PHILIPS

Data handbook

Electronic components and materials

Components and materials

Part 6 September 1975

# Electric motors and accessories

# COMPONENTS AND MATERIALS

**Part 6** **September 1975**


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# DATA HANDBOOK SYSTEM

Our Data Handbook System is a comprehensive source of information on electronic components, subassemblies and materials; it is made up of three series of handbooks each comprising several parts.

| | |
|---|---|
| **ELECTRON TUBES** | **BLUE** |
| **SEMICONDUCTORS AND INTEGRATED CIRCUITS** | **RED** |
| **COMPONENTS AND MATERIALS** | **GREEN** |

The several parts contain all pertinent data available at the time of publication, and each is revised and reissued periodically.

Where ratings or specifications differ from those published in the preceding edition they are pointed out by arrows. Where application information is given it is advisory and does not form part of the product specification.

If you need confirmation that the published data about any of our products are the latest available, please contact our representative. He is at your service and will be glad to answer your inquiries.



December 1972

# ELECTRON TUBES (BLUE SERIES)

This series consists of the following parts, issued on the dates indicated.

**Part 1a** **Transmitting tubes for communications and Tubes for r.f. heating** **Types PB2/500 ÷ TBW15/125** — **April 1973**

**Part 1b** **Transmitting tubes for communication**
**Tubes for r.f. heating**
**Amplifier circuit assemblies** — **August 1974**

**Part 2** **Microwave products** — **October 1974**

Communication magnetrons
Magnetrons for micro-wave heating
Klystrons
Traveling-wave tubes
Diodes
Triodes
T-R Switches
Microwave Semiconductor devices
Isolators Circulators

**Part 3** **Special Quality tubes;**
**Miscellaneous devices** — **January 1975**

**Part 4** **Receiving tubes** — **March 1975**

**Part 5a** **Cathode-ray tubes** — **April 1975**

**Part 5b** **Camera tubes; Image intensifier tubes** — **May 1975**

**Part 6** **Products for nuclear technology**
**Photodiodes** — **July 1975**

Neutron tubes
Channel electron multipliers
Geiger-Mueller tubes
N.B. Photomultiplier tubes and Photo diodes will be issued in Part 9

**Part 7** **Gas-filled tubes** — **August 1975**

Voltage stabilizing and reference tube
Counter, selector, and indicator tubes
Trigger tubes
Switching diodes
Thyratrons
Ignitrons
Industrial rectifying tubes
High-voltage rectifying tubes

**Part 8** **T.V. Picture tubes** — **May 1974**

# SEMICONDUCTORS AND INTEGRATED CIRCUITS (RED SERIES)

This series consists of the following parts, issued on the dates indicated.

**Part 1a Rectifier diodes and thyristors** — **June 1974**

Rectifier diodes
Voltage regulator diodes (> 1,5 W)
Transient suppressor diodes
Thyristors, diacs, triacs
Rectifier stacks

**Part 1b Diodes** — **July 1974**

Small signal germanium diodes
Small signal silicon diodes
Special diodes
Voltage regulator diodes (< 1,5 W)
Voltage reference diodes
Tuner diodes

**Part 2 Low frequency transistors** — **July 1974**

**Part 3 High frequency and switching transistors** — **October 1974**

**Part 4a Special semiconductors** — **November 1974**

Transmitting transistors
Microwave devices
Field-effect transistors
Dual transistors
Microminiature devices for thick- and thin-film circuits

**Part 4b Devices for opto-electronics** — **December 1974**

Photosensitive diodes and transistors
Light emitting diodes
Photocouplers
Infra-red sensitive devices
Photoconductive devices

**Part 5 Linear integrated circuits** — **March 1975**

**Part 6 Digital integrated circuits** — **April 1974**

DTL (FC family)
CML (GX family)
MOS (FD family)
MOS (FE family)

# COMPONENTS AND MATERIALS (GREEN SERIES)

These series consists of the following parts, issued on the dates indicated.

**Part 1 Functional units, Input/output devices, Electro-mechanical components, Peripheral devices** — **June 1974**

- High noise immunity logic FZ/30-Series
- Circuit blocks 40-Series and CSA70
- Counter modules 50-Series
- Norbits 60-Series, 61-Series
- Circuit blocks 90-Series
- Input/output devices
- Electro-mechanical components
- Peripheral devices

**Part 2a Resistors** — **September 1974**

- Fixed resistors
- Variable resistors
- Voltage dependent resistors (VDR)
- Light dependent resistors (LDR)
- Negative temperature coefficient thermistors (NTC)
- Positive temperature coefficient thermistors (PTC)
- Test switches

**Part 2b Capacitors** — **November 1974**

- Electrolytic and solid capacitors
- Paper capacitors and film capacitors
- Ceramic capacitors
- Variable capacitors

**Part 3 Radio, Audio, Television** — **February 1975**

- FM tuners
- Loudspeakers
- Television tuners, aerial input assemblies
- Components for black and white television
- Components for colour television *)

**Part 4a Soft ferrites** — **April 1975**

- Ferrites for radio, audio and television
- Beads and chokes
- Ferroxcube potcores and square cores
- Ferroxcube transformer cores

**Part 4b Piezoelectric ceramics, Permanent magnet materials** — **May 1975**

**Part 5 Ferrite core memory products** — **July 1975**

- Ferroxcube memory cores
- Matrix planes and stacks
- Core memory systems

**Part 6 Electric motors and accessories** — **September 1975**

- Small synchronous motors
- Stepper motors
- Miniature direct current motors

**Part 7 Circuit blocks** — **September 1971**

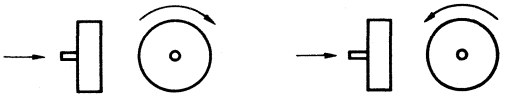
- Circuit blocks 100 kHz-Series
- Circuit blocks 1-Series
- Circuit blocks 10-Series
- Circuit blocks for ferrite core memory drive

**Part 8 Variable mains transformers** — **July 1975**

*) Deflection assemblies for camera tubes are now included in handbook series "Electron tubes", Part 5b.

# GENERAL REMARKS

- All mechanical drawings have been laid out according to the European (third-angle) projection method.
- The dimensions of the products are given in mm.
- Forces are given in newton (N); 1 N = 100 g = 3,53 ounce (oz).
- Torques are given in millinewtonmetre (mNm); 1 mNm = 10 gcm = 0,139 ounce inch.
- The curves of the performance graphs are derived from measurements made on arbitrary motors.
- The sense of rotation, clockwise (cw) or counter-clockwise (ccw), is that seen when looking towards the spindle, as shown by the arrow.



clockwise (cw) 7Z98289 counter-clockwise (ccw)

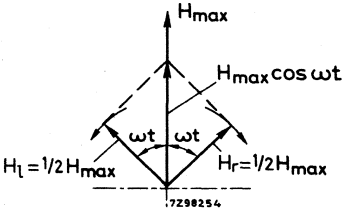
- To order a product please use the relevant catalogue number.
- The information given in this book does not imply a license under any patent.

# Small synchronous motors


| | |
|---|---|
| General | A3 |
| Unidirectional motors | A19 |
| Reversible motors | A41 |

# PRINCIPLES

In a two-pole synchronous motor fitted with a permanent-magnet rotor, a sinusoidally alternating magnetic field is set up in the stator by the sinusoidal exciting current. The alternating field can be assumed to be the resultant of two magnetic fields of equal and constant strength but rotating in opposite directions. The vector diagram at a time t can then be drawn (Fig. below).




The constant fields are here represented by the vectors $H_\ell$ and $H_r$. The permanent magnet (the rotor) can now follow either the field rotating counterclockwise or the one rotating clockwise. Fundamentally, therefore, a synchronous motor can rotate in either direction. However, more advanced constructions like our synchronous motors rotate in one direction which is determined electrically as will be explained later on.

During one cycle of the alternating supply current a motor with two poles, that is one pair of poles, will make one revolution. In a motor with p pole pairs the rotor turns through 360/p angular degrees. The speed of the motor is thus determined by the frequency and the number of pole pairs and can be calculated with the formula:

$$n = \frac{60f}{p} \text{ rev/min}$$

where f = frequency and p = number of pole pairs.

## PERMANENT-MAGNETIC ROTOR

As described above, the speed of the motor is governed by the number of pole pairs. How many pole pairs can be provided on a magnet ring depends on the space available along the periphery of the ring, and on the properties of the magnetic material. The magnetic material is characterized by a high coercive force so that a great number of poles can be accommodated in a small space. Moreover, the residual flux will not be attenuated by the alternating field. In our synchronous motors as many as 24 poles can be made along the periphery of the magnet ring. Thus, the speed of these motors operating from 50 Hz mains is:

$$n = \frac{60x50}{12} = 250 \text{ rev/min}$$

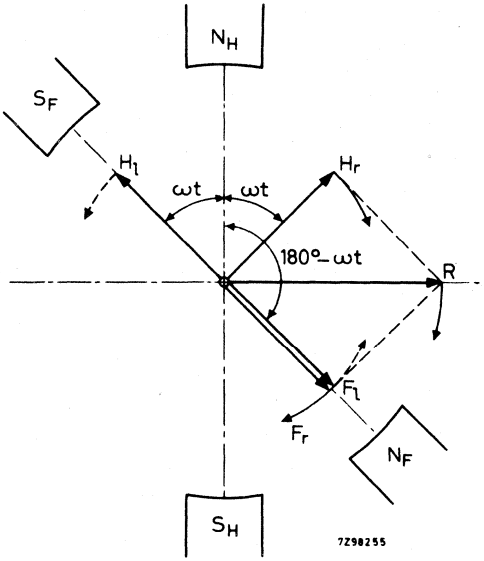
and with 60 Hz mains:

$$n = \frac{60x60}{12} = 300 \text{ rev/min}$$

The low motor speed means that for most applications the gearing-down ratio can be very small. This results in gearboxes of simple design which show very little wear in the bearings.

## SYNCHRONOUS MOTORS WITH A SINGLE CONSTANT ROTATING FIELD

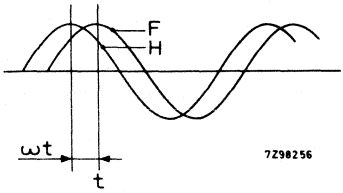
The figure below shows the situation at a time t in a synchronous motor with an auxiliary field added. Both the main field and the auxiliary one are again represented as being the resultant of two magnetic fields of equal and constant strength but rotating in opposite directions.




The main field, which changes sinusoidally, is represented by the vectors $H_l$ and $H_r$. The poles of the main field are indicated by $N_H$ and $S_H$.
If the rotor is driven by, for example, $H_r$ (clockwise), then $H_l$ (counterclockwise) will give rise to a vibration at double the frequency of the main field. To control the rotation of the motor and, as in this example, make it run clockwise only, and to eliminate the vibration at the same time, $H_l$ must be eliminated. This can be achieved by the compensating or auxiliary field F (with its component fields $F_l$ and $F_r$, identical and rotating in opposite directions), between poles $N_F$ and $S_F$. We see that $F_l$, rotating counterclockwise, will always oppose $H_l$ (also counterclockwise), and even eliminate it when fields H and F are of equal strength. We also see that $F_r$ and $H_r$ combine to the resulting rotating field R. The rotor will rotate in the direction of R because it is the only remaining field. Evidently R can also be chosen such that the motor can only run counterclockwise.

Finally, we see that in the figures the auxiliary field F lags behind the main field H by an angle (phase shift) $\omega t$.

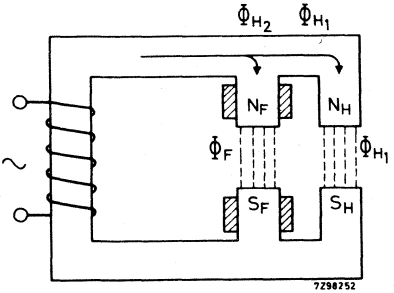
The above explanation applies to a two-pole motor; in motors with more poles the auxiliary poles must be uniformly distributed between them.

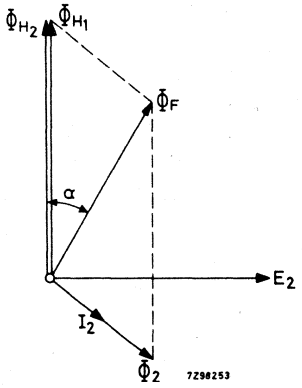



Two methods are available for obtaining a single constant rotating magnetic field:
- an auxiliary lagging field is derived from the main field; our unidirectional motors operate on this principle (see below)
- two stators are used yielding alternating fields with a certain phase shift between them, as in our reversible types of motors (see the next page).

**SYNCHRONOUS MOTORS WITH ONE DIRECTION OF ROTATION** (catalogue numbers 9904 110 .....)

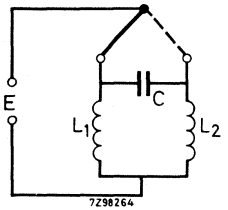
All these motors are provided with a copper ring around each of the auxiliary poles. The effect is that an induction current is produced through the rings, lagging behind the voltage $E_2$ (induced by the field $\phi_{H_2}$). The induced magnetic flux $\phi_2$ forms with the main flux $\phi_{H_2}$ the desired auxiliary flux $\phi_F$, which lags behind the main flux, $\phi_{H_2}$, by the angle $\alpha$. The construction is such that the auxiliary field, though weaker than the main field, ensures unidirectional operation of the motor.

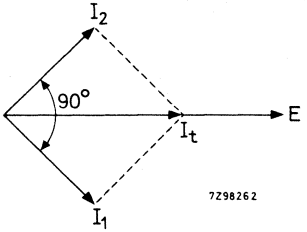


## SYNCHRONOUS MOTORS WITH AN ELECTRICALLY REVERSIBLE DIRECTION OF ROTATION (catalogue numbers 9904 111 .....)

As mentioned on the preceding page, the rotation of a synchronous motor can be made stable by incorporating two stators in one casing. The required phase shift is obtained by means of a capacitor which can be connected in series with either stator coil.

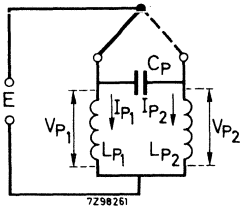


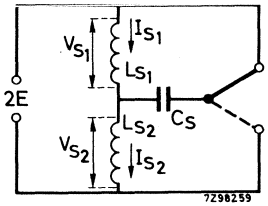

Current $I_1$ in coil $L_1$ will lag behind voltage E by 45°. With the aid of a capacitor, current $I_2$ in coil $L_2$ can be made to lead the voltage by 45°, giving a phase angle between $I_1$ and $I_2$ of 90°. The total current $I_t$ will then be approximately in phase with the voltage so that the maximum torque, and hence a high efficiency, is attained at a very low power consumption. From the above explanation it follows that the poles of the two stators must be an angle of 180-90° apart.
With $L_1$ and $L_2$ in parallel, as above, either the intersection of $L_1$ and the capacitor, or of $L_2$ and the capacitor, can be connected to the supply. Switching over will, however, reverse the rotation of the motor.
An arrangement with the two stator coils connected in series is also possible; this point is dealt with in some detail in the next subsection.

## PARALLEL AND SERIES CONNECTION OF THE STATOR COILS IN REVERSIBLE MOTORS

The reversible synchronous motors can be made to produce a higher torque by connecting the stator coils in series, with the exception of the type 9904 111 06... which is available only with parallel-connected coils.
The figures below show the circuit diagrams.




Parallel-connected stator coils

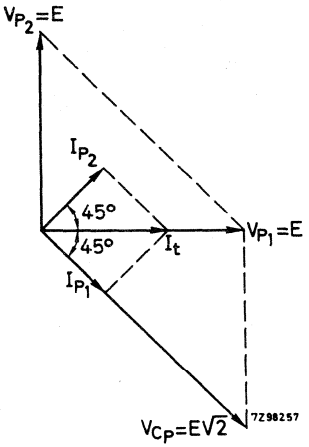



Series-connected stator coils

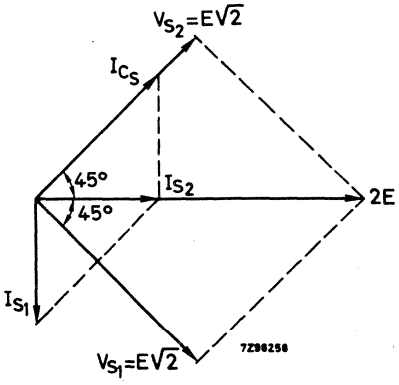
With series-connected coils the motors require about double the supply voltage.

Evidently a motor suitable for operation from a 24-volt source with parallel-connected coils may be operated from a 48-volt source when the coils are connected in series. In this way we get:

| parallel-connection | series-connection |
|---|---|
| 24 V | 48 V |
| 48 V | 110 V |
| 110 V | 220 V |
| 220 V | 380 V |




Vector diagram for parallel-connected stator coils




Vector diagram for series-connected stator coils

The vector diagrams show that the voltage across each coil in the series arrangement is $\sqrt{2}$ times that in the parallel arrangement. The same is true of the current through each coil. Therefore the maximum torque produced by a motor with series-connected coils is considerably higher than that of a motor with parallel-connected coils.

However, not only the torque but the power consumption as well increases in the case of series connection. This is accompanied by a rise in the temperature of the stator coils ($\Delta T$). As most of the materials used in the motors cannot withstand a temperature exceeding 110 °C, users of reversible motors with series-connected coils will have to make sure that the sum of the ambient temperature and $\Delta T$ never exceeds 110 °C, when the motors are in continuous operation.
With intermittent operation a higher ambient temperature may be acceptable, depending on the ratio between "switched-on time" and "switched-off time". We think it wise to explain this point to you with the aid of Figs. a, b and c.

Fig.a shows, for the motor type 9904 111 05311, with series-connected coils, the warm-up and cool-down curves; the maximum temperature rise occurs in the coils after about 90 minutes of continuous operation (see also the Note). Fig.b indicates that with a duty cycle of, say, 30 minutes, of which 20 minutes is switched-on time

and 10 minutes switched-off time, the coil temperature rises 49 °C after the first switched-on interval, then drops by 15 °C during the first switched-off interval, next rises again by 24 °C, etc., until eventually the maximum temperature rise of 60 °C is attained.
With the "total" temperature limit being 110 °C it is clear that this type of series-connected motor may be operated intermittently if the ambient temperature does not exceed 110-60 = 50 °C.

Finally Fig.c shows the maximum permissible ambient temperature plotted as a function of the duty cycle for different on/off ratios. The upper limit is 70 °C (motor may be used intermittently), the lower one is 40 °C (motor may be used continuously).

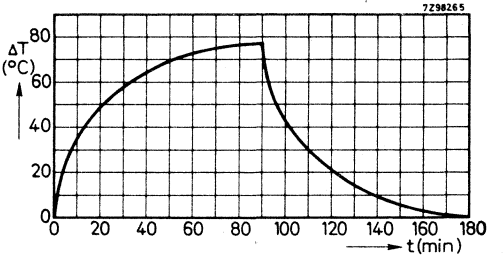



Fig.a

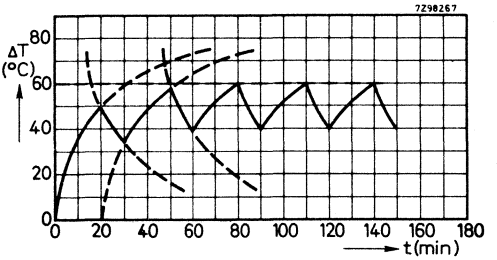



Fig.b

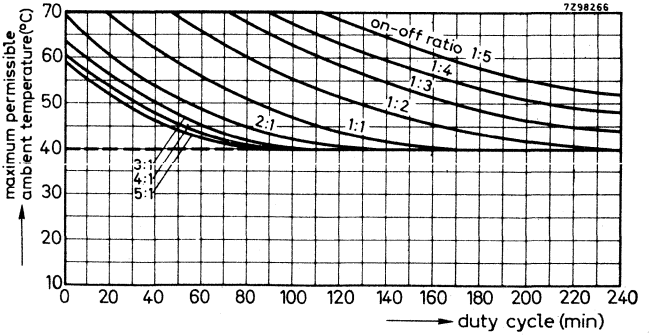



Fig.c

Note - The curve of Fig.a is measured on an abitrary motor 9904 111 05311 at maximum supply voltage and with a phasing capacitor with maximum value. For other motors and/or in other circumstances the temperature rise (ΔT) can be lower or higher.

## STARTING CHARACTERISTICS

Among the factors determining how fast synchronous motors using permanent magnets will start and whether the direction of rotation is correct, the following two deserve our attention:
- the loading conditions
- the relative positions of stator and rotor upon starting.

Loading may be as follows:
1. No load is present.
2. The torques are equal in both directions of rotation but they are below the maximum available motor torque.
3. The clockwise torque is equal to the maximum available motor torque but the counterclockwise torque is much lower.
4. The counterclockwise torque is infinitely high (that is: a mechanical stop is applied) but the clockwise torque equals the maximum available motor torque.
5. A torque is placed on the motor even when it is not energized (the load takes the form of a spring) but it does not exceed the motor's stalling torque.
6. The load has a high moment of inertia.

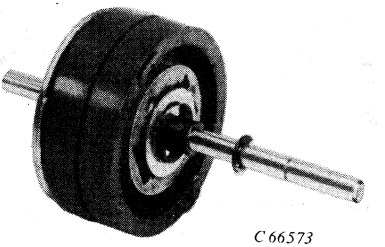
These loads can be applied directly to the motor spindle or via gears. In the latter case there will normally exist some backlash between the gearwheels which is sufficient to enable the motor to start in the unloaded mode and there will be no difficulty in handling the loads except in case 5. This is a special case because one can never be sure that a smooth start in the desired direction is made. To understand this we must realize that before the motor is excited the load torque equals a holding torque produced by the motor's magnetic circuit, otherwise the rotor would turn round. When the supply voltage is switched on, the holding torque may be reduced which will result in the motor being driven in the wrong direction by the load torque. The field operating in the wrong direction will have to be suppressed first.

The above phenomenon is most pronounced in unidirectional motors with the auxiliary field derived from the main one; the constant rotating field motors with two stator coils are less sensitive to it. In extreme cases it will be necessary to introduce a mechanical stop to neutralize the effect.

In case 6 the high inertia moment, when placed direct on the spindle, may cause the load not to be accelerated enough to reach synchronous speed; the rotor may then oscillate. Given sufficient amplitude these oscillations may after a longer or shorter time - depending on the nature and magnitude of the load, and on the motor excitation - develop into a steady rotation. The sense of rotation is determined by the direction of the oscillation which is the first to attain the necessary maximum. Hence it may well happen that the motor starts running in the wrong direction. It will continue to do so when the load in this direction is small enough. To avoid this effect one must make sure that the inertia moment of the load does not surpass a certain maximum.

Stronger motors are hampered by the inertia moment of the rotor which is so high that not much is left for the load. For this reason the motors 9904 111 06... have been equipped with a so-called resonance rotor, with a flexible connection between rotor and spindle. The rotation of this rotor upon switching-on is first an oscillating one but here too the oscillations develop into the steady rotation. Thanks to this rotor construction this type of motor starts rapidly, practically noiseless and without vibrations.

Laboratory measurements have demonstrated that unidirectional motors when starting under adverse loads need a starting time of about 250 ms. However, in most cases the starting time is considerably shorter. Twin-stator types of electrically reversible motors need, under adverse conditions, a starting time of about 80 ms.



C66573

Resonance rotor

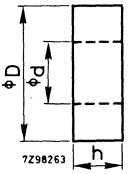
Note

The mass inertia moment of the pinion can be calculated with the formula

$$J = \frac{\pi}{32} \times \gamma \times h \times (D^4 - d^4)$$

for an annular object (see the sketch alongside) with

| | | |
|---|---|---|
| outer diameter | (D) | in cm |
| inner diameter | (d) | in cm |
| height | (h) | in cm |
| mass density | ($\gamma$) | in g/cm$^3$ |




In the case of a pinion we may have:

D = 4 mm (outer diameter over the teeth; this simplifies the calculation and provides a safety margin)

d = 1.6 mm (spindle diameter)

h = 4.5 mm

mass density = 7.6 g/cm$^3$

Its mass inertia moment may then work out to be 0.0086 gcm$^2$.

Any pinion with an outer diameter smaller than that of the centring rim on the motor will, as a rule, have a sufficiently small inertia moment.

## SOME NOTES ON THE STRAY FIELD

For the major part our synchronous motors are provided with a steel casing which minimizes the stray field. Exceptions are the types 9904 111 05... and 9904 111 06....

The strength of a stray field decreases as a function of the distance from the motor. It can be determined by measuring the e.m.f. induced in a coil placed in the stray field, and using the formula:

$$H_{eff} = C \times e_{eff}$$

where $H_{eff}$ = effective value of the field strength at the location of the measuring coil;

C = a constant representing the size and the number of turns of the coil (can be found by calculation or calibration);

$e_{eff}$ = value read from the tube voltmeter.

Example: In the case of the 9904 111 06211 motor the following values were determined:
at the motor casing: 5680 A/m;
at 1 cm distance : 992 A/m;
at 2 cm distance : 376 A/m.

## SOME MECHANICAL NOTES

### Braking torque

In all the types of synchronous motor a considerable braking torque is produced when the current is interrupted due to the strong rotor magnet poles moving close to the stator poles. The rotor is strongly braked, so that the motor stops almost immediately. The angle through which the rotor can still turn after switching off depends on the magnitude and moments of inertia of the load. In normal use it will not be more than 20°. For most applications additional mechanical brakes are, therefore, not required.

### Bearings

It has been found that the following materials were best suitable for manufacturing bearings of sound construction and meeting the wide variety of demands imposed on the motors.

1. Plastic slide bearings
   A polyamide of a high quality with a very finely graded emulsion of molybdenum disulphide ($MoS_2$) which gives self-lubricating properties, is used in the motors 9904 110 02..., 9904 110 05..., 9904 110 07 and 9904 110 08... .
   Water absorption: negligible (<1, 5%).
   Coefficient of friction: low (<0, 15), so the losses due to friction are very small.
   Chemical resistance: very high; it is resistant to the normal organic solvents, esters, ketones, lubricating oil, petrol, paraffin, and solutions of organic salts.
2. Sintered-metal slide bearings
   a. Sintered-bronze self-aligning slide bearings are used in the motors 9904 110 06..., 9904 110 09..., 9904 111 04... and 9904 111 07... .
   b. Sintered-iron is used in the type 9904 111 06... motors.
3. Needle bearings
   These bearings are used in the type 9904 111 05... motors.

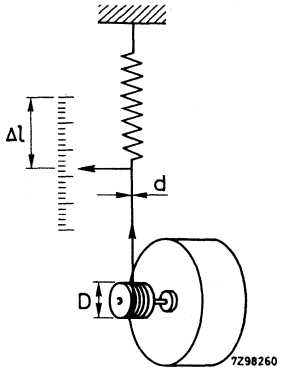
## MEASURING THE MOTOR TORQUE

The adjoining sketch illustrates the set-up for measuring the maximum motor torque. A pulley with diameter D is placed on the spindle, and a string is fastened at one end around the pulley and at the other to a helical spring with diameter d.

Next the motor is started, and it will wind the string around the pulley thereby stretching the spring. This goes on until the force exerted by the spring equals the maximum motor torque. The motor then stops and $\Delta l$, that is the total displacement of a needle fixed to the spring, is measured.

The motor torque can be calculated with the aid of the formula: $M = (\frac{1}{2}D + \frac{1}{2}d) \times C \times \Delta l$, where C is a constant characteristic for the spring and $\Delta l$ is the displacement of the needle.

It is also possible to mark the scale in such a way that the motor torque can be read directly from it. Attention should be paid to the fact that the mass of the pulley should be as small as possible for accurate results.




## NOTE

The unidirectional motors 9904 110 07... and 9904 110 08... are specifically designed for domestic appliances, the design having been adapted to achieve the most economic motor types. They are provided with 6 pole-pairs, which gives a speed of 500 rev/min at 50 Hz. A mechanical ratchet is included in the design to prevent starting in the wrong direction.

# QUALITY CONTROL

Quality control is the prime concern from the moment a development is started until the product has been series-produced.
Thus, checks are carried out:

- during the development by testing the most important properties,
- at the end of development by approval tests on hand-made samples to make sure that the motor conforms to specifications; there is a standard programme of checks and tests subdivided into six groups (see below),
- during the first trial run in the factory, when the same programme of tests is carried out,
- during manufacture, when sometimes all individual products are tested, sometimes random tests are conducted.

The finished product is examined by an independent testing organization making random tests thus checking whether the manufacturer's quality control is up to standard. Also, any complaints on the part of customers are investigated by the quality department of the factory and by the independent testing organization.

There is a great difference between the tests carried out before full production starts and those performed during production, as becomes clear from the schedules given below.

## QUALITY CONTROL BEFORE MANUFACTURING STARTS

The following so-called "release approval" tests are made:

1. Functional tests

   The motors are subjected to:
   - voltage fluctuations between −10 and +10% or between −15 and +10%
   - on-off switching, up to 250 000 times
   - a functional test at −20 °C, unless otherwise specified.

2. Tests on the resistance to damage during transport

   These tests comprise:
   - simulated transport tests on packed motors
   - bump tests on motors mounted on a frame.

3. Climatic tests

   To examine the behaviour of the motors under various conditions of shelving, the motors are subjected to:
   - a temperature-cycle test, −40 to +85 °C, 30% R.H. (30 hours)
   - a cycle damp test, 6 days
   - a cold dry shelf test at −40 °C (16 hours), unless otherwise specified.

4. Life tests

No system of life tests yet devised gives a sure approval of the conduct of the motors over a long period. Some insight is gained from standard life tests and, in addition, a number of motors are operated for years at the rated voltage and under normal climatic conditions, both loaded and unloaded. The combination of life tests and practical experience gives a reasonable basis for predicting the motor life.

The standard life tests are not intended to cover the whole normal service life, because this would imply extremely prolonged test periods. Extrapolation of the test results allows us to assure that our synchronous motors are fit for continuous service for many years.
The standard life tests are as follows:
- operation for 2000 hours at room temperature and maximum load;
- operation for 2000 hours at 70 °C unless otherwise specified and 70% of maximum load.

5. Dimensional checks

The product is checked visually; the dimensions are compared with those specified on the drawings.

6. Checks on whether the safety requirements are met

The motors should comply with the safety requirements according to CEE 10, Class 2 → except motors 9904 110 05..., 9904 110 06..., and 9904 111 07... which come under CEE 10, Class 1 and motors 9904 110 09... which come under CEE 10, Class 3. Examples of the requirements are: air gaps - 8 mm; creeping distances - 8 mm; high voltages - 2500 V between live parts and casing, for one minute. The connecting wires for all 60 Hz motors should be in accordance with CSA and UL requirements.

## QUALITY CONTROL DURING PRODUCTION

The following tests are performed during production:

1. Random checks on motor components.
2. Random checks on sub-assemblies for the motor.
3. Tests during manufacturing, on such properties as:
   - direction of rotation;
   - current;
   - torque;
   - spindle deviation;
   - height of motor;
   - resistance to insulation test voltage as given in the technical performance.

All the products are checked for major defects according to MIL-STD 105, inspection level II, AQL: 1%.

## LIFE

It is very difficult to give an exact value for the expected life of our products since the circumstances in which they are used are often very different. Accelerated life tests can only give an indication.

There are accelerated life tests carried out during 2000 hours, including tests under high ambient temperatures. After these severe tests, the motors still have to conform to the specifications and to be able to work for a long time. Some "informal" tests are carried out; for example, one of the motors has run continuously for more than 5 years under full load under normal (dusty) conditions. No excessive wear or other undesirable results were noted.

## RELIABILITY

Synchronous motors are mostly used in applications where they are required to operate for a long time and where failures are highly undesirable because many functions are controlled, as in the case of timers or programme switches. A synchronous motor must therefore be trouble-free. The only way to achieve high reliability is to use a very simple design and to check the quality during all phases of production.

Our motors have:

- no ratchets that wear out
- closed casings hence, the air gap between rotor and stator is protected
- a coil which is wound in a simple way
- a one-piece rotor moulded to the spindle
- been checked regularly during development and manufacture.

# APPLICATIONS

The synchronous motors can be used in a wide range of applications.

Industrial

Different types of clocks:

- control clocks
- master clocks
- secondary clocks
- signal clocks
- rate change clocks
- switch clocks

Different types of time devices:

- delay relays
- time printers and stamps
- time checking devices
- time recorders
- time switches

Signal apparatus for air traffic control and waterway traffic control
Recording instruments
Electric stage control stands
Control equipment for the processing industry, and for heating and airconditioning installations
Remote control units
Programme switches

Entertainment

Record players
Slide projectors
Television selector units
Tape recorders
Toy drivers
Television sets

Domestic

Timers and programme switches for:

- defroster sections in refrigerators and deepfreezers
- washing machines
- dish washers
- cooking ranges and ovens
- ultraviolet lamps
- automatic vending machines.

# REMARKS ON THE TECHNICAL DATA

- The current, power and temperature increase values are guidance values and are measured at 20 °C, in free circulating air and at nominal voltage
- The torque values are minimum ones, for the values at nominal voltage see the performance graph
- Derating of torque is given in a percentage per deg C above the ambient temperature of 20 °C
- The curves of the performance graphs are measured on arbitrary motors of basic types; they apply also to the derived versions, e.g. curves of motor 9904 110 02101 apply also to motor 9904 110 02111.
- At the lower end of the ambient temperature range the moment in which the motors reach their synchronous speed will be delayed.

# UNIDIRECTIONAL MOTORS

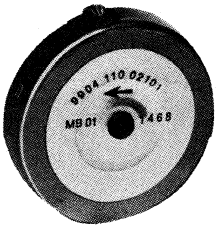
## SURVEY

The range of unidirectional motors comprise the following types:

| | |
|---|---|
| - standard type | catalogue number 9904 110 02... |
| - small type | catalogue number 9904 110 05... |
| - silent type | catalogue number 9904 110 06... |
| - 500 rev/min types | catalogue numbers 9904 110 07... and 9904 110 08... |
| - miniature type | catalogue number 9904 110 09... |

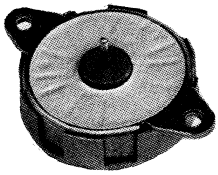
A mounting bracket for motors 9904 110 02... is given in the chapter "Accessories".

*71 548 H5*




Standard type, catalogue number 9904 110 02...

*750516-07-01*



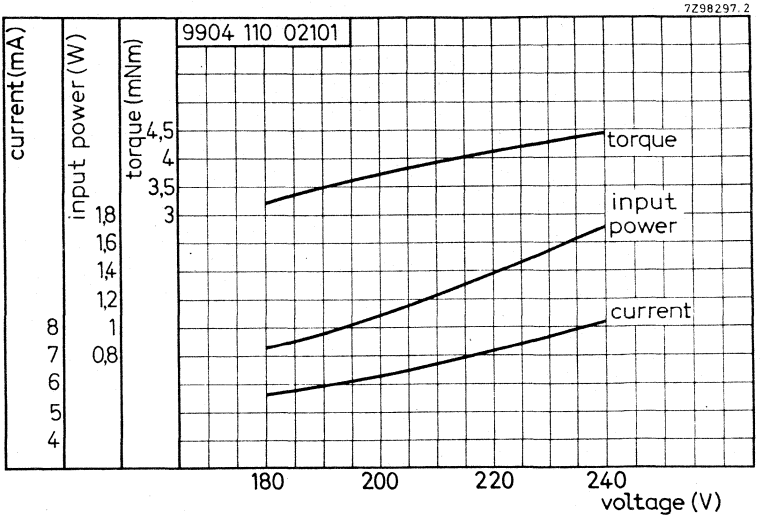
Small type, catalogue number 9904 110 05...

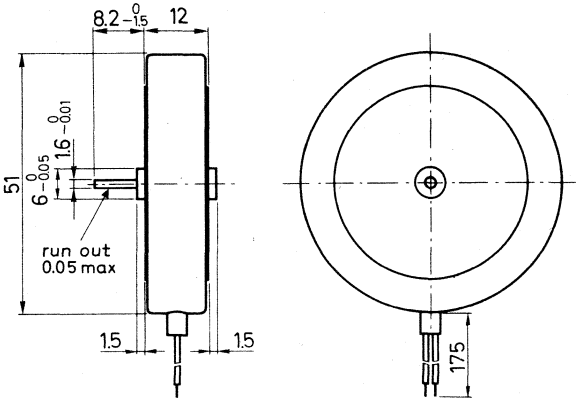
Silent type, catalogue number 9904 110 06...

## STANDARD TYPE

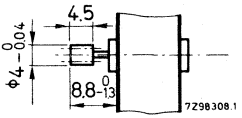
### TECHNICAL DATA

| | | catalogue number | |
|---|---|---|---|
| clockwise rotation<br>counterclockwise rotation | | 9904 110 02101<br>9904 110 02111 | 9904 110 02301<br>9904 110 02311 |
| Nominal voltage | (V) | 220 | 110 |
| Frequency | (Hz) | 50 | 50 |
| Speed | (rev/min) | 250 | 250 |
| Current | (mA) | 7,5 | 17 |
| Input power | (W) | 1,6 | |
| Starting torque | (mNm) | 2,5 | |
| Working torque | (mNm) | 3 | |
| Torque derating | (%) | 0,6 | |
| Temperature increase of the motor | (degC) | 30 | |
| Ambient temperature range | ($^{o}$C) | −20 to +70 | |
| Permissible voltage fluctuations | (%) | −15 to +10 | |
| Insulation according to CEE10 | | class 2 | |
| Insulation test voltage | (V) | 2500 | |
| Bearings | | slide bearings | |
| Maximum radial force | (N) | 0,9 | |
| Maximum axial force | (N) | 0,5 | |
| Maximum inertial load | ($gcm^2$) | 0,15 | |
| Housing | | zinc plated | |
| Weight | (g) | 90 | |




**Note:** - Motors with different voltage ratings or provided with a pinion (see figure below) are available on request only in minimum order quantities, and involve longer delivery times.




version with pinion

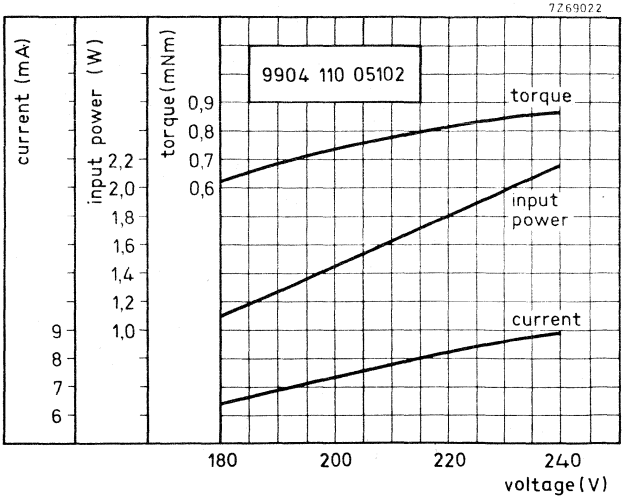
number of teeth = 10
module = 0.3
addendum modification = +0.2

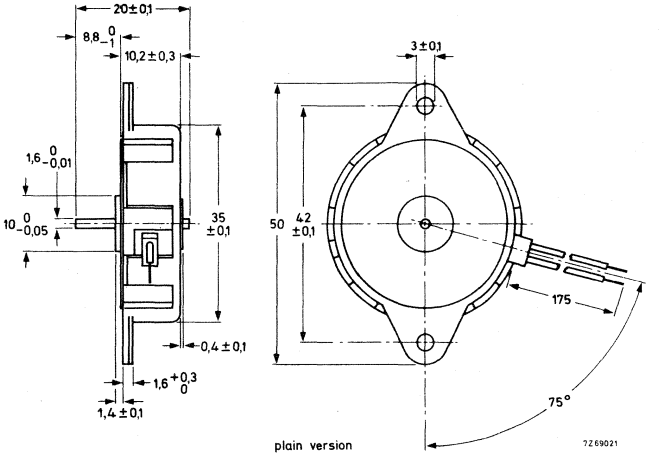
## SMALL TYPE

### TECHNICAL DATA

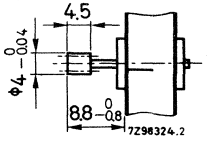
| | | catalogue number | |
|---|---|---|---|
| clockwise rotation<br>counterclockwise rotation | | 9904 110 05102 [1]<br>9904 110 05112 [1] | 9904 110 05301<br>9904 110 05311 |
| Nominal voltage | (V) | 220 | 110 |
| Frequency | (Hz) | 50 | 50 |
| Speed | (rev/min) | 250 | 250 |
| Current | (mA) | 8 | 5 |
| Input power | (W) | 1,8 | 0,5 |
| Starting torque | (mNm) | 0,5 | |
| Working torque | (mNm) | 0,5 | |
| Torque derating | (%) | 0,6 | |
| Temperature increase of the motor | (degC) | 20 | |
| Ambient temperature range | (°C) | −20 to +70 | |
| Permissible voltage fluctuations | (%) | −15 to +10 | |
| Insulation according to CEE10 | | class 1 | |
| Insulation test voltage | (V) | 2500 | |
| Bearings | | slide bearings | |
| Maximum radial force | (N) | 0,3 | |
| Maximum axial force | (N) | 0,1 | |
| Maximum inertial load | ($gcm^2$) | 0,05 | |
| Housing | | zinc plated | |
| Weight | (g) | 40 | |

[1]) This motor has to be used with a series resistor (20 kΩ, 2 W), which can be supplied on request.




**Note**: - Motors with different voltage ratings or provided with a pinion (see figure below) are available on request only in minimum order quantities, and involve longer delivery times.




version with pinion

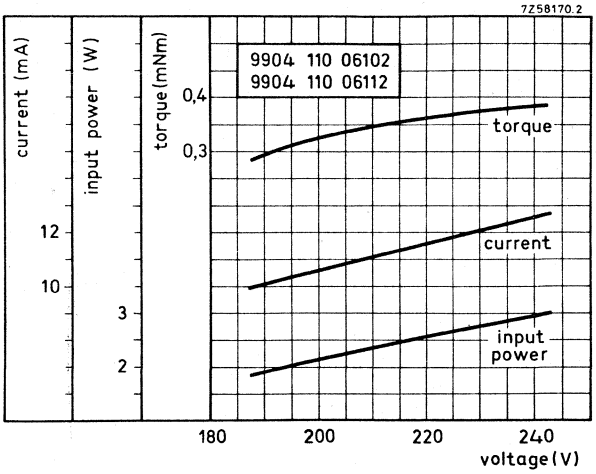
number of teeth = 10
module = 0.3
addendum modification = +0.2

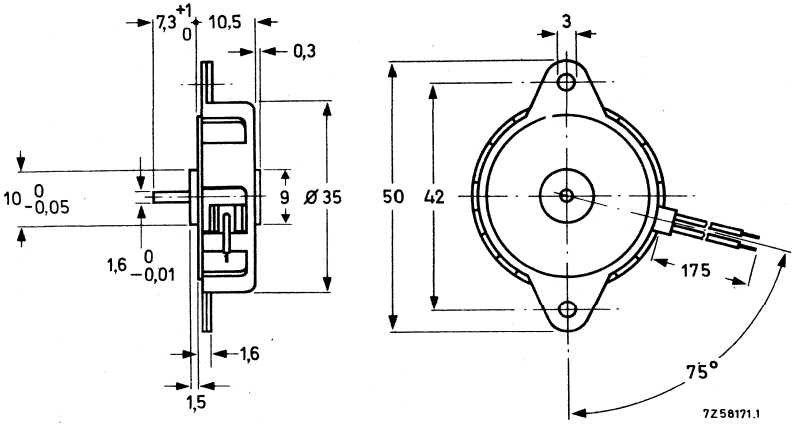
## SILENT TYPE

### TECHNICAL DATA

| | | catalogue number | |
|---|---|---|---|
| clockwise rotation<br>counterclockwise rotation | | 9904 110 06102 [1]<br>9904 110 06112 [1] | 9904 110 06301<br>9904 110 06311 |
| Nominal voltage | (V) | 220 | 110 |
| Frequency | (Hz) | 50 | 50 |
| Speed | (rev/min) | 250 | 250 |
| Current | (mA) | 12 | 10 |
| Input power | (W) | 2,6 | 1 |
| Starting torque | (mNm) | 0,25 | |
| Working torque | (mNm) | 0,25 | |
| Torque derating | (%) | 0,4 | |
| Temperature increase of the motor | (degC) | 40 | |
| Ambient temperature range | ($^{o}$C) | −5 to +50 | |
| Permissible voltage fluctuations | (%) | −15 to +10 | |
| Insulation according to CEE10 | | class 1 | |
| Insulation test voltage | (V) | 2500 | |
| Bearing | | sintered bronze slide bearing | |
| Maximum radial force | (N) | 0,2 | |
| Maximum axial force | (N) | 0,15 | |
| Maximum inertial load | (gcm$^2$) | 0,02 | |
| Housing | | passivated zinc plating | |
| Weight | (g) | 40 | |

[1]) This motor has to be used with a series resistor (12 kΩ, ± 5%, 2W).

