- **Nanometer resolution**
- **Analog control**
- **Low power consumption**
- **Small size**

The PMCM31 is a 1-axis analog driver for use with Piezo LEGS motors from PiezoMotor. The driver enables single digit nanometer positioning in combination with mm/s speeds.

Functional principle

The driver controls the Piezo LEGS motor by feeding waveform signals which elongates and bends each of the piezo drive legs. The waveforms are specially designed to make the motor drive legs perform a precise walking motion. The motion of the drive legs is transferred via friction contact to a linear rod or to a rotary disc.

For each waveform cycle the Piezo LEGS motor will take steps, by definition called *waveform-steps* (wfm-steps). The wfm-step length is load dependant and also depends on the signal phase shift. With maximum phaseshift (90°) the step size is in the range of a few micrometers for a linear Piezo LEGS motor. Rotary Piezo LEGS motors have their drive legs working on the perimeter of a drive disc. The wfm-step angle depends on the diameter of the rotary motor but is usually less than one milliradian.

The maximum step length (and hence the speed) is reduced by internal phase shifting of the waveform signal, and fine positioning is performed through analog bending of the drive legs. The user of the PMCM31 driver will only need to change the control signal voltage level in order to go from full step size down to high precision positioning.

Quick Start

1. Important note before connecting terminals:
   - *+12V* terminal is not overvoltage protected and should be within ±0.5 V.
   - *An* signal should not exceed ±20 V.
   - *Rst* signal should be open collector (active low).
2. Connect a Piezo LEGS to the motor connector on the PMCM31 front panel.
3. Connect the *+12V* and *GND* terminals to a stabilized 0.3 A power supply with an output voltage of 12 ±0.5 V.
4. Connect a ±9.6 V adjustable voltage source to the *An* and *GND* terminals.
5. At power on the driver checks the capacitance of the motor (phase 1). After this check, the *LED* is turned ON. If the *LED* remains OFF, please check the power supply.
6. The following error indication may occur: If *LED* starts blinking after power ON, this indicates that motor capacitance check failed, e.g. no motor is connected (or motor is broken).
7. After power ON the driver will wait until *An*=0 V in order to prevent motor motion if no external *An* signal is available.
8. Motor is now ready to run, varying the voltage of the *An* signal to create motion. For an *An* voltage level less than ±0.6 V the motion is extremely slow. Below ±0.3 V the motion is stopped. For voltage level above ±0.6 V the motor velocity is set according to figure 1. Positive voltages refer to forward motion.

The PMCM31 interface

This driver is intended for use with Piezo LEGS motors, and driver outputs are designed not to stress the motors beyond their specifications.

Use DC power supply (12 V, 0.3 A) and an analog control voltage (±9.6 V DC) which can be a part of a closed loop controller design. The velocity will depend on the magnitude of the applied control voltage whereas the direction will be according to the polarity.

Picture below shows the front side of the PMCM31. The connectors, LED and push-button is described in more detail below.

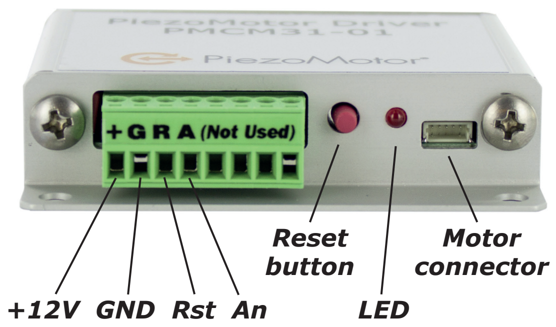

Table 1. Terminals on socket on driver defined.

+	**[+12V]**	DC Power Supply input (12 V, 0.3 A)
G	**[GND]**	Ground reference for both power supply and control signals
R	**[Rst]**	The reset control signal
A	**[An]**	The analog control signal (±9.6 V) sets the motor velocity

Terminals socket

The green 8 pole socket should preferably be interfaced using a matching plug (Phoenix type). The four terminals on the right are not connected (marked *Not Used*). The other terminals are according to table 1 above.

Motor connector

The male connector used in the driver is a JST SR connector which is interfaced with a JST SR female connector model 05SR-3S. Model SHR-05V-S female connector is an alternative. The female contact on the cable fits on the male counterpart on the motor and driver in one way only, which ensures that the motor is always properly connected to the driver. When connecting twin type motor, be sure to connect both top and bottom in parallel.

