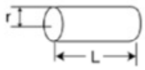
Stepper Motor Selection Guide

A stepper motor should provide an output torque larger than load torque and be required to start and stop at a proper step rate against load inertia. Also, while operating the motor at a rate higher than the starting pulse rate, the rate needs to be varied within a proper acceleration time. Here are some basic formulas to help you determine the torque, inertia and acceleration/deceleration time you require of the stepper motor to fit your application.

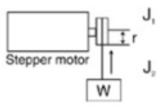
Obtaining Load Inertia

$$= \frac{Mr^2}{2} = \frac{W}{g} \times \frac{r^2}{2} = \frac{\pi r^2 \cdot L \cdot \rho \cdot r^2}{981 \times 2} = \frac{\pi \cdot \rho \cdot Lr^4}{1962}$$



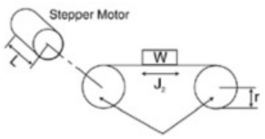
where:
J = Load inertia (kg • cm • s²)
π = Ratio of the circumference of a circle to its diameter (3.14)
ρ = Specific gravity of cylinder material (kg/cm³)
(Iron = 7.8 x 10^{-3}, Aluminum = 2.7 x 10^{-3})
L = Length of cylinder (cm)
r = Radius (cm)
g = Gravitational acceleration 981 (cm • s²)

$$J = J_1 + J_2 = \frac{\pi\rho \cdot L \cdot r^4}{1962} + \frac{Wr^2}{981}$$



where:
J = Load inertia (kg • cm • s²)
J_1 = Inertia of pulley (kg • cm • s²)
J_2 = Inertia of take-up (kg • cm • s²)
W = Weight of material to be wound (kg)
r = Radius of pulley (cm)

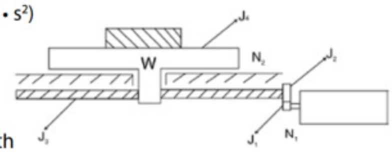
$$J = 2 \times J_1 + J_2 = 2\left(\frac{\pi\rho Lr^4}{1962}\right) + \frac{Wr^2}{981}$$



Pulley J_1 x 2

where:
J = Load inertia (kg • cm • s²)
J_1 = Inertia of pulley (kg • cm • s²)
J_2 = Inertia of linear movement (kg • cm • s²)
W = Weight of belt and material (kg)
r = Radius of pulley (cm)
L = Length (cm)

$$J_0 = J_1 + (J_2 + J_3)\left(\frac{N_1}{N_2}\right)^2 + J_4$$

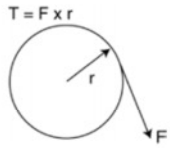


$$J_4 = \frac{W}{981}\left(\frac{\delta}{\frac{\pi}{180} \cdot \alpha}\right)^2$$

$$\text{or } J_4 = \frac{W}{981}\left(\frac{P}{2\pi} \cdot \frac{N_1}{N_2}\right)^2$$

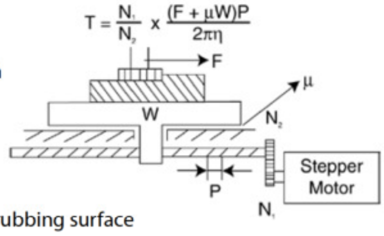
where:
J_0 = Load inertia (kg • cm • s²)
J_1 = Inertia of pinion (kg • cm • s²)
J_2 = Inertia of gear (kg • cm • s²)
J_3 = Inertia of feed screw (kg • cm • s²)
J_4 = Inertia of work and table (kg • cm • s²)
N_1 = Number of pinion teeth
N_2 = Number of gear teeth
W = Weight of work and table (kg)
π = Ratio of the circumference of a circle to its diameter (3.14)
α = Step angle per pulse (°)
δ = Table movement per pulse (cm)
P = Pitch of feed screw (cm)