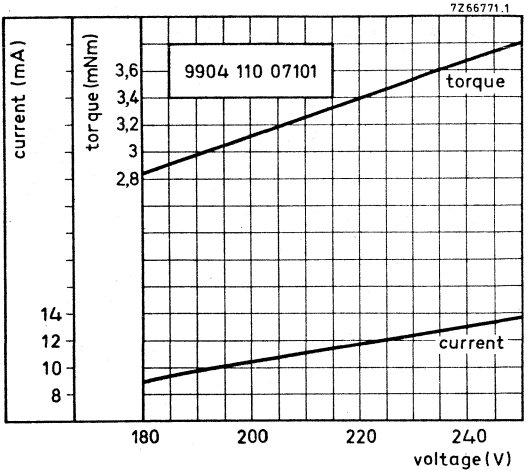

7Z58170.2
current (mA)
input power (W)
torque (mNm)
9904 110 06102
9904 110 06112
0,4
0,3
12
10
3
2
torque
current
input power
180
200
220
240
voltage (V)

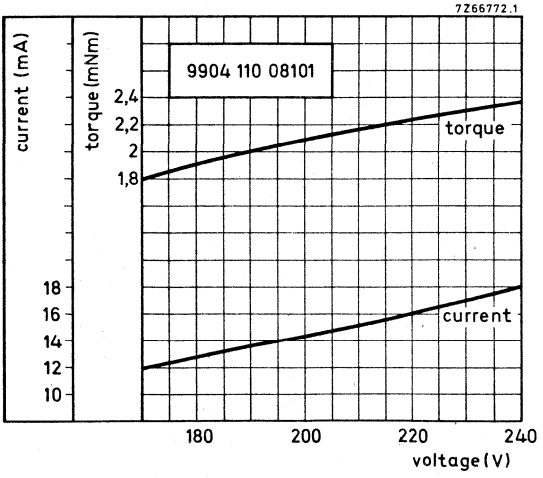

7,3 +1 0
10,5
0,3
10 0 -0,05
9
Ø 35
1,6 0 -0,01
1,6
1,5
3
50
42
175
75°
7Z58171.1

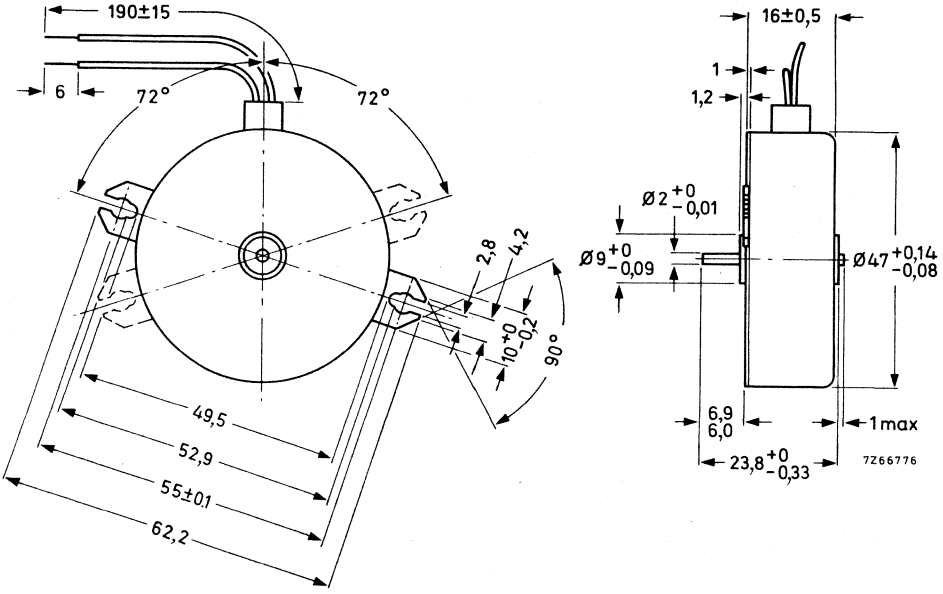
## 500 rev/min TYPES

### TECHNICAL DATA

| | | catalogue number | |
|---|---|---|---|
| clockwise rotation | | 9904 110 07101 | 9904 110 08101 |
| counterclockwise rotation | | 9904 110 07111 | 9904 110 08111 |
| Nominal voltage | (V) | 220 | |
| Frequency | (Hz) | 50 | |
| Speed | (rev/min) | 500 | |
| Current | (mA) | 13 | 16 |
| Input power | (W) | 2,5 | 3,5 |
| Starting torque | (mNm) | 1,5 | 1 |
| Working torque | (mNm) | 3 | 2 |
| Torque derating | (%) | 0,6 | 0,6 |
| Temperature increase of the motor | (deg C) | 35 | 40 |
| Ambient temperature range | ($^{o}$C) | +5 to +80 | |
| Permissible voltage fluctuations | (%) | −15 to +10 | |
| Insulation according to CEE10 | | class 2 | |
| Insulation test voltage | (V) | 2500 | |
| Bearings | | slide bearings | |
| Maximum radial force | (N) | 1 | |
| Maximum axial force | (N) | 1 | |
| Maximum inertial load | ($gcm^2$) | 0,15 | |
| Housing | | cadmium plated | |
| Weight | (g) | 85 | 65 |

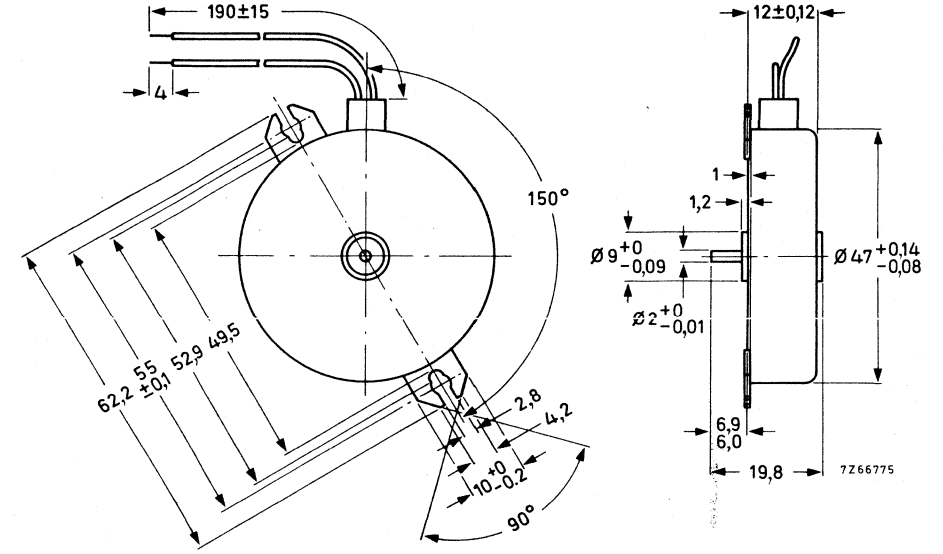

7Z66771.1
9904 110 07101
current (mA)
torque (mNm)
3,6
3,4
3,2
3
2,8
torque
14
12
10
8
current
180
200
220
240
voltage (V)


7Z66772.1
9904 110 08101
current (mA)
torque (mNm)
2,4
2,2
2
1,8
torque
18
16
14
12
10
current
180
200
220
240
voltage (V)




Synchronous motors 9904 110 07...

The position of the lugs of motors which rotates counterclockwise are given with dotted lines.




Synchronous motors 9904 110 08...

# MINIATURE SYNCHRONOUS TIMING MOTORS

| QUICK REFERENCE DATA | | | | |
|---|---|---|---|---|
| Nominal voltage | 12 V, 50 Hz | 24 V, 50 Hz | 24 V, 50 Hz [1] | 110 V/220 V, 50 Hz |
| Speed | 375 rev/min | 375 rev/min | 375 rev/min | 375 rev/min |
| Input power | 0,2 W | 0,2 W | 0, 12 W | 0,75 W/1,5 W |
| Torque | 0,08 mNm | 0,08 mNm | 0,03 mNm | 0,08 mNm |

## APPLICATION

These miniature timing motors have been designed to drive small clock mechanisms specifically where low power consumption (thus low temperature rise) is required and where small dimensions are preferred.
Versions for 12 V as well as for 24 V are available. Their low power consumption allowes battery operation (via an electronic d.c./a.c.-converter to provide the required a.c. supply of 12 V or 24 V, 50 Hz).
For applications which normally use hysteresis motors with their unfavourable volume-to-output ratio, the silent version for 24 V supply is a much better proposition.
For operation from the mains the 12 V and 24 V versions can also be used, however it is preferable to use the version especially designed for 110 V/220 V supply to obtain optimum results, provided that the appropriate resistor or capacitor is connected in series with the motor coil.
Typical applications are:
- electronic car clocks
- rate change clocks in electricity meters
- central heating control clocks
- miniature time switches
- miniature elapsed-time indicators.

## DESCRIPTION

These miniature timing motors are of the synchronous permanent magnet type; the direction of rotation is determined electrically. The absence of a mechanical ratchet which avoids friction losses and noise, contributes to the high efficiency and silent rotation of the motor.
With suitable precautions in the application, such as the use of plastics, adequate safety can be achieved to fulfil the international safety requirements for 220 V operation via a series resistor or capacitor.

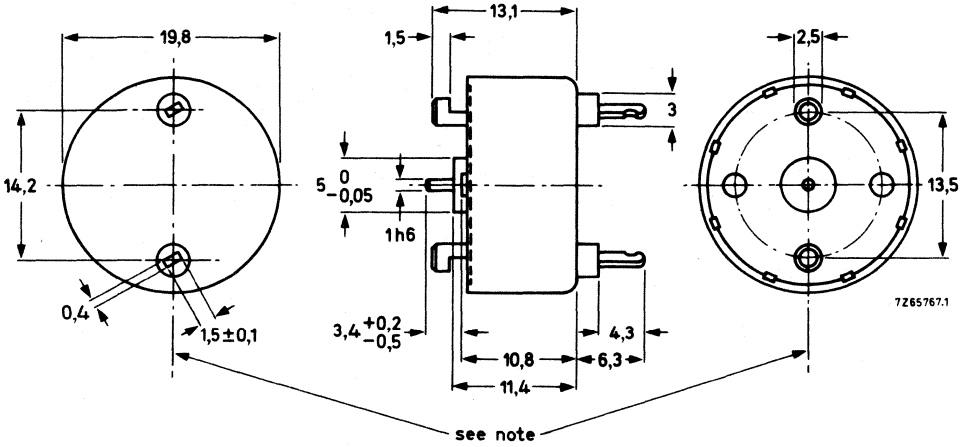
[1]) Silent version.

Two solder tags are provided for the electrical connection. These tags ensure 2 mm air gap and creepage distances, thus enabling the motor to withstand a 500 V test voltage.

To fit a pinion a light press-fit sufficient to withstand the working torque of the motor is required to avoid destruction of the motor interior. A plastic pinion is recommended as it has the added advantage of damping the running noise of the mating gearwheel.

## TECHNICAL DATA

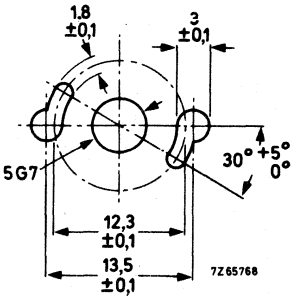
Dimensions in mm




Note – The angle between the axial plane through the centres of the mounting pins and the axial plane through the centres of the solder tags is maximum 2° 30'.

Mounting

Two plastic twist-lock mounting pins are provided, but can be cut off if desired. Maximum thickness of mounting plate is 0,8 mm.



12 V version

| | | catalogue number | | |
|---|---|---|---|---|
| clockwise rotation | | 9904 110 09701 | | |
| counterclockwise rotation | | 9904 110 09711 | | |
| Nominal voltage | (V) | 12 | 6 | 1) |
| Frequency | (Hz) | 50 | 50 | |
| Speed | (rev/min) | 375 | 375 | |
| Current | (mA) | 18 | 9 | |
| Input power | (W) | 0,2 | 0,05 | |
| Starting torque 2) | (mNm) | 0,08 | 0,02 | |
| Working torque 3) | (mNm) | 0,08 | 0,02 | |
| Torque derating | (%) | 0,6 | 0,6 | |
| Temperature increase of the motor | (degC) | 16 | 4 | |
| Ambient temperature range | | | | |
| operating | (°C) | −30 to + 85 | −10 to + 85 | |
| storage | (°C) | −40 to +100 | −40 to +100 | |
| Permissible voltage fluctuations | (%) | −15 to + 10 | 0 to +110 | |
| Insulation according to CEE 10 | | class 3 | | |
| Insulation test voltage | (V) | 500 | | |
| Bearings | | sintered bronze | | |
| Maximum radial force | (N) | 0,05 | | |
| Maximum axial force | (N) | 0,05 | | |
| Maximum inertial load | ($gcm^2$) | 0,002 | | |
| Housing | | steel, zinc plated | | |
| Weight | (g) | 14 | | |

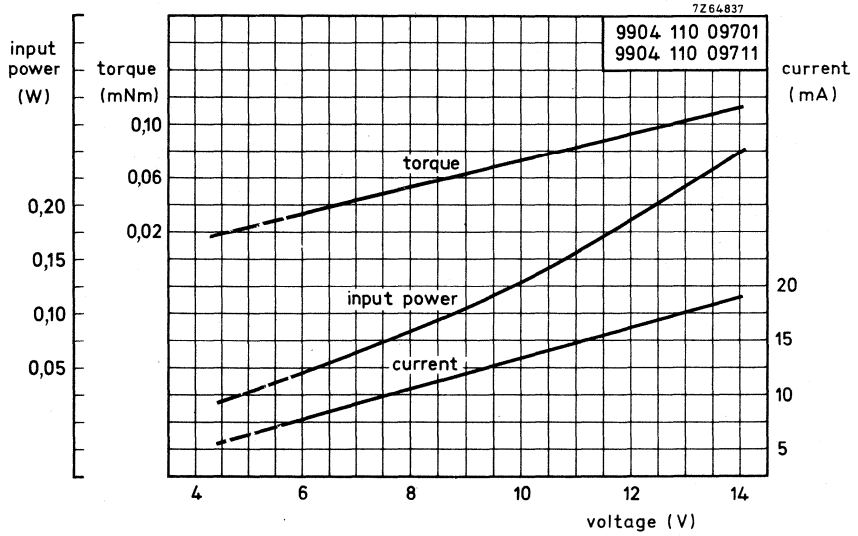
For typical curves, see next page.

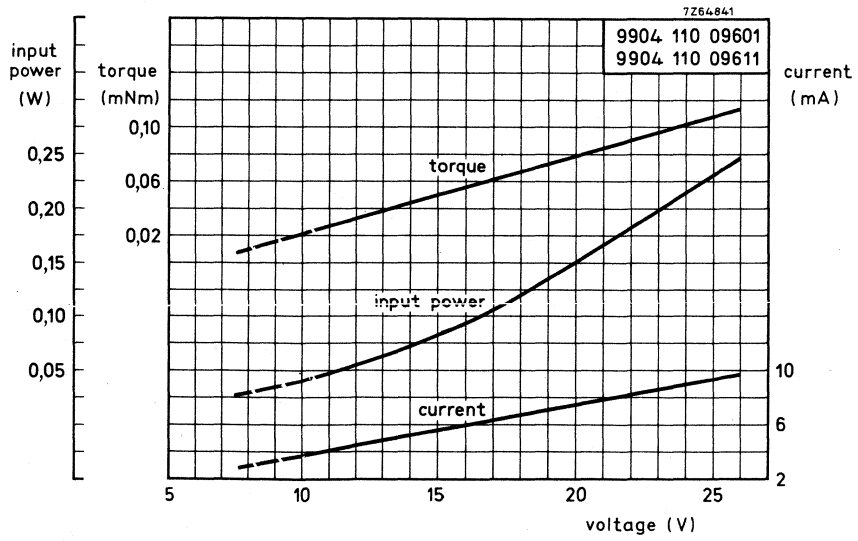
This version can also be used for operation from 110 V/220 V, 50 Hz supply, provided that the appropriate resistor or capacitor is in series with the motor coil see "Additional information".

1) These figures for 6 V operation are for guidance only; they are not guaranteed but in practice ensured.

2) If allowed for sufficient free movement of the motor spindle at the initial stage of starting (e.g. a gearbox).

3) At 1 rev/min the working torque is 30 mNm (guidance value 7,5 mNm), without taking into account the efficiency of the gearbox.


7Z64837
9904 110 09701
9904 110 09711
input power (W)
torque (mNm)
current (mA)
0,10
0,06
0,02
0,20
0,15
0,10
0,05
torque
input power
current
20
15
10
5
4
6
8
10
12
14
voltage (V)


7Z64841
9904 110 09601
9904 110 09611
input power (W)
torque (mNm)
current (mA)
0,10
0,06
0,02
0,25
0,20
0,15
0,10
0,05
torque
input power
current
10
6
2
5
10
15
20
25
voltage (V)

24 V version

| | | catalogue number | | |
|---|---|---|---|---|
| clockwise rotation<br>counterclockwise rotation | | 9904 110 09601<br>9904 110 09611 | | |
| Nominal voltage | (V) | 24 | 12 | |
| Frequency | (Hz) | 50 | 50 | |
| Speed | (rev/min) | 375 | 375 | |
| Current | (mA) | 9 | 4,5 | |
| Input power | (W) | 0,2 | 0,05 | |
| Starting torque [2] | (mNm) | 0,08 | 0,02 | |
| Working torque [3] | (mNm) | 0,08 | 0,02 | [1] |
| Torque derating | (%) | 0,6 | 0,6 | |
| Temperature increase of the motor | (degC) | 16 | 4 | |
| Ambient temperature range | | | | |
| operating | ($^{o}$C) | -30 to +85 | -10 to +85 | |
| storage | ($^{o}$C) | -40 to +100 | -40 to +100 | |
| Permissible voltage fluctuations | (%) | -15 to +10 | 0 to +110 | |
| Insulation according to CEE10 | | class 3 | | |
| Insulation test voltage | (V) | 500 | | |
| Bearings | | sintered bronze | | |
| Maximum radial force | (N) | 0,05 | | |
| Maximum axial force | (N) | 0,05 | | |
| Maximum inertial load | ($gcm^2$) | 0,002 | | |
| Housing | | steel, zinc plated | | |
| Weight | (g) | 14 | | |

For typical curves, see preceding page.

This version can also be used for operation from 110 V/220V, 50 Hz supply provided that the appropriate resistor or capacitor is in series with the motor coil, see "Additional information".

1) These figures for 12 V operation are for guidance only; they are not guaranteed but in practice ensured.

2) If allowed for sufficient free movement of the motor spindle at the initial stage of starting (e.g. a gearbox).

3) At 1 rev/min the working torque is 30 mNm (guidance value 7,5 mNm) without taking into account the efficiency of the gearbox.

Versions for mains operation

| | | catalogue number | | | |
|---|---|---|---|---|---|
| Clockwise rotation | | 9904 110 09101 | | | |
| Counterclockwise rotation | | 9904 110 09111 | | | |
| Mains voltage | (V) | 110 | | 220 | |
| | | low torque mode [1] | high torque mode | low torque mode [1] | high torque mode |
| Required series resistor, ± 5% | (kΩ) | 22 | 12 | 47 | 30 |
| Maximum power dissipation | (W) | 0,5 | 0,7 | 1,1 | 1,6 |
| Frequency | (Hz) | 50 | 50 | 50 | 50 |
| Speed | (rev/min) | 375 | 375 | 375 | 375 |
| Current | (mA) | 4 | 7 | 4 | 7 |
| Input power | (W) | 0,47 | 0,75 | 0,94 | 1,5 |
| Starting torque [2] | (mNm) | 0,02 | 0,08 | 0,02 | 0,08 |
| Working torque [3] | (mNm) | 0,02 | 0,08 | 0,02 | 0,08 |
| Torque derating | (%) | 0,6 | 0,6 | 0,6 | 0,6 |
| Temperature increase of the motor | (degC) | 5 | 17 | 5 | 17 |
| Ambient temperature range | | | | | |
| operating | (°C) | −15 to +85 | | | |
| storage | (°C) | −40 to +100 | | | |
| Permissible voltage fluctuations | (%) | −15 to +10 | | | |
| Insulation according to CEE10 | | class 3 | | | |
| Insulation test voltage | (V) | 500 | | | |
| Bearings | | sintered bronze | | | |
| Maximum radial force | (N) | 0,05 | | | |
| Maximum axial force | (N) | 0,05 | | | |
| Maximum inertial load | ($gcm^2$) | 0,002 | | | |
| Housing | | steel, zinc plated | | | |
| Weight | (g) | 14 | | | |

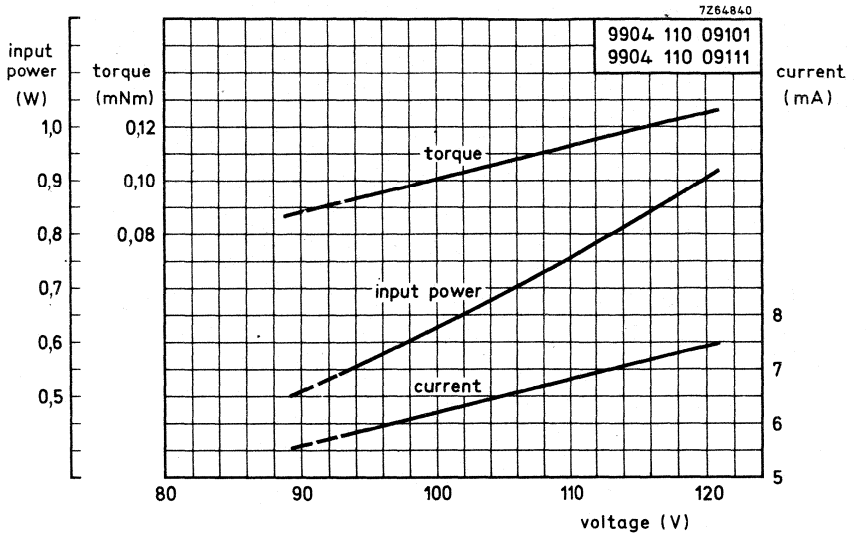
For typical curves, see next pages.

For use of a series capacitor instead of a series resistor, see "Additional information".

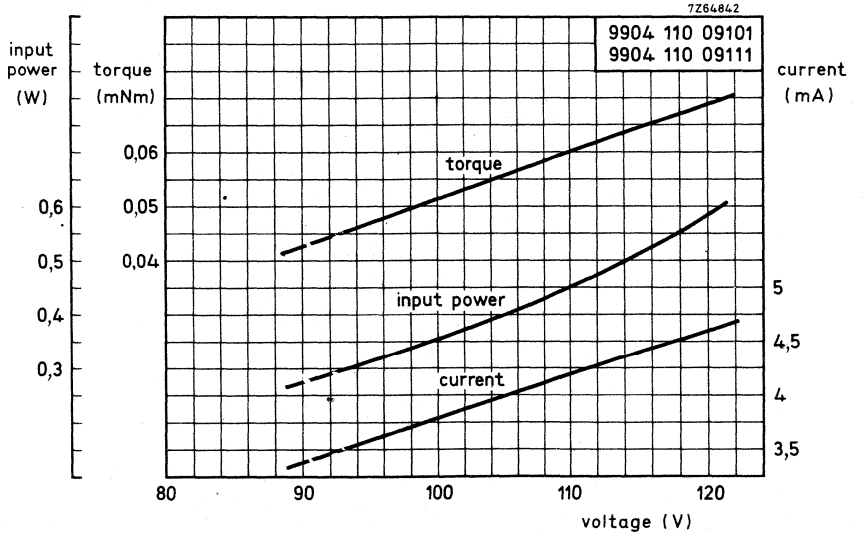
[1]) If used in low torque mode, the motor noise is reduced at minimum.

[2]) If allowed for sufficient free movement of the motor spindle at the initial stage of starting.

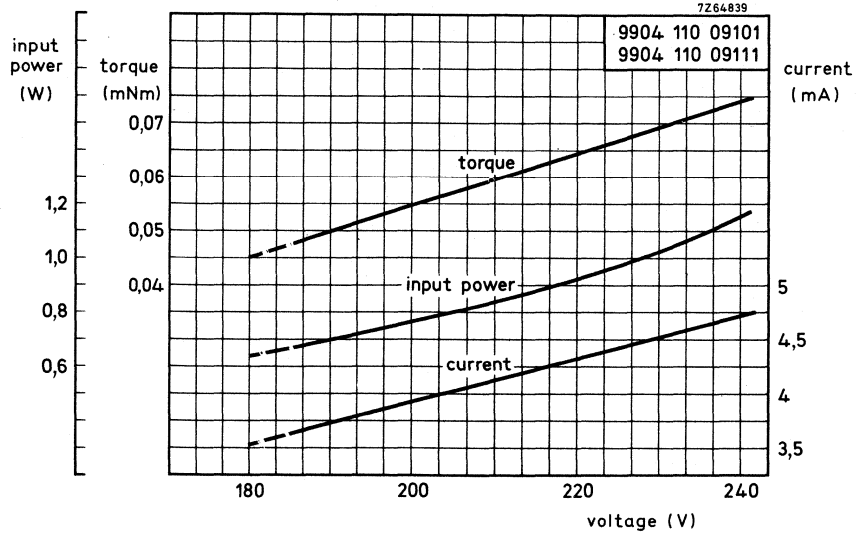
[3]) At 1 rev/min the working torque is 7,5 mNm if used in low torque mode and 30 mNm if used in high torque mode, without taking into account the efficiency of the gearbox.



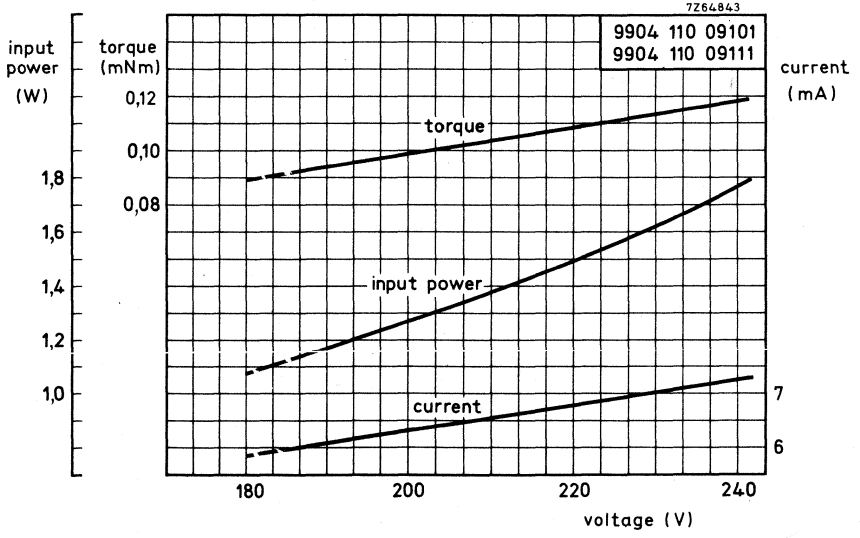

Typical curves for motors used with a series resistor of 12 kΩ.




Typical curves for motors used with a series resistor of 22 kΩ.




Typical curves for motors used with a series resistor of 47 kΩ.




Typical curves for motors used with a series resistor of 30 kΩ.

Silent version

| | | catalogue number |
|---|---|---|
| clockwise rotation | | 9904 110 09501 |
| counterclockwise rotation | | 9904 110 09511 |
| Nominal voltage | (V) | 24 |
| Frequency | (Hz) | 50 |
| Speed | (rev/min) | 375 |
| Current | (mA) | 5 |
| Input power | (W) | 0,12 |
| Starting torque [1] | (mNm) | 0,03 |
| Working torque [2] | (mNm) | 0,03 |
| Torque derating | (%) | 0,6 |
| Temperature increase of the motor | (degC) | 10 |
| Ambient temperature range | | |
| operating | ($^{o}$C) | -10 to +85 |
| storage | ($^{o}$C) | -40 to +100 |
| Permissible voltage fluctuations | (%) | -15 to +10 |
| Insulation according to CEE10 | | class 3 |
| Insulation test voltage | (V) | 500 |
| Bearings | | sintered bronze |
| Maximum radial force | (N) | 0,05 |
| Maximum axial force | (N) | 0,05 |
| Maximum inertial load | ($gcm^2$) | 0,002 |
| Housing | | steel, zinc plated |
| Weight | (g) | 14 |
| Noise level [3] | (dB - A scale) | 30 (typical value) |

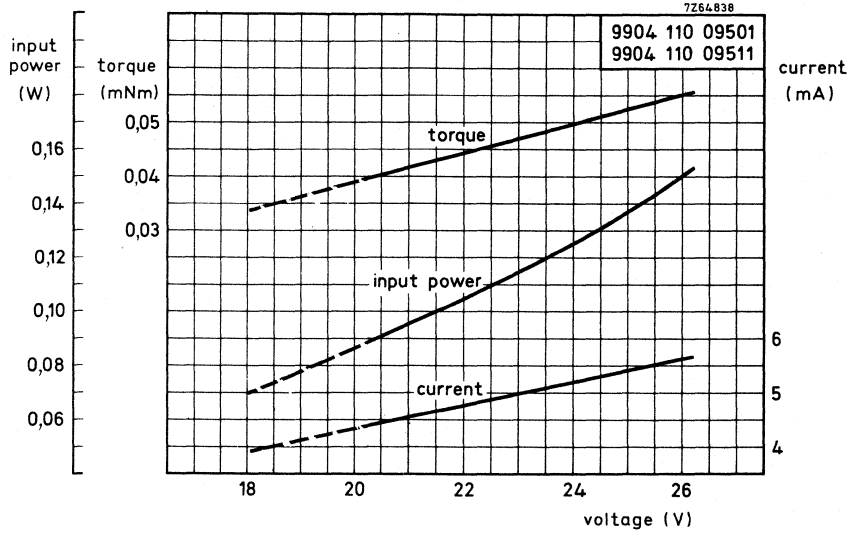
For typical curves, see next page.

This version can also be used for operation from 110 V/220 V, 50 Hz supply, provided that the appropriate resistor or capacitor is in series with the motor coil, see "Additional information".

1) If allowed for sufficient free movement of the motor spindle at the initial stage of starting (e.g. a gearbox).

2) At 1 rev/min the working torque is 11,2 mNm without taking into account the efficiency of the gearbox.

3) Measured with Brüel and Kjaer sonometer, type 2203; microphone at 40 mm from the motor, which is mounted on a gearbox.


7Z64838
9904 110 09501
9904 110 09511
input power (W)
torque (mNm)
current (mA)
0,16
0,14
0,12
0,10
0,08
0,06
0,05
0,04
0,03
6
5
4
torque
input power
current
18
20
22
24
26
voltage (V)

## ADDITIONAL INFORMATION

For operation from the mains, a resistor or capacitor must be connected in series with the motor coil of all versions. Any small changes in the specified motor data should then be taken into account [1]. These changes are minimized by using the resistor and capacitor values shown in the table below.

| motor | 110 V | | | | 220 V | | | |
|---|---|---|---|---|---|---|---|---|
| | R ± 5% | | C ± 10%, 125 Va.c. | | R ± 5% | | C ± 10%, 250 Va.c. | |
| | low torque mode [2] | high torque mode [3] | low torque mode [2] | high torque mode [3] | low torque mode [2] | high torque mode [3] | low torque mode [2] | high torque mode [3] |
| 9904 110 09601<br>09611 | 18 kΩ<br>(0,7 W) | 10 kΩ<br>(1,2 W) | 0,15 µF | 0,22 µF | 39 kΩ<br>(1,4 W) | 24 kΩ<br>(2,0 W) | 0,068 µF | 0,12 µF |
| 9904 110 09701<br>09711 | 10 kΩ<br>(1,4 W) | 5,6 kΩ<br>(2,2 W) | 0,33 µF | 0,47 µF | 20 kΩ<br>(2,9 W) | 12 kΩ<br>(4 W) | 0,15 µF | 0,22 µF |
| 9904 110 09101<br>09111 | 22 kΩ<br>(0,5 W) | 12 kΩ<br>(0,7 W) | 0,12 µF | 0,18 µF | 47 kΩ<br>(1,1 W) | 30 kΩ<br>(1,6 W) | 0,056 µF | 0,082 µF |
| 9904 110 09501<br>09511 | 12 kΩ (1 W) [4] | | 0,18 µF [4] | | 27 kΩ (2 W) [4] | | 0,082 µF [4] | |

1) Not applicable to versions for mains operation with a series resistor.
2) Working torque is 0,02 mNm.
3) Working torque is 0,08 mNm.
4) Working torque is 0,03 mNm.

# REVERSIBLE MOTORS

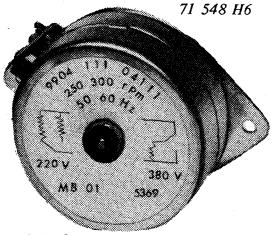
## SURVEY

The range of reversible motors comprises the following types:

- medium torque type, catalogue number 9904 111 04...
- high torque type, catalogue number 9904 111 05...
- high torque, slender type, catalogue number 9904 111 06...
- small type, catalogue number 9904 111 07...

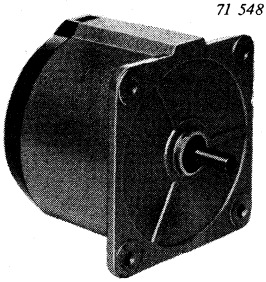
For required values of phasing capacitors see paragraph "Technical Data" of the relevant motors.

*71 548 H6*



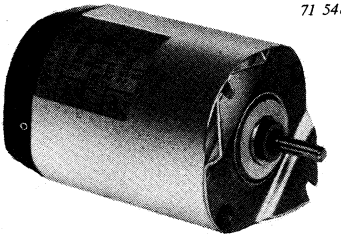

Medium torque type, catalogue number 9904 111 04...

*71 548 H1*



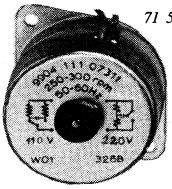
High torque type, catalogue number 9904 111 05...

*71 548 H2*



High torque slender type, catalogue number 9904 111 06...

*71 548 H8*




Small type, catalogue number 9904 111 07...

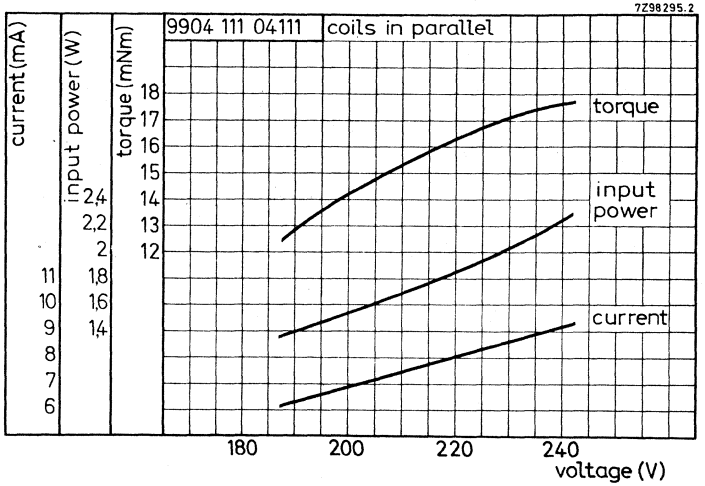
## MEDIUM TORQUE TYPE

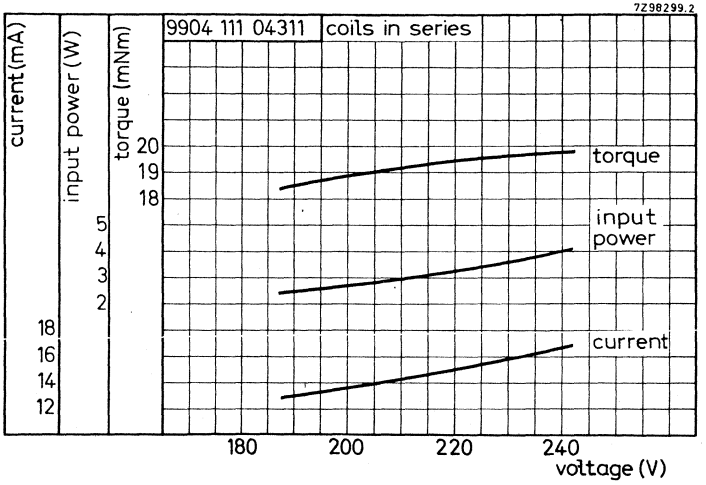
### TECHNICAL DATA

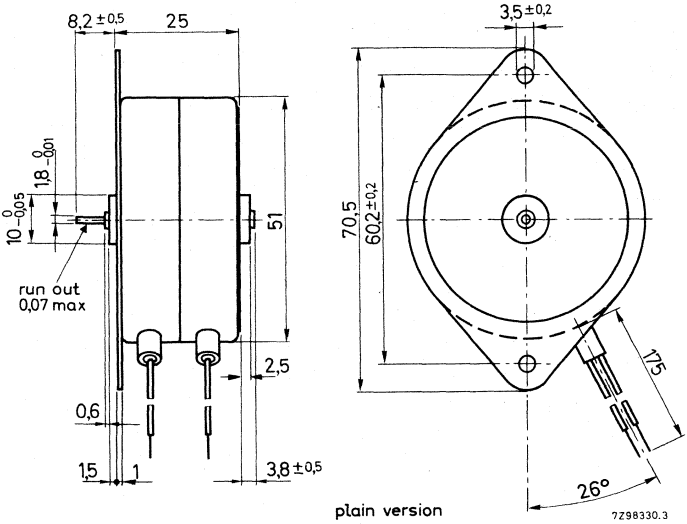
| | | catalogue number 9904 111 04... | | | |
|---|---|---|---|---|---|
| | | coils in parallel | | | |
| plain version | | 111 | 311 | 411 | 511 |
| version with pinion | | 131 | 331 | 431 | 531 |
| Nominal voltage | (V) | 220 | 110 \| 117 | 48 | 24 |
| Frequency | (Hz) | 50 \| 60 | 50 \| 60 | 50 \| 60 | 50 \| 60 |
| Speed | (rev/min) | 250 \| 300 | 250 \| 300 | 250 \| 300 | 250 \| 300 |
| Current | (mA) | 8 | 18 | 38 | 75 |
| Input power | (W) | 1,8 | | | |
| Starting torque | (mNm) | 10 | | | |
| Working torque | (mNm) | 10 | | | |
| Torque derating | (%) | 0,25 | | | |
| Temperature increase of the motor | (degC) | 25 | | | |
| Ambient temperature range [1] | (°C) | -20 to +70 | | | |
| Permissible voltage fluctuations | (%) | -15 to +10 | | | |
| Insulation according to CEE10 | | class 2 | | | |
| Insulation test voltage | (V) | 2500 | | | |
| Bearings | | slide bearings | | | |
| Maximum radial force | (N) | 5 | | | |
| Maximum axial force | (N) | 1,5 | | | |
| Housing | | zinc plated | | | |
| Weight | (g) | 160 | | | |
| Required phasing capacitor | (µF) | 0,056 \| 0,039 | 0,22 \| 0,18 | 1,2 \| 1 | 4,7 \| 3,3 |
| permissible a.c. voltage | (V) | 330 | 250 | 160 | 63 |

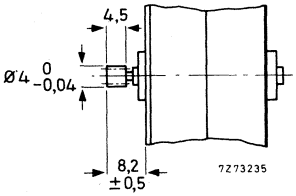
[1]) Continuous operation. Intermittent operation must allow for a maximum permissible stator temperature of 110 °C. See also paragraph "Parallel and series connection of the stator coils in reversible motors".

| catalogue number 9904 111 04... | | | |
|---|---|---|---|
| coils in series | | | |
| 111<br>131 | 311<br>331 | 411<br>431 | 511<br>531 |
| 380 | 220 | 110 \| 117 | 48 |
| 50 \| 60<br>250 \| 300 | 50 \| 60<br>250 \| 300 | 50 \| 60<br>250 \| 300 | 50 \| 60<br>250 \| 300 |
| 9 | 16 | 32 | 75 |
| 3,5 | | | |
| 15 | | | |
| 15 | | | |
| 0,25 | | | |
| 50 | | | |
| −20 to +50 | | | |
| −15 to +10 | | | |
| class 2 | | | |
| 2500 | | | |
| slide bearings | | | |
| 5 | | | |
| 1,5 | | | |
| zinc plated | | | |
| 160 | | | |
| 0,15 \| 0,12 | 0,47 \| 0,39 | 1,8 \| 1,5 | 10 \| 8 |
| 330 | 250 | 160 | 160 |


7Z98295.2
9904 111 04111
coils in parallel
current (mA)
input power (W)
torque (mNm)
torque
input power
current
voltage (V)
180
200
220
240

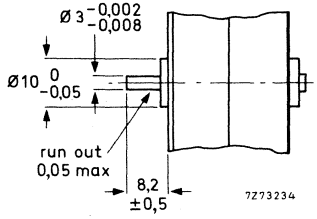

7Z98299.2
9904 111 04311
coils in series
current (mA)
input power (W)
torque (mNm)
torque
input power
current
voltage (V)
180
200
220
240



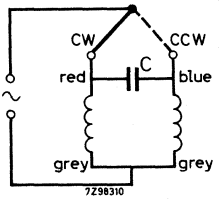




version with pinion

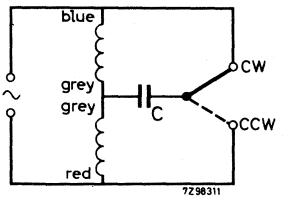
number of teeth = 10
module = 0, 3
addendum modification = +0, 2




Version with $\phi$3 mm spindle is available on request, only in minimum order quantities, and involves longer delivery times than versions above.




Coils in parallel




Coils in series

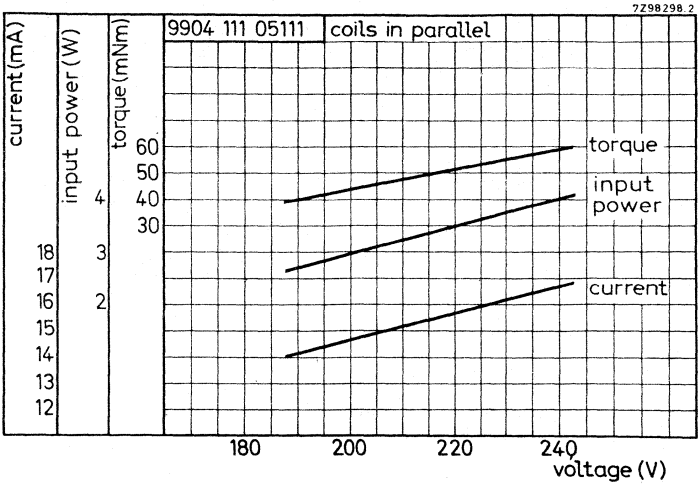
Connection diagrams

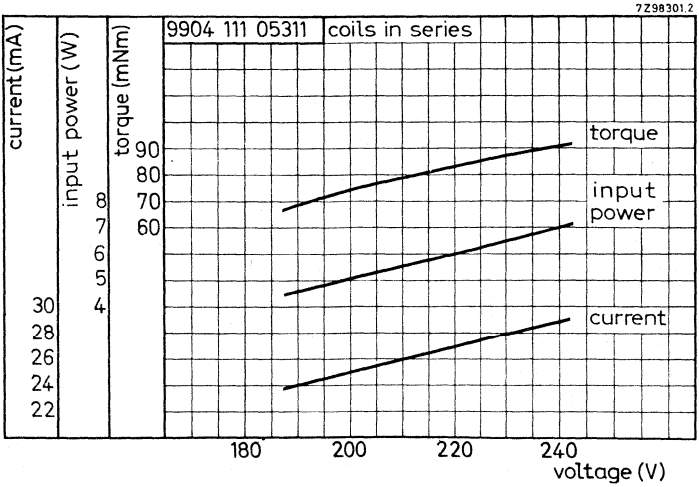
## HIGH TORQUE TYPE

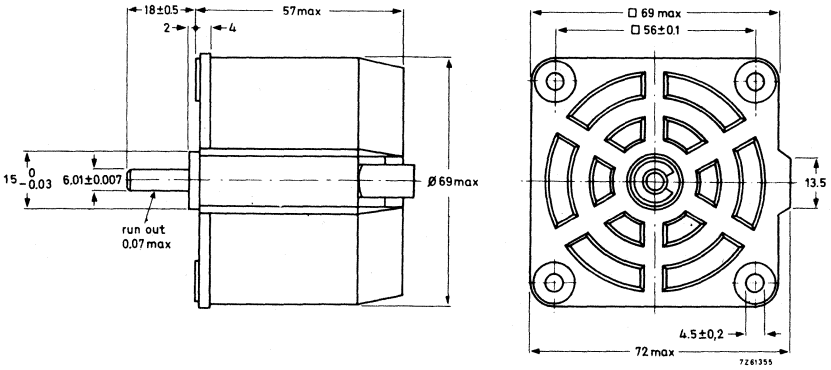
### TECHNICAL DATA

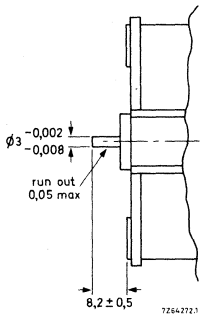
| | | catalogue number 9904 111 05... | | | |
|---|---|---|---|---|---|
| | | coils in parallel | | coils in series | |
| | | 111 | 311 | 111 | 311 |
| Nominal voltage | (V) | 220 | 110 | 380 | 220 |
| Frequency | (Hz) | 50 | 50 | 50 | 50 |
| Speed | (rev/min) | 250 | 250 | 250 | 250 |
| Current | (mA) | 17 | 30 | 10 | 30 |
| Input power | (W) | 3,3 | 4,5 | 3,7 | 6 |
| Starting torque | (mNm) | 32,5 | 32,5 | 40 | 55 |
| Working torque | (mNm) | 37,5 | 37,5 | 45 | 60 |
| Torque derating | (%) | 0,25 | 0,25 | 0,25 | 0,25 |
| Temperature increase of the motor | (degC) | 40 | 40 | 45 | 60 |
| Ambient temperature range [1] | (°C) | −20 to +70 | | −20 to +40 | |
| Permissible voltage fluctuations | (%) | −15 to +10 | | | |
| Insulation according to CEE10 | | class 2 | | | |
| Insulation test voltage | (V) | 2500 | | | |
| Bearings | | needle bearings | | | |
| Maximum radial force | (N) | 15 | | | |
| Maximum axial force | (N) | 5 | | | |
| Housing | | aluminium | | | |
| Weight | (g) | 550 | | | |
| Required phasing capacitor | (μF) | 0,12 | 0,47 | 0,18 | 0,82 |
| Permissible a.c. voltage | (V) | 330 | 250 | 330 | 250 |

[1]) Continuous operation. Intermittent operation must allow for a maximum permissible stator temperature of 110 °C. See also paragraph "Parallel and series connection of the stator coils in reversible motors".

