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3-Axis Motion Made Simple in 3 Ways using CLICK PLUS PLC

AutomationDirect CLICK PLUS PLCs, when combined with stepper motors, make advanced motion control and edge integration simple for smaller systems.

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Electric motors provide the motive force for many types of machinery and equipment. Sometimes standard AC and DC motors are operated at fixed speed, and other times they are driven using a variable frequency drive (VFD) or DC drive to vary the speed and acceleration. But to perform the powerful, rapid, accurate, and energy-efficient movement of parts and mechanisms associated with industrial machinery, electronic motion control becomes necessary.

Devices for providing electric motor motion control were introduced in the 1960s and have developed significantly since then, with many improvements along the way. Early approaches were complicated and required coordination among many individual devices. Later on, the inclusion of motion control instructions into high-end industrial programmable logic controllers (PLCs) provided better automation capabilities, but these solutions remained expensive and complex, and they were therefore reserved for only the most demanding applications.

Two developments have improved these circumstances dramatically, making PLC-controlled motion easy and cost-effective, suitable for industrial, commercial, and hobbyist applications:

- Micro-PLCs with motion-specific instructions:
  CLICK PLUS PLCs now include essential motion instructions, and when combined with their available computing power and networking capabilities, means they can monitor and control motion applications with up to three coordinated axes.
- DC and AC stepper motors/drives:
  AutomationDirect stepper motors, with separate or integrated drive options, are available in standard DC and higher-power AC versions to provide reliable open-loop motor motion control.

This white paper describes how users can implement modern micro-PLCs and steppers to accomplish motion control easily and economically with the power, speed, and accuracy necessary for a wide range of applications (Figure 1).

Figure 1: The AutomationDirect CLICK PLUS, shown here, is a modern micro-PLC enhanced with high-speed pulse train outputs and a straight-forward instruction set, making it practical, economical, and easy for users to implement motion control with open-loop stepper motors for applications of three axes or less.

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Motion Control Basics

For motor-driven motion control, each motor to be controlled is called an axis, and for larger machines it is often necessary to coordinate the operation of many axes. The motor for each axis may operate equipment directly, or indirectly via a gearbox or other mechanism.

PLCs are commonly used for all types of machinery control, and for the greatest flexibility and streamlined integration some PLCs have included motion control command capabilities right on board. Historically, this functionality was only available with premium product lines. Small and micro-PLCs, which work well for other aspects of machine control, lacked built-in means of integrating with motors for streamlined motion control.

A large or complicated application may need a high-end PLC because of the large overall input/output (I/O) count, the need to coordinate many axes of motion, and other required functionality. For example, a printing press with multiple material rollers and moving elements will typically require a full-featured PLC.

However, there are numerous applications where no more than three axes are needed—often the X, Y, and Z positioning of equipment—so a large PLC would be overkill. Designers are now finding it appealing that many features have trickled down from large PLCs to micro-PLCs. While there is no hard definition of a micro-PLC, typical features include:

- Form factors like self-contained bricks, along with more flexible stackable and modular configurations, so users can select appropriate I/O types and counts
- Reasonable I/O counts on the order of 15 to 128 points, including discrete and analog inputs and outputs
- High-speed inputs, needed for triggering, timing, and counting functions
- Comprehensive logic control with the most useful instructions
- PID loop control
- Extended communications options, especially over Ethernet
- Data handling and processing
- Simplified programming development environments
- Motion control computing/instruction capabilities

Micro-PLCs are well equipped for direct control, smart remote I/O, or data acquisition and industrial internet of things (IIoT) projects. Modern micro-PLCs—in contrast with large PLC platforms—are certainly a more approachable way to incorporate motion control into many projects.

