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WHITE PAPER

# CLINICAL DIAGNOSTICS AND FLUID HANDLING: HOW INNOVATIVE MOTORS ARE IMPROVING LABORATORY PRODUCTIVITY

## INTRODUCTION

In laboratories around the world, scientists spend their days performing research with the aim of improving our quality of life. This research is key to driving growth in industries such as healthcare, pharmaceutical, and agriculture, among many others. While investment in these industries was already on the rise due to socioeconomic factors like aging populations, the increase in preventative care and the recent pandemic have been catalysts for increased growth within the industry.

This growth has also led to an increasing workload in laboratories, with motorized tools and equipment taking center stage and allowing scientists to cope with increasing daily demands. This article will focus on the motor options for automated machines which support scientists in sample preparation, management, and analyses.

## HANDHELD ELECTRONIC PIPETTES

### Introduction

Prior to analyzing a sample, the lab technician must complete a series of steps which can include dissolution, extraction, reaction with some chemical species, pulverizing, treatment with a chelating agent, masking, filtering, dilution, sub-sampling, and more. In many cases, the sample is in liquid form and must be handled with a pipette when transferring from one test receptacle to the next. Pipettes have existed for over a century but have evolved to such an extent that modern versions do not have much in common with their predecessors. The pipette itself was an evolution of the syringe and applies the same principle when it is used. These devices typically consist of a system of cams, pistons, and cylinders. When the piston is moved, a partial vacuum is created, and the liquid is drawn into the pipette tip. Pipettes come in a variety of sizes, with volumes ranging from

*Figure 1 - Example of a Multi-Channel Pipette*

a few microliters to a few hundred milliliters. In most cases, pipettes are used in sterile environments where preventing cross contamination is imperative. Hence, prior to each manipulation, the user clips on a brand-new tip to ensure no cross-contamination between samples occurs. At the end of the manipulation, the operator ejects the pipetting tip. The tips can be either disposable or reusable after being put through a sterilization cycle. Multi-channel pipettes are also now quite common (typically with 8, 12 or 16 channels), allowing lab technicians to perform several fluid transfer operations at the same time.

## BENEFITS OF MOTION SOLUTIONS FOR PIPETTES

Due to the lower cost and improvement of electronics, it is possible to integrate a miniature electric motor inside the pipette, resulting in certain benefits:

- Accuracy and repeatability: Electronic pipettes allow a specific volume of liquid to be dispensed very accurately and precisely. Pipettes typically have a resolution of 1 microliter per increment, with an inaccuracy below 1%. Equally as important is repeatability, or being sure that exactly the same volume of liquid has been drawn or dispensed for a given volume during each subsequent manipulation.
- Cost Savings: This improvement in accuracy and repeatability, as well as the fact that pipettes can now handle smaller and smaller volumes, have led to companies being able to use smaller amounts of reagents during analysis. This, in turn, results in reduced costs.
- Ergonomics: Switching to electronic pipettes requires less manual force and hand movement, which drastically reduces the risk of repetitive strain injury. Once the electronic pipette is set, the user only clicks on a button to fill, empty, and in some cases eject the tip.
- Productivity: Thanks to the built-in automation of electronic pipettes, they can perform quicker than their mechanical counterparts, leading to an increase in the number of samples that can be processed over a given time.
- Flexibility: Some features have also been added to the pipette such as “save” mode, multi-dispensing, mixing and more.

At the very heart of the electronic pipette lies the motor. Let’s look at the role of the motor in this application.

## MOTOR TECHNOLOGY OPTIONS FOR ELECTRONIC PIPETTES

### Stepper Motor

The stepper motor (Figure 2), especially the linear stepper motor or digital linear actuator (DLA), is a ready-made solution that fits the e-pipette application. The built-in lead screw interfaces directly with the piston of the e-pipette to provide the linear movement required for operating the device. In addition, as it is a stepper, no additional feedback sensor or encoder is required for controlling the motor. The stepper motor rotates incrementally at each current pulse, making it easy to control. The linear travel accuracy of the motor, as well as the possibility for micro-stepping, provides a very high resolution which matches the high demands for accuracy and repeatability of the electronic pipettes. Additionally, this motor can maintain its position without being powered, which extends the use of the device.

Collaborating with motor suppliers such as Portescap allows for optimum stepper motor selection or motor customization.

