MIGA Motor Company

Application Notes

-DM01 Linear Shape Memory Alloy Actuator

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DM01-Series Displacement Multiplied ™ Shape Memory Alloy (SMA) Actuator Operating Guide

The DM01-Series of SMA linear actuators provides 1/2" of stroke in three different force ranges up to 4.5 #f. The DM01 is a new device, intended for use only by those experienced in the operation of electro-mechanical devices. When used properly, the DM01 actuators will provide tens-of-thousands of cycles of trouble-free operation. As there is no built-in over-power protection, care must be taken to operate them safely and properly.

Caution: Do not operate DM01 actuators before fully understanding the operating guidelines below.

Operating Basics

The operating principles of the DM01-Series actuators are relatively simple: SMA wire segments form a series-resistive electrical circuit within the DM01 actuator. Input current ohmically heats the SMA wire elements, which begin to contract when they reach a temperature of roughly 75˚C (167˚F). The wires are fully contracted at roughly 110˚C (230˚F) and should not be heated above roughly 150˚C (302˚F). Both PUSH and PULL models of the DM01 operate on the principle of contracting SMA wires.

When power is removed, the SMA wire must cool below roughly 60˚C (140˚F) to return fully to the un-powered position. The actuator does not need to fully return to the un-powered position to actuate again, however. In fact, using control methods (described below), the actuators could maintain any position along the design stroke (though we do not recommend this type of operation).

The DM01 provides force only in the powered direction, returning to the un-powered position if un-constrained. An external restoring force (such as a bias-spring or opposing actuator) is required in order to return an un-powered actuator to the rest position if it is under load.

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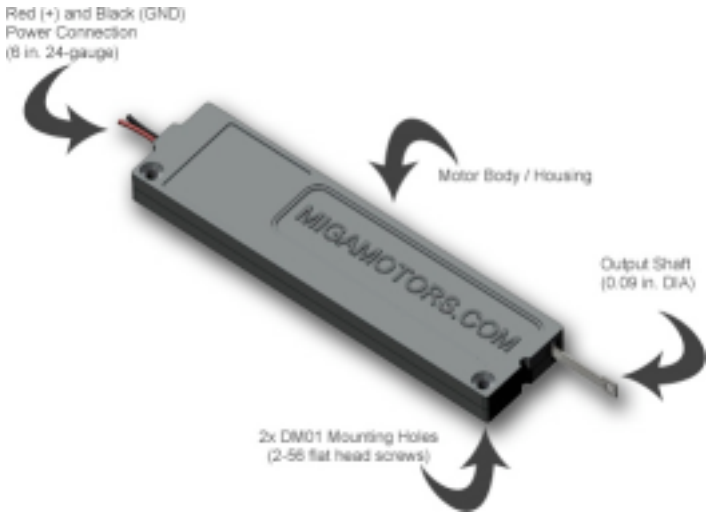
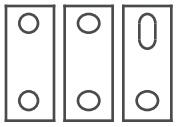
Mounting Considerations

The DM01 Housing/Motor Body is designed to be mounted on a flat plane, and is not designed to support the weight of other objects, or to be torqued or compressed other than at the mounting holes as shown. A sample mounting-kit is provided with each actuator, and includes miscellaneous hardware to simplify attachment for your application. Included are: various #2 screws (2-56 x 1/2" and 9/16"), nuts, washers, angle brackets / mounting adapters, and output shaft adapters, illustrated below.

Motion of the DM01 actuator may be affected if the mounting screws are over-tightened, or if the actuator is not properly mounted (flat mounting surfaces, linear motion of load, etc. should be used). Do not mount the actuators in a manner that will impede or otherwise affect their operation. Fasteners should be torqued properly, so they are not under-, or over-tightened. For the included 18-8 or 300-series 2-56 fasteners, the maximum torque should be 2.5 in-lb (0.28 N-M).

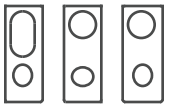


Mounting Adapters



Clearance holes/slots for #2 fasteners.
Fold at centerline for angle brackets.

