

How to Properly Drive a Stepper Motor Linear Actuator

Introduction

Stepper motor linear actuators (SMLAs) are integral to precision motion control systems across industries – from medical devices and lab automation to packaging and robotics. Thomson motorized lead screws (MLS) and motorized lead nuts (MLN) combine hybrid stepper motors with high-performance lead screws, offering compact, efficient and reliable linear motion. This guide provides a comprehensive overview of how to properly drive, integrate and optimize these actuators.



Understanding Stepper Motor Linear Actuator Architecture

Thomson SMLAs are designed to simplify motion system integration while delivering high thrust, precision and customization.

Core components found in all SMLAs are:

- (1) Stepper motor
- (2) Lead screw
- (3) Lead nut

MLS

- The motor rotates the lead screw directly.
- The nut is fixed to the load and translates linearly.
- Ideal for modular systems, prototyping and applications requiring external nut customization.



MLN

- The motor rotates an internally mounted nut.
- The screw is fixed to the load and translates linearly.
- Offers a more compact footprint and dual-end load handling.



Note: All SMLA units need to be properly mounted and guided to function properly. For more information on how to mount these units, see installation manual on the [Thomson website](#).

These configurations are available in NEMA frame sizes from 08 to 23, supporting a wide range of force, speed and space requirements.

Frame Size	Available Stack	Available Current (Amps)	Available Configuration
NEMA 8	Single	0.50	MLS
NEMA 11	Single	1.00	MLS, MLN
NEMA 14	Single	1.35	MLS, MLN
NEMA 17	Single and double	1.50	MLS, MLN
NEMA 23	Single and double	1.55 & 3.00 (single), 1.90 (double)	MLS, MLN

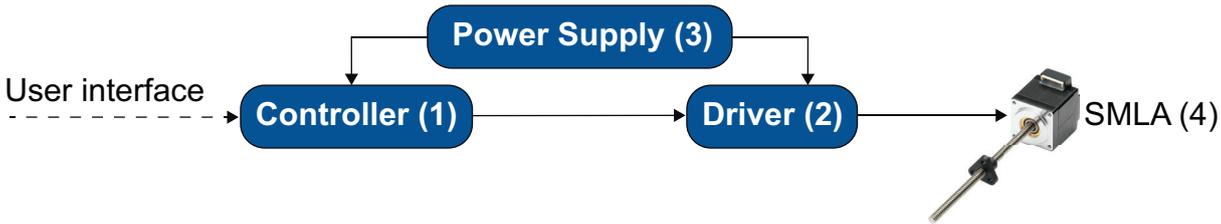
Basic System Setup

SMLA systems generally fall into two categories: open-loop and closed-loop configurations. The following sections will provide an overview of each.

Open-Loop Systems

Open-loop systems consist of the following main components:

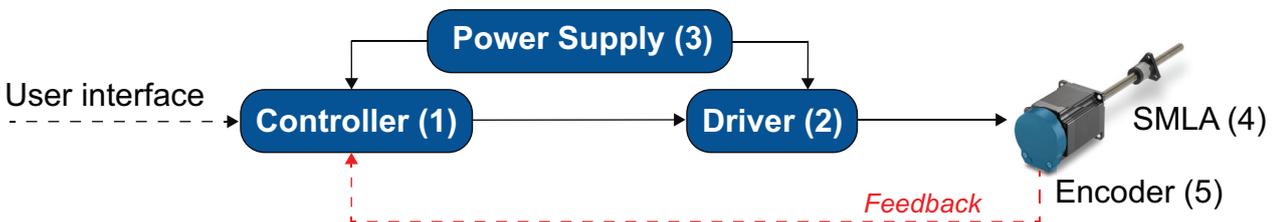
- (1) *Controller*: Sends pulse signals to the driver based on desired motion.
- (2) *Driver (Drive Circuit)*: Amplifies control signals and powers the motor.
- (3) *Power Supply*: Provides the necessary voltage and current.
- (4) *Stepper Motor*: Converts electrical pulses into discrete mechanical movements.