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Motor Options

To understand how to produce and control motion with electric motors, knowledge of these available technologies is needed:

- Standard DC motor:
  Also good for on/off or continuous operation, or it can be run at variable speeds using a drive. Good torque at low speeds.
- Standard AC induction motor:
  Good for on/off or continuous operation at a fixed speed using a contactor, or at adjustable speeds using a VFD. Powerful, efficient, and low maintenance.
- Stepper motor: Works together with a drive to convert pulse commands—typically very rapid— into small discrete step movements performed open-loop. Stepper motors have varying speed and torque capabilities, and because torque decreases as speed increases, they typically work best below 1,000 rotations per minute. They can be operated at fixed or varying speeds like a standard motor, or they can be driven to specific velocities and positions as desired.
- Servo motor:
  Works with a servo drive using closed-loop feedback to ensure accurate and responsive operation. Comparatively complex and costly, but necessary for high-performance positioning, executing velocity/acceleration profiles, and performing intermittent movements.

Motion control requires the motor, an associated drive, and a motion controller. The drive is usually separate from the motor, but it may be integrated within the motor. Sometimes a drive offers motion control capability, or the motion controller may be a separate and independent device. Even when a dedicated motion controller is used, it often must still be integrated with other supervisory PLC controls.

For motion applications, an AC or DC motor is usually not suitable. A servo motor system provides the ultimate combination of full torque at all speeds and ultra-precise motion, but it can cost up to four times more than a stepper system.

Stepper motors combine some of the best aspects of other electric motor types, and they are available in DC and high bus voltage (AC) versions. While most stepper motors are operated open-loop, it is becoming more common to implement them in a closed-loop manner with sensors. Open-loop steppers are a popular choice for commercial applications such as 3D printers, and they are useful for operating many types of industrial machinery, such as lathes and CNC machines.

Motion with Micro-PLCs and Steppers

The CLICK PLUS PLC offers the high-speed pulse train discrete outputs, and dedicated motion instructions, required for controlling stepper motors.

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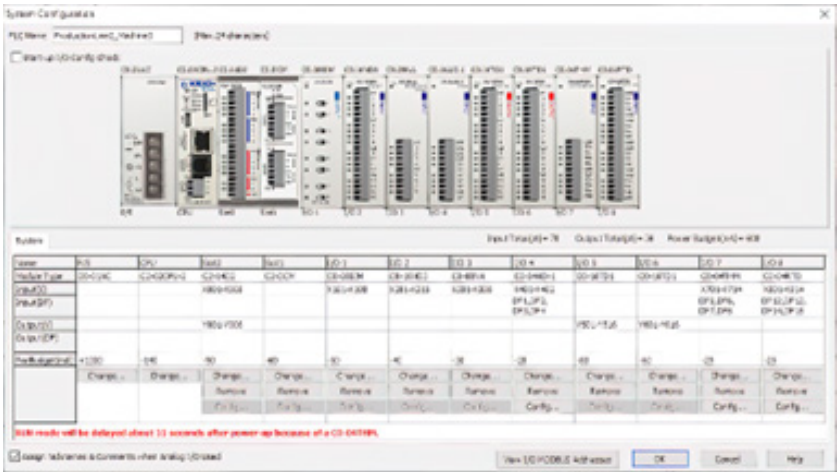
Micro-PLC high-speed pulse train discrete outputs are used to drive a stepper motor controller, and in fact can even drive some servo motor controllers. Each stepper motor controller needs connections from two micro-PLC outputs: one pulse frequency for steps and the other for direction.

One pulse of a step signal commands the motor to move one step. Stepper motors can operate in several modes, such as full-step (200 steps per revolution), half-step (400 steps per revolution), and all the way up to 50,000 steps per revolution. Finer step modes improve accuracy and smoothness but limit maximum speed. Therefore, users must select a step mode appropriate to the application by balancing these characteristics.

The CLICK PLUS PLC includes a dedicated hardware configuration mode, providing an intuitive interface for users to define the overall PLC arrangement, which digital outputs are associated with a stepper drive, and the proper axis properties (Figures 2 and 3). This setup helps users easily commission and maintain their systems.



