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Introduction to Permanent Magnet DC Motors

Introduction

Permanent magnet DC motors are useful in a range of applications from conveyors to pumps. PMDC motors have a linear speed-torque curve well suited to adjustable speed applications where the motor will operate at less than 3000 rpm.

Inside these motors, permanent magnets replace the field windings found in shunt motors. A wound armature and commutator brushes complete the motor.

Permanent magnets supply the field flux, eliminating the need for external field current. This design yields a smaller, lighter, energy-efficient motor.

The PMDC motor's field has a high reluctance (low permeability) that eliminates significant armature interaction. High reluctance yields a constant field, permitting linear operation over the motor's entire speed-torque range. In operation with a constant armature voltage, as speed decreases, available torque increases. As armature voltage increases, the linear speed-torque curves shift upwards. Thus, a series of parallel speed-torque curves, for different armature voltages, represents the speed-torque properties of a PMDC motor. Speed is proportional to voltage and torque is proportional to current.

Form Factor

The voltage used to power a PMDC motor is not a pure DC. It is derived DC voltage by rectifying an AC voltage. Thus, the DC voltage has a ripple component related to the frequency of the AC input.

Form factor is the ratio of I_{rms} to I_{dc} and indicates how close the driving voltage is to pure DC. Form factor for a pure DC source, such as a battery, is 1.0. The higher the form factor is above 1.0, the more it deviates from pure DC. The table here shows typical form factors for common voltage sources.

Form Factor: Comparing Driving Voltage to Pure DC	
Form Factor	***DC Voltage Source***
1.0	Battery – Pure DC
1.05 *	Pulse Width Modulation (PWM)
1.35 **	Full Wave Rectification (Single Phase)
1.9 ***	Half Wave Rectification (Single Phase)

** All DC-input IronHorse GSD series DC drives are 1.05.*
IronHorse AC-input GSD5 DC drive is 1.05.
*** Single phase full wave rectification is the most common form of DC drive in 0.33–2 hp range. All IronHorse GSD series DC drives are 1.35 or better.*
**** Not Recommended.*

For Ironhorse PMDC motors it is recommended that form factor not exceed 1.4 for continuous operation. Half wave rectification is not recommended because it increases the form factor.

Driving a Ironhorse PMDC motor with a higher form factor control than intended can cause premature brush failure and excessive internal heating.

PMDC motors can generate high momentary starting and acceleration torques, typically 10 to 12 times full rated torque. Thus, they suit applications requiring high starting torques or momentary bursts of power. However, they are not intended for continuous operation at these higher levels of torque. This can cause overheating, which can result in non-reversible demagnetization of the field magnets.

Torque (current) limiting in the drive limits stall conditions and current draw, particularly during high torque demand, and protects against detrimental overload.

Enclosure and Electrical Insulation Systems

Other considerations for PMDC motor selection include proper choice of enclosure and electrical insulation system. If safety factors dictate a totally enclosed motor, it may be non-ventilated (TENV) or fan-cooled (TEFC).

Electrical insulation systems, as shown is the following table, are tested for 20,000 hours at a rated temperature without degradation (as recognized by UL, CSA, BSI, and VDE). Subtract ambient temperatures (usually 25 °C or 40 °C) to determine allowable rise.

Electrical Insulation Systems	
Class A	105 °C
Class B	130 °C
Class F	155 °C
Class H	180 °C

Permanent Magnets

A number of magnetic materials are available for permanent magnets. These include ceramic oriented ferrites, rare earth permanent magnets, and Alnico. The following table compares common magnet materials.

Comparing Permanent Magnet Motor Materials			
Type	***Cost***	***Demagnetizing Resistance***	***Energy Product***
Ceramic Oriented Ferrites *	Low	Medium	Low
Samarium Cobalt	High	High	High
Neodymium Iron Boron	High	High	High
** Ironhorse PMDC motors contain ceramic oriented ferrite magnets.*			

Ceramic oriented ferrites, typically made with barium or strontium have become the material of choice in most PM motors, replacing Alnico, because of their greater resistance to demagnetization and low cost.

Rare earth magnets may allow a downsized PM motor or boost its power rating. They include samariumcobalt and neodymium-iron-boron. Their characteristics, include high energy and low susceptibility to demagnetization; however, the cost of these materials remains high.

Brushes

PMDC motors use a mechanical commutator to switch current to the armature winding. Commutator bars connect to the armature windings. Spring loaded brushes make mechanical contact with the commutator bars, carrying the current to the armature. The armature commutator and the brushes act as a rotary switch for energizing the windings.

The ideal brush offers low voltage loss, negligible dust formation, no arcing, little commutator wear, and generates little noise.

Commonly used brush materials include carbon and carbon graphite, graphite, electro-graphitic, and metal-graphite. The following table compares these brush materials.

Comparing Motor Brush Materials			
Material Type	***Voltage Drop***	***Current Capacity***	***Limitations of Use***
Carbon, Carbon-Graphite *	High	Low	High Voltage, Low Speed, Fractional hp Only
Natural Graphite	Medium	Medium	Medium Speed / High Voltage
Electro-Graphitic	Medium	High	Medium to High Speed / High Voltage
Copper Graphite	Low	Low	Low Voltage / Low Speeds
Silver Graphite	Very Low	Very Low	Very Low Voltage / Low Speeds
** PMDC motors use resin-class graphite brushes, which puts them in the category of carbon-graphite brushes.*			

Resin-Bonded Brushes (Including resin-class graphite / carbon-graphite brushes)

The raw material is graphite, bonded with resin, which is pressed and heat treated in a special process. The advantage of special graphite brushes is their high contact drop and low internal resistance. They also have good oxidation resistance. These properties are very valuable for machines with high commutating requirements. The main field of application for special graphite brushes covers machines with high commutating requirements, but with relatively low brush current. These include small PMDC motors.

Other factors also affect brush life and performance, including temperature, humidity, altitude, spring pressure, control form factor, size and duty cycle.

If spring pressure is too low, excessive electrical wear may occur. If it is too high, excessive mechanical wear may occur. The optimal spring-pressure range for minimal wear is between the high electrical and mechanical wear regions.

Low humidity, high temperature or high altitude environments may not have enough moisture present to form the necessary lubricating film between brush and commutator bar. Special lubricant impregnated brushes can correct the problem.

Under light load conditions, the low current draw can cause poor lubrication of the commutator. Smutting of the commutator and uneven commutation often result.

Ironhorse PMDC brushes have been specifically manufactured for optimal performance with the Ironhorse PMDC motors.
We do not recommend using other manufacturer's brushes.

Power Supply

Ironhorse PMDC motors are designed for use with NEMA code K power supplies, but can be supplied by five basic types of power sources: batteries, generators, six-step SCR, three-step SCR, and single phase SCR. These types of supplies are divided into four NEMA codes, based on the quality of the output power as shown below.

Common PMDC Power Supplies				
NEMA Code	**Description**	**Power Quality**	**Use**	**Form Factor**
A	Batteries, Generators	Excellent	Limited	1.0
C	3 Phase / 6-Step SCR (Solid State)	Excellent	High (for high hp)	C: 1.04
D				D: 1.13
E	3 Phase / 3-Step SCR (Solid State)	Average	Limited	1.05
K	1 Phase SCR (Solid State)	Poor	High (for low hp)	1.35

The most common way to provide DC voltage to a motor from an AC line is through the use of an electronic drive. Depending on the construction, a drive will provide a pulse wave form similar to the voltage from a battery. These pulses are characterized by a form factor which is defined by NEMA (National Electrical Manufacturers' Association) as a power supply code. Codes are based on the quality of the power output. Application concerns include drive cost, operational cost (efficiency), reliability, and output power quality.

NEMA Power Code A

This power supply is a pure DC power supply such as a battery or a generator. High frequency PWM power supplies will approach NEMA power code A.

NEMA Power Codes C and D

This power supply is close to being pure and consists of six silicon controlled rectifiers (SCRS) connected in a three phase, full-wave bridge configuration.

NEMA Power Code E

This power supply has average quality and consists of three controlled rectifiers (SCRS) connected in a three phase, halfwave bridge configuration. Most DC motors will require some derating when used on this type of power supply.

NEMA Power Code K

This power supply has limited applications and consists of two controlled rectifiers (SCRs) and two diode style rectifiers connected in a single phase full-wave bridge configuration. A freewheeling rectifier may be used across the motor armature terminals. This type of power supply is normally used for motors rated up to 7-1/2 HP.

Ironhorse MTPM series motors are rated for use with Code K DC power supplies.

Single-Phase Power Supply Considerations

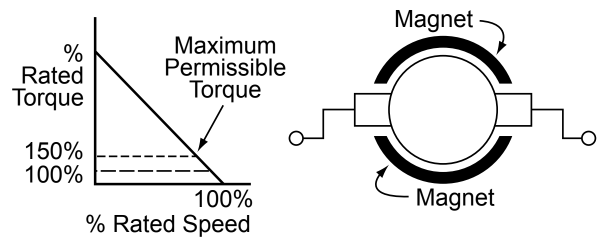
This type of power supply is limited to motors fractional through 7-1/2hp. Drive application is limited due to simplicity of power supply.

DC Motor Types

There are four kinds of DC motors commonly used in industrial applications: shunt, series, compound wound or stabilized shunt, and permanent magnet. Ironhorse MTPM series motors are permanent magnet DC motors.

Permanent Magnet Motors

Permanent magnet motors are generally used where response time is a factor. They are built with a conventional type of armature, but have permanent magnets in the field section rather than windings. Permanent magnet motors are considered less expensive to operate as they require no field supply.



Controlling Speed

The method of controlling the speed of a PM direct current motor is armature voltage control.

Armature Voltage Control

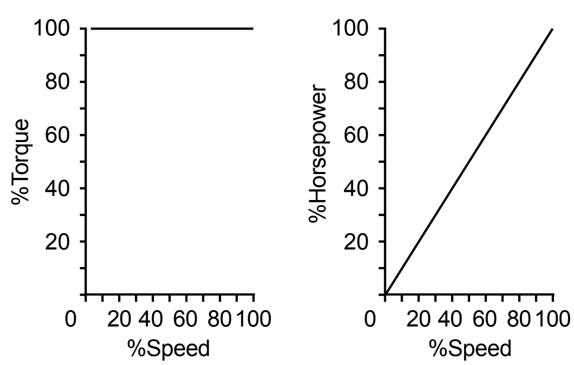
For this type of speed control the armature voltage is varied. The output torque of a DC motor is proportional to the product of the main pole flux, armature current, and a machine constant which is a function of armature windings. With armature voltage speed control, the torque is dependent upon the armature current only; that is, at rated armature current the torque is constant.