Closed-Loop Systems

Closed-loop systems are just like open-loop systems, consisting of the same main components (1-4 above) plus an additional device:

- (5) *Feedback Device*: Used in closed-loop systems to monitor motor position. Typically an encoder, it can provide feedback to controller, driver, user-interface or any combination of all three.



System Components Overview

Controllers (1)

In an SMLA system, the controller is the brains of the operation. It determines how and when the motor should move and sends precise electrical pulses to the driver, which then powers the motor to rotate in discrete steps.

Main Functions of a Controller

- *Generates step and direction signals*: These signals tell the motor how many steps to take and in which direction.
- *Controls speed and acceleration*: By adjusting the timing of pulses, it manages how fast the motor moves.
- *Interfaces with other systems*: Controllers often connect to computers, PLCs or microcontrollers to receive commands.

Controller Types

Examples of common controller types are shown in the following table:

Controller Type	Description	Example Models/Brands
Microcontroller-Based	Small, programmable boards ideal for DIY and embedded systems	Arduino Uno, Raspberry Pi, STM32
Motion Controllers	Dedicated hardware for precise multi-axis control in industrial settings	Trinamic TMC4671, Galil DMC-41x3, ACS SPiiPlus
PC-Based Controllers	Software-driven control via USB/Ethernet, often used in CNC and 3D printing	Mach3, LinuxCNC, UCCNC
PLCs	Programmable Logic Controllers used in factory automation	Siemens S7-1200, Allen-Bradley MicroLogix
Integrated Controllers	Combine motor, driver and controller in one compact unit	Leadshine iHSS57, Teknic ClearPath-SD
Digital Signal Controllers (DSCs)	Hybrid between microcontroller and digital signal processor (DSP) for high-speed control	Microchip dsPIC series
FPGA-Based Controllers	Ultra-fast, customizable logic for high-performance systems	Xilinx Spartan series, Intel Cyclone

Key Considerations for Selecting a Controller

- **Control Interface:** Choose based on system architecture. Options include step/direction, serial (RS-232/RS-485), USB, CANopen or EtherCAT.
- **Axis Count:** Determine how many motors need to be controlled simultaneously.
- **Programming Environment:** Consider ease of integration with your software (e.g., G-code, PLC ladder logic, or C/C++ APIs).
- **Real-Time Capabilities:** For time-critical applications, ensure the controller supports deterministic timing.
- **Pulse Frequency:** Ensure controllers max output frequency lines up with motor speed requirements (Hz).

Drivers (2)

In an SMLA system, the drive (or driver) is the component that receives low-power control signals from the controller and converts them into high-power electrical pulses to move the motor. It acts as the intermediary between the controller and the motor, ensuring the motor receives the correct voltage and current to step accurately.

Main Functions of a Driver

- **Amplifies signals:** Boosts low-voltage control signals to levels suitable for the motor.
- **Controls current:** Regulates current to prevent overheating and ensure efficient operation.
- **Manages stepping modes:** Supports full-step, half-step and microstepping for smoother motion.
- **Protects the motor:** Can include features like overcurrent, overvoltage and thermal protection.

Driver Types

Driver Type	Description	Example Brands/Models
Unipolar Driver	Drives motors with center-tapped windings. Simpler design, lower torque.	Sanyo Denki PMM Series, ULN2003, Allegro UDN2981
Bipolar Driver	Uses H-bridge to reverse current. Higher torque, no center tap needed. Standard for SMLAs.	Kollmorgen P7000 Series, Pololu A4988, Trinamic TMC2208, GeckoDrive G201X
Chopper Driver	Regulates current via PWM. Efficient and good for high-speed operation.	Kollmorgen P6000 Series, TI DRV8825, Leadshine DM542, GeckoDrive G540
Microstepping Driver	Divides steps into finer increments for smoother motion and less noise.	Kollmorgen P7000 Series, Trinamic TMC2130, STMicro L6470, Leadshine AM882
Closed-Loop Driver	Uses feedback (e.g., encoder) to correct position errors. Prevents missed steps.	Kollmorgen AKD Stepper, Leadshine HBS57, Oriental Motor AR Series, Yaskawa SigmaStep
Digital Stepper Driver	Offers programmable settings via software. Ideal for automation systems.	Kollmorgen P7000 with RS-485, Parker Hannifin PDX Series, SMC LECP6, GeckoDrive G250

