

British Standard Specification for
**Rotating electrical machines
of particular types or
for particular applications**
Part 60. Stepping motors

Spécification des machines électriques tournantes de types
particuliers ou à usage particulier
Partie 60. Moteurs pas à pas

Spezifikation für elektrische umlaufende Maschinen bestimmter
Ausführungen oder für bestimmte Verwendungszwecke
Teil 60. Schrittmotoren

Contents

	Page		Page
Foreword	Inside front cover	6a. Shaft dimensions for standard frame sizes (inches)	16
Cooperating organizations	Back cover	6b. Approximate shaft dimensions for standard frame sizes (mm)	16
Specification		Figures	
1. Scope	1	1. Winding connections for bipolar drives	4
2. References	1	2. Two wire hanging method to determine rotor inertia	5
3. Definitions	1	3. Typical circuit for measuring inductance by an inductance bridge	6
4. Abbreviations, symbols and units	2	4. Circuit for measuring inductance by the current discharge method	6
5. Typical modes	2	5. Illustrations of values to be given by the manufacturer, where appropriate	9
6. Values to be indicated by the manufacturer	2	6. Basic performance curves	10
7. Lead identification and terminal numbering	2	7. Method of applying a torque to a small motor	11
8. Dimensions	4	8. Test rig for pull-out torque measurement using torque transducer and particle brake	12
9. Tests	4	9. Test rig for pull-out torque measurement using dynamometer	12
10. Minimum rating plate information	7	10. Method of pull-out torque measurement using cord and spring balance	12
Appendices		11. Method of pull-out torque measurement using cord and two spring balances	12
A. Typical modes for a three-phase stepping motor	8	12. Mounting dimensions applicable to frame sizes 05, 08, 20 and 42	17
B. Catalogue presentation	8	13. Mounting dimensions applicable to frame sizes 11, 15, 18 and 23	17
C. Basic performance curves	8	14. Mounting dimensions applicable to frame sizes 23, 34 and 42	17
D. Additional test methods	10		
E. Dimensions	13		
Tables			
1. List of abbreviations, symbols and units	3		
2. Lead identification and terminal numbering	4		
3. Test voltage for high voltage test	7		
4. Typical modes for a three-phase stepping motor	8		
5a. Installation dimensions for standard frame sizes (inches)	14		
5b. Approximate installation dimensions for standard frame sizes (mm)	15		

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Foreword

This Part of this British Standard has been prepared under the direction of the Power Electrical Engineering Standards Committee and forms a Part of BS 5000 which together with BS 4999 'General requirements for rotating electrical machines' will eventually contain a comprehensive series of British Standards for rotating electrical machines.

This standard is based upon a report by ERA Technology Ltd. representing the culmination of a two year study carried out in collaboration with industry, universities and the UK Government. It became evident as a result of this study that there was a real need for standardization of terminology used in connection with stepping motors, for detailing the important performance parameters for which manufacturers should indicate values and for the establishment of recognized test methods for checking these values. This standard concentrates on these aspects.

The standardization of dimensions has presented a particularly difficult problem as a large proportion of stepping motors has been designed for military applica-

tions with the inch system of dimensions primarily used by NATO (and with performance parameters specified in imperial units); with the rapidly increasing use by industry and a tendency towards metric dimensions for future designs, a first step in this direction has been taken by including in appendix E the most common existing inch dimensions and giving approximate metric equivalents of these for the guidance of future designers.

Appendices A, B, C and D are included giving, respectively, typical modes of operation, recommended details for catalogue presentation, typical basic performance curves and additional test methods for parameters for which the indication of values is not a requirement of the standard.

A list of the contents of BS 5000 showing all the Parts envisaged in the foreseeable future is given in the general introduction and index which will be brought up to date as new Parts are published. The contents of BS 4999 are given in a separate index and introduction to that standard.

Amendment No. 1
published and effective from 29 July 1988
to BS 5000 : Part 60 : 1982

Specification for rotating electrical machines of
particular types or for particular applications
Part 60. Stepping motors

Revised text

AMD 5630
July 1988

Foreword

In paragraph 5, delete the last sentence and substitute the following :
'The contents of BS 4999 are given in Part 0 of that standard.'

AMD 5630
July 1988

Clause 9.5 High voltage test (routine test)

In line 3, delete 'BS 4999 : Part 60' and substitute 'BS 4999 : Part 101'.

AMD 5630
July 1988

Table 3. Test voltage for high voltage test

In column 2, delete 'BS 4999 : Part 60' and substitute 'BS 4999 : Part 101'.

AMD 5630
July 1988

Appendix E. Dimensions

In paragraph 5, lines 2 and 3, delete '10.3.2.2 of BS 4999 : Part 10 : 1976' and substitute '3.2.2 of BS 4999 : Part 141 : 1987'.

In paragraph 6, line 3, delete '10.3.2.4 of BS 4999 : Part 10 : 1976' and substitute '3.2.3 of BS 4999 : Part 141 : 1987'.