Output Adapters



Clearance holes/slots for #2 and #4 fasteners.

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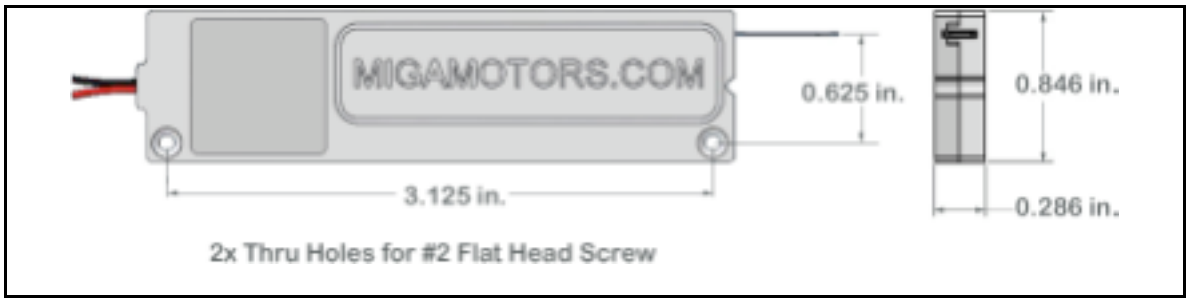

Side-loading
DM01 devices have not been tested extensively for side loading. However, they are very robust devices, and qualitative testing indicates that they perform well under all conditions at the rated loads.

Force Rating and High Load Conditions
Under high load conditions (beyond the design force rating), the actuator may not reach the end of stroke, and if input power is high, the actuator may be damaged. Note that the actuation time is slightly *longer* for an actuator under load, than for an un-loaded actuator.

Design Force Rating of DM01 Actuators

Model No.	Force Rating # (N)
DM01-10	*2.0 lb.-f (9 N)*
DM01-12	*2.75 lb.-f (12 N)*
DM01-15	*4.5 lb.-f (20 N)*

Operating Temperature Range
The maximum ambient temperature for the DM01-Series actuators is 75˚C (167˚F); while the minimum tested operating temperature is -20˚C (-4˚F). Long-term exposure to ambient temperatures beyond 75˚C will result in passive (un-powered) actuation of the actuator.

To avoid damaging SMA wire, the wire temperature should never exceed 150˚C (302˚F).

The DM01-Series actuators consist largely of molded Delrin™ (custom high-temperature PEEK and PES plastics are available with different model numbers). The bodies and some internal components are made of black Delrin™, which has the following thermal characteristics:

Temperature Limits of Molded Delrin™

Maximum long-term operating temperature:	85˚C (185˚F)
Maximum short-term operating temperature:	150˚C (300˚F)
Melting temperature:	175˚C (347˚F)

Always Use Black Wire as Electrical GROUND
The stainless steel output shaft of the DM01 is connected electrically to the black lead-wire, intended for use as power supply 'ground'. To avoid electrical shock or shorts, do not connect the black lead-wire to live power. Future models of DM actuators will have electrically insulated output shafts.

Caution: The steel output shaft of the DM01 actuator is at the same electrical potential as the BLACK lead-wire. The RED lead-wire should be used for positive applied voltage.

Actuation Time
The actuation time of the DM01 depends on the input power, from ~25 ms to 'position-hold'. The actuation time also changes with load and ambient temperature. For a given input power, actuation time *increases* for higher loads. Actuation time also *increases* for lower ambient temperatures, since additional power is required simply to raise the wire to room temperature.

If actuated rapidly, the SMA wire passes through the transition temperature range very quickly, and can become overheated if power is not removed quickly when the actuator reaches the end of stroke. Overheating the SMA wire can damage the actuator: potentially melting the internal plastic components, and decreasing the usable life (number of actuation cycles).

The repetition rate of the DM01 is governed by the time required to cool and return to the un-powered position. Unconstrained, the DM01 returns fully to the un-powered position in 3-15 seconds, depending on ambient conditions and the SMA wire diameter. Forced cooling can increase the repetition rate by up to 100x if high rate operation is a requirement.