Key Considerations for Selecting a Driver

- *Motor Compatibility:* Match the driver to your motor type (bipolar/unipolar), voltage and current ratings.
- *Microstepping Support:* Choose a driver with appropriate microstepping resolution for your precision and smoothness needs.
- *Control Interface:* Ensure the driver supports your controller's output (e.g., step/direction, serial, CAN or Ethernet).
- *Closed-Loop Capability:* Consider feedback-enabled drivers if your application demands high reliability or dynamic load handling.
- *Thermal and Power Management:* Check for features like current limiting, thermal protection and efficient power handling.
- *Application Requirements:* Factor in speed, torque, noise and environmental conditions (e.g., vibration, temperature).

Power Supplies (3)

A power supply is a critical component in any motion control system, including SMLAs. It converts electrical energy from a source (typically AC mains) into a regulated DC output suitable for powering drivers, motors and control electronics.

Main Functions of a Power Supply

- *Voltage Conversion:* Converts high-voltage AC (e.g., 120/240V) to low-voltage DC (e.g., 24–48V).
- *Current Delivery:* Supplies sufficient current to meet the demands of motors and drivers.
- *Voltage Regulation:* Maintains stable output voltage under varying load conditions.
- *Protection:* Prevents damage via overvoltage, overcurrent, short-circuit and thermal safeguards.
- *Noise Filtering:* Reduces electrical noise and ripple that can interfere with sensitive control signals.

Power Supply Types

Type	Description	Typical Use Cases	Example Models/Brands
Switching Power Supply	Uses high-frequency switching for efficient DC conversion	Stepper motor systems, industrial automation	Mean Well LRS-350-24, TDK-Lambda HWS, Omron S8VK
Linear Power Supply	Converts AC to DC using transformer and regulator	Audio equipment, analog circuits	HP 6236B, BK Precision 1550
Programmable Power Supply	Allows dynamic control of voltage/current via software or interface	R&D labs, robotics, automated test setups	Kollmorgen AKD Module, Rigol DP832, Keysight E36313A
Uninterruptible Power Supply (UPS)	Provides backup power during outages using batteries	Servers, CNC machines, critical systems	APC Smart-UPS, CyberPower CP1500PFCLCD
Battery-Based Supply	Uses rechargeable or disposable batteries for portable DC power	Mobile robotics, field instruments	Li-ion packs (24V 10Ah), SLA batteries

Key Considerations for Selecting a Power Supply

- *Power Demands:* The power supply must be sized to handle the system's peak power demands reliably.
- *Voltage:* Must match the driver's input range (commonly 24–48 VDC for stepper systems).
- *Current Capacity:* Should exceed the total current draw of all motors and drivers by 20–30% to account for startup surges and inefficiencies.
- *Regulation and Stability:* A regulated supply ensures consistent performance under varying loads.
- *Protection Features:* Look for overvoltage, overcurrent and thermal shutdown capabilities.

Feedback Devices (5)

In SMLA systems, a feedback device is a sensor or signal-generating component that monitors the motor's position, speed or motion status and relays this information to the controller and/or driver. While traditional stepper motors operate in open-loop mode (without feedback), integrating feedback devices enables closed-loop control, improving accuracy, reliability and fault detection.

Main Functions of Feedback Devices

- *Position Monitoring:* Tracks the motor's actual position to verify commanded movement.
- *Speed Measurement:* Measures rotational or linear speed for dynamic control.
- *Error Detection:* Identifies missed steps, stalls or overloads.
- *Limit Detection:* Signals when the actuator reaches its travel limits to prevent mechanical damage.
- *System Calibration:* Provides reference points for homing and zeroing routines.