Figures 2 and 3: The AutomationDirect CLICK PLUS PLC development environment is intuitive and graphical, empowering users to rapidly define the hardware and high-speed discrete output configurations, and to coordinate them with stepper systems.

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From a software instruction standpoint, some esoteric motion applications may require advanced commands. However, the reality is that most applications are readily implemented with a compressed and simplified instruction set incorporating the following aspects:

- Homing (Figure 4):
  Stepper motor systems do not typically use encoder feedback, so it is necessary to periodically drive the hardware to a known location using input from one or more limit switches to verify or "home" the calibration of each axis. There are six common homing approaches based on the application:
  - Move to switch 1, creep to switch 2, then halt
  - Move to switch 1, then halt
  - Move to switch 1, then decelerate
  - Move to switch 1, then away and back
  - Move to switch 1, then decelerate a distance (registration)
  - Set the current position as home

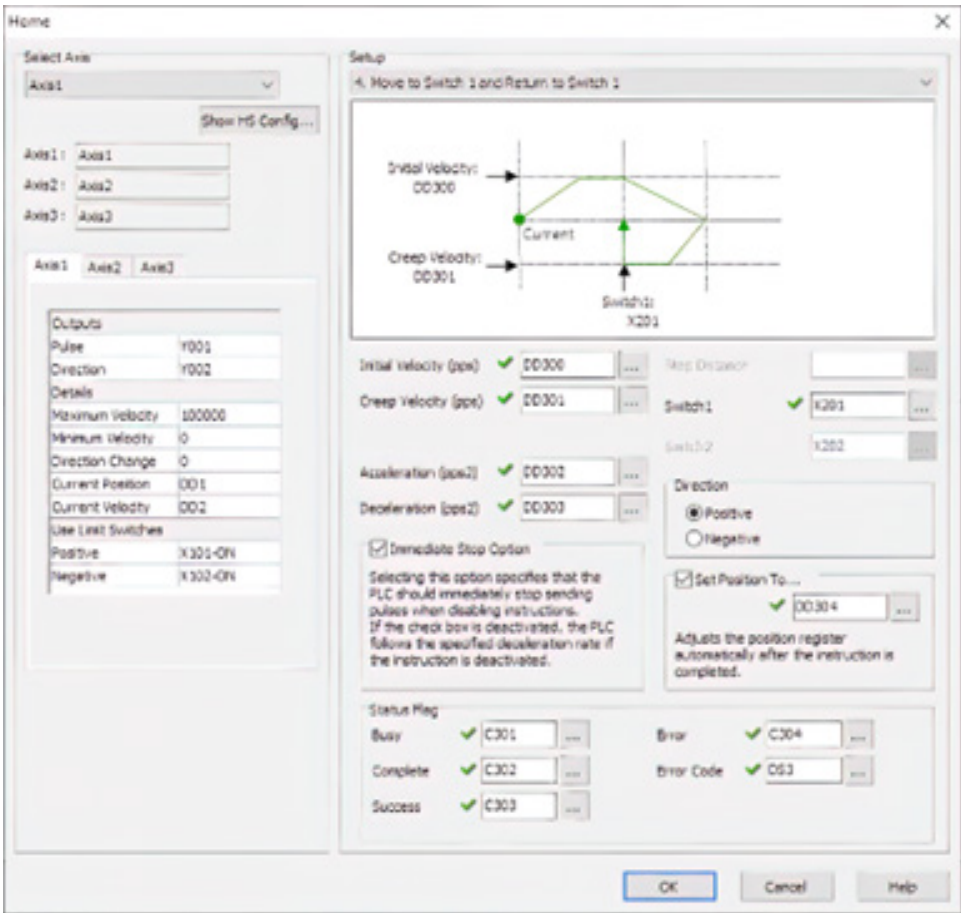

Figure 4: The "Home" instruction in the simplified instruction set includes the six most common standard homing methods, prompting users to select the necessary information.