LED – Power on

About 0.4 s after power ON, the driver checks the capacitance of the connected motor. After this check, the *LED* is turned ON. If the *LED* starts to blink after power ON, this indicates that the motor capacitance check failed, e.g. no motor connected or motor is broken. If the *LED* remains OFF, check the +12 V supply voltage. After power on the driver will wait until *An* = 0 V in order to prevent motion if no external signal is available.

Reset button

The brown push button next to the *LED* can be used for manually resetting the driver. This could be useful if e.g. there is a need to change the motor while the driver is powered up. By pushing the reset button, a new capacitance check is initiated. Motor capacitance is temperature dependant and for optimum performance of the motor a new capacitance check is recommended if the motor temperature has changed more than about 30ºC. Pushing the reset button will also deactivate the motor driver outputs and can thus be used as an emergency brake. Note that the *An* signal must be 0 V until motor motion can start again after an emergency brake.

Reset control signal

Connecting the *Rst* pin to ground will switch off the power for all driver logics. This can be used to implement an emergency stop. The external *Rst* signal should be of the open collector type.

The analog control signal

By applying an analog signal of 0 to ±9.6 V, the motor velocity will range from 0 up to a maximum velocity which depends on the capacitance of the connected motor. For example, the LL10 linear Piezo LEGS motor with power consumption of 5 mW/Hz will give a maximum drive frequency of about 700 wfm-steps per second [Hz] since at maximum motor velocity the power consumption for the PMCM31 driver is 3.6 W.

The device controlling the ±9.6 V analog signal should be able to provide 1 mA signal current (source/ sink). The driver converts the voltage into 32 velocity channels in each direction. In the text below, only positive (Forward) voltages are discussed. Negative voltages give an equivalent behaviour but in the reverse direction. Each velocity channel is 0.3 V wide. For the first velocity channel, 0–0.3 V, motor motion is stopped. Below 0.6 V is a bending mode which can give slow motion at very high resolution, whereas a velocity command >0.6 V gives a fast stepping mode. The voltage range and corresponding drive mode are shown in table 2 and further described below.

Table 2. Voltage range and corresponding drive mode (only positive voltages are given in the table).

Voltage range	Mode
0–0.6 V	Bending mode (motion is stopped at <0.3 V)
0.6–9.6 V	Stepping mode

Bending mode 0 < *An* < 0.6 V

This mode is for fine positioning, with the ability to reach nanometer resolution. When entering the bending mode, the velocity is set relatively high in order to reach a target position quickly. After the first target overshoot, a much lower velocity will be chosen. This will ensure negligible overshooting even for a slow sensor feedback on the nm level. It may take several seconds though, before the position is steady on the nm level. With an *An* signal in the range 0–0.3 V the motor motion is stopped.

If the maximum bending range is exceeded, the driver will issue a "parking" sequence, i.e. the drive leg is returned to its center position, and thereafter continues to bend. This may cause some minor positional fluctuation. After parking, the driver starts with a relatively high velocity.

Stepping mode 0.6 V < *An* < 9.6 V

In stepping mode, the average velocity is governed by both cycle step length and the delay after each drive cycle. As seen in Figure 1. below, the step length is linear to *An*, reaching maximum length at ±8 V. A signal of ±9.6 V is enough to reach maximum velocity, whereas higher voltages are acceptable, e.g. ±12 V.

After each step cycle, there is a delay according to the *An* signal, where after the step length for the next cycle is determined from a lookup table. At minimum velocity, the step delay is around 9 ms. The resulting step frequency depends on the step cycle time as well, which is roughly 1.5 ms using the LL10 linear Piezo LEGS motor (motor dependant). The velocity can therefore differ somewhat from the curve shown in Figure 1. A 0.3 ms delay is inserted before the first step to allow the analog signal to settle, and an extra 5 ms delay is added after the first step in order to make one-step operations easier. In order to minimize overshoot tendencies at target position, the *An* signal is checked for a stop command (*An*<0.6) after every half step cycle, in which case the remaining step cycle will be truncated. However, a detailed control of the cycle step length is only done at the end of each full cycle.