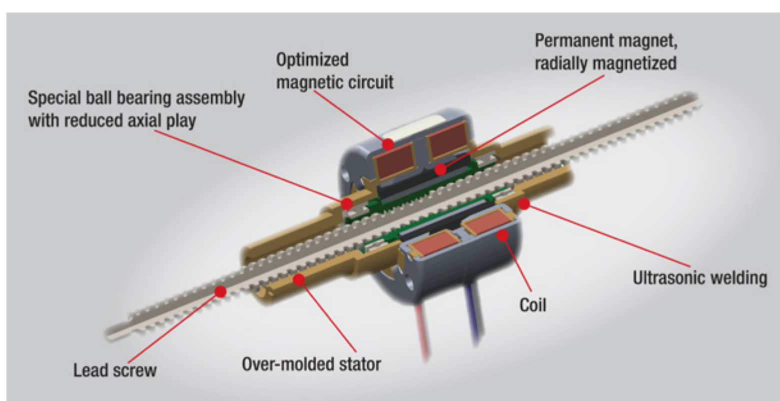



*Figure 2 - Linear Stepper Motor Components Explained*

### DC Motor

An alternative solution is in the form of the brush DC motor. The coreless brush DC motor (Figure 3) is the most efficient technology, where the rotor is only composed of a coil and a shaft (as opposed to iron core motors). As a result, the coreless motor does not have any iron losses, which significantly improves the efficiency and acceleration of the motor. As electronic pipettes are battery powered, this increase in efficiency leads to usage over longer periods on a single charge.

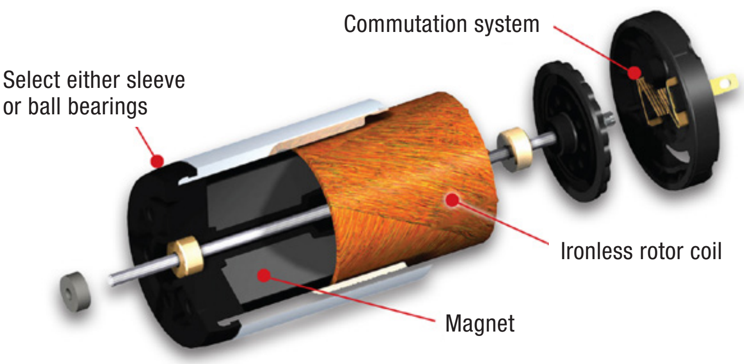



*Figure 3 - Coreless Brush DC Motor*

For pipetting applications, the brush DC motor requires additional components, such as belt drives and encoders, for the conversion of rotational motion into linear motion and control of the motor.

### Motor Technology Recommendations for Electronic Pipettes

Both the stepper and DC motor come in a small and lightweight package that allows electronic pipette designers to optimize the weight of their devices. However, there are a few tradeoffs between these motors that designers must consider when selecting which technology will pair best with their device. For example, few DC motors are typically cheaper than the linear stepper motors, but additional costs of components for the transmission (rotational to linear conversion) must be considered. An additional consideration is the potential errors/tolerances of adding more links in the chain.  The selection of the technology depends on the commercial and technical requirements of the electronic pipette manufacturer.

## LABORATORY AUTOMATION

### Introduction

As mentioned, automation is key in dealing with the increased workload of laboratories and medical institutions. Today's machinery used to automate laboratory tasks comes in various shapes and sizes and fulfills a wide range of operations, from simple liquid handling to end-to-end sample preparation to the final analysis result.

Typical functions of lab automation include:

- **Identification and scanning:** All samples are identified. Cameras and scanners are used to identify, track, and record results.
- **Cap and De-cap:** The samples are stored in containers such as test tubes. When the samples are processed, the container must be opened and then closed.
- **Transfer:** Tiny samples need to be transferred from one location to the next. In general, these can be of various sizes or volumes.
- **Manipulation:** Trays and conveyors need to be moved from one station to the next.
- **Analysis:** Typical diagnostic operations include steps such as centrifuge, chemical reaction with reagents, and spectrometry, to name just a few.