In paragraph 7, line 2, delete '10.3.2.1 of BS 4999 : Part 10 : 1976' and substitute '3.2.1 of BS 4999 : Part 141 : 1987'.

AMD 5630
July 1988

Standards publications referred to

In the list of standards publications, delete the references to BS 4999 and substitute the following:

'BS 4999 General requirements for rotating electrical machines
 *Part 0 General introduction and index
 Part 101 Specification for rating and performance
 Part 141 Specification for standard dimensions'.

Insert the following footnote:

'**Referred to in the foreword only.'

British Standard Specification for

Rotating electrical machines of particular types or for particular applications

Part 60. Stepping motors

1. Scope

This Part of this British Standard specifies requirements for electromagnetic stepping motors. It defines the terminology used for this type of motor, lists the items for which values are to be indicated by the manufacturer and specifies the test methods to be adopted. Dimensions are specified for given frame sizes; however, the standard is also applicable to motors in frames having any other dimensions.

Hydraulic and 'ratchet' type stepping motors are not included.

2. References

The titles of the standards publications referred to in this standard are listed on the inside back cover.

3. Definitions

For the purposes of this Part of BS 5000, the following definitions apply.

3.1 stepping motor. A reversible brushless d.c. motor, the rotor of which rotates in discrete angular increments when its stator windings are energized in a programmed manner. Rotation occurs because of the magnetic interaction between the rotor poles and the poles of the sequentially energized stator phases. The rotor has no electrical winding but rather salient or magnetized poles.

NOTE. Particular types of stepping motor are defined in 3.1.1, 3.1.2 and 3.1.3.

3.1.1 permanent magnet (PM) stepping motor. A stepping motor utilizing a rotor that has permanently magnetized poles.

3.1.2 variable reluctance (VR) stepping motor. A stepping motor utilizing a rotor that has salient poles of low residual magnetic material.

3.1.3 hybrid (HY) stepping motor. A stepping motor utilizing a permanent magnet to polarize salient pole pieces of low residual magnetic material on the rotor.

3.2 damper. A device for damping step oscillations.

3.3 dead range or dead band. The angle between the clockwise and counter-clockwise limits under specified load conditions, within which the rotor of an energized stepping motor can stop.

3.4 detent position. That position where the rotor of a permanent magnet or hybrid stepping motor comes to rest when unenergized and unloaded.

3.5 detent torque. The maximum steady torque that can be applied to the shaft of an unenergized stepping motor without causing continuous rotation.

3.6 direction of rotation. The direction of rotation of the shaft is the one observed when facing the shaft end associated with the mounting surfaces. Counter-clockwise rotation of the shaft is regarded as positive and clockwise rotation as negative.

3.7 drive circuit. A combination of the translator logic and a power amplifier that switches the phases of the stepping motor in a predetermined mode.

NOTE. The available drive circuit configurations are defined in 3.7.1 to 3.7.5.

3.7.1 bipolar drive. A drive circuit in which the excitation applied is such that the torque generating current reverses in the windings.

3.7.2 chopper drive. A drive circuit in which the form of excitation is an initial high voltage applied to the phase winding until the current in that winding reaches a predetermined value when the supply is switched off. When the current has decayed to a second predetermined value, the voltage is re-applied.

3.7.3 constant current drive. A drive circuit that attempts to maintain a constant current in the windings irrespective of motor speed.

3.7.4 multi-level drive. A drive circuit in which two or more levels of voltage are sequentially applied to a stepping motor winding.

3.7.5 unipolar drive. A drive circuit in which the excitation is such that the torque-generating current in each winding occurs in one direction only.

3.8 holding torque. The maximum steady torque at a specified current that can be applied to the shaft of an energized stepping motor without causing continuous rotation.

3.9 incremental motion. The motion caused by a single pulse or a programme of steps.

3.10 line. A terminal or wire of the motor to which a logic function from the motor driver is applied. In the case of an electronic drive circuit, a power device will be connected to a line.

3.11 load angle. The angle between the magnetic axis of the rotor and the stator magnetic field. In practice this is the angle between the loaded and unloaded positions of the rotor under otherwise identical conditions.

3.12 maximum reversing rate. The maximum pulse rate at which the unloaded stepping motor is able to reverse and remain in synchronism under specified drive conditions.

3.13 maximum safe working temperature. The maximum temperature the stepping motor, either continuously or intermittently rated, may safely be allowed to achieve

(measured by the change of winding resistance method). This may bear little or no relation to the class of insulation used in the construction of the motor but may be dictated by considerations such as bearing lubricant, etc.

3.14 maximum slew rate. The maximum pulse rate at which the unloaded stepping motor can remain in synchronism under specified drive conditions.

3.15 mini-stepping. The subdivision of the motor's basic step angle by partial energization of a phase or phases.

3.16 mode or step sequence. A particular sequence of excitation defined by the drive circuit which, when applied to a stepping motor, will energize certain windings or phases.

3.17 overshoot or transient overshoot. The amount the shaft of the stepping motor rotates beyond the final commanded step position.

3.18 phase. A part of the winding between a line and the centre tap or star point, or the winding between two lines if no centre tap or star point exists.

