A Parker Hannifin Technical Paper

Parker Hannifin
Precision Fluidics Division
26 Clinton Drive – Unit 103
Hollis, NH 03049
603-595-1500
www.parker.com/precisionfluidics

Benefits of Using a Micro Pumps and Miniature Valves in Sidestream Capnography

By John Beauregard
Division Sales Manager

Jonathan DeSousa
Division Applications Engineer

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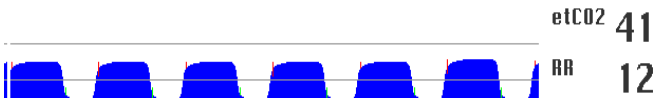
Introduction

Our bodies produce Carbon Dioxide (CO_2) as a result of cellular metabolism. The circulatory system picks up the CO_2 and delivers it to the alveoli of our lungs, where it is eliminated when we exhale. Medical professionals such as anesthesiologists capture and measure the exhaled CO_2, displaying the results on a patient monitor typically referred to as a Capnometer or Capnograph.

Capnography measures the concentration or partial pressure of CO_2 expelled in respiratory gases. It is used as a monitoring tool during the delivery of anesthesia and in the intensive care of patients. Capnography results display a graph of expiratory CO_2 plotted against time, or less commonly but more usefully, it shows the expired volume of CO_2.

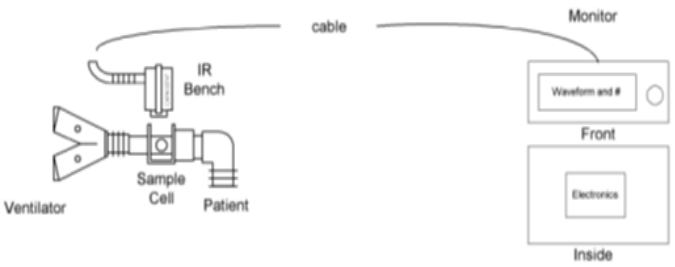


Example of a capnograph measured output

There are two types of CO_2 patient monitors:

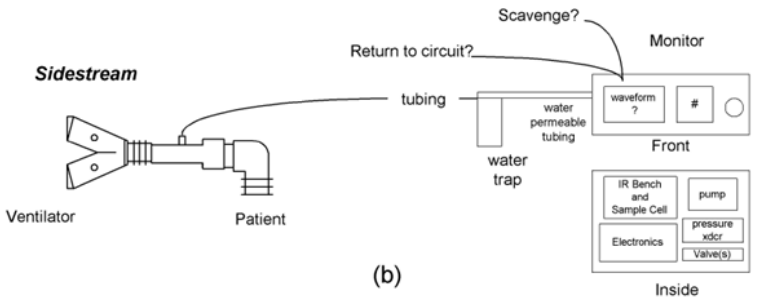
1. **Mainstream Capnography** uses an in-line infrared CO_2 sensor connected directly to the airway, between the endotracheal tube and the breathing circuit.

2. **Sidestream Capnography** pulls a sample of the patients' exhaled gas from the breathing circuit through tubing to the infrared sensor located in a remote monitor.



Typical Schematic of Mainstream Capnography

Figure provided by Respironics Novametrix, Inc., Wallingford CT Michael B. Jaffe, PhD



Typical Schematic of Sidestream Capnography

Sidestream capnography requires a vacuum source, typically a diaphragm pump (sampling pump) that pulls a sample of the expired air from the patient's breathing circuit, through a length of tubing, into the remote monitor and across the CO_2 sensor.

The CO_2 sensor requires regular calibration to ensure sensor accuracy and system integrity. This is done through "auto-zeroing" the sensor by switching a solenoid valve in line with the sensor to expose it to ambient air. The sensor auto-zero valve acts to shut off flow from the system to the CO_2 sensor in order for the sensor to self-calibrate.

Depending on the complexity of the capnograph, the equipment can also include other solenoid valves that divert the airflow of the pump away from the sensor and perform a purge of the tubing to prevent occlusion.

Parker Hannifin has developed several innovative fluidic control products that manufacturers can easily integrate into the development of sidestream capnography devices. These pump and valves address the constraints that engineers of sidestream capnography devices face when designing the next generation of patient monitors.

Design Challenges

Capnography has continued to advance since its introduction in the 1950's and it has rapidly become the standard of care in anesthesia and respiratory therapy.

