INGRID
Feasibility Study For Cryogenic Motors

Authors: Paul Jolley

Revision 0.1 18th June, 2001

Revision History

0.1 First Draft

Summary

After looking through various manufacturers of stepper motors, cryogenically prepared ones are now commercially available. Three different manufactures were compared with the existing zebotronic in-house prepared motors.

The conclusion drawn was that we should purchase the Phytron motors for all the wheel mechanisms in INGRID and leave the other mechanisms for the time being. The Phytron was chosen for its compliance with the existing system. It also has a side benefit of providing extra resolution (more steps). Once confidence is achieved with them, then a complete change over can be done.

Introduction

INGRID is the ING's only instrument that needs to be maintained and operated at cryogenic temperatures (60K-80K). The design of this instrument includes 5 mechanisms, which are driven via stepper motors. No mechanical feedthrough's could be designed in. As a result, all motors have to operate inside the instrument and must withstand temperature variations from ambient (300K) down to its operating temperature (~70K).

At present we use standard 'off the shelf' stepper motors. These are then specially prepared for vacuum and cryogenic work. Obviously this is time consuming and has inherent risks associated with it. The motors may loose magnetic flux or they can seize during operation. If the later occurs we will loose the mechanism with possible loss of telescope time.

At the time of INGRIDs commissioning, special cryogenic motors were not available. A search on the Internet shows that they are now becoming commercially available. Therefore, is there a case for changing over to them?

Selection Criteria

Any replacement motors will need to be compatible with the existing system. Below is a list of the most relevant selection criteria used. The associated cost of each motor is not considered at this point.

- Size
- Detent Torque
- Motor Steps

Size

Due to the space restrictions inside INGRID it is vital that we ensure any change in the motors' size will still fit. Therefore the physical size of them must be similar or smaller the existing motors.

Detent Torque

This is the torque present when the motor is de-energised. It needs to be as high as possible to keep the mechanisms (especially the pupil wheel) in place during observations. Therefore the detent torque must be equal to or greater than the existing motors.

Motor Steps

The number of steps is crucial to the positioning of the mechanisms. The new system must employ no less than before. At present the motors are driven in half step mode to increase the resolution. It would be advantageous to drive in full step mode if we can get the correct step count. The motor must be capable of driving at least 400 steps/rev.

Choices

Below is a table giving outline features of the existing zebotronic stepper motor. We currently use motor SM 56.1.18.

A search over the Internet has found 3 possible suppliers of cryogenically prepared motors. They are, in no particular order, Empire Magnetics Inc. Mission Research Corp. and Phytron.

	Zebotronic SM56.1.18	Empire CYVX-U22	MRC	Phytron VSS 52
Body Diameter (mm)	**56.5**	58	57	52
Body Length (mm)	**66.0**	83	76	65
Detent Torque (Nmm)	**10**	N/A	N/A	13
Drive Torque @ 300 rpm (Nmm)	**300**	N/A	N/A	280
Steps/rev (Full)	**200**	200	200	500

Full details of these motors can be found in the company’s literature at the end of this report.

Discussion

Looking firstly at the physical size of the motors shows that only one of them will fit with no apparent modifications. The current motors are machined back to reduce their length, depending on the type purchased (lead or cast connections). This may also be possible with the Empire and MRC motors.

The diameters look acceptable and no major modifications off mounting brackets would be required. The combination of length and diameter needs to be considered, especially for the wheel motors. The edges of the current motors are extremely close to the inside of the radiation shield. We may be able to accept a larger diameter if the length is shorter and vice versa. Alternatively, a redesign of the whole drive unit may allow larger motors to be used.

A redesign of the whole drive unit is undesirable. As a consequence the Empire motors would be the least suitable. Minor modifications would need to be made to interface with the existing units (e.g. the mounting holes will be in different positions).

The detent torque settings are vital if we are to hold the wheels in place during observing. Values for the detent torque for the Empire and MRC motors are not available at present, even after specific requests to them. Phytron, however quote a value of 13 Nmm which is slightly better than the present motor (10 Nmm).

We need to be careful when considering the drive torque. There will be different values depending on whether we use the motor in half or full step mode. We currently use the zebotronic motor in half step mode. Therefore the quoted drive torque of 300 Nmm should be modified accordingly. The actual drive torque is estimated to be 71% of the full step torque (i.e. 213 Nmm). Again, drive torques are not available for the Empire or MRC motors at present. The Phytron motor is driven in full step mode and so the full torque is available. This means that they will be adequate for the application.

The full 400 steps/rev is only achievable with the Phytron motor without having to resort to half step mode. In fact this motor will out perform the others without resorting to half step mode. The benefits of these extra full steps are in the resolution of the wheels. At present with 400 half steps per revolution we obtain 3.7 steps/arcmin of the wheels. We would increase this to 5.0 steps/arcmin. This has obvious repeatability enhancements.

From work conducted at NOAO (http://www.noao.edu/ets/gnirs/SDN0015.htm), it transpires that motors need great care and experience in order to prepare one for cryogenic use. Also, once a motor is operated the most likely reason for seizing is due to thermal gradients and not the actual temperature. These thermal gradients are caused by the demand cycle being too high and are exacerbated by the material choice and clearances. After their study comparing Phytron motors with two modified ‘normal’ motors, they decided to use the Gemini standard Phytron motors.

Costs

In-house modification

Base cost of motor £250
Bearings/coating £10
Re-magnitise £150
Time 3hrs @ £30/hr = £90

Total £500/motor

Bought In

Phytron 288.200 pts (£1130)
Empire $5400 (£4150)

Conclusion

It seems that the most suitable commercially available cryogenic motor considered is the Phytron motor. This not only increases the available step count (at full step mode), but also has a history of being used by other institutes. From a risk basis, this would be the one to purchase. The only question is whether to change from in-house prepared ones to bought-in ones.

With recent breakdowns of the filter wheel motors, modifying motors in-house does not always guarantee results. Reliability is the main cause for concern. Newly modified motors failed as well as old ones. Also, it is obviously an advantage not to rely on in-house resources to modify motors.

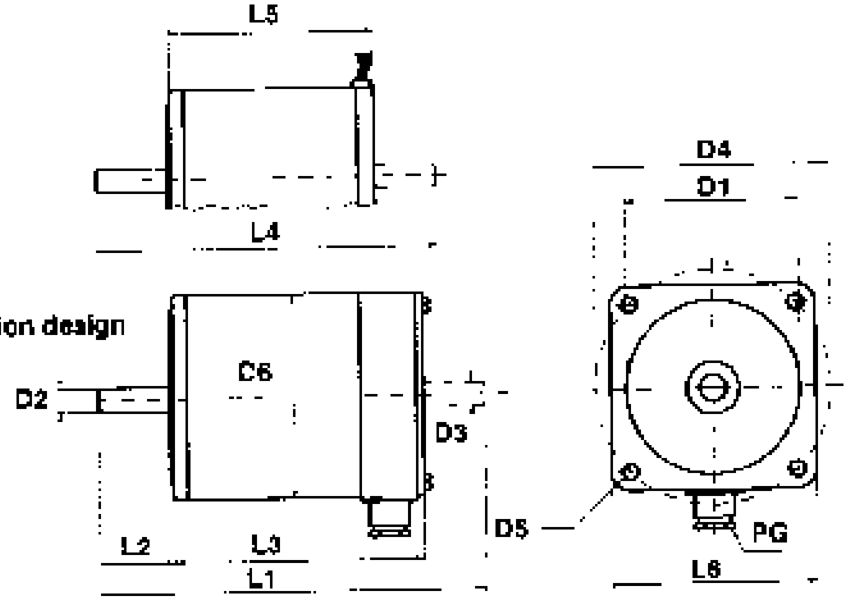
A course of action, which would suit our needs, would be to purchase 3/4 Phytron motors and use these to replace those on the wheels. This will give us experience with them. The other two mechanisms can carry on with the existing in-house modified motors and use the old wheel motors as spares. When funds become available, replace the focus drive and pupil imager motors with Phytron motors.

Appendix 1

Zebertronics

leads design

cast connection design



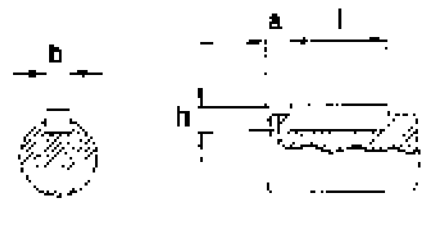
For new motor application design use series SM 56, SM 87, SM 107 and SM 168.