Types of Feedback Devices

Device Type	Description	Typical Use Cases	Example Models / Brands
Rotary Encoders*	Mounted to motor shaft; measure angular position and speed	Closed-loop stepper control, missed step detection	US Digital E5, CUI AMT102, Kollmorgen SFD Series
Linear Encoders	Measure actual linear displacement along the actuator's travel path	Precision metrology, fluid dispensing systems	Renishaw LM10, Heidenhain LIC Series
Limit Switches	Detect end-of-travel positions; prevent overrun	Safety stops, homing routines	Omron D2HW, Honeywell V7 Series
Proximity Sensors	Non-contact detection of position or obstacles	Obstacle detection, soft limits	Pepperl+Fuchs Inductive Sensors, Banner Engineering
Hall Effect Sensors	Detect magnetic fields for position or speed feedback	Compact systems, brushless motor feedback	Allegro A3144, Honeywell SS495A

* Thomson offers rotary encoders for all SMLAs.

Key Considerations for Selecting a Feedback Device

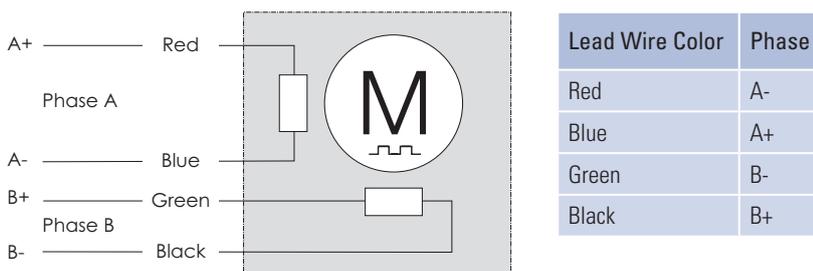
- Match the feedback type to your application (rotary encoder, linear encoder, limit switch, etc.).
- Ensure compatibility with your driver or controller (signal format and voltage levels).
- Choose resolution based on required positioning accuracy.
- Consider environmental factors like temperature, dust and vibration.
- Verify mounting options and wiring integration with your system.

Wiring and Shielding

Proper wiring and shielding are essential for ensuring reliable and noise-free operation in SMLA systems, especially in environments with electrical noise or high-speed switching. Below are some recommendations:

- Use twisted pair wires for motor phases to reduce electrical noise.
- Use shielded cables for motor and signal lines; ground the shield at one end only.
- Keep power and signal cables physically separated to avoid interference.
- Minimize cable lengths and use proper wire gauge for current load.
- Avoid routing cables near high-EMI sources like AC mains or relay.

Note: All Thomson SMLAs utilize a four wire, bipolar configuration as shown in the diagram below.



Setup and Programming

Proper setup and programming of your controllers and drivers not only enhance performance but also extend the lifespan of your motion system. Below are some key principles for proper setup and programming of controllers and drivers in your SMLA system.

Electrical Configuration

Voltage and Current Matching. Select a driver that matches the motor's rated voltage and current. Undersupplying current can lead to missed steps and torque loss, while oversupplying can cause overheating, premature wear or damage to the motor. Use drivers with programmable current limits and thermal protection features when possible.

SMLA motor configurations with appropriate drive currents are outlined in the following table.

Configuration	Motor	Rated / RMS Current (Amps)	Full Stepping Drive Current (Amps)	Microstepping Drive Current (Amps)
MLx08A05	NEMA 8, single	0.50	0.50	0.71
MLx11A10	NEMA 11, single	1.00	1.00	1.41
MLx14A13	NEMA 14, single	1.35	1.35	1.90
MLx17A15	NEMA 17, single	1.50	1.50	2.12
MLx17B15	NEMA 17, double	1.50	1.50	2.12
MLx23A15	NEMA 23, single	1.55	1.55	2.19
MLx23A30	NEMA 23, single	3.00	3.00	4.23
MLx23B19	NEMA 23, double	1.90	1.90	2.68
MLx23A30	NEMA 23, single	3.00	3.00	4.23
MLx23B19	NEMA 23, double	1.90	1.90	2.68

Step Mode Selection. Choose between full-step, half-step and microstepping modes based on your application's resolution and smoothness requirements.