Obtaining Load Torque



where:
T = Load torque (kg • cm)
F = Force to rotate the coupling shaft of a stepper motor (cm)
r = Radius to apply the force (F) (cm)

$$T = \frac{N_1}{N_2} \times \frac{(F + \mu W)P}{2\pi\eta}$$



where:
T = Load torque (kg • cm)
N_1 = Number of pinion teeth
N_2 = Number of gear teeth
W = Weight of table and work (kg)
F = Cutting resistance (kg)
μ = Frictional resistance of rubbing surface
P = Pitch of feed screw (cm)
η = Transfer efficiency of the system including feed screw and gear

Obtaining Acceleration/Deceleration Time

$$t_{acc} = (J_r + J_l)\, 2\pi * (f_h - f_l) / (nq * T_a)$$

where:
t_{acc} = Acceleration time (S)
J_r = Rotor inertia (g • cm • s²)
J_l = Load inertia (g • cm • s²)
f_h = Slew speed (pps)
f_l = Starting speed (pps)
nq = Step/revolution
T_a = Acceleration torque (g • cm)

Obtaining Acceleration/Deceleration Torque

$$T_a = (J_r + J_l)\, 2\pi * (f_s)^2 / (nq * n)$$

where:
T_a = Acceleration torque (g • cm)
J_r = Rotor inertia (g • cm • s²)
J_l = Load inertia (g • cm • s²)
f_s = Max no load slew rate under specific drive conditions (pps)
nq = Step/revolution
n = Index No for drive method (Full step mode = 2; Half step mode = 4)

Calculating Output Torque From Gearhead

$$T_{gh} = T_m \times G_r \times 0.85^n$$

where:
T_{gh} = Torque from Gearhead
T_m = Torque from motor
G_r = Gearhead ratio (# of times motor turns per 1 turn of gearhead)
example: 1/3 gearhead G_r = 3
n = Number of gears

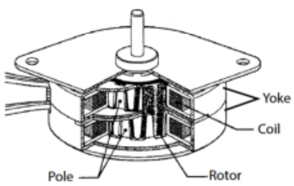
Permanent Magnet Motors

Nippon Pulse's permanent magnet (PM) step motors (PF series tin-can steppers) have been well-established in the engineering world, and have many advantages over other kinds of stepper motors. PM motors strike the perfect balance between efficiency and affordability, as they are low-inertia, low-resolution motors that are a low-priced alternative to hybrid stepper motors in many applications.

PM step motors have a typical step angle between 3.75 and 18 degrees, and offer position resolution on the order of ±5 percent. Its structure demonstrates ferromagnetism, with alternating north and south poles set in a straight, parallel line to the rotor shaft. The rotor is moved through the action of permanent magnets, providing increased magnetic flux intensity. This intensity results in improved torque characteristics for the PM motor, compared to variable resistance step motors.

Nippon Pulse provides high-quality PM motors to industries and professionals all over the world. Take a look at our standard PM motors over the following pages to find the one that most closely fits your needs. An application engineer can work with you to make any customizations necessary to make our PM motors a perfect fit.

Basic Structure of 2-Phase Permanent Magnet Motor



Below are Nippon Pulse's permanent magnet stepper motors:

- **PF series** - Nippon Pulse's original PM stepper motors
- **PFC series** - PF series tin-can steppers with a fully automated coil assembly
- **PFL series (Linearstep)** - linear actuators that utilize the PF series construction
- **NFC series** - high-force, short-stroke linear actuators that utilize the PF series construction
- **PTM/PTMC series** - synchronous timing motors based on the PF series.

Terminology

Continuous Rating
Specifications are continuously applicable to the rated output.

Dielectric Strength
The maximum voltage between the case and the coils that can be sustained for one minute without damaging the motor.

- 500Vac for one minute with operating voltage <30V
- 1000Vac for one minute with operating voltage 30-150V
- 1500Vac for one minute with operating voltage >150V

Intermittent Rating
Specifications are applicable for a specific time length to the rated output.