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- Velocity Move (Figure 5):
  Many applications call for a single motor axis to reach a target velocity and direction via a specified acceleration or deceleration profile. An enhancement option called "S-curve" can be enabled to ensure that acceleration and deceleration rates are started and finished smoothly, preventing position loss or unintended product motion due to inertia or friction loss.

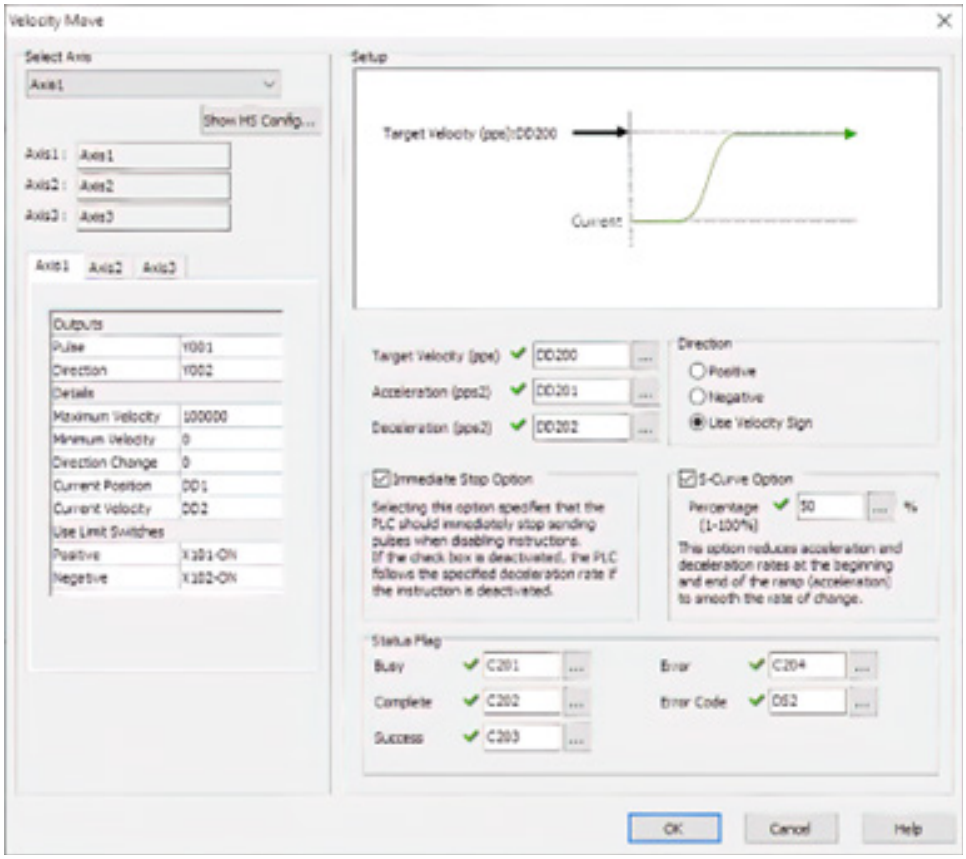

Figure 5: With the "Velocity Move" instruction, users can control the motor direction and target velocity, as well as the acceleration and deceleration.

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- Position Move (Figure 6):
  Mimicking the action of a servo, this move allows the user to define the target position that up to three axes should be driven to, including the associated acceleration, deceleration, and velocity to achieve the position. S-curve is also an option for this type of move.

