Stepper Motor Linear Actuators Driving Guide

THOMSON®
Linear Motion. Optimized.™

Rev. 01_20190326

DISTRIBUIDOR AUTORIZADO MEX (55) 53 63 23 31 MTY (81) 83 54 10 18
QRO (442) 1 95 72 60 ventas@industrialmagza.com

Contents

About Stepper Motor Linear Actuators

Stepper Motor Linear Actuators (SMLA) are stepper motor-based actuator assemblies. The main components of SMLA assemblies are:

1. Stepper motor
2. Lead screw
3. Lead nut

Motion is achieved by supplying controlled, electrical pulses to the internal stepper motor coils. Energizing these coils in specific time sequences enables the programmer to manipulate the rotation of the motor shaft and induce motion.

SMLAs come in three standard configurations (Figure 1).

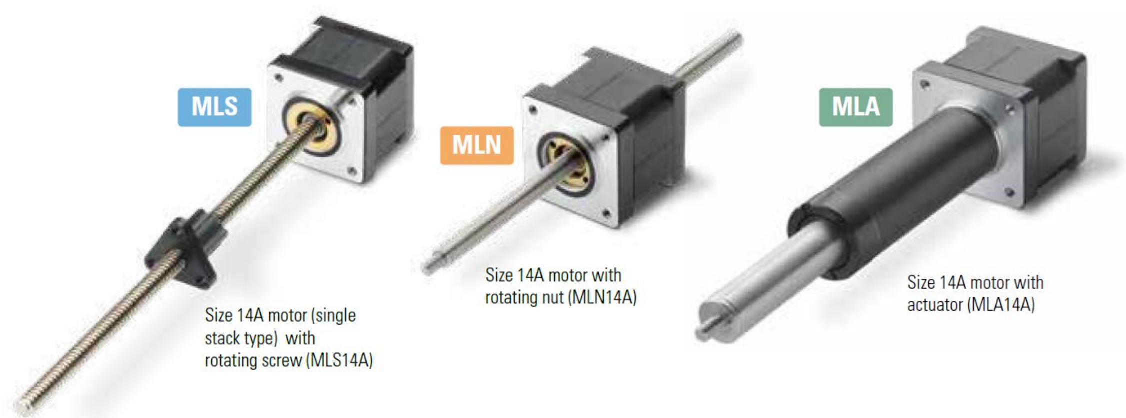

Figure 1: SMLA configurations. Although each configuration has a slightly different arrangement, at their core, each assembly primarily consists of a stepper motor, lead screw and lead nut.

Rotating Screw (MLS)

Rotating screw (MLS) configurations have a lead screw directly attached to the stepper motor shaft so when the motor is driven, the lead screw will rotate, causing the lead nut to translate axially across the lead screw. External guidance of the lead nut is required for motion to occur.

Rotating Nut (MLN)

Rotating nut (MLN) configurations have the lead nut directly integrated into the motor shaft so when the motor is driven, the lead nut will rotate, causing the lead screw to actuate in and out of the motor. External guidance of the lead screw is required for motion to occur.

Actuator (MLA)

Actuator (MLA) configurations are MLS-style assemblies with added components to provide guidance to the lead nut and act as a barrier to outside contaminations. Unlike MLS assemblies, MLA assemblies do not require external guidance of the lead nut for motion to occur.

SMLA - Standard Stepper Motors

The stepper motors utilized for SMLA assemblies come in various sizes and configurations. Table 1 outlines those offered by Thomson.

Frame Size	Available Stack	Available Current [Amps]	Available Configuration
NEMA 8	Single	0.50	MLS, MLA
NEMA 11	Single	0.51, 1.00	MLS, MLN, MLA
NEMA 14	Single	0.88, 1.35	MLS, MLN, MLA
NEMA 17	Single and double	1.00, 1.50 (single and double)	MLS, MLN, MLA
NEMA 23	Single and double	1.55 & 3.00 (single), 1.90 & 3.90 (double)	MLS, MLN, MLA

Table 1: SMLA Standard Stepper Motor Configurations. Custom motor windings are available – contact Thomson for more info.

Motor Wiring Diagram

The standard stepper motors offered by Thomson come in a four wire, bipolar configuration, as illustrated in Figure 2 and Table 2. Connecting to the stepper motor will require a bipolar compatible driver to be interfaced with the flying leads coming from the motor.