Motor Speed
Number of revolutions per minute.

Operating Temperature Range
Ambient temperature range in which the motor can normally be driven.

Operating Voltage Range
The voltage range in which the motor can normally be driven with Constant Voltage drive.

Temperature Rise
The temperature of the motor rises whenever power is applied. Temperature rise is determined by applying the motor's rated voltage and measuring the increased coil resistance or the change in surface temperature of the motor.

Abbreviations/Units

A
SI base unit for current (ampere)

AC
Alternating current

CCW
Counterclockwise

CW
Clockwise

DC
Direct Current

Hz
SI induced unit for frequency (cycles per second)

K
SI base unit for temperature (Kelvin); often used for temperature rise

PPS
Pulses per second

RPM
Revolutions per minute

V
SI induced unit for voltage (volts)

RoHS Compliance

All Nippon Pulse stepper motor products are RoHS compliant.

RoHS

PFL35T and PFC25

Tin-Can Models by Outer Diameter

OD (mm)	Tin-Can	Synchronous		Linear Stepper
		Dual Direction	Single Direction	
10	PFC10	--	--	--
20	PFCU20 PFC20T	--	--	--
25	PF(C)25 PFCU25	PTM-24P	--	PFCL25
30	PFCU30	--	--	--
35	PF35 PF35T	PTM-24M PTM-24T	PTM-24B	PFL35T
42	PF42 PFC42H PF(C)42T	PTM-24H PTMC-24S2	PTM-12K PTM-12E	--
55	PF(C)55 PFC55H	PTM-24F	--	--

Insulation Ratings

Insulation Class	Y	A	E	B	F	H	C
Allowable Temp (°C)	90	105	120	130	155	180	>180

Note: All tin-can motors and linear steppers in this catalog are insulation Class E unless otherwise noted.

Permanent Magnet Motor Features and Customization Options

Coil
An encapsulated and welded stator design gives stronger design, greater dimensional control and improved thermal characteristics.

Mounting Plate
Custom and standard shaped mounting plates are available. Mounting holes can be threaded, tapped, slotted or customized to your application requirements.

Permanent Magnet Rotor
Three types of permanent magnets are available: ferrite anisotropic, ferrite isotropic, and neodymium.

Bushings and Bearings
Long life oil-impregnated bushings are standard in our PF, PFC, NFC, PTM and PTMC motors. Ball bearings can be requested, and are standard in the PFL series Linearstep motors.

Shaft
A variety of shaft options are available.
- Custom lengths
- Single and double shafts
- D-cut(s)
- Turn downs
- Threaded
- Knurled
- Grooved

Gears & Pulleys
A variety of gear and pulley options are available.
- Machined
- Plastic molded
- Powdered metal (sintered)

Connector
Motor side connection method. Lead wire options available.

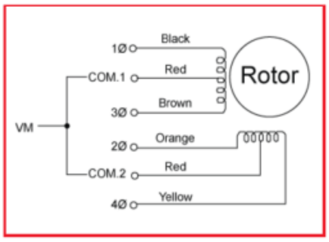
Lead Wire
Options to change the lead wire exit direction and exit angle.

Wire Leads
Driver side connector options.
- Standard flying leads
- Customer-selected connectors

See page 41 for additional motor customization options and for information about creating a fully custom step motor.

