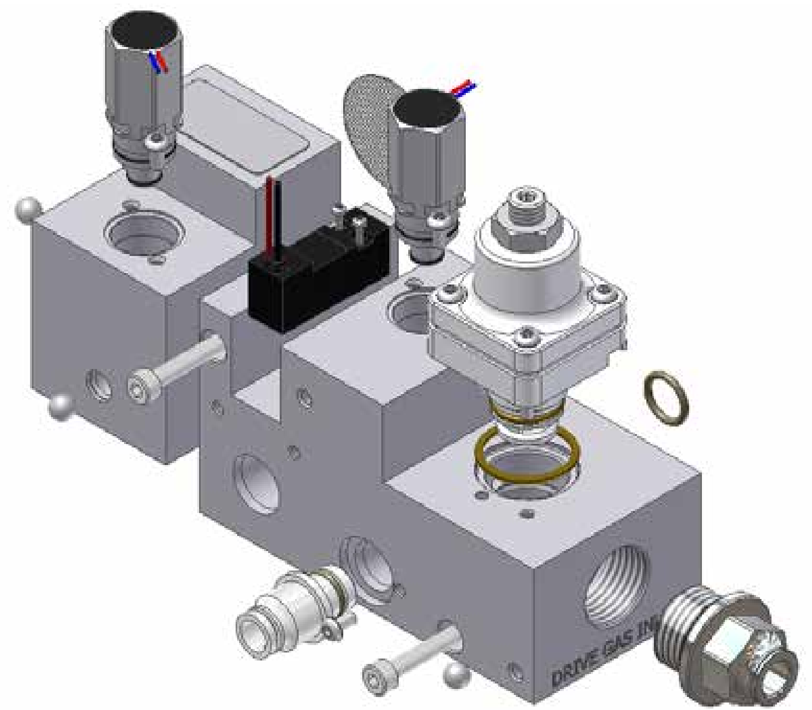
Pneumatics in Small Medical Devices

Al Presher, Contributing Editor, ***Automation & Control,*** **January 5, 2011**

With the design of medical devices moving toward smaller sizes, a hospital-to-home treatment model and reduced power consumption, electro-pneumatic device makers are seizing the opportunity by providing more potent, miniaturized control solutions. By using proportional control to precisely profile the delivery of air, for example, pneumatic devices are solidifying their position as a low cost technology ideal for a wide variety of handheld and portable medical devices.

"There is a lack of awareness of how pervasive the pneumatic solutions are in medical applications," says Ed Howe, president of Enfield Technologies. "Most people don't realize how much pneumatics is used in surgical and life support equipment. In the artificial heart made by SynCardia, for example, basically the whole drive system is pneumatic and some of the components are similar to what is being used in factory automation."



Rise of Proportional Control

One clear trend is the move to proportional control and electro-pneumatics for more precise control solutions. Howe says that with devices such as ventilators or respirators, the operation of units in the past has been largely on and off, pushing a breath in and taking a breath out. But now medical device manufacturers are using pneumatics to profile the breath provided to the patient to be more natural and assist in the recovery process.

"We are working on a ventilator that will work with infants through adults, so that when it's used in an ambulance, air care helicopter or within a hospital, there isn't a need for two expensive devices," says Howe. "The unit uses a proportional servo valve with embedded electronics and software, and it has a very specialized shape to the orifice and poppet - all together these carefully control the air flow."

Another application using proportional pneumatic controls is the process of growing cells either for biomedical research or transplants such as bone marrow cells. Grown in a Petri dish, the yields are very low. But researchers discovered that putting the cells on a flexible membrane and pulsing the membrane, stresses and pulls the cell. It's not certain how growth is encouraged but the obvious theory is that cells recognize the motion and, surrounded by other cells, sense it is in a living host.

"Using a very smooth and fast valve, we are able to replicate the heartbeat of the host animal rather than just turning the valve on and off," says Howe. "We are even able to perfectly replicate the heartbeat of a hummingbird. This is an example of pneumatics bringing real benefits to the medical field by doing things that couldn't be done before. In this case, we are substantially increasing yields."