Stepping Motor series	type	D1 -0.05 M	D1 -0.05 J	D2 -0.02 M	D2 -0.02 J	D3 -0.02 M	D3 -0.02 J	D4 M	D4 J	D5	D6	L1	L2 ±0.5	L3 ±1	L4	L5 ±1	L6	PG
56	SM 56.1.18		38.1		6.35		6.35		56.5	5.3	56.5	109	21	68	90	50	56.5	9
	SM 56.2.18											134		94	116	76		
	SM 56.3.18											182		122	144	104		
87	SM 87.1.18	73		10	9.52	10 (12)[1]	9.52	99		6.5	86	137	31.5	79.5	137	60.5	86	9
	SM 87.2.18											169		111.5	169	92.5		
	SM 87.3.18											201		143.5	201	124.5		
	SM 87.4.18											233		175.5	233	156.5		
107 and 109	SM 107.1.18 SM 109.1.18	60	55.54	13	12.7	10	12.7	127.5	125.5	8.5	108	170	32	111			108	13.5
	SM 107.2.18 SM 109.2.18											238	50	161				
	SM 107.3.18 SM 109.3.18			16	15.87	12						288		211				
	SM 107.4.18 SM 109.4.18											338		261				
168	SM 168.1.18	180		24		19		215		15	168	269	50.5	179			182	16
	SM 168.2.18											343		254				

[1] Series SM 87 also with 12 mm axis dia available

Keyway:
Series 107, 109 and 168 have standard keyways. Not standard for series SM 56 and SM 87. Please use listed options.

e.G.: SM 56.2.18 J3 F
SM 87.3.18 M6 N



Stepping Motor series	Keyway DIN 6885 - 1 Type A a	b	h	l
87 Standard: without keyway	6	3	3	15
107 and **109**	5	5	5	20
168	6	8	7	25

Series **SM 56:** also available with woodruff

Electrical and mechanical specifications

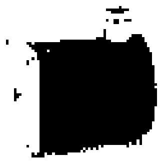
Weights and rotor inertia are based on standard motors with cast connection, without double ended shaft.

Stepping Motor		electrical data				mechanical data						
		resistance /ph.	inductance /ph.	current /ph. unipolar	current /ph. bipolar	step angle	holding torque	detent torque	rotor inertia	bearing thrust load	bearing overhang load	weight
series	type	Ω	mH	A	A	°	Nm	Nm	$kgcm^2$	N	N	kg
56	SM 56.1.18 J1	4.75	9	1	1.4	1.8	0.45	0.01	0.125	80	150	0.6
	SM 56.1.18 J3	0.72	1	3	4.2							
	SM 56.1.18 J3.9	0.42	0.64	3.9	5.5							
	SM 56.2.18 J1.5	3.9	9	1.5	2.1	1.8	0.85	0.017	0.25	80	150	1
	SM 56.2.18 J2	2.6	5	2	2.8							
	SM 56.2.18 J3	1.2	2.6	3	4.2							
	SM 56.3.18 J1.5	4.3	9	1.5	2.1	1.8	1.25	0.025	0.375	80	150	1.35
	SM 56.3.18 J3	1.46	3	3	4.2							
	SM 56.3.18 J4.6	0.72	1.2	4.6	6.5							
87	SM 87.1.18 M1.6	2.9	6	1.6	2.3	1.8	1.8	0.026	0.65	180	280	1.7
	SM 87.1.18 M3	0.72	1.6	3	4.2							
	SM 87.1.18 M5	0.28	0.7	5	7							
	SM 87.2.18 M3.5	0.74	3	3.5	5	1.8	3.6	0.05	1.3	180	280	2.65
	SM 87.2.18 M4.6	0.48	1.5	4.6	6.5							
	SM 87.2.18 M6	0.38	1	6	8.4							
	SM 87.3.18 M3.5	1.1	5	3.5	5	1.8	5.4	0.08	1.95	180	280	3.65
	SM 87.3.18 M6	0.43	1.7	6	8.4							
	SM 87.3.18 M7	0.33	1	7	10							
	SM 87.4.18 M6	0.55	2.3	6	8.4	1.8	7.2	0.1	2.6	180	280	4.6
	SM 87.4.18 M7	0.42	1.8	7	10							
107 and (109)	SM 107.1.18 M6	0.3	1.6	5	7	1.8	5 (4.5)	0.11	4	400	650	4.3
	SM 107.1.18 M8	0.225	1.2	5.7	8							
	SM 107.1.18 M12	0.1	0.55	8.8	12.5							
	SM 107.2.18 M8	0.38	2.4	5.7	8	1.8	9 (8.4)	0.21	8	400	650	7.2
	SM 107.2.18 M10	0.25	1.6	7.1	10							
	SM 107.2.18 M12	0.175	1.15	8.8	12.5							
	SM 107.3.18 M10	0.38	2.7	7.1	10	1.8	13 (12)	0.3	12	400	650	9.8
	SM 107.3.18 M12	0.28	1.9	8.8	12.5							
	SM 107.4.18 M12	0.34	2.7	8.8	12.5	1.8	17(16)	0.4	16	400	650	12.5
168	SM 168.1.18 M12	0.18	2.5	8.8	12.5	1.8	19	0.3	31.2	660	1000	18
	SM 168.2.18 M12	0.28	5	8.8	12.5	1.8	38	0.6	62.4	660	1000	23

typical values

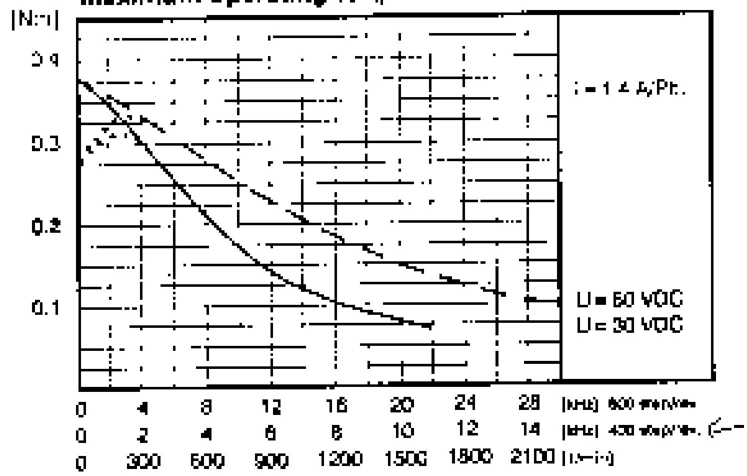
All printed torque performance curves are measured with **Zebotronics motion control amplifiers.**

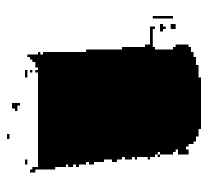
- —— measured with 30 VDC
- -+- measured with 60 VDC
- . . . . without boost



SM 56.1.18

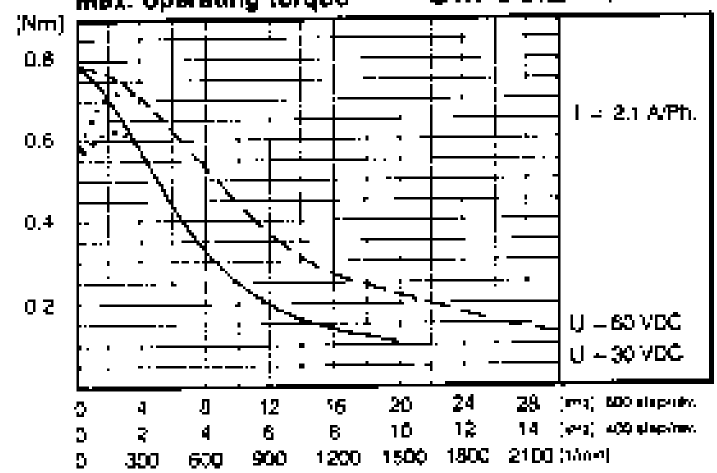
Maximum operating torque **SM 56.1.18 J 1**





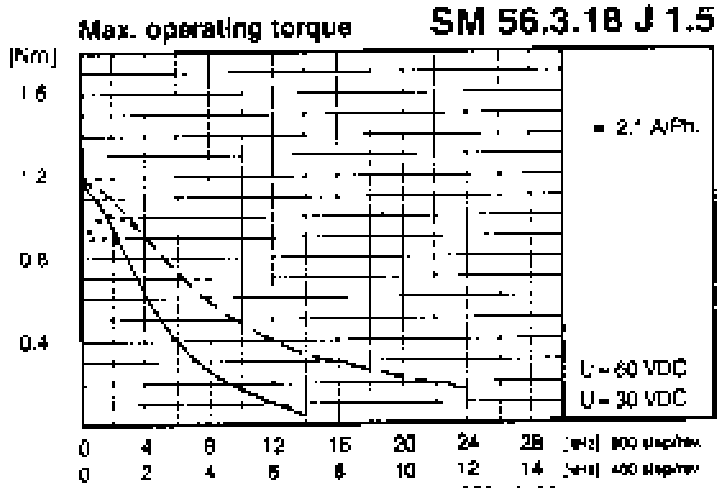
SM 56.2.18

Max. operating torque **SM 56.2.18 J1.5**



SM 56.3.18

Max. operating torque **SM 56.3.18 J 1.5**



Appendix 2

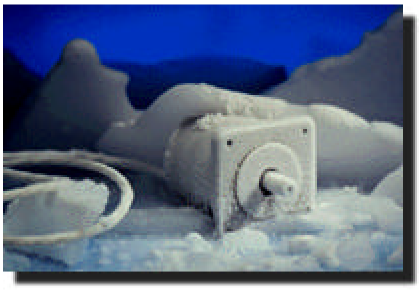
Empire Magnetics Inc

Empire Magnetics Inc.

