to single exit points labeled EA (Exhaust A) and EB (Exhaust B). These ports have brass mufflers to lower the noise levels produced when the device is in operation (**Figure 7**).

The sound pressure levels generated by a device are an important consideration as long term exposure to loud sounds can lead to hearing loss. In some cases, the sound made by the venting gas could be detrimental to the operation of the finished device itself. If you're using pneumatics in an animatronic device to sync jaw motions to a sound track or if you're using a pneumatically controlled musical instrument of some type, the hiss of air may detract from the performance of the unit. In these cases, routing the exhaust air through a muffler is the simplest way to avoid the hiss associated with actuator air being vented.

Pneumatic Actuator: Typically, air cylinders are used to get motion from compressed air. With air cylinders, you usually see two types: single acting and double acting cylinders. A single acting cylinder will have a single port for air to enter/exit (**Figure 8**). These cylinders usually rely on a spring to return them to a start position and will move to the end of their travel when air is applied. They will return to their start position when air pressure is exhausted.

Double acting cylinders have two ports, typically designated A and B. When pressure is applied to the A port, the cylinder rod will move to the end of its travel. You then apply pressure to the second port (typically designated B) in order for the cylinder rod to return to its start position. Also, you must remember that if pressure is applied to the A port, the B port *must* be routed to exhaust (and vice versa) in order to allow the cylinder to move.

In most cases, single and double acting cylinders will move a rod in and out in order to perform work. The rod may extend from only one end of the cylinder or, in some cases, may extend from both ends (**Figure 9**). Some cylinders are mounted in rigid enclosures with guide rods that will allow the device to move precisely without rotating or deviating from its path.

There are also rotary actuators that will rotate from one position to another (i.e, 0 to 180 degrees) when air is applied (**Figure 10**). These are sometimes used to rotate a turntable to position parts or can be used to open/close a door on a mechanism.

Air Reservoir: (**Figure 11**) Though this is usually optional, some designs may call for a higher volume of air than may be provided by the compressor tank itself. If you want to store up "extra" or if your device is at the end of a long hose run, you can place an air reservoir near your solenoid valve and cylinder in order to insure a sufficient supply of air for a given pneumatic assembly.

SCARY AIR!

My first foray into using pneumatics was when I was building props for my haunted house — the Spiders Preyground (see Resources). I wanted to build a prop affectionately called a "Trash Can Trauma." This is a specially modified trashcan that can pop its top on command to give folks a good startle. I researched designs online and they all used pneumatics to provide the motive force to get a fast acting and reliable pop-up action. After looking over a few plan sets I found on the Internet, I started compiling a list of the things I would need to make my own TCT.

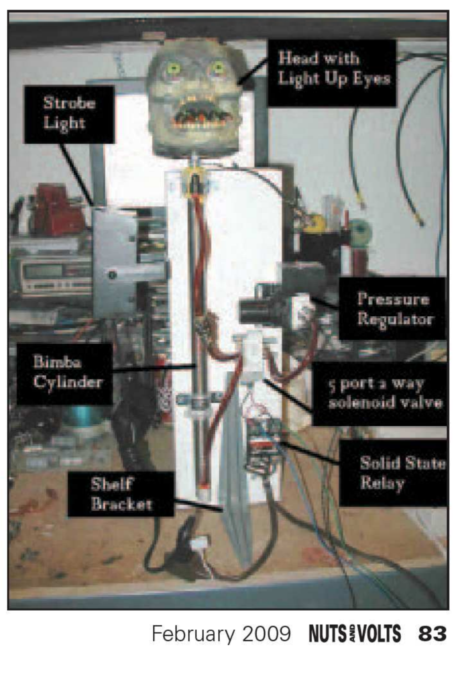
I found everything I needed for my first pneumatic prop in my junk bin, on eBay, and through a couple of surplus component websites. In short order, I had a 17 inch Bimba air cylinder, a Surplus Center five port, two way solenoid valve, and a pressure regulator. I mounted all the parts on a piece of scrap wood (**Figure 12**) and then added some simple electronics (solid state relay, colored light bulb, and a strobe light). I then placed the device into a galvanized trashcan. When connected to power and given only 45 psi of air, this made for a very fun and scary Halloween prop. Simply press a button and the trashcan lid pops up with a scary skull

■ Figure 8. A 1.75" single-acting, spring return pneumatic cylinder.

■ Figure 9. A dual-acting guided cylinder with 1" of travel.

■ Figure 10. A Festo brand adjustable rotary actuator with 180 degrees of rotation.

■ Figure 11. A typical, inexpensive five gallon air reservoir.



■ Figure 12. The trashcan pop-up mechanism before mounting.

grinning mischievously at you!