A DC motor, operated with armature voltage control and fixed field excitation, will develop rated torque at rated armature current independent of the speed. This is commonly called constant torque operation.

Load Considerations

Constant Torque

Many industrial applications such as conveyors, mixers, squeeze rolls, continuous processing machinery, etc., require nearly constant torque over their operating speed range. Direct current motors operated with fixed shunt field excitation and adjustable armature voltage have an approximately constant torque capacity over their speed range as shown below.



High Temperature Considerations

Overload is only one cause of over-temperature problems. High ambient temperatures or improper cleaning of filters on the machine itself contribute to short service life by increasing operating temperatures. This in turn causes abnormally high differential expansion stress resulting in cracks in the insulation which usually propagate through to the bare conductor, opening the circuit to contamination failure. In addition, the commonly known effect is the more rapid degradation of the insulation materials which shrink and harden, then gradually lose both strength and insulating characteristics.

Ambient temperatures greater than 40°C are also harmful to grease, cables, brushes, and commutation.

Contamination Considerations

Nonconducting contaminants such as factory dust and sand gradually promote over-temperature by restricting cooling air circulation. In addition, these may erode the insulation and the varnish, gradually reducing their effectiveness.

Conducting contaminants such as metal dust, carborundum, carbon, and salt, in addition to promoting over-temperature, also provide immediate conducting paths for shorting or grounding leakage currents wherever the electrical circuit is contacted. Normal differential expansion, rotational stresses, and thermal expansion of trapped air in voids within the insulation system eventually open the insulated circuit at unpredictable locations. Depending on the severity of the operating voltage, service life may be measured in years, months, days, or hours.

Oil deposits promote easy adhesion of contaminants to the internal insulated and exposed un-insulated surfaces to promote early service life problems.

Water from splashing or condensation seriously degrades an insulation system. The water alone is conducting. Nonconducting contaminants are readily converted into leakage current conductors. Intermittent or occasional wetness ultimately causes service failure because successive leakage situations gradually deposit a permanent path for continuation of the damaging shorting or grounding currents.

Vibration Considerations

High vibration promotes service life problems by subjecting the shaft to stress, which finally results in actual shorting of conductors between turns or between layers. In addition, the severe stress causes fissures and cracks in the conductor insulation exposing the electrical circuit to contamination failure. Another important factor is the work hardening effect that this vibration has on the conductor itself, resulting in an open circuit by conduction or cracking. Commutation problems may arise because of brush bouncing. Continued severe vibration fatigues metals and could cause failure in casting or bearings.

Altitude Considerations

Standard motor ratings are based on operation at any altitude up to 3300 feet (1000 meters). All altitudes up to and including 3300 feet are considered to be the same as sea level. High altitude derating is required because of lower air density which requires a greater amount of cooling.

DC motors are derated by 3% per 1000 feet above the 3300 feet. In some cases, a blower will be sufficient to cool the motor instead of using a larger frame motor.

Ambient Temperature

Motors for use in abnormally hot places are usually designed to accommodate the higher ambient by having a lower winding temperature rise. If the ambient temperature is above 50°C, special consideration must also be made of the lubricant. Although it's possible to operate in ambients above 50°C, application should be referred to the manufacturer to determine what steps must be taken.

In general, the simplest method of derating for high ambient temperatures is to derate the horsepower rating of the motor. In this way, the armature will operate at reduced current. For ambients lower than 40°C, a standard 40°C machine is normally used at rated load. In the case when the ambient is maintained well below 40°C, a standard ambient motor may be used at overload, provided the following factors are known:

1) *The ambient is known always to be low.*
2) *Shaft stresses, bearing loading and commutation are approved by the factory.*
3) *Overload protection for the motor from an over load or stalled condition is available and used.*

Operation of motors in ambients below 0°C results in severe duty on the machine component parts. Of major concern are the lubrication system and the insulation system.

Typical Performance Data for Small-Frame PMDC Motors

12/24VDC Small-Frame PMDC Motors

Typical Small-Frame PMDC Motor Performance Data – MTPM-P10-1JK43						
Powered with 12VDC						
Torque (oz·in)	**Speed (rpm)**	**Current (A)**	**Horse-power (hp)**	**Efficiency (%)**	**Motor Design Data and Constants**	
0.0	2407	0.54	0.000	0.00	**Ke (V/krpm)**	4.8240 ±10%
5.0	2292	1.30	0.011	54.17	**Kt (oz·in/A)**	6.5269 ±10%
10.0	2178	2.07	0.022	64.80	**Ra (Ω)**	0.6025 ±7.5%
15.0	2063	2.83	0.031	67.19	**Rt (Ω)**	0.7230 ±12.5%
20.0	1948	3.60	0.039	66.60	**Friction Torque (nominal) (oz·in)**	3.5000
25.0	1833	4.37	0.045	64.60	**Friction Torque (maximum) (oz·in)**	6.0000
30.0	1718	5.13	0.051	61.82	**Ja (inertia) (oz·in·s^2)**	0.0066
35.0	1604	5.90	0.056	58.56	**La (inductance) (mH)**	1.3294
40.0	1489	6.66	0.059	54.99	**Te (electric time const) (ms)**	1.8387
Primary Load Point					**Tm (mechanical time const) (ms)**	15.7504
28.0	1764	4.83	0.049	63.00	**Theoretical Accel at Stall (rad/s^2)**	16005
Continuous Duty Rating – Form Factor = 1.05					**Bandwidth (Hz)**	10.10
28.0	1764	4.83	0.049	63.00		
Stall Torque (oz·in)		104.83 (for reference only)				
Stall Current (A)		16.60 (for reference only)				
Powered with 24VDC						
Torque (oz·in)	**Speed (rpm)**	**Current (A)**	**Horse-power (hp)**	**Efficiency (%)**	**Motor Design Data and Constants**	
0.0	4895	0.54	0.000	0.00	**Ke (V/krpm)**	4.8240 ±10%
10.0	4665	2.07	0.046	69.41	**Kt (oz·in/A)**	6.5269 ±10%
20.0	4436	3.60	0.088	75.83	**Ra (Ω)**	0.6025 ±7.5%
30.0	4206	5.13	0.125	75.66	**Rt (Ω)**	0.7230 ±12.5%
40.0	3976	6.66	0.157	73.44	**Friction Torque (nominal) (oz·in)**	3.5000
50.0	3747	8.20	0.185	70.33	**Friction Torque (maximum) (oz·in)**	6.0000
60.0	3517	9.73	0.209	66.75	**Ja (inertia) (oz·in·s^2)**	0.0066
70.0	3287	11.26	0.228	62.89	**La (inductance) (mH)**	1.3294
80.0	3058	12.79	0.242	58.85	**Te (electric time const) (ms)**	1.8387
Primary Load Point					**Tm (mechanical time const) (ms)**	15.7504
28.0	4252	4.83	0.118	75.92	**Theoretical Accel at Stall (rad/s^2)**	32544
Continuous Duty Rating – Form Factor = 1.05					**Bandwidth (Hz)**	10.10
28.0	4252	4.83	0.118	75.92		
Stall Torque (oz·in)		213.6 (for reference only)				
Stall Current (A)		33.20 (for reference only)				

Typical Performance Data for 12/24VDC Small-Frame PMDC Motors (continued)

Typical Small-Frame PMDC Motor Performance Data – MTPM-P13-1JK42

Powered with 12VDC

Torque (oz·in)	Speed (rpm)	Current (A)	Horse-power (hp)	Efficiency (%)
0.0	2328	0.66	0.000	0.00
5.0	2249	1.40	0.011	49.32
10.0	2171	2.14	0.021	62.37
15.0	2092	2.88	0.031	67.05
20.0	2014	3.62	0.040	68.48
25.0	1935	4.36	0.048	68.31
30.0	1856	5.10	0.055	67.25
35.0	1778	5.84	0.062	65.62
40.0	1699	6.57	0.067	63.62
Primary Load Point				
32.0	1825	5.39	0.058	66.65
Continuous Duty Rating – Form Factor = 1.05				
32.0	1825	5.39	0.058	66.65
Stall Torque (oz·in)		148.04 (for reference only)		
Stall Current (A)		22.54 (for reference only)		

Motor Design Data and Constants	
Ke (V/krpm)	5.0025 ±10%
Kt (oz·in/A)	6.7684 ±10%
Ra (Ω)	0.4590 ±7.5%
Rt (Ω)	0.5325 ±12.5%
Friction Torque (nominal) (oz·in)	4.5000
Friction Torque (maximum) (oz·in)	7.0000
Ja (inertia) ($oz·in·s^2$)	0.0081
La (inductance) (mH)	1.1882
Te (electric time const) (ms)	2.2316
Tm (mechanical time const) (ms)	13.3887
Theoretical Accel at Stall (rad/s^2)	18209
Bandwidth (Hz)	11.89

Powered with 24VDC

Torque (oz·in)	Speed (rpm)	Current (A)	Horse-power (hp)	Efficiency (%)
0.0	4727	0.66	0.000	0.00
10.0	4570	2.14	0.045	65.64
20.0	4412	3.62	0.087	75.03
30.0	4255	5.10	0.126	77.07
40.0	4098	6.57	0.162	76.73
50.0	3941	8.05	0.195	75.30
60.0	3783	9.53	0.225	73.31
70.0	3626	11.01	0.251	70.97
80.0	3469	12.48	0.275	68.41
Primary Load Point				
32.0	4224	5.39	0.134	77.13
Continuous Duty Rating – Form Factor = 1.05				
32.0	4224	5.39	0.134	77.13
Stall Torque (oz·in)		300.57 (for reference only)		
Stall Current (A)		45.07 (for reference only)		

Motor Design Data and Constants	
Ke (V/krpm)	5.0025 ±10%
Kt (oz·in/A)	6.7684 ±10%
Ra (Ω)	0.4590 ±7.5%
Rt (Ω)	0.5325 ±12.5%
Friction Torque (nominal) (oz·in)	4.5000
Friction Torque (maximum) (oz·in)	7.0000
Ja (inertia) ($oz·in·s^2$)	0.0081
La (inductance) (mH)	1.1882
Te (electric time const) (ms)	2.2316
Tm (mechanical time const) (ms)	13.3887
Theoretical Accel at Stall (rad/s^2)	36971
Bandwidth (Hz)	11.89