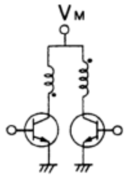
Unipolar Drive

Six lead wires are connected



Current: Single direction
Coil: Bifilar winding
Leadwires: 6

The basic circuit (constant voltage) is shown to the right



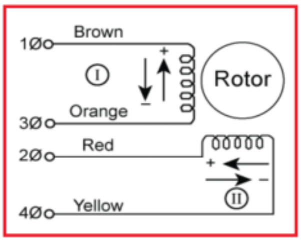
2-2 phase excitation sequence

Step	Black	Brown	Orange	Yellow	Step
1	ON	OFF	ON	OFF	4
2	OFF	ON	ON	OFF	3
3	OFF	ON	OFF	ON	2
4	ON	OFF	OFF	ON	1

CW ↓ ↑ CCW

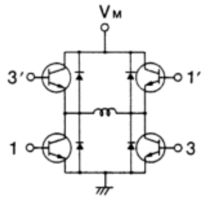
Bipolar Drive

Four lead wires are connected



Current: Dual direction
Coil: Monofilar winding
Leadwires: 4

The basic circuit (constant voltage) is shown to the right



2-2 phase excitation sequence

Step	I	II
1	+	+
2	-	+
3	-	-
4	+	-

CW ↓ ↑ CCW

		Unipolar	Bipolar
Number of Transistors		1	2
To ensure the same temperature rise of motor	Current	1	1/√2
	Torque	1	√2
	High-speed performance	1	0.5
	Voltage	1	√2
To obtain same torque	Current	1	0.5
	Temperature rise	1	0.5
	High-speed performance	1	0.5
	Voltage	1	1

This chart shows the comparison between bipolar and unipolar drives with parameters of unipolar set to one.

Model Number Explanation (for PF and PFC series)

PF(C) -	42	T -	48	C	1	G	1/50
1	2	3	4	5	6	7	8

1 - Series Designation
- PF: Flying lead joint type
- PFC: Connector joint type

2 - Outer Diameter in mm

3 - Type
- Blank: Standard
- T: Thin stack
- H: High torque

4 - Steps per Revolution
- 24: 15°/step
- 48: 7.5°/step
- 96: 3.75°/step

5 - Winding
- C: 12V unipolar
- D: 5V unipolar
- P: 12V bipolar
- Q: 5V bipolar

6 - Magnet Material
- 1: Ferrite Anisotropic
- 3: Ferrite Isotropic
- 4: Neodymium
- 6: Molded Neodymium*

7 - Gear Head
- Blank: No Gear Head
- G: Gear Head Integrated

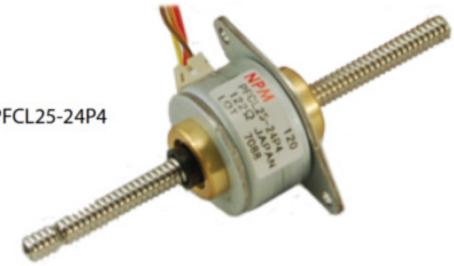
8 - Gear Ratio
- With geared models only

*Only applicable for PFC10 and PFC20T.

Nippon Pulse LINEARSTEP® Motors

Our tin-can linear actuators (LINEARSTEP®) are designed to provide a simple system at a fraction of the cost of a conventional rotary-to-linear stepper system. Offered in diameters of 25mm and 35mm, the LINEARSTEP® series can also be ordered with one of three thread pitches on the lead screw (0.48mm, 0.96mm, and 1.2mm). The LINEARSTEP® series is available with either a bipolar or unipolar winding.

PFL35T-48C4



PFCL25-24P4

Relationship Between Pulse Rate and Speed

When the thread pitch and the pulse rate change, the speed will also change.

48 steps/revolution unit: mm/s

Thread Pitch (mm)	Pulse Rate (pps)						
	100	200	300	400	500	600	700
0.48	1	2	3	4	5	6	7
0.96	2	4	6	8	10	12	14
1.20	2.5	5.0	7.5	10	12.5	15	17.5

24 steps/revolution unit: mm/s

Thread Pitch (mm)	Pulse Rate (pps)						
	100	200	300	400	500	600	700
0.48	2	4	6	8	10	12	14
0.96	4	8	12	16	20	24	28
1.20	5.0	10	15	20	25	30	35

