Miniature Motors Deliver Big Performance for Medical Analyzers

Selecting the right motor to control the movements of a medical analyzer can be difficult given the range of options available to designers. How does one best determine if their application calls for a stepper motor, a brush DC coreless motor, or a hybrid motor? What benefits does each offer that make them suitable to a given device? This article clarifies the selection criteria to enable a more informed decision process.

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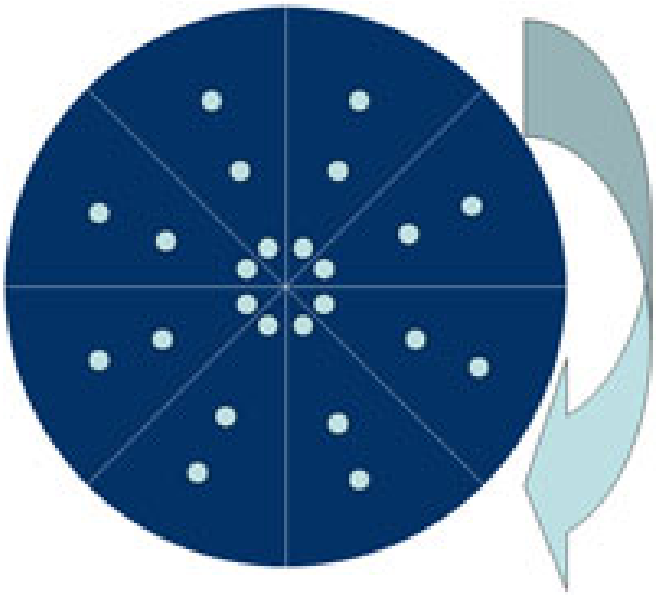

Motorized turn table with assays. The quantity of assays would depend on the required throughput.

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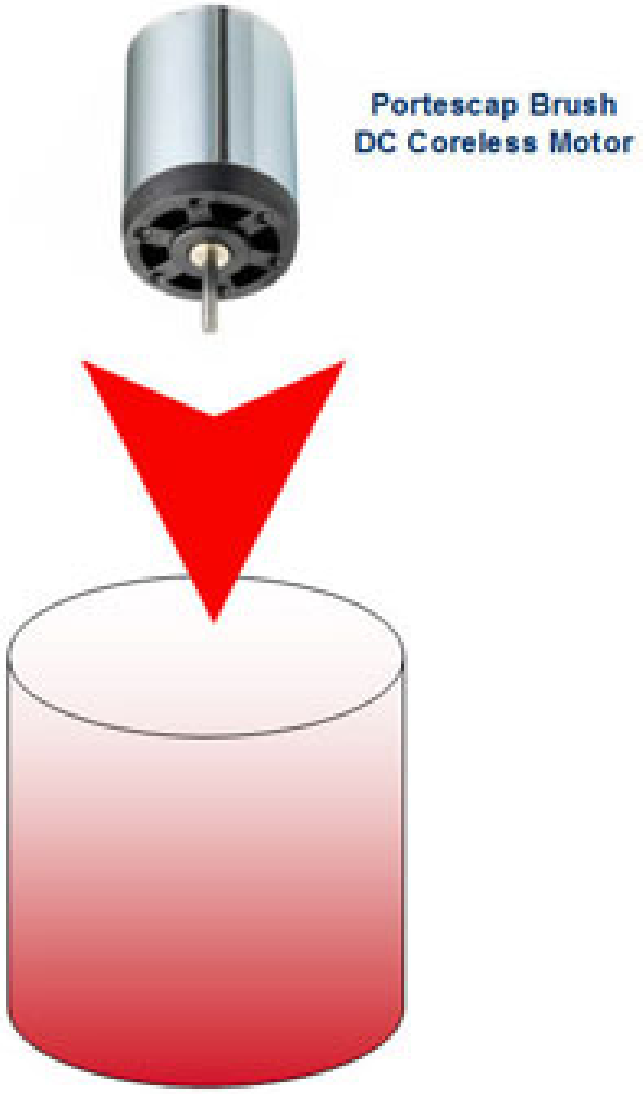
Medical analyzers are the workhorse of the medical diagnostics industry. They are versatile tools with multiple functions&#151from testing human bodily fluids such as blood and urine to processing drug-protein interaction studies that deliver key information for the diagnosis, prevention, and treatment of disease.

Different types of analyzers perform sample movements for analysis with different motorized solutions (motor, encoder) and transmission mechanisms (pulley, belt,

gearing). In the quest to design medical analyzers to deliver better, safer, more personalized, and cost efficient healthcare, the most common criteria for analyzer automation are high quality, low noise, and long life&#151all at an attractive cost.

Stepper Motors



An assay being punctured and sample withdrawn for analysis using a brush coreless DC mechanism in a plunger drive.

Numerous motors/gearing/encoders are used to transport fluids, vials, or assays within medical analyzers. Stepper motors are ideally suited for low rate sampling analyzers such as blood sugar testers that run one to ten samples an hour, while state of the art brush and brushless coreless motor technologies function well in high throughput applications (on the order of more than 1,000 assays an hour), such as immunochemistry or DNA screening. Some medical analyzers use a turn table-based approach (Figure 1) to stack assays that are identified, marked, and serialized to track human fluids, enabling labs to deliver timely and accurate feedback to the healthcare professionals.