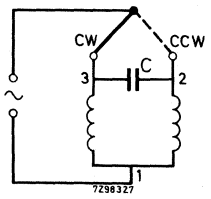

7Z98298.2
9904 111 05111
coils in parallel
current (mA)
input power (W)
torque (mNm)
18
17
16
15
14
13
12
4
3
2
60
50
40
30
torque
input power
current
180
200
220
240
voltage (V)


7Z98301.2
9904 111 05311
coils in series
current (mA)
input power (W)
torque (mNm)
30
28
26
24
22
8
7
6
5
4
90
80
70
60
torque
input power
current
180
200
220
240
voltage (V)

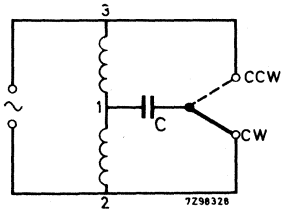



→ Note: - Motors with different voltage ratings or with ϕ3 mm spindle are available on request, only in minimum order quantities, and involve longer delivery times than standard versions.




Coils in parallel



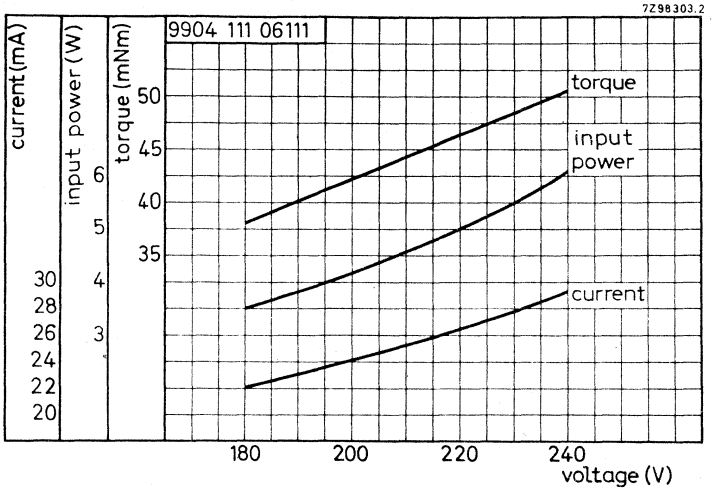

Coils in series

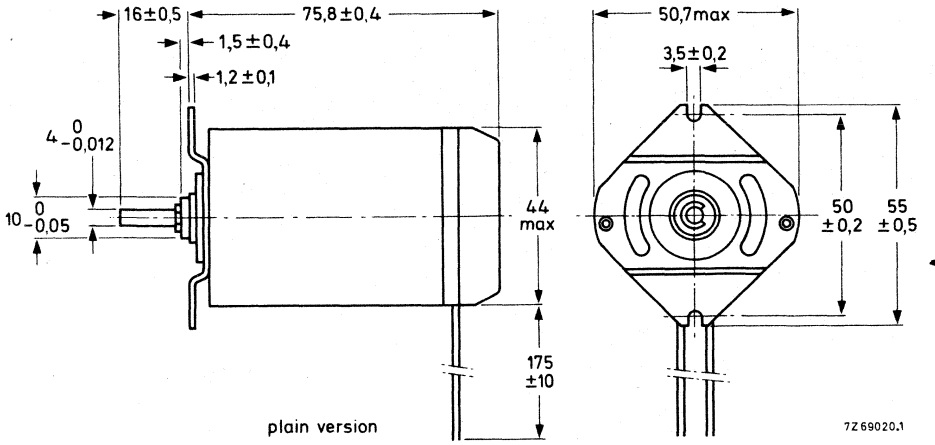
Connection diagrams

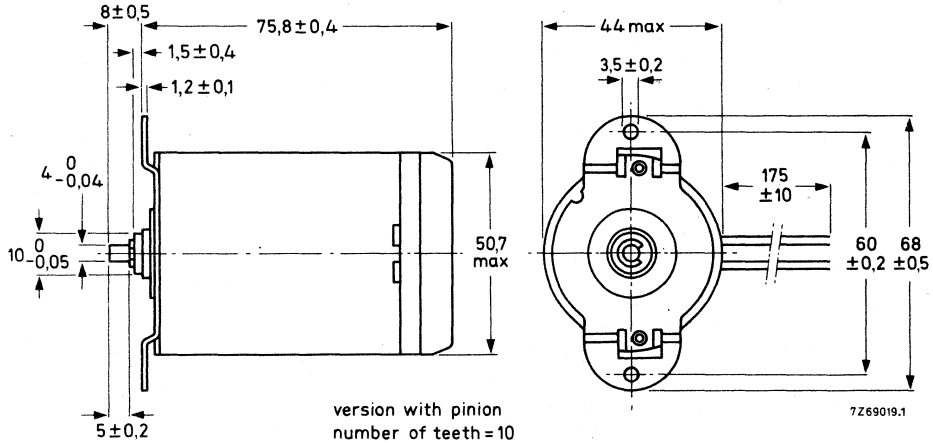
## HIGH TORQUE, SLENDER TYPE

### TECHNICAL DATA

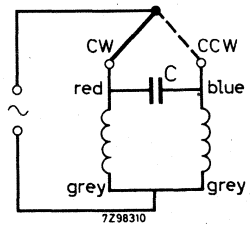
| | | catalogue number 9904 111 06... | | | | |
|---|---|---|---|---|---|---|
| plain version | | 111 | 211 | 311 | 411 | 511 |
| version with pinion | | 131 | | 331 | 431 | 531 |
| Nominal voltage | (V) | 220 | 117 | 110 | 48 | 24 |
| Frequency | (Hz) | 50 | 60 | 50 | 50 | 50 |
| Speed | (rev/min) | 250 | 300 | 250 | 250 | 250 |
| Current | (mA) | 27 | 60 | 50 | 110 | 200 |
| Input power | (W) | 5 | 6 | 5 | 5 | 5 |
| Starting torque | (mNm) | 30 | 30 | 30 | 25 | 30 |
| Working torque | (mNm) | 37,5 | 37,5 | 37,5 | 35 | 37,5 |
| Torque derating | (%) | 0,25 | 0,25 | 0,25 | 0,25 | 0,25 |
| Temperature increase of the motor | (degC) | 35 | 45 | 35 | 35 | 35 |
| Ambient temperature range | ($^{o}$C) | -20 to +70 | | | | |
| Permissible voltage fluctuations | (%) | -10 to +10 | | | | |
| Insulation according to CEE10 | | class 2 | | | | |
| Insulation test voltage | (V) | 2500 | | | | |
| Bearings | | slide bearings | | | | |
| Maximum radial force | (N) | 15 | | | | |
| Maximum axial force | (N) | 1,5 | | | | |
| Housing | | aluminium | | | | |
| Weight | (g) | 300 | | | | |
| Required phasing capacitor | (µF) | 0,18 | 0,68 | 0,68 | 3,5 | 14 |
| Permissible a.c. voltage | (V) | 330 | 250 | 250 | 160 | 160 |


7Z98303.2
9904 111 06111
current (mA)
input power (W)
torque (mNm)
30
28
26
24
22
20
6
5
4
3
50
45
40
35
torque
input power
current
180
200
220
240
voltage (V)



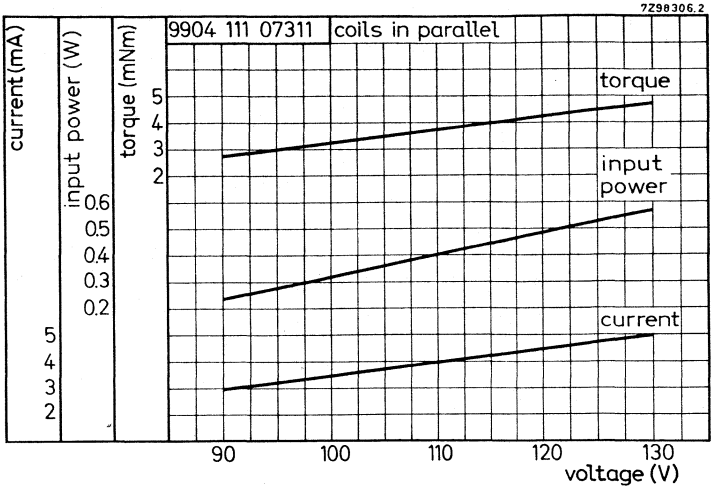

version with pinion
number of teeth = 10
module = 0,3
addendum modification = +0,2

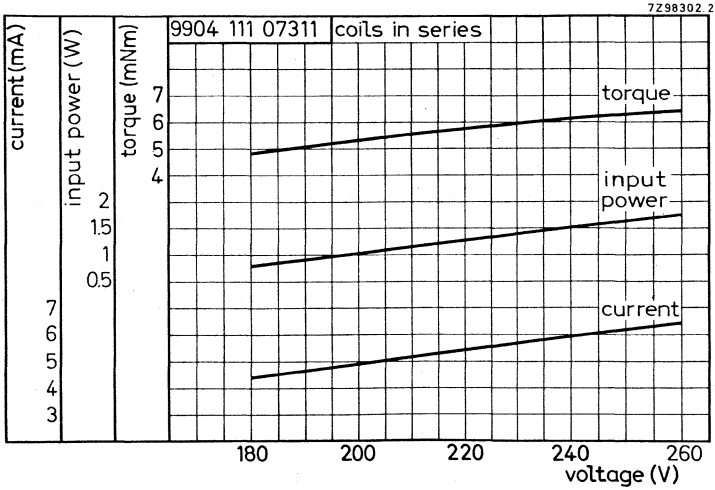


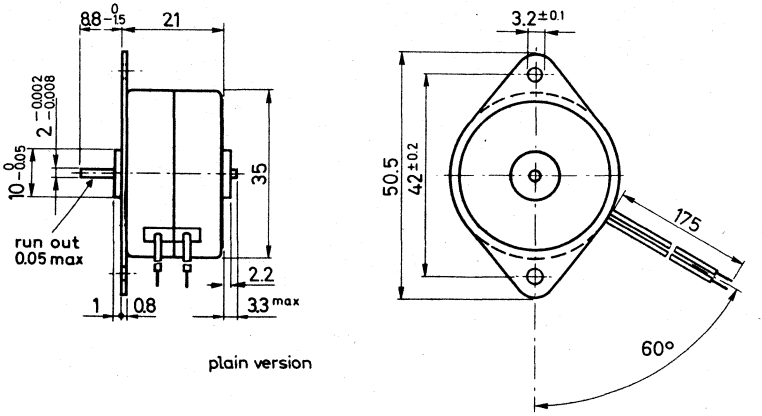
## SMALL TYPE

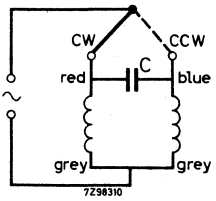
### TECHNICAL DATA

| | | catalogue number 9904 111 07... | | | | | |
|---|---|---|---|---|---|---|---|
| | | coils in parallel | | | coils in series | | |
| plain version | | 311 | 411 | 511 | 311 | 411 | 511 |
| version with pinion | | 331 | 431 | 531 | 331 | 431 | 531 |
| Nominal voltage | (V) | 110/117 | 48 | 24 | 220 | 110/117 | 48 |
| Frequency | (Hz) | 50/60 | | | | | |
| Speed | (rev/min) | 250/300 | | | | | |
| Current | (mA) | 4,5 | 8 | 18 | 5,5 | 12 | 18 |
| Input power | (W) | 0,5 | 0,4 | 0,45 | 1,3 | 1,2 | 0,9 |
| Starting torque | (mNm) | 2,5 | | | 4,5 | | |
| Working torque | (mNm) | 2,5 | | | 4,5 | | |
| Torque derating | (%) | 0,25 | | | 0,25 | | |
| Temperature increase of the motor | (degC) | 10 | | | 25 | | |
| Ambient temperature range | (°C) | −20 to +70 | | | | | |
| Permissible voltage fluctuations | (%) | −15 to +10 | | | | | |
| Insulation according to CEE 10 | | class 1 | | | | | |
| Insulation test voltage | (V) | 2500 | | | | | |
| Bearings | | slide bearings | | | | | |
| Maximum radial force | (N) | 2,5 | | | | | |
| Maximum axial force | (N) | 0,75 | | | | | |
| Housing | | zinc plated | | | | | |
| Weight | (g) | 75 | | | | | |
| Required phasing capacitor | (μF) | 0,047 | 0,22 | 1 | 0,18 | 0,68 | 2 |
| permissible a.c. voltage | (V) | 250 | 160 | 160 | 160 | 160 | 160 |

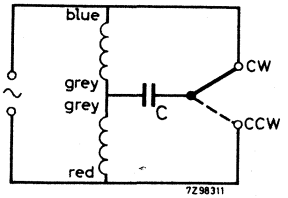

7Z98306.2
9904 111 07311
coils in parallel
current (mA)
input power (W)
torque (mNm)
torque
input power
current
voltage (V)
90
100
110
120
130


7Z98302.2
9904 111 07311
coils in series
current (mA)
input power (W)
torque (mNm)
torque
input power
current
voltage (V)
180
200
220
240
260




Coils in parallel




Coils in series

Connection diagrams

**Note:** - Motors with different voltage ratings and/or provided with a pinion (see above) are available on request only in minimum order quantities and involve longer delivery times.

# Stepper motors


| | |
|---|---|
| General | B3 |
| 4-phase unipolar stepper motors | B23 |
| 8-phase unipolar stepper motors | B73 |
| 2-phase bipolar stepper motors | B91 |
| 4-phase bipolar stepper motors | B117 |

# INTRODUCTION

A stepper motor converts digital information into proportional mechanical movement; it is an electro-mechanical device whose spindle rotates in discrete steps, following command pulses in number and speed, when operated from a source that provides programmed current reversals.

After the appearance of the stepper motor in applications traditionally employing digital control, the advantages of precise and rapid positioning of objects using electronics became more obvious and this, in turn, led to a greater variety of applications. These now include:

- paper and magnetic tape drives
- teletype and strip printers
- camera iris control, film transport and colour film sorting
- co-ordinate plotters, incremental chart recorders and variable speed chart drives
- medical equipment, e.g. blood samplers, lung analysers and kidney pumps
- fuel flow control, valve control and variable speed syringe pumps
- taxi-meters, card readers, production line pulse counters, and automatic weighing and labelling systems
- digital-to-analogue converters and remote position indicating equipment.

All have one thing in common - controlled motion. Wherever controlled movement and/or positioning is necessary, the stepper motor can be applied. And usually to advantage.

From a mechanical viewpoint, the stepper motor has simple positional control, reliability and precision - it has, however, introduced the need for electronics. Where previously, simple, mechanically operated switches often provided adequate control, the need for a better method has arisen. The advantages of stepper motor systems have been gained at some expense to the simplicity of the motor control: although still unsophisticated by modern standards, some electronic circuits are necessary.

The full benefit of a stepper motor can only be realized if it is correctly driven. It requires a d.c. supply, an electronic switch and a source of control pulses (digital information). The appropriate d.c. supply is routed to the motor via the electronic switch. In effect, the motor moves through one step for each control pulse applied to the electronic switch. The angle of the step depends upon the type of motor and can be from as little as $3^{o}$ 45' to as much as $15^{o}$. Consequently, if 24 pulses are fed to the switch, the shaft of a motor with a $15^{o}$ step-angle will complete one revolution. The time taken for this action is entirely a function of the rate at which control pulses are applied. These may be generated by an oscillator with adjustable frequency, or derived from one of a variety of sources: perforated tape, magnetic tape, etc.

# PRINCIPLES

## MOTORS

The position assumed by the spindle of a stepper motor depends upon the relationship between a number of magnetic poles on its stator assembly and a number of magnetic poles on its rotor. Since the latter is a permanent magnet, the poles are fixed. The stator assembly, however, comprises two or more stators, each having a coil through which current is passed to form a magnet. By reversing the direction of current flowing in a coil, therefore, the north and south poles can be transposed. Reversing the current-flow through successive stator coils creates a rotating magnetic field which the permanent-magnet rotor follows. Speed of rotation is thus governed by the rate at which the stator coils (and hence the electro-magnetic poles) are switched and the direction of rotation by the actual switching sequence.

There are two methods by which the current-flow through stator coils can be reversed and this has led to two classes of stepper motor: those designed for uni-polar drive and those for bi-polar drive.

For ease of description, illustrations in this section which give a diagramatic representation of a stepper motor show only a 2-pole rotor although it could have as many as 24: the operating principles, however, are the same.

### Motors for Uni-polar Drive

Each stator coil of a motor designed for uni-polar drive is provided with a centre-tap which is connected to one side of the supply, say, the positive. The direction of current flowing through a coil is then determined by the end to which the negative supply line is connected via a switching device. Switching coil-halves results in the magnetic poles of the relevant stator being reversed.

#### 2-stator motors (4-phase)

Fig. 1a shows a 4-phase stepper motor in which phases P and R are energized: the rotor assumes the position indicated. If switch S1 is now operated (phases Q and R energized), the conditions illustrated in Fig. 1b obtain, i.e. the rotor has moved through 90 degrees. From this it can be seen that by operating switches S1 and S2 alternately, the rotor can be made to rotate in $90^{o}$ steps. The direction of rotation can be reversed by altering the switching sequence.

#### 4-stator motors (8-phase)

The 8-phase motor illustrated in Fig. 2 functions in the same manner as the 4-phase motor described previously. In this case, the angle through which the rotor turns at each step is halved. This is because the stator assembly now has twice the number of magnetic poles.

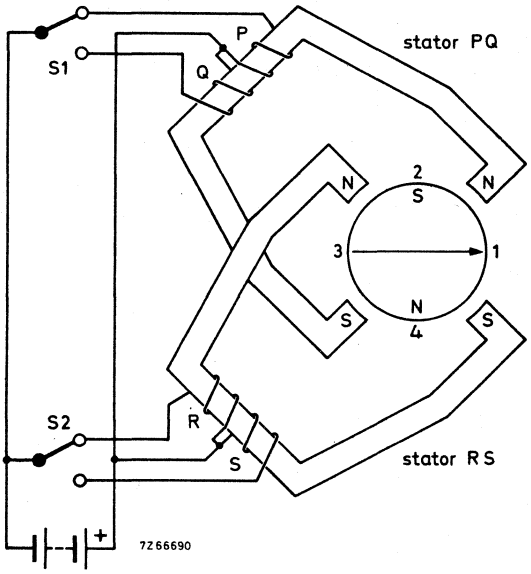

P
S1
Q
stator PQ
N
2
S
N
3
1
N
4
S
S
S2
R
S
stator RS
+
7Z66690

Fig. 1a

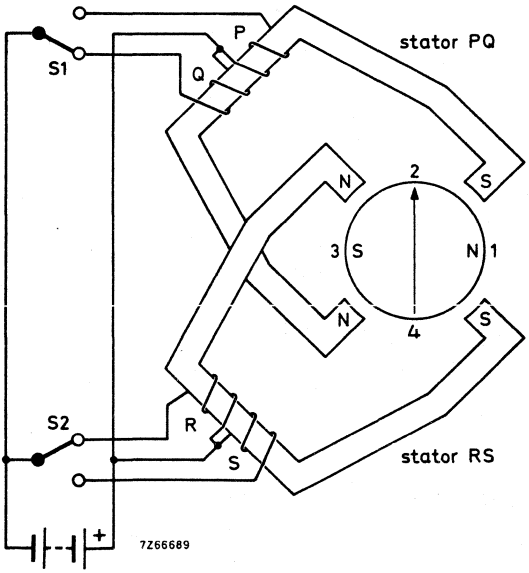

P
S1
Q
stator PQ
N
2
S
3
S
N
1
N
4
S
S2
R
S
stator RS
+
7Z66689

Fig. 1b

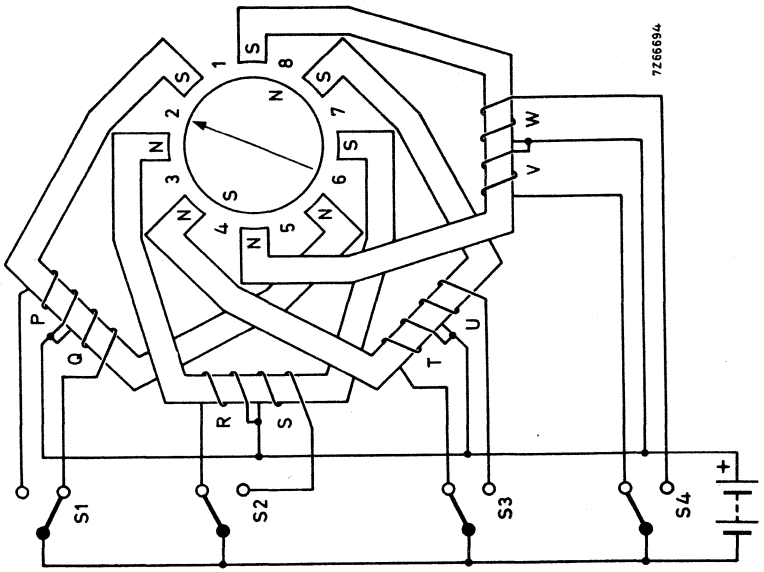

7Z66694
1
2
3
4
5
6
7
8
N
S
P
Q
R
S
T
U
V
W
S1
S2
S3
S4
+
-

Fig. 2b

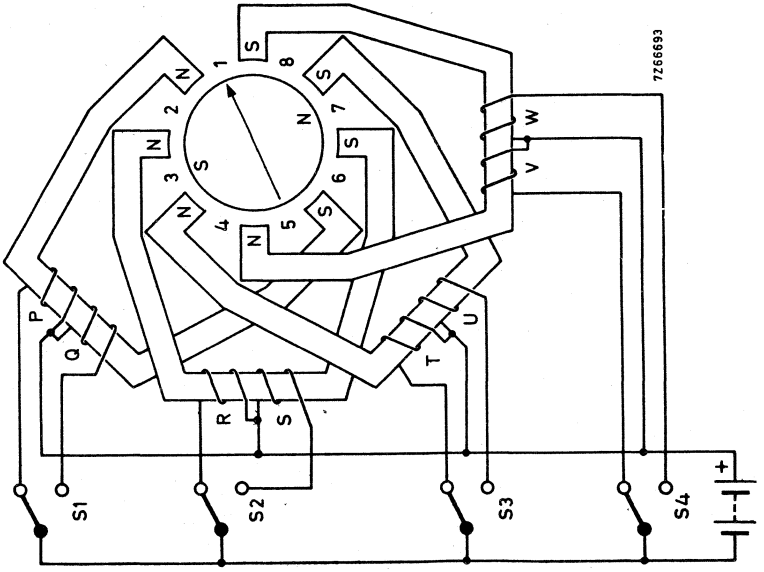

7Z66693
1
2
3
4
5
6
7
8
N
S
P
Q
R
S
T
U
V
W
S1
S2
S3
S4
+
-

Fig. 2a

**Motors for Bi-polar Drive**

The stator coils of a motor designed for bi-polar drive have no centre-tap. Instead of using alternate coil-halves to produce a reversal of current-flow through the stator windings (as for uni-polar drive), the current is now reversed through the entire coil by switching both supply lines. Operation of a motor with bi-polar drive is identical to that of one with uni-polar drive.

2-stator motors (2-phase)

Operation of a 2-phase motor with bi-polar drive is shown in Fig.3.

4-stator motors (4-phase)

The 4-phase motor with bi-polar drive is shown in Fig. 4.

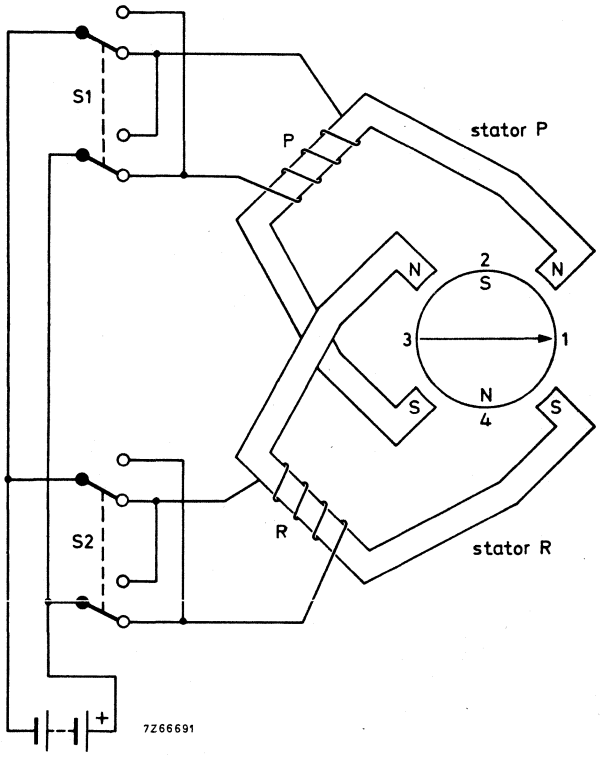



Fig. 3a

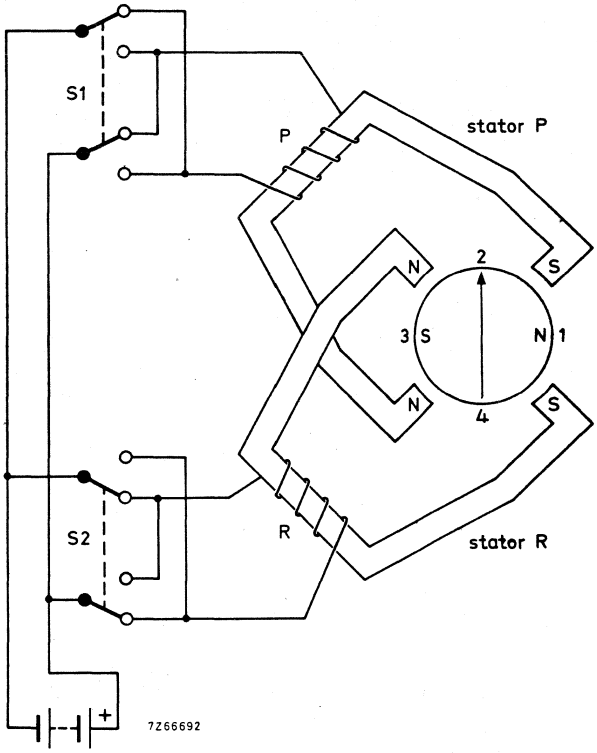



Fig. 3b

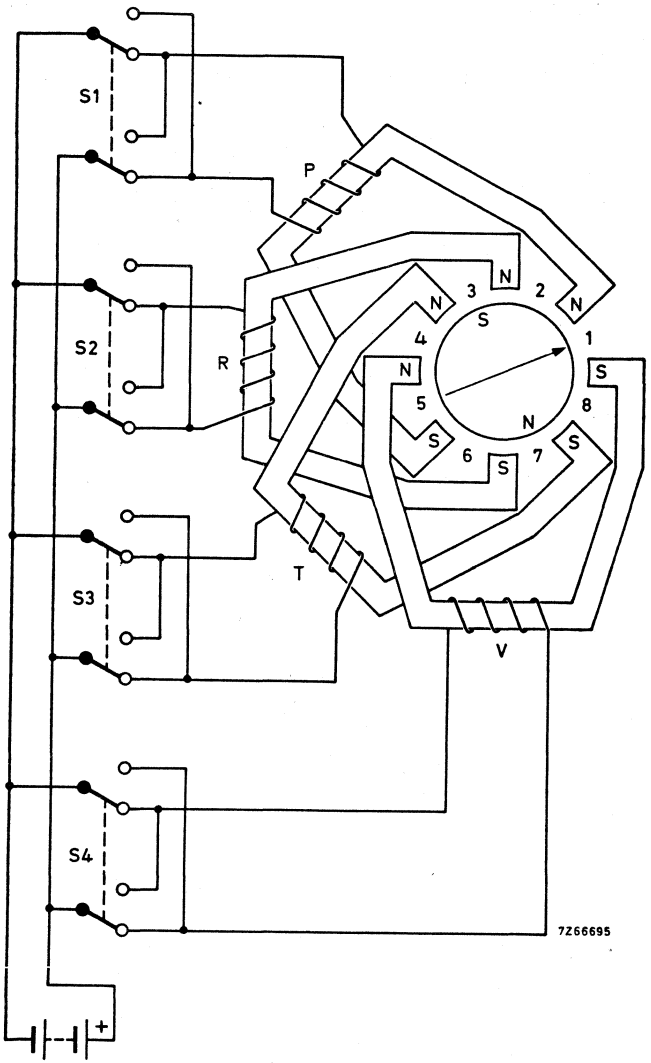



Fig. 4a

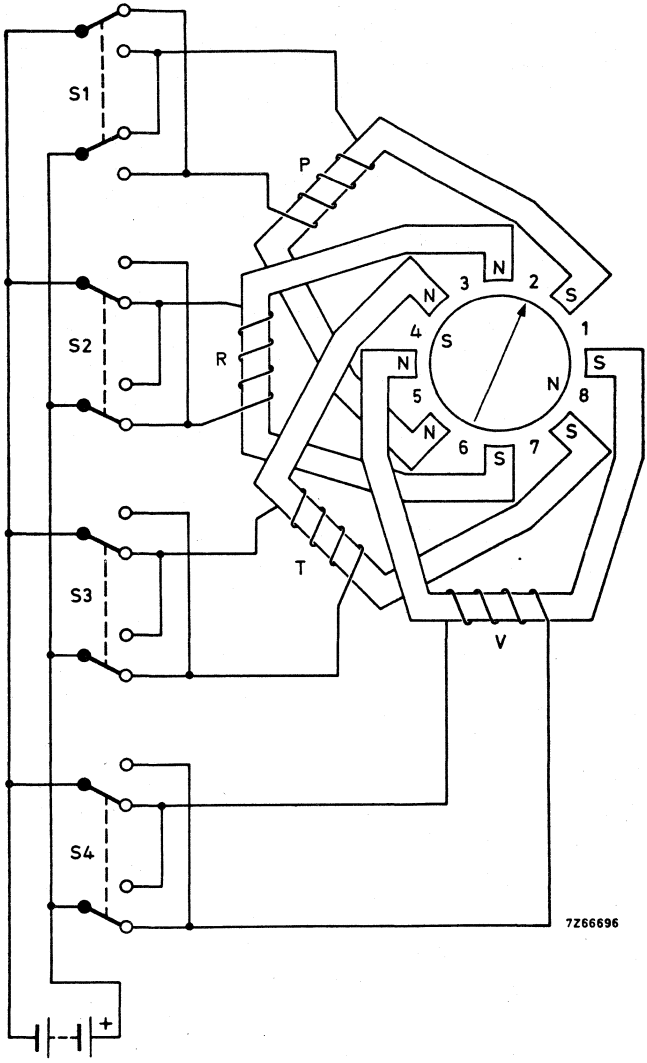



Fig. 4b

**Features of the bi-polar drive**

The advantages of using motors with bi-polar drive are shown in Fig. 5. This compares the performance of type PD16 motors when employing uni-polar and bi-polar drive. A considerable increase in available torque is apparent using the bi-polar version: the associated electronics, however, are necessarily somewhat more complex.

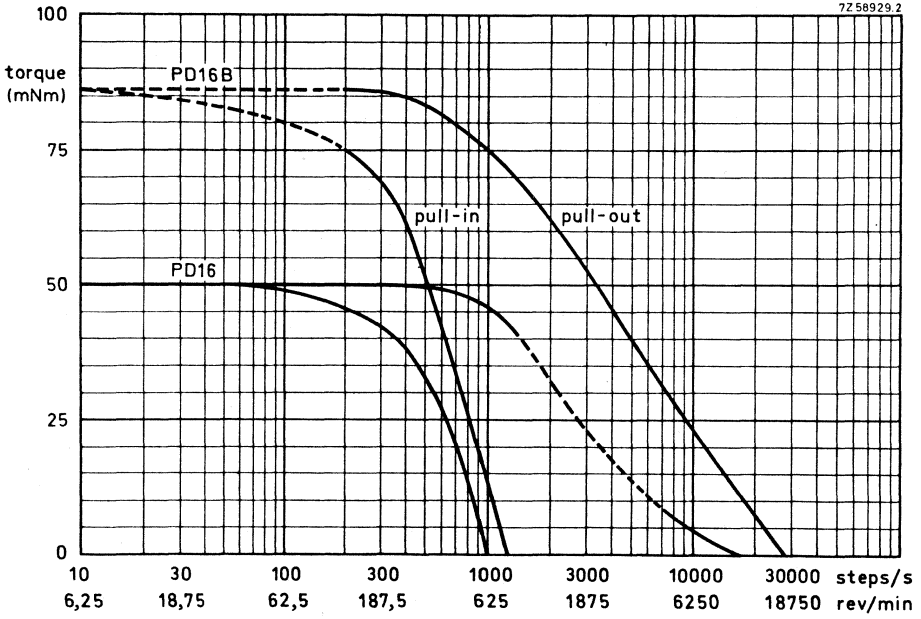



Fig. 5

## THE ELECTRONICS

As indicated previously, stepper motors operate from a d.c. supply via sequential switching which produces current reversals through successive stator windings. A d.c. supply, appropriate to the particular motor-type and the method of drive, is usually derived from the a.c. mains by means of a transformer and rectifier circuit. Switching is performed either by a mechanical switch (Fig. 6a) or by an electronic switch (Fig. 6b).

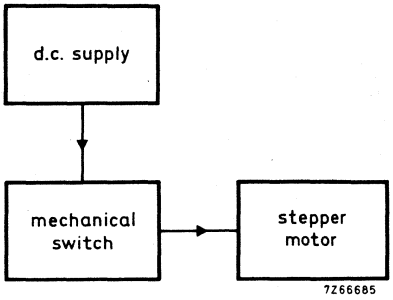



Fig. 6a

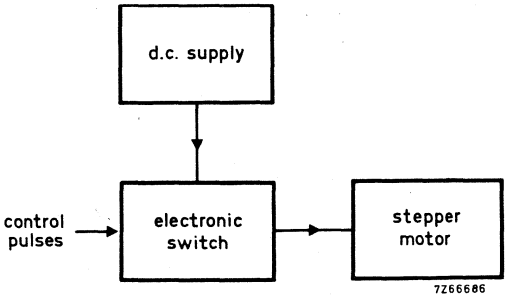



Fig. 6b

The mechanical switch requires a physical force to produce the required switching, whereas the electronic switch provides the necessary control directly from a series of pulses (i.e. digital information). In general, a mechanical system has several disadvantages when compared with its electronic counterpart:

- lower switching speeds
- wear on moving parts and, hence, increased maintenance
- contact vibration, leading to lower efficiency and decreased reliability
- longer switch-over times.

The features listed detract from the characteristics of the stepper motor itself. The electronic switch, however, optimizes the motor characteristics; this is because it has:

- a high switching speed
- high reliability
- no maintenance requirements
- a very short switch-over time
- a low power control capability.

Fig. 7 illustrates the detrimental effect upon current-flow through a coil, and hence torque, caused by the extended switching time inherent in mechanical switches.

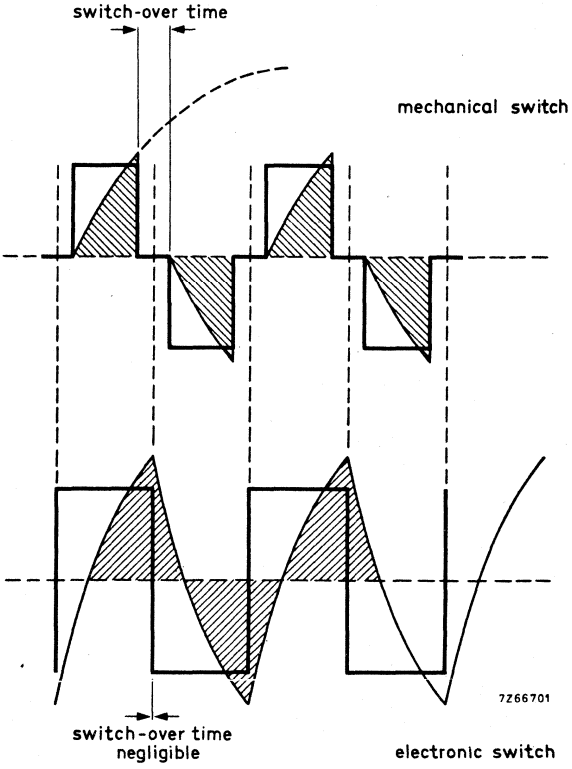



Fig. 7

**Uni-polar Drive**

Stepper motors operated with a uni-polar drive system require the following electronics (Fig. 8):

- a transformer, to reduce the value of the available a.c. mains
- a rectifier, to convert the low a.c. supply into the appropriate d.c. motor supply voltage
- a source of control pulses (e.g. an oscillator)
- an electronic switch, this arranges the incoming control pulses into the sequential phase switching necessary for the stator coils
- a compensating network, to improve the rise-time of current through a stator coil when power is initially applied.

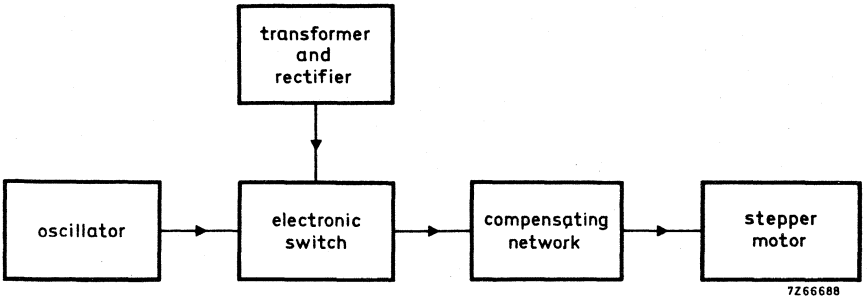



Fig. 8

The compensating network (Fig. 9) consists of a resistor $R_V$ and a capacitor $C_V$ for each phase. The resistor $R_V$ is connected in series with the stator phase P and the capacitor is connected in parallel with the phase and the switching element TR. This arrangement allows the capacitor to discharge, thereby providing a current peak (Fig. 10), at the amount its associated phase is switched into circuit. The capacitor regains its charge during the period for which the switching element is in the off state.

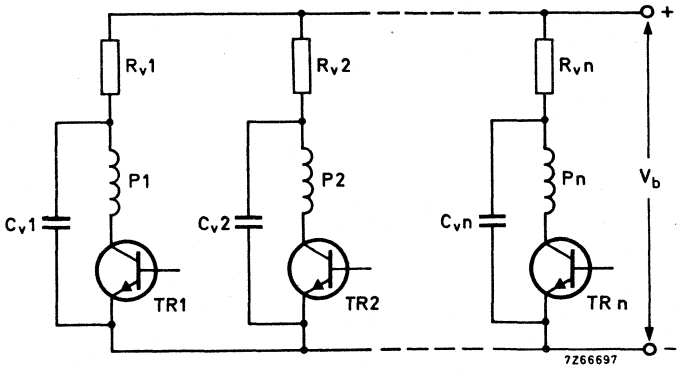



Fig. 9

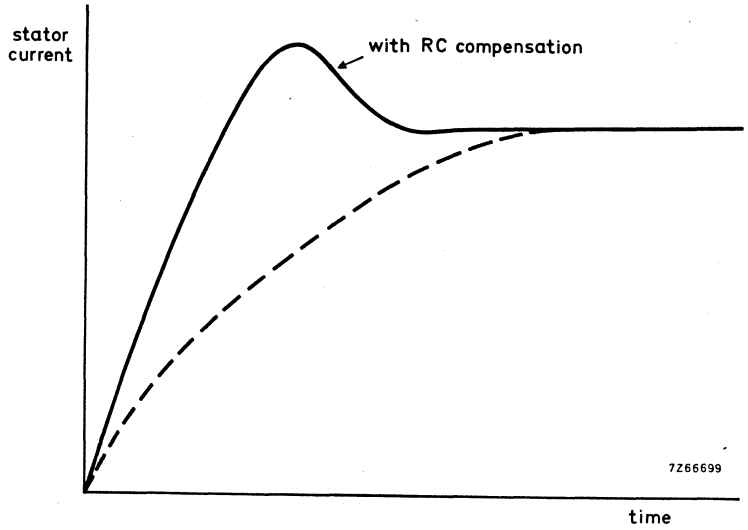



Fig. 10

**Bi-polar Drive**

Stepper motors operated with a bi-polar drive system require the following electronics (Fig. 11):

- a transformer, to reduce the value of the available a.c. mains
- a rectifier, to convert the low a.c. supply into the appropriate d.c. motor supply voltage
- a source of control pulses (external to the electronics, as such)
- an electronic switch, known as a "bi-polar constant current drive" (BCCD).

The BCCD unit converts the incoming control pulses into the requisite current reversals through successive stator coils, supplying them from a 60 V source which employs a chopper circuit. This ensures that the current through a stator coil reaches its maximum value in the shortest possible time, maintains that value irrespective of opposing currents generated by the rotor and reduces the power consumption of the overall system.

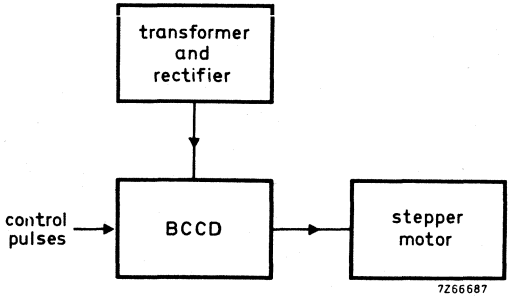



Fig. 11

Fig. 12 shows a basic constant current, bi-polar drive circuit for one stator coil. Transistors TR1 to TR4 perform the bi-polar switching function for a stator coil L and correct sequential switching of a number of these circuits, to provide "step-wise" rotation of the motor in either direction, is controlled by the logic circuit. If TR1 and TR4 are conducting (TR2 and TR3 off), conventional current-flow through the stator coil is from 1 to 2 (Fig. 12): if TR2 and TR3 are conducting (TR1 and TR4 off), it is in the opposite direction i.e. from 2 to 1.

When TR1 and TR4 are switched on by the control logic, current starts to flow and quickly increases exponentially through resistor R1, transistor TR1, stator coil L and transistor TR4. On reaching a predetermined maximum permissible value, the voltage developed across R1 causes the level detector to operate. The output from the level detector is fed to gate A and this switches off TR4 as soon as that value is reached. At this moment, the energy stored in the magnetic field of the stator coil maintains a temporarily increasing voltage across the coil and an exponential fall in current results through the circuit R1, TR1, L and diode D2, reducing the voltage across R1. When a predetermined minimum value is reached, the level detector causes TR4 to conduct again and this action continues for as long as the logic circuit demands the conduction of TR1 and TR4: resultant current-flow is shown in Fig. 13.

A similar action occurs when the control logic demands the conduction of TR2 and TR3 but, in this case, TR3 is switched by gate B.

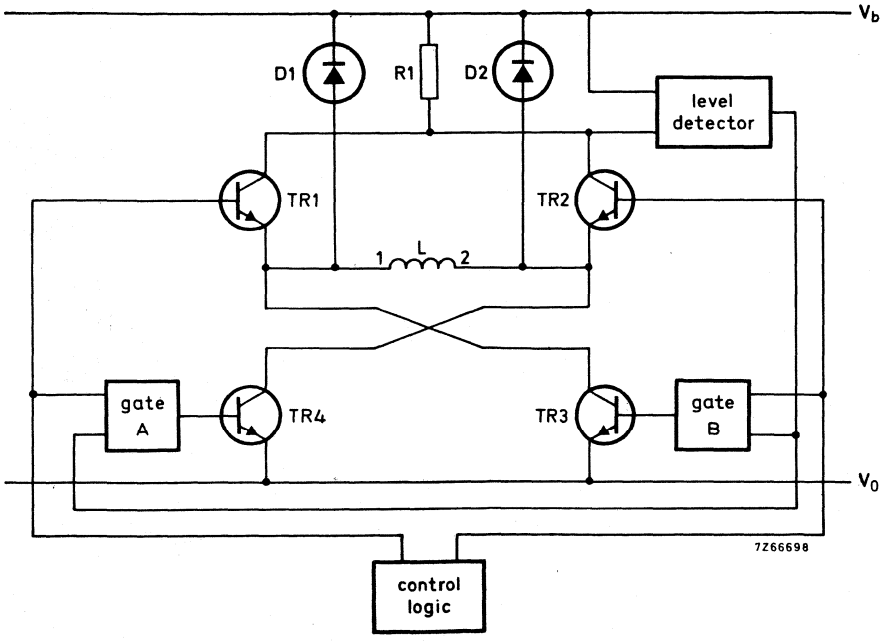



Fig. 12

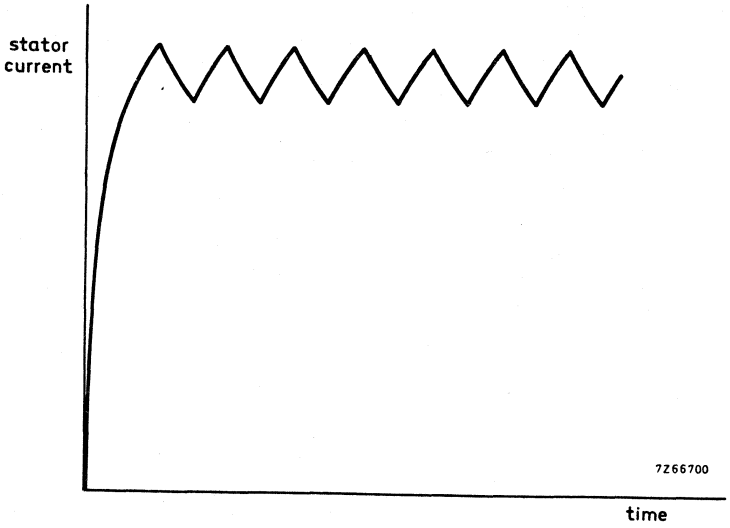



Fig. 13

# TERMINOLOGY

(in alphabetical order)

Detent Torque: The maximum torque that can be applied to the spindle of an unexcited motor without causing continuous rotation. Unit: mNm.