Typical Performance Data for 12/24VDC Small-Frame PMDC Motors (continued)

Typical Small-Frame PMDC Motor Performance Data – MTPM-P17-JK43

Powered with 12VDC

Torque (oz·in)	Speed (rpm)	Current (A)	Horse-power (hp)	Efficiency (%)
0.0	2352	1.21	0.000	0.00
10.0	2230	2.72	0.022	50.56
20.0	2109	4.22	0.042	61.46
30.0	1987	5.73	0.059	64.01
40.0	1865	7.24	0.074	63.43
50.0	1744	8.75	0.086	61.34
60.0	1622	10.26	0.096	58.40
70.0	1500	11.77	0.104	54.95
80.0	1379	13.27	0.109	51.15
Primary Load Point				
42.0	1841	7.54	0.077	63.10
Continuous Duty Rating – Form Factor = 1.05				
42.0	1841	7.54	0.077	63.10
Stall Torque (oz·in)		193.37 (for reference only)		
Stall Current (A)		30.38 (for reference only)		

Motor Design Data and Constants	
Ke (V/krpm)	4.8997 ±10.0%
Kt (oz·in/A)	6.6293 ±10.0%
Ra (Ω)	0.2634 ±7.5%
Rt (Ω)	0.3951 ±12.5%
Friction Torque (nominal) (oz·in)	8.0000
Friction Torque (maximum) (oz·in)	12.0000
Ja (inertia) (oz·in·s²)	0.0173
La (inductance) (mH)	1.0366
Te (electric time const) (ms)	2.6240
Tm (mechanical time const) (ms)	22.0216
Theoretical Accel at Stall (rad/s²)	11184
Bandwidth (Hz)	7.23

Powered with 24VDC

Torque (oz·in)	Speed (rpm)	Current (A)	Horse-power (hp)	Efficiency (%)
0.0	4801	1.21	0.000	0.00
10.0	4679	2.72	0.046	53.04
20.0	4558	4.22	0.090	66.42
30.0	4436	5.73	0.132	71.45
40.0	4314	7.24	0.171	73.35
50.0	4193	8.75	0.208	73.74
60.0	4071	10.26	0.242	73.29
70.0	3950	11.77	0.274	72.31
80.0	3828	13.27	0.303	71.00
Primary Load Point				
42.0	4290	7.54	0.178	73.52
Continuous Duty Rating – Form Factor = 1.05				
42.0	4290	7.54	0.178	73.52
Stall Torque (oz·in)		394.73 (for reference only)		
Stall Current (A)		60.75 (for reference only)		

Motor Design Data and Constants	
Ke (V/krpm)	4.8997 ±10.0%
Kt (oz·in/A)	6.6293 ±10.0%
Ra (Ω)	0.2634 ±7.5%
Rt (Ω)	0.3951 ±12.5%
Friction Torque (nominal) (oz·in)	8.0000
Friction Torque (maximum) (oz·in)	12.0000
Ja (inertia) (oz·in·s²)	0.0173
La (inductance) (mH)	1.0366
Te (electric time const) (ms)	2.6240
Tm (mechanical time const) (ms)	22.0216
Theoretical Accel at Stall (rad/s²)	22830
Bandwidth (Hz)	7.23

Typical Performance Data for 12/24VDC Small-Frame PMDC Motors (continued)

Typical Small-Frame PMDC Motor Performance Data – MTPM-P25-1JK40

Powered with 12VDC

Torque (oz·in)	Speed (rpm)	Current (A)	Horse-power (hp)	Efficiency (%)	Motor Design Data and Constants	
0.0	2151	1.35	0.000	0.00	Ke (V/krpm)	5.4672 ±10.0%
25.0	2042	4.73	0.051	66.41	Kt (oz·in/A)	7.3971 ±10.0%
50.0	1933	8.11	0.096	73.33	Ra (Ω)	0.1010 ±7.5%
75.0	1823	11.49	0.135	73.25	Rt (Ω)	0.1767 ±12.5%
100.0	1714	14.87	0.170	70.95	Friction Torque (nominal) (oz·in)	10.0000
125.0	1605	18.25	0.199	67.66	Friction Torque (maximum) (oz·in)	15.0000
150.0	1496	21.63	0.222	63.84	Ja (inertia) (oz·in·s^2)	0.0411
175.0	1386	25.01	0.240	59.71	La (inductance) (mH)	0.4720
200.0	1277	28.39	0.253	55.38	Te (electric time const) (ms)	2.6703
Primary Load Point					Tm (mechanical time const) (ms)	18.8191
96.0	1732	14.33	0.165	71.40	Theoretical Accel at Stall (rad/s^2)	11971
Continuous Duty Rating – Form Factor = 1.05					Bandwidth (Hz)	8.46
96.0	1732	14.33	0.165	71.40		
Stall Torque (oz·in)		492.23 (for reference only)				
Stall Current (A)		67.89 (for reference only)				

Powered with 24VDC

Torque (oz·in)	Speed (rpm)	Current (A)	Horse-power (hp)	Efficiency (%)	Motor Design Data and Constants	
0.0	4346	1.35	0.000	0.0	Ke (V/krpm)	5.4672 ±10.0%
50.0	4128	8.11	0.204	78.30	Kt (oz·in/A)	7.3971 ±10.0%
100.0	3909	14.87	0.387	80.90	Ra (Ω)	0.1010 ±7.5%
150.0	3691	21.63	0.548	78.76	Rt (Ω)	0.1767 ±12.5%
200.0	3472	28.39	0.688	75.28	Friction Torque (nominal) (oz·in)	10.0000
250.0	3254	35.15	0.805	71.22	Friction Torque (maximum) (oz·in)	15.0000
300.0	3035	41.91	0.901	66.86	Ja (inertia) (oz·in·s^2)	0.0411
350.0	2816	48.67	0.976	62.34	La (inductance) (mH)	0.4720
400.0	2598	55.43	1.029	57.70	Te (electric time const) (ms)	2.6703
Primary Load Point					Tm (mechanical time const) (ms)	18.8191
80.0	3996	12.17	0.317	80.87	Theoretical Accel at Stall (rad/s^2)	24184
Continuous Duty Rating – Form Factor = 1.05					Bandwidth (Hz)	8.46
80.0	3996	12.17	0.317	80.87		
Stall Torque (oz·in)		994.45 (for reference only)				
Stall Current (A)		135.79 (for reference only)				

Typical Performance Data for 12/24VDC Small-Frame PMDC Motors (continued)

Typical Small-Frame PMDC Motor Performance Data – MTPM-P25-JK44

Powered with 12VDC

Torque (oz·in)	Speed (rpm)	Current (A)	Horse-power (hp)	Efficiency (%)	Motor Design Data and Constants	
0.0	2303	1.74	0.000	0.00	Ke (V/krpm)	5.1050 ±10.0%
25.0	2204	5.36	0.055	63.30	Kt (oz·in/A)	6.9071 ±10.0%
50.0	2104	8.98	0.104	72.14	Ra (Ω)	0.0801 ±7.5%
75.0	2005	12.60	0.149	73.48	Rt (Ω)	0.1401 ±12.5%
100.0	1906	16.22	0.189	72.33	Friction Torque (nominal) (oz·in)	12.0000
125.0	1806	19.83	0.224	70.06	Friction Torque (maximum) (oz·in)	15.0000
150.0	1707	23.45	0.253	67.19	Ja (inertia) (oz·in·s²)	0.0531
175.0	1607	27.07	0.279	63.95	La (inductance) (mH)	0.3825
200.0	1508	30.69	0.299	60.48	Te (electric time const) (ms)	2.7294
Primary Load Point					Tm (mechanical time const) (ms)	22.1208
113.0	1854	18.10	0.207	71.25	Theoretical Accel at Stall (rad/s²)	10902
Continuous Duty Rating – Form Factor = 1.05					Bandwidth (Hz)	7.19
113.0	1854	18.10	0.207	71.24		
Stall Torque (oz·in)		579.45 (for reference only)				
Stall Current (A)		85.63 (for reference only)				

Powered with 24VDC

Torque (oz·in)	Speed (rpm)	Current (A)	Horse-power (hp)	Efficiency (%)	Motor Design Data and Constants	
0.0	4654	1.74	0.000	0.00	Ke (V/krpm)	5.1050 ±10.0%
50.0	4455	8.98	0.221	76.37	Kt (oz·in/A)	6.9071 ±10.0%
100.0	4256	16.22	0.421	80.78	Ra (Ω)	0.0801 ±7.5%
150.0	4057	23.45	0.603	79.86	Rt (Ω)	0.1401 ±12.5%
200.0	3859	30.69	0.764	77.38	Friction Torque (nominal) (oz·in)	12.0000
250.0	3660	37.93	0.906	74.24	Friction Torque (maximum) (oz·in)	15.0000
300.0	3461	45.17	1.028	70.75	Ja (inertia) (oz·in·s²)	0.0531
350.0	3263	52.41	1.131	67.05	La (inductance) (mH)	0.3825
400.0	3064	59.65	1.213	63.23	Te (electric time const) (ms)	2.7294
Primary Load Point					Tm (mechanical time const) (ms)	22.1208
70.0	4375	11.87	0.303	79.40	Theoretical Accel at Stall (rad/s²)	22030
Continuous Duty Rating – Form Factor = 1.05					Bandwidth (Hz)	7.19
70.0	4375	11.87	0.303	79.40		
Stall Torque (oz·in)		1170.90 (for reference only)				
Stall Current (A)		171.26 (for reference only)				

Typical Performance Data for Small-Frame PMDC Motors (continued)

90VDC Small-Frame PMDC Motors

Typical Small-Frame PMDC Motor Performance Data – MTPM-P03-1L18						
Powered with 90VDC						
Torque (oz·in)	**Speed (rpm)**	**Current (A)**	**Horse-power (hp)**	**Efficiency (%)**	**Motor Design Data and Constants**	
0.0	2130	0.06	0.000	0.00	**Ke (V/krpm)**	41.0040 ±10.0%
5.0	2038	0.15	0.010	54.57	**Kt (oz·in/A)**	55.4784 ±10.0%
10.0	1945	0.24	0.019	65.60	**Ra (Ω)**	41.2764 ±7.5%
15.0	1853	0.33	0.028	68.39	**Rt (Ω)**	42.1019 ±12.5%
20.0	1760	0.42	0.035	68.20	**Friction Torque (nominal) (oz·in)**	3.5000
25.0	1667	0.51	0.041	66.60	**Friction Torque (maximum) (oz·in)**	6.0000
30.0	1575	0.60	0.047	64.21	**Ja (inertia) (oz·in·s^2)**	0.0066
35.0	1482	0.69	0.051	61.36	**La (inductance) (mH)**	96.0471
40.0	1390	0.78	0.055	58.19	**Te (electric time const) (ms)**	2.2813
Primary Load Point					**Tm (mechanical time const) (ms)**	12.6947
18.0	1797	0.39	0.032	68.50	**Theoretical Accel at Stall (rad/s^2)**	17572
Continuous Duty Rating – Form Factor = 1.40					**Bandwidth (Hz)**	12.54
18.0	1797	0.39	0.032	68.50		
Stall Torque (oz·in)		115.09 (for reference only)				
Stall Current (A)		2.14 (for reference only)				