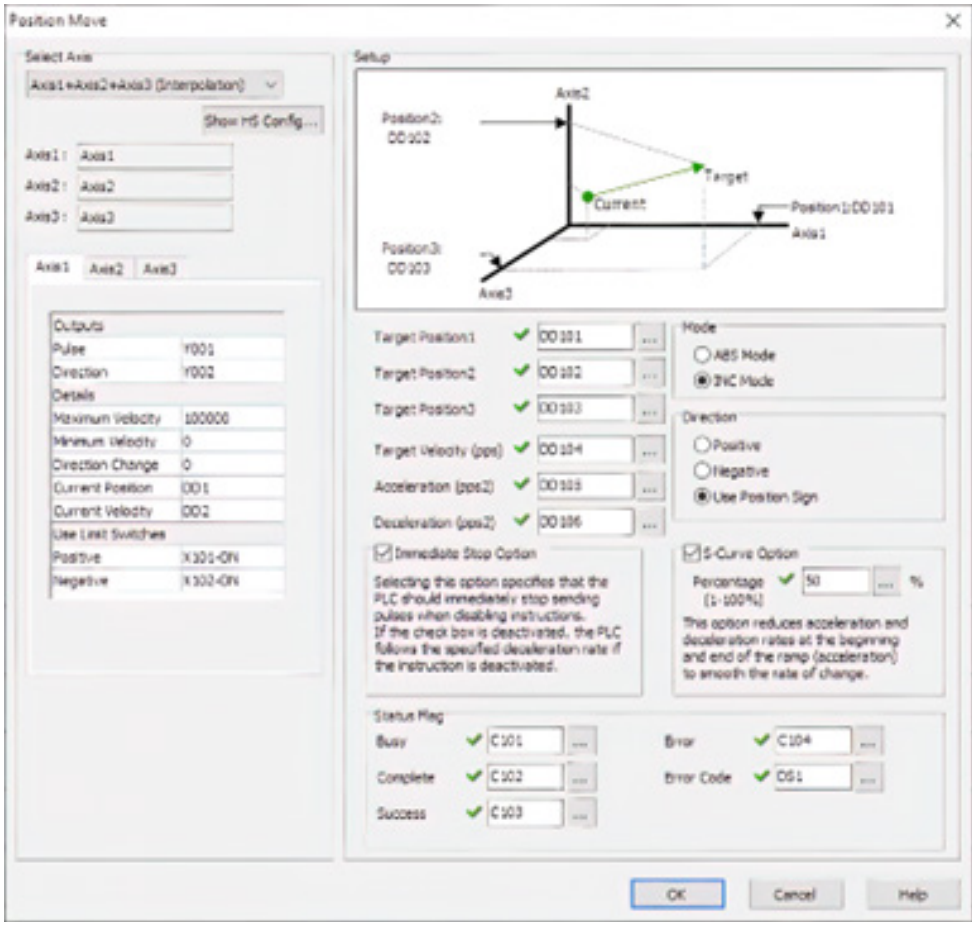

Figure 6: The "Position Move" instruction depicted here makes it straightforward for users to implement synchronized two-axis or three-axis combined movements, which are needed for many common machine automation applications.

The availability of a single instruction to join two or three axes for combined movements, resulting in a combined vector, is especially powerful. The micro-PLC internally calculates the acceleration, velocity, and deceleration of each individual axis so all axes begin and end in complete synchronization. Joined movement of this type is a common need for equipment using X-Y or X-Y-Z motion..

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Motion Made Simple

Motion applications require designers to make several informed implementation decisions, considering elements such as:

- Motor speed and power
- Monitoring and status information
- Means and frequency of homing operations (e.g., once per cycle, mid-cycle, or more/less often)
- How to logically integrate the necessary velocity and position moves
- Appropriate failure mode

Traditional motion solutions using servos are very capable but require significant effort—not to mention relatively high hardware and installation costs—for implementation and support. Certainly, servo technology remains important and necessary in many cases, but many times a simpler solution would suffice.

Improved micro-PLC and stepper technologies now provide users with the option to easily and economically add one, two, or three axis coordinated motion control to a wide variety of applications. Developers will find that advanced motion control is greatly simplified when using AutomationDirect CLICK PLUS micro-PLCs—which include basic yet powerful configuration provisions, along with homing, velocity, and position instructions—in conjunction with stepper motor controllers. And in addition to using these micro-PLCs for motion, users can also seamlessly automate other aspects of the same machine, providing real-time control, edge and IIoT connectivity, and other functionality.

Figures all courtesy of AutomationDirect unless otherwise noted