In the simplest versions of such turn table analyzers where speed is not a primary issue, stepper motors are a reliable, cost effective method of meeting the analyzer's functional requirements. A stepper motor is essentially a BLDC motor with many poles; thus, the current in each phase has to be commuted many times per revolution. For instance, a two-phase stepper with 100 steps/revolution will need 25 current reversions in each phase to make one full revolution. A primary advantage to analyzers that utilize stepper motors is that they have many stable positions (steps) per revolution while providing a high torque for a given size. The disadvantage of utilizing a stepper motor is that it is not able to run at high speed (&gt2,000 rpm), due to the inductance combined with the commutation frequency, and iron losses (current reversed so many times).

That said, a range of steppers&#151from permanent magnet to hybrid to linear&#151are available to satisfy analyzer application needs. Permanent magnet can-stack steppers are suitable for analyzers when space and power demands are critical. Hybrid steppers are small, powerful, and cost effective enough to be used in analyzers. Linear stepper systems are also ideally suited for many analyzer applications, offering advantages such as limited maintenance or wear, simplicity of integration, and part reduction versus standard rotary systems. Rotary systems typically need translation mechanisms to transfer rotary motion to linear motion, thus increasing part count and integration complexity. Linear steppers are ideal for analyzers requiring light loads and open-loop performance, and due to the lower inertia associated with fewer components, they can typically accelerate faster than rotary systems.

Brush DC Coreless Motors

For high throughput applications&#151those where over 1,000 assays are analyzed in an hour&#151high efficiency and higher speed motors such as brush DC coreless motors are a suitable choice. Their low rotor inertia along with short mechanical time constant makes them ideally suited for such applications. As an example, a Portescap 22-mm motor brush coreless DC motor offers no-load speed of 8,000 rpm and a mechanical time constant of 6.8 milliseconds. The time required for the motor to attain such speeds is governed by the equation:
$\omega = \omega_o (1- \exp (-t/\tau_m))$
where ω_o is the no load speed, τ_m is the mechanical time constant of the motor and ω is the speed attained after a certain lapse in time t. Based on the motor characteristics, 90% of the no load speed can be attained in the turn table application in about 15 milliseconds as shown in the graph. It should be noted that the load characteristics on the motor, depending on the torque required to turn the assay sample table at a certain speed, would determine the actual time the motor takes to ramp up to a certain speed.

Disc magnet stepper motors and brushless DC motors can also work in variants of this application based on speed, acceleration, performance, and cost requirements. Another analyzer function that plays a vital role in their output is collecting samples from the vials or assays, and serving them up to measurement systems based on

photometry, chromatography, or other appropriate schemes. Open tube or close tube format samples assays are typically presented to a piercing or plunging mechanism via the turn table for suction of the sample from the vial, with disposition to a measurement system (Figure 2).
In some critical applications where the sample size available for analysis is limited, motor characteristics such as speed, torque, efficiency, and positioning accuracy play a significant role. Here again, a brush DC coreless motor is highly applicable due to the power density it packs in a small frame size. And as mentioned earlier, the low inertia of a brush DC coreless motor aids in efficient fluid transport, especially in cases where the requirements for sample availability are in the micro liter range. Typically, an incremental encoder can be used for feedback with a brush DC coreless gearmotor (Figure 3) to gauge motor position and speed. Such incremental encoders can be optical or magnetic, and produce pulses (Figure 4) that are proportional to speed and distance. High encoder resolution of &gt128 lines is typically desired at lower speeds of &lt1,000 rpm, such as during the final stages of suctioning fluids from the vials.

Portescapbrush DC coreless gear motor with encoder.

Hybrid Motors

An extension of the previous application uses pumps with stepper motors to dispense certain reagents into the assays in order to aid the analysis process. Such stepper motors can be controlled using open or closed loop feedback. A hybrid motor, such as that shown in Figure 5, can be used in different axes to position the test samples under appropriate reagent dispensers, and a closed loop system, although more expensive, might be justifiable in such a case.

Portescap Hybrid h3 step motor.

A typical can stack motor has discrete angular positions where the shaft is retained in discrete positions using a holding torque. As an example, a 15-mm can stack motor with an 18 degree step angle can be run in open loop without a feedback sensor, but the positioning would be crude. On the other hand, a hybrid motor with closed loop system can have an encoder for position feedback to the drive electronics, with added encoder costs of $10 to $25, and costs for drive electronics enhancements.

Conclusion

The performance-to-price consideration of an appropriate motion solution ultimately depends on the complexity of the analyzer, along with the precision, efficiency, and environmental conditions required for the operation. A range of different motor technologies are applicable for different motion requirements and axes of operation in a medical analyzer, as shown in the table.

If power density, efficiency, speed, and value are primarily important criteria, then brush DC coreless might be the technology of choice. If positioning without added electronics and low cost are the primary requirements, as in low rate sampling analyzers, then steppers could be the preferred option. The user has to make a selection based on performance-to-price needs, keeping in perspective the costs associated with control electronics and drives, along with the life span of such analyzers&#151approximately 15 to 20 years&#151and the application needs the analyzers serve in the healthcare segment.

Note

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Online

For additional information on the technologies and products discussed in this article, see MDTonline at www.mdtmag.com or Portescap at www.portescap.com.

Graph: This graph illustrates the amount of time it takes for a brush coreless DC motor to attain no-load operating speeds.

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