Typical Small-Frame PMDC Motor Performance Data – MTPM-P04-1L17						
Powered with 90VDC						
Torque (oz·in)	**Speed (rpm)**	**Current (A)**	**Horse-power (hp)**	**Efficiency (%)**	**Motor Design Data and Constants**	
0.0	2047	0.08	0.000	0.00	**Ke (V/krpm)**	42.6880 ±10.0%
5.0	1979	0.16	0.010	49.38	**Kt (oz·in/A)**	57.7569 ±10.0%
10.0	1911	0.25	0.019	62.49	**Ra (Ω)**	31.5737 ±7.5%
15.0	1844	0.34	0.027	67.22	**Rt (Ω)**	33.4681 ±12.5%
20.0	1776	0.42	0.035	68.71	**Friction Torque (nominal) (oz·in)**	4.5000
25.0	1708	0.51	0.042	68.60	**Friction Torque (maximum) (oz·in)**	7.0000
30.0	1640	0.60	0.049	67.60	**Ja (inertia) (oz·in·s^2)**	0.0081
35.0	1572	0.68	0.054	66.03	**La (inductance) (mH)**	86.5239
40.0	1504	0.77	0.060	64.09	**Te (electric time const) (ms)**	2.5853
Primary Load Point					**Tm (mechanical time const) (ms)**	11.5569
22.0	1749	0.46	0.038	68.81	**Theoretical Accel at Stall (rad/s^2)**	18550
Continuous Duty Rating – Form Factor = 1.40					**Bandwidth (Hz)**	13.77
22.0	1749	0.46	0.038	68.81		
Stall Torque (oz·in)		150.82 (for reference only)				
Stall Current (A)		2.69 (for reference only)				

Typical Performance Data for 90VDC Small-Frame PMDC Motors (continued)

Typical Small-Frame PMDC Motor Performance Data – MTPM-P05-1L19						
Powered with 90VDC						
Torque (oz·in)	**Speed (rpm)**	**Current (A)**	**Horse-power (hp)**	**Efficiency (%)**	**Motor Design Data and Constants**	
0.0	2212	0.15	0.000	0.00	**Ke (V/krpm)**	39.1976 ±10.0%
10.0	2106	0.34	0.021	50.93	**Kt (oz·in/A)**	53.0343 ±10.0%
20.0	2001	0.53	0.040	62.21	**Ra (Ω)**	16.9866 ±7.5%
30.0	1896	0.72	0.056	65.13	**Rt (Ω)**	21.9127 ±12.5%
40.0	1790	0.91	0.071	64.93	**Friction Torque (nominal) (oz·in)**	8.0000
50.0	1685	1.09	0.083	63.21	**Friction Torque (maximum) (oz·in)**	12.0000
60.0	1579	1.28	0.094	60.65	**Ja (inertia) (oz·in·s²)**	0.0173
70.0	1474	1.47	0.102	57.57	**La (inductance) (mH)**	66.3453
80.0	1368	1.66	0.108	54.15	**Te (electric time const) (ms)**	3.0277
Primary Load Point					**Tm (mechanical time const) (ms)**	19.0855
28.0	1917	0.68	0.053	64.88	**Theoretical Accel at Stall (rad/s²)**	12136
Continuous Duty Rating – Form Factor = 1.40					**Bandwidth (Hz)**	8.34
28.0	1917	0.68	0.053	64.88		
Stall Torque (oz·in)		209.82 (for reference only)				
Stall Current (A)		4.11 (for reference only)				

Typical Small-Frame PMDC Motor Performance Data – MTPM-P13-1L19						
Powered with 90VDC						
Torque (oz·in)	**Speed (rpm)**	**Current (A)**	**Horse-power (hp)**	**Efficiency (%)**	**Motor Design Data and Constants**	
0.0	2041	0.17	0.000	0.00	**Ke (V/krpm)**	43.7376 ±10.0%
50.0	1956	1.01	0.097	79.15	**Kt (oz·in/A)**	59.1770 ±10.0%
100.0	1871	1.86	0.185	82.60	**Ra (Ω)**	5.1647 ±7.5%
150.0	1786	2.70	0.265	81.31	**Rt (Ω)**	4.3979 ±12.5%
200.0	1701	3.55	0.337	78.67	**Friction Torque (nominal) (oz·in)**	10.0000
250.0	1616	4.39	0.400	75.46	**Friction Torque (maximum) (oz·in)**	15.0000
300.0	1531	5.24	0.455	71.95	**Ja (inertia) (oz·in·s²)**	0.0411
350.0	1446	6.08	0.501	68.28	**La (inductance) (mH)**	30.2054
400.0	1361	6.93	0.539	67.49	**Te (electric time const) (ms)**	6.8681
Primary Load Point					**Tm (mechanical time const) (ms)**	7.3169
73.0	1917	1.40	0.139	81.87	**Theoretical Accel at Stall (rad/s²)**	29207
Continuous Duty Rating – Form Factor = 1.40					**Bandwidth (Hz)**	21.75
73.0	1917	1.40	0.139	81.87		
Stall Torque (oz·in)		1201.00 (for reference only)				
Stall Current (A)		20.46 (for reference only)				

Typical Performance Data for 90VDC Small-Frame PMDC Motors (continued)

Typical Small-Frame PMDC Motor Performance Data – MTPM-P14-1L19						
Powered with 90VDC						
Torque (oz·in)	***Speed (rpm)***	***Current (A)***	***Horse-power (hp)***	***Efficiency (%)***	***Motor Design Data and Constants***	
0.0	1971	0.20	0.000	0.00	***Ke (V/krpm)***	44.9240 ±10.0%
25.0	1904	0.61	0.047	64.18	***Kt (oz·in/A)***	60.7822 ±10.0%
50.0	1837	1.02	0.091	73.90	***Ra (Ω)***	5.6800 ±7.5%
75.0	1770	1.43	0.131	76.11	***Rt (Ω)***	7.3272 ±12.5%
100.0	1703	1.84	0.169	75.84	***Friction Torque (nominal) (oz·in)***	12.0000
125.0	1636	2.25	0.202	74.45	***Friction Torque (maximum) (oz·in)***	15.0000
150.0	1569	2.67	0.233	72.45	***Ja (inertia) (oz·in·s²)***	0.0531
175.0	1502	3.08	0.260	70.10	***La (inductance) (mH)***	29.6208
200.0	1435	3.49	0.284	67.51	***Te (electric time const) (ms)***	4.0426
Primary Load Point					***Tm (mechanical time const) (ms)***	14.9355
86.0	1740	1.61	0.148	76.19	***Theoretical Accel at Stall (rad/s²)***	13821
Continuous Duty Rating – Form Factor = 1.40					***Bandwidth (Hz)***	10.66
86.0	1740	1.61	0.148	76.19		
Stall Torque (oz·in)		734.58 (for reference only)				
Stall Current (A)		12.28 (for reference only)				

180VDC Small-Frame PMDC Motors

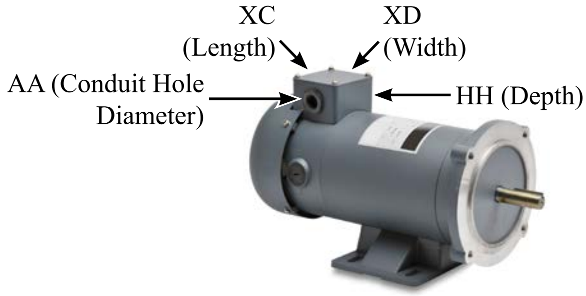
Typical Small-Frame PMDC Motor Performance Data – MTPM-P07-1M24						
Powered with 180VDC						
Torque (oz·in)	***Speed (rpm)***	***Current (A)***	***Horse-power (hp)***	***Efficiency (%)***	***Motor Design Data and Constants***	
0.0	2727	0.09	0.000	0.00	***Ke (V/krpm)***	64.0730 ±10.0%
10.0	2625	0.21	0.026	51.87	***Kt (oz·in/A)***	88.6908 ±10.0%
20.0	2522	0.32	0.050	64.09	***Ra (Ω)***	44.1455 ±7.5%
30.0	2420	0.44	0.072	67.95	***Rt (Ω)***	56.9477 ±12.5%
40.0	2317	0.55	0.092	68.69	***Friction Torque (nominal) (oz·in)***	8.0000
50.0	2215	0.67	0.110	67.91	***Friction Torque (maximum) (oz·in)***	12.0000
60.0	2112	0.78	0.125	66.29	***Ja (inertia) (oz·in·s²)***	0.0173
70.0	2010	0.90	0.139	64.16	***La (inductance) (mH)***	177.2726
80.0	1907	1.02	0.151	61.67	***Te (electric time const) (ms)***	3.1129
Primary Load Point					***Tm (mechanical time const) (ms)***	18.5632
28.0	2440	0.42	0.068	67.51	***Theoretical Accel at Stall (rad/s²)***	15385
Continuous Duty Rating – Form Factor = 1.40					***Bandwidth (Hz)***	8.57
28.0	2440	0.42	0.068	67.51		
Stall Torque (oz·in)		266.01 (for reference only)				
Stall Current (A)		3.16 (for reference only)				

Typical Performance Data for 180VDC Small-Frame PMDC Motors (continued)