Initial Powering of the DM01-Series Actuators
To safely explore the optimal input power for the DM01 actuator, connect a battery or power supply capable of supplying several amps between the actuator ground (black wire) and power (red wire). Initial testing should be done with no external load on the actuator. A momentary switch in the power line will provide safe operator control of applied voltage. Begin with low voltages, and increase the voltage to a level appropriate for the desired actuation speed. To avoid over-heating the SMA wire, always be sure to remove power quickly upon reaching the end of stroke.

Voltages above 12V are capable of damaging (overheating) the wire, so pulse-timing, limit switches, or other power cutoff circuitry must be used. For safest operation, note the one-second rule below. Once initial power levels are determined, increase the load on the actuator, further incrementing the input power to accommodate the higher loads.

If too little power is applied to an actuator (or if it is applied too slowly), the wire looses heat to the environment more quickly than it is provided by the power source. The actuator will not function if too little power is applied.

One-Second Rule
The so-called "one-second" rule applies for all DM01 actuators, and safely assumes that, for an un-constrained actuator, the voltage and current settings that result in actuation time of one-second will not damage (overheat) the SMA wire elements, even if power is left on continuously. That is, at this power level, you cannot overheat the wire by leaving the power ON for too long (although we do not recommend this mode of operation). The safest way to determine these settings is to begin with very low voltage, and increase it slowly until full actuation occurs in one second. The following approximate values apply for the DM01 actuators:

Model Number	Resistance (Ω)	Current @9V (1.0-s actuation*)	Current @12V (0.5-s actuation*)	Current @28V (0.1-s actuation*)
DM01-10	*7.5*	*1.2 amps*	*1.6 amps*	*3.7 amps*
DM01-12	*5.0*	*1.8 amps*	*2.4 amps*	*5.6 amps*
DM01-15	*3.0*	*3.0 amps*	*4.0 amps*	*9.3 amps*

**Ambient temperature, load, and lifetime may affect these values.*

End-switches or Limit-switches
To avoid overheating of the SMA elements, external (user supplied) end- or limit-switches should be used to remove actuator power when the actuator reaches the intended end of stroke.

Pulse Width Modulation (PWM) and Control Loops
Pulse Width Modulated power can be used to optimize actuator power consumption for battery operation, or to control the relative position along the design stroke. After actuating, an SMA wire requires time to cool before returning to the un-powered position. If power is removed at mid-stroke, for instance, and re-applied when the wire first begins to cool, a PWM control loop can safely maintain a load at any position along the stroke.

Intended Operation and Limitations
DM01-Series SMA actuators do have their limitations, and it is important to understand these limitations in order to utilize them to their fullest potential.

1) The optimal uses for the DM01-Series are those involving powered motion in one direction only: powering OFF the actuator the moment the end of stroke is reached. The ideal example is a latch-release mechanism, whereby a spring-loaded door is released using a DM01 actuator.

2) While it is possible to do very high precision operations with DM01 actuators (using various position encoders, for instance), SMA wires stretch or "creep" slightly with age. This may mean that periodic adjustment would be required for high accuracy positioning tasks.

3) DM01 actuators have not been designed for "continuous" operation, holding a load in place for extended periods. This type of operation is possible, but not without paying

careful attention to the temperature environment. The maximum “duty cycle” depends upon ambient temperature conditions and load.

4) DM01 actuators do not have built in springs to return an un-powered actuator to the rest position. If unconstrained, the DM01 actuators do return when the SMA wire cools below the transition temperature. If constrained by a load or any residual friction or drag, however, an external bias spring may be necessary to return the actuator to the starting position. Since external bias springs reduce the available output force of the device, bias springs should be sized no larger than 20% of the design force rating.

DM01 linear actuators are a well-proven and reliable technology, but we can’t predict the numerous applications in which they will be used. Please contact us for assistance in safely using the DM01 in your application.

When used properly, the DM01 actuators will provide many cycles of trouble-free operation. We hope you find that MIGA Motor Company devices are the solution to your motion problems.

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