Motors That Survive

5780-B LaBath Avenue
Rohnert Park, CA 94928
Phone: 707-584-2801
Fax: 707-584-3418

Cryogenic Products (CYVX)



Cryogenic Motors

Cryogenic temperatures (to 20 degrees Kelvin) call for motors designed with materials carefully selected for compatible thermal expansion characteristics and resistance to brittleness. CY Series motors feature special cryogenic dry lubrication and exotic chromium-nickel steel alloy components. Contact the factory about motors wound with superconducting wire.

Choose a product:

- Stepper Motors
- Stand Alone Resolvers

Typical applications:

- **Satellite and Antenna Controls**
- **Observatory Instrumentation**
- **Liquid Oxygen Pumping**
- **Superconductor Research**
- **Plasma Processing**
- **Frozen Food Handling**
- **Paper Mills**
- **Steel Forming**
- **Metal Coating**

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Empire Magnetics Inc.

Cryogenic Stepper Motors
Frame Sizes

More Information

Frame size families:

Stepper Motors

Frame size selection:

Motors are typically made in groups or families, the families are identified by the outer diameter or size of the square, these references are called frame sizes. In the American system, a 23 frame is a nominal 2.3 inches in diameter. For motors less than one inch in diameter, the reference is typically known as a size. Herein is a list of the frame sizes offered by Empire Magnetics Inc. and some of the characteristics of the group that will allow you to select from them.

Frame Size 11: Nominal outer dimension of 1.1 inches, these motors are very low power, suitable primarily for instrumentation applications. Torque range of .5 to 2.5 oz-in. Cylindrical shaped motor with square front flange.

Frame Size 15: Nominal outer dimension of 1.5 inches, these motors are low power, typically used for instrumentation applications. Torque range of 5 to 10 oz-in. Cylindrical shaped motor.

Frame Size 17: Nominal outer dimension of 1.7 inches, these motors are relatively low power useful for a wide range of industrial applications. Torque range of 13 to 26 oz-in. Cylindrical shaped motor laminations, with square end flanges front and rear. Since this motor does not have a housing, it is not available in all environments.

Frame size 23: Nominal outer dimension of 2.3 inches. Extremely popular size useful for a wide range of industrial applications. Torque range of 60 to 150 oz-in. Cylindrical shaped motor with square front flange.

Frame size 34: Nominal outer dimension of 3.4 inches. Power range of 80- 240 watts, useful for a wide range of applications. Torque range of 150 to 450 oz-in. Cylindrical shaped motor with square front flange.

Frame size 42: Nominal outer dimension of 4.2 inches. Power range of 240-700 watts, relatively high power in the stepper motor range. Torque range of 400 to 1600 oz-in. Cylindrical shaped motor with square front flange.

Frame size 65: Nominal outer dimension of 6.5 inches, Power range of 1200-1800 watts, These jumbo size stepper motors are more powerful than many servo systems. Torque range of 1600 to 8000 oz-in. Cylindrical shaped motor with square front flange

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Cryogenic Stepper Motors
23 Family Size - U Series

Options:

- Feedback Devices

Modifications:

- Keyways
- Custom Shafts

Speed/Torque (oz-in) Charts

- U21
- U22
- U23

Price List

CAD Drawings

FAQ

Individual Motor Specifications

Model Number	CYVX-U21	CYVX-U22	CYVX-U23
Drawing Number	list	list	list
Environment	CYVX	CYVX	CYVX
Motor	U21	U22	U23
NEMA Frame Size	23	23	23
Number of Magnetic Stacks	1	2	3
Step Angle	1.8	1.8	1.8
Accuracy Grade (%)	3	3	3
Detent Torque (oz-in)	C/F	C/F	C/F
Static Torque At Thermal Current {unipolar} (oz-in)	C/F	C/F	C/F
Static Torque At Thermal Current {parallel} (oz-in)	C/F	C/F	C/F
Static Torque At Thermal Current {series} (oz-in)	C/F	C/F	C/F
Thermal Current {unipolar} (A)	C/F	C/F	C/F
Thermal Current {parallel} (A)	C/F	C/F	C/F

Thermal Current {series} (A)	C/F	C/F	C/F
Single Coil Inductance (mH)	C/F	C/F	C/F
Single Coil Resistance (ohm)	C/F	C/F	C/F
Series Inductance (mH)	C/F	C/F	C/F
Series Resistance (ohm)	C/F	C/F	C/F
Bearing Type	C/F	C/F	C/F
Bearing Thrust Load (lbs)	C/F	C/F	C/F
Bearing Radial Load (lbs)	C/F	C/F	C/F
Bearing End Play (10^{-3} in)	C/F	C/F	C/F
Bearing Radial Play (10^{-3} in)	C/F	C/F	C/F
Rotor Inertia (oz-in^2)	C/F	C/F	C/F
Body Diameter (in)	C/F	C/F	C/F
Body Length (in)	C/F	C/F	C/F
Weight (lbs)	C/F	C/F	C/F

*C/F - Contact Factory

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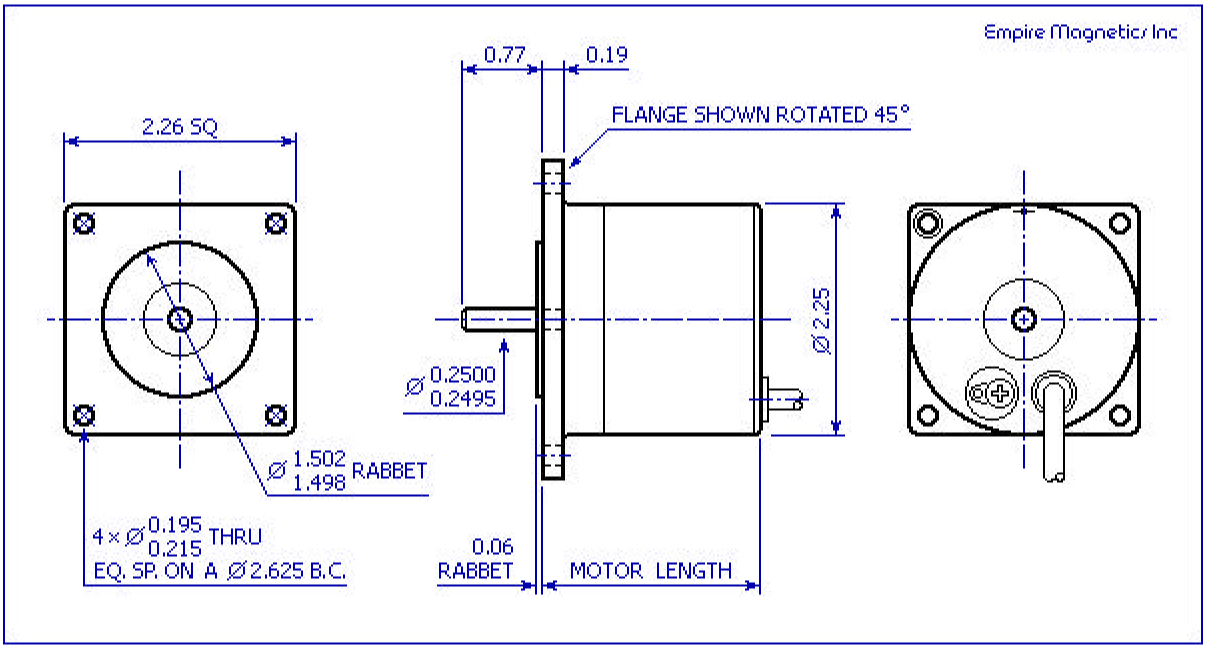
CAD Drawing for Frame 23 Cryogenic Stepper Motor (Model Number CY-U2X)



P/N	Motor Length	Description
CY-U21	2.08	Single Stack
CY-U22	3.08	Double Stack
CY-U23	4.08	Triple Stack

To download the DXF format "zip file" for Frame 23 Cryogenic Stepper Motor, click here: m2400070

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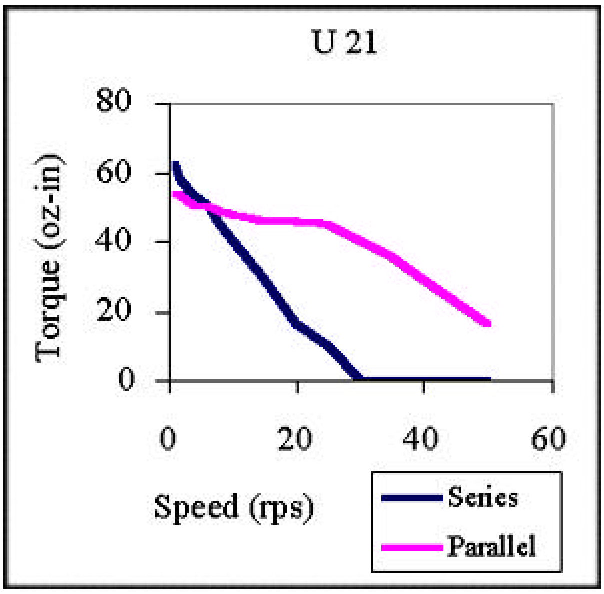
Empire Magnetics Inc.