Deviation: The change in spindle position from the unloaded holding position when a certain torque is applied to the spindle of an excited motor. Unit: degrees.

Holding Torque: The maximum steady torque that can be externally applied to the spindle of an excited motor without causing continuous rotation. Unit: mNm.

Maximum Pull-In Rate (Speed): The maximum switching rate (speed) at which an unloaded motor can start without losing steps. Unit: steps/s (rev/min).

Maximum Pull-Out Rate (Speed): The maximum switching rate (speed) which the unloaded motor can follow without losing steps. Unit: steps/s (rev/min).

Maximum Working Torque: The maximum torque that can be obtained from the motor. Unit: mNm.

Overshoot: The maximum amplitude of the oscillation around the final holding position of the rotor after cessation of the switching pulses. Unit: degrees.

Permanent Overshoot: The number of steps the rotor moves after cessation of the switching pulses. Unit: steps.

Phase: Each winding connected across supply voltage.

Pull-In Rate (Speed): The maximum switching rate (speed) at which a frictionally loaded motor can start without losing steps. Unit: steps/s (rev/min).

Pull-In Torque: The maximum torque that can be applied to a motor spindle when starting at the pull-in rate. Unit: mNm.

Pull-Out Rate (Speed): The maximum switching rate (speed) which a frictionally loaded motor can follow without losing steps. Unit: steps/s (rev/min).

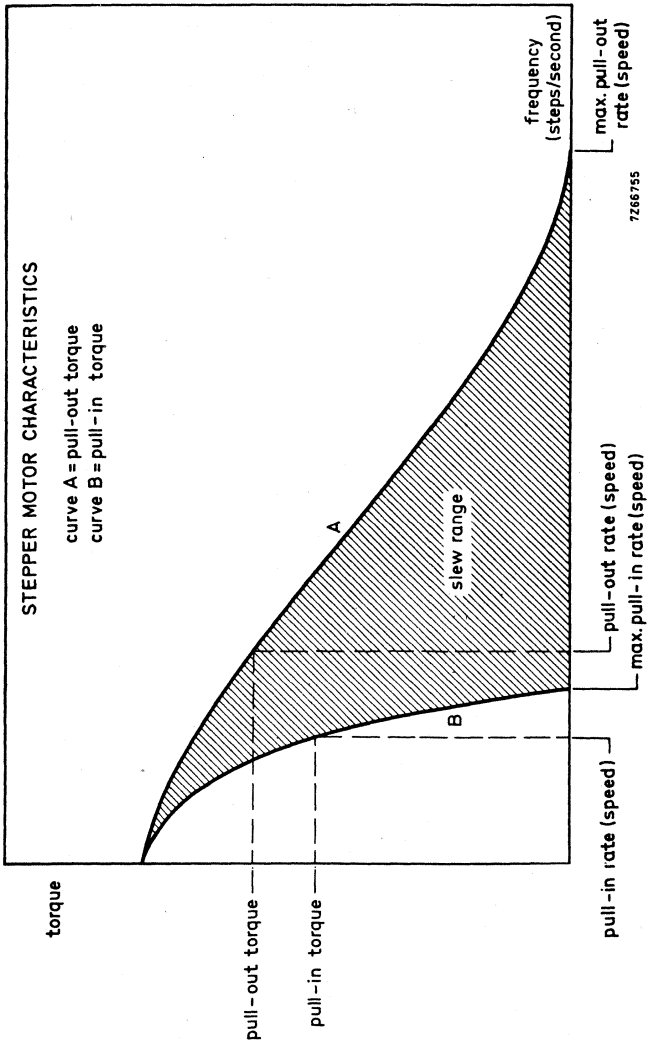
Pull-Out Torque: The maximum torque that can be applied to a motor spindle when running at the pull-out rate. Unit: mNm.

Start Range: The range of switching rates within which a motor can start without losing steps.

Step Angle: The nominal angle that the motor spindle must turn through between adjacent step positions. Unit: degrees.

Stepping Rate: The number of step positions passed by a fixed point on the rotor per second. Unit: steps/s.

Slew Range: The range of switching rates within which a motor can run unidirectionally and follow the switching rate (within a certain maximum acceleration) without losing steps, but cannot start, stop or reverse.




Typical stepper motor curves illustrating the terminology used.

# MOTOR SPECIFICATIONS

The following pages contain full specifications for each motor type. Values given are typical, they apply at an ambient temperature of 15 °C to 35 °C, an atmospheric pressure of 860 to 1060 mbar and a relative humidity of 45 to 75 %.

The following points should be noted:

Maximum motor temperatures are as follows:

- PD-series: 125 °C
- ID -series: 100 °C.

Temperature increase in these motors depends upon their power consumption. Motors employing unipolar drive 9904 131 03003, 9904 131 03004, or SAA1027, operate from a low supply voltage and have a low power input which limits the increase in motor temperature. If motors with unipolar drive are operated at low ambient temperatures, a higher supply voltage, giving correspondingly higher torque, is permissible.

Motors employing bipolar constant current drive 4322 027 90070 operate from a high (60 V) supply voltage and have a higher input power which causes a greater increase in motor temperature. They should either be mounted on a surface that will act as a heat-sink or have forced cooling (for further details see Description of the bipolar constant current drive).

At ambient temperatures above 25 °C, the torque of motors, both for unipolar and bipolar drive, will decrease by approximately 0,2 % per °C. There is also a derating at low ambient temperatures, more so for unipolar motors operating in the slew range: pull-in, however, is not affected.

Instability of a stepper motor's performance can occur under certain circumstances. The mass moment of the rotor and its load, together with the magnetic stiffness, forms a spring system which causes:

- a resonance at low stepping rates
- hunting around the required speed at high stepping rates (this is more pronounced with 8-phase motors operating in their slew range).

These unstable areas are indicated by broken lines on the performance curves appearing in this section.

Resonance can be minimized by applying the correct amount of friction to the motor drive-spindle.

Hunting can be minimized by attaching a "Lancaster damper" to the motor spindle. A Lancaster damper basically consists of a disc that is frictionally attached over the motor spindle. Ordinarily the disc rigidly follows the rotational speed of the spindle but when hunting occurs, it moves through a small angle in relation to the spindle and absorbs the fluctuation in speed. The mass moment of the disc and the required friction depend entirely upon the application and must be individually determined in each case.

# 4-PHASE UNIPOLAR STEPPER MOTORS

This range comprises nine types of permanent magnet stepper motor:

- 5 industrial digital (ID) types;
- 4 professional digital (PD) types.

The ID types may be used in systems for which the environmental conditions are less demanding. The PD types are intended for better class instruments and for computer peripherals. All motors of this range are very suitable for positioning applications and for use in variable speed drives.

## DESCRIPTION

The motors have a 4-phase stator and a permanent magnet rotor with 24 poles (step angle of 7° 30') or 12 poles (step angle of 15°) in a rugged and simple construction. The motor coils are adapted to the unipolar electronic switch 9904 131 03003 or the unipolar integrated circuit SAA1027 (see relevant data sheets).

## CONNECTION DIAGRAMS

ID types with unipolar electronic switch 9904 131 03003

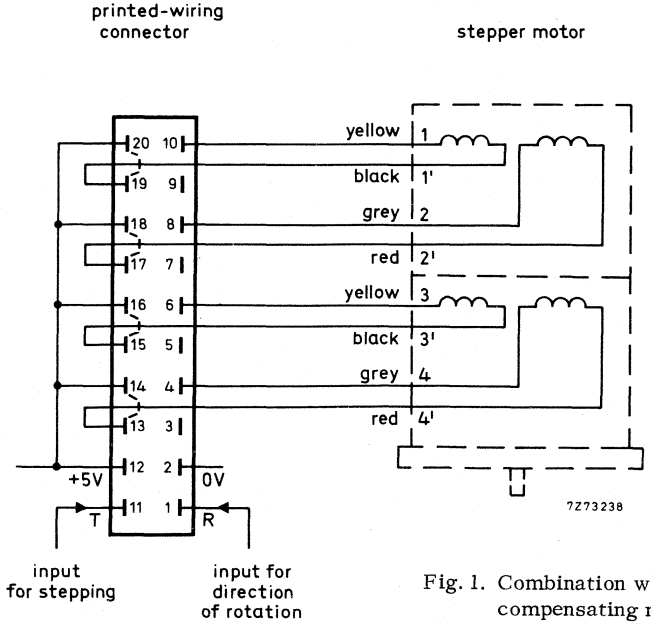



Fig. 1. Combination without compensating network.

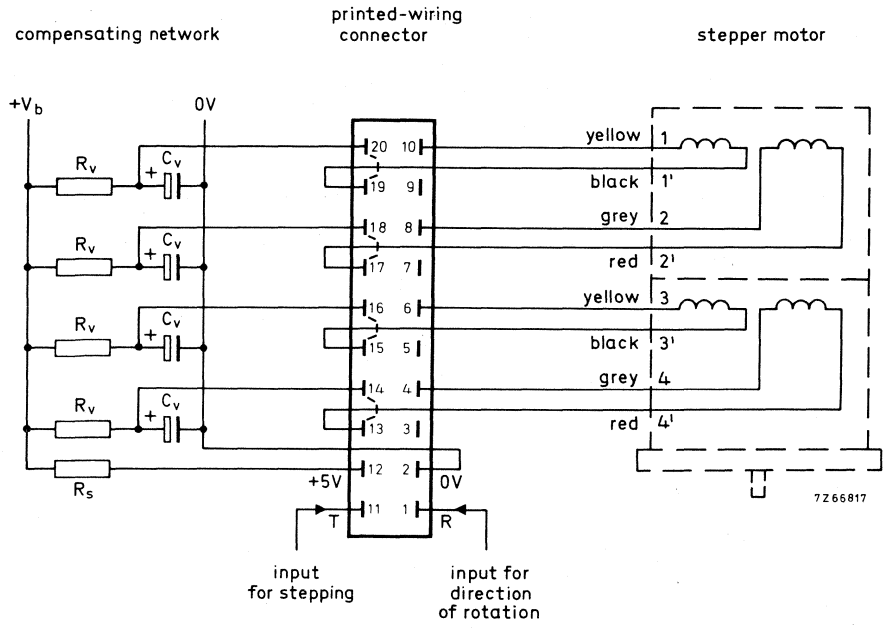



Fig. 2. Combination with compensating network. Resistor and capacitor values can be found in the data sheet of the relevant motor type.

ID types with unipolar integrated circuit SAA1027

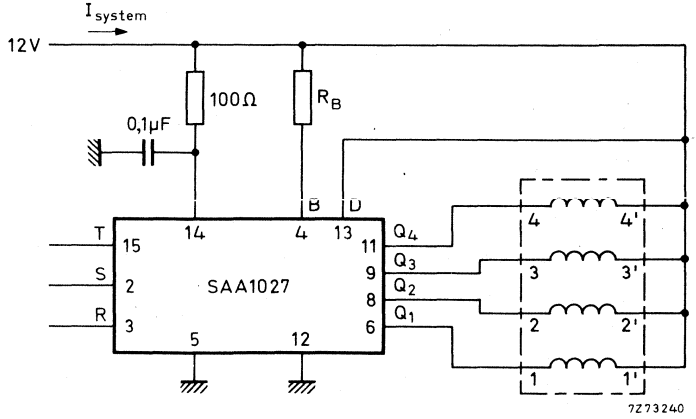



Fig. 3. Resistor value $R_B$ can be found in the data sheet of the relevant motor type.

PD types with unipolar electronic switch 9904 131 03003

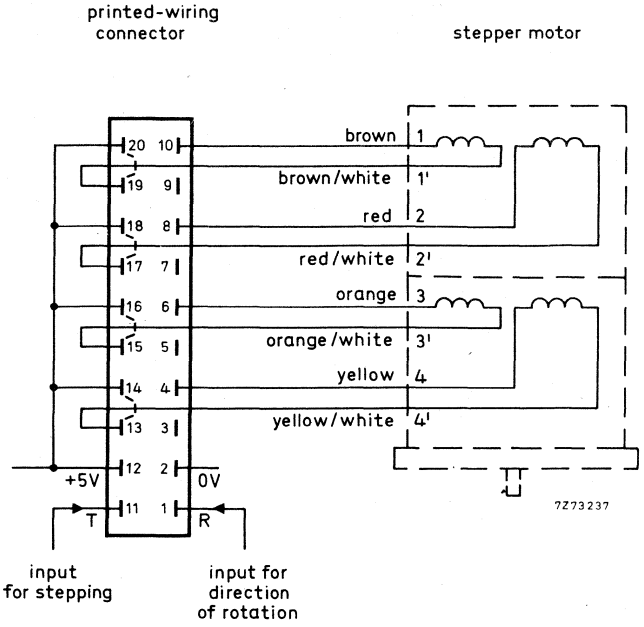



Fig. 4. Combination without compensating network.

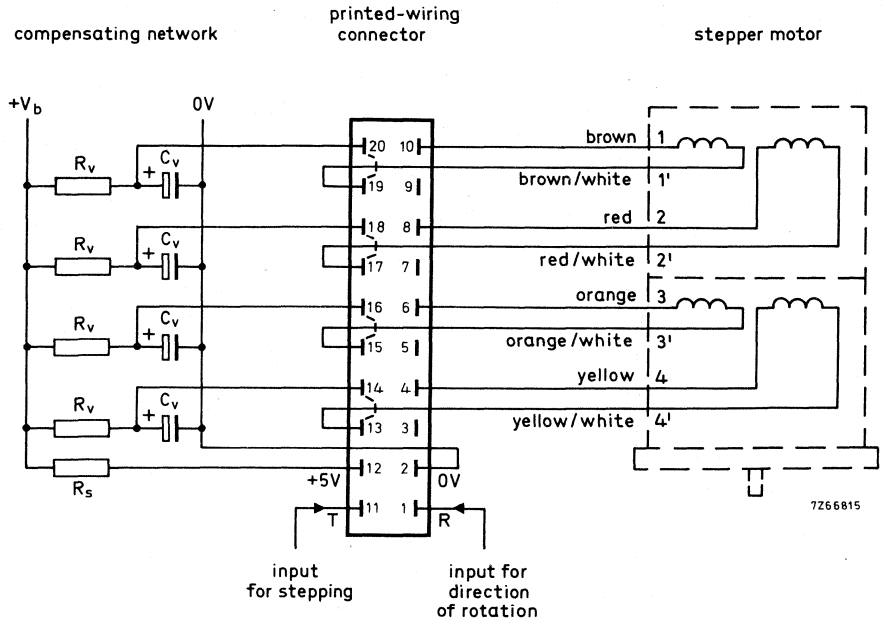
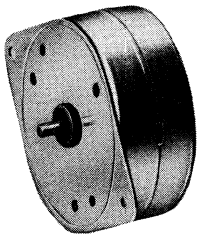



Fig. 5. Combination with compensating network. Resistor and capacitor values can be found in the data sheet of the relevant motor type.

# 4-PHASE UNIPOLAR STEPPER MOTORS

| QUICK REFERENCE DATA | | | |
|---|---|---|---|
| motor type | 9904 112 04002 | 9904 112 04101 | |
| performance obtained with | integrated circuit SAA1027 | electronic switch 9904 131 03003 | |
| | | without RC network | with RC network |
| Step angle | 7° 30' | 7° 30' | 7° 30' |
| Max. working torque | 12 mNm | 14 mNm | 15 mNm |
| Holding torque | 16 mNm | 22,5 mNm | 22,5 mNm |
| Max. pull-in rate | 230 steps/s | 300 steps/s | 350 steps/s |
| Max. pull-out rate | - | 350 steps/s | 550 steps/s |

*RZ 26753-7*



## APPLICATION

Motor 9904 112 04002 has coils adapted to the 350 mA per phase output capability of the SAA1027. This motor is intended for applications where the system efficiency factor prevails and circuit complexity is to be kept at a minimum.
Motor 9904 112 04101 operated via electronic switch 9904 131 03003, without RC network, is especially suited for applications where the motor is used only in the pull-in range, and system efficiency is of importance.
Motor 9904 112 04101 operated via electronic switch 9904 131 03003, with RC network, is ideally suited for variable speed drives where the pull-out capabilities of the motor are required.

## TECHNICAL DATA

Dimensions (mm)

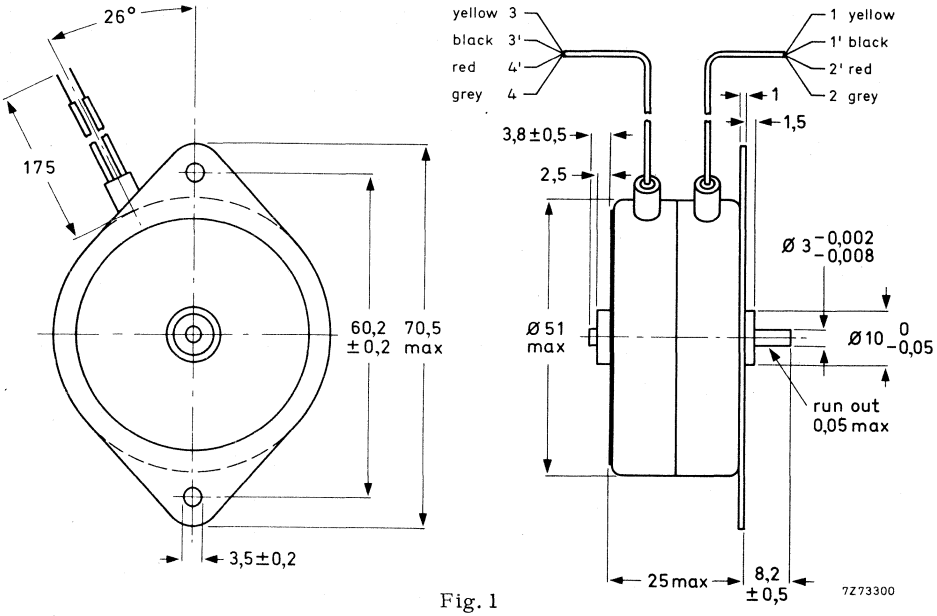



Fig. 1

Marking and connection

The connecting leads are colour-coded (see Fig. 1) and are connected to the electronic switch or to the integrated circuit as shown in General section of 4-phase unipolar stepper motors.

| | | motor | |
|---|---|---|---|
| | | 9904 112 04002 | 9904 112 04101 |
| Power consumption of motor only | (W) | 3 | 3,3 |
| Maximum working torque | (mNm) | 12 | 15 |
| Holding torque | (mNm) | 16 | 22,5 |
| Max. pull-in rate | (steps/s) | 230 [1] | 350 [2] |
| Max. pull-out rate | (steps/s) | – | 550 [2] |
| Number of phases | | 4 | 4 |
| Resistance per coil | (Ω) | 94 | 15 |
| Inductance per coil | (mH) | 260 | 30 |
| Current per coil | (mA) | 125 | 330 |
| Permissible ambient temperature range | (°C) | −20 to +60 | −20 to +70 |
| Permissible storage temperature range | (°C) | −40 to +100 | −40 to +100 |

1) When driven by integrated circuit SAA1027 (see General section, Fig. 3. $R_B$ = 470 Ω).
2) When driven by electronic switch 9904 131 03003 with RC network (see General section, Fig. 2. $R_V$ = 22 Ω; $C_V$ = 27 μF; $V_b$ = 12 V d.c.; $R_S$ = ($V_b$ - 5)/0,230 Ω).

| | | | |
|---|---|---|---|
| Permissible motor temperature | (°C) | 100 | 100 |
| Insulation resistance at 500 V d.c. | (MΩ) | 100 | 100 |
| Step angle | | 7° 30' | 7° 30' |
| Step-angle tolerance (non-cumulative) | | ±20' | ±20' |
| Number of steps per revolution | | 48 | 48 |
| Direction of rotation | | reversible | reversible |
| Rotor inertia | ($gcm^2$) | 11 | 11 |
| Bearings | | sleeve | sleeve |
| Weight | (g) | 160 | 160 |
| Maximum radial force | (N) | 5 | 5 |
| Maximum axial force | (N) | 1,5 | 1,5 |

Motor 9904 112 04002 with integrated circuit SAA1027

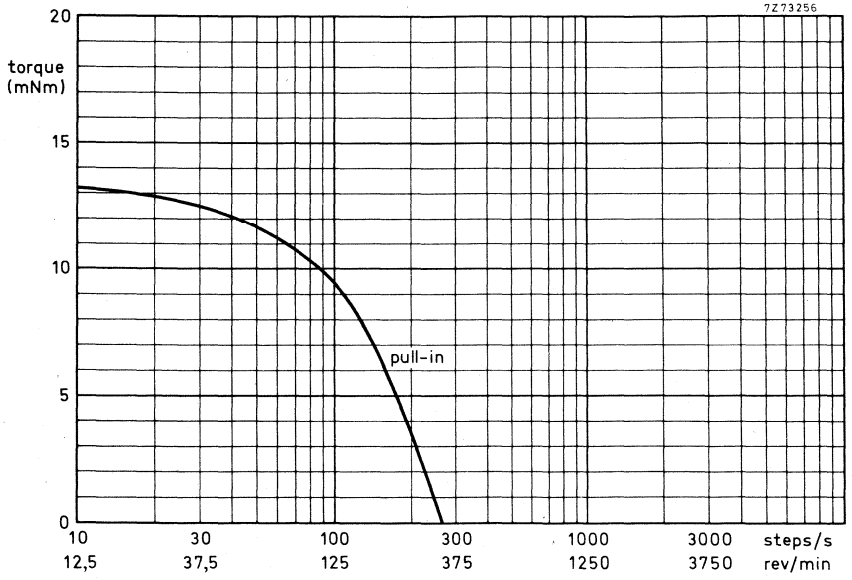



Fig. 2 Torque versus stepping rate, measured at room temperature

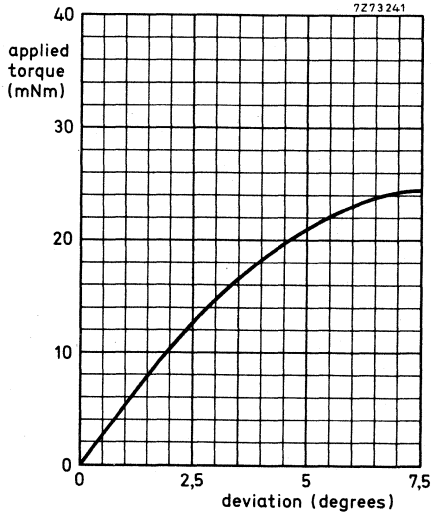



Fig. 3. Applied torque versus deviation.

Motor 9904 112 04101 with electronic switch 9904 131 03003

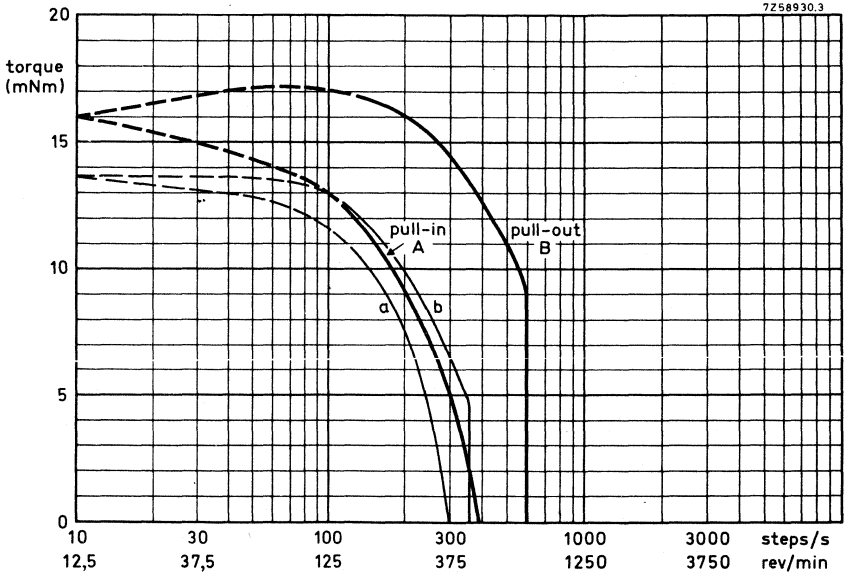



Fig. 4. Torque versus stepping rate, measured at room temperature (thin lines-without RC network, thick lines-with RC network; a and A for pull-in, b and B for pull-out).

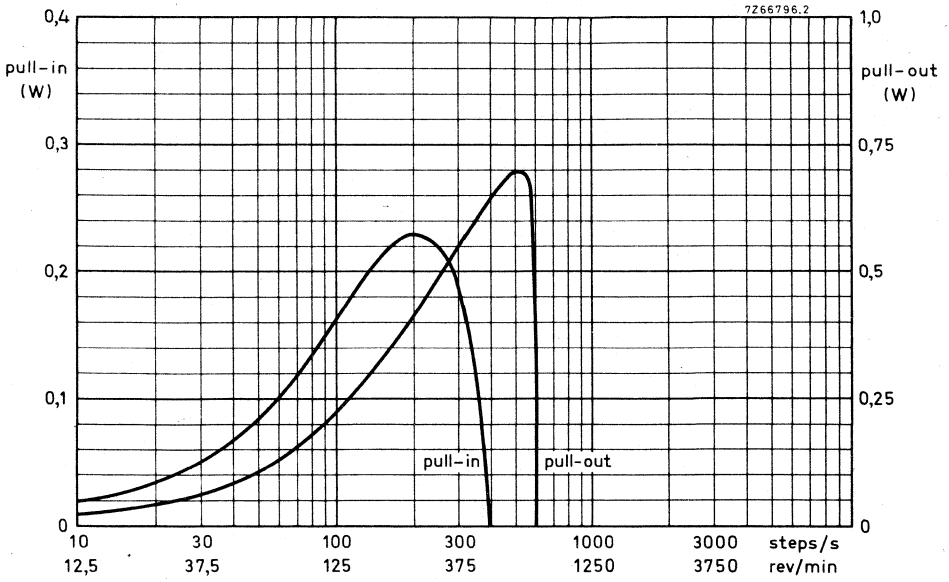



Fig. 5. Output power versus stepping rate measured at room temperature.

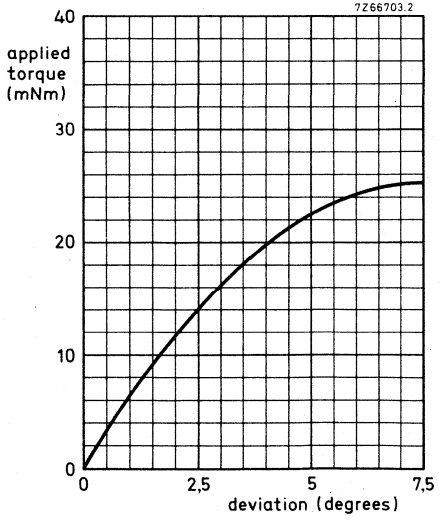
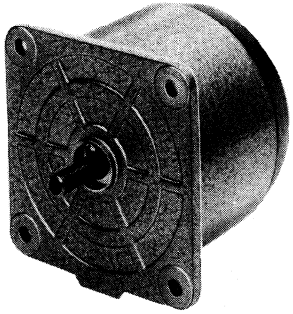



Fig. 6. Applied torque versus deviation.

# 4-PHASE UNIPOLAR STEPPER MOTORS

| QUICK REFERENCE DATA | | | |
|---|---|---|---|
| motor type | 9904 112 05001 | 9904 112 05101 | |
| performance obtained with | integrated circuit SAA1027 | electronic switch 9904 131 03003 | |
| | | without RC network | with RC network |
| Step angle | 7° 30' | 7° 30' | 7° 30' |
| Max. working torque | 60 mNm | 60 mNm | 65 mNm |
| Holding torque | 85 mNm | 90 mNm | 90 mNm |
| Max. pull-in rate | 120 steps/s | 200 steps/s | 240 steps/s |
| Max. pull-out rate | – | 225 steps/s | 360 steps/s |

*A53191*



## APPLICATION

Motor 9904 112 05001 has coils adapted to the 350 mA per phase output capability of the SAA1027. This motor is intended for applications where the system efficiency factor prevails and circuit complexity is to be kept at a minimum.
Motor 9904 112 05101 operated via electronic switch 9904 131 03003, without RC network, is especially suited for applications where the motor is used only in the pull-in range, and system efficiency is of importance.
Motor 9904 112 05101 operated via electronic switch 9904 131 03003, with RC network, is ideally suited for variable speed drives where the pull-out capabilities of the motor are required.

## TECHNICAL DATA

Dimensions (mm)

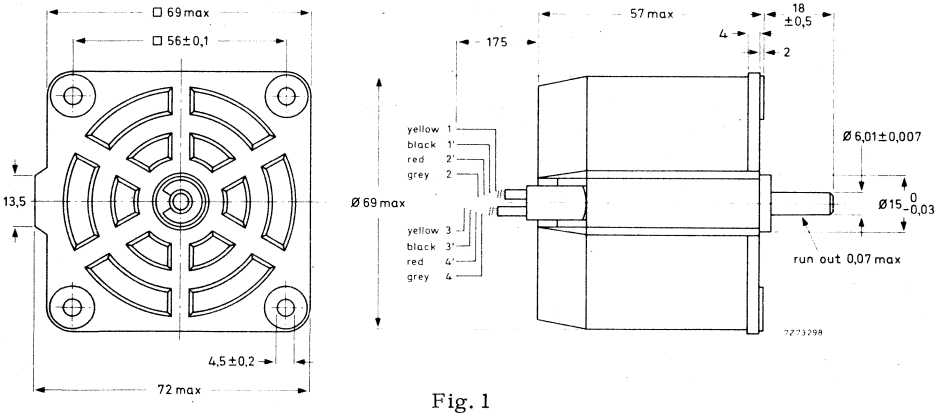



Fig. 1

Marking and connection

The connecting leads are colour-coded (see Fig. 1) and are connected to the electronic switch or to the integrated circuit as shown in General section of 4-phase unipolar stepper motors.

| | | motor | |
|---|---|---|---|
| | | 9904 112 05001 | 9904 112 05101 |
| Power consumption of motor only | (W) | 6,4 | 5,5 |
| Maximum working torque | (mNm) | 60 | 65 |
| Holding torque | (mNm) | 85 | 90 |
| Max. pull-in rate | (steps/s) | 120 [1] | 240 [2] |
| Max. pull-out rate | (steps/s) | – | 360 [2] |
| Number of phases | | 4 | 4 |
| Resistance per coil | (Ω) | 45 | 9 |
| Inductance per coil | (mH) | 130 | 25 |
| Current per coil | (mA) | 250 | 550 |
| Permissible ambient temperature range | (°C) | −20 to + 60 | −20 to + 70 |
| Permissible storage temperature range | (°C) | −40 to + 100 | −40 to + 100 |

1) When driven by integrated circuit SAA1027 (see General section, Fig. 3. $R_B$ = 220 Ω).
2) When driven by electronic switch 9904 131 03003 with RC network (see General section, Fig. 2. $R_V$ = 15 Ω; $C_V$ = 100 μF; $V_b$ = 12 V d.c.; $R_S$ = ($V_b$ - 5)/0,230 Ω).

| | | | |
|---|---|---|---|
| Permissible motor temperature | (°C) | 100 | 100 |
| Insulation resistance at 500 V d.c. | (MΩ) | 100 | 100 |
| Step angle | | 7° 30' | 7° 30' |
| Step-angle tolerance (non-cumulative) | | ±20' | ±20' |
| Number of steps per revolution | | 48 | 48 |
| Direction of rotation | | reversible | reversible |
| Rotor inertia | ($gcm^2$) | 93 | 93 |
| Bearings | | needle | needle |
| Weight | (g) | 500 | 500 |
| Maximum radial force | (N) | 15 | 15 |
| Maximum axial force | (N) | 5 | 5 |

Motor 9904 112 05001 with integrated circuit SAA1027

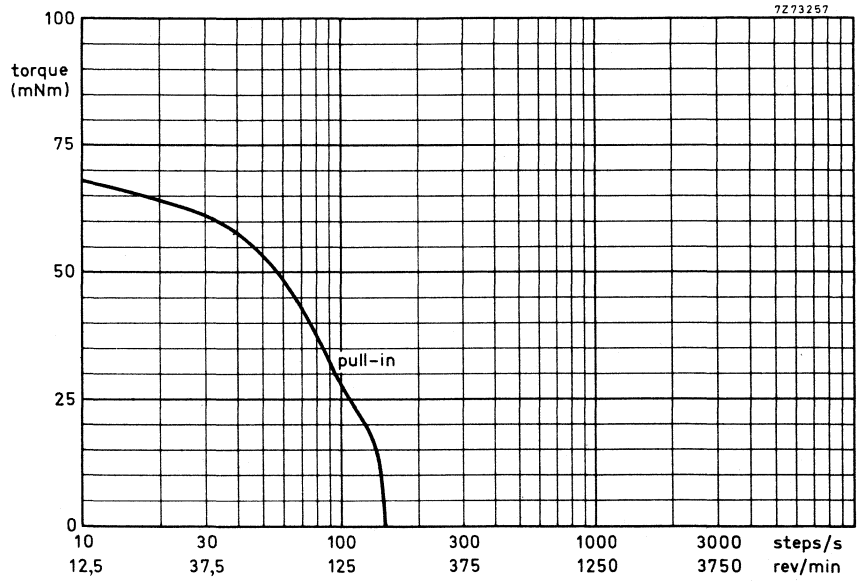



Fig. 2. Torque versus stepping rate, measured at room temperature

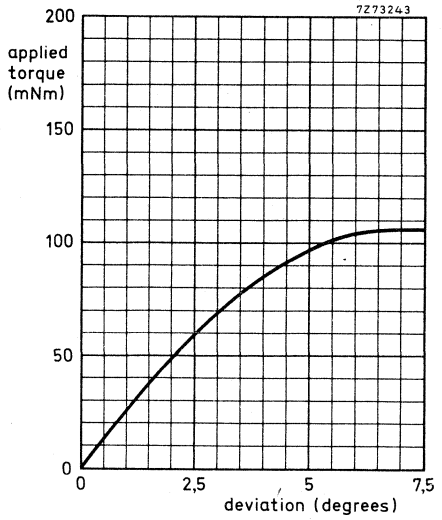



Fig. 3. Applied torque versus deviation.

Motor 9904 112 05101 with electronic switch 9904 131 03003

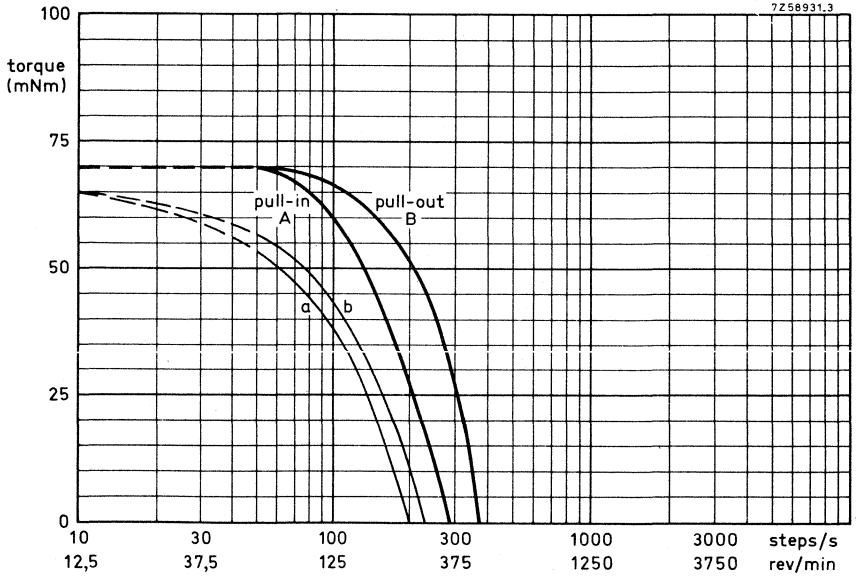



Fig. 4. Torque versus stepping rate, measured at room temperature (thin lines-without RC network, thick lines-with RC network; a and A for pull-in, b and B for pull-out).

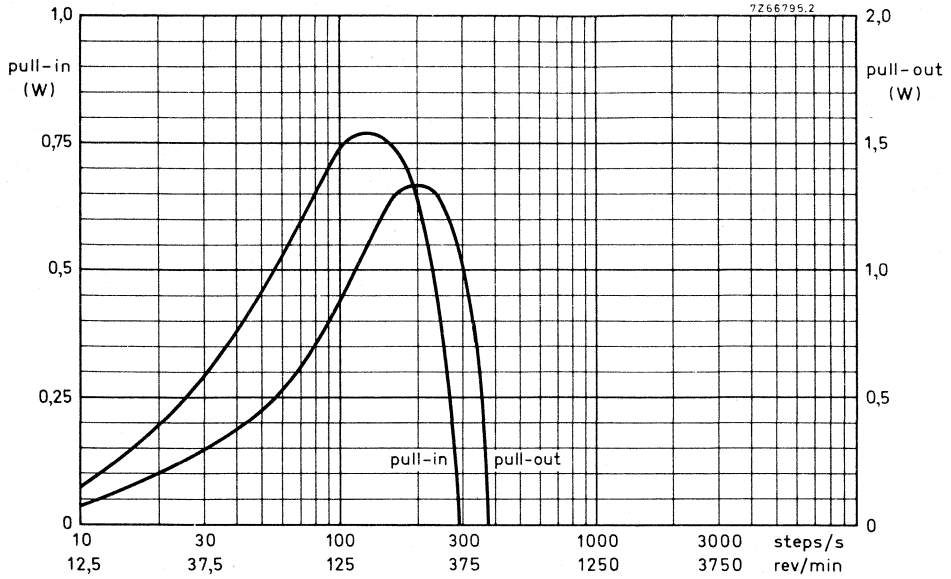



Fig. 5. Output power versus stepping rate measured at room temperature.

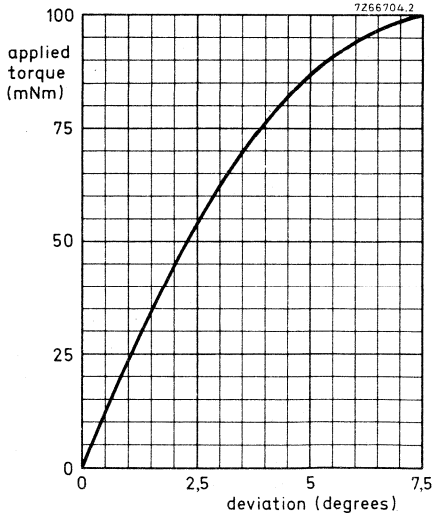
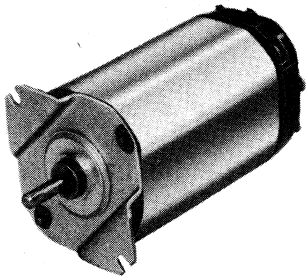



Fig. 6. Applied torque versus deviation.

# 4-PHASE UNIPOLAR STEPPER MOTORS

| QUICK REFERENCE DATA | | | |
|---|---|---|---|
| motor type | 9904 112 04002 | 9904 112 04101 | |
| performance obtained with | integrated circuit SAA1027 | electronic switch 9904 131 03003 | |
| | | without RC network | with RC network |
| Step angle | 7° 30' | 7° 30' | 7° 30' |
| Max. working torque | 40 mNm | 40 mNm | 50 mNm |
| Holding torque | 60 mNm | 70 mNm | 70 mNm |
| Max. pull-in rate | 110 steps/s | 150 steps/s | 200 steps/s |
| Max. pull-out rate | – | 175 steps/s | 320 steps/s |

*RZ 26753-4*



## APPLICATION

Motor 9904 112 06001 has coils adapted to the 350 mA per phase output capability of the SAA1027. This motor is intended for applications where the system efficiency factor prevails and circuit complexity is to be kept at a minimum.
Motor 9904 112 06101 operated via electronic switch 9904 131 03003, without RC network, is especially suited for applications where the motor is used only in the pull-in range, and system efficiency is of importance.
Motor 9904 112 06101 operated via electronic switch 9904 131 03003, with RC network, is ideally suited for variable speed drives where the pull-out capabilities of the motor are required.

## TECHNICAL DATA

Dimensions (mm)

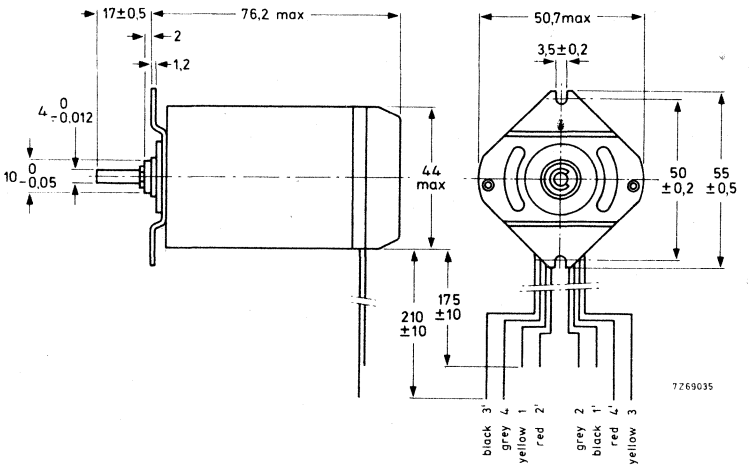



Fig. 1

Marking and connection

The connecting leads are colour-coded (see Fig. 1) and are connected to the electronic switch or to the integrated circuit as shown in General section of 4-phase unipolar stepper motors.

| | | motor | |
|---|---|---|---|
| | | 9904 112 06001 | 9904 112 06101 |
| Power consumption of motor only | (W) | 6,4 | 4 |
| Maximum working torque | (mNm) | 40 | 50 |
| Holding torque | (mNm) | 60 | 70 |
| Max. pull-in rate | (steps/s) | 110 [1] | 200 [2] |
| Max. pull-out rate | (steps/s) | – | 320 [2] |
| Number of phases | | 4 | 4 |
| Resistance per coil | (Ω) | 45 | 12 |
| Inductance per coil | (mH) | 130 | 35 |
| Current per coil | (mA) | 250 | 400 |
| Permissible ambient temperature range | (°C) | −20 to +50 | −20 to +70 |
| Permissible storage temperature range | (°C) | −40 to +100 | −40 to +100 |

1) When driven by integrated circuit SAA1027 (see General section, Fig. 3. $R_B$ = 220 Ω).
2) When driven by electronic switch 9904 131 03003 with RC network (see General section, Fig. 2. $R_V$ = 15 Ω; $C_V$ = 50 μF; $V_b$ = 12 V d.c.; $R_S$ = ($V_b$ - 5)/0,230 Ω).

| | | | |
|---|---|---|---|
| Permissible motor temperature | (°C) | 100 | 100 |
| Insulation resistance at 500 V d.c. | (MΩ) | 100 | 100 |
| Step angle | | 7° 30' | 7° 30' |
| Step-angle tolerance (non-cumulative) | | ±20' | ±20' |
| Number of steps per revolution | | 48 | 48 |
| Direction of rotation | | reversible | reversible |
| Rotor inertia | ($gcm^2$) | 90 | 90 |
| Bearings | | sleeve | sleeve |
| Weight | (g) | 320 | 320 |
| Maximum radial force | (N) | 15 | 15 |
| Maximum axial force | (N) | 1,5 | 1,5 |

Motor 9904 112 06001 with integrated circuit SAA1027

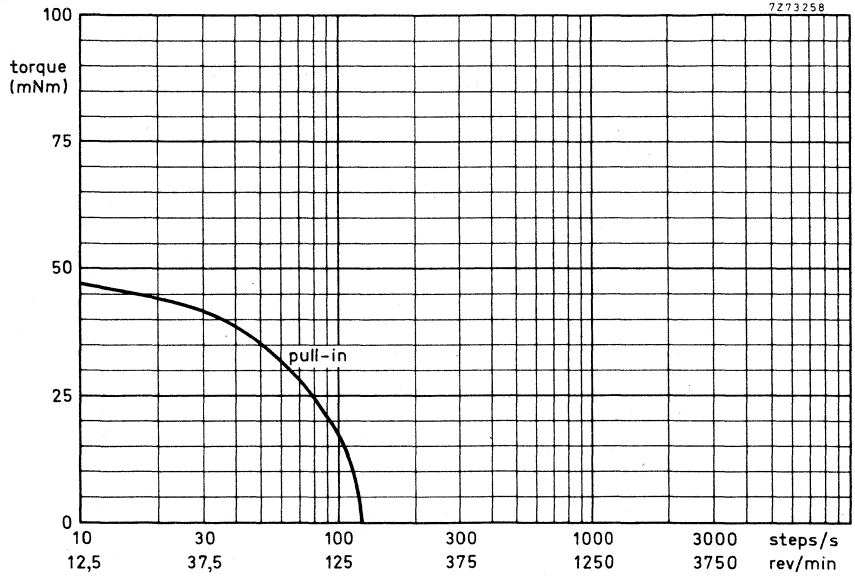



Fig. 2. Torque versus stepping rate, measured at room temperature

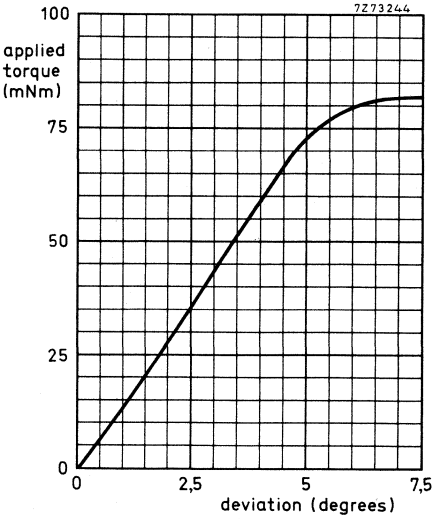



Fig. 3. Applied torque versus deviation.