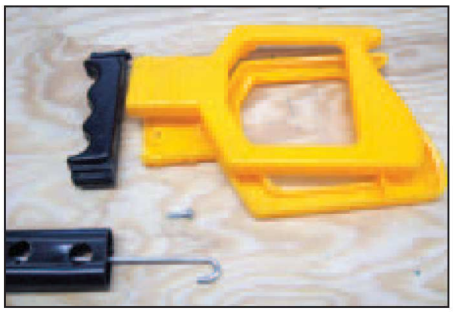
After I had successfully tackled the TCT, I decided to try to animate a much larger prop. I crafted a spider body out of PVC pipe with a pneumatic cylinder to raise and lower the front of the prop (**Figure 13**). With legs attached, the width was just over 20 feet! Once wrapped in black fake fur, placed in our darkened dining room, and revealed by a well timed curtain drop, the spider made for a fantastic finale for our haunted house. See the Resources section for a video of this prop in action.

■ Figure 13. Close-up of the 17" pneumatic cylinder used to cause the giant spider to bounce and lunge.

A SIMPLE PNEUMATIC GRIPPER

So now that we're familiar with some of the basic components of a pneumatic system and their usage, I'm going to walk through the creation of a simple pneumatically activated gripper using a toy robot arm and a small double acting air cylinder. The finished gripper is actually capable of doing simple work and is very straightforward in design, construction, and operation.

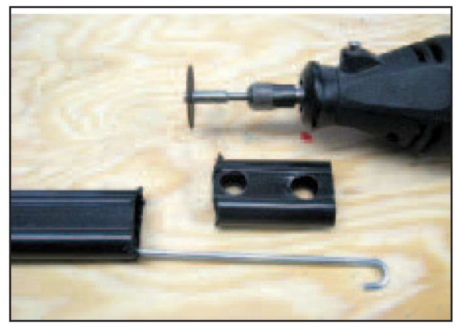
■ Figure 15. The handle and trigger after being removed.

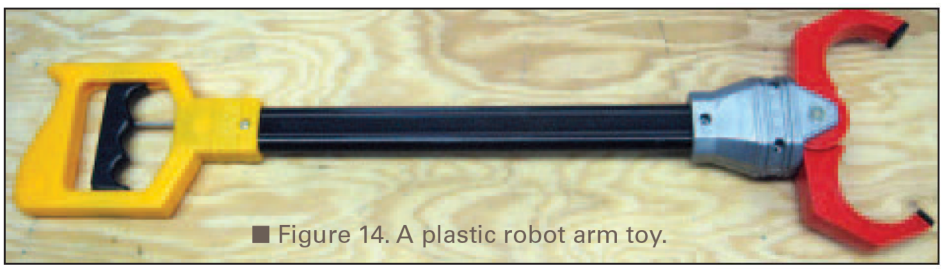


I started with an inexpensive plastic robot griper from a toy store (**Figure 14**). I removed the handle (**Figure 15**) and then using a Dremel tool, I cut off some of the plastic arm to reveal more of the actuator rod (**Figure 16**). I then bent the actuator rod into a Z shape (**Figure 17**) and did a test fit on my pneumatic cylinder.

With the arm all prepped, it was time to create a bracket to hold the cylinder to the arm. I used a "nibbler"

■ Figure 16. Cutting the end of the robot arm reveals more of the push-rod. Remove the "holed" section to increase durability.





■ Figure 14. A plastic robot arm toy.

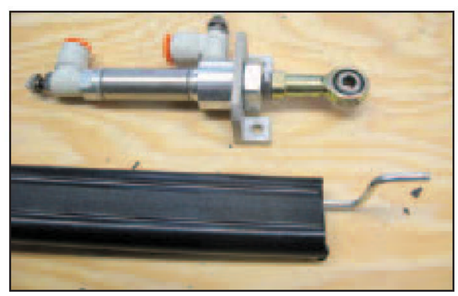
DIY vs. Safety

While working with various home and commercial haunted houses over the last few years, I've seen many pneumatic systems used to power props. Some used home-brew actuators. A bit of digging on the Internet will reveal a plethora of designs for converting non-pneumatic devices for pneumatic use. Some of the most common are plans to convert a bicycle tire pump or a screen door closer mechanism into an air cylinder. It's also easy to find plans that show how to build pneumatic devices out of PVC pipe (pistons, cylinders, and air reservoirs are the most common).

Before you head down this path, take a moment to consider that using compressed air can be very dangerous! As commercially-built air cylinders are widely available on the surplus market at bargain-basement prices, I strongly discourage the use of non-pressure rated or DIY devices in pneumatic systems. Not only will converting or creating an air pressure operated device consume your time, but in many cases there are additional hidden costs in air fittings/adapters and the like that can make the DIY device more expensive (yet less reliable) than a commercially built unit!

If you are planning to make a device to which people may be exposed (i.e., a pop-up scare in a haunted house), please make sure you use only commercially-produced cylinders and actuators to keep everyone safe!

■ Figure 17. The push-rod after being bent into a "Z" configuration. An "eye" has been added to the end of the cylinder for connection to the rod.



■ Figure 18. Using a metal "nibbler" to cut an old PC cover plate into a suitable bracket for the pneumatic cylinder.