Model Number Explanation

PF(C)	L	25	T	-	48	Q	4	-	048	-	30
1	2	3	4		5	6	7		8		9

1 - Series Designation
PF: Standard
PFC: Connector
2 - LINEARSTEP® Designation
3 - Motor Diameter (mm)
25mm
35mm
4- Thin stack
5 - Steps per Revolution
24: 15°/step
48: 7.5°/step
6 - Winding
C: 12V unipolar
D: 5V unipolar
P: 12V bipolar (PFCL25 only)
Q: 5V bipolar
R: 12V bipolar (PFL35T only)
7 - Magnet Material
4: Neodymium
8 - Thread Pitch
048: 0.48mm
096: 0.96mm
120: 1.20mm
9 - Shaft Stroke in mm
30: 30mm stroke, 60mm shaft
60: 60mm stroke, 90mm shaft

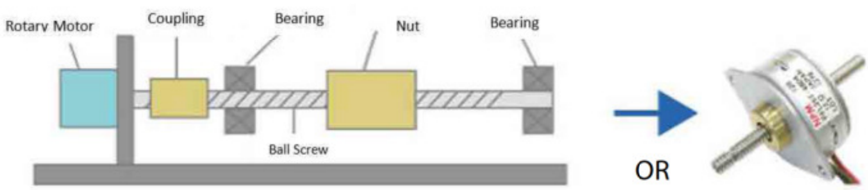
Additional winding options are available to meet your needs.

Features

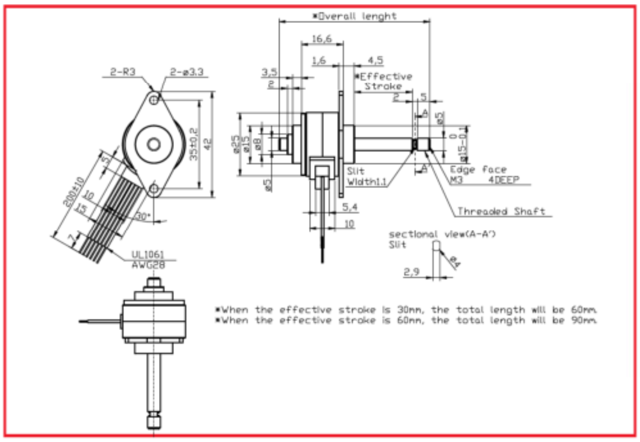
- Easily controllable stepper motor
- Simple structure: threaded rotor hub and lead screw
- Lead screw designed to achieve high efficiency and high thrust
- Ball bearings support the low-friction screw for long product life
- Variety of motor options and customizations available (see page 41 for more information)

LinearStep Benefits for Rotary-to-Linear Motion

- Save space (no mechanical parts needed for linear motion)
- Motor's simple structure saves design time
- Cost saving (reduces number of mechanical parts)
- Efficient



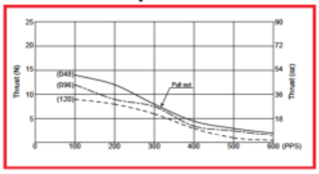
Converting Rotary Motion to Linear Motion



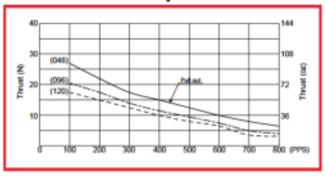
		PFCL25-24											
Type Of Winding		Unipolar						Bipolar					
Steps Per Revolution*		24											
Thread Pitch	mm	0.48	0.96	1.2	0.48	0.96	1.2	0.48	0.96	1.2	0.48	0.96	1.2
Travel/Step	mm	0.02	0.04	0.05	0.02	0.04	0.05	0.02	0.04	0.05	0.02	0.04	0.05
Stroke	mm	30 or 60											
Force @ 200pps	N	11	9.5	8	11	9.5	8	16	14	11	16	14	11
Rated Voltage	V	12			5			12			5		
Rated Current	A/Ø	0.10			0.31			0.10			0.30		
Resistance	Ω	120			16			122			15		
Inductance	mH/Ø	27			3.7			59			7.1		
Operating Temp. Range	°C	-10 to +50											
Temperature Rise*	°K	70											
Weight	g	60											