Motor 9904 112 06101 with electronic switch 9904 131 03003

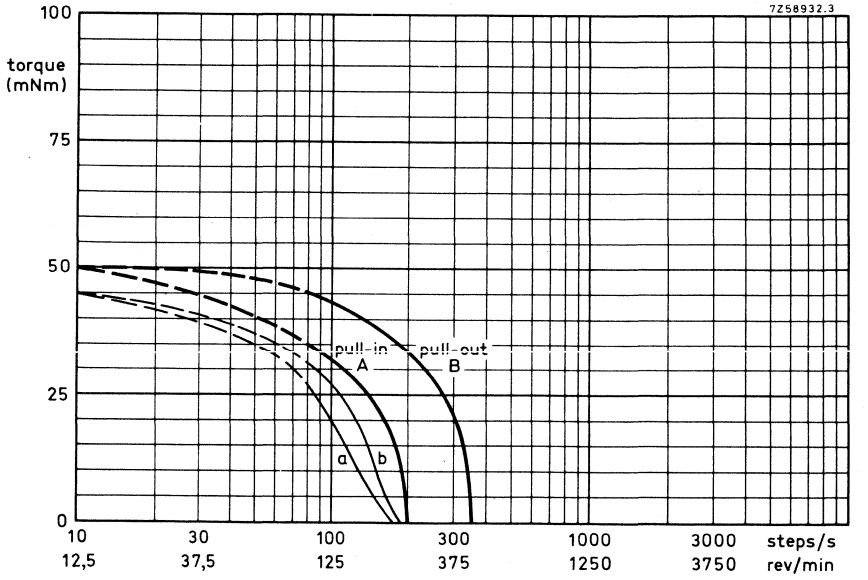



Fig. 4. Torque versus stepping rate, measured at room temperature (thin lines-without RC network, thick lines-with RC network; a and A for pull-in, b and B for pull-out).

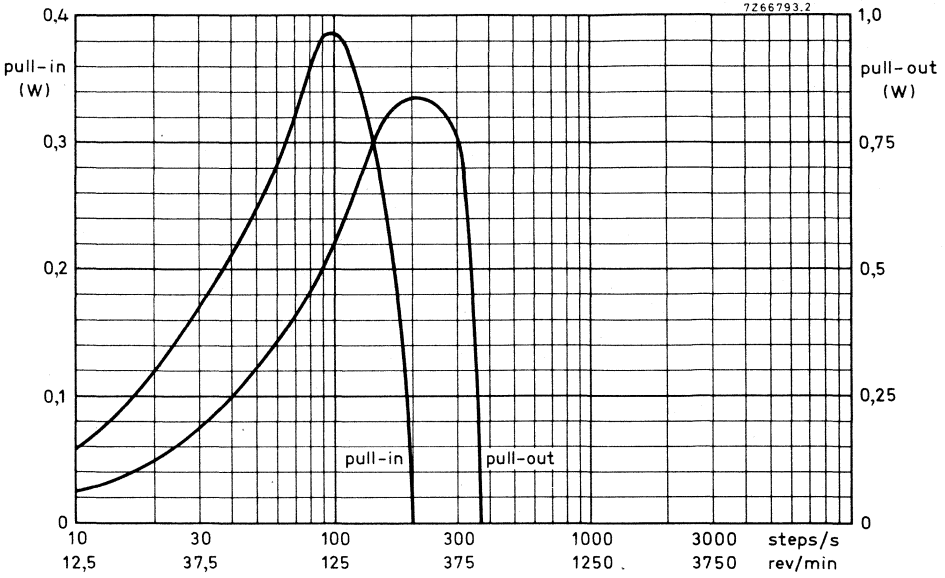



Fig. 5. Output power versus stepping rate measured at room temperature.

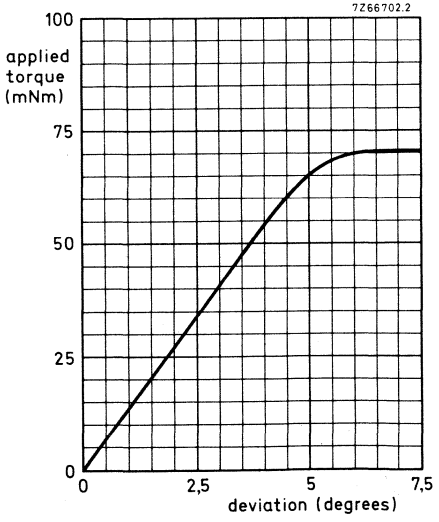
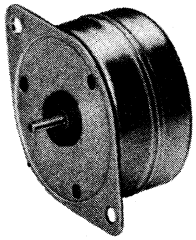



Fig. 6. Applied torque versus deviation.

# 4-PHASE UNIPOLAR STEPPER MOTORS

| QUICK REFERENCE DATA | | | |
|---|---|---|---|
| motor type | 9904 112 07005 | 9904 112 07101 | |
| performance obtained with | integrated circuit SAA1027 | electronic switch 9904 131 03003 | |
| | | without RC network | with RC network |
| Step angle | 7° 30' | 7° 30' | 7° 30' |
| Max. working torque | 4,5 mNm | 6 mNm | 6 mNm |
| Holding torque | 6,5 mNm | 8 mNm | 8 mNm |
| Max. pull-in rate | 350 steps/s | 400 steps/s | 500 steps/s |
| Max. pull-out rate | – | 750 steps/s | 1000 steps/s |

*RZ 26753-10*



## APPLICATION

Motor 9904 112 07005 has coils adapted to the 350 mA per phase output capability of the SAA1027. This motor is intended for applications where the system efficiency factor prevails and circuit complexity is to be kept at a minimum.
Motor 9904 112 07101 operated via electronic switch 9904 131 03003, without RC network, is especially suited for applications where the motor is used only in the pull-in range, and system efficiency is of importance.
Motor 9904 112 07101 operated via electronic switch 9904 131 03003, with RC network, is ideally suited for variable speed drives where the pull-out capabilities of the motor are required.

## TECHNICAL DATA

Dimensions (mm)

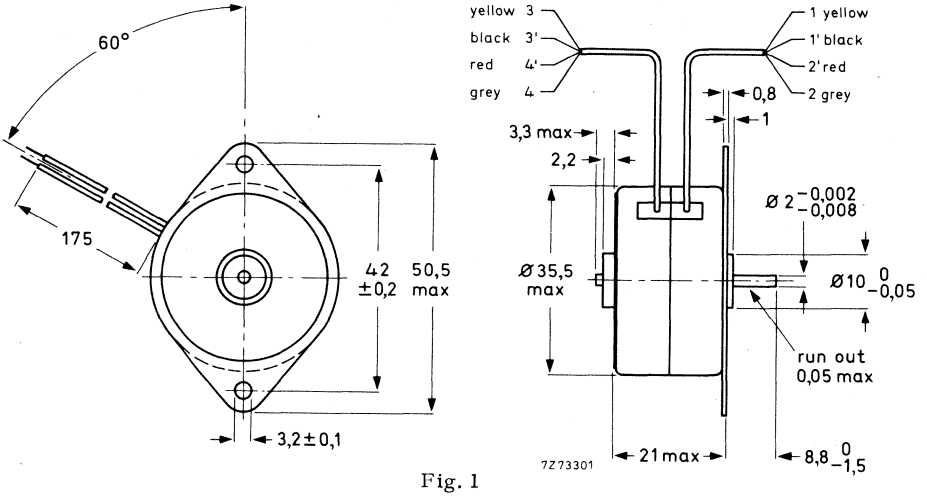



Fig. 1

Marking and connection

The connecting leads are colour-coded (see Fig. 1) and are connected to the electronic switch or to the integrated circuit as shown in General section of 4-phase unipolar stepper motors.

| | | motor | |
|---|---|---|---|
| | | 9904 112 07005 | 9904 112 07101 |
| Power consumption of motor only | (W) | 1,9 | 1,7 |
| Maximum working torque | (mNm) | 4,5 | 6 |
| Holding torque | (mNm) | 6,5 | 8 |
| Max. pull-in rate | (steps/s) | 350 [1] | 500 [2] |
| Max. pull-out rate | (steps/s) | - | 1000 [2] |
| Number of phases | | 4 | 4 |
| Resistance per coil | (Ω) | 150 | 25 |
| Inductance per coil | (mH) | 150 | 30 |
| Current per coil | (mA) | 80 | 175 |
| Permissible ambient temperature range | (°C) | -20 to +60 | -20 to +70 |
| Permissible storage temperature range | (°C) | -40 to +100 | -40 to +100 |

1) When driven by integrated circuit SAA1027 (see General section, Fig. 3. $R_B$ = 620 Ω).
2) When driven by electronic switch 9904 131 03003 with RC network (see General section, Fig. 2. $R_V$ = 34 Ω; $C_V$ = 27 μF; $V_b$ = 12 V d.c.; $R_S$ = ($V_b$ - 5)/0,230 Ω).

| | | | |
|---|---|---|---|
| Permissible motor temperature | (°C) | 100 | 100 |
| Insulation resistance at 500 V d.c. | (MΩ) | 100 | 100 |
| Step angle | | 7° 30' | 7° 30' |
| Step-angle tolerance (non-cumulative) | | ±20' | ±20' |
| Number of steps per revolution | | 48 | 48 |
| Direction of rotation | | reversible | reversible |
| Rotor inertia | ($gcm^2$) | 2,6 | 2,6 |
| Bearings | | sleeve | sleeve |
| Weight | (g) | 75 | 75 |
| Maximum radial force | (N) | 2,5 | 2,5 |
| Maximum axial force | (N) | 0,75 | 0,75 |

Motor 9904 112 07005 with integrated circuit SAA1027

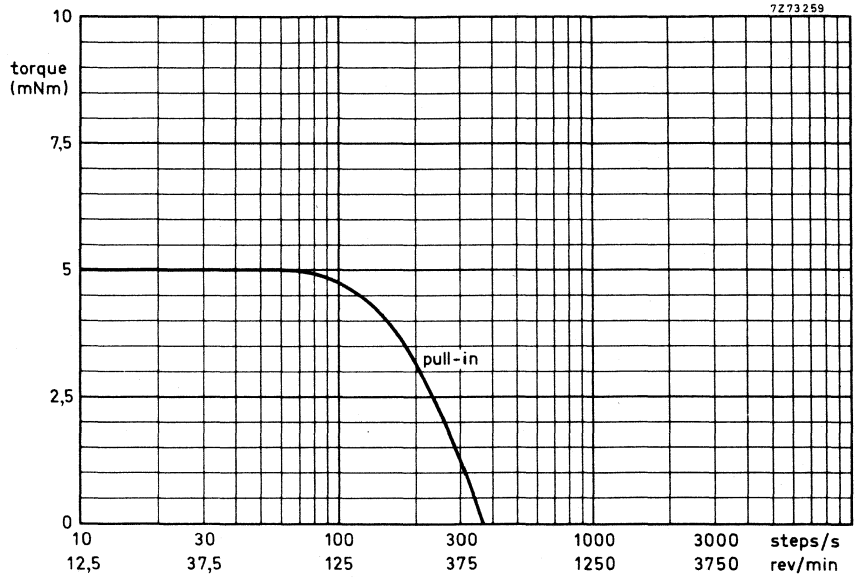



Fig. 2. Torque versus stepping rate, measured at room temperature

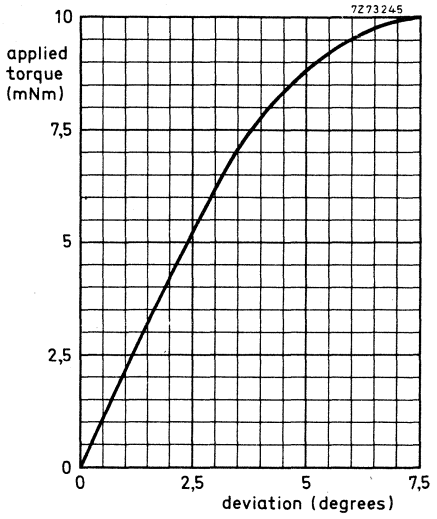



Fig. 3. Applied torque versus deviation.

Motor 9904 112 07101 with electronic switch 9904 131 03003

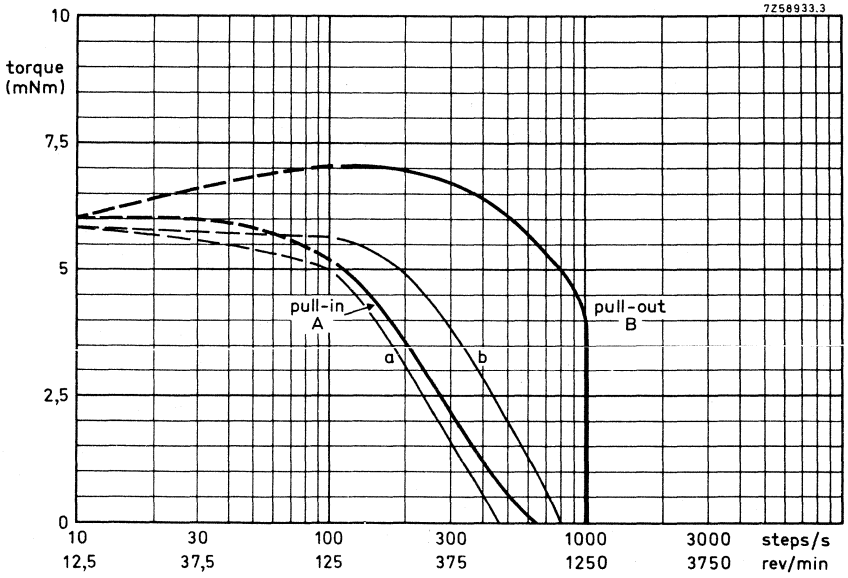



Fig. 4. Torque versus stepping rate, measured at room temperature (thin lines-without RC network, thick lines-with RC network; a and A for pull-in, b and B for pull-out).

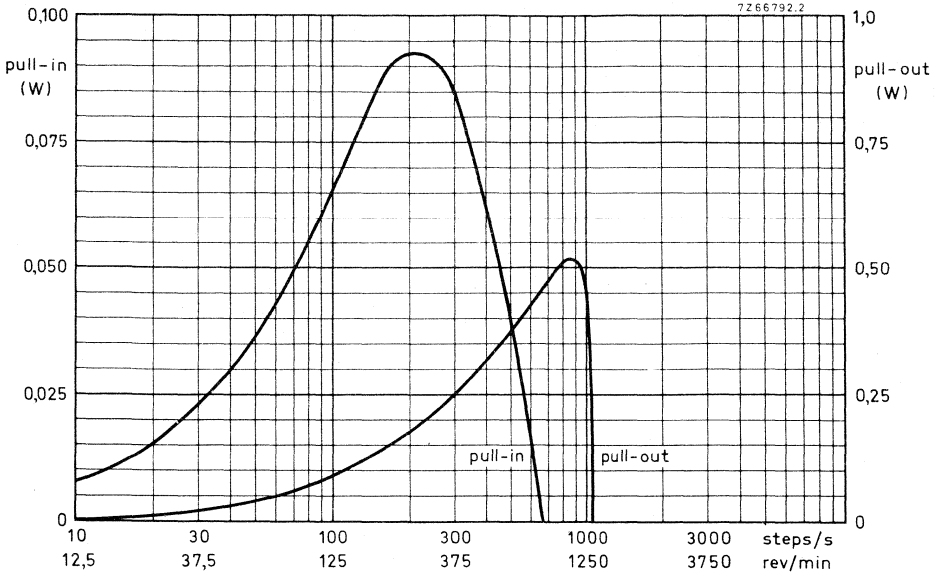



Fig. 5. Output power versus stepping rate measured at room temperature.

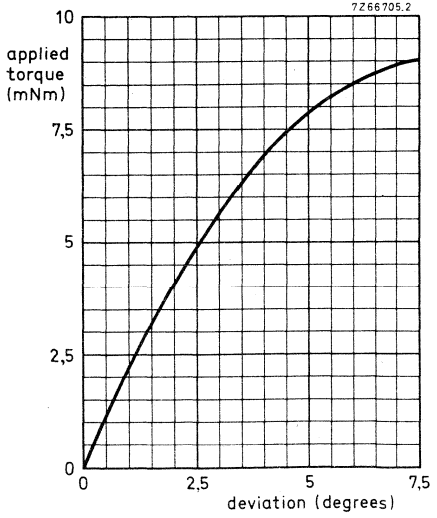
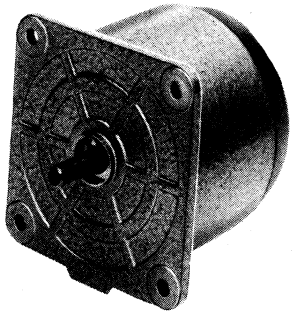



Fig. 6. Applied torque versus deviation.

# 4-PHASE UNIPOLAR STEPPER MOTORS

| QUICK REFERENCE DATA | | | |
|---|---|---|---|
| motor type | 9904 112 08001 | 9904 112 08101 | |
| performance obtained with | integrated circuit SAA1027 | electronic switch 9904 131 03003 | |
| | | without RC network | with RC network |
| Step angle | 15° | 15° | 15° |
| Max. working torque | 35 mNm | 35 mNm | 35 mNm |
| Holding torque | 55 mNm | 65 mNm | 65 mNm |
| Max. pull-in rate | 120 steps/s | 130 steps/s | 160 steps/s |
| Max. pull-out rate | – | 240 steps/s | 400 steps/s |

*A 53191*



## APPLICATION

Motor 9904 112 08001 has coils adapted to the 350 mA per phase output capability of the SAA1027. This motor is intended for applications where the system efficiency factor prevails and circuit complexity is to be kept at a minimum.
Motor 9904 112 08101 operated via electronic switch 9904 131 03003, without RC network, is especially suited for applications where the motor is used only in the pull-in range, and system efficiency is of importance.
Motor 9904 112 08101 operated via electronic switch 9904 131 03003, with RC network, is ideally suited for variable speed drives where the pull-out capabilities of the motor are required.

## TECHNICAL DATA

Dimensions (mm)

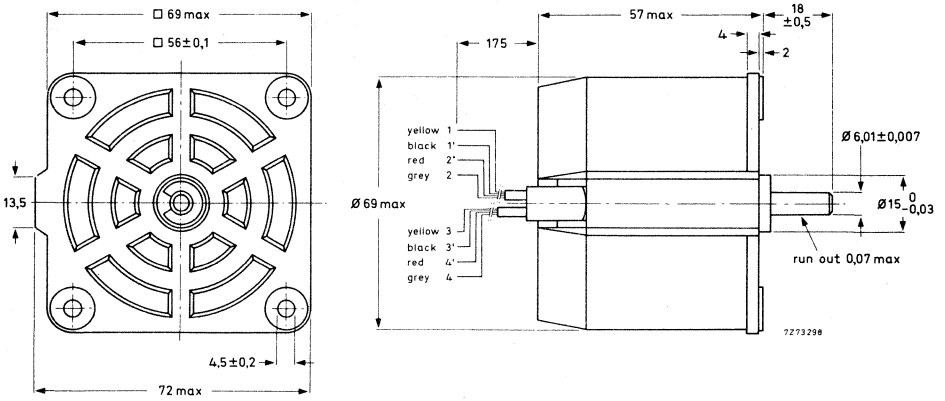



Fig. 1

Marking and connection

The connecting leads are colour-coded (see Fig. 1) and are connected to the electronic switch or to the integrated circuit as shown in General section of 4-phase unipolar stepper motors.

| | | motor | |
|---|---|---|---|
| | | 9904 112 08001 | 9904 112 08101 |
| Power consumption of motor only | (W) | 6,4 | 5,5 |
| Maximum working torque | (mNm) | 35 | 35 |
| Holding torque | (mNm) | 55 | 65 |
| Max. pull-in rate | (steps/s) | 120 [1] | 160 [2] |
| Max. pull-out rate | (steps/s) | – | 400 [2] |
| Number of phases | | 4 | 4 |
| Resistance per coil | (Ω) | 45 | 9 |
| Inductance per coil | (mH) | 110 | 20 |
| Current per coil | (mA) | 250 | 550 |
| Permissible ambient temperature range | (°C) | −20 to +60 | −20 to +70 |
| Permissible storage temperature range | (°C) | −40 to +100 | −40 to +100 |

1) When driven by integrated circuit SAA1027 (see General section, Fig. 3. $R_B$ = 220 Ω).
2) When driven by electronic switch 9904 131 03003 with RC network (see General section, Fig. 2. $R_V$ = 15 Ω; $C_V$ = 100 μF; $V_b$ = 12 V d.c.; $R_S$ = ($V_b$ - 5)/0,230 Ω).

| | | | |
|---|---|---|---|
| Permissible motor temperature | (°C) | 100 | 100 |
| Insulation resistance at 500 V d.c. | (MΩ) | 100 | 100 |
| Step angle | | 15° | 15° |
| Step-angle tolerance (non-cumulative) | | ± 30' | ± 30' |
| Number of steps per revolution | | 24 | 24 |
| Direction of rotation | | reversible | reversible |
| Rotor inertia | ($gcm^2$) | 93 | 93 |
| Bearings | | needle | needle |
| Weight | (g) | 500 | 500 |
| Maximum radial force | (N) | 15 | 15 |
| Maximum axial force | (N) | 5 | 5 |

Motor 9904 112 08001 with integrated circuit SAA1027

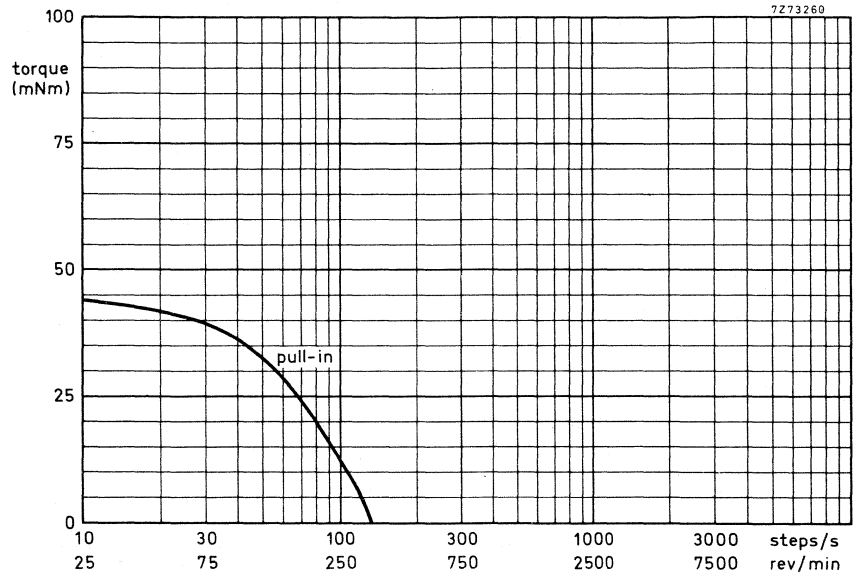



Fig. 2. Torque versus stepping rate, measured at room temperature ($R_B$ = 220 Ω, 0,67 W).

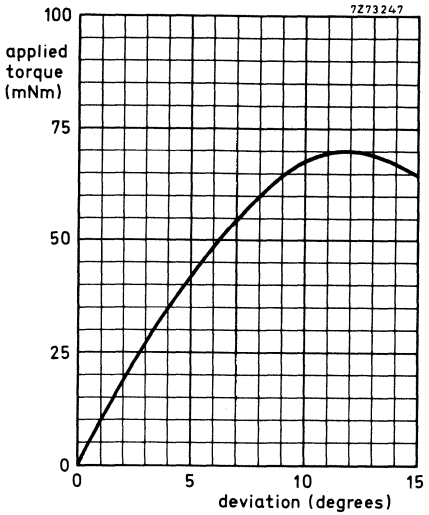



Fig. 3. Applied torque versus deviation.

Motor 9904 112 08101 with electronic switch 9904 131 03003

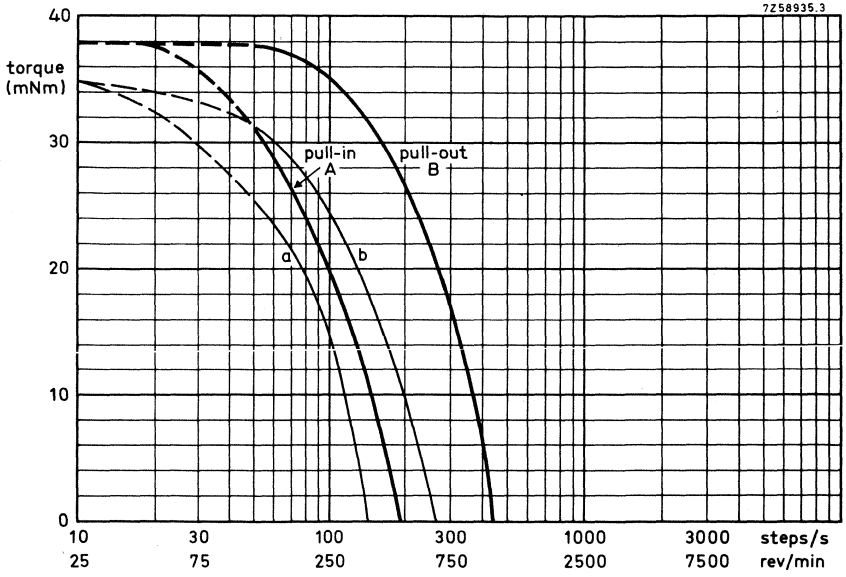



Fig. 4. Torque versus stepping rate, measured at room temperature (thin lines-without RC network, thick lines-with RC network; a and A for pull-in, b and B for pull-out).

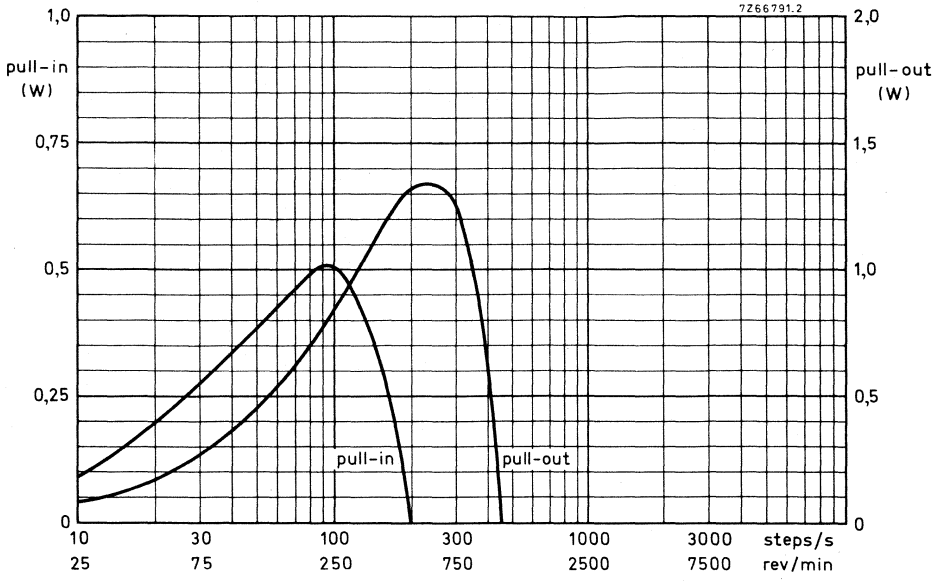



Fig. 5. Output power versus stepping rate measured at room temperature.

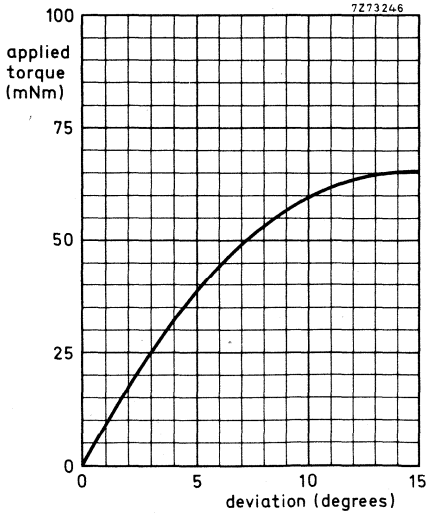



Fig. 6. Applied torque versus deviation.

# 4-PHASE UNIPOLAR STEPPER MOTOR

| QUICK REFERENCE DATA | | |
|---|---|---|
| performance obtained with | electronic switch 9904 131 03003 | |
| | without RC network | with RC network |
| Step angle | 7° 30' | 7° 30' |
| Max. working torque | 7 mNm | 7 mNm |
| Holding torque | 10 mNm | 10 mNm |
| Max. pull-in rate | 400 steps/s | 500 steps/s |
| Max. pull-out rate | 550 steps/s | 1000 steps/s |

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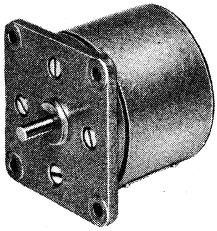

## APPLICATION

Motor 9904 112 10001 operated via electronic switch 9904 131 03003, without RC network, is especially suited for applications where the motor is used only in the pull-in range, and system effeciency is of importance. This combination, with RC network, is ideally suited for variable speed drives where the pull-out capabilities of the motor are required.

## TECHNICAL DATA

Dimensions (mm)

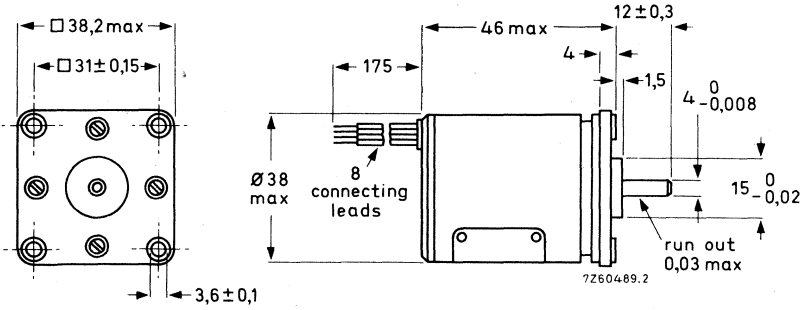


Fig. 1

Marking and connection

The connecting leads are colour-coded and are connected to the electronic switch as shown in General section of 4-phase unipolar stepper motors.

| | |
|---|---|
| Power consumption of motor only | 1,75 W |
| Maximum working torque | 7 mNm |
| Holding torque | 10 mNm |
| Maximum pull-in rate *) | 500 steps/s |
| Maximum pull-out rate *) | 1000 steps/s |
| Number of phases | 4 |
| Resistance per coil | 27 Ω |
| Inductance per coil | 20 mH |
| Current per coil | 175 mA |
| Permissible ambient temperature range | −30 to + 85 °C |
| Permissible storage temperature range | −62 to + 110 °C |
| Permissible motor temperature | 125 °C |
| Insulation resistance at 500 V d.c. | 100 MΩ |
| Step angle | 7° 30' |
| Step-angle tolerance | ±20' non-cumulative |
| Number of steps per revolution | 48 |
| Direction of rotation | reversible |
| Rotor inertia | 3,5 gcm$^2$ |
| Bearings | ball |
| Weight | 140 g |
| Maximum axial play (axial force 1,5 N) | 0,07 mm |
| Maximum radial force | 10 N |
| Maximum axial force | 5 N |

*) When driven by electronic switch 9904 131 03003 with RC network (see General section, Fig. 2. $R_V$ = 47 Ω ± 5%, 2 W; $C_V$ = 10 μF, 64 V d.c.; $V_b$ = 12 V d.c.; $R_S = (V_b - 5)/0{,}230$ Ω).

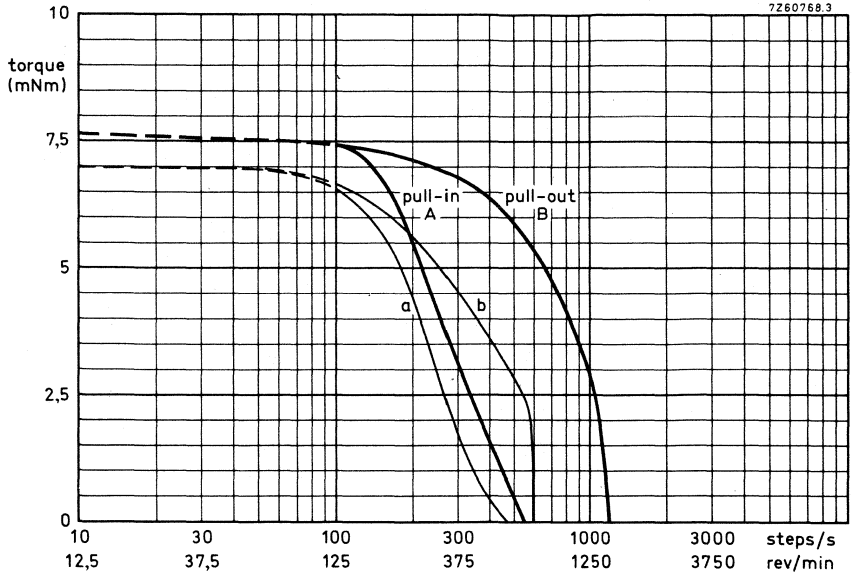


Fig. 2. Torque versus stepping rate, measured at room temperature (thin lines-without RC network, thick lines-with RC network; a and A for pull-in, b and B for pull-out).

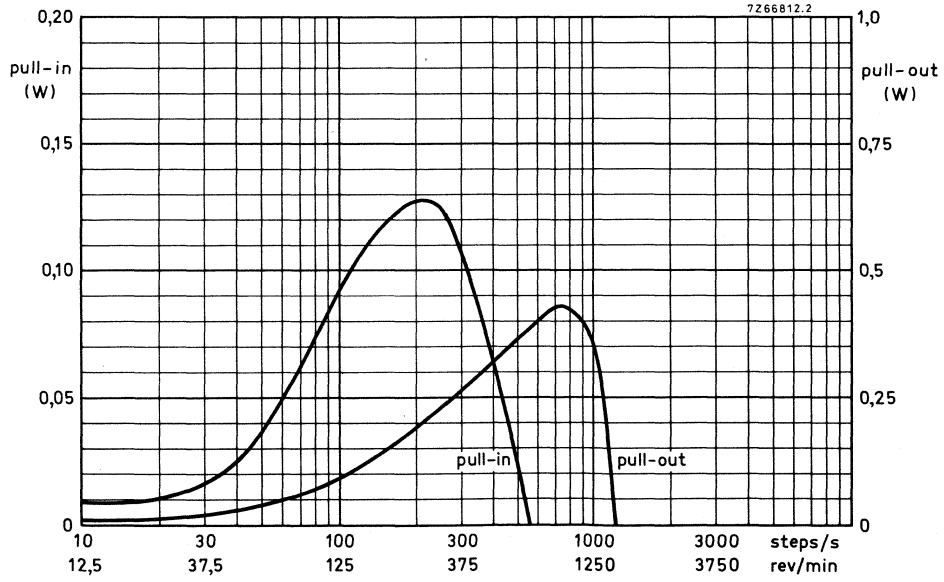


Fig. 3. Output power versus stepping rate, measured at room temperature.

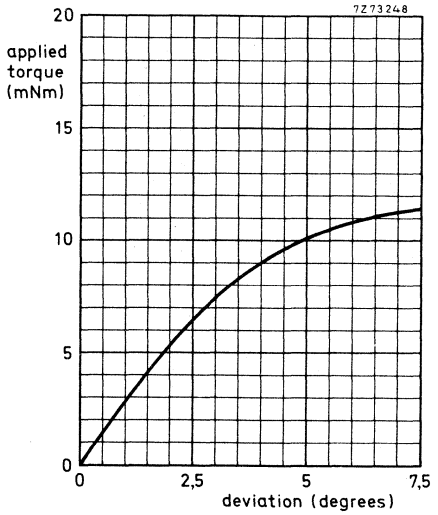


Fig. 4 Applied torque versus deviation.

# 4-PHASE UNIPOLAR STEPPER MOTOR

| QUICK REFERENCE DATA | | |
|---|---|---|
| performance obtained with | electronic switch 9904 131 03003 | |
| | without RC network | with RC network |
| Step angle | 7o 30' | 7o 30' |
| Max. working torque | 25 mNm | 25 mNm |
| Holding torque | 32,5 mNm | 32,5 mNm |
| Max. pull-in rate | 300 steps/s | 360 steps/s |
| Max. pull-out rate | 400 steps/s | 550 steps/s |

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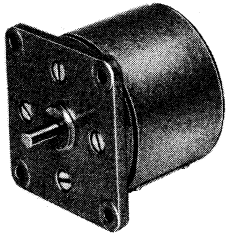

## APPLICATION

Motor 9904 112 14001 operated via electronic switch 9904 131 03003, without RC network, is especially suited for applications where the motor is used only in the pull-in range, and system efficiency is of importance. This combination, with RC network, is ideally suited for variable speed drives where the pull-out capabilities of the motor are required.

## TECHNICAL DATA

Dimensions (mm)

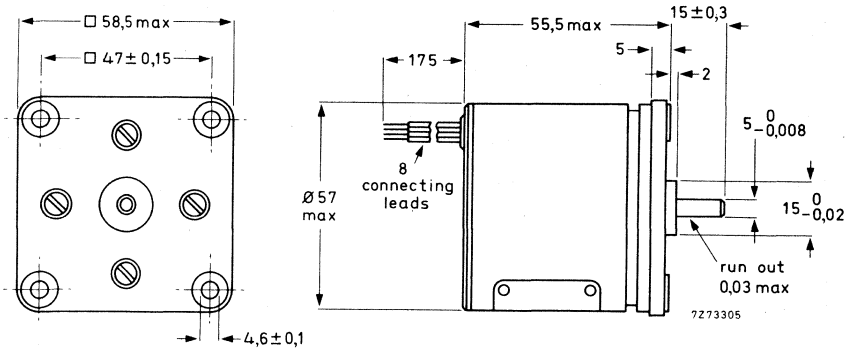


Fig. 1

Marking and connection

The connecting leads are colour-coded and are connected to the electronic switch as shown in General section of 4-phase unipolar stepper motors.

| | |
|---|---|
| Power consumption of motor only | 3,7 W |
| Max. working torque | 25 mNm |
| Holding torque | 32,5 mNm |
| Maximum pull-in rate *) | 360 steps/s |
| Maximum pull-out rate *) | 550 steps/s |
| Number of phases | 4 |
| Resistance per coil | 15 Ω |
| Inductance per coil | 25 mH |
| Current per coil | 350 mA |
| Permissible ambient temperature range | −30 to + 85 °C |
| Permissible storage temperature range | −62 to + 110 °C |
| Permissible motor temperature | 125 °C |
| Insulation resistance at 500 V d.c. | 100 MΩ |
| Step angle | 7o 30' |
| Step-angle tolerance | ± 10' non-cumulative |
| Number of steps per revolution | 48 |
| Direction of rotation | reversible |
| Rotor inertia | 18 gcm$^2$ |
| Bearings | ball |
| Weight | 500 g |
| Maximum axial play of spindle measured with axial force of 5 N | 0,07 mm |
| Maximum radial force | 15 N |
| Maximum axial force | 7,5 N |

*) When driven by electronic switch 9904 131 03003 with RC network (see General section, Fig. 2. $R_V$ = 18 Ω ± 5%, 5 W; $C_V$ = 50 μF, 40 V d.c.; $V_b$ = 12 V d.c.; $R_S$ = ($V_b$ - 5)/0,230 Ω).

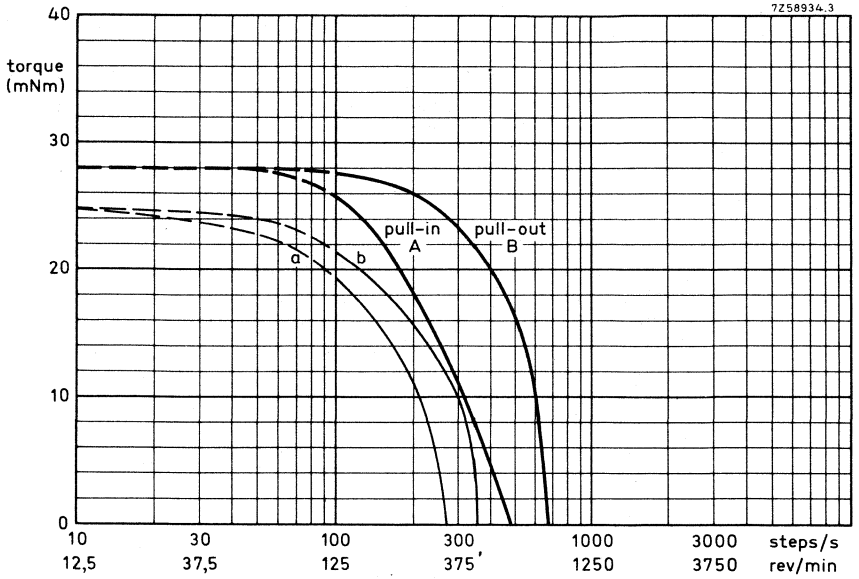


Fig. 2. Torque versus stepping rate, measured at room temperature (thin lines-without RC network, thick lines-with RC network; a and A for pull-in, b and B for pull-out).

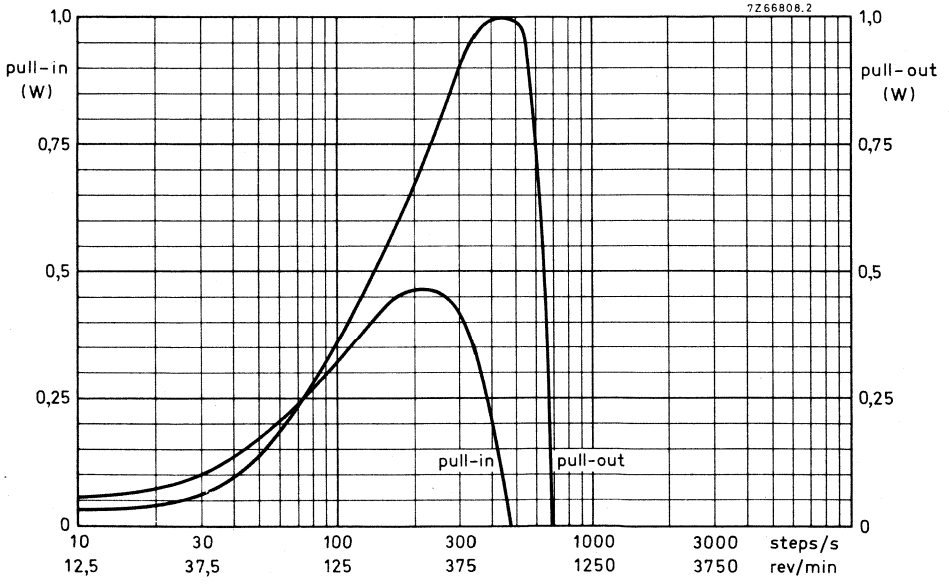


Fig. 3. Output power versus stepping rate, measured at room temperature.

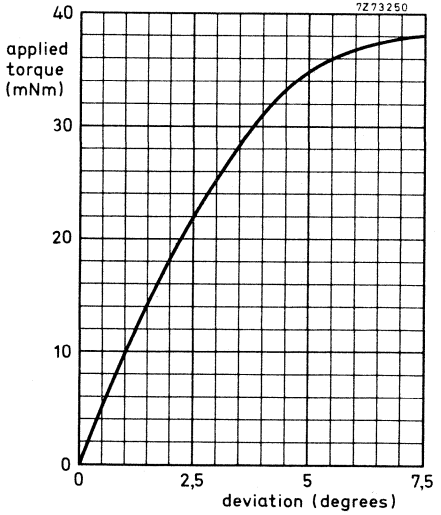


Fig. 4 Applied torque versus deviation.

# 4-PHASE UNIPOLAR STEPPER MOTOR

| QUICK REFERENCE DATA | | |
|---|---|---|
| performance obtained with | electronic switch 9904 131 03003 | |
| | without RC network | with RC network |
| Step angle | 7° 30' | 7° 30' |
| Max. working torque | 100 mNm | 100 mNm |
| Holding torque | 140 mNm | 140 mNm |
| Max. pull-in rate | 180 steps/s | 260 steps/s |
| Max. pull-out rate | 200 steps/s | 340 steps/s |

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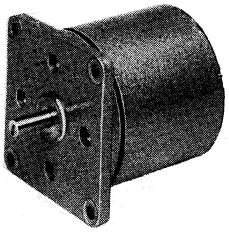

## APPLICATION

Motor 9904 112 18001 operated via electronic switch 9904 131 03003, without RC network, is especially suited for applications where the motor is used only in the pull-in range, and system efficiency is of importance. This combination, with RC network, is ideally suited for variable speed drives where the pull-out capabilities of the motor are required.