Growth of Pneumatics

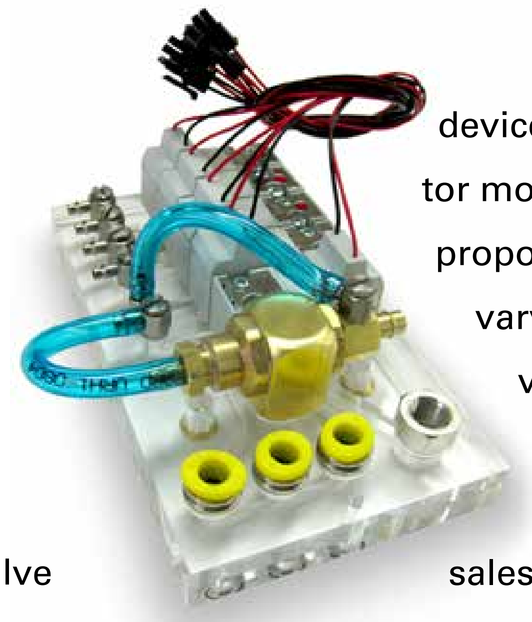
The underlying theme to this transition is the use of more proportional pneumatics and better use of control theory.

Mechanical elements in the valves are becoming more sophisticated, along with better design tools and mathematical modeling. Systems are using more sensors, electronics and advanced controls to manage pneumatic systems and compressed gases, which has always been the real challenge.

"Pneumatic systems are able to profile the air and deliver it in a more natural way," says Howe. "Along with the air pressure profiling, systems consume less air by only providing what is needed and lower the wear on components, but the big developments are linked to therapeutic contribution."

Compared to the past where respirators used large glass tubes with bellows and were primarily electric systems, respirators now use compressed air in a small cylinder, or a small compressor and valves, to modulate a system where the devices have been miniaturized.

Another proportional valve application is controlling the pressure of a ventilator that is actually breathing for patients. These more sophisticated ventilators provide pressure control or PEEP (positive end-expiratory pressure), which allows the ventilator to be more effective in the transfer of oxygen into the nodules of the lungs that complete the transfer of oxygen into enriched blood.



"With PEEP, the pressure control device makes the ventilator more effective by using proportional controls to vary the pressure as the ventilator expands the lungs," says Rob Clippard, vice president, sales & marketing for Clippard Instrument Lab.

Electro-pneumatic systems are also being used in automated blood pressure monitoring devices where a valve both inflates the cuff and controls the rate of deflation. The electronic valve is cycling on and off, and the pressure drops as the device exhausts the air in the cuff. Valves used on these more sophisticated blood pressure monitoring devices not only recognize systolic and diastolic pressures, but actually measure the point at which the blood begins flowing.

"When the cuff is inflated, the blood vessels are restricted and create a tourniquet," says Clippard. "When the pressure is slowly released, there is a point at which some of the blood vessels release and blood starts to flow."

Sophisticated devices use techniques to notice how quickly the blood flow recovers and use that information to diagnose different maladies with the patient. The devices use very precise pressure control, versus a device which turns on and off, and provide a gross control. The proportional valve allows the application to inexpensively add fine pressure control at the point where those blood vessels are just beginning to open and blood is beginning to flow.

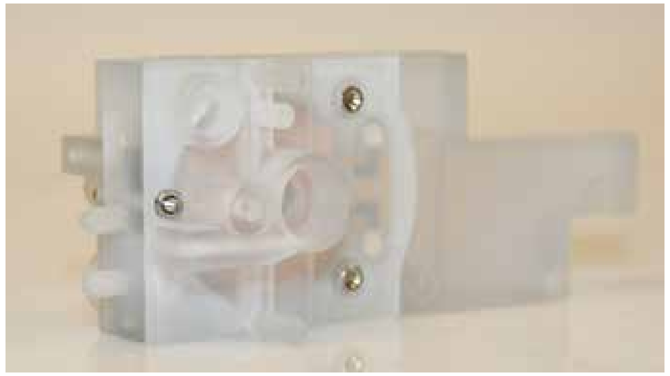
Designers Focus on Size and Power

In pneumatics for medical applications, the trends are mirroring the changes in the medical devices themselves. One trend is portability and movement where in the past the focus was more on in-hospital treatment. Now there is a clear shift to more out-of-the-hospital and home clinical treatment.