Capnography is being used widely as a method for diagnosis and treatment beyond the operating room, including pre- and post-operative scenarios, as well as by first responders, in respiratory therapy and in metabolic monitoring. Capnography helps verify endotracheal tube placement and monitor its position, assess ventilation and treatment, and evaluate resuscitative efforts during cardiopulmonary resuscitation (CPR). Capnography is non-invasive, easy to use, and offers great promise in the assessment of acute and critically ill patients.

The increased use and functionality of capnography has resulted in manufacturers needing to enhance the devices with more complex technology including greater fluidic controls. Often these devices use two or more solenoid valves mounted on the PCB.

Multi-parameter patient monitors, anesthesia machines and ventilators incorporate advanced features such as:

- Addition of portable capabilities
- Ability to run on battery power
- Need for sidestream CO_2 OEM modules

Bottom line: These devices need compact, high performance, low power pumps and valves.

Previous Options

Previously, the pneumatic circuitry in a capnograph used larger pumps such as Parker's CTS Series or T2-03 and included larger solenoid valves such as Parker's S-11 and V2.

The increased footprint made it more challenging for manufacturers to mount both the pump and the valve onto the PCB, especially when the device required multiple valves. Although these components more than met the required performance in sidestream CO_2, they are limited in power, size, weight, and ease of integration.

Parker Solution

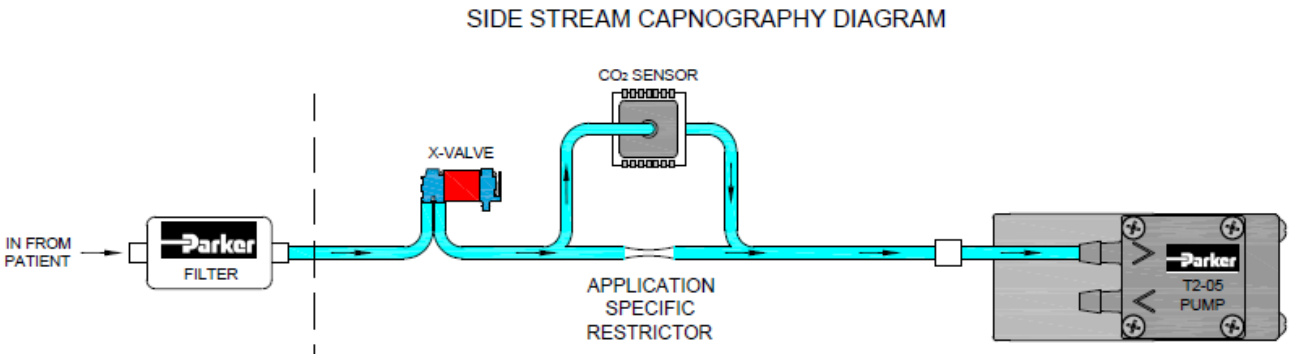
Parker Precision Fluidics Division addresses the evolving needs of patient monitor designers and OEM's by continuing to reduce the power required by its pumps and valves, while ensuring the highest performing fluidic components with the smallest size and weight.

The T2-05LI pump combined with our miniature X-Valve®:

- **Eases** integration concerns of fluidic components onto a PCB board
- **Increases** the battery life of the instrument
- **Increases** the reliability with pumps and valves
- **Extends** the life of the medical device

Advantages of using Parker valves and pumps in capnograph devices include:

- Small Size
- Low Power Consumption
- Long Life
- Simplified Supply Chain
- Ease of Implementation



Typical sidestream CO_2 fluidic path with Parker's T2-05LI pump and X-Valve

Small Size

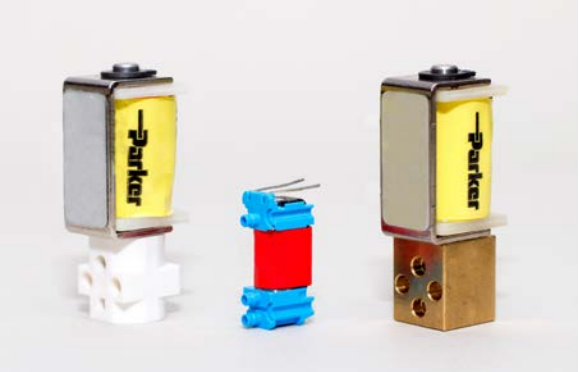
Most next-generation medical devices trend toward smaller, more portable designs. In order to support this trend, system developers must evolve the corresponding technologies to meet these new performance needs.

Although the device size must decrease to help reduce weight and facilitate portability, the performance requirements of the device, and by extension the components, should not diminish. This is the design challenge.