## TECHNICAL DATA

Dimensions (mm)

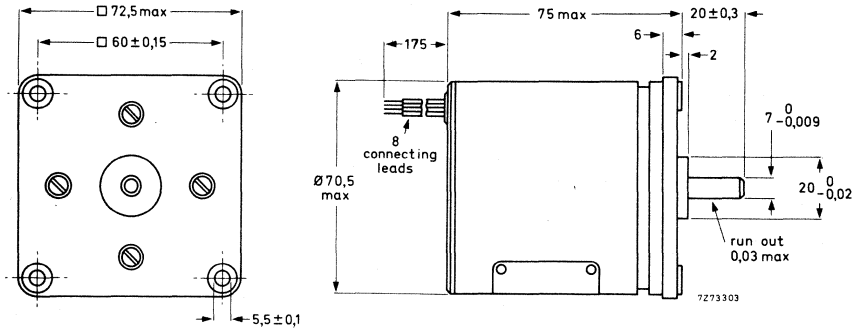


Fig. 1

Marking and connection
The connecting leads are colour-coded and are connected to the electronic switch as shown in General section of 4-phase unipolar stepper motors.

| | |
|---|---|
| Power consumption of motor only | 6,5 W |
| Maximum working torque | 100 mNm |
| Holding torque | 140 mNm |
| Maximum pull-in rate *) | 260 steps/s |
| Maximum pull-out rate *) | 340 steps/s |
| Number of phases | 4 |
| Resistance per coil | 9 Ω |
| Inductance per coil | 25 mH |
| Current per coil | 600 mA |
| Permissible ambient temperature range | −30 to + 85 °C |
| Permissible storage temperature range | −62 to + 110 °C |
| Permissible motor temperature | 125 °C |
| Insulation resistance at 500 V d.c. | 100 MΩ |
| Step angle | 7° 30' |
| Step-angle tolerance | ± 10' non-cumulative |
| Number of steps per revolution | 48 |
| Direction of rotation | reversible |
| Rotor inertia | 110 gcm$^2$ |
| Bearings | ball |
| Weight | 800 g |
| Maximum axial play of spindle measured with axial force of 1,5 N | 0,07 mm |
| Maximum radial force | 50 N |
| Maximum axial force | 20 N |

*) When driven by electronic switch 9904 131 03003 with RC network (see General section, Fig. 2. $R_V$ = 10 Ω ± 5%, 8 W; $C_V$ = 50 μF, 40 V d.c.; $V_b$ = 12 V d.c.; $R_S$ = ($V_b$ - 5)/0,230 Ω).

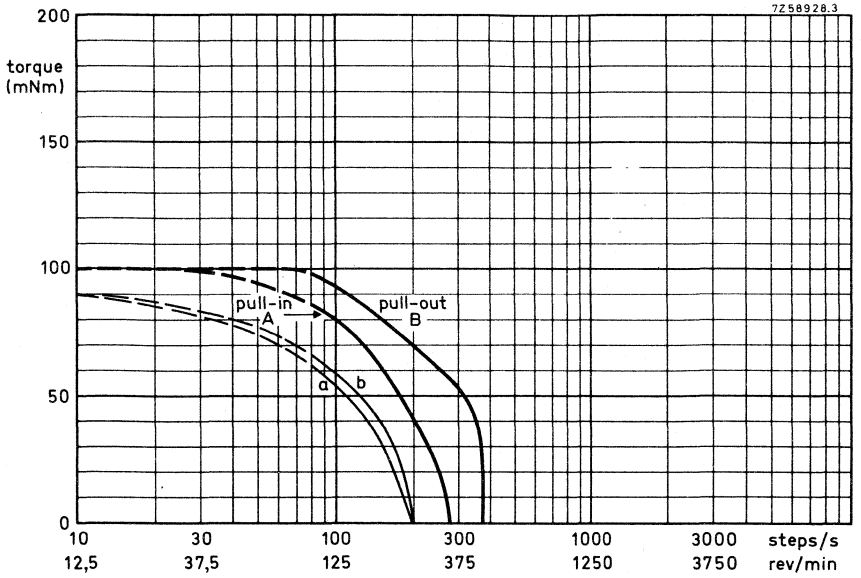


Fig. 2. Torque versus stepping rate, measured at room temperature (thin lines-without RC network, thick lines-with RC network; a and A for pull-in, b and B for pull-out).

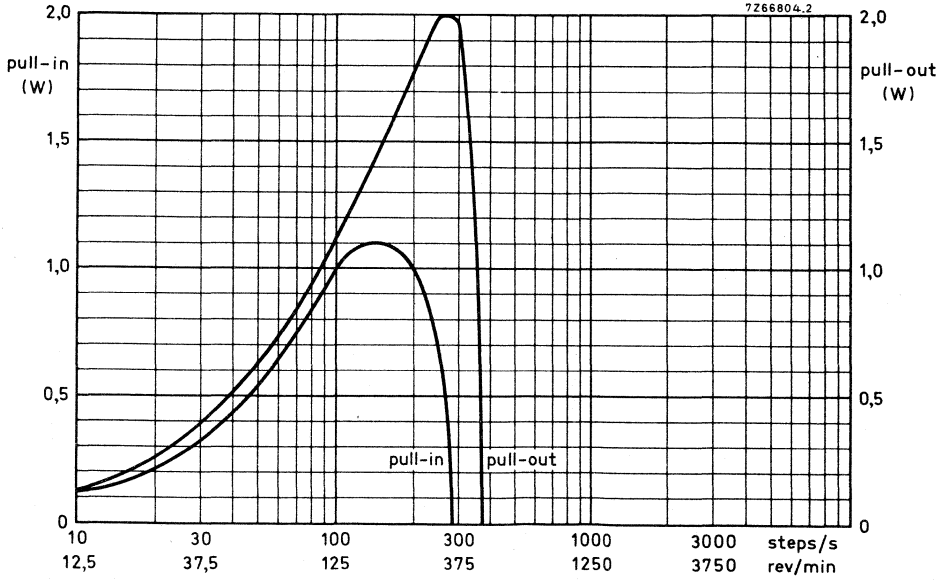


Fig. 3. Output power versus stepping rate, measured at room temperature.

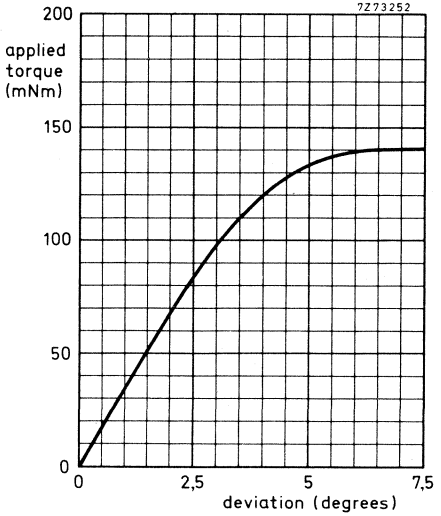


Fig. 4 Applied torque versus deviation.

# 4-PHASE UNIPOLAR STEPPER MOTOR

| QUICK REFERENCE DATA | | |
|---|---|---|
| performance obtained with | electronic switch 9904 131 03003 | |
| | without RC network | with RC network |
| Step angle | 15° | 15° |
| Max. working torque | 60 mNm | 60 mNm |
| Holding torque | 80 mNm | 80 mNm |
| Max. pull-in rate | 140 steps/s | 140 steps/s |
| Max. pull-out rate | 200 steps/s | 460 steps/s |

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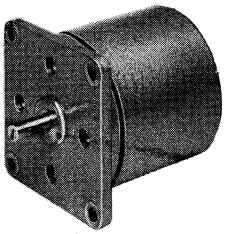

## APPLICATION

Motor 9904 112 22001 operated via electronic switch 9904 131 03003, without RC network, is especially suited for applications where the motor is used only in the pull-in range, and system efficiency is of importance. This combination, with RC network, is ideally suited for variable speed drives where the pull-out capabilities of the motor are required.

## TECHNICAL DATA

Dimensions (mm)

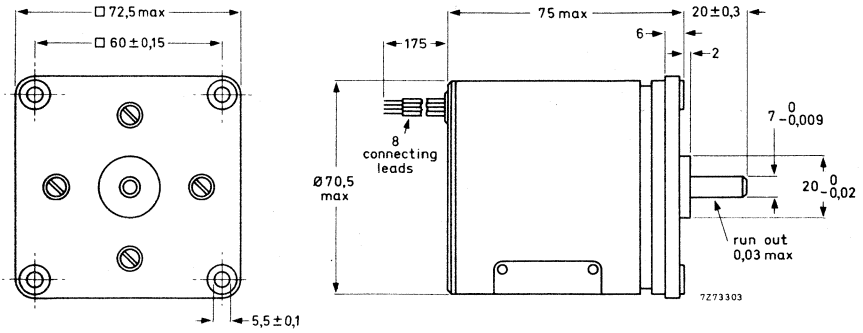


Fig. 1

Marking and connection

The connecting leads are colour-coded and are connected to the electronic switch as shown in General section of 4-phase unipolar stepper motors.

| | |
|---|---|
| Power consumption of motor only | 6,5 W |
| Maximum working torque | 60 mNm |
| Holding torque | 80 mNm |
| Maximum pull-in rate *) | 140 steps/s |
| Maximum pull-out rate *) | 460 steps/s |
| Number of phases | 4 |
| Resistance per coil | 9 Ω |
| Inductance per coil | 20 mH |
| Current per coil | 600 mA |
| Permissible ambient temperature range | −30 to + 85 °C |
| Permissible storage temperature range | −62 to + 110 °C |
| Permissible motor temperature | 125 °C |
| Insulation resistance at 500 V d.c. | 100 MΩ |
| Step angle | 15° |
| Step-angle tolerance | ± 15' non-cumulative |
| Number of steps per revolution | 24 |
| Direction of rotation | reversible |
| Rotor inertia | 110 gcm$^2$ |
| Bearings | ball |
| Weight | 800 g |
| Maximum axial play of spindle measured with axial force of 1,5 N | 0,07 mm |
| Maximum radial force | 50 N |
| Maximum axial force | 20 N |

*) When driven by electronic switch 9904 131 03003 with RC network (see General section, Fig. 2. $R_V$ = 10 Ω ± 5%, 8 W; $C_V$ = 50 μF, 40 V d.c.; $V_b$ = 12 V d.c.; $R_S = (V_b - 5)/0,230$ Ω).

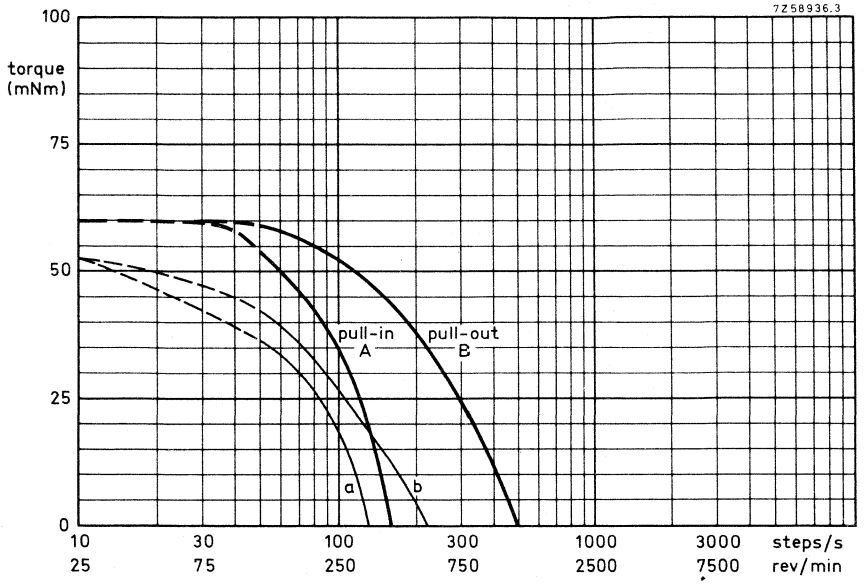


Fig. 2. Torque versus stepping rate, measured at room temperature (thin lines-without RC network, thick lines-with RC network; a and A for pull-in, b and B for pull-out).

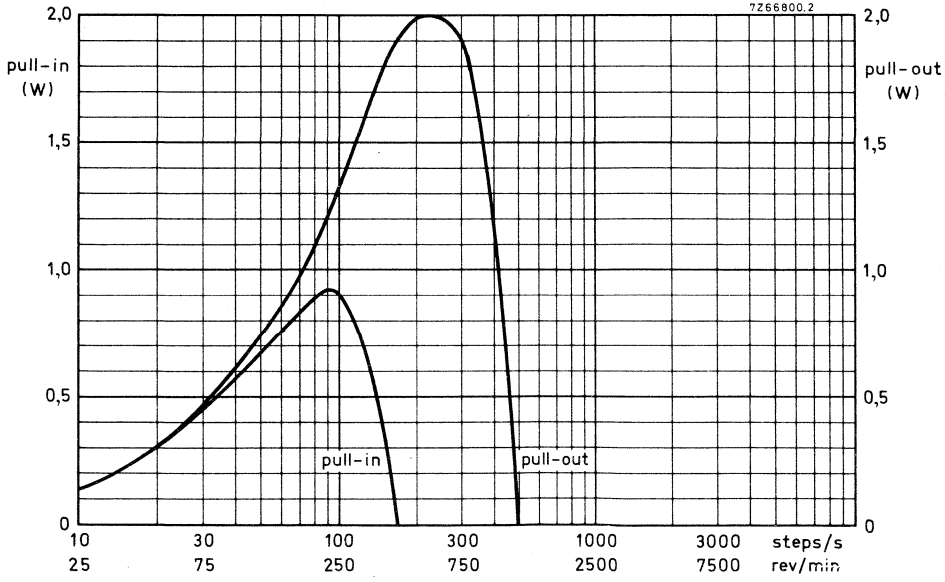


Fig. 3. Output power versus stepping rate, measured at room temperature.

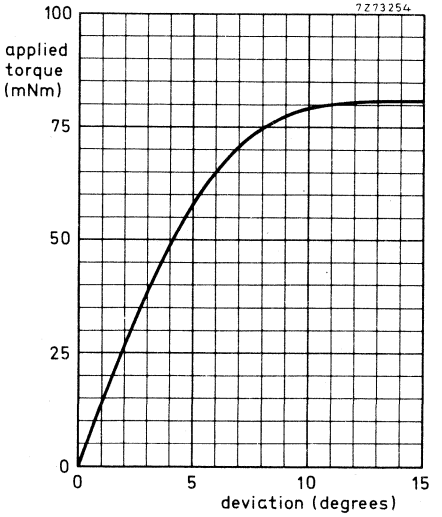


Fig. 4 Applied torque versus deviation.

# 8-PHASE UNIPOLAR STEPPER MOTORS

This range comprises four types of professional digital (PD) permanent magnet stepper motors. They are intended for better class instruments and for computer peripherals, to be used for positioning applications and for use in variable speed drives.

## DESCRIPTION

The motors have an 8-phase stator and a permanent magnet rotor with 24 poles (step angle of 3° 45') or 12 poles (step angle of 7° 30') in a rugged and simple construction. The motor coils are adapted to the unipolar electronic switch 9904 131 03004 (see relevant data sheet).

## CONNECTION DIAGRAMS

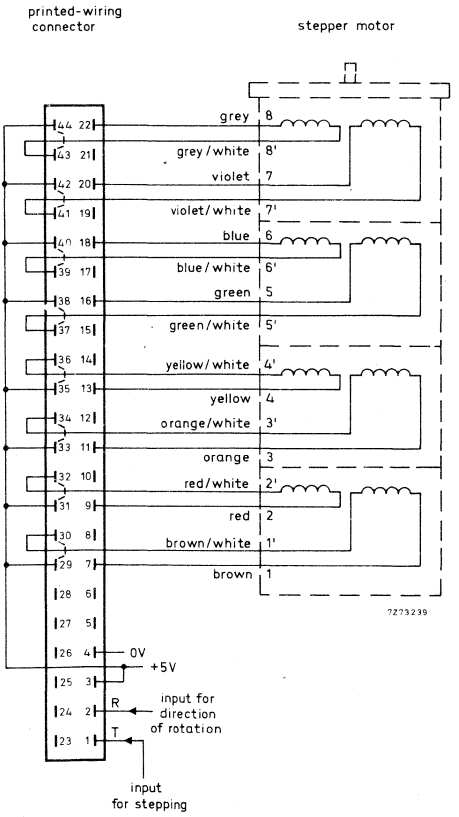


Fig. 1
Diagram for connecting the motor to the electronic switch 9904 131 03004, without compensating network.

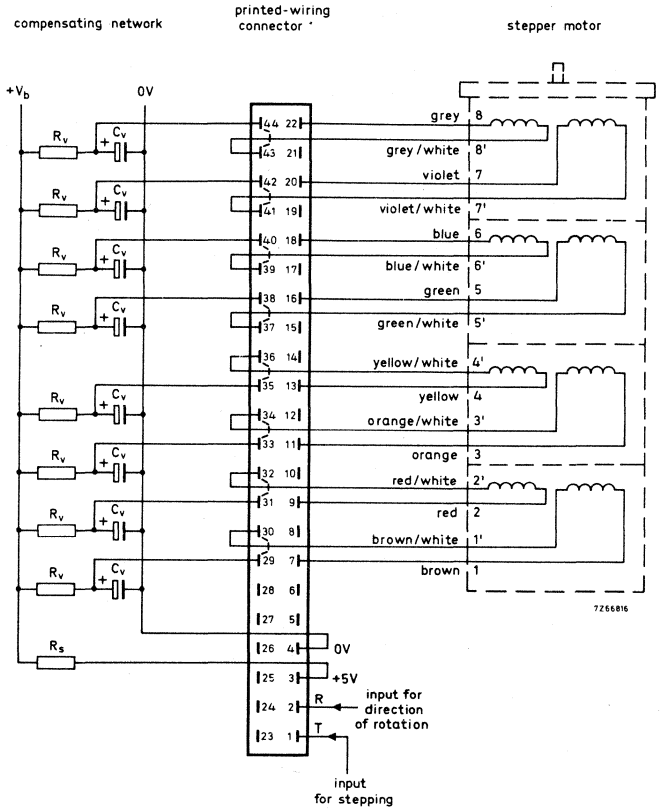


Fig. 2. Diagram for connecting the motor to the electronic switch 9904 131 03004, with compensating network.

# 8-PHASE UNIPOLAR STEPPER MOTOR

| QUICK REFERENCE DATA | | |
|---|---|---|
| performance obtained with | electronic switch 9904 131 03004 | |
| | without RC network | with RC network |
| Step angle | 3° 45' | 3° 45' |
| Max. working torque | 15 mNm | 15 mNm |
| Holding torque | 18 mNm | 18 mNm |
| Max. pull-in rate | 800 steps/s | 1200 steps/s |
| Max. pull-out rate | 1000 steps/s | 16000 steps/s |

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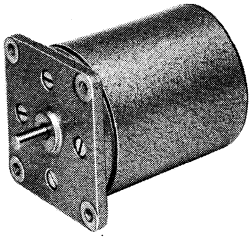

## APPLICATION

Motor 9904 112 12001 operated via electronic switch 9904 131 03004, without RC network, is especially suited for applications where the motor is used only in the pull-in range, and system efficiency is of importance.
This combination, with RC network, is ideally suited for variable speed drives where the pull-out capabilities of the motor are required.

## TECHNICAL DATA

Dimensions (mm)

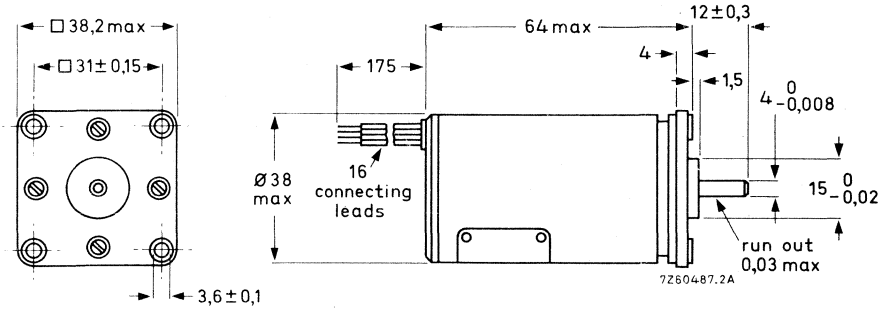


Fig. 1

Marking and connection

The connecting leads are colour-coded and are connected to the electronic switch as shown in General section of 8-phase unipolar stepper motors.

| | |
|---|---|
| Power consumption of motor only | 3,5 W |
| Maximum working torque | 15 mNm |
| Holding torque | 18 mNm |
| Maximum pull-in rate *) | 1200 steps/s |
| Maximum pull-out rate *) | 16000 steps/s |
| Number of phases | 8 |
| Resistance per coil | 27 Ω |
| Inductance per coil | 20 mH |
| Current per coil | 175 mA |
| Permissible ambient temperature range | −30 to + 85 °C |
| Permissible storage temperature range | −62 to + 110 °C |
| Permissible motor temperature | 125 °C |
| Insulation resistance at 500 V d.c. | 100 MΩ |
| Step angle | 3° 45' |
| Step-angle tolerance | ±20' non-cumulative |
| Number of steps per revolution | 96 |
| Direction of rotation | reversible |
| Rotor inertia | 7 gcm$^2$ |
| Bearings | ball |
| Weight | 220 g |
| Maximum axial play of spindle measured with axial force of 1,5 N | 0,07 mm |
| Maximum radial force | 10 N |
| Maximum axial force | 5 N |

*) When driven by electronic switch 9904 131 03004 with RC network (see General section, Fig. 1. $R_V = 91\ \Omega \pm 5\%$, 5 W; $C_V = 10\ \mu F$, 64 V d.c.; $V_b = 20$ V d.c.; $R_S = (V_b - 5)/0,440\ \Omega$).

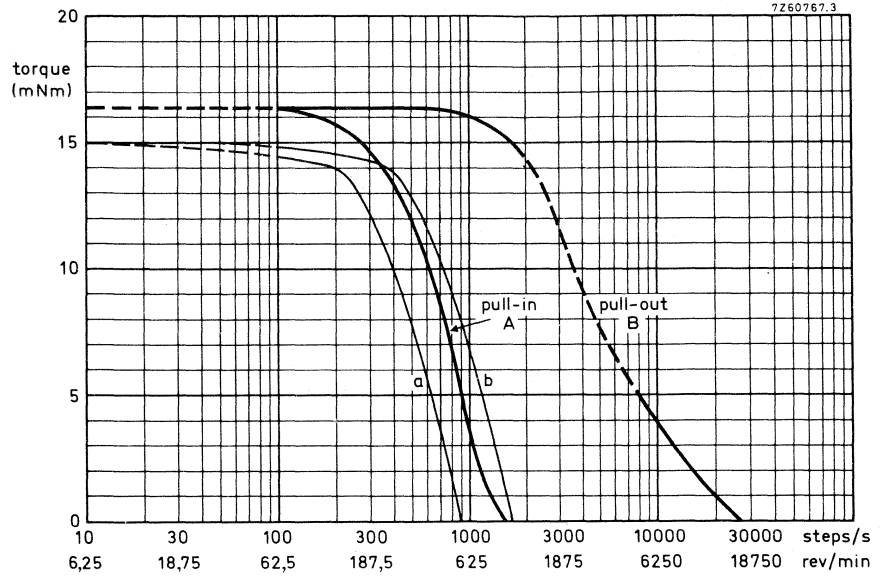


Fig. 2. Torque versus stepping rate, measured at room temperature (thin lines-without RC network, thick lines-with RC network; a and A for pull-in, b and B for pull-out).

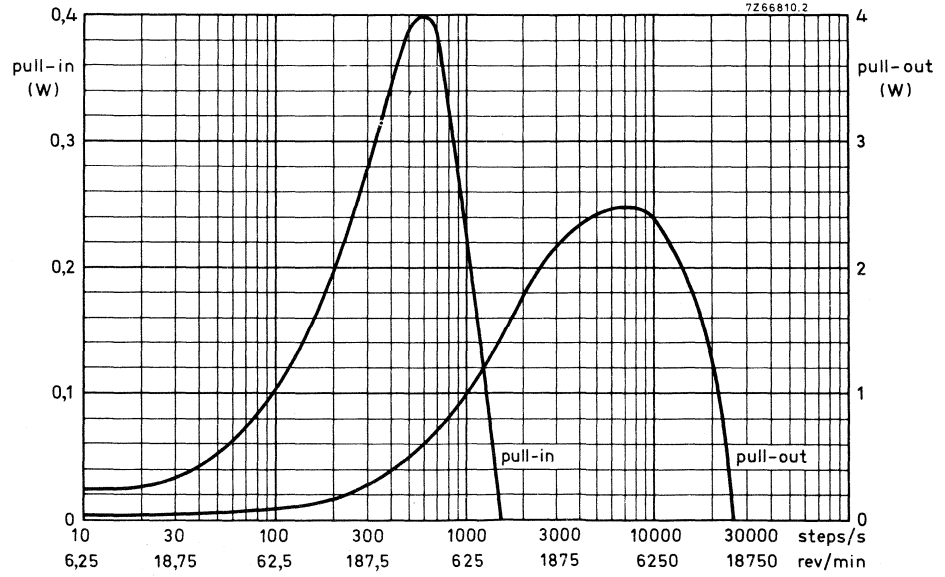


Fig. 3. Output power versus stepping rate, measured at room temperature.

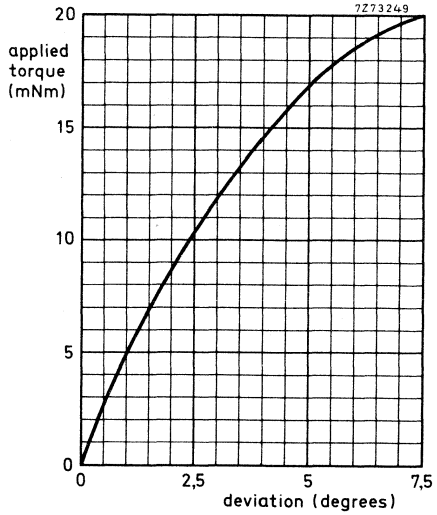


Fig. 4 Applied torque versus deviation.

# 8-PHASE UNIPOLAR STEPPER MOTOR

| QUICK REFERENCE DATA | | |
|---|---|---|
| performance obtained with | electronic switch 9904 131 03004 | |
| | without RC network | with RC network |
| Step angle | 3° 45' | 3° 45' |
| Max. working torque | 40 mNm | 40 mNm |
| Holding torque | 50 mNm | 50 mNm |
| Max. pull-in rate | 700 steps/s | 900 steps/s |
| Max. pull-out rate | 900 steps/s | 7500 steps/s |

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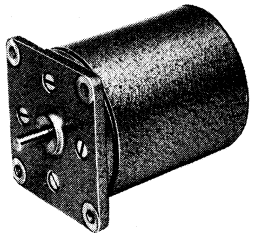

## APPLICATION

Motor 9904 112 16001 operated via electronic switch 9904 131 03004, without RC network, is especially suited for applications where the motor is used only in the pull-in range, and system efficiency is of importance.
This combination, with RC network, is ideally suited for variable speed drives where the pull-out capabilities of the motor are required.

## TECHNICAL DATA

Dimensions (mm)

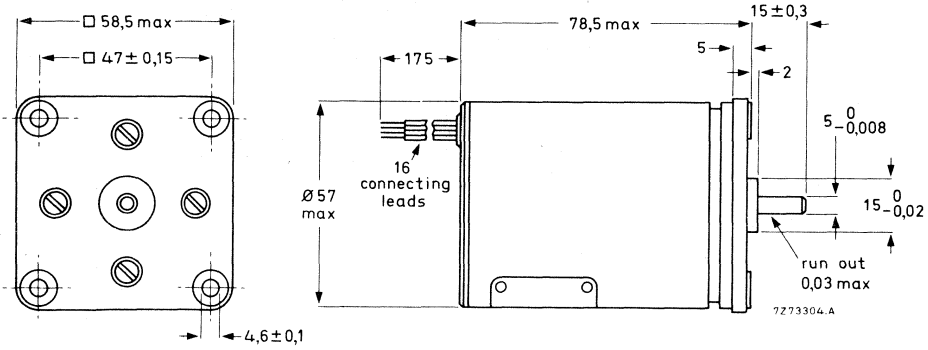


Fig. 1

Marking and connection

The connecting leads are colour-coded and are connected to the electronic switch as shown in General section of 8-phase unipolar stepper motors.

| | |
|---|---|
| Power consumption of motor only | 6,5 W |
| Maximum working torque | 40 mNm |
| Holding torque | 50 mNm |
| Maximum pull-in rate *) | 900 steps/s |
| Maximum pull-out rate *) | 7500 steps/s |
| Number of phases | 8 |
| Resistance per coil | 15 Ω |
| Inductance per coil | 25 mH |
| Current per coil | 350 mA |
| Permissible ambient temperature range | −30 to + 85 °C |
| Permissible storage temperature range | −62 to + 110 °C |
| Permissible motor temperature | 125 °C |
| Insulation resistance at 500 V d.c. | 100 MΩ |
| Step angle | 3° 45' |
| Step-angle tolerance | ± 10' non-cumulative |
| Number of steps per revolution | 96 |
| Direction of rotation | reversible |
| Rotor inertia | 32 gcm$^2$ |
| Bearings | ball |
| Weight | 600 g |
| Maximum axial play of spindle measured with axial force of 1,5 N | 0,07 mm |
| Maximum radial force | 15 N |
| Maximum axial force | 7,5 N |

*) When driven by electronic switch 9904 131 03004 with RC network (see General section, Fig. 2. $R_V = 50\ \Omega \pm 5\%$, 8 W; $C_V = 25\ \mu F$, 40 V d.c.; $V_b = 20$ V d.c.; $R_S = (V_b - 5)/0,440\ \Omega$).

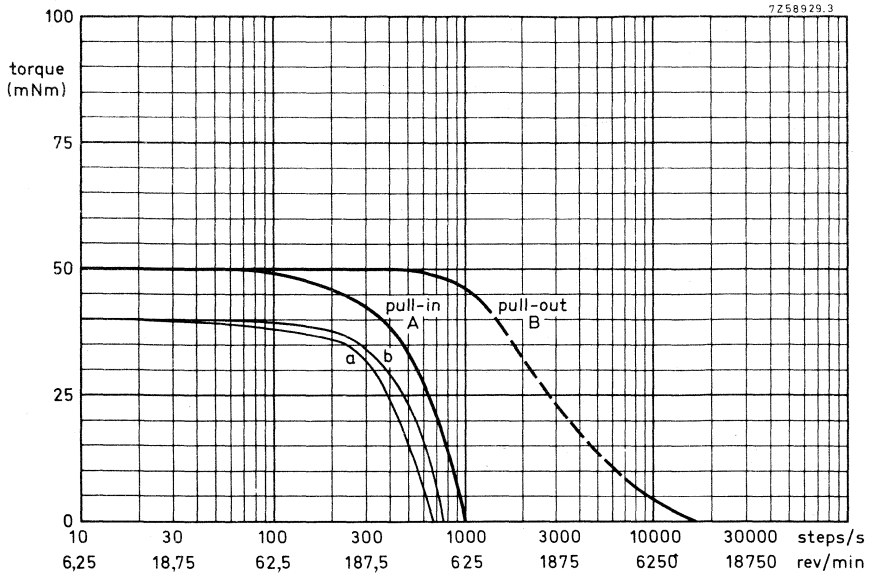


Fig. 2. Torque versus stepping rate, measured at room temperature (thin lines-without RC network, thick lines-with RC network; a and A for pull-in, b and B for pull-out).

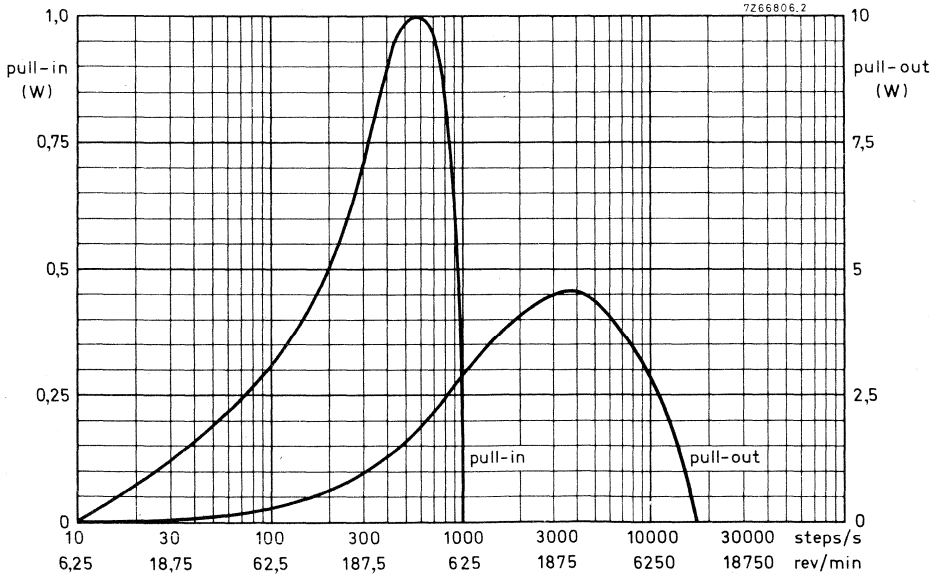


Fig. 3. Output power versus stepping rate, measured at room temperature.

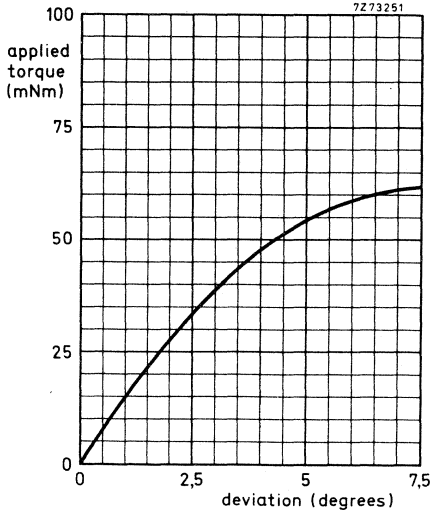


Fig. 4 Applied torque versus deviation.

# 8-PHASE UNIPOLAR STEPPER MOTOR

| QUICK REFERENCE DATA | | |
|---|---|---|
| performance obtained with | electronic switch 9904 131 03004 | |
| | without RC network | with RC network |
| Step angle | 3° 45' | 3° 45' |
| Max. working torque | 160 mNm | 160 mNm |
| Holding torque | 190 mNm | 190 mNm |
| Max. pull-in rate | 400 steps/s | 650 steps/s |
| Max. pull-out rate | 400 steps/s | 6000 steps/s |

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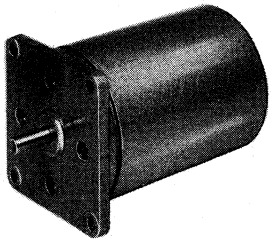


## APPLICATION

Motor 9904 112 20001 operated via electronic switch 9904 131 03004, without RC network, is especially suited for applications where the motor is used only in the pull-in range, and system efficiency is of importance.
This combination, with RC network, is ideally suited for variable speed drives where the pull-out capabilities of the motor are required.

## TECHNICAL DATA

Dimensions (mm)

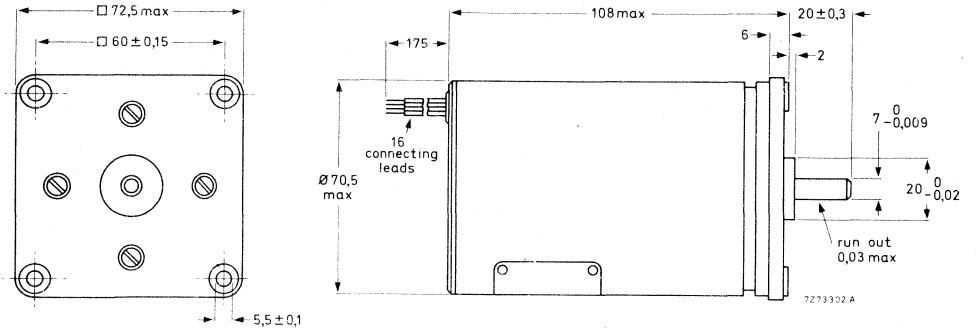



Fig. 1

Marking and connection

The connecting leads are colour-coded and are connected to the electronic switch as shown in General section of 8-phase unipolar stepper motors.

| | |
|---|---|
| Power consumption of motor only | 11 W |
| Maximum working torque | 160 mNm |
| Holding torque | 190 mNm |
| Maximum pull-in rate *) | 650 steps/s |
| Maximum pull-out rate *) | 6000 steps/s |
| Number of phases | 8 |
| Resistance per coil | 9 Ω |
| Inductance per coil | 25 mH |
| Current per coil | 550 mA |
| Permissible ambient temperature range | −30 to + 85 °C |
| Permissible storage temperature range | −62 to + 110 °C |
| Permissible motor temperature | 125 °C |
| Insulation resistance at 500 V d.c. | 100 MΩ |
| Step angle | 3° 45' |
| Step-angle tolerance | ± 10' non-cumulative |
| Number of steps per revolution | 96 |
| Direction of rotation | reversible |
| Rotor inertia | 220 gcm$^2$ |
| Bearings | ball |
| Weight | 1400 g |
| Maximum axial play of spindle measured with axial force of 1,5 N | 0,07 mm |
| Maximum radial force | 50 N |
| Maximum axial force | 20 N |

*) When driven by electronic switch 9904 131 03004 with RC network (see General section, Fig. 2. $R_V = 30\ \Omega \pm 5\%$, 16 W; $C_V = 100\ \mu F$, 64 V d.c.; $V_b = 20$ V d.c.; $R_S = (V_b - 5)/0,440\ \Omega$).

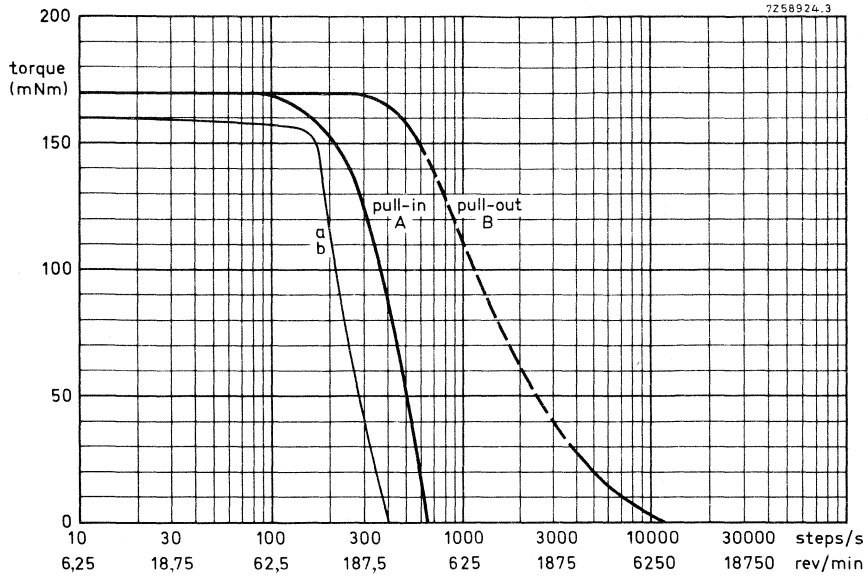



Fig. 2. Torque versus stepping rate, measured at room temperature (thin lines-without RC network, thick lines-with RC network; a and A for pull-in, b and B for pull-out).

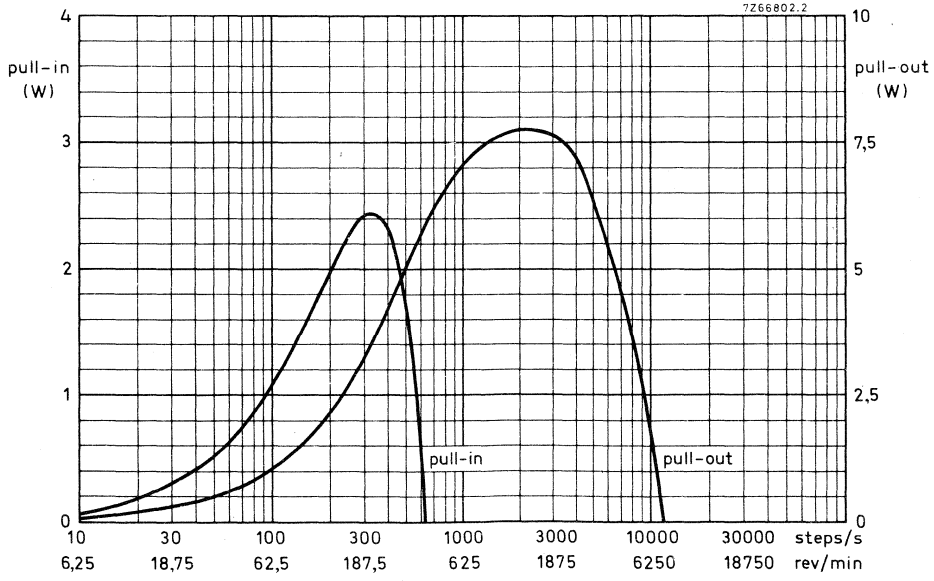



Fig. 3. Output power versus stepping rate, measured at room temperature.

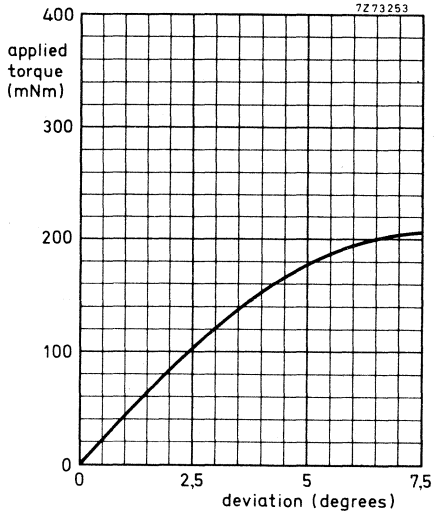
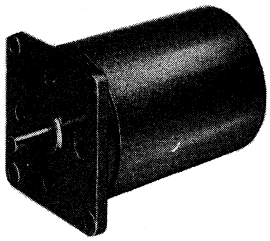



Fig. 4 Applied torque versus deviation.

# 8-PHASE UNIPOLAR STEPPER MOTOR

| QUICK REFERENCE DATA | | |
|---|---|---|
| performance obtained with | electronic switch 9904 131 03004 | |
| | without RC network | with RC network |
| Step angle | 7° 30' | 7° 30' |
| Max. working torque | 90 mNm | 90 mNm |
| Holding torque | 110 mNm | 110 mNm |
| Max. pull-in rate | 250 steps/s | 350 steps/s |
| Max. pull-out rate | 400 steps/s | 3500 steps/s |

*720808-16-01*



## APPLICATION

Motor 9904 112 24001 operated via electronic switch 9904 131 03004, without RC network, is especially suited for applications where the motor is used only in the pull-in range, and system efficiency is of importance.
This combination, with RC network, is ideally suited for variable speed drives where the pull-out capabilities of the motor are required.

## TECHNICAL DATA

Dimensions (mm)

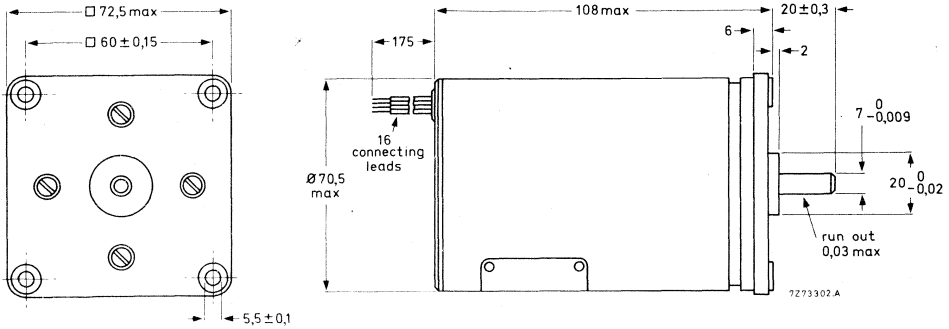



Fig. 1

Marking and connection

The connecting leads are colour-coded and are connected to the electronic switch as shown in General section of 8-phase unipolar stepper motors.

| | |
|---|---|
| Power consumption of motor only | 11 W |
| Maximum working torque | 90 mNm |
| Holding torque | 110 mNm |
| Maximum pull-in rate *) | 350 steps/s |
| Maximum pull-out rate *) | 3500 steps/s |
| Number of phases | 8 |
| Resistance per coil | 9 Ω |
| Inductance per coil | 25 mH |
| Current per coil | 550 mA |
| Permissible ambient temperature range | −30 to + 85 °C |
| Permissible storage temperature range | −62 to + 110 °C |
| Permissible motor temperature | 125 °C |
| Insulation resistance at 500 V d.c. | 100 MΩ |
| Step angle | 7° 30' |
| Step-angle tolerance | ± 15' non-cumulative |
| Number of steps per revolution | 48 |
| Direction of rotation | reversible |
| Rotor inertia | 220 gcm$^2$ |
| Bearings | ball |
| Weight | 1400 g |
| Maximum axial play of spindle measured with axial force of 1,5 N | 0,07 mm |
| Maximum radial force | 50 N |
| Maximum axial force | 20 N |

*) When driven by electronic switch 9904 131 03004 with RC network (see General section, Fig. 2. $R_V$ = 30 Ω ± 5%, 16 W; $C_V$ = 100 μF, 64 V d.c.; $V_b$ = 20 V d.c.; $R_S = (V_b - 5)/0,440$ Ω).