		PFCL25-48											
Type Of Winding		Unipolar						Bipolar					
Steps Per Revolution		48											
Thread Pitch	mm	0.48	0.96	1.2	0.48	0.96	1.2	0.48	0.96	1.2	0.48	0.96	1.2
Travel/Step	mm	0.01	0.02	0.025	0.01	0.02	0.025	0.01	0.02	0.025	0.01	0.02	0.025
Stroke	mm	30 or 60											
Force @ 200 pps	N	22	17.5	15	22	17.5	15	31	22.5	20.5	31	22.5	20.5
Rated Voltage	V	12			5			12			5		
Rated Current	A/Ø	0.10			0.31			0.10			0.33		
Resistance	Ω	120			16			122			15		
Inductance	mH/Ø	33			4.5			73			8.7		
Operating Temp. Range	°C	-10 to +50											
Temperature Rise	°K	70											
Weight	g	60											

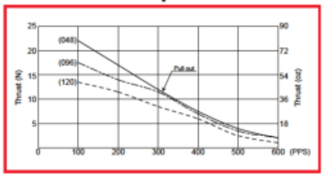
Unipolar Constant Voltage 24C4 Torque Curve



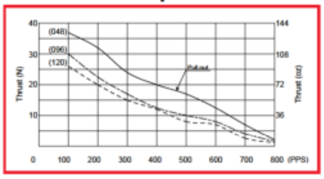
Unipolar Constant Voltage 48C4 Torque Curve



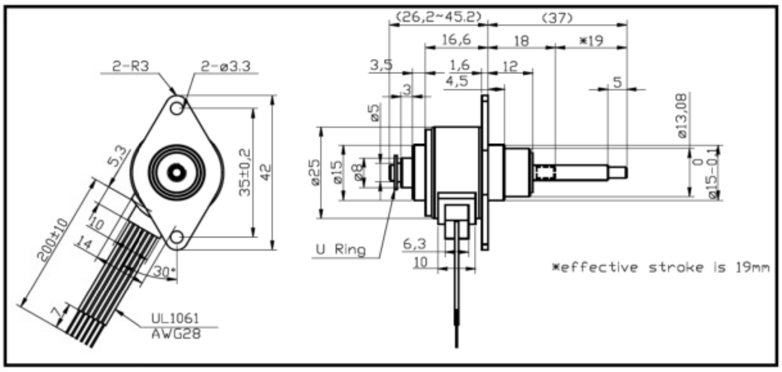
Bipolar Constant Voltage 24P4 Torque Curve



Bipolar Constant Voltage 48P4 Torque Curve

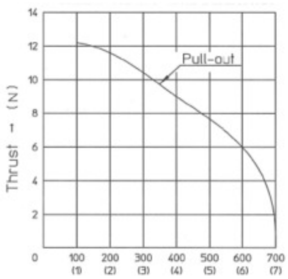


All tin-can motor specifications are based on full-step constant voltage operation
Magnet type: Neodymium
Torque curves are for reference only and are not guaranteed.

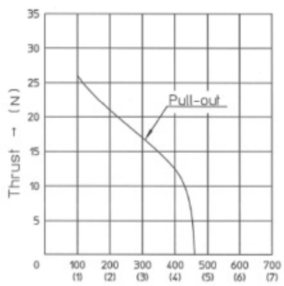


		PFCL25-48 w/ Captive			
Type Of Winding		Unipolar		Bipolar	
Steps Per Revolution		48			
Thread Pitch	mm	0.48			
Travel/Step	mm	0.01			
Stroke	mm	19			
Rated Voltage	V	12	5	12	5
Rated Current	A/Ø	0.10	0.31	0.10	0.30
Resistance	Ω	120	16	122	15
Inductance	mH/Ø	33	4.5	73	8.7
Operating Temp. Range	°C	-10 to +50			
Temperature Rise	°K	70			
Weight	g	60			