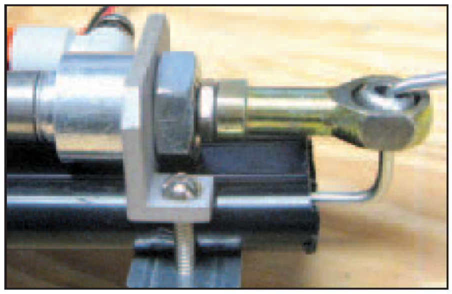
tool to cut a spare back plate from a PC case (**Figure 18**). I then placed the cylinder at the end of the arm and put two screws through to clamp the cylinder into place (**Figure 19**).

Next, I picked a Surplus Center SY3120 12V five port, two position solenoid valve from my pneumatic parts junk bin and assembled it with a barb style input for pressure, barb style connectors for A and B outputs, and dual exhaust mufflers. I used flexible pneumatic rubber hosing to connect the valve to the air cylinder on the arm (**Figure 20**).

To get air pressure for the system, I put together a regulator/adapter to connect my workbench compressor to the pneumatic arm. I joined a 1/4" NPT (common connector on most compressors) to an 1/8" barb fitting adapter, connected it through a short piece of hose to the regulator, then fitted a press fit collar adapter to the output side of the regulator (**Figure 21**). Lastly, to control the solenoid valve I connected a 12 volt power supply with a N.O. switch to the 12V connector of the solenoid valve.

I fired up the compressor and set the regulator for about 35 psi. I was then able to use the N.O. pushbutton switch to open and close the gripper quickly and reliably. In order to help visualize the operation of the gripper, I've created a short video showing the pneumatic arm in operation on my workbench (again, see Resources).

■ Figure 19. The pneumatic cylinder attached to the robot arm with screws.



IT'S YOUR TURN NOW!

If you decide to build an air-powered robotic device of some sort, you'll be in good company. One of my first jobs right out of high school was as an Animatrionics Technician for a division of Atari (I worked on the singing/dancing robots for a *Chuck-E-Cheese Pizza Time Theater*). Most all of the animatronic devices used for pizza parlors and theme parks are pneumatically actuated.

Another factor to consider about pneumatic actuators is that they are usually compatible with harsh environments that would normally destroy electronics. I've seen dual acting cylinders operate without failure while completely immersed in water.

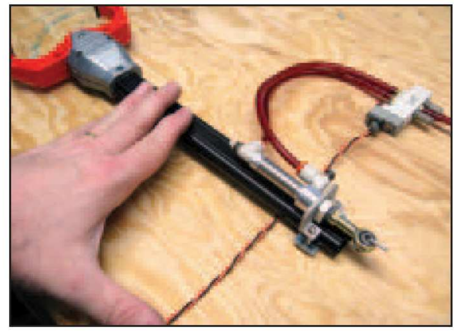
If you haven't done so already, I hope this article will inspire you to experiment with pneumatics in your robotic creations. As always, if you have any questions or comments, please feel free to contact me directly via email at vern@txis.com **NV**

A Bench-side Compressor

For years, I used small cans of compressed air that were actually full of liquid that would vaporize when released. Not only is this "canned air" expensive, the fumes released into the atmosphere may be dangerous to your health, and possibly to the environment as a whole. When I started experimenting with pneumatic cylinders, I decided to purchase a compressor and now I can't imagine how I ever lived without one. Not only can it be used to replace those little cans of air (at $4 a pop!), but it can be used to drive low cost nail guns, inflate tires, fill up air mattresses, and clean out PC cases and power supplies.

Now that I've got a compressor under my workbench, I wouldn't go without one! The compressor I purchased was only $125 but I'm sure it has paid for itself many times over. One caveat, however, would be noise. Some compressor designs are louder than others so I recommend that you ask for and compare the DBA levels of any unit you are considering purchasing. The unit I settled on was sold by my local Sears store and featured “QuietDrive” technology so it produces less noise than many other types.

■ Figure 20. The finished pneumatic gripper with solenoid valve connected. Those with sharp eyes may notice that. I swapped the 90 degree barb-connectors for straight-through connectors so the assembly would lie flat for the photo!)



■ Figure 21. All the parts to connect the 1/4 inch "NTP" style workbench compressor to the robot arm.

RESOURCES

■ The Robot Group
www.robotgroup.org

■ Common symbology in pneumatics
www.rosscontrols.com/symbols2.htm

■ Source for pneumatic valves and cylinders
www.surpluscenter.com

■ Spiders Preyground Video 2004 showing Trash Can Trauma and Giant Spider
www.youtube.com/watch?v=lCf6EjPZtNI

■ Spiders Preyground Video 2005 showing rotary pneumatic actuator "Spider Slammer" and Giant Spider
www.youtube.com/watch?v=lCf6EjPZtNI

■ Video of the pneumatic arm in operation
www.youtube.com/VernGraner