"What we are seeing with medical devices is that they're getting smaller and are often made to be ambulatory where they need to be disconnected from the wall for the patient to be able to move around," says Randy Rieken, sales leader, Americas for Norgren Life Sciences.

In some cases, there is a need for the patient to take the device home. A patient might use a ventilator in the hospital, and the same device might be taken home by the patient and used remotely. With the devices getting smaller and the requirements for pneumatics changing, components are getting smaller and power consumption is an important design issue. Audible noise levels are critical because, if a patient takes an O2 concentrator or ventilator home, they don't want to hear the valves actuating.

"Because the components are



smaller, issues such as accuracy and reliability are even more important," says Rieken. "The flow capabilities of valves, even though they are getting smaller, are often the same as before. Medical device manufacturers are looking for higher performance components in a smaller package."

Rieken says it used to be that miniature valves were 16 mm, and then 10 mm. But now many are 8 mm and there is work on valves in the 4 to 5 mm ranges. At some point as devices continue to get smaller and smaller, the actual technology may change but now valves are still using the same technologies. The current goal is to miniaturize and optimize designs to be smaller but, in the future, technologies such as shape metal alloys and piezo actuator technology may come to the forefront as devices get smaller.

One area where pneumatics continues to provide effective components for portable devices is ventilator products. We may think of a big ventilator next to a patient's bed, but units are becoming smaller and some companies are targeting the C-PAP market (devices that help patients with sleep apnea breathe properly while asleep), where the patient can wear the ventilator on their waist or carry it in a small bag. With oxygen concentrators, devices often weigh five pounds and less and the size of the pneumatics internally is a huge consideration.

"The design focus in on size and power, and there are things you can do with power," says Rieken. "We actually have a PWM (pulse width modulation) valve with a processor that can detect when the plunger is moving to optimize the power but most design decisions are based on the size of the device and battery usage. An oxygen concentrator may need a 12-hour battery life and, if there are four valves in the unit, they need to be extremely low power."

One area where suppliers are concentrating to provide greater value to customers is engineering expertise specific to applications. The device manufacturer comes with requirements, schematics and a willingness to consider more highly integrated pneumatic modules. Often these modules include flow control, filtration, switching valves, fittings and safety relief valves all manufactured specifically for the application and designed into a compact, optimized module that is fully assembled and tested.

Energy-Efficient Piezo Solutions

"In handheld instrumentation and medical devices, power budgets are being scrutinized more than ever, as a result of a delicate balance between added functionality and power consumption," says Richard McDonnell, piezo products program manager for Parker Hannifin Corp.

As portable or handheld analyzers continue to shrink in size and device functionality continues to increase, customers are expecting next-generation products to operate longer between battery charges. In the past, instrument engineers might have considered using a hit-and-hold circuit to reduce a valve's power consumption which uses a higher voltage to open the valve and then a lower voltage to hold it open. Power consumption is decreased, but it is not as efficient as piezoelectric valves.

But McDonnell says that option is no longer good enough. For example,

one client cited that in an application of two 0.5W valves, the valve's parasitic power loss was second only to the instrument's cooling fans. New piezoelectric actuator technology enables the valves to operate in the 100 mW range and, coupled with negligible heat generation, self-latching function and the ability to stay in position without power being applied, are reasons for growing interest in piezoelectric technology.

"How that relates in the world of pneumatics is to provide customers with multi-function valves. It was that idea that led us to developing advanced piezoelectric actuator technologies to augment or perhaps even replace solenoids in the future," says McDonnell.

Parker has opted to develop its piezo technology around two types of actuators: a 25 mm round, short stroke, low force RLP actuator and its ViVa, a family of actuators with mechanical amplification for applications requiring large displacement and high force. Either type can be used as an independent actuator or as an alternative to solenoid and voice coil type actuators.

McDonnell says Parker's compliant actuator design increases the piezo displacement well beyond the traditional stack-type piezo, while generating more exploitable forces when compared with Bender-type piezo actuators.

"Because the ViVa actuator is inherently proportional, we can apply the technology in a variety of applications to precisely profile the delivery of compressed air or gases while minimizing power consumption," says McDonnell. He says that there is also significant interest in energy recovery and ultra-low-power technology with energy harvesting to create energy independent systems. ■