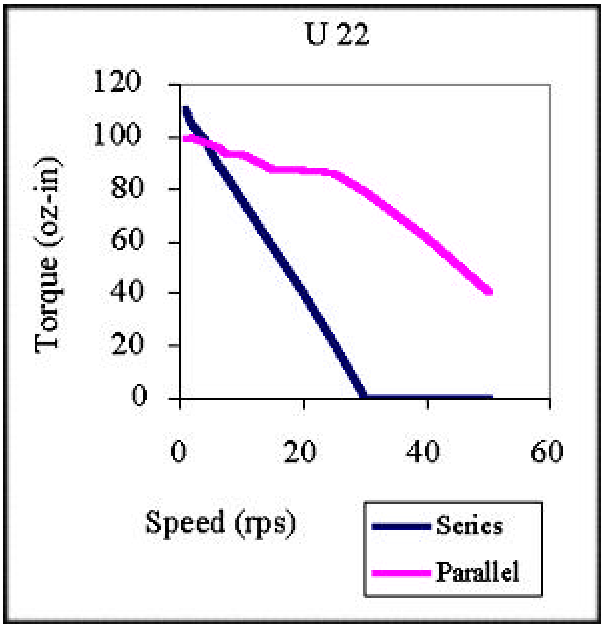
Stepper Motors
U 21
Torque Chart



U21 - Series		U21 - Parallel	
Speed (rps)	**Torque (oz-in)**	**Speed (rps)**	**Torque (oz-in)**
1	62	1	54
2	58	2	54
4	54	4	51
6	50	6	50
8	45	8	49
10	40	10	48
15	30	15	46
20	16	20	46
25	10	25	45
30	n/a	30	40
35	n/a	35	35
40	n/a	40	29
50	n/a	50	16
Series connected with 150 volt bipolar drive such as the Compumotor S/SX		Parallel connected with 150 volt bipolar drive such as the Compumotor S/SX	

Empire Magnetics Inc.

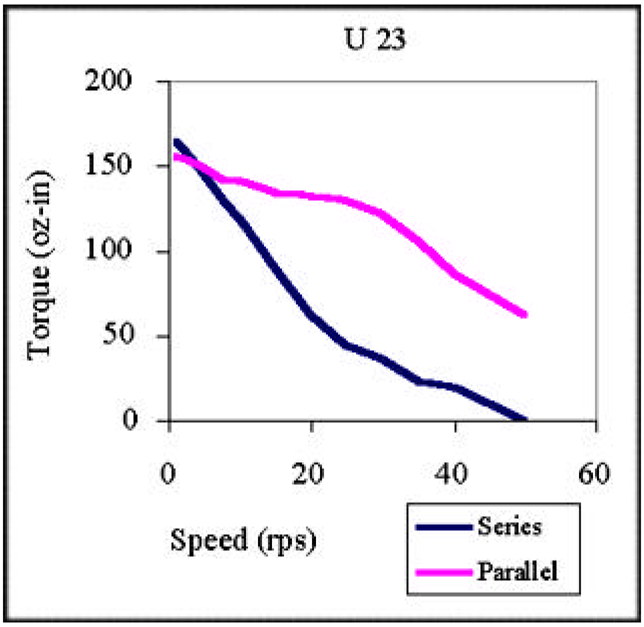
Stepper Motors
U 22
Torque Chart



U22 - Series		U22 - Parallel	
Speed (rps)	**Torque (oz-in)**	**Speed (rps)**	**Torque (oz-in)**
1	110	1	99
2	104	2	100
4	99	4	98
6	90	6	96
8	84	8	93
10	76	10	93
15	58	15	88
20	40	20	87
25	21	25	86
30	n/a	30	79
35	n/a	35	70
40	n/a	40	61
50	n/a	50	40
Series connected with 150 volt bipolar drive such as the Compumotor S/SX		Parallel connected with 150 volt bipolar drive such as the Compumotor S/SX	

Empire Magnetics Inc.

Stepper Motors
U 23
Torque Chart



U23 - Series		U23 - Parallel	
Speed (rps)	**Torque (oz-in)**	**Speed (rps)**	**Torque (oz-in)**
1	165	1	156
2	160	2	155
4	150	4	151
6	139	6	146
8	129	8	141
10	119	10	141
15	89	15	135
20	62	20	132
25	45	25	130
30	37	30	122
35	23	35	106
40	20	40	87
50	n/a	50	62
Series connected with 150 volt bipolar drive such as the Compumotor S/SX		Parallel connected with 150 volt bipolar drive such as the Compumotor S/SX	

Empire Magnetics Inc.

Motors That Survive

5780-B LaBath Avenue
Rohnert Park, CA 94928
Phone: 707-584-2801
Fax: 707-584-3418

Cryogenic Vacuum Products Stepper Motors - Frame 23 CYVX - Price List - July 1995 Prices Subject To Change						
Frame 23			1	2-4	5-9	10-24
Motor, stepper	CYVX	U21	$ 6,000	$ 5,400	$ 4,860	$ 4,374
Motor, stepper	CYVX	U22	$ 8,000	$ 7,200	$ 6,480	$ 5,832
Motor, stepper	CYVX	U23	$ 10,000	$ 9,000	$ 8,100	$ 7,290
Resolver	CYVX	R	$6,000	$5,400	$4,860	$4,374
Square Keyseat		SK	$ 146	$ 131	$ 118	$ 106
Woodruff Keyseat		WK	$ 146	$ 131	$ 118	$ 106

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Appendix 3

MRC

Cryogenic Motors

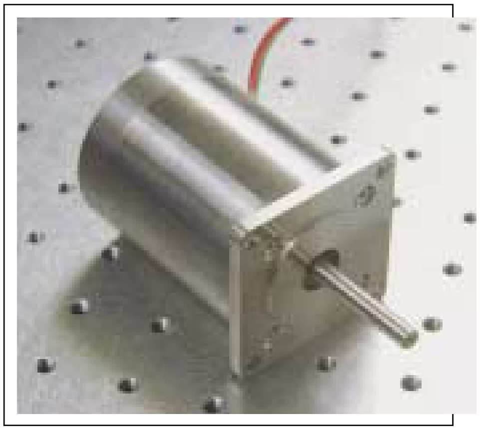
Assuring the robust and routine operation of mechanical motors in cryo-vacuum environment is challenging. MRC's cryomotor is used where precise and repeatable stepper motors are required in opto-mechanical systems. The cryomotor has successfully driven linear stages, circular wheels, and rotating mirrors in a variety of applications.

MRC has several motor types available, including variable reluctance and permanent magnet steppers.

A 12269 stepper motor

FEATURES

- Operational temperature range 20K to 300K
- Low–outgassing
- Additional configurations can be furnished with minimal charge



A 12458 stepper motor

Rear and side views of a 12915 stepper motor

Part No.	NEMA Size	Motor Type	Motor Length (inch)	Motor Body OD (inch)	Holding Torque (oz-in)	Weight (oz)	# Leads	Phase Voltage (VDC)	Phase Amps
12915	NEMA 15	Variable reluctance	1.50	1.437	6	6.5	5	2.8	1.5
12269	NEMA 17	Permanent magnet stepper	1.56	1.645	14	9.9	4	2.6	2.0
12459	NEMA 23	Permanent magnet stepper	1.60	2.25	36	19	4	3.4	2.0
12458	NEMA 23	Permanent magnet stepper	3.00	2.25	113	38	4	4.0	2.0
12728	NEMA 34	Permanent magnet stepper	3.80	3.38	315	121	4	4.3	3.5
12955	NEMA 34	Permanent magnet stepper	2.18	3.38	465	133	4	7.2	2.0

Appendix 4

Phytron

Stepper Motors
ZSS 19 – 56

Diameter: 19 to 56 mm (0.75” to 2.2”)
Torque: 3.8 to 700 mNm (0.54 to 99 oz-in)

phytron

ZSS

About ZSS Stepper Motors

- Two-phase hybrid stepper motors for unipolar or bipolar control
- Holding torque from 0.54 to 99 oz-in
- Diameters from 19 to 56 mm
- Up to 3 motor types and 3 different standard windings per size
- Standard number of steps: 200
  Optional: 8, 24, 56, 72, 500
- Minimum protection: IP 40
- Optional: IP 50, IP 65 depending on the size (see Mechanical table)
- Insulation class: F
- Permissible surface temperature: -20°C to +120°C
- CE mark

Options (see Options Table, pg. 4)

- 8, 24, 56, 72 or 500 full steps per revolution
- Double shaft
- Heat sink with radial (K1) or axial (K2) fins
- PLG planetary gearing for motor sizes ZSS 25 - 56
- GPL Low backlash planetary gearing for motor sizes ZSS 19 - 56
- HD Harmonic Drive gearing for motor sizes ZSS 25 - 52
- Brake for motor sizes ZSS 52 and 56
- Incremental encoder for motor sizes 25 - 56

Extreme Environment

ZSS series of stepper motors can be adapted to operate in

- Vacuum up to 10^{-11} Torr
- Temperature range -454°F to 600°F
- Radiation-resistant up to 10^{8} Rad
- Clean rooms
- Combination of all the above
- Space

The dimensions of the special versions of the ZSS series may differ slightly from those of the standard types. See VSS Catalog.