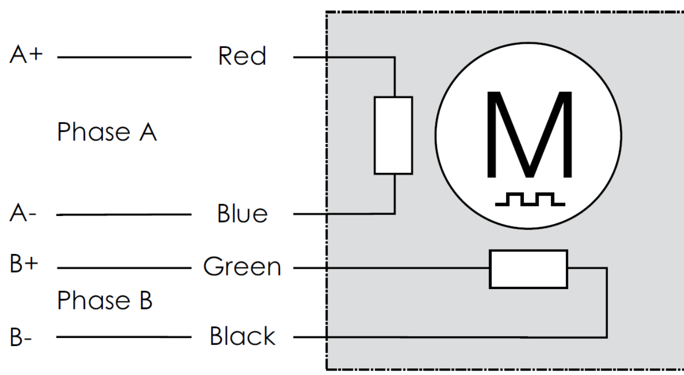

Figure 2: SMLA Motor Phase and Lead Wire Diagram.

Lead Wire Color	Phase
Red	A-
Blue	A+
Green	B-
Black	B+

Table 2: Standard SMLA Wire Color Code.

Basic System Setup

The most basic open loop system setup for driving a SMLA (Figure 3) and can consist of the following components:

- Programmable logic controller (PLC), personal computer (PC) or microcontroller
- Motion controller
- Stepper motor drive

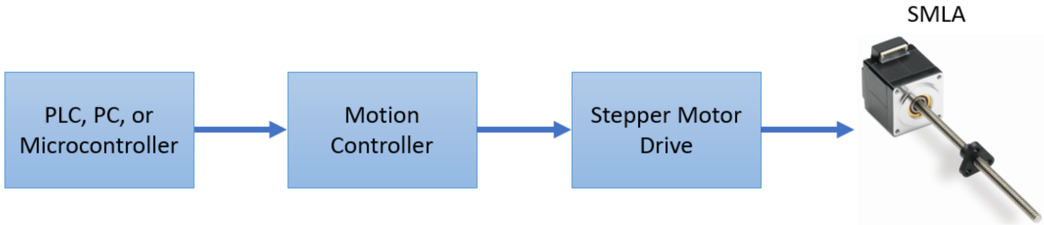

Figure 3: Basic open loop system setup for driving an SMLA unit.

PLC, PC or Microcontroller

A PLC, PC or microcontroller can be considered the brains, or central processing unit (CPU), of the entire system. This is where the main program will be stored, acting as the primary interface between the user and the system as well as the central unit to interface with all other peripherals and sensors in the system. A PLC, PC or microcontroller would also provide supervisory control and coordination between multiple SMLAs and peripherals/sensors in the system if needed.

Although functionality is generally the same between PLCs, PCs and microcontrollers, slight differences exist:

Programmable Logic Controller (PLC)

A PLC is a barebones computer with no keyboard, monitor or mouse attached to it. It is a purpose-built computer for industrial applications where it may be exposed to harmful conditions (dirt, debris, shock, etc.). A PLC is usually programmed via a computer running a proprietary software provided by the manufacturer, so an experienced programmer may not be required.

Personal Computer (PC)

In some cases, a standard computer can be used as the CPU for a SMLA system. With the right interface cards and/or ports, a PC can be directly connected to a motion controller and/or driver. Oftentimes, motion controllers and drives can also come with proprietary software, allowing them to be run without a PLC. If a motion programming software is not included with the motion controller or stepper drive, an experienced programmer will be required to properly interface and run the SMLA system.

Microcontrollers

Microcontrollers are similar to PLCs but are much more stripped down (no enclosure, no proprietary software, etc.). Microcontrollers are meant to be incorporated into a greater electrical system or circuit board. Although it would be considered much more "ground up" to utilize a microcontroller, there is much more freedom with regards to programming and electrical integration into a greater system as well as an overall lower cost over PLCs and PCs. Since microcontrollers are more minimal than PLCs, an experienced programmer is often required to build the software from the ground up.

Motion Controller

In some cases, the signal being sent out from the PLC, PC or microcontroller is inadequate for the stepper drive to utilize. In these cases, a motion controller is required to take the instructions from the PLC, PC or microcontroller and convert it to something that can be employed to the stepper motor drive. Simple signals can be sent to the motion controller that can manipulate the step position, speed and torque of the SMLA. A motion controller can often be called a "pulse generator" due to it communicating with the stepper drive by sending out electrical pulses at different amplitudes and frequencies.

A lot of newer stepper drives have a controller directly integrated into them. This eliminates the need for an external controller and allows for the signal from the PLC, PC or microcontroller to be directly utilized. A basic system illustrating a combination controller and drive is shown in Figure 4.

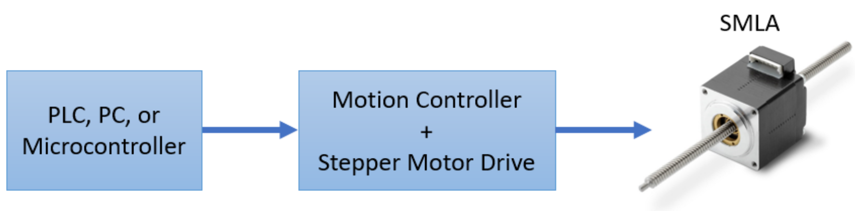

Figure 4: Basic SMLA system setup utilizing a combined motion controller and stepper drive.