Parker designed the T2-05 LI pump and X-Valve solenoid valve with these new requirements in mind. As a result, **the T2-05 LI pump has the highest flow rate to power consumption ratio on the market**. This results in a significantly smaller and highly efficient pump that still meets the high flow rate needs of sidestream capnography devices.

Pumps commonly used in sidestream capnography applications (*T2-05 LI Series Is in the center*)

The X-Valve, at just 8mm wide and 23.5mm long has a very compact form that enables portability and smaller overall device size.



Valves commonly used in sidestream capnography applications (*X-valve is In the center*)

Low power consumption

Along with small size, low power consumption is also needed to enable portability while eliminating the need to frequently replace a device's batteries.

In order to provide a product that meets the functional requirements of the application while consuming the minimum power possible, developers must optimize the design of components to obtain the highest possible efficiencies.

Parker designed the T2-05 LI pump to consume 0.36 Watts if operated at full voltage and the X-Valve to consume only 0.5 Watts. ***Together, the T2-05 LI pump and X-Valve provide two major fluidic components in sidestream capnography for less than 1 Watt of total power consumption***. This minimum power usage results in longer battery life and extends the portable range of the system.

We

Long life

As healthcare costs continue to rise, device manufacturers are designing for longer device life expectancy; however, a device's life capability is only as good as its weakest components. Consequently, component life is fast becoming a limiting design requirement in component selection.

> With longer life expectancy needed in sidestream capnographs, OEMs must find pumps capable of operation ratings in excess of 5000 hours of use. **The T2-05 LI pump has been successful in achieving this requirement** given the generally low load (vacuum) levels used in sidestream capnography. The T2-05LI pump is rated to 6000 hours of operation and can achieve 10,000 hours or more with the T2-05 HE version dependent upon the system operating conditions.

The X-Valve, which is commonly used for calibration of the CO_2 sensor, is **rated for 25 million cycles** of operation. Given the infrequency of sensor calibration over its life, the X-Valve far exceeds the life requirements of the capnography module.

Simplified Supply Chain

Parker Precision Fluidics Division has over 30 years of pump and valve competency and application knowledge of designing fluidic components and systems for manufacturers of patient monitors, anesthesia, ventilators and other respiratory devices around the world.

Parker is the only company that can design and manufacture pumps, valves, filters, tubing, fitting and all fluidic components—simplifying the supply chain, logistics and total overall costs. With a single solution provider that can design, prototype, and manufacture, our customers benefit from shortened design and production cycles. By working with a lean enterprise, manufacturers can simplify procedures and enjoy convenient customer service and one point of contact.

Implementation

When developing a system, engineers are frequently faced with the obstacle of effectively coordinating the integration of several sub-components into a functional layout. Components that are large and not well designed for easy integration with other components will further increase the challenge an engineer has to manage.

Ease of component integration is a core engineering philosophy at Parker, enabling our customers' engineers to focus on their system functionality and not on the problem of neatly integrating a system's components together.

As can be seen in the following example, Parker designed the T2-05 LI pump and X-Valve to easily integrate both mechanically and electrically onto a PCB board, minimizing the overall system footprint and ensuring efficiency in system assembly.

Sidestream capnography module with Integrated T2-05 LI and X-Valve

Summary

Parker solves the challenge of combining miniaturization, low power, and high performance in capnography applications.

Sidestream CO_2 monitors require a micro-diaphragm sampling pump to pull a sample of the expired air from the patient's breathing circuit across a CO_2 sensor. Parker's T2-05 LI pump incorporates a highly efficient design requiring minimal power, long life, and low noise. It meets the demanding performance levels for flow, pressure and vacuum control needed in capnography technology.

The X-Valve is an ideal switching solenoid valve for sensor auto calibration, purge and occlusion prevention.

The small size and weight of T2-05 LI and the X-Valve is ideal for portable applications and manufacturers can easily mount the valve directly onto the PCB in a CO_2 module, even when the device requires multiple valves. The low power design extends the battery life of these patient monitors.

The T2-05 LI and X-valve replaces larger pumps and valves previously used in the life sciences marketplace with a compact, efficient valve and pump, reducing the overall space required.

Parker provides the ability to simplify logistics by being the only manufacturer of both pumps and valves. The ability to partner with a global fluidics expert who understands the complexity of life sciences applications reduces a manufacturer's risk and time to market, and helps ensure a device with the highest level of performance.

For more information regarding the T2-05 LI Micro-Diaphragm pump or the X-Valve Miniature Solenoid Valve please email ppfinfo@parker.com *or read more product details on the web*:

http://www.parker.com/precisionfluidics/t5
http://www.parker.com/precisionfluidics/xvalve