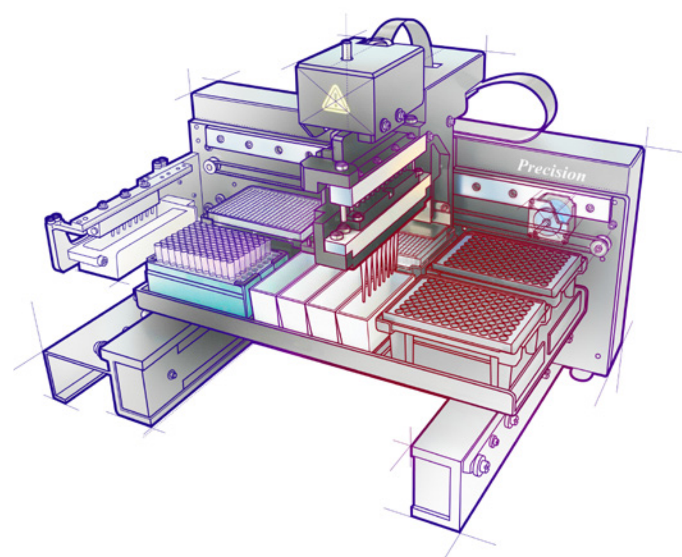



*Figure 4 - Laboratory Automation Machine*

## BENEFITS OF MOTION SOLUTIONS FOR LABORATORY AUTOMATION

There are many possible areas and axis' when it comes to integrating miniature electric motors inside a laboratory automation application. The benefits include:

- **Long life:** The automated equipment usually works continuously for many years, meaning the motor life is an important requirement for motor selection.
- **Reliability:** Any failures or maintenance issues delay the diagnostic and the patient's treatment. This means that motor reliability is paramount.
- **High speed:** Fast motors allow a higher productivity rate and increase the number of diagnostics per day.
- **Precise positioning:** Accurate and precise solutions are needed. Motors control the amount of reagent being placed into the samples; any inconsistent motion could affect the diagnostic result. Due to some applications having multiple automated axis', there are various motion technologies that can be selected and optimized. Let's look at what technologies are typically recommended.

## MOTOR TECHNOLOGY OPTIONS FOR LABORATORY AUTOMATION

### Stepper Motors

Stepper motors have an electronic commutation, meaning that there is no mechanical wear. Accordingly, these motors have a long lifespan, making them ideal for laboratory automation machines.

The stepper motors have several magnetized poles, meaning that the current commutates several times during one rotation, leading to stable positions with a high torque performance. They can be driven with ease and high precision without the need of an encoder. They are typically used in applications where positioning is important.

One of the tradeoffs with steppers is speed. A high frequency commutation is needed to work quickly. Due to the inductance effect of the coil, the current needs some time to rise. If the commutation frequency is too high, the current does not have enough time to rise. As a result, stepper motors are limited in speeds and are typically an ideal solution for output speed below 1,000 RPM.  For designing large, automated laboratory equipment, engineers select stepper motors for medium power applications.

### BLDC Motors

Brushless DC (BLDC) motors combine the advantages of brush DC and stepper motors. As with stepper motors, brushless motors have an electronic commutation, allowing for a long lifetime. However, BLDC motors have a limited number of magnet poles (generally two or four); fewer commutations are needed for one revolution of the motor. With the same commutation frequency, the brushless DC motor works much quicker due to a well-balanced rotor and a strong ball bearing assembly, with some specific motors reaching speeds of up to 100,000 RPM. This means that for high-speed requirements, brushless DC motors are the preferred technology.

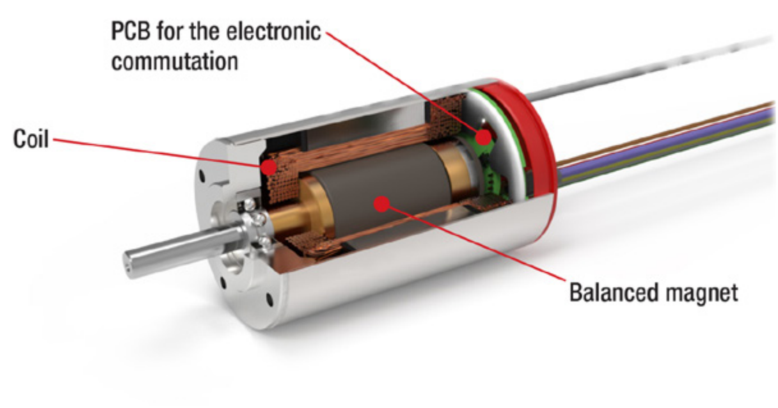



*Figure 5 – Brushless DC Motor Components Explained*

BLDC motors are generally controlled by using positioning feedback, such as integrated hall sensors or encoders. As the rotor position is always known, BLDC motors are a reliable technology without the risk of losing steps as with a stepper motor.