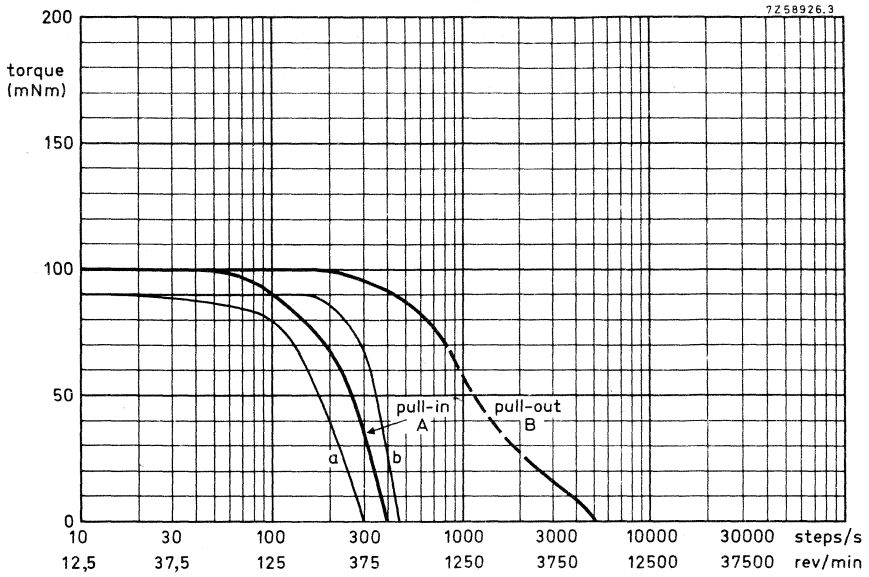



Fig. 2. Torque versus stepping rate, measured at room temperature (thin lines-without RC network, thick lines-with RC network; a and A for pull-in, b and B for pull-out).

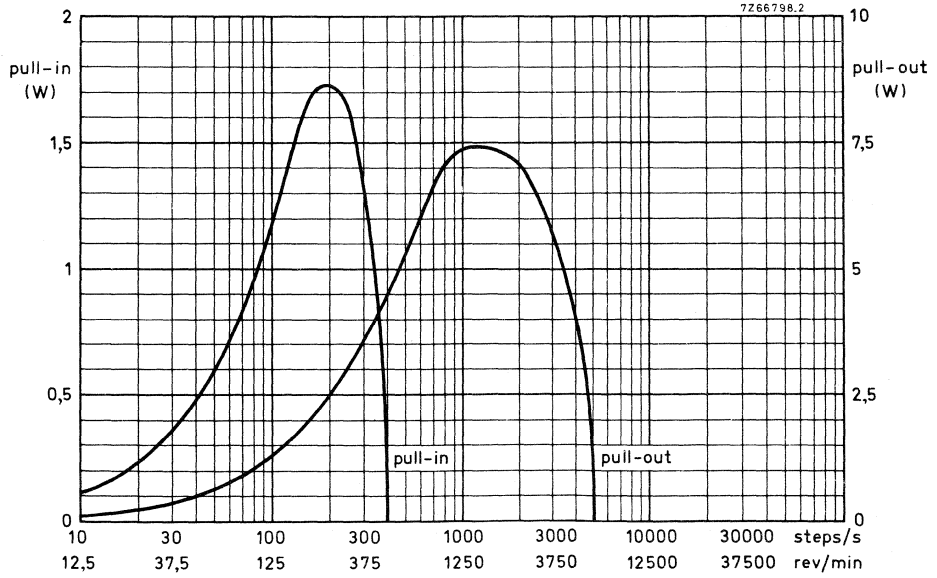



Fig. 3. Output power versus stepping rate, measured at room temperature.

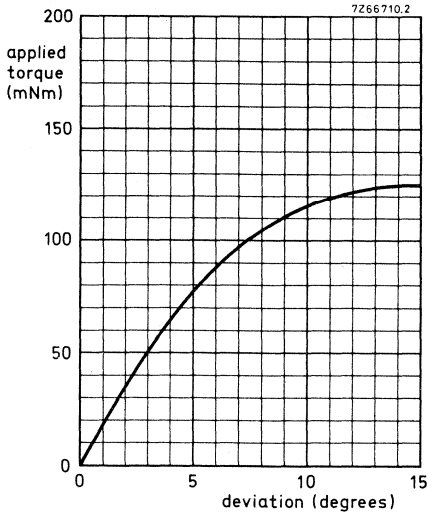



Fig. 4 Applied torque versus deviation.

# 2-PHASE BIPOLAR STEPPER MOTORS

This range comprises six types of permanent magnet stepper motor:

- 2 industrial digital (ID) types;
- 4 professional digital (PD) types.

They are ideally suited for incremental motion control in telecommunication equipment and computer peripherals.

## DESCRIPTION

The motors have a 2-phase stator and a permanent magnet rotor with 24 poles (step angle of $7^{o}$ 30') or 12 poles (step angle of $15^{o}$) in a rugged and simple construction. They are derived from the 4-phase unipolar motors, so that their design is similar. The motor coils are adapted to the bipolar constant current drive (BCCD) 4322 027 90070 (see relevant data sheet). Driven via the BCCD unit the stepper motors are able to achieve extremely high stepping rates in the slew range. However, it should be noted that the motors are NOT designed for continuous operation at these high stepping rates since the iron losses within the motor result in an unacceptable temperature rise.

## CONNECTION DIAGRAM

See next page.

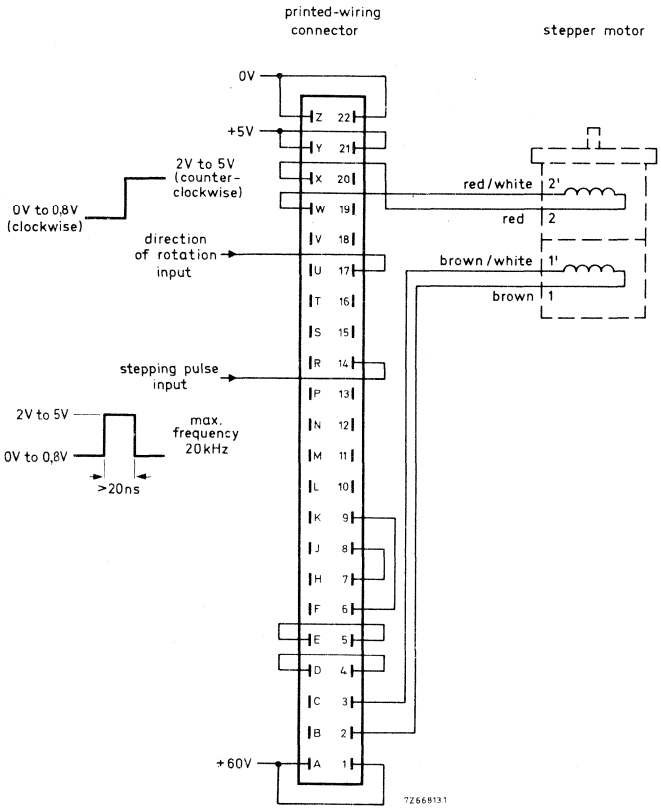
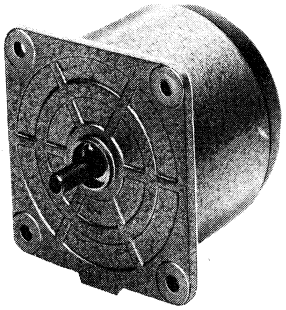



Diagram for connecting the motor to the bipolar constant current drive 4322 027 90070 via a printed-wiring connector.

# 2-PHASE BIPOLAR STEPPER MOTOR

| QUICK REFERENCE DATA | |
|---|---|
| performance obtained with bipolar constant current drive 4322 027 90070 | |
| Step angle | 7° 30' |
| Maximum working torque | 105 mNm |
| Holding torque | 125 mNm |
| Maximum pull-in rate | 400 steps/s |
| Maximum pull-out rate | 4500 steps/s |

*A53191*



## TECHNICAL DATA

Dimensions (mm)

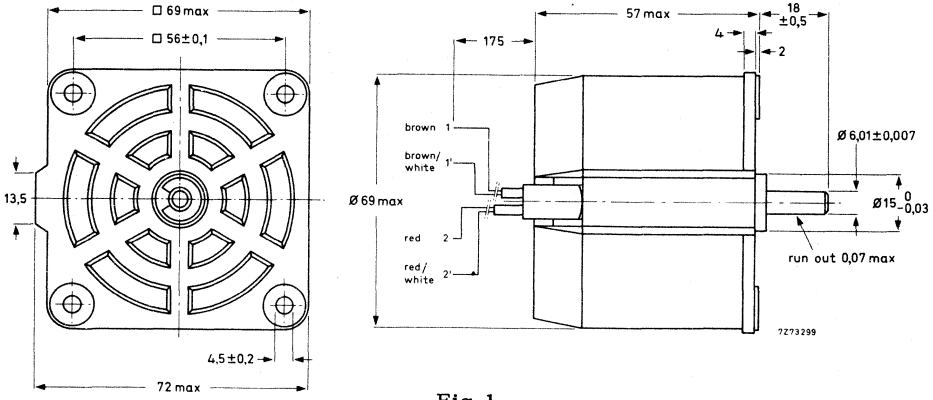



Fig. 1

Marking and connection

The connecting leads are colour-coded (see Fig. 1) and are connected to the bipolar constant current drive as shown in General section of 2-phase bipolar stepper motors.

| | |
|---|---|
| Power consumption of motor only | 8 W |
| Maximum working torque | 105 mNm |
| Holding torque | 125 mNm |
| Maximum pull-in rate *) | 400 steps/s |
| Maximum pull-out rate *) | 4500 steps/s |
| Number of phases | 2 |
| Resistance per coil | 16 Ω |
| Inductance per coil | 80 mH |
| Current per coil | 500 mA |
| Permissible ambient temperature range | see General section of Stepper motors |
| Permissible storage temperature range | −40 to + 100 °C |
| Permissible motor temperature | 100 °C |
| Insulation resistance at 500 V d.c. | 100 MΩ |
| Step angle | 7° 30' |
| Step-angle tolerance | ±20' non-cumulative |
| Number of steps per revolution | 48 |
| Direction of rotation | reversible |
| Rotor inertia | 93 $gcm^2$ |
| Bearings | needle |
| Weight | 500 g |
| Maximum radial force | 15 N |
| Maximum axial force | 5 N |

*) When driven by BCCD unit 4322 027 90070.

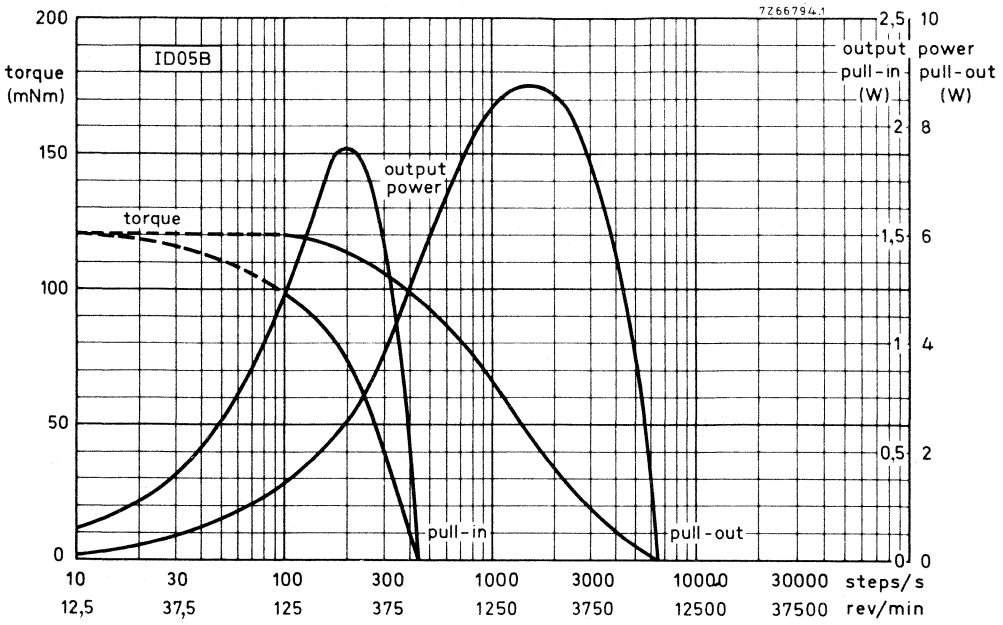



Fig. 2 Torque (left scale) and relevant output power (right scale) versus stepping rate, measured at room temperature.

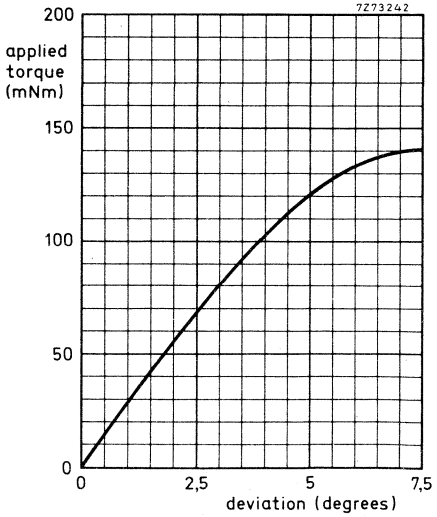
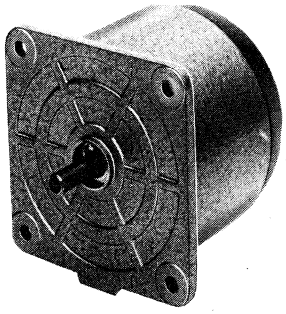



Fig. 3 Applied torque versus deviation.

# 2-PHASE BIPOLAR STEPPER MOTOR

| QUICK REFERENCE DATA | |
|---|---|
| performance obtained with bipolar constant current drive 4322 027 90070 | |
| Step angle | 15° |
| Maximum working torque | 70 mNm |
| Holding torque | 100 mNm |
| Maximum pull-in rate | 200 steps/s |
| Maximum pull-out rate | 3000 steps/s |

*A53191*



## TECHNICAL DATA

Dimensions (mm)

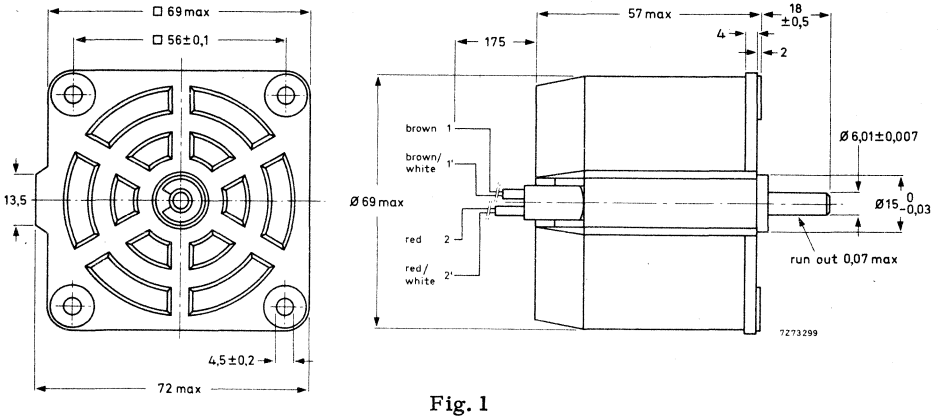



Fig. 1

Marking and connection

The connecting leads are colour-coded (see Fig. 1) and are connected to the bipolar constant current drive as shown in General section of 2-phase bipolar stepper motors.

| | |
|---|---|
| Power consumption of motor only | 8 W |
| Maximum working torque | 70 mNm |
| Holding torque | 100 mNm |
| Maximum pull-in rate *) | 200 steps/s |
| Maximum pull-out rate *) | 3000 steps/s |
| Number of phases | 2 |
| Resistance per coil | 16 Ω |
| Inductance per coil | 50 mH |
| Current per coil | 500 mA |
| Permissible ambient temperature range | see General section of Stepper motors |
| Permissible storage temperature range | −40 to + 100 °C |
| Permissible motor temperature | 100 °C |
| Insulation resistance at 500 V d.c. | 100 MΩ |
| Step angle | 15° |
| Step-angle tolerance | ± 30' non-cumulative |
| Number of steps per revolution | 24 |
| Direction of rotation | reversible |
| Rotor inertia | 93 $gcm^2$ |
| Bearings | needle |
| Weight | 500 g |
| Maximum radial force | 15 N |
| Maximum axial force | 5 N |

*) When driven by BCCD unit 4322 027 90070.

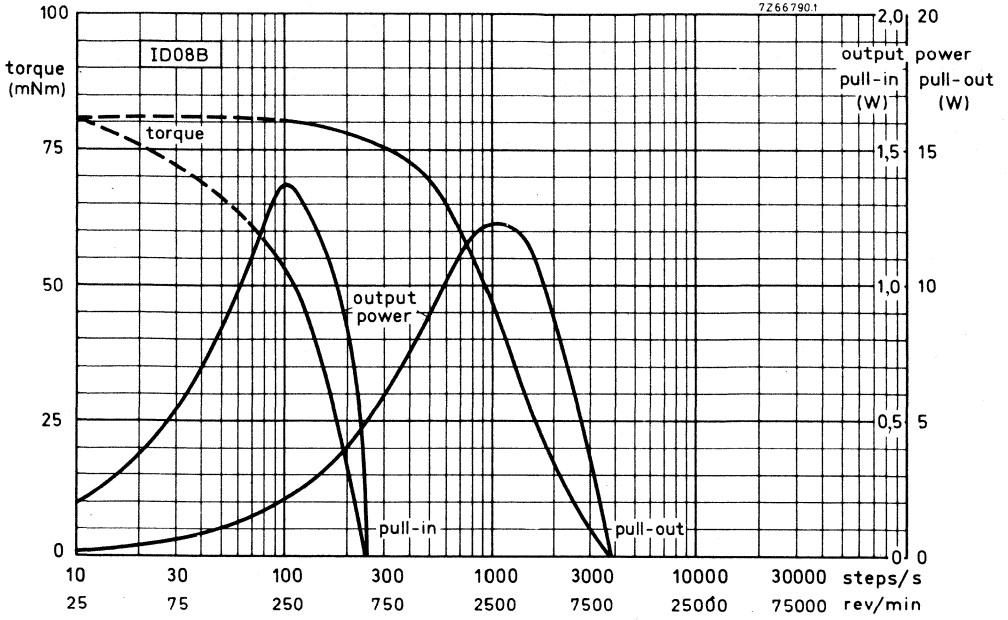



Fig. 2 Torque (left scale) and relevant output power (right scale) versus stepping rate, measured at room temperature.

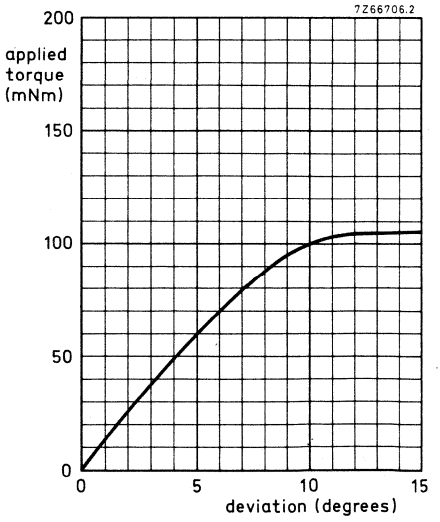



Fig. 3 Applied torque versus deviation.

# 2-PHASE BIPOLAR STEPPER MOTOR

| QUICK REFERENCE DATA | |
|---|---|
| performance obtained with bipolar constant current drive 4322 027 90070 | |
| Step angle | 7° 30' |
| Maximum working torque | 13 mNm |
| Holding torque | 16 mNm |
| Maximum pull-in rate | 750 steps/s |
| Maximum pull-out rate | 15000 steps/s |

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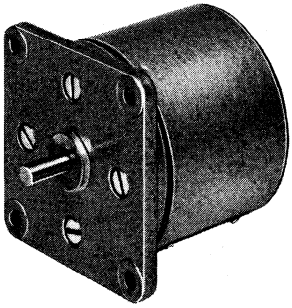


## TECHNICAL DATA

Dimensions (mm)

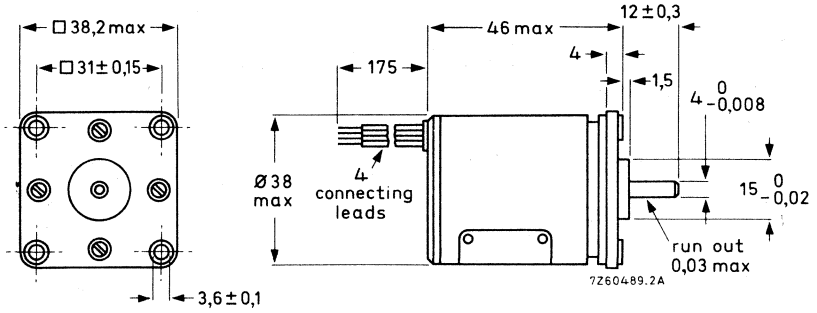



Fig. 1

Marking and connection
The connecting leads are colour-coded and are connected to the bipolar constant current drive as shown in General section of 2-phase bipolar stepper motors.

| | |
|---|---|
| Power consumption of motor only | 3,25 W |
| Maximum working torque | 13 mNm |
| Holding torque | 16 mNm |
| Maximum pull-in rate *) | 750 steps/s |
| Maximum pull-out rate *) | 15000 steps/s |
| Number of phases | 2 |
| Resistance per coil | 6,5 Ω |
| Inductance per coil | 10 mH |
| Current per coil | 500 mA |
| Permissible ambient temperature range | see General section of Stepper motors |
| Permissible storage temperature range | −62 to + 110 °C |
| Permissible motor temperature | 125 °C |
| Insulation resistance at 500 V d.c. | 100 MΩ |
| Step angle | 7° 30' |
| Step-angle tolerance | ±20' non-cumulative |
| Number of steps per revolution | 48 |
| Direction of rotation | reversible |
| Rotor inertia | 3,5 gcm$^2$ |
| Bearings | ball |
| Weight | 140 g |
| Maximum axial play (axial force 1,5 N) | 0,07 mm |
| Maximum radial force | 10 N |
| Maximum axial force | 5 N |

*) When driven by BCCD unit 4322 027 90070.

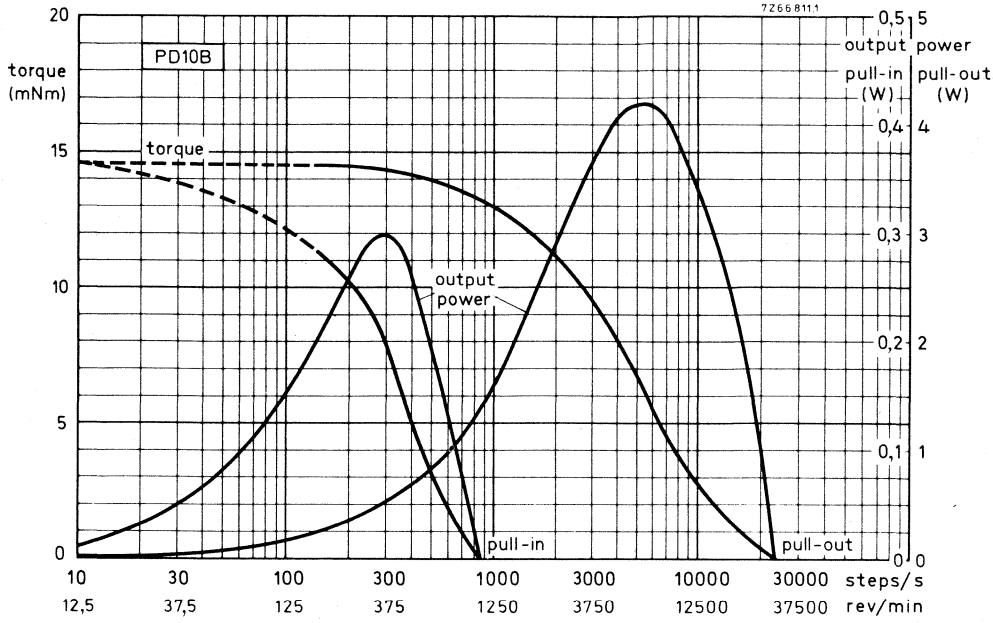



Fig. 2 Torque (left scale) and relevant output power (right scale) versus stepping rate, measured at room temperature.

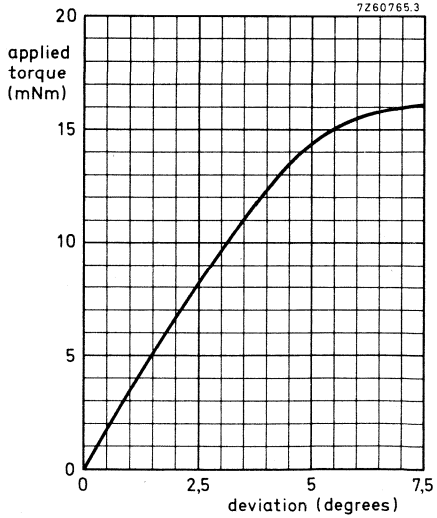
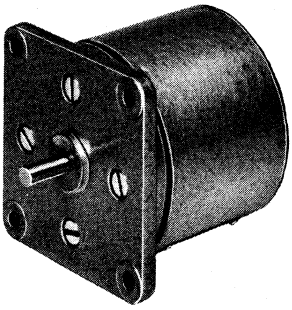



Fig. 3 Applied torque versus deviation.

# 2-PHASE BIPOLAR STEPPER MOTOR

| QUICK REFERENCE DATA | |
|---|---|
| performance obtained with bipolar constant current drive 4322 027 90070 | |
| Step angle | 7° 30' |
| Maximum working torque | 30 mNm |
| Holding torque | 40 mNm |
| Maximum pull-in rate | 580 steps/s |
| Maximum pull-out rate | 12000 steps/s |

*720808-16-02*



## TECHNICAL DATA

Dimensions (mm)

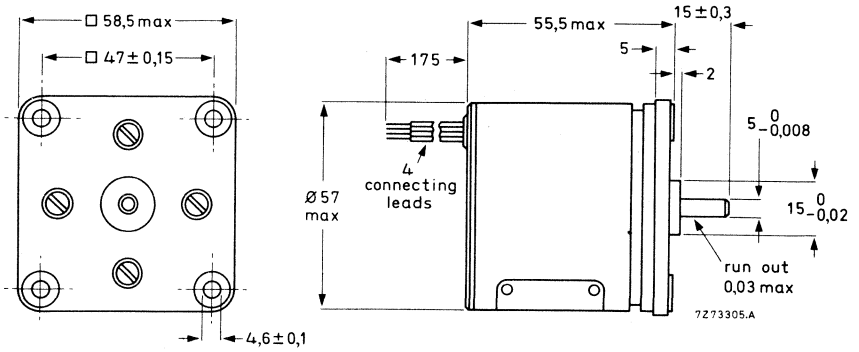



Fig. 1

Marking and connection

The connecting leads are colour-coded and are connected to the bipolar constant current drive as shown in General section of 2-phase bipolar stepper motors.

| | |
|---|---|
| Power consumption of motor only | 4 W |
| Maximum working torque | 30 mNm |
| Holding torque | 40 mNm |
| Maximum pull-in rate *) | 580 steps/s |
| Maximum pull-out rate *) | 12000 steps/s |
| Number of phases | 2 |
| Resistance per coil | 8 Ω |
| Inductance per coil | 25 mH |
| Current per coil | 500 mA |
| Permissible ambient temperature range | see General section of Stepper motors |
| Permissible storage temperature range | −62 to + 110 °C |
| Permissible motor temperature | 125 °C |
| Insulation resistance at 500 V d.c. | 100 MΩ |
| Step angle | 7° 30' |
| Step-angle tolerance | ± 10' non-cumulative |
| Number of steps per revolution | 48 |
| Direction of rotation | reversible |
| Rotor inertia | 18 gcm$^2$ |
| Bearings | ball |
| Weight | 500 g |
| Maximum axial play (axial force 5 N) | 0,07 mm |
| Maximum radial force | 15 N |
| Maximum axial force | 7,5 N |

*) When driven by BCCD unit 4322 027 90070.

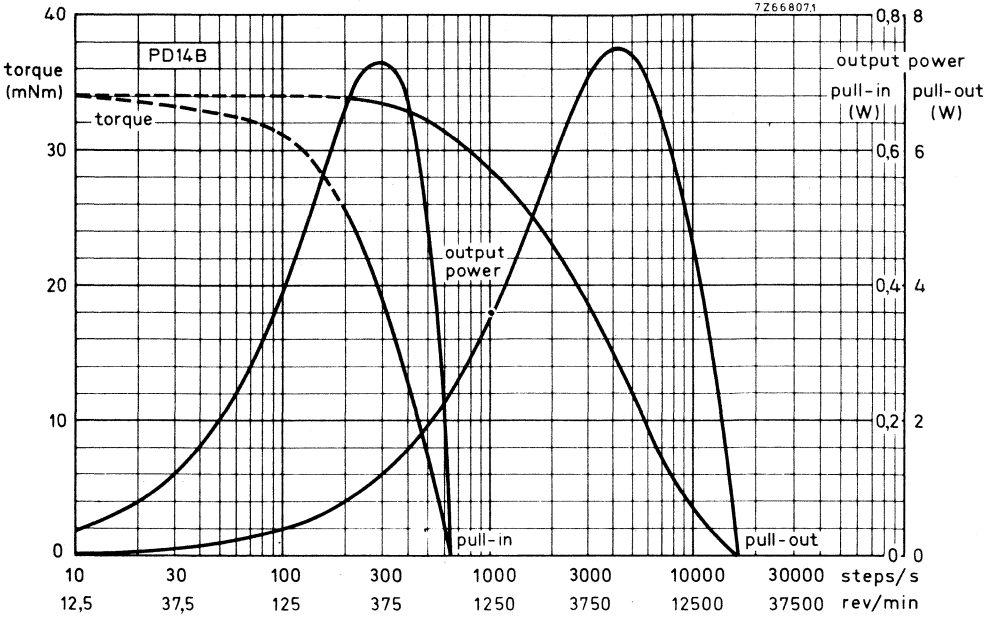



Fig. 2 Torque (left scale) and relevant output power (right scale) versus stepping rate, measured at room temperature.

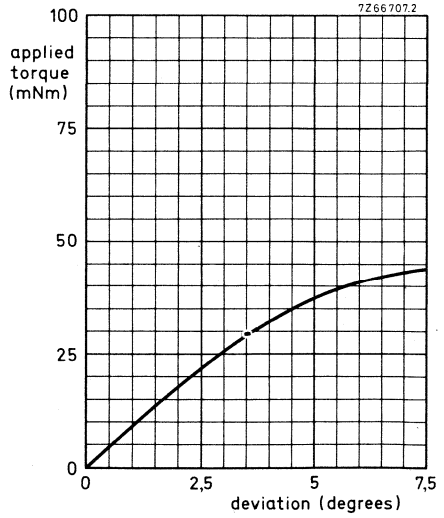
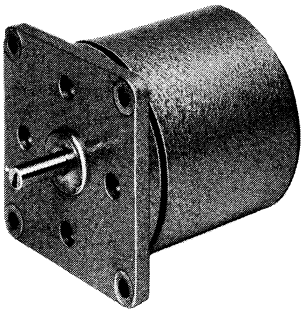



Fig. 3 Applied torque versus deviation.

# 2-PHASE BIPOLAR STEPPER MOTOR

| QUICK REFERENCE DATA | |
|---|---|
| performance obtained with bipolar constant current drive 4322 027 90070 | |
| Step angle | 7° 30' |
| Maximum working torque | 130 mNm |
| Holding torque | 170 mNm |
| Maximum pull-in rate | 375 steps/s |
| Maximum pull-out rate | 5000 steps/s |

*720808-16-04*



## TECHNICAL DATA

Dimensions (mm)

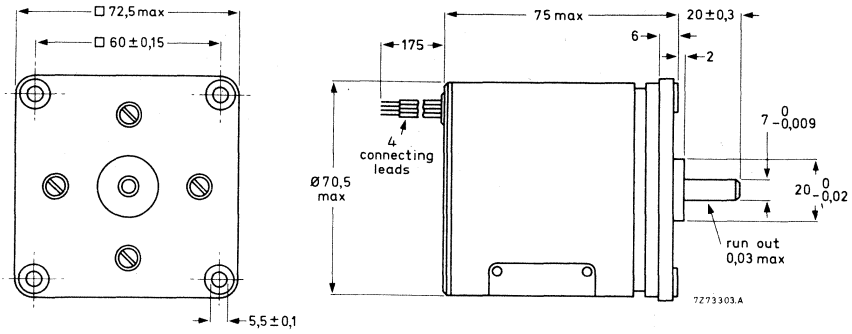



Fig. 1

Marking and connection
The connecting leads are colour-coded and are connected to the bipolar constant current drive as shown in General section of 2-phase bipolar stepper motors.

| | |
|---|---|
| Power consumption of motor only | 8 W |
| Maximum working torque | 130 mNm |
| Holding torque | 170 mNm |
| Maximum pull-in rate *) | 375 steps/s |
| Maximum pull-out rate *) | 5000 steps/s |
| Number of phases | 2 |
| Resistance per coil | 16 Ω |
| Inductance per coil | 80 mH |
| Current per coil | 500 mA |
| Permissible ambient temperature range | see General section of Stepper motors |
| Permissible storage temperature range | −62 to + 110 °C |
| Permissible motor temperature | 125 °C |
| Insulation resistance at 500 V d.c. | 100 MΩ |
| Step angle | 7° 30' |
| Step-angle tolerance | ± 10' non-cumulative |
| Number of steps per revolution | 48 |
| Direction of rotation | reversible |
| Rotor inertia | 110 gcm$^2$ |
| Bearings | ball |
| Weight | 800 g |
| Maximum axial play (axial force 1,5 N) | 0,07 mm |
| Maximum radial force | 50 N |
| Maximum axial force | 20 N |

*) When driven by BCCD unit 4322 027 90070.

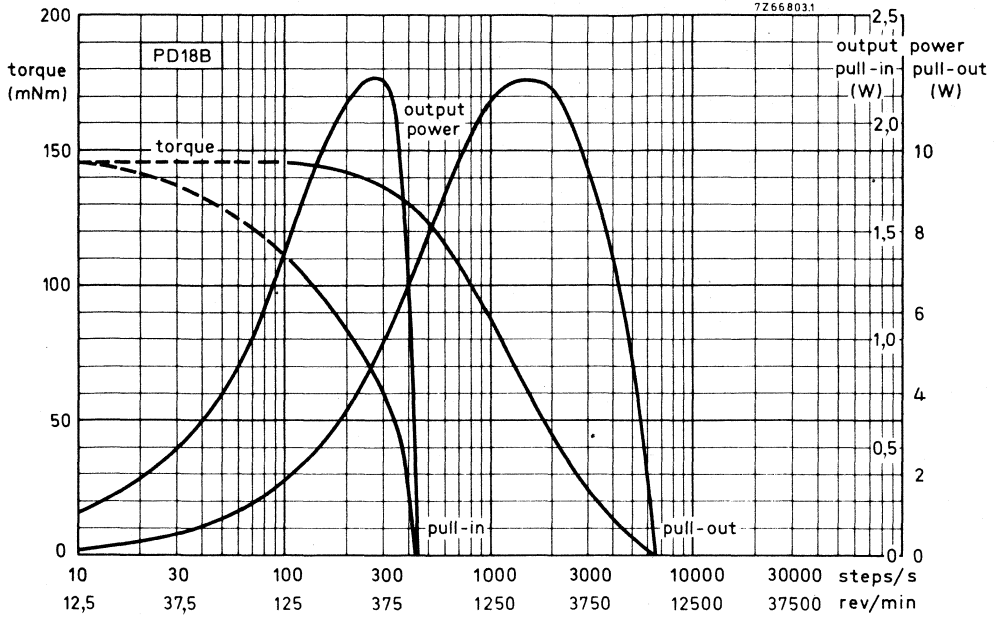



Fig. 2 Torque (left scale) and relevant output power (right scale) versus stepping rate, measured at room temperature.

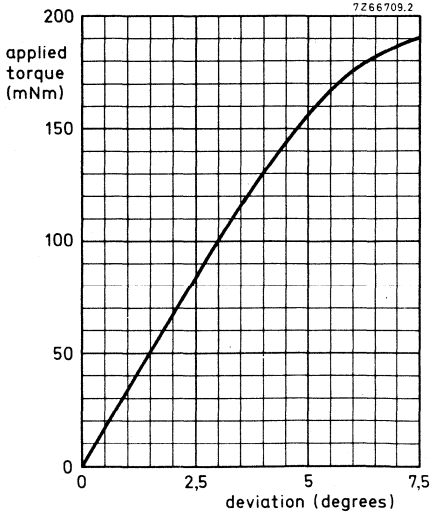
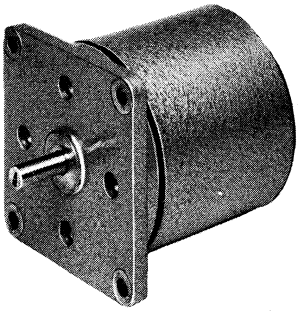



Fig. 3 Applied torque versus deviation.

# 2-PHASE BIPOLAR STEPPER MOTOR

| QUICK REFERENCE DATA | |
|---|---|
| performance obtained with bipolar constant current drive 4322 027 90070 | |
| Step angle | 15° |
| Maximum working torque | 80 mNm |
| Holding torque | 120 mNm |
| Maximum pull-in rate | 220 steps/s |
| Maximum pull-out rate | 3200 steps/s |

*720808-16-04*



## TECHNICAL DATA

Dimensions (mm)

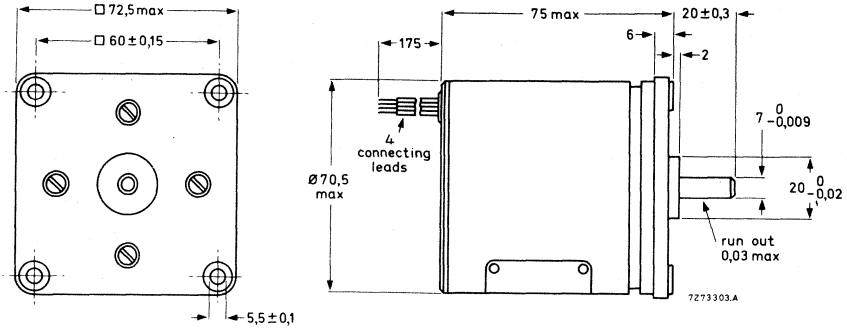



Fig. 1

Marking and connection

The connecting leads are colour-coded and are connected to the bipolar constant current drive as shown in General section of 2-phase bipolar stepper motors.

| | |
|---|---|
| Power consumption of motor only | 8 W |
| Maximum working torque | 80 mNm |
| Holding torque | 120 mNm |
| Maximum pull-in rate *) | 220 steps/s |
| Maximum pull-out rate *) | 3200 steps/s |
| Number of phases | 2 |
| Resistance per coil | 16 Ω |
| Inductance per coil | 50 mH |
| Current per coil | 500 mA |
| Permissible ambient temperature range | see General section of Stepper motors |
| Permissible storage temperature range | −62 to + 110 °C |
| Permissible motor temperature | 125 °C |
| Insulation resistance at 500 V d.c. | 100 MΩ |
| Step angle | 15° |
| Step-angle tolerance | ± 15' non-cumulative |
| Number of steps per revolution | 24 |
| Direction of rotation | reversible |
| Rotor inertia | 110 gcm$^2$ |
| Bearings | ball |
| Weight | 800 g |
| Maximum axial play (axial force 1,5 N) | 0,07 mm |
| Maximum radial force | 50 N |
| Maximum axial force | 20 N |

*) When driven by BCCD unit 4322 027 90070.

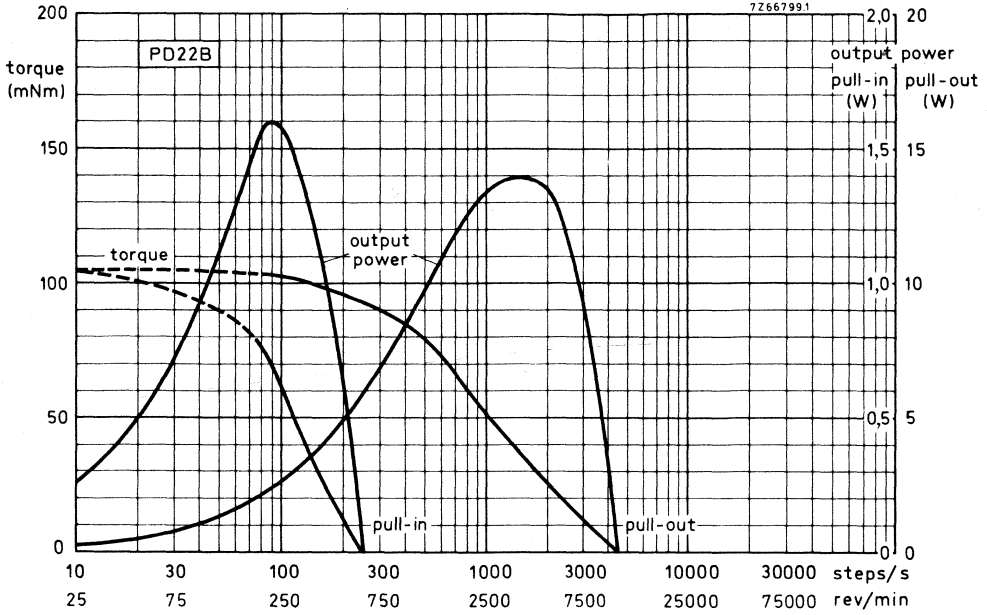



Fig. 2 Torque (left scale) and relevant output power (right scale) versus stepping rate, measured at room temperature.

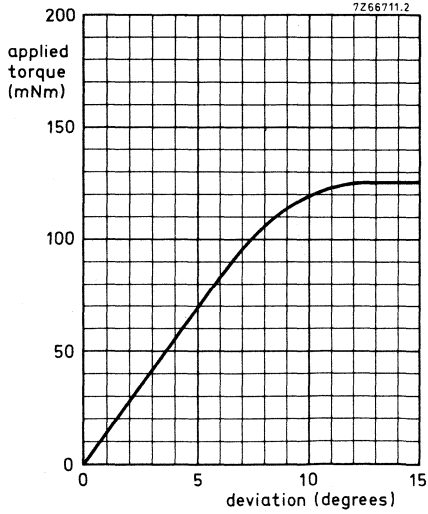



Fig. 3 Applied torque versus deviation.

# 4-PHASE BIPOLAR STEPPER MOTORS

This range comprises four types of professional digital (PD) permanent magnet stepper motor. The high torque, high speed and small step angle make these motors very suitable for accurate and fast positioning functions in telecommunication equipment and computer peripherals.

## DESCRIPTION

The motors have a 4-phase stator and a permanent magnet rotor with 24 poles (step angle of 3° 45') or 12 poles (step angle of 7° 30') in a rugged and simple construction. They are derived from the 8-phase unipolar motors, so that their design is similar. The motor coils are adapted to the bipolar constant current drive (BCCD) 4322 027 90070 (see relevant data sheet). Two BCCD units are required to operate one of the 4-phase bipolar motors.
Driven via the BCCD unit the stepper motors are able to achieve extremely high stepping rates in the slew range. However, it should be noted that the motors are NOT designed for continuous operation at these high stepping rates since the iron losses inside the motor result in an unacceptable temperature rise.

## CONNECTION DIAGRAM

See next page.

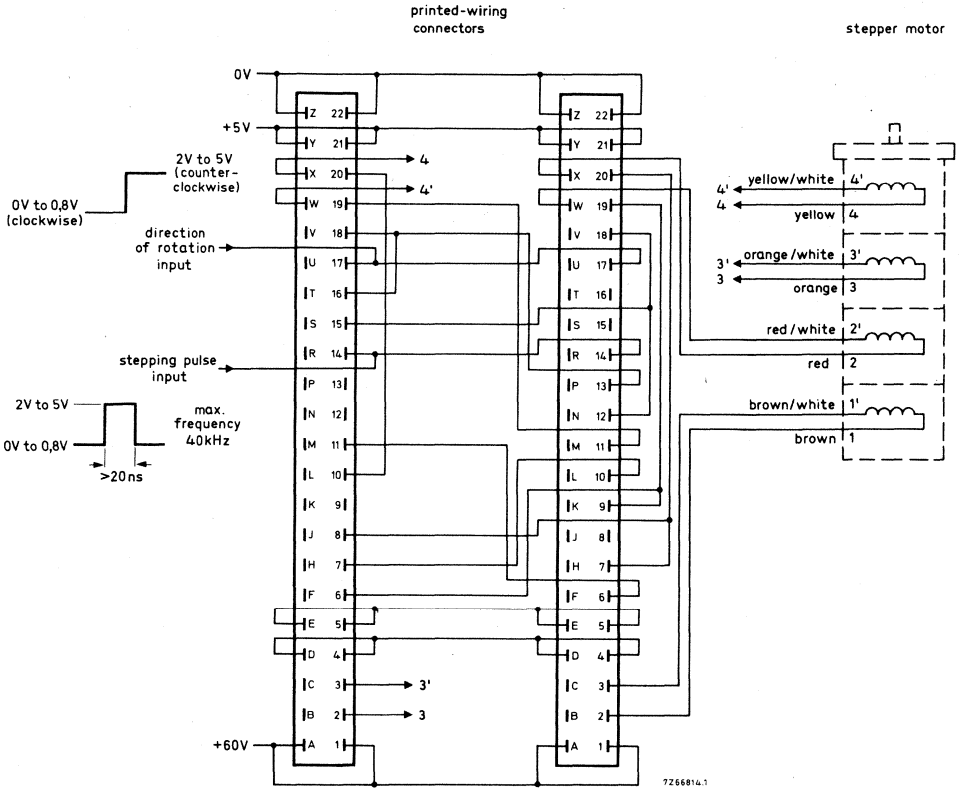
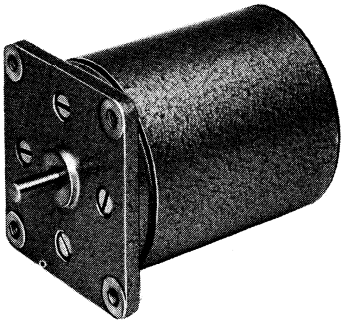



Diagram for connecting the motor to the two bipolar constant current drives 4322 027 90070 via printed-wiring connectors.