Typical Small-Frame PMDC Motor Performance Data – MTPM-P13-1M19						
Powered with 180VDC						
Torque (oz·in)	***Speed (rpm)***	***Current (A)***	***Horse-power (hp)***	***Efficiency (%)***	***Motor Design Data and Constants***	
0.0	2113	0.09	0.000	0.00	***Ke (V/krpm)***	83.8304 ±10.0%
25.0	2028	0.31	0.050	67.43	***Kt (oz·in/A)***	113.4225 ±10.0%
50.0	1943	0.53	0.096	75.38	***Ra (Ω)***	25.0243 ±7.5%
75.0	1859	0.75	0.138	76.33	***Rt (Ω)***	32.2813 ±12.5%
100.0	1774	0.97	0.176	75.05	***Friction Torque (nominal) (oz·in)***	10.0000
125.0	1689	1.19	0.209	72.78	***Friction Torque (maximum) (oz·in)***	15.0000
150.0	1604	1.41	0.238	69.99	***Ja (inertia) (oz·in·s²)***	0.0411
175.0	1519	1.63	0.263	66.88	***La (inductance) (mH)***	110.9630
200.0	1434	1.85	0.284	63.57	***Te (electric time const) (ms)***	3.4374
Primary Load Point					***Tm (mechanical time const) (ms)***	14.6195
73.0	1865	0.73	0.135	76.36	***Theoretical Accel at Stall (rad/s²)***	15137
Continuous Duty Rating – Form Factor = 1.40					***Bandwidth (Hz)***	10.89
73.0	1865	0.73	0.135	76.36		
Stall Torque (oz·in)		622.44 (for reference only)				
Stall Current (A)		5.58 (for reference only)				

Typical Small-Frame PMDC Motor Performance Data – MTPM-P14-1M18						
Powered with 180VDC						
Torque (oz·in)	***Speed (rpm)***	***Current (A)***	***Horse-power (hp)***	***Efficiency (%)***	***Motor Design Data and Constants***	
0.0	2065	0.10	0.000	0.00	***Ke (V/krpm)***	85.7640 ±10.0%
25.0	1995	0.32	0.049	64.17	***Kt (oz·in/A)***	116.0387 ±10.0%
50.0	1924	0.53	0.095	73.88	***Ra (Ω)***	21.7410 ±7.5%
75.0	1854	0.75	0.138	76.09	***Rt (Ω)***	28.0459 ±12.5%
100.0	1783	0.97	0.177	75.81	***Friction Torque (nominal) (oz·in)***	12.0000
125.0	1713	1.18	0.212	74.41	***Friction Torque (maximum) (oz·in)***	15.0000
150.0	1642	1.40	0.244	72.40	***Ja (inertia) (oz·in·s²)***	0.0531
175.0	1572	1.61	0.272	70.04	***La (inductance) (mH)***	107.9568
200.0	1501	1.83	0.297	67.44	***Te (electric time const) (ms)***	3.8493
Primary Load Point					***Tm (mechanical time const) (ms)***	15.6853
84.0	1828	0.83	0.152	76.17	***Theoretical Accel at Stall (rad/s²)***	13786
Continuous Duty Rating – Form Factor = 1.40					***Bandwidth (Hz)***	10.15
84.0	1828	0.83	0.152	76.17		
Stall Torque (oz·in)		732.74 (for reference only)				
Stall Current (A)		6.42 (for reference only)				

Junction Box Dimensions for 56C-Frame Motors



Junction Box Dimensions				
Frame Size	***XD Width***	***XC Length***	***HH Depth***	***AA Conduit Hole (NPT)***
56	2.5 in	2.76 in	1.55 in	1/2 in

Shipping Crate Dimensions for 56C-Frame Motors

Nominal Shipping Crate Dimensions		
Frame Size	***HP***	***Width x Depth x Height (in)***
56C	1/3	13.2 x 7.5 x 8.5
	1/2	
	3/4	15.2 x 7.5 x 8.5
	1	15.9 x 7.5 x 8.5
	1-1/2	18.1 x 7.5 x 8.5
	2	18.7 x 9.8 x 10.6
Motor and shipping weights are listed in the Motor Specifications tables in "Chapter 1: Getting Started."		

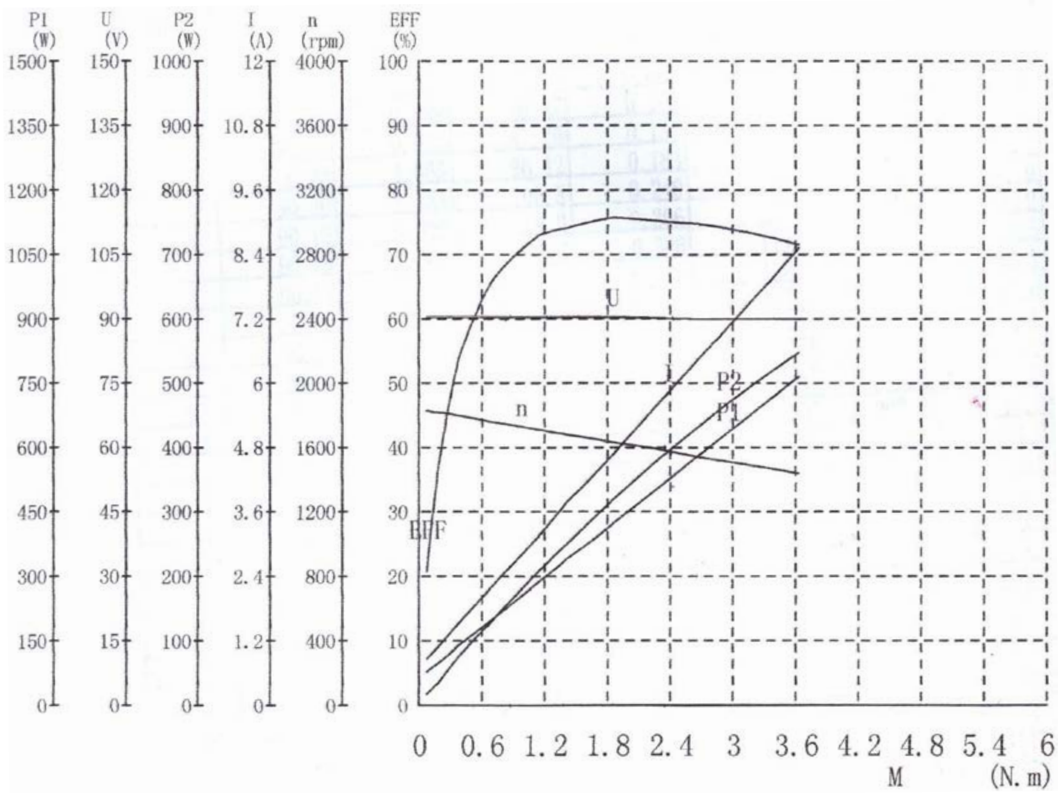
Decibel Levels for 56C-Frame Motors

The decibel (sound) level of an IronHorse PMDC motor should be measured after initial startup, after 30 days, and after six months of use. Decibel levels should remain fairly consistent, and can be an indication of misalignment and premature bearing wear. If the measured decibel level for your IronHorse model exceeds the value listed below by more than 10%, contact AutomationDirect or a local motor service technician found at www.easa.com.

Average Decibel Levels		
Frame Size	***HP***	***Noise Level: Lw dB (A)***
56	All	55.0

Performance Curves for 56C-Frame Motors

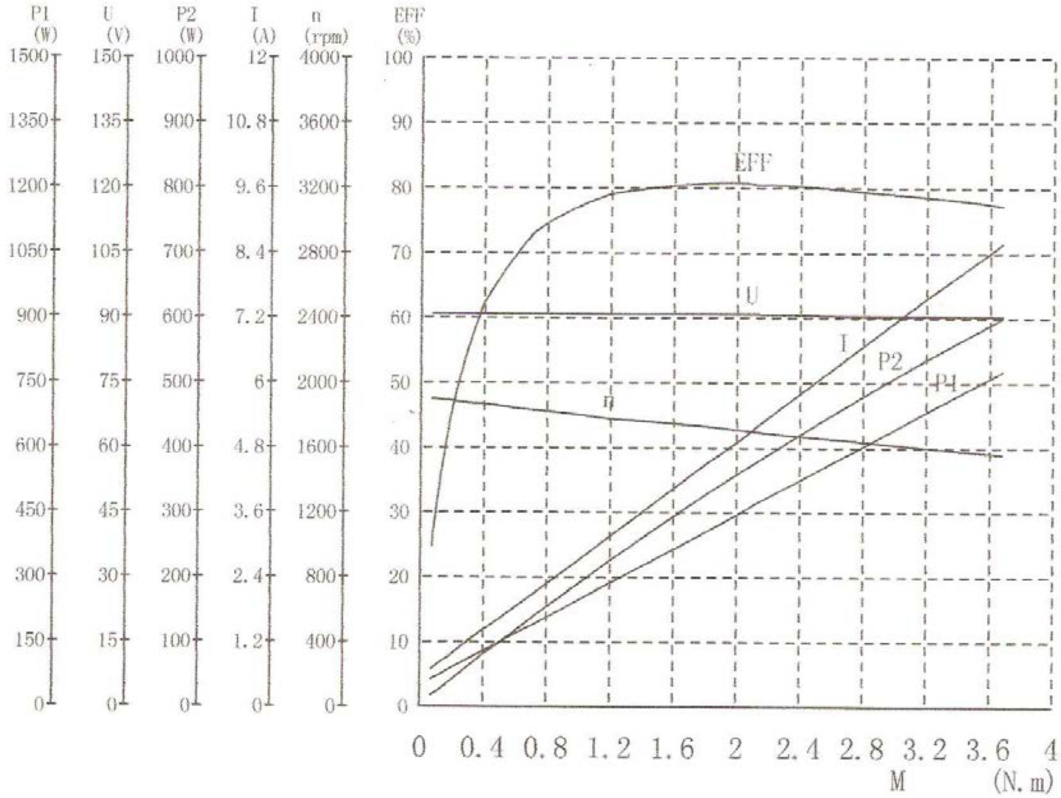
MTPM-P33-1L18



Performance Data – MTPM-P33-1L18							
Description	***U (V)***	***I (A)***	***P1 (W)***	***M (N·m)***	***n (rpm)***	***P2 (W)***	***Eff***
No Load	90.23	0.850	76.71	0.083	1828	15.92	20.7
Rated	90.07	3.752	337.9	1.422	1678	250.0	73.9
Max Eff	90.03	4.680	421.4	1.869	1630	319.9	75.6
Max P_{out}	89.91	8.502	764.4	3.640	1435	546.9	71.5
Max Torque	89.91	8.502	764.4	3.640	1435	546.9	71.5
End	89.91	8.502	764.4	3.640	1435	546.9	71.5

Performance Curves for 56C-Frame Motors (continued)