Ordering Information

ZSS 42 . 200 . 1.2 - E - K1 - HD 11 / 50 - FD

Stepper motor series

Size
(see Options Table, pg. 4, for size)

Steps per revolution
8 / 24 / 56 / 72 / 200 / 500

Winding
0.3 / 0.6 / 1.2 / 2.5 / 5 Amp

Options
Double shaft: E (IP 40)
Incremental Encoder: HEDL 5540 (IP 20, ZSS 59:IP 65)
Brake: KEB 02 (IP 00)

Heat sink
K1 radial / K2 axial

Gearing / Reduction ratio
PLG / GPL / HD

Flying leads: FD
for size 42 to 56 without brake

Stepper Motors
ZSS 19 – 56

Diameter: 19 to 56 mm (0.75” to 2.2”)
Torque: 3.8 to 700 mNm (0.54 to 99 oz-in)

		Electrical									Mechanical					
		Parallel (4-leads)			Series (4-leads)			Unipolar (5 or 6 leads)			Torque[4]			Loads		Mass
	Standard part number	I/ph[1]	R/ph[2]	L/ph[3]	I/ph[1]	R/ph[2]	L/ph[3]	I/ph[1]	R/ph[2]	L/ph[3]	holding	detent	inertia	axial	radial	
Size	(200 steps/rev.)	A	Ω	mH	A	Ω	mH	A	Ω	mH	mNm[5] (oz-in)	mNm[5] (oz-in)	kg-cm²	N (lb$_f$)	N (lb$_f$)	kg (lb$_m$)
19	ZSS 19.200.0.3	0.3	6	2.2	0.15	24	8.8	0.21	12	2.2	3.8 (0.54)	0.9 (0.13)	0.0009	3 (0.67)	3 (0.67)	0.04 (0.08)
	ZSS 19.200.0.6	0.6	2.1	0.55	0.3	8.4	2.2	0.42	4.2	0.55						
	ZSS 19.200.1.2	1.2	0.625	0.15	0.6	2.5	0.6	0.84	1.25	0.15						
	ZSS 20.200.0.6	0.6	3.45	1.1	0.3	13.8	4.4	0.42	6.9	1.1	5 (0.71)	1 (0.14)	0.0016	3 (0.67)	3 (0.67)	0.065 (0.14)
25	ZSS 25.200.0.3	0.3	12	6	0.15	48	24	0.21	24	6	13 (1.86)	2 (0.29)	0.0025	5 (1.13)	5 (1.13)	0.07 (0.15)
	ZSS 25.200.0.6	0.6	3.25	1.5	0.3	13	6	0.42	6.5	1.5						
	ZSS 25.200.1.2	1.2	0.95	0.4	0.6	3.8	1.6	0.84	1.9	0.4						
	ZSS 26.200.0.3	0.3	21.5	12	0.15	86	48	0.21	43	12	25 (3.57)	2.2 (0.31)	0.006	5 (1.13)	5 (1.13)	0.11 (0.24)
	ZSS 26.200.0.6	0.6	5.85	3.2	0.3	23.4	12.8	0.42	11.7	3.2						
	ZSS 26.200.1.2	1.2	1.7	1	0.6	6.8	4	0.84	3.4	1						
32	ZSS 32.200.0.6	0.6	4.65	5.3	0.3	18.6	21.2	0.42	9.3	5.3	50 (7.14)	3 (0.43)	0.01	5 (1.13)	15 (3.38)	0.15 (0.33)
	ZSS 32.200.1.2	1.2	1.3	1.2	0.6	5.2	4.8	0.84	2.6	1.2						
	ZSS 32.200.2.5	2.5	0.3	0.3	1.25	1.2	1.2	1.75	0.6	0.3						
	ZSS 33.200.0.6	0.6	7.5	9.3	0.3	30	37.2	0.42	15	9.3	75 (10.71)	3.3 (0.47)	0.018	5 (1.13)	15 (3.38)	0.35 (0.77)
	ZSS 33.200.1.2	1.2	1.75	2.2	0.6	7	8.8	0.84	3.5	2.2						
	ZSS 33.200.2.5	2.5	0.47	0.6	1.25	1.88	2.4	1.75	0.94	0.6						
42	ZSS 41.200.0.6	0.6	5.1	7.6	0.3	20.4	30.4	0.42	10.2	7.6	100 (14.29)	4 (0.57)	0.025	20 (4.5)	40 (9.01)	0.26 (0.57)
	ZSS 41.200.1.2	1.2	1.35	2	0.6	5.4	8	0.84	2.7	2						
	ZSS 41.200.2.5	2.5	0.275	0.4	1.25	1.1	1.6	1.75	0.55	0.4						
	ZSS 42.200.0.6	0.6	7.25	11	0.3	29	44	0.42	14.5	11	140 (20)	5 (0.71)	0.045	20 (4.5)	40 (9.01)	0.32 (0.70)
	ZSS 42.200.1.2	1.2	1.6	3	0.6	6.4	12	0.84	3.2	3						
	ZSS 42.200.2.5	2.5	0.35	0.7	1.25	1.4	2.8	1.75	0.7	0.7						
	ZSS 43.200.0.6	0.6	9.5	22.9	0.3	38	91.6	0.42	19	22.9	260 (37.14)	7 (1.0)	0.077	20 (4.5)	40 (9.01)	0.47 (1.04)
	ZSS 43.200.1.2	1.2	2.6	5.2	0.6	10.4	20.8	0.84	5.2	5.2						
	ZSS 43.200.2.5	2.5	0.5	1.2	1.25	2	4.8	1.75	1	1.2						
52	ZSS 52.200.1.2	1.2	2.65	7	0.6	10.6	28	0.84	5.3	7	450 (64.29)	13 (1.86)	0.15	25 (5.63)	70 (15.77)	0.65 (1.43)
	ZSS 52.200.2.5	2.5	0.6	1.6	1.25	2.4	6.4	1.75	1.2	1.6						
	ZSS 52.200.5	5	0.165	0.4	2.5	0.66	1.6	3.5	0.33	0.4						
56	ZSS 56.200.1.2	1.2	2.85	6.7	0.6	11.4	26.8	0.84	5.7	6.7	400 (57.14)	30 (4.29)	0.17	40 (9.01)	80 (18.02)	0.7 (1.54)
	ZSS 56.200.2.5	2.5	0.65	1.7	1.25	2.6	6.8	1.75	1.3	1.7						
	ZSS 56.200.5	5	0.185	0.5	2.5	0.74	2	3.5	0.37	0.5						
	ZSS 57.200.1.2	1.2	3.9	9.5	0.6	15.6	38	0.84	7.8	9.5	700 (100)	50 (7.14)	0.24	40 (9.01)	80 (18.02)	0.9 (1.98)
	ZSS 57.200.2.5	2.5	0.8	2.4	1.25	3.2	9.6	1.75	1.6	2.4						
	ZSS 57.200.5	5	0.25	0.8	2.5	1	3.2	3.5	0.5	0.8						
	ZSS 59.200.1.2	1.2	3.9	9.5	0.6	15.6	38	0.84	7.8	9.5	700 (100)	50 (7.14)	0.24	40 (9.01)	80 (18.02)	1.05 (2.32)
	ZSS 59.200.2.5	2.5	0.8	2.4	1.25	3.2	9.6	1.75	1.6	2.4						
	ZSS 59.200.5	5	0.25	0.8	2.5	1	3.2	3.5	0.5	0.8						

1) I/ph: Phase current 2) R/ph: Resistance per phase 3) L/ph: Inductivity per phase
4) Holding torque in bipolar mode with 2 phases ON at nominal current 5) 7 mNm ≈ 1 in-oz