3.19 positional error. The deviation from the theoretical final position after a sequence of steps, expressed as a percentage of basic step angle.

3.20 pull-in rate. The (constant) maximum pulse rate at which the energized stepping motor will start driving a specified load without missing steps, under specified drive conditions.

3.21 pull-in torque. The maximum torque at which an energized stepping motor will start driving a specified load, and run in synchronism without losing steps, on application of a fixed pulse rate.

3.22 pull-out rate. The (constant) maximum pulse rate at which the energized stepping motor can run, driving a specified load under specified drive conditions, without missing steps.

3.23 pull-out torque. The maximum torque that can be applied to the rotating shaft of a stepping motor driven at a given pulse rate under specified drive conditions, without missing steps.

3.24 pulse rate. The rate at which the successive steps are initiated.

3.25 resolution. The reciprocal of the number of steps per revolution of the motor shaft.

3.26 resonant rate. A stepping rate at which the stepping motor will miss steps when operating below the pull-out torque curve, under specified load and drive conditions.

3.27 response range. The range of pulse rates over which the motor can start, stop or reverse without missing steps under specified load and drive conditions.

3.28 salient pole. A projecting pole on a rotor or stator.

3.29 settling time. The total time from the application of the command signal until the motor shaft comes to rest.

3.30 slew range. The range of pulse rates over which the motor will not miss steps unidirectionally under specified load and drive conditions, but within which the motor cannot start, stop or reverse at a fixed pulse rate.

NOTE. This is illustrated in figure 6.

3.31 step. The movement of the rotor from one energized position to the next in sequence.

3.32 step angle (basic). The angle through which the shaft of an unloaded stepping motor can be made to turn when two adjacent phases are energized, singly in sequence.

3.33 step angle error. The maximum percentage deviation from the theoretical step angle.

3.34 step position. The angular position that the shaft of an unloaded stepping motor assumes when it is energized without causing continuous rotation. The step position is not necessarily the same as the detent position.

3.35 stepping rate. The number of step angles through which the stepping motor shaft rotates in a specified time.

3.36 synchronism. The state that exists when the stepping rate of the rotor equals the applied pulse rate.

3.37 torque gradient. The average slope of the torque displacement curve over a specified angle through the origin.

3.38 translator logic. The logic that translates the input pulse train into the selected mode pattern to be applied to a stepping motor.

4. Abbreviations, symbols and units

The abbreviations, symbols and units commonly used are listed in table 1 or are defined in BS 5555.

5. Typical modes

There are three preferred sequences of excitation, mode A, mode B and mode AB. Typical modes for a three-phase motor are detailed in appendix A.

6. Values to be indicated by the manufacturer

The manufacturer shall indicate values for parameters listed below. These shall be confirmed, where appropriate, by the tests specified in clause 9. Where the parameters are affected by the drive circuit or load, details of that drive circuit or load shall be included in the declaration. The parameters are:

- (a) detent torque;
- (b) step angle (basic);
- (c) step angle error;
- (d) steps per revolution;
- (e) d.c. volts or amperes per phase;
- (f) inductance per phase;
- (g) d.c. resistance per phase;
- (h) holding torque;
- (i) volts (peak to peak) per thousand revolutions per minute as generator (where applicable);
- (j) rotor inertia;
- (k) insulation class;
- (l) maximum safe working temperature.

7. Lead identification and terminal numbering

For motors with loose leads the colours of the leads (or marker sleeves fitted to the leads) shall be as given in table 2. Colours in parenthesis are non-preferred alternatives. Motors with terminal boards or strips shall have the terminals identified by numbers as given in table 2.

Where bipolar drives are used in conjunction with eight-lead motors, it is necessary to connect the windings so that the torques associated with each winding are added, not subtracted; in compliance with table 2, the winding connections will then be as shown in figure 1.

Table 1. List of abbreviations, symbols and units

Term	Abbreviation or symbol	Unit	Unit symbol
Dead range	—	degree	°
Detent torque	T_d	newton metre*	N·m
Holding torque	T_h	newton metre*	N·m
Maximum slew range	—	steps per second	—
Mode	A, B or AB	—	—
Overshoot (transient)	—	degree	°
Phase	ϕ	—	—
Positional error	—	per cent basic step angle	%
Pull-in rate	Fpi	steps per second	—
Pull-out rate	Fpo	steps per second	—
Pull-in torque	Tpi	newton metre*	N·m
Pull-out torque	Tpo	newton metre*	N·m
Pulse rate	pps	pulses per second	Hz
Resolution	—	steps per revolution	—
Resonant rate	—	steps per second	—
Response range	—	steps per second	—
Settling time	—	second	s
Slew range	—	steps per second	—
Step angle	—	degree	°
Step angle error	—	per cent basic step angle	%
Stepping rate	—	steps per second	—
Torque gradient	—	newton metre per degree†	N·m/°

*May also be expressed in ounce inches (oz·in) (see foreword).

†May also be expressed in ounce inches per degree (oz·in/°) (see foreword).