Technical Report

RAININ
Pipetting 360°

Stepper motors technology
Higher performance and reliability

Electronic pipettes rely on two types of electromagnetic motors to move the piston: direct current (DC) or stepper. While each follows the same electromagnetic properties, they operate in distinctly different ways. This paper explains the basic operating principle of each motor and the advantages and disadvantages of each with respect to electronic pipettes.

Stepper versus DC motor technologies

Stepper motor concepts
Stepper motors operate in a very simple manner: a central rotor with fixed magnetic poles is placed between electromagnetic end-pieces, known as stators. The stators (see Figure 1) are individually switched off and on with N or S bias in a defined order. The N and S polarization is dependent upon the direction that the current flows through the electromagnet. Properly sequenced switching of the stators' polarization precisely moves the rotor to the corresponding stator at a controlled speed. Hence, stepper motors have both positional and speed control built into their drive mechanism. In effect, the rotor takes a precise, defined "step" to the next position as needed. Finer control of the rotor is possible by increasing the number of stators as in Figure 2.

Stepper motors are simple devices but require electronic control and drive circuitry, as each stator must be switched on and off with a set polarity in a very defined sequence for smooth operation. Fortunately, circuits, batteries, and motors to do this have been "microsized" to fit within the confines of a pipette.

As the circuit that controls the stepper motor has two very convenient advantages – outstanding position and speed control – the motor can be directly attached to a linear actuator to drive a piston in precise increments. Thus, the control circuitry can be programmed to compensate for a number of additional properties encountered in any given use. An excellent application of this capability accounts for the accuracy of a RAININ EDP3 electronic pipette with Automatic Linearity Correction (see RAININ Technical Report "*Automatic linearity correction (ALC) – Improving accuracy*" for more detail). ALC is a control circuit program that compensates for non-linear dispensing across a wide range of volumes.

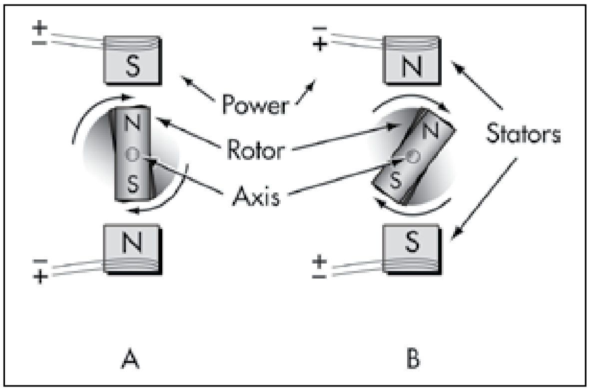

Figure 1- Stepper / motor sequence

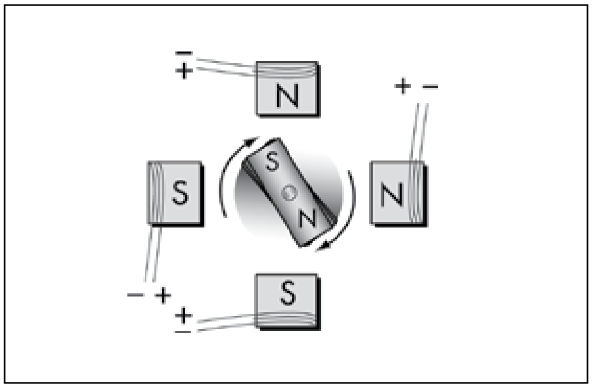

Figure 2- Multiple stators

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DC motor concepts
Direct current (DC) motors are simple to operate and do not rely upon a control circuit. Simply attach a DC power supply to the DC motor and it will run. However, precisely controlling the motion, speed and position of DC motors is difficult. DC motors do not make finite steps and need additional components to control speed. The DC motor either spins or doesn't spin, and lacks the inherent position and speed control of the stepper motor. Like a stepper motor, DC motors have stators and rotors. But unlike a stepper motor, the rotor motion does not follow sequentially-magnetized stators. Instead, the stators are fixed magnets. When current is supplied to wire coils that are wrapped around the ends of the rotor, a magnetic field is created, causing the rotor to move. Figure 3 shows the basic parts of a simple DC motor.

Disadvantages of DC motors
As mentioned above, DC motors do not have inherent positional control. Hence, optical sensors are often added to determine the position of the rotor. Optical sensors may malfunction because of dust or wear particles created by the mechanical braking system. This can have a negative effect on achieving the accuracy and precision of piston movement required in an application like pipetting.

DC motors also lack the braking control of stepper motors. A stepper motor can be stopped rapidly and held firmly when the switching pulse stops and allows the rotor to orient itself in a set position. DC motors however, must incorporate additional mechanisms, such as gearing, clutches, and a solenoid brake to control speed and stop the rotor in desired positions (see Figure 4). These additional components increase the mechanical complexity of the system and are susceptible to wear and tear. Thus, the reliability of the DC motor system is frequently an issue.

Conclusion

DC motor system:
A DC motor system requires a DC motor, optical sensor, and mechanical braking components. The mechanical braking system is subject to wear, and the optical sensor can malfunction from dust or wear particles. This can reduce reliability, accuracy, and precision.

Stepper motor system:
A modern stepper motor system consists of the motor itself and the electronic circuitry required to automatically brake motor rotation and control position. Therefore, stepper motors are better suited for use in electronic pipettes than DC motors particularly when accuracy, precision and reliability are required.

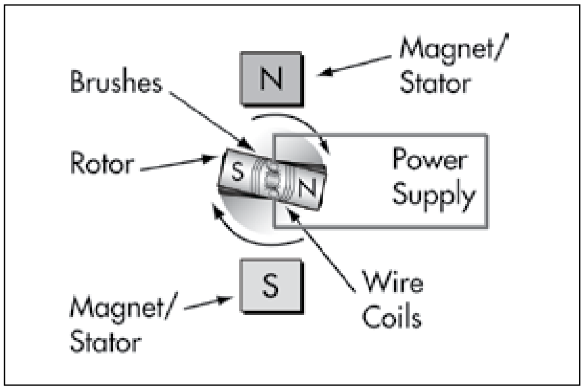

Figure 3- DC motor

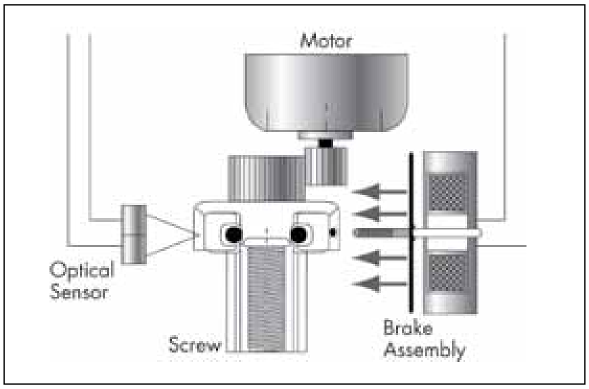

Figure 4- Mechanisms of a DC motor system