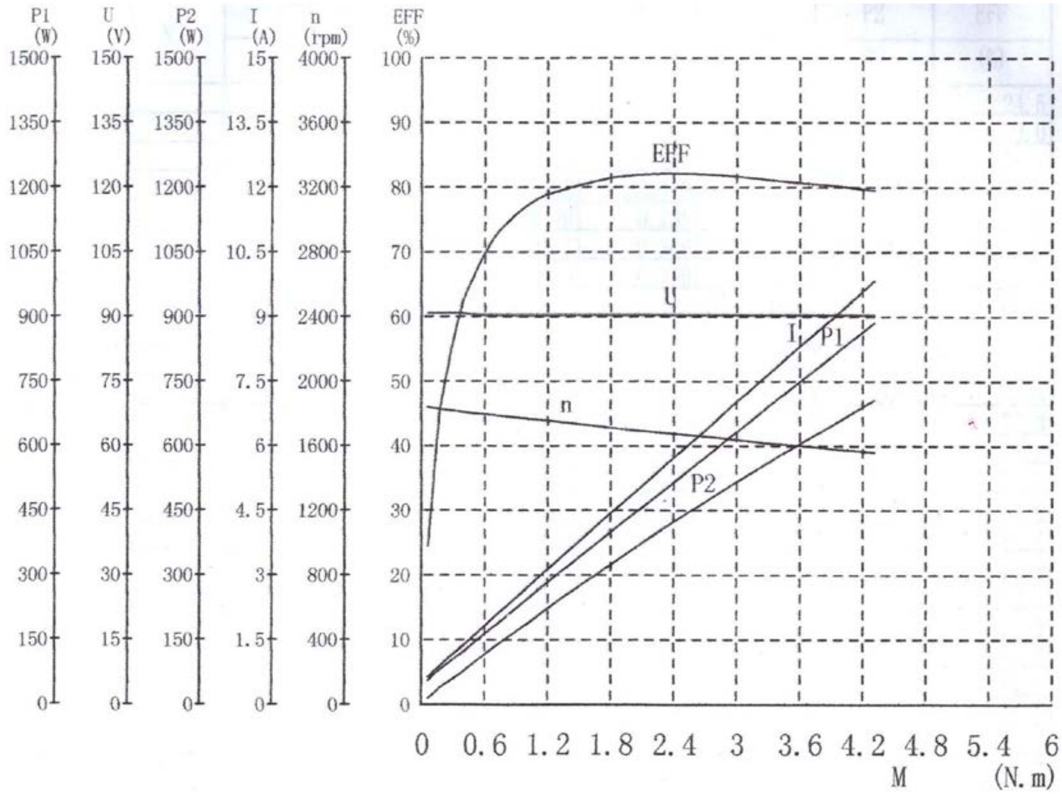
MTPM-P50-1L18



Performance Data – MTPM-P50-1L18							
Description	**U (V)**	**I (A)**	**P1 (W)**	**M (N·m)**	**n (rpm)**	**P2 (W)**	**Eff**
No Load	90.67	0.690	62.60	0.077	1896	15.40	24.6
Rated	90.40	5.146	465.3	2.115	1693	375.0	80.5
Max Eff	90.41	5.067	458.1	2.092	1696	371.4	81.0
Max P_{out}	90.30	8.576	774.5	3.684	1551	598.3	77.2
Max Torque	90.30	8.576	774.5	3.684	1551	598.3	77.2
End	90.30	8.576	774.5	3.684	1551	598.3	77.2

Performance Curves for 56C-Frame Motors (continued)

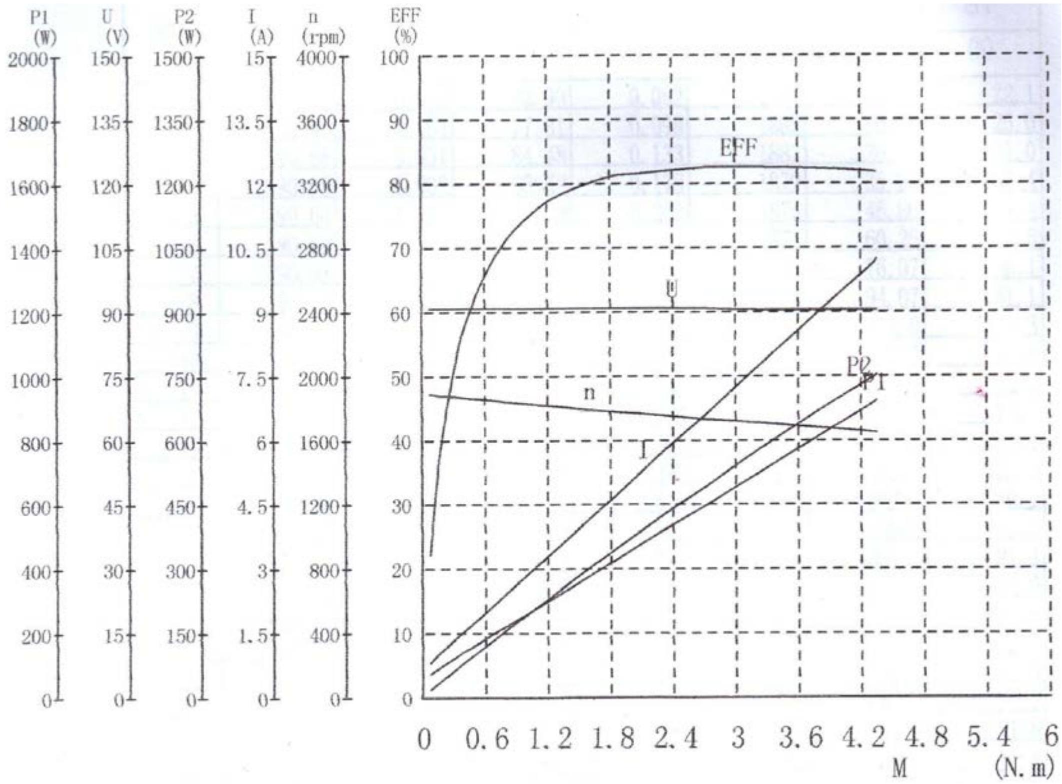
MTPM-P75-1L18



Performance Data – MTPM-P75-1L18							
Description	***U (V)***	***I (A)***	***P1 (W)***	***M (N·m)***	***n (rpm)***	***P2 (W)***	***Eff***
No Load	90.44	0.615	55.68	0.071	1833	13.66	24.5
Rated	90.11	7.519	677.5	3.244	1619	550.0	81.1
Max Eff	90.17	5.634	508.1	2.383	1673	417.4	82.1
Max P_{out}	90.05	9.803	882.8	4.313	1555	702.2	79.5
Max Torque	90.05	9.803	882.8	4.313	1555	702.2	79.5
End	90.05	9.803	882.8	4.313	1555	702.2	79.5

PERFORMANCE CURVES FOR 56C-FRAME MOTORS (CONTINUED)

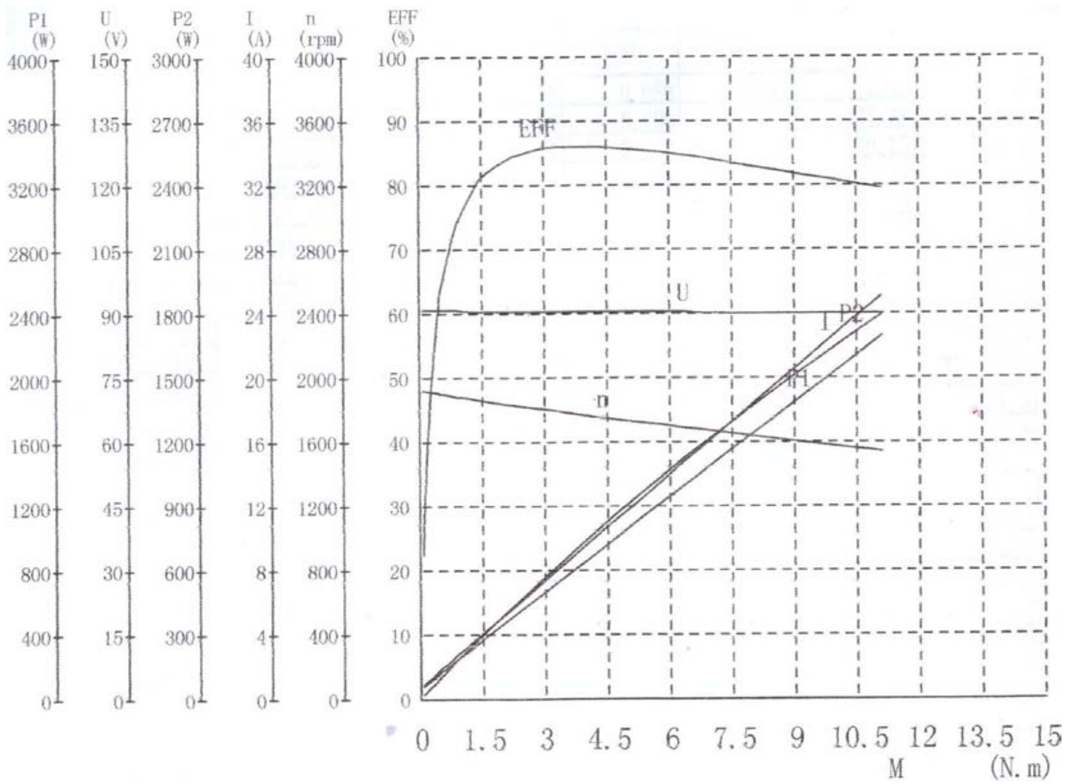
MTPM-001-1L18



Performance Data – MTPM-001-1L18							
Description	**U (V)**	**I (A)**	**P1 (W)**	**M (N·m)**	**n (rpm)**	**P2 (W)**	**Eff**
No Load	90.67	0.816	73.99	0.082	1887	16.35	22.1
Rated	90.30	10.16	918.4	4.345	1647	750.0	81.6
Max Eff	90.34	8.131	734.6	3.418	1694	606.2	82.5
Max P_{out}	90.30	10.21	922.2	4.364	1647	752.9	81.6
Max Torque	90.30	10.21	922.2	4.364	1647	752.9	81.6
End	90.30	10.21	922.2	4.364	1647	752.9	81.6

Performance Curves for 56C-Frame Motors (continued)