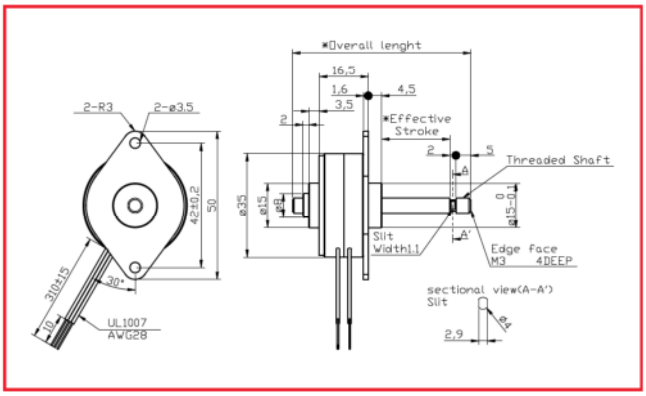
PFCL25-48x4-C
Unipolar Constant Voltage



PFCL25-48x4-C
Bipolar Constant Voltage Drive

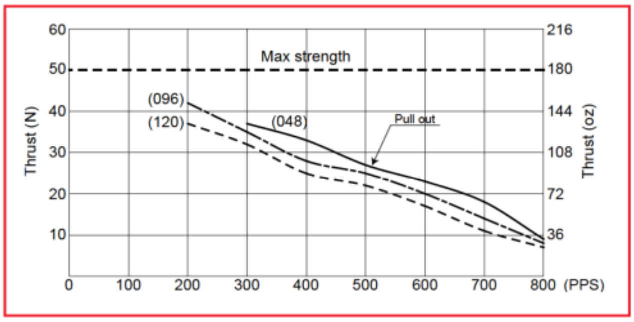


All tin-can motor specifications are based on full-step constant voltage operation.



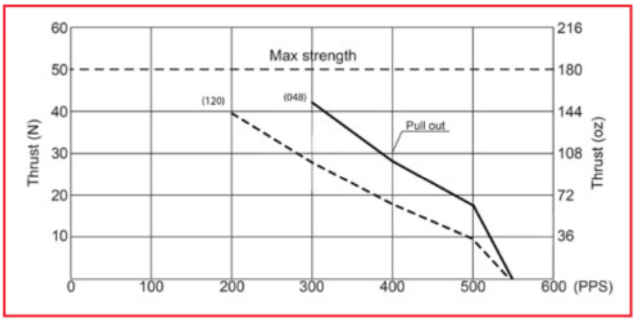
		PFL35T-48											
Type Of Winding		Unipolar						Bipolar					
Steps Per Revolution		48											
Thread Pitch	mm	0.48	0.96	1.2	0.48	0.96	1.2	0.48	0.96	1.2	0.48	0.96	1.2
Travel/Step	mm	0.01	0.02	0.025	0.01	0.02	0.025	0.01	0.02	0.025	0.01	0.02	0.025
Stroke	mm	30 or 60											
Force @ 200pps	N	35	32	30	35	32	30	39.5	38	35	39.5	38	35
Rated Voltage	V	12			5			12			5		
Rated Current	A/Ø	0.17			0.33			0.17			0.34		
Resistance	Ω	70			12			72			16		
Inductance	mH/Ø	27			5			54			6.4		
Operating Temp. Range	°C	-10 to +50											
Temperature Rise	°K	70											
Weight	g	95											

PFL35T-48C4 w/ Unipolar Constant Voltage



Driver: PS-2LD-5
Power: 12Vdc
Excitation: Full-step

PFL35T-48R4 w/ Bipolar Constant Voltage



Driver: BCD404B1
Power: 12Vdc
Excitation: Full-step

All characteristics are for reference only.