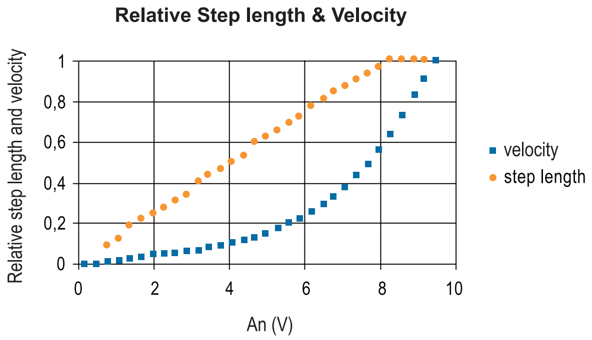

Figure 1. Resulting relative step length and velocity for a given voltage level of the *An* control signal.

Additional notes for the analog control signal

If the analog signal is lost, the floating *An* pin will make the driver run at slow velocity. This can be avoided by connecting/soldering a 2k7 resistor between the *An* pin and ground, although this enhances the analog signal current about five times.

The driver reacts to changes in the analog signal within 0.3 ms. The first step mode channel (0.6 ... 0.9 V) is a special case though, and the signal is monitored for an additional 1 ms. If the signal returns to bending mode, the driver will stay in bending mode. It will however assume a new target position and set the bending velocity high. The velocity for continuous motion in bending mode is around 0.5 µm/s using the LL10 linear Piezo LEGS motor.

Using the PMCM31

Manual operation

The driver can be tested manually to give a first hint on performance. Connect the motor and power supply, and connect a wire between the *An* pin and the *GND* pin. Then disconnect the wire, whereby the floating *An* signal results in a slow forward motion of the motor. Connecting the *An* pin to *+12V* results in maximum forward speed, whereas connecting the *An* pin to *GND* via a 10k resistor will run the motor very slowly, of the order of 0.5 µm/s using the LL10 linear Piezo LEGS motor.

Sensor feedback drive

Automatic sensor feedback requires a PC with the ability to read the sensor signal and control the analog signal. Stand-alone controllers can be used as well. The analog command signal should simply be proportional to the positional error. 8 V gives the maximum step length. If the maximum cycle step length for the motor is 6 µm, then set the proportional gain to around 8V/6µm=1.3V/µm. The analog gain factor can be tuned experimentally. If there are severe target overshoots then reduce the gain. This initial positioning should result in a positional error less than 1/30 of the maximum cycle step length (typically 200 nm using LL10 linear Piezo LEGS motor).

A typical procedure for reaching a target position may look like the following: First the driver is used in stepping mode for a quick close in on the target position. As the position error becomes smaller, the *An* voltage is set according to the gain factor, and when the *An* signal drops below 0.6 V the driver enters the bending mode. This will close in further to the target until the signal goes below 0.3 V, typically at 200 nm using the LL10 Piezo LEGS motor. One must then increase the gain in order to reach nm precision, but still avoid entering the stepping mode. For a standard Piezo LEGS linear motor the gain can be as high as 0.2 V/nm. To avoid entering the stepping mode the maximum voltage for the *An* signal must be limited to ±0.5 V when fine-tuning.

150082-00

Technical Specification		
Type	**PMCM31-01**	**Note**
Number of Axis	1	
Electrical Phases per Axis	4	
Control Signal Range	± 9.6 V	
Waveform Voltage	47 ±3 V	
Waveform	Trapetzodal	
Power Supply Current	0.3 A <0.02 A	at maximum speed at standby
Open Loop Operation	Yes	
Closed Loop Operation	Yes	
Number of Sensor Axis	1	
Temperature range	+10 to +50 °C	
Storage temperature	– 25 to +85 °C	
Motor Connector	JST BM05B-SRSS-TB	
Port Connector	8-pol socket	Phoenix type
Power Supply Voltage	12 ±0.5 V DC	stabilized
Dimensions	73.6 x 71 x 17.2 mm	
Weight	70 gram	
Part Number	PMCM31-01	PMCM31 revision 01

Visit our website for application examples, CAD files, videos and more...

www.piezomotor.com

PiezoMotor

PiezoMotor Uppsala AB
Stålgatan 14
SE-754 50 Uppsala, Sweden

Telephone: +46 18 489 5000
Fax: +46 18 489 5001

info@piezomotor.com
www.piezomotor.com