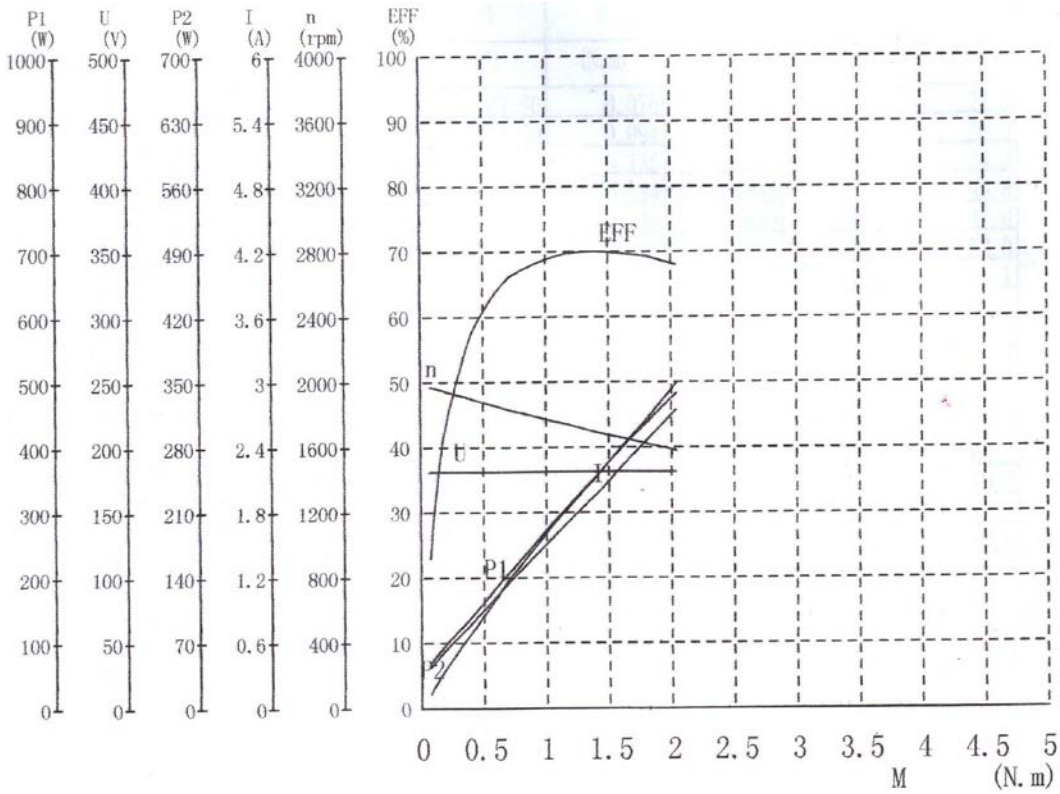
MTPM-1P5-1L18



Performance Data – MTPM-1P5-1L18							
Description	***U (V)***	***I (A)***	***P1 (W)***	***M (N·m)***	***n (rpm)***	***P2 (W)***	***Eff***
No Load	90.51	0.852	77.18	0.086	1917	17.42	22.5
Rated	90.01	14.75	1328	6.373	1686	1125	84.7
Max Eff	90.13	9.510	857.2	3.992	1765	737.8	86.0
Max P_{out}	89.77	25.07	2251	11.110	1537	1787	79.4
Max Torque	89.77	25.07	2251	11.110	1537	1787	79.4
End	89.77	25.07	2251	11.110	1537	1787	79.4

Performance Curves for 56C-Frame Motors (continued)

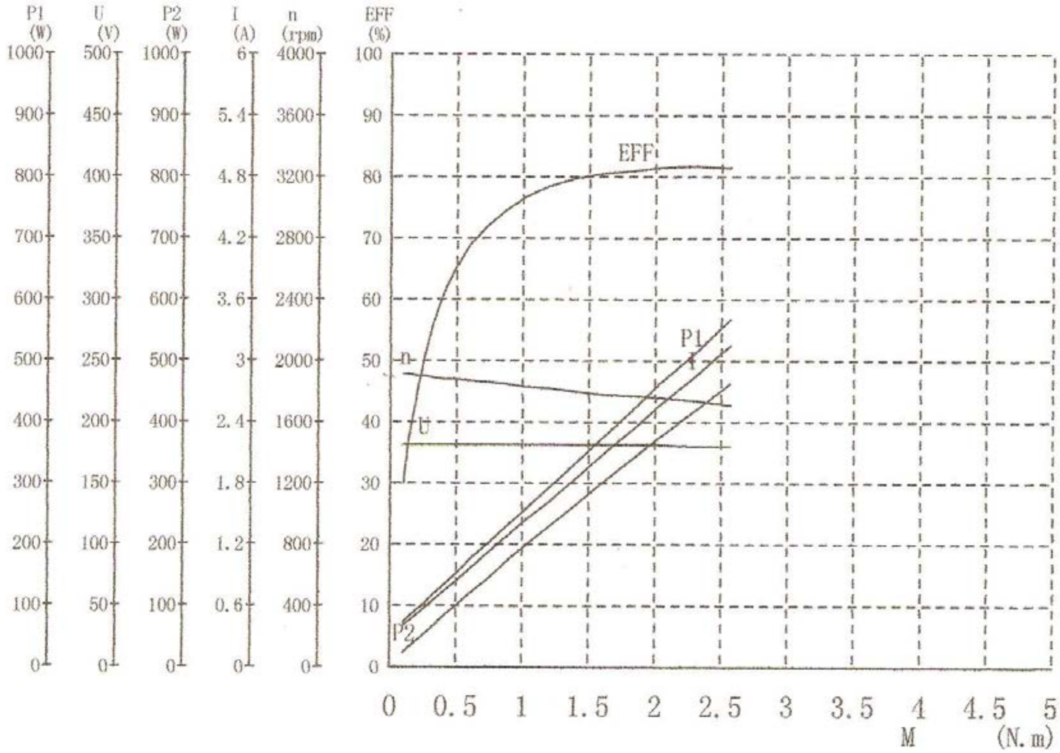
MTPM-P33-1M18



Performance Data – MTPM-P33-1M18							
Description	***U (V)***	***I (A)***	***P1 (W)***	***M (N·m)***	***n (rpm)***	***P2 (W)***	***Eff***
No Load	180.6	0.375	67.90	0.076	1966	15.64	23.0
Rated	180.5	1.980	357.5	1.414	1687	250.0	69.9
Max Eff	180.5	1.980	357.5	1.414	1687	250.0	69.9
Max P_{out}	180.4	2.744	495.2	2.046	1573	337.0	68.0
Max Torque	180.4	2.744	495.2	2.046	1573	337.0	68.0
End	180.4	2.744	495.2	2.046	1573	337.0	68.0

PERFORMANCE CURVES FOR 56C-FRAME MOTORS (CONTINUED)

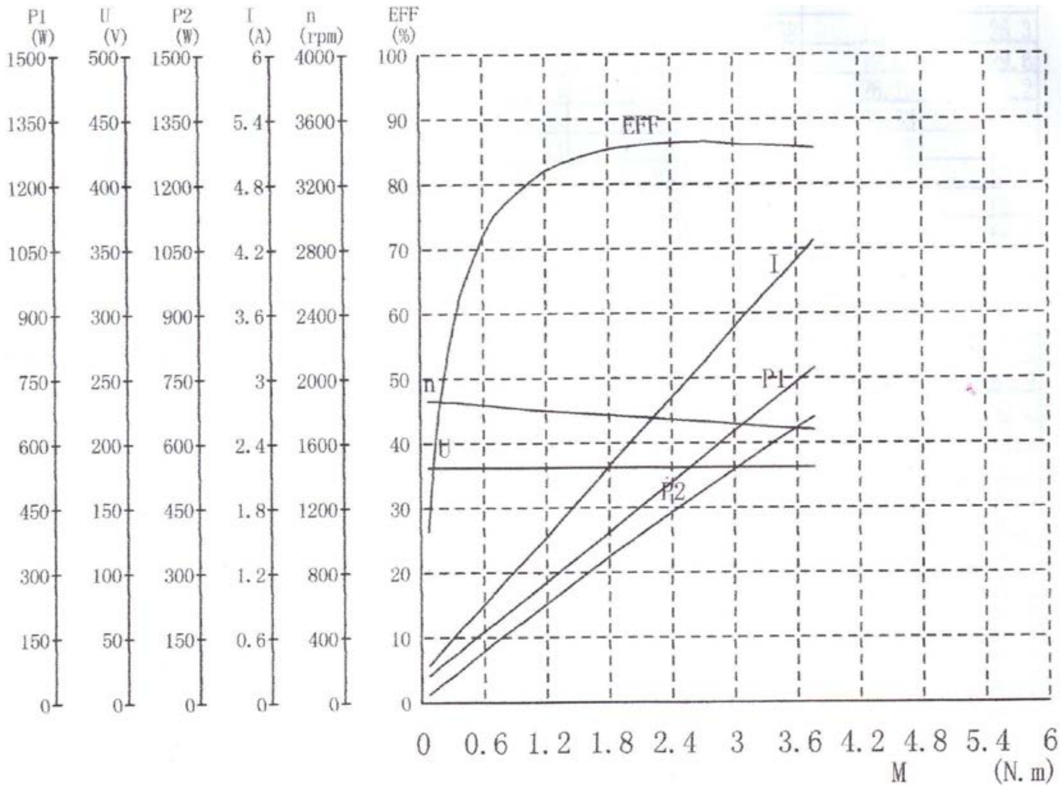
MTPM-P50-1M18



Performance Data – MTPM-P50-1M18							
Description	**U (V)**	**I (A)**	**P1 (W)**	**M (N·m)**	**n (rpm)**	**P2 (W)**	**Eff**
No Load	180.2	0.391	70.66	0.106	1905	21.22	30.0
Rated	180.1	2.554	460.2	2.044	1752	375.0	81.4
Max Eff	180.0	2.812	506.4	2.278	1734	413.6	81.6
Max P_{out}	180.0	3.142	565.9	2.571	1710	460.4	81.3
Max Torque	180.0	3.142	565.9	2.571	1710	460.4	81.3
End	180.0	3.142	565.9	2.571	1710	460.4	81.3

Performance Curves for 56C-Frame Motors (continued)