Stepper Drive

The stepper motor drive is the link between the controller and the stepper motor on the SMLA. This unit can be considered a translator between the controller and stepper motor. The signals from the controller are interpreted by the driver and converted/amplified to a usable current into the motor. It provides the necessary power to drive the stepper motor. Maximum current and micro-stepping resolution are often configured on the driver in the form of DIP switches directly on the unit.

Closed Loop Systems

In some situations, feedback from the SMLA is required within a system. Feedback can give you an instantaneous position of the SMLA unit by interpreting the signal coming from the encoder attached directly to the motor. A compatible PLC/PC/microcontroller, driver and/or motion controller can read this signal from the encoder and make necessary adjustments and corrections to the motion of the SMLA if necessary. Two potential SMLA feedback systems are illustrated in Figures 5 and 6.

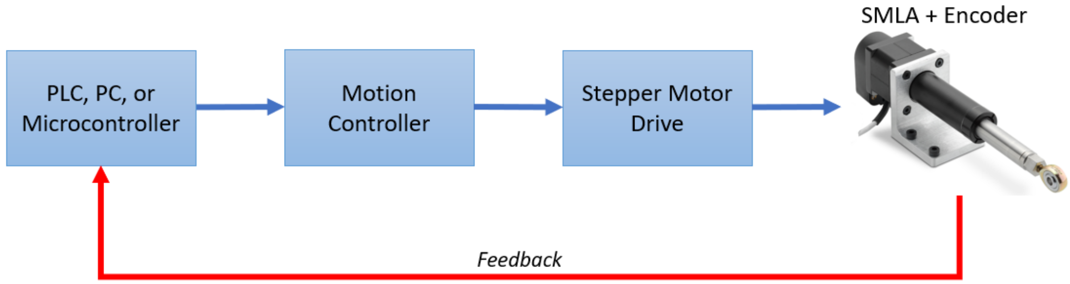

Figure 5: Example of a basic closed loop SMLA system.

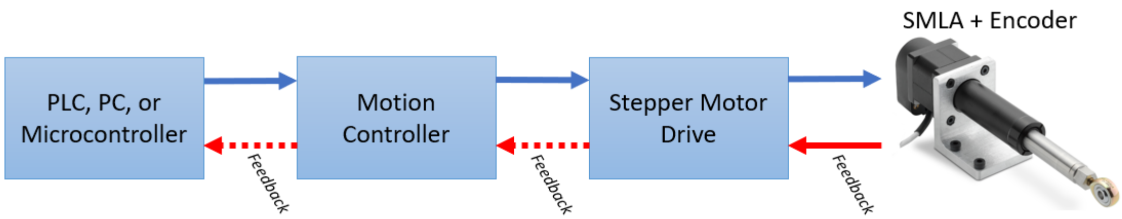

Figure 6: Alternative example of basic closed loop SMLA system where feedback can go directly to the motor drive and/or the motion controller and CPU.

Building Your System

When selecting components for a new SMLA system build, ultimately experience is the best tool at one's disposal. There are many preferences system designers have when it comes to PLCs, motion controllers, drives, etc., and there is no single correct setup. However, there are some general guidelines that can be used, which are outlined in the following sections.

SMLA Selection

When selecting the appropriate SMLA for your requirements, there are many different factors to consider such as load/speed, available drive current/voltage, preferred configuration (MLS, MLN or MLA) and so on.

Depending on the system requirements, the motor within the SMLA can be programmed to the desired speed, acceleration and general motion profile required. The main consideration is that the appropriate motor size is selected for the desired load and speed requirements. Individual motor performance plots can be found within the SMLA brochure and should be examined. Typically, a margin of at least 50% is recommended when sizing a motor. For critical and/or detailed sizing, discuss your requirements with a Thomson engineer.

Motor Current

When driving a stepper motor, the most important consideration is the current rating of the motor and available current from the stepper drive. If not enough current is supplied, the motor output torque will not be optimized, and the system will be underperforming. Too much current and the motor may overheat and damage to the motor windings can occur. The appropriate current to be utilized by Thomson standard configurations is summarized in Table 3.