Stepper Motors
ZSS 19 – 56

Diameter: 19 to 56 mm (0.75” to 2.2”)
Torque: 3.8 to 700 mNm (0.54 to 99 oz-in)

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ZSS

Options

Size	Type	Number of full steps/rev.						Design Voltage[1]		Double shaft	Brake[2]	Encoder[3]	Heat Sink		Gear heads[4] Planetary/ Harmonic			Protection class			Insulation	Test voltage
		8	24	56	72	200	500	<100V	<200V		KEB	HEDL	K1	K2	PLG	GPL	HD	IP40	IP50[5]	IP65	F	
19	ZSS 19	□			■	■		■		□			□	□		□		■[6]			■	700 V / 1 min
	ZSS 20					■		■		□			□	□		□		■[6]			■	
25	ZSS 25	□	□		■	■	■	■		□		□	□	□	□	□	□	■[6]			■	
	ZSS 26					■	■	■		□		□	□	□	□	□	□	■[6]			■	
32	ZSS 32				■	■		■		□		□	□	□	□	□	□	■[7]			■	
	ZSS 33				□	■		■		□		□	□	□	□	□	□	■[7]			■	
42	ZSS 41					■	■	■		□		□	□	□	□	□	□	□	■		■	
	ZSS 41/1					■	■		■	□		□	□	□	□	□	□	□	■		■	
	ZSS 42				□	■	■	■		□		□	□	□	□	□	□	□	■		■	
	ZSS 42/1				□	■	■		■	□		□	□	□	□	□	□	□	■		■	
	ZSS 43					■	■	■		□		□	□	□	□	□	□	□	■		■	
	ZSS 43/1					■	■		■	□		□	□	□	□	□	□	□	■		■	
52	ZSS 52			□	■	■	■		■	□	□	□	□	□	□	□	□	□	■[8]		■	
56	ZSS 56					■	□		■	□	□	□	□	□	□	□		□	■[8]		■	1500 V/1 min
	ZSS 57					■	□		■	□	□	□	□	□	□	□		□	■[8]		■	
	ZSS 59					■			■			□								■	■	

Motor Brake type KEB 02

For vertical positioning systems, stepper motors with built-in brakes are recommended.

- Supply voltage 24 V_{DC}
- Electrical connection of the brake by means of a connector
- Current consumption approx. 350 mA
- Dimensions on request.

Heat Sink

ZSS 19 – 57 are also available with an integrated heat sink.

Depending on the motor’s mounting position, a heat sink with radial fins (K1) or with axial fins (K2) can be selected.

The use of a K1 heat sink increases the stepper motor’s thermal dissipation surface by a factor of approx. 3.9. With K2 heat sink, it is increased by a factor of approx. 3.4.

A heat sink can be mounted subsequently, preferably by Phytron.

Incremental Encoder HEDL 5540

ZSS stepper motors can be equipped with an incremental encoder when each step needs to be monitored.

- Optical encoder
- Standard resolution: 500 lines
- Output signals:
  - Channel A and B
  - A and B shifted by 90°
  - 0 - reference pulse

These outputs are also available as inverted signals

- Supply voltage 5 V_{DC}
- Connection through flat cable with 10-point connector. Soldered for ZSS 59.
- Dimensions on request.

Remarks to Options

■ Standard - popular types
□ Options

1) <100 V: motor without earth-screw
<200 V: motor with earth-screw

2) Brake option (IP 00)
Motor connection via terminal box (soldered connection) and cable gland
Brake connection via a round connector

3) Incremental encoder option:
ZSS 25-57: motor with flying leads and encoder connection via flat cable with 10 point ICD-connector (IP 20)
ZSS 59: Motor and encoder connection via terminal box (soldered connection) and cable gland (IP 65)

4) Refer to pages 9-15

5) Cable outlet diameter:
max. 4.5 mm for size 42
max. 5 mm for size 52-56

6) AWG 28, flying leads 250 mm

7) AWG 26, flying leads 250 mm

8) ZSS 52-57 with 5-Amp winding:
Motor connection via terminal box (soldered connection) and cable gland (IP 50)

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Stepper Motors
ZSS 19 – 56

Diameter: 19 to 56 mm (0.75” to 2.2”)
Torque: 3.8 to 700 mNm (0.54 to 99 oz-in)

Dimensions

Size	Type	Dimensions in mm															
		A	B1	B2	C	D	E	F1	F2	$G1_{g5}$	$G2_{g5}$	K	L	M	N	P	R
19	ZSS 19	19	26.5			1	2	7.5	6.5	2.5	2.5	19	10	16	M2.5	26	20.5
	ZSS 20	19	43			1	2	7.5	6.5	2.5	2.5	19	10	16	M2.5	26	37
25	ZSS 25	25	31			1	2.5	9.5	8.5	3	3	25	14	21.5	2.2	35	24
	ZSS 26	25	47			1	2.5	9.5	8.5	3	3	25	14	21.5	2.2	35	40
32	ZSS 32	32	38.5			1	3	11	10	4	4	32	18	27	2.8	42	30
	ZSS 33	32	57.5			1	3	11	10	4	4	32	18	27	2.8	42	49
42[3)]	ZSS 41 ZSS 41/1	42		49	39	1	3	16	15	5	4	42	22	36	3.2	55	30
	ZSS 42 ZSS 42/1	42		64	54	1	3	16	15	5	4	42	22	36	3.2	55	45
	ZSS 43 ZSS 43/1	42		79	69	1	3	16	15	5	4	42	22	36	3.2	55	60
52	ZSS 52[2)]	52		77	65	1.5	3.5	17.5	16	6	4	52	28	44	4.3	65	58
56	ZSS 56[2)]	56.4		69.1	57.1	1.5	4.5	22	20.5	6.35	6.35	60	38.1	47.15	5.2	78	44
	ZSS 57[2)]	56.4		85.1	73.1	1.5	4.5	22	20.5	6.35	6.35	60	38.1	47.15	5.2	78	60
	1)																

ZSS 19 – 32 stepper motor with flying leads

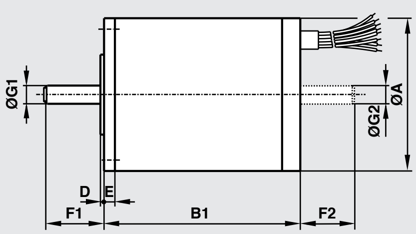

Fig. 1

ZSS 19 – 56 stepper motor flange

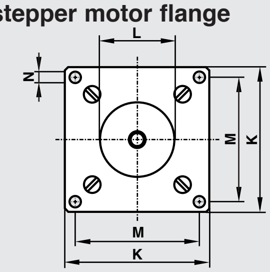

Fig. 4

ZSS 42 – 56 with terminal block and protective cover

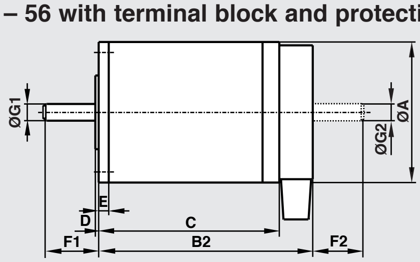

Fig. 2

K1 heat sink for ZSS 19-57

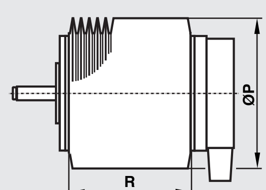

Fig. 5

K2 heat sink for ZSS 19-57

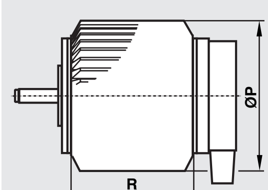

Fig. 6

ZSS 59 stepper motor (IP65) with cable gland

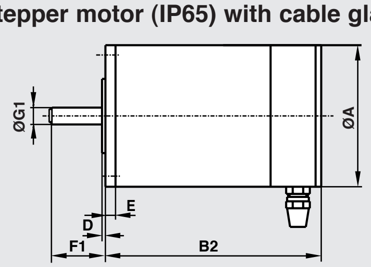

Fig. 3

Remarks

1) ZSS 59 dimensions with IP 65 protection are shown in fig. 3.
2) ZSS 52, 56 and 57 with 5 Amp winding are supplied with terminal box and cable gland. Therefore the dimension B2 is increased by 11 mm.
3) Size 42 motors have same dimension for both the 100 V (ZSS 41, 42, 43) and 200 V (ZSS 41/1, 42/1, 43/1).

Other motor dimensions on request.

- Round mounting flange
- With brake
- With encoder
- With gear heads
- Vacuum motors

Stepper Motors
ZSS 19 – 56

Diameter: 19 to 56 mm (0.75” to 2.2”)
Torque: 3.8 to 700 mNm (0.54 to 99 oz-in)

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Electrical Characteristics

Phytron ZSS stepper motors are 8-lead version (fig.7).

These motors can be used in the unipolar or bipolar mode as the windings can be connected in different manners.

In the unipolar mode, the motors are controlled using a 5-lead or 6-lead connection.