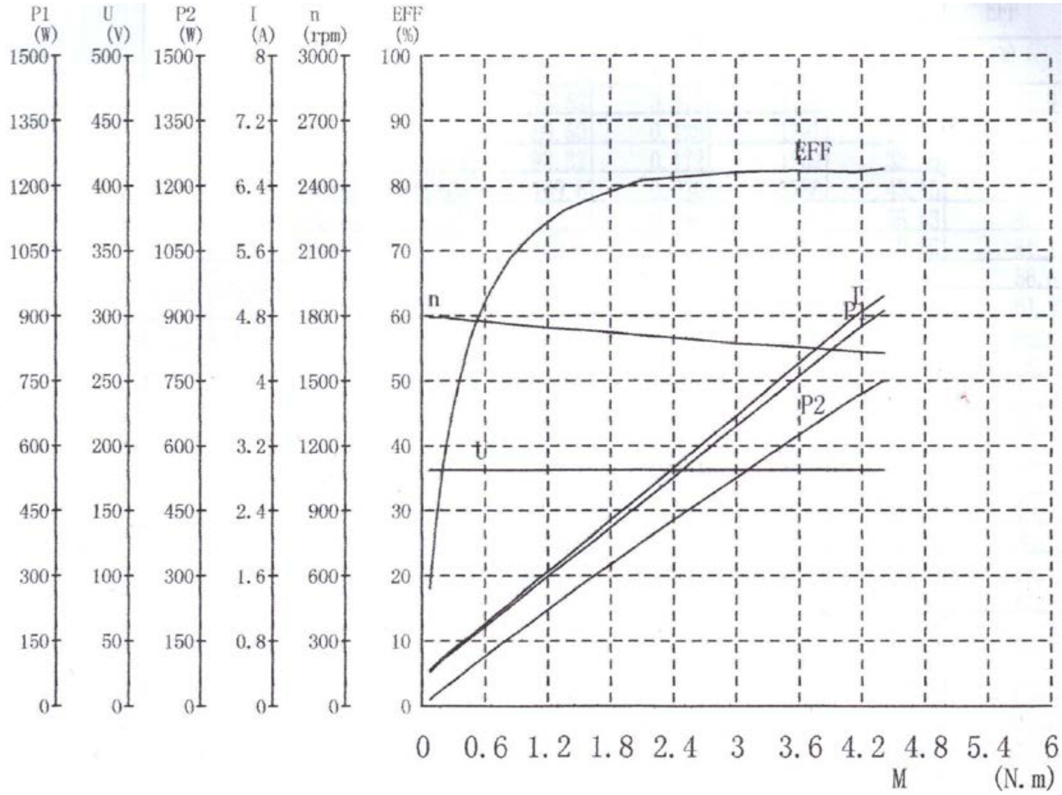
MTPM-P75-1M18



Performance Data – MTPM-P75-1M18							
Description	***U (V)***	***I (A)***	***P1 (W)***	***M (N·m)***	***n (rpm)***	***P2 (W)***	***Eff***
No Load	180.8	0.333	60.35	0.081	1858	15.87	26.3
Rated	180.5	3.547	640.7	3.081	1704	550.0	85.8
Max Eff	180.6	3.164	571.4	2.736	1722	493.3	86.3
Max P_{out}	180.5	4.272	771.4	3.766	1672	659.3	85.4
Max Torque	180.5	4.272	771.4	3.766	1672	659.3	85.4
End	180.5	4.272	771.4	3.766	1672	659.3	85.4

PERFORMANCE CURVES FOR 56C-FRAME MOTORS (CONTINUED)

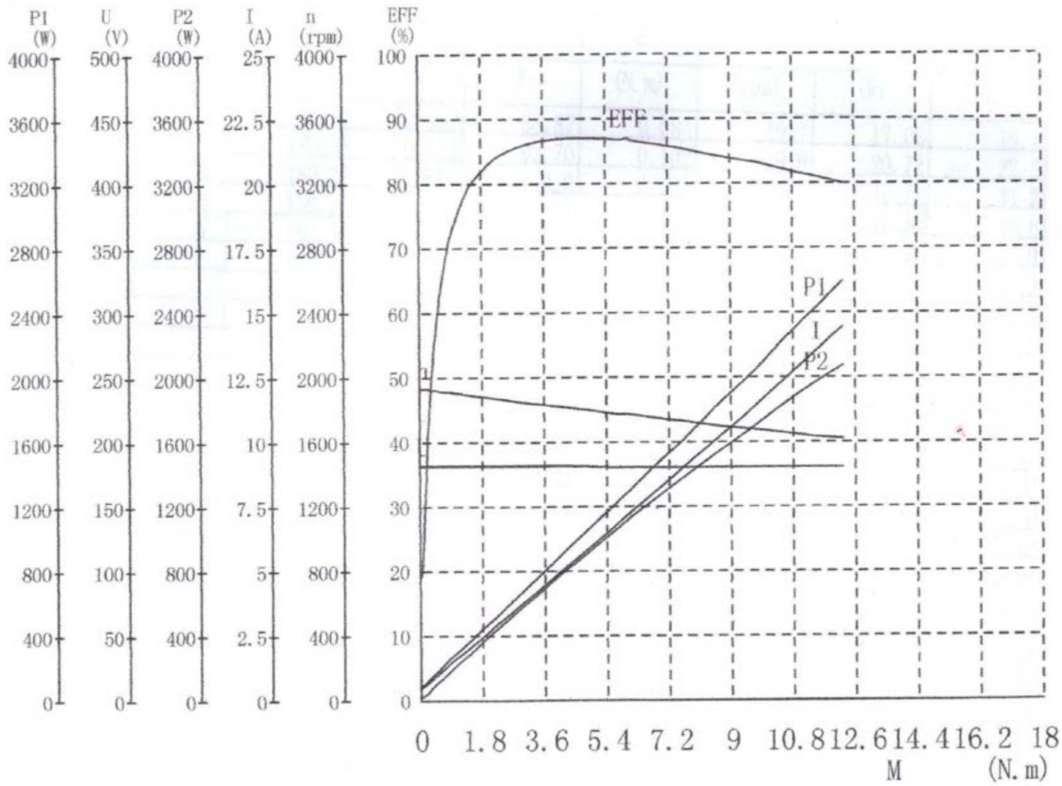
MTPM-001-1M18



Performance Data – MTPM-001-1M18							
Description	***U (V)***	***I (A)***	***P1 (W)***	***M (N·m)***	***n (rpm)***	***P2 (W)***	***Eff***
No Load	180.6	0.434	78.52	0.075	1792	14.10	17.9
Rated	180.4	5.026	909.7	4.412	1623	750.0	82.4
Max Eff	180.4	5.026	909.7	4.412	1623	750.0	82.4
Max P_{out}	180.4	5.026	909.7	4.412	1623	750.0	82.4
Max Torque	180.4	5.026	909.7	4.412	1623	750.0	82.4
End	180.4	5.026	909.7	4.412	1623	750.0	82.4

Performance Curves for 56C-Frame Motors (continued)

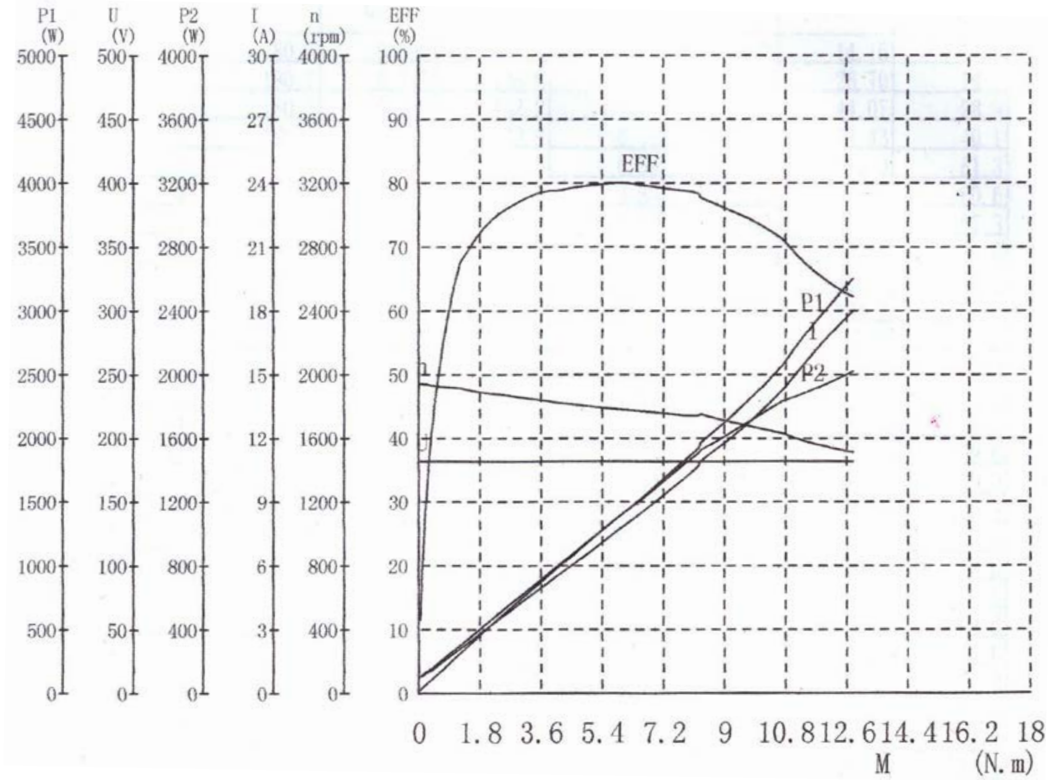
MTPM-1P5-1M18



Performance Data – MTPM-1P5-1M18							
Description	**U (V)**	**I (A)**	**P1 (W)**	**M (N·m)**	**n (rpm)**	**P2 (W)**	**Eff**
No Load	180.3	0.492	88.87	0.084	1927	17.02	19.1
Rated	180.0	7.198	1296	6.099	1761	1125	86.8
Max Eff	180.1	5.337	961.5	4.427	1804	836.2	86.9
Max P_{out}	179.8	14.40	2590	12.261	1612	2069	79.8
Max Torque	179.8	14.40	2590	12.261	1612	2069	79.8
End	179.8	14.40	2590	12.261	1612	2069	79.8

Performance Curves for 56C-Frame Motors (continued)

MTPM-002-1M18



Performance Data – MTPM-002-1M18							
Description	***U (V)***	***I (A)***	***P1 (W)***	***M (N·m)***	***n (rpm)***	***P2 (W)***	***Eff***
No Load	180.7	0.690	124.8	0.07	1933	14.16	11.3
Rated	180.3	10.58	1910	8.25	1733	1500	78.5
Max Eff	180.4	8.374	1510	6.54	1763	1207	79.9
Max P_{out}	180.1	18.00	3244	12.82	1502	2017	62.1
Max Torque	180.1	18.00	3244	12.82	1502	2017	62.1
End	180.1	18.00	3244	12.82	1502	2017	62.1

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