Step Mode	About
Full-Step	Maximum torque, lowest resolution
Microstepping	Reduced vibration and noise, higher resolution, slightly lower torque

Decay Mode Tuning. Drivers often support fast, slow or mixed current decay modes. Mixed decay is generally preferred for balancing torque and smooth motion, especially at higher speeds.

Motion Profile Programming

Acceleration and Deceleration Curves. Sudden changes in speed can excite mechanical resonance and cause missed steps. Implement trapezoidal or S-curve acceleration profiles to gradually ramp speed.

Acceleration Profile	About
Trapezoidal	Simple and effective for most applications
S-curve	Ideal for delicate or high-precision tasks

Step Pulse Timing. Configure the controller to generate clean, jitter-free step pulses. Pulse frequency determines motor speed, and pulse width must meet the driver's minimum timing requirements.

To calculate pulse rate, the following equation can be used:

$$\text{Pulse rate (Hz)} = \left(\frac{\text{linear speed}}{\text{lead}} \right) \times (\text{motor steps per rev}) \times (\text{pulses per step}) \times (\text{microstep})$$

- *Linear speed*: desired linear travel speed (in/s)
- *Lead*: lead screw travel per one full revolution of the screw (in/rev)
- *Motor steps per rev*: steps per one full revolution of the motor (steps/rev). All SMLAs are 200 steps per revolution.
- *Pulses per step*: pulses per step (pulse/step). SMLAs are 1 pulse per 1 step.
- *Microstep*: Microstepping resolution (microstep/step)

Dynamic Speed Control. For applications requiring variable speed, use programmable motion controllers that support real-time speed adjustments via software or external inputs.

Feedback and Closed-Loop Control

Encoder Integration. In closed-loop systems, encoders provide real-time position feedback. This allows the controller to detect and correct missed steps, improving reliability under dynamic loads.

Stall Detection and Recovery. Advanced drivers can detect stalls and automatically re-home or adjust motion to maintain accuracy. This is critical in high-load or safety-sensitive environments.

PID Tuning. For systems using vector control or PID loops, tuning gain parameters ensures stable and responsive motion. Use manufacturer tools or motion analysis software to assist.

Safety and Diagnostics

Thermal Management. Program temperature thresholds and enable automatic current reduction or shutdown to prevent overheating.

Fault Handling. Configure fault detection for overcurrent, undervoltage and communication errors. Define recovery routines to minimize downtime.

Diagnostic Logging. Enable motion logging and error reporting to analyze performance trends and troubleshoot issues. Many modern drivers offer built-in diagnostics via USB or Ethernet.

Communication and Integration

Interface Protocols. Select drivers and controllers that support your system's communication needs (RS-485, CANopen, Modbus, Ethernet/IP, etc.).

Software Tools. Use vendor-provided configuration software to visualize motion profiles, tune parameters and update firmware. Examples: Kollmorgen WorkBench, Leadshine Motion Studio, Trinamic TMCL-IDE.

System Synchronization. For multi-axis systems, synchronize controllers using master-slave configurations or real-time bus protocols to ensure coordinated motion.

Conclusion

Ultimately, experience is the best tool at one's disposal for building a stepper motor-based system. The guidance mentioned in this document should only be utilized as a way of getting into the ballpark for a system build. Some experimentation with trial and error may need to be conducted to attain a completely functional system. Always utilize the help of an experienced system designer and add a decent margin to system calculations when possible. When it comes to SMLA selection, Thomson can help recommend a product to get the performance you need. Controller, driver, power supply and feedback device manufacturers will also have dedicated engineers to help assist you in selecting one of their products.

For configuration tools, datasheets, and support, visit the [Thomson SMLA page](#).