Configuration	Motor	Rated / RMS Current [Amps]	Drive Current [full stepping]	Drive Current [micro stepping]
MLx08A05	NEMA 8, single	0.50	0.50	0.71
MLx11A05	NEMA 11, single	0.51	0.51	0.72
MLx11A10	NEMA 11, single	1.00	1.00	1.41
MLx14A08	NEMA 14, single	0.88	0.88	1.24
MLx14A13	NEMA 14, single	1.35	1.35	1.90
MLx17A10	NEMA 17, single	1.00	1.00	1.41
MLx17A15	NEMA 17, single	1.50	1.50	2.12
MLx17B10	NEMA 17, double	1.00	1.00	1.41
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
MLx23B39	NEMA 23, double	3.90	3.90	5.50

Table 3: SMLA Stepper Motor Drive Current. This table outlines the required current level of each standard SMLA configuration. Typically, if the motor is utilizing full stepping motion, the drive current = the RMS current. If micro-stepping is utilized, a multiplication factor of 1.41 is applied to the RMS current to get optimal torque output (drive current = 1.41 x RMS current).

PLC, PC or Microcontroller Selection

Selection of a CPU is completely up to the system designer. Often, an existing PLC, PC or microcontroller within your system can utilized. If starting from scratch, you can ask yourself the following questions: Will the CPU be exposed to harsh industrial conditions where a PLC may be beneficial? Will I be writing my own software where utilizing a PC would make things easier? Or would integrating this CPU onto a circuit board and a small-scale microcontroller make the most sense?

Motion Controller and Driver Selection

Motion Controller

The first thing that should be checked when selecting a motion controller is compatibility with other system components such as the PLC/PC, stepper driver and voltage sources.

Motor speed is controlled by the pulse rate (pulses per second) supplied by the driver via the controller. Depending on the speed required, one must ensure that the motion controller can output the corresponding pulse rate to reach that speed. The motion controller must be able to output this pulse rate, and the stepper drive must be able to receive this pulse rate and send over to the SMLA. The equation for determining required pulse rate is shown in the following page.

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

- **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**: how many 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**: Micro-stepping resolution (micro-step/step)

After calculating the required pulse rate, it may come to light that your PLC, PC or microcontroller is capable of sending out this frequency to the stepper drive without the need of a separate motion controller.

Stepper Drive

Like a controller, the user should select a drive based on its ability to interface with all other components in the system – specifically the stepper motor and controller. For Thomson standard SMLA stepper motors, a drive must be able to allow the connection of a four-wire, bipolar motor. Electrical properties of the system must also be taken into consideration. Items such as desired output current to the motor, max input voltage from the power supply, and motor inductance will need to be reviewed. Just like a controller, required pulse rate will also need to be considered to ensure the driver is capable of driving the motor to the required speed.

Micro-stepping

There are many unique stepper motor drives out there that offer various micro-stepping resolutions. Depending on your requirement, micro-stepping may be worth considering, specifically if a smooth motion is required. Micro-stepping essentially takes the standard 200 steps per revolution of the SMLA motor and breaks down each step to smaller increments such as from ½ step, ¼ step and even all the way to 1/256 step. Figure 7 illustrates the difference between full-stepping and micro-stepping.

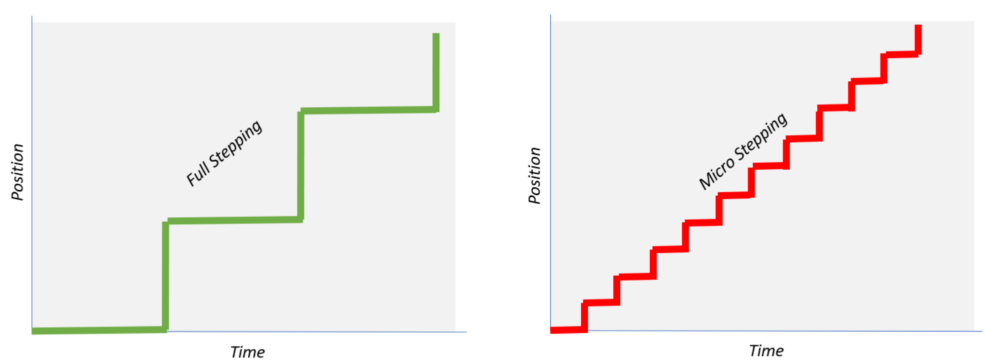

Figure 7: Simple illustration comparing the motion between full stepping and micro-stepping.

An important thing to note about micro-stepping is that it does not improve positional accuracy by going to finer resolutions. A typical rotational accuracy for a stepper motor is approximately +/- 0.09 degrees regardless of micro-stepping resolution.

Final Considerations

Ultimately, experience is the best tool at one's disposal for building a stepper motor-based system. The guidance mentioned above should only be utilized as a way of getting in the ballpark for a system build. Some experimentation with trial and error may need to be conducted to get 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. PLC, motion controller and drive manufacturers will also have dedicated engineers to help assist you in selecting one of their products.

Revisions

Revision	About	Date
01	Initial release	3/26/2019