In the bipolar mode, the motors are controlled using a 4-lead connection. Both windings of a phase can be connected in parallel or in series. We recommend connecting the windings in parallel (fig.8).

8-lead stepper motor ZSS

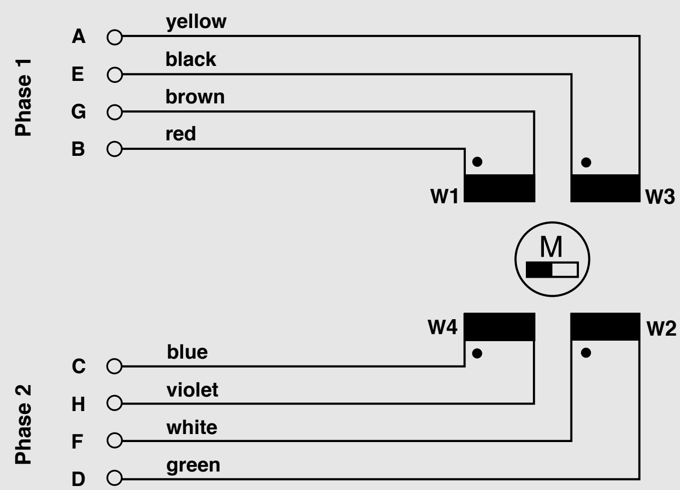

Fig. 7

When connecting the motor, follow the user’s manual! ZSS 41/1 - ZSS 59: With the earthing screw, the motor can be safely connected to the system’s ground.

EU and CE marks

Phytron ZSS stepper motors fulfill the requirements of the EMC and Low Voltage Directives, when installed appropriately. ZSS stepper motors are marked CE and comply with EN 60034-1 European standard.

When wired correctly, ZSS stepper motors fulfill the requirements of EMC Directive. Corresponding tests have been carried out with ZSS stepper motors with Phytron control units. Please, refer to the motor connection leaflet, the corresponding control unit and power stage manuals for further information on wiring according to EMC requirements.

According to Machine Directive, the stepper motor is only a part of a machine. The machine manufacturer must take appropriate measures to ensure that the entire system fulfills the requirements of the applicable EU-Directives.

Connection configurations for 8-lead stepper motors

For bipolar control signals:

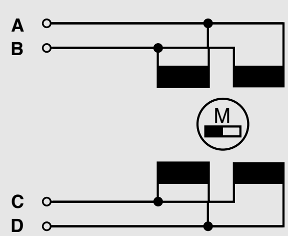

Fig. 8

4-lead/parallel winding connection

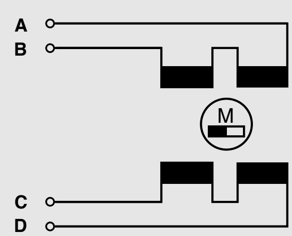

Fig. 10

4-leads/series winding connection

For unipolar control signals:

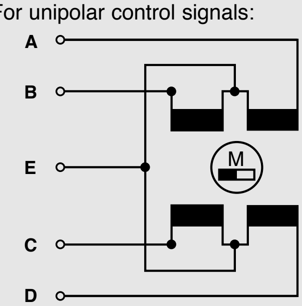

Fig. 9

5-lead connection

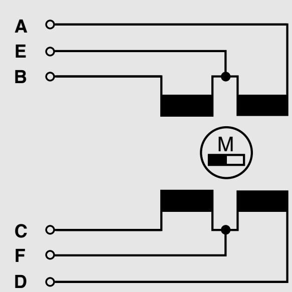

Fig. 11

6-leads connection

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Stepper Motors
ZSS 19 – 56

Diameter: 19 to 56 mm (0.75” to 2.2”)
Torque: 3.8 to 700 mNm (0.54 to 99 oz-in)

ZSS

Frequency characteristics

The curves correspond to the limit values of the operational torque (M) as a function of the control pulses (frequency), for two different supply voltages of the power stage.

The windings are connected in parallel (fig. 8), the motors are controlled by means of bipolar stepper motor power stages, in the half-step mode.

Power characteristics

For each frequency curve, the power characteristic indicates the power (P) delivered to the output shaft.

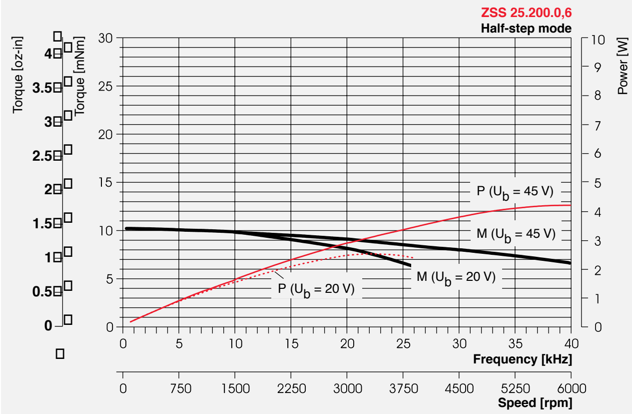

Fig. 14

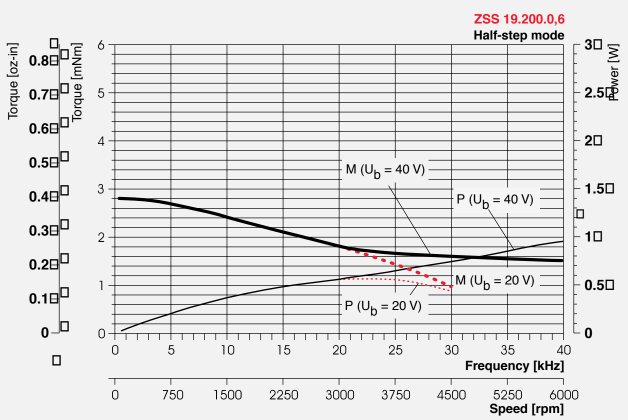

Fig. 12

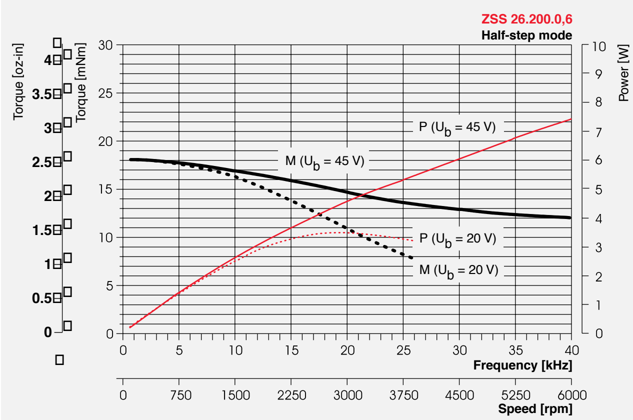

Fig. 15

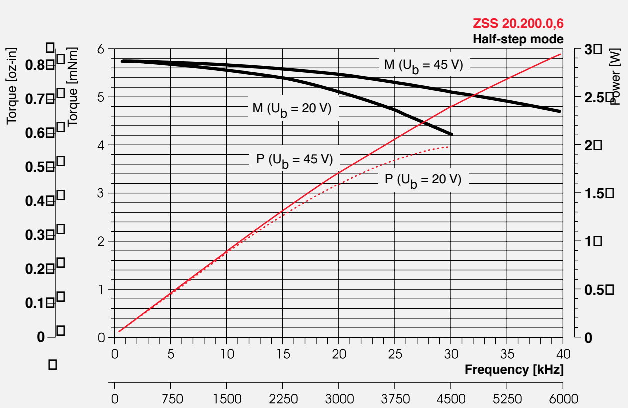

Fig. 13

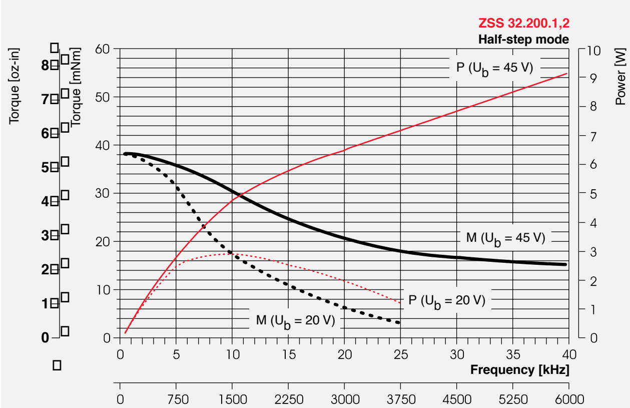

Fig. 16

Stepper Motors
ZSS 19 – 56

Diameter: 19 to 56 mm (0.75” to 2.2”)

Torque: 3.8 to 700 mNm (0.54 to 99 oz-in)

