Motion solution specification for electronic pipettes

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Ubiquitous throughout laboratories in specializations such as life sciences and clinical diagnostics, pipettes are a vital tool for transferring liquid samples. Repeated activation of manual devices presents strain for lab technicians, and while electronic pipettes improve ease of use, they also increase accuracy and repeatability of dispensing. To optimise the requirements of liquid dispensing, as well as meeting the needs of ergonomic design, specifying the right motion system is crucial.

Bill Burton of Portescap explains the ideal motion system specification process for electronic pipette design.

Within sectors such as life sciences and clinical diagnostics, many laboratories are turning to electronic pipettes. Traditionally manually operated, these fundamental tools for transferring liquid samples are today equipped with functions that enhance the ease, speed, and accuracy for lab technicians.

Electric actuation relieves the strain of the thumb press on a mechanical device, experienced by technicians hundreds of times per day, by ensuring precise and reliable automated dispensing. The motion system is central to an electronic pipette's function, and its specification has wide ranging implications for the device's other features that are built around it. For this reason, involving motion system design as early as possible within the development process will lead to a more effective and efficient outcome.

Motion design requirements

A key requirement of the motion system is accuracy and repeatability. Pipette devices are typically programmable to dispense the precise amount of liquid, every time, which demands control over linear motion. To achieve accuracy, the design requires either a motor feedback device, which reports on the position of the motion system, or alternatively a motor that confirms its position in open loop by its mode of operation. In addition to control accuracy, the dispensing cycle should also be achieved as quickly as possible in order to both minimise valuable laboratory time and make the process easier for the lab technician.

The motion system also needs to deliver sufficient linear force to propel the fluid. The force required is impacted by the fluid's viscosity. Many pipettes are intended to operate with a range of fluids with varying viscosities, so the greater the force that a motor can deliver, the more flexible its use to a laboratory; force requirements are also multiplied if a pipette is intended for multi-channel dispensing. As well as the force required to propel the fluid, a pipette's greatest peak torque requirement is for the ejection of the disposable pipette tip, typically removed to avoid sample cross-contamination.

To optimise use by the lab technician, the pipette should also be as compact and lightweight as possible. Motor type and its control method significantly impact the device's total footprint and weight. This means that motor performance demands, including considerations relating to its power supply, have to be balanced with ergonomic requirements. This wider impact, further to the consideration of piston actuation alone, highlights the need for motion system specification to take place as soon as possible within a pipette's complete design process.

Motion technology

Transposing lab technicians' requirements into a pipette's motion design, actuation characteristics remain however a fundamental basis. Starting with control accuracy, a brush DC motor with an encoder provides precision over piston actuation. Alternatively, a can stack stepper motor rotates in defined steps for each current pulse, meaning that its position, relative to the angle of each step, is always known. While this doesn't provide the same precision as a DC motor with an encoder, a stepper gives high accuracy across most pipette applications. Stepper positioning can also be optimised by designing small step angles as well as driving the motor in micro-stepping mode. The pitch of the lead screw, connecting the motor to the piston, can also be customised for fine control.

If the pipette requires higher torque, such as for multi-channel dispensing, a DC brush motor has an advantage. The DC motor can run faster than a stepper, which enables the incorporation of gearing or the use of a narrower lead screw pitch. The pipette can generate greater force yet still maintain the desired dispense rate.

As a stepper doesn't require an encoder to control its position, this helps achieve a more compact, lightweight design. And, as the motor can be designed to include a threaded rotor and an integrated lead screw, this achieves a linear motion solution that connects coaxially with the piston, enabling a thinner pipette profile. From an OEM's design perspective, this also makes the integration of a linear stepper motor a relatively simple approach, saving time and cost in development. Alternatively, to convert rotary motion to linear motion, a DC motor needs a gear or pulley that links the motor to the lead screw and piston on a separate, parallel axis. This approach increases design complexity and adds size and mass, requiring a wider pipette body to accommodate the design.

To power the motion solution, battery size and weight are important considerations for ergonomics, but these attributes are trade-offs with charge life. A battery needs to last for a day's use with the desired number of dispenses, but to optimise ease of use for the lab technician, the battery needs to be as compact as possible. This impacts motor winding design and its torque output, and as a result, a balance must be found between performance at the available voltage with the specific current draw, and battery capacity and charge life.

Pipette design process

Stepper motors are the common approach for pipette design, not least because they are more cost effective. However, brush DC motors might be considered if higher torque and higher accuracy are required. Whichever technology is selected, accurately defining its specification, including sizing, is vital. Considering the broad implications, engaging with a motion solution designer ahead of any specification decisions keeps flexibility open for optimised design of the pipette as a whole.

Customising a motion solution to achieve customer requirements in pipette design demands a multitude of considerations, covering areas from the windings and magnets, through to the mechanical integration with the syringe. The pipette has a fundamental reliance on the motion solution, and there's a high level of design integration required. As a result, a collaborative approach between the motion solution and pipette design engineering teams is vital from outset.

Image captions:

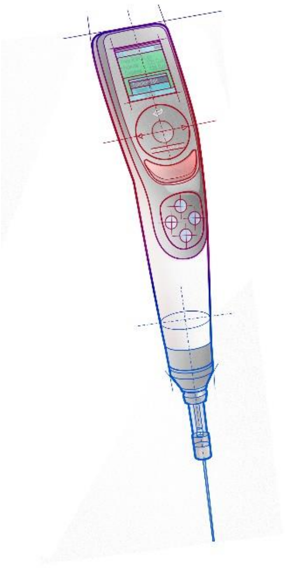

Image 1: Electronic pipette design example.

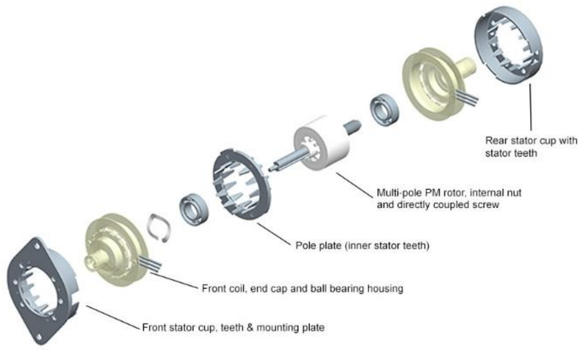

Image 2: Linear actuator exploded view.

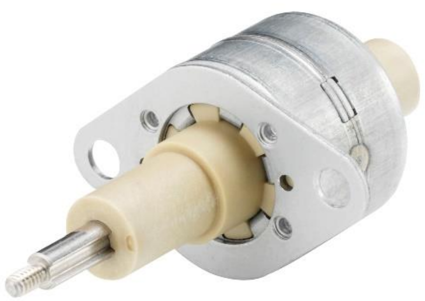

Image 3: Linear actuator examples.

Image 4: Linear actuator examples.

Image 5: Linear actuator examples.

About Portescap

Portescap offers the broadest miniature and specialty motor products in the industry, encompassing coreless brush DC, brushless DC, stepper can stack, gearheads, digital linear actuators, and disc magnet technologies. Portescap products have been serving diverse motion control needs in wide spectrum of medical and industrial applications, lifescience, instrumentation, automation, aerospace and commercial applications, for more than 70 years.

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