Brushless motors come in two versions:

1. Cylindrical motors will typically have a longer length compared to their diameter. They are usually used in robotic pipettes. (Figure 6, left column)
2. Flat motors (or "pancake" motors), usually have a larger diameter compared to length. Disc magnets and flat coils are used for this motor design. They are typically used in robotic arms. (Figure 6, right column)

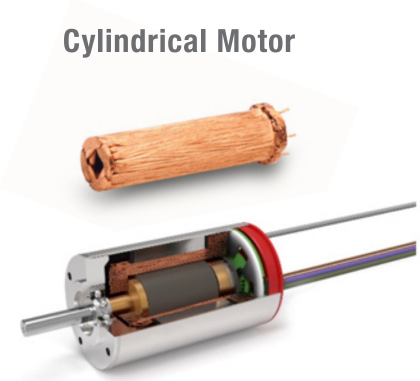
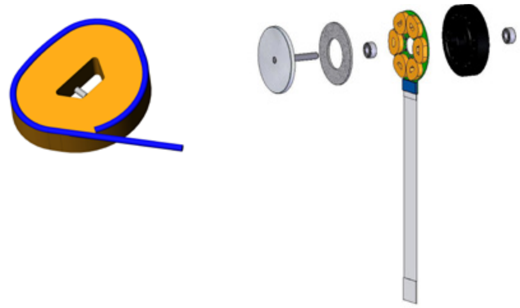
| | Cylindrical Motor | Flat Motor |
|---|---|---|
| **Coil** |  |  |
| **Motor** |  |  |

*Figure 6 - Interior View of Cylinder Motor and Flat Motor*

Thanks to their high-power density capabilities, BLDC motors are ideal for applications requiring high power in a compact package. In laboratory automation machines, brushless DC motors are an ideal solution for reliable and high productivity tasks.

Brushless motors are being used more and more for various laboratory automation applications, including robotic pipettes functionality, as well as arms and grippers:

### SPOTLIGHT: ROBOTIC PIPETTE EXAMPLE

A typical example of BLDC motors in the laboratory is the robotic pipette. A brushless motor with an encoder is the typical solution for automated pipettes for the following reasons:

- Test tubes have a small diameter. For space optimization, engineers try to locate pipettes close to each other, so pipettes have a limited dimension, and motors need to have enough power within a limited package (small diameter requested).
- Small sample sizes are necessary for the analysis, leading to a need for a BLDC motor in conjunction with an encoder for a reliable and accurate manipulation.
- Speed is also critical; the samples need to be processed fast to get the results quickly.

**SPOTLIGHT: ARMS & GRIPPERS EXAMPLE**

Laboratory machines have robotic arms, including grippers, which handle containers such as test tube. Any imprecisions can lead to mishandling of containers which lead in turn to failed analysis. BLDC motors combined with hall sensors or high-resolution encoders allow accurate and reliable control. Gearboxes can be mounted to the motor for higher torque whenever required.

## Motor Technology Recommendations for Laboratory Automation

BLDC motors are typically used for axis requiring high power density solutions. Their advantage is the high-speed performance.

Stepper motors are typically used for moving trays, whereas smaller steppers can be used to control small valves.

## CONCLUSION AND NEW TRENDS

The trend in laboratories is to have increasingly automated and faster equipment, as well as higher accuracy in applications, which rely on electric motors to achieve Advances in electronic component technologies are continuing to provide the optimization needed to power these critical applications. A second trend is the transition of diagnosis or testing/ monitoring for health conditions from being made directly at a laboratory to instead being made at the point where the patient is being cared for, whether it is within the hospital, the doctor's practice, or the home of the patient itself. This enables for a quicker diagnosis, leading to early detection of health conditions or negative trends that could other lead to adverse consequences.

This new trend is possible thanks to the development of a series of mini analyzers, called the Point of Care (POC) analyzers. These are compact portable machines that are usually battery-powered and include reagent cartridges that allow for rapid diagnostic within minutes. These POC devices are typically used by hospitals, home care facilities, by the patient themselves, or at pharmacies for specific detections, such as infectious diseases.

In terms of motion, POC analyzers utilize of miniature motor solutions for some operations, including mixing reagents, moving the cartridge, and rotating the mirror (for spectrometry test). The criteria for the selection are mainly around size, performance, price, and efficiency. Most engineers choose either coreless brush DC motors which are a cost-effective solution with high performance, or small stepper motors which are easy to control.

There is no universal motor technology that fits every application; instead, there are several motion solutions, each with their own benefits, that allow machine designers the flexibility to make their machines smaller and faster. Working in collaboration with a trusted motor manufacturer helps develop unique and customized laboratory machines and selecting the right motor solution ensures that the laboratory machine remains reliable during continuous operations. P

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