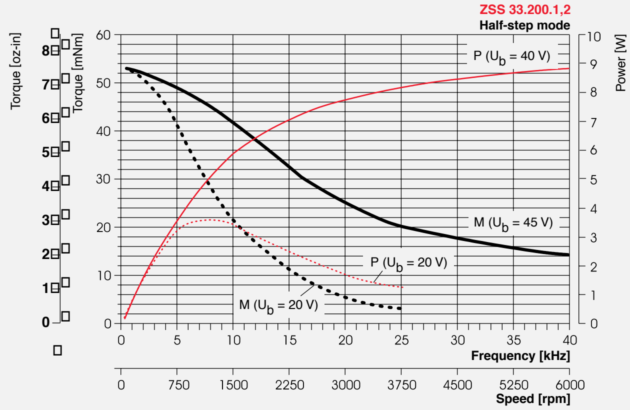

Fig. 17

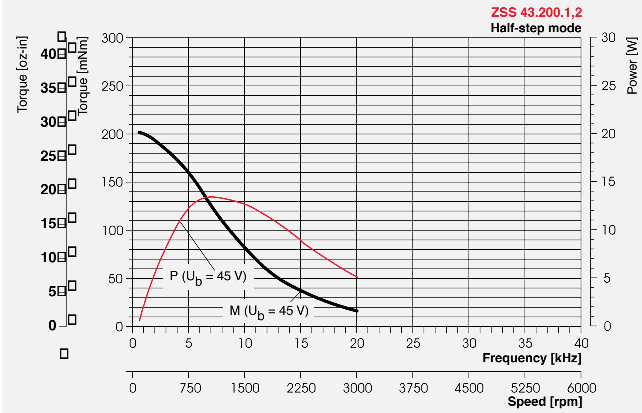

Fig. 20

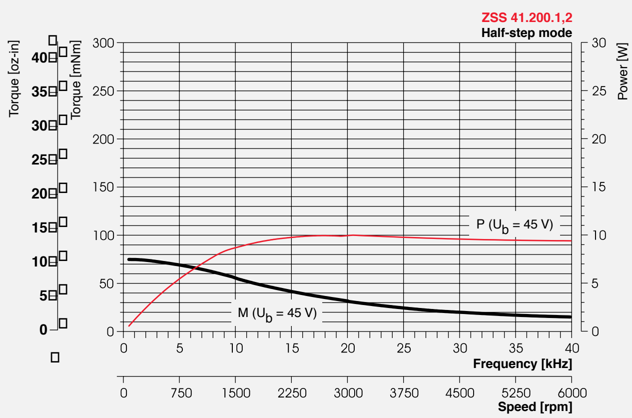

Fig. 18

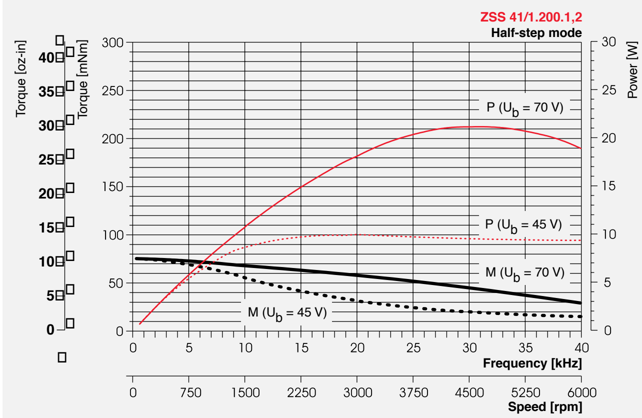

Fig. 21

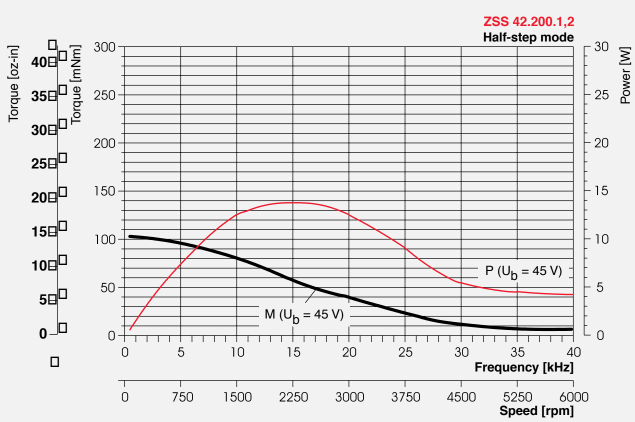

Fig. 19

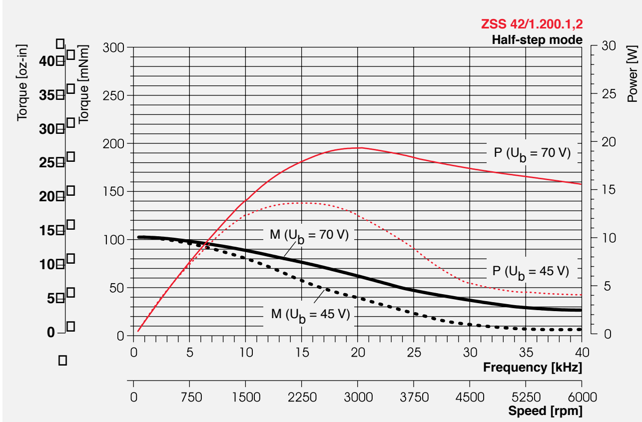

Fig. 22

Stepper Motors
ZSS 19 – 56

Diameter: 19 to 56 mm (0.75” to 2.2”)
Torque: 3.8 to 700 mNm (0.54 to 99 oz-in)

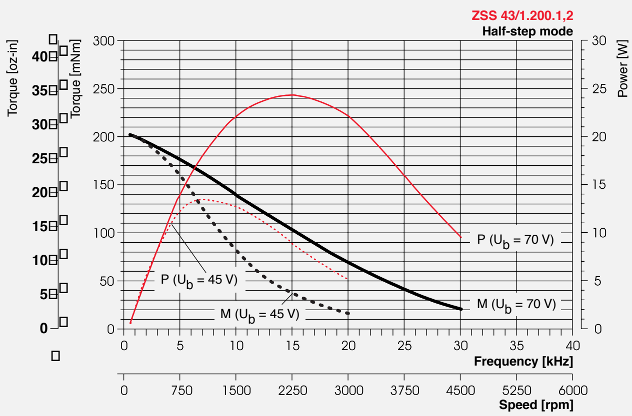

Fig. 23

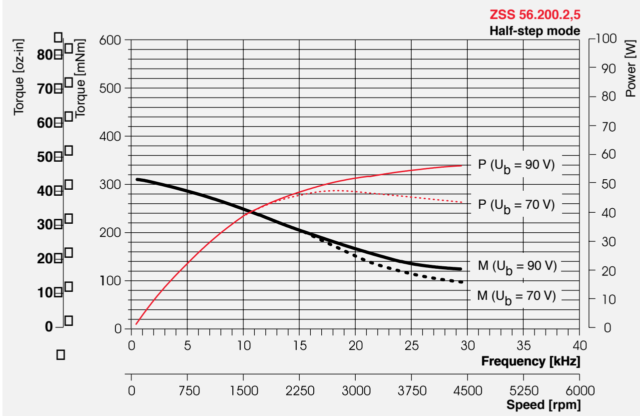

Fig. 25

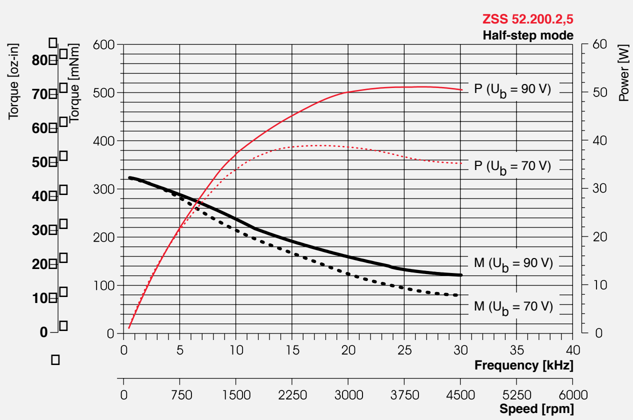

Fig. 24

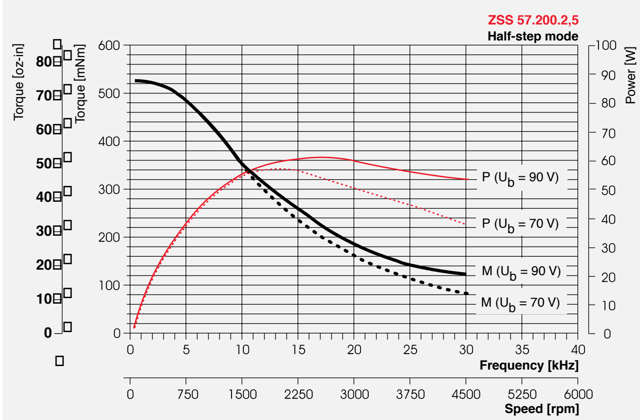

Fig. 26