# 4-PHASE BIPOLAR STEPPER MOTOR

| QUICK REFERENCE DATA | |
|---|---|
| performance obtained with bipolar constant current drives 4322 027 90070 | |
| Step angle | 3° 45' |
| Maximum working torque | 25 mNm |
| Holding torque | 27 mNm |
| Maximum pull-in rate | 1500 steps/s |
| Maximum pull-out rate | 2500 steps/s |

*720808-16-03*



## TECHNICAL DATA

Dimensions (mm)

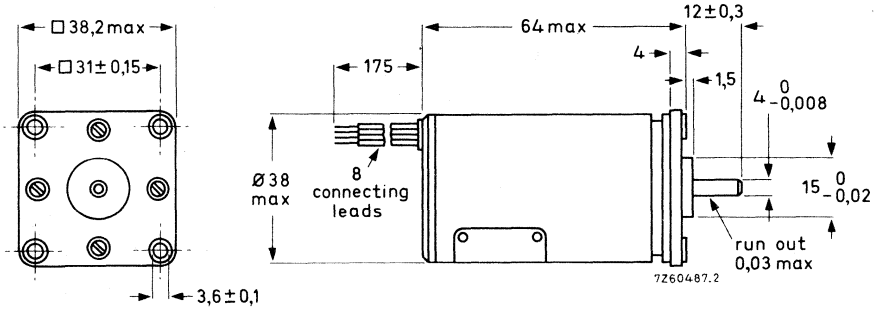



Fig. 1

Marking and connection
The connecting leads are colour-coded and are connected to the bipolar constant current drives as shown in General section of 4-phase bipolar stepper motors.

| | |
|---|---|
| Power consumption of motor only | 6,5 W |
| Maximum working torque | 25 mNm |
| Holding torque | 27 mNm |
| Maximum pull-in rate *) | 1500 steps/s |
| Maximum pull-out rate *) | 25000 steps/s |
| Number of phases | 4 |
| Resistance per coil | 6,5 Ω |
| Inductance per coil | 10 mH |
| Current per coil | 500 mA |
| Permissible ambient temperature range | see General section of Stepper motors |
| Permissible storage temperature range | −62 to + 110 °C |
| Permissible motor temperature | 125 °C |
| Insulation resistance at 500 V d.c. | 100 MΩ |
| Step angle | 3° 45' |
| Step-angle tolerance | ±20' non-cumulative |
| Number of steps per revolution | 96 |
| Direction of rotation | reversible |
| Rotor inertia | 7 gcm$^2$ |
| Bearings | ball |
| Weight | 220 g |
| Maximum axial play (axial force 1,5 N) | 0,07 mm |
| Maximum radial force | 10 N |
| Maximum axial force | 5 N |

*) When driven by two BCCD units 4322 027 90070.

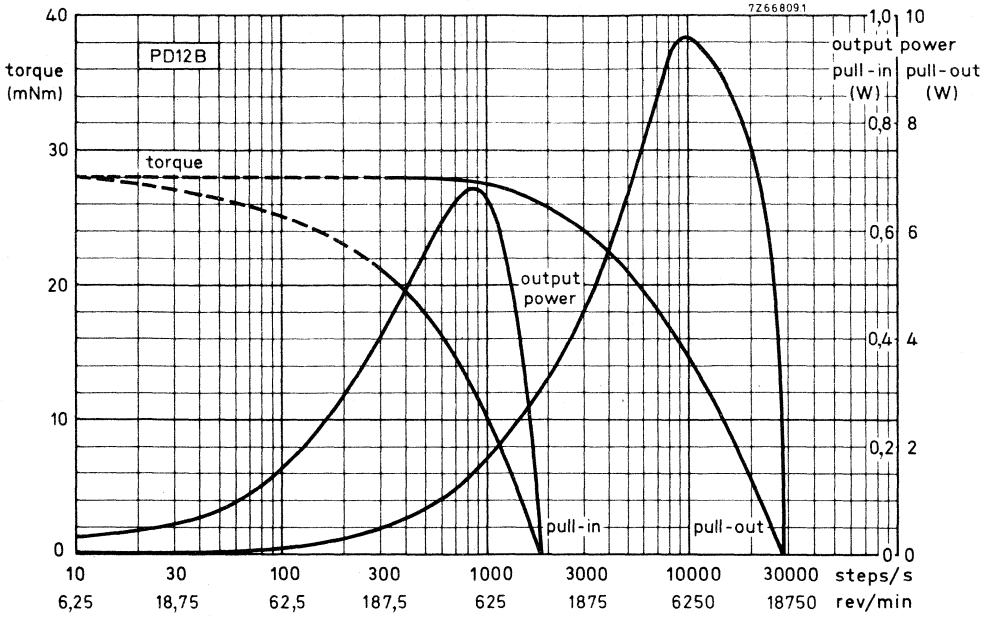



Fig. 2 Torque (left scale) and relevant output power (right scale) versus stepping rate, measured at room temperature.

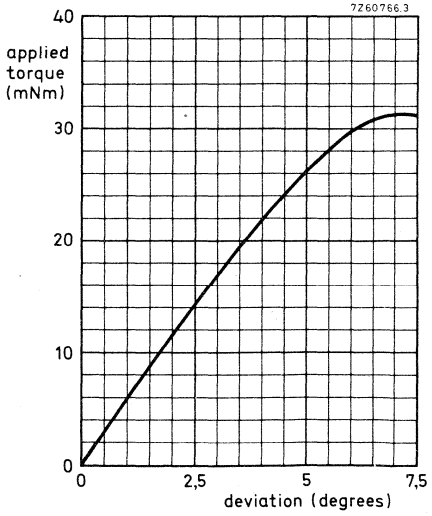



Fig. 3 Applied torque versus deviation.

# 4-PHASE BIPOLAR STEPPER MOTOR

| QUICK REFERENCE DATA | |
|---|---|
| performance obtained with bipolar constant current drives 4322 027 90070 | |
| Step angle | 3° 45' |
| Maximum working torque | 75 mNm |
| Holding torque | 83 mNm |
| Maximum pull-in rate | 1150 steps/s |
| Maximum pull-out rate | 20000 steps/s |

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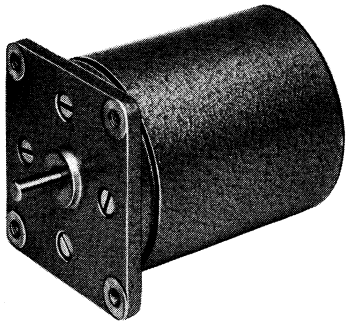

## TECHNICAL DATA

Dimensions (mm)

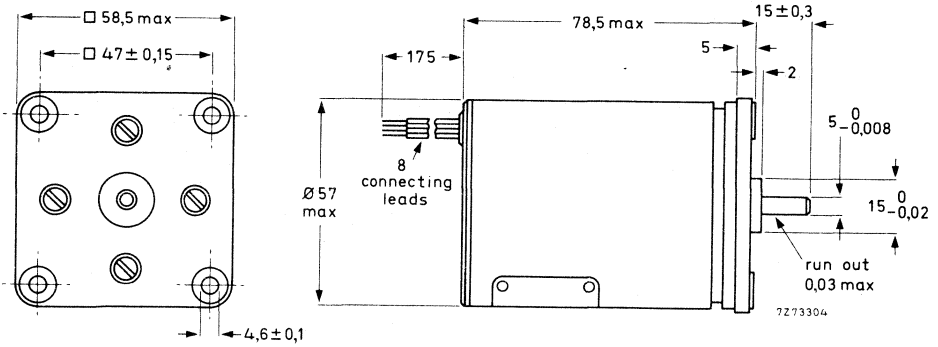


Fig. 1

Marking and connection
The connecting leads are colour-coded and are connected to the bipolar constant current drives as shown in General section of 4-phase bipolar stepper motors.

| | |
|---|---|
| Power consumption of motor only | 8 W |
| Maximum working torque | 75 mNm |
| Holding torque | 83 mNm |
| Maximum pull-in rate *) | 1150 steps/s |
| Maximum pull-out rate *) | 20000 steps/s |
| Number of phases | 4 |
| Resistance per coil | 8 Ω |
| Inductance per coil | 25 mH |
| Current per coil | 500 mA |
| Permissible ambient temperature range | see General section of Stepper motors |
| Permissible storage temperature range | −62 to + 110 °C |
| Permissible motor temperature | 125 °C |
| Insulation resistance at 500 V d.c. | 100 MΩ |
| Step angle | 3° 45' |
| Step-angle tolerance | ± 10' non-cumulative |
| Number of steps per revolution | 96 |
| Direction of rotation | reversible |
| Rotor inertia | 32 gcm$^2$ |
| Bearings | ball |
| Weight | 600 g |
| Maximum axial play (axial force 1, 5 N) | 0, 07 mm |
| Maximum radial force | 15 N |
| Maximum axial force | 7, 5 N |

*) When driven by two BCCD units 4322 027 90070.

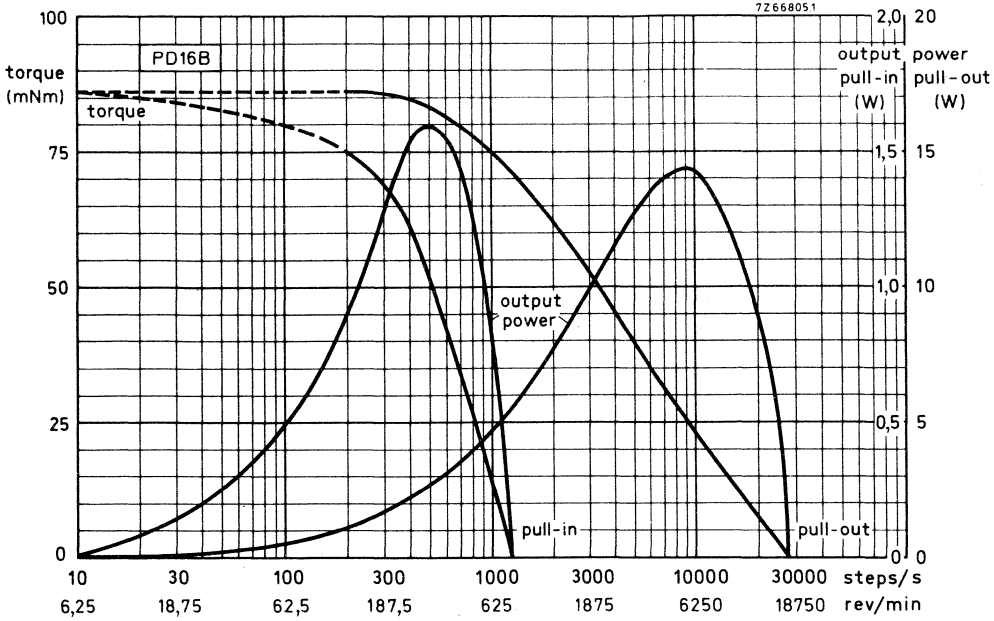


Fig. 2 Torque (left scale) and relevant output power (right scale) versus stepping rate, measured at room temperature.

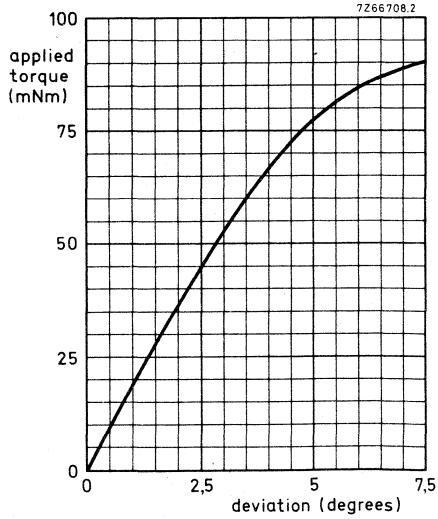


Fig. 3 Applied torque versus deviation.

# 4-PHASE BIPOLAR STEPPER MOTOR

| QUICK REFERENCE DATA | |
|---|---|
| performance obtained with bipolar constant current drives 4322 027 90070 | |
| Step angle | 3° 45' |
| Maximum working torque | 260 mNm |
| Holding torque | 300 mNm |
| Maximum pull-in rate | 750 steps/s |
| Maximum pull-out rate | 10800 steps/s |

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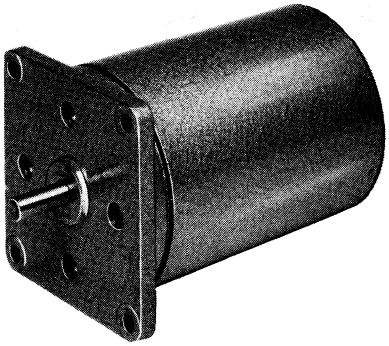

## TECHNICAL DATA

Dimensions (mm)

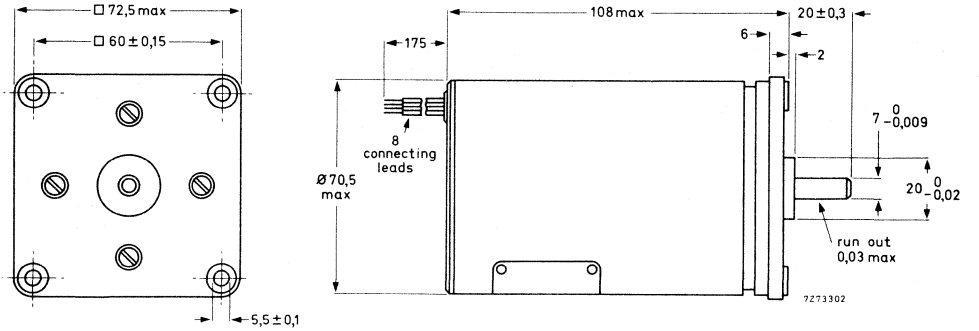


Fig. 1

Marking and connection
The connecting leads are colour-coded and are connected to the bipolar constant current drives as shown in General section of 4-phase bipolar stepper motors.

| | |
|---|---|
| Power consumption of motor only | 16 W |
| Maximum working torque | 260 mNm |
| Holding torque | 300 mNm |
| Maximum pull-in rate *) | 750 steps/s |
| Maximum pull-out rate *) | 10800 steps/s |
| Number of phases | 4 |
| Resistance per coil | 16 Ω |
| Inductance per coil | 30 mH |
| Current per coil | 500 mA |
| Permissible ambient temperature range | see General section of Stepper motors |
| Permissible storage temperature range | −62 to + 110 °C |
| Permissible motor temperature | 125 °C |
| Insulation resistance at 500 V d.c. | 100 MΩ |
| Step angle | 3° 45' |
| Step-angle tolerance | ± 10' non-cumulative |
| Number of steps per revolution | 96 |
| Direction of rotation | reversible |
| Rotor inertia | 220 gcm$^2$ |
| Bearings | ball |
| Weight | 1400 g |
| Maximum axial play (axial force 1,5 N) | 0,07 mm |
| Maximum radial force | 50 N |
| Maximum axial force | 20 N |

*) When driven by two BCCD units 4322 027 90070.

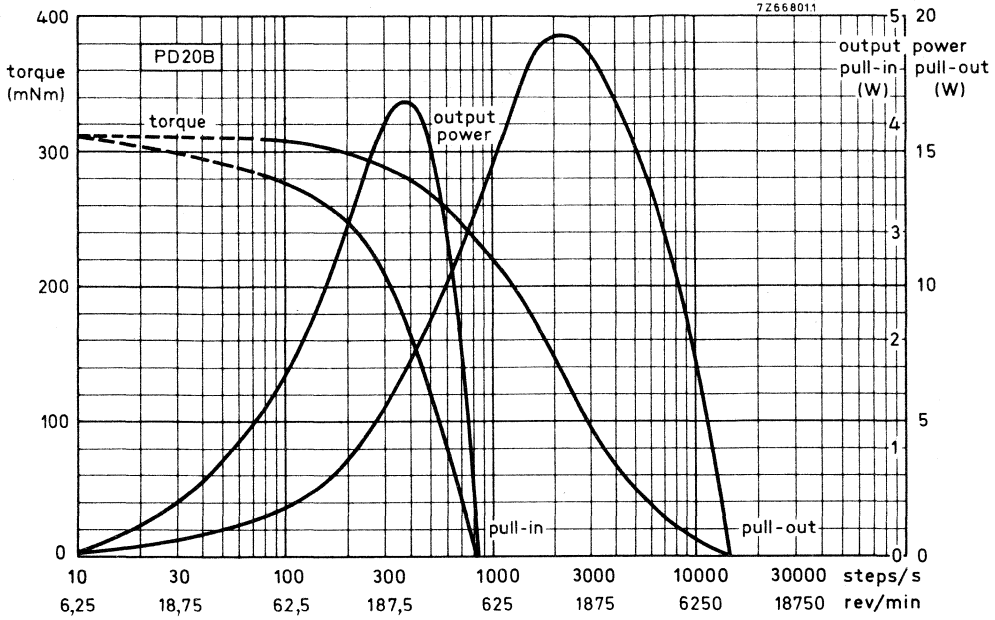


Fig. 2 Torque (left scale) and relevant output power (right scale) versus stepping rate, measured at room temperature.

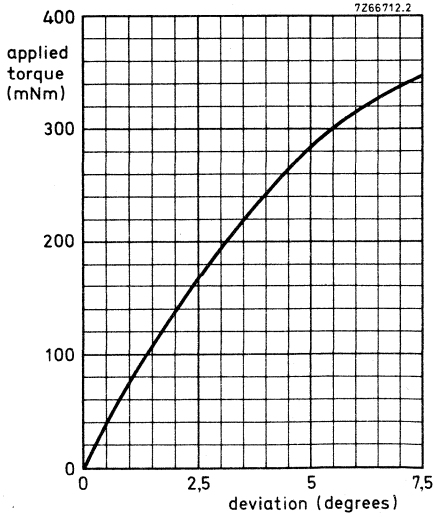


Fig. 3 Applied torque versus deviation.

# 4-PHASE BIPOLAR STEPPER MOTOR

| QUICK REFERENCE DATA | |
|---|---|
| performance obtained with bipolar constant current drives 4322 027 90070 | |
| Step angle | 7° 30' |
| Maximum working torque | 180 mNm |
| Holding torque | 210 mNm |
| Maximum pull-in rate | 500 steps/s |
| Maximum pull-out rate | 6400 steps/s |

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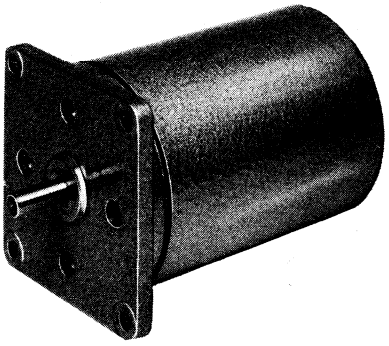


## TECHNICAL DATA

Dimensions (mm)

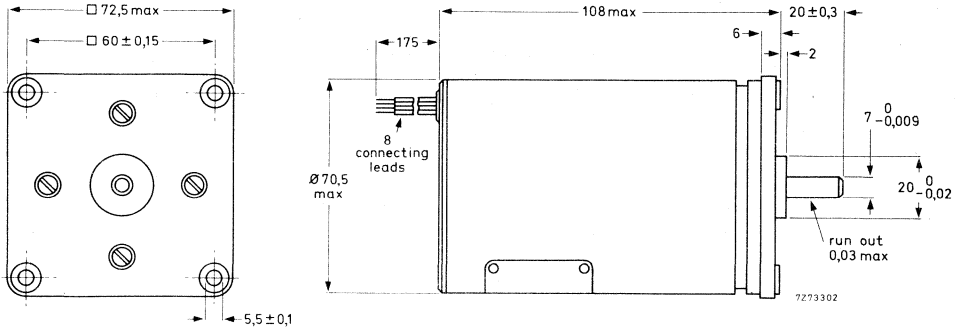



Fig. 1

Marking and connection
The connecting leads are colour-coded and are connected to the bipolar constant current drives as shown in General section of 4-phase bipolar stepper motors.

| | |
|---|---|
| Power consumption of motor only | 16 W |
| Maximum working torque | 180 mNm |
| Holding torque | 210 mNm |
| Maximum pull-in rate *) | 500 steps/s |
| Maximum pull-out rate *) | 6400 steps/s |
| Number of phases | 4 |
| Resistance per coil | 16 Ω |
| Inductance per coil | 50 mH |
| Current per coil | 500 mA |
| Permissible ambient temperature range | see General section of Stepper motors |
| Permissible storage temperature range | −62 to + 110 °C |
| Permissible motor temperature | 125 °C |
| Insulation resistance at 500 V d.c. | 100 MΩ |
| Step angle | 7° 30' |
| Step-angle tolerance | ± 15' non-cumulative |
| Number of steps per revolution | 48 |
| Direction of rotation | reversible |
| Rotor inertia | 220 gcm$^2$ |
| Bearings | ball |
| Weight | 1400 g |
| Maximum axial play (axial force 1,5 N) | 0,07 mm |
| Maximum radial force | 50 N |
| Maximum axial force | 20 N |

*) When driven by two BCCD units 4322 027 90070.

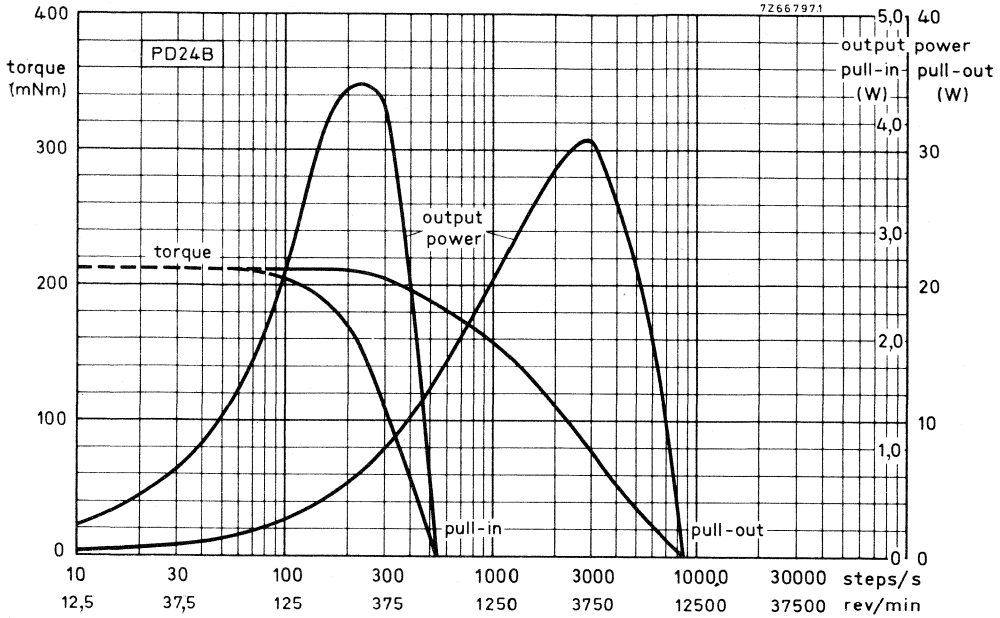



Fig. 2 Torque (left scale) and relevant output power (right scale) versus stepping rate, measured at room temperature.

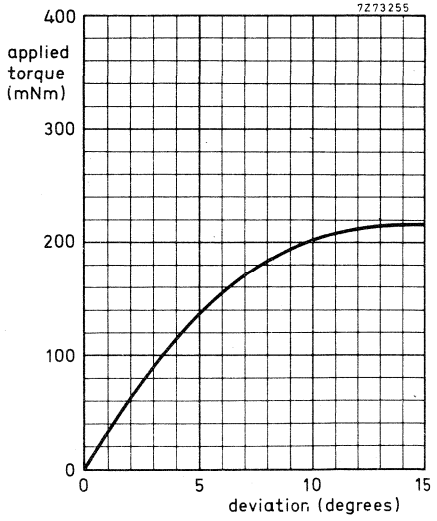



Fig. 3 Applied torque versus deviation.

# Miniature direct current motors

# CONSTRUCTION

Our direct current motors are available in two basic types:

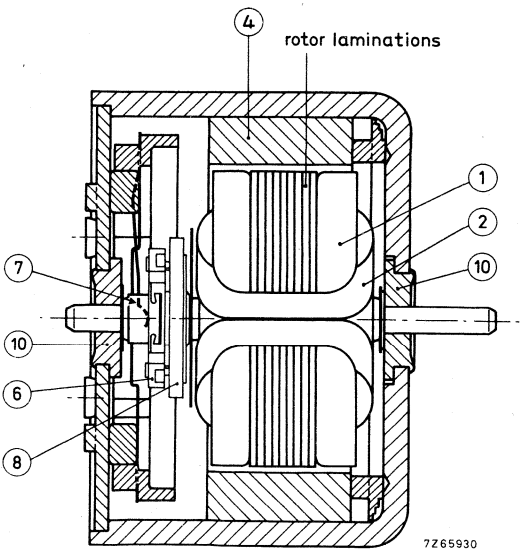
- iron rotor motors;
- ironless rotor motors.

Iron rotor motors (Fig. 1)

All motors of this type have a three-pole laminated iron rotor and a flat commutator. A VDR (voltage dependent resistor) disc spark suppressor, mounted between the commutator and coils, provides interference suppression and also considerably increases brush life. All motors except those of the 9904 120 52... series have a gold-plated commutator; the two-leaf metal brushes are silver-plated and damped so that long life and low noise level are guaranteed. The stator consists of a Ferroxdure ring and the magnetic circuit is closed by the motor housing.
In the motors of the 9904 120 52... series, carbon brushes and copper commutators are used; a steel ring closes the magnetic circuit and also provides a foundation for the plastic motor housing. In all other respects these motors are the same as the other iron rotor motors.

Fig. 1

1 = rotor
2 = rotor winding
4 = stator magnet
6 = commutator
7 = brush
8 = VDR
10 = bearing



Ironless rotor motors (Fig. 2)

In this type of motor, the rotor consists of a plastic cup moulded onto the spindle and upon which nine coils are wound. A nine-segment gold-plated flat commutator is used. Voltage peaks during commutation are so small in this type of motor that no special arrangements for interference suppression are necessary. The stator is a ticonal cylindrical magnet located inside the rotor before the latter is wound. Upon assembly, a spigot in the housing is pressed into the stator magnet ring, leaving the rotor free to rotate in its bearings with the stator supported inside the rotor windings. The motor housing completes the magnetic circuit. The silver-plated brushes have three leaves each but are otherwise similar in form and damping to those in the iron rotor motors.

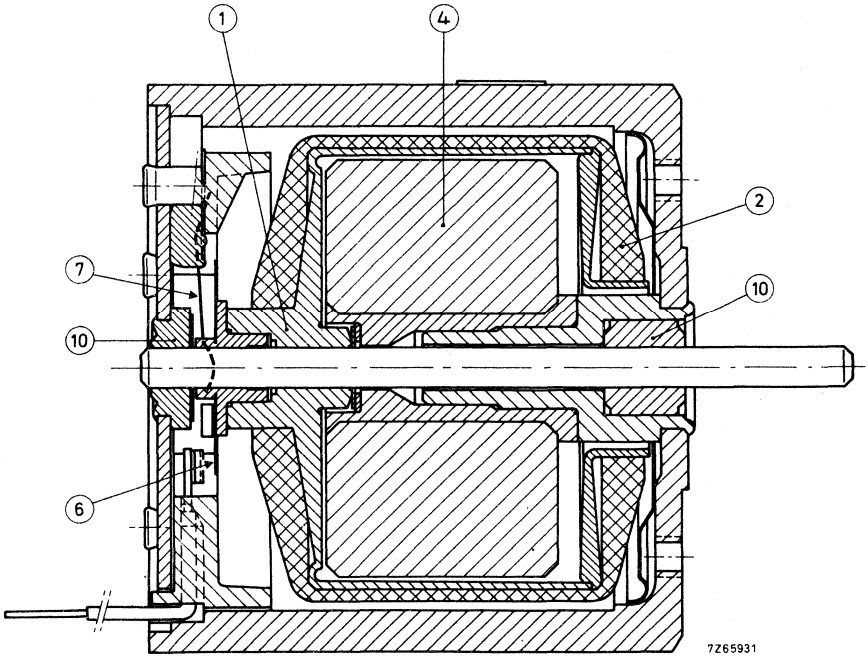



Fig. 2

1 = rotor
2 = rotor winding
4 = stator magnet
6 = commutator
7 = brush
10 = bearing

# APPLICATION

All direct current motors have properties - good and bad - that are more or less important depending upon the particular application. These properties are listed in the table below, and each type of motor is graded 1, 2 or 3 (1 being the best) for each property. Thus, for a given application, the most suitable type of motor can be chosen. One of the factors in the table is the price; this of course depends of the motor size and also on production quantities, the comparison shown being for motors of approximately similar power and based upon similar quantities.

Comparison of d.c. motor properties

| | iron rotor motors | ironless rotor motors |
|---|---|---|
| life | 1000 h | 2000 h |
| audible noise | 3 | 3 |
| electrical noise | 3 | 2 |
| reliability | 3 | 3 |
| efficiency | 3 | 1 |
| acceleration | 2 | 1 |
| wow and flutter | 2 | 1 |
| price | x | 1, 5x |

Iron rotor motors are used in those applications which require an optimum compromise between technical properties and economic price.

Applications: cassette recorders;
record players;
film cameras;
calculators;
dictating machines;
telephone answering equipment;
weather balloons;
rotating light for vehicles;
car radio aerial drive, etc.

Ironless rotor motors are used in those applications requiring better performance in certain properties, such as shorter acceleration time and lower wow and flutter levels, even though the price is higher than that of the iron rotor types.

Applications: hi-fi reel-to-reel recorders;
hi-fi cassette recorders;
educational recorders;
digital computer cassette and cartridge recorders;
recording measuring equipments;
printer drive calculators and computer printers;
ribbon transport computer printers;
card readers;
professional film cameras, etc.

# SURVEY

| type | nom. voltage (V) | speed at nom. load (rev/min) | input power (W) | nom. torque (mNm) | catalogue number |
|---|---|---|---|---|---|
| iron rotor | 4,3 | 2050 | 0,6 | 1 | 9904 120 01501 |
| | 4,5 | 2000 | 0,6 | 1,1 | 01502 |
| | 7 | 2050 | 0,6 | 1 | 01806 |
| | 6,8 | 2000 | 0,45 | 1 | 01809 [1] |
| | 12 | 330 | 2,2 | 25 | 52602 |
| | 12 | 60 | 2,2 | 150 | 52605 |
| | 12 | 23 | 1,2 | 150 | 52607 |
| | 12 | 8,2 | 0,7 | 150 | 52609 |
| | 3 | 96 | 0,45 | 15 | 53101 [3] |
| | 3 | 162 | 0,45 | 9 | 53102 [3] |
| | 3 | 258 | 0,45 | 5,5 | 53103 [3] |
| | 3 | 1600 | 0,45 | 1,1 | 53104 [3] |
| | 12 | 2815 | 4,35 | 10 | 9904 120 10601 |
| ironless rotor | 24 | 2815 | 4,35 | 10 | 10803 |
| | 24 | 2800 | 4,2 | 10 | 10804 [1] |
| | 12 | 3900 | 3,6 | 5 | 12601 |

[1] Provided with frequency tachogenerator.

[2] Also available in 6 V (9904 120 524..) and 24 V (9904 120 527..) versions.

[3] Maintenance type.

[4] Motors with reduction.

# DIRECT CURRENT MOTORS

| QUICK REFERENCE DATA | | |
|---|---|---|
| | 9904 120 01501 | 9904 120 01806 |
| Nominal voltage (d.c.) | 4,3 V | 7 V |
| Nominal speed | 2050 rev/min | 2050 rev/min |
| Nominal torque | 1 mNm | 1 mNm |

**APPLICATION**

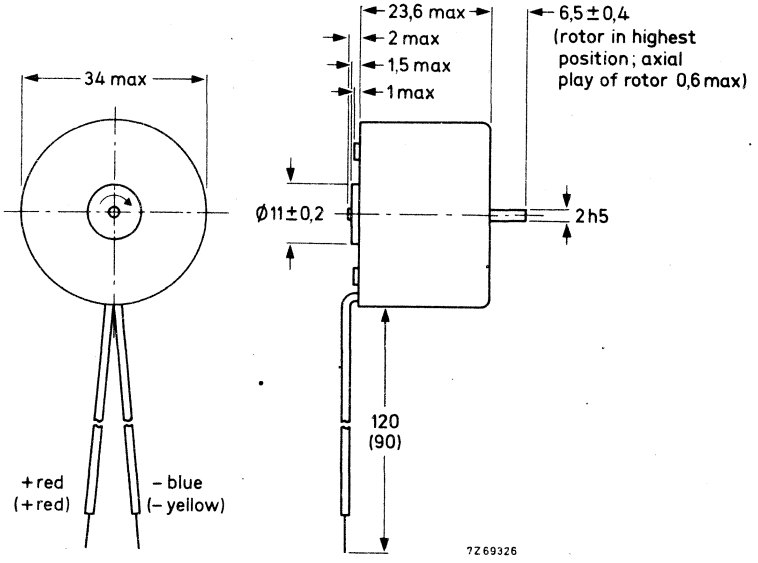
These motors have been designed for applications which require low noise level, smooth running and accurate speed control by an electronic speed control unit.
Examples:
- cassette recorders and players
- record players
- telephone answering equipment
- dictating machines
- echo sounders

## DESCRIPTION

The motor has been provided with a permanent magnet system, consisting of a ring magnet with which a very low holding torque has been obtained.
The gold plated flat commutator with 3 segments and the silver plated brushes of two parts ensure optimal commutation; the built in spark suppressor (VDR) increases as well the collector life considerably.
The motor has a nickel-plated deep drawn steel housing.

## TECHNICAL DATA

Dimensions in mm




The lead length and lead colour given between brackets apply to motor 9904 120 01806.
The direction of rotation is given in connection with the polarity.

Weight approx. 82 g

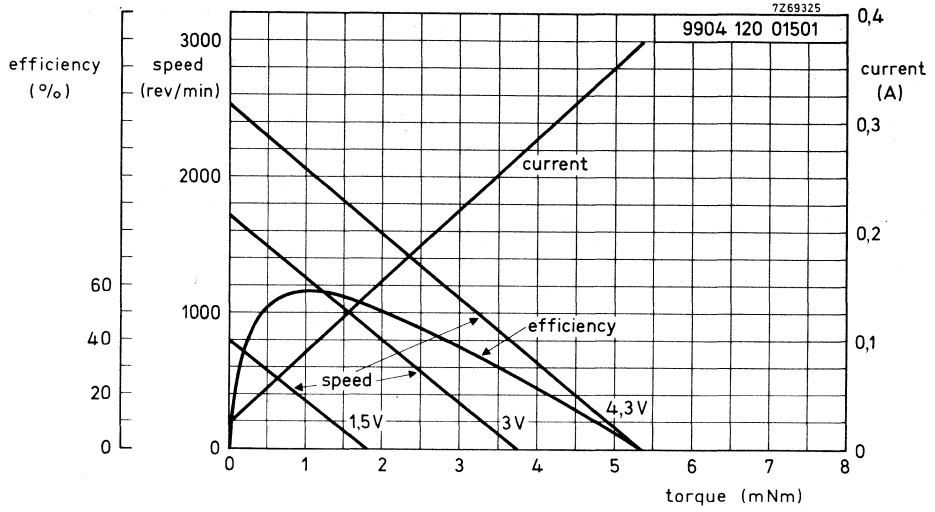
The values given below apply at an ambient temperature of 22 ± 5 °C, an atmospheric pressure of 860 to 1060 mbar and a relative humidity of 45 to 75%.

| | 9904 120 01501 | 9904 120 01806 |
|---|---|---|
| Voltage (d.c.) | 4,3 V | 7 V |
| Torque | 1 mNm | 1 mNm |
| Speed at nominal load<br>at no load | 2050 ± 300 rev/min<br>2550 ± 300 rev/min | 2050 ± 300 rev/min<br>2550 ± 315 rev/min |
| Current at nominal load<br>at no load | max. 110 mA<br>max. 35 mA | max. 65 mA<br>max. 25 mA |
| Starting torque | 4,6 mNm | 4,4 mNm |
| Specific input current | 60,4 to 72,1 mA/mNm | 37,1 to 44,5 mA/mNm |
| Induced voltage | 1,45 to 1,73 mV per rev/min | 2,35 to 2,82 mV per rev/min |
| Rotor resistance | 10 Ω ± 10% | 27 Ω ± 10% |
| Direction of rotation | reversible | reversible |
| Ambient temperature range | −10 to +50 °C | −10 to +50 °C |
| Rotor moment of inertia | 10 gcm$^2$ | 10 gcm$^2$ |
| Motor constant | typ. 44 ms | typ. 44 ms |
| Bearings | slide bearings | slide bearings |
| Maximum radial force,<br>4 mm from bearing | 1 N | 1 N |
| Maximum axial force | 0,1 N | 0,1 N |
| Maximum axial play | 0,6 mm | 0,6 mm |
| Housing material | steel | steel |

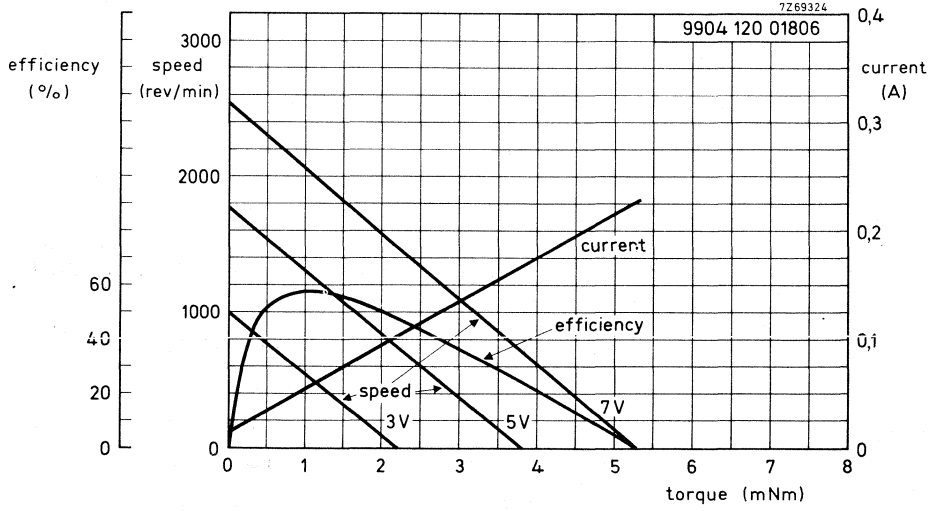
Limiting conditions

The following maximum values indicate those circumstances under which the motor can run continuously without being damaged, but under these circumstances the motor life is greatly reduced.

| | 9904 120 01501 | 9904 120 01806 |
|---|---|---|
| Maximum voltage (d.c.) | 6 V | 10 V |
| Maximum permissible load | 2 mNm | 2 mNm |
| Max. permissible current | 150 mA | 90 mA |
| Maximum speed | 3500 rev/min | 3500 rev/min |
| Maximum output power | 0,5 W | 0,5 W |




Typical curves at $T_{amb}$ = 20 °C




Typical curves at $T_{amb}$ = 20 °C

# DIRECT CURRENT MOTOR

## with interference-suppression filter

| QUICK REFERENCE DATA | |
|---|---|
| Nominal voltage (d.c.) | 4,5 V |
| Nominal speed | 2000 rev/min |
| Nominal torque | 1,1 mNm |

### APPLICATION

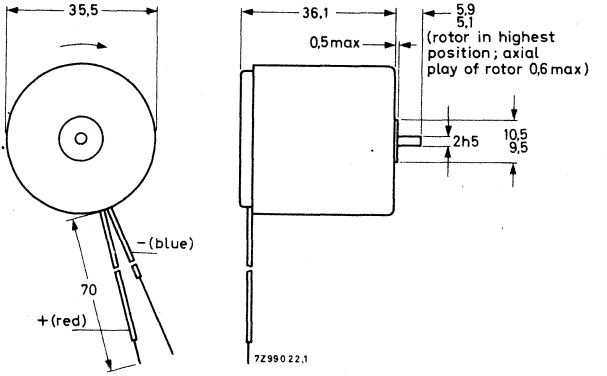
This small d.c. motor has been designed for applications which require a high quality, e.g. musical equipment.

### DESCRIPTION

The motor has been provided with a permanent magnet system, consisting of a ring magnet with which a very low holding torque has been obtained. It has a housing of extruded aluminium. The built-in spark suppressor (VDR) increases the collector life considerably. An interference-suppression filter has been incorporated in the housing. The motor is suitable for operation in tropical environments.

## TECHNICAL DATA

Dimensions in mm




The direction of rotation is given in connection with the polarity.

| | |
|---|---|
| Weight | 100 g |

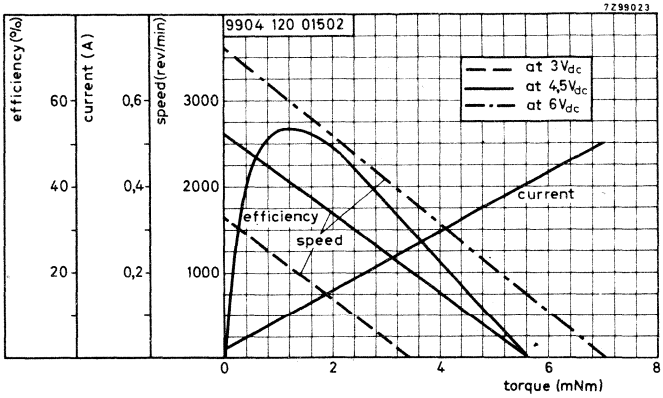
The values given below apply to an ambient temperature of 22 ± 5 °C, an atmospheric pressure of 860 to 1060 mbar and a relative humidity of 45 to 75%.

| | |
|---|---|
| Nominal voltage (d.c.) | 4,5 V |
| Nominal torque | 1,1 mNm |
| Speed | |
| at nominal load | 2000 rev/min |
| at no load | 2650 ± 250 rev/min |
| Current | |
| at nominal load | max. 0,110 A |
| at no load | max. 0,035 A |
| Starting torque | min. 5 mNm |
| Input power | max. 0,6 W |
| Induced voltage at 3000 rev/min | 4,4 – 5,1 V |
| Rotor resistance measured statically | |
| with brushes | 10 ± 0,7 Ω |
| Direction of rotation | reversible |
| Ambient temperature range | −10 to +50 °C |
| Bearings | slide bearings |
| Maximum radial force on the bearings | 1 N |
| Maximum axial force | 0,1 N |
| Maximum axial play | 0,6 mm |
| Rotor inertia | 10,2 gcm$^2$ |
| Housing material | aluminium, extruded |

Limiting conditions

The following maximum values indicate those circumstances under which the motor can run continuously without being damaged, but under these circumstances the motor life is greatly reduced.

| | |
|---|---|
| Maximum voltage (d.c.) | 6 V |
| Maximum permissible load | 1,8 mNm |
| Maximum permissible input current | 0,15 A |
| Maximum speed | 3000 rev/min |
| Maximum output power | 0,5 W |




The curves are measured on an arbitrary motor.

# DIRECT CURRENT MOTOR
## with frequency tachogenerator

| QUICK REFERENCE DATA | | | |
|---|---|---|---|
| Motor | | Tachogenerator | |
| Nominal voltage (d.c.) | 7 V | Number of pole pairs | 72 |
| Nominal speed | 2000 rev/min | Generated voltage at 2000 rev/min | 1535 mV |
| Nominal torque | 1 mNm | Frequency wobble at 3000 Hz | ≤ 0,1% |

### APPLICATION

This motor-tachogenerator combination has been designed for applications which require a direct current drive system the speed of which can be controlled in a very accurate and reliable way (no mechanical contacts).
Examples:
- hi-fi cassette recorders;
- hi-fi record players;
- recording measuring instruments.

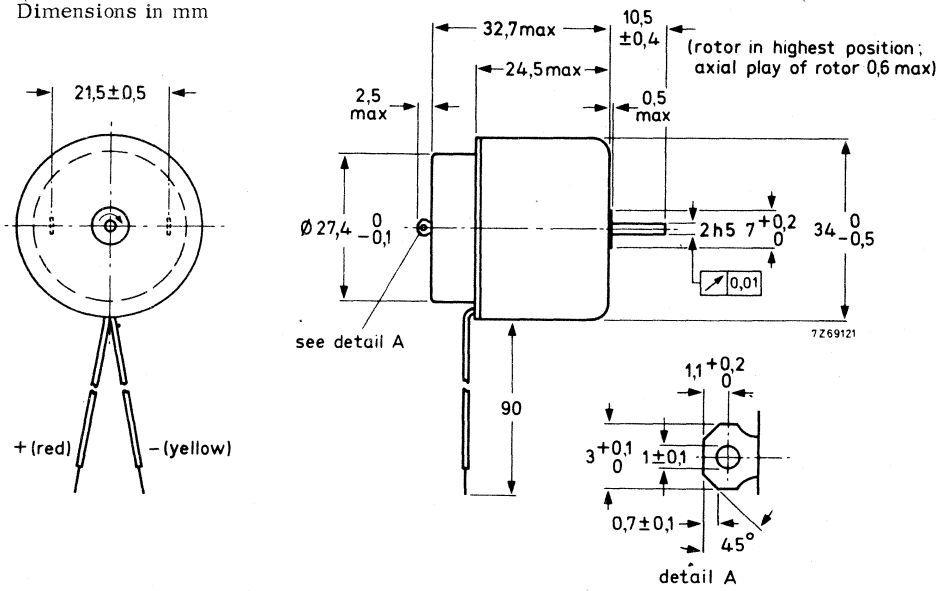
### DESCRIPTION

The motor has been provided with a permanent magnet system, consisting of a ring magnet with which a very low holding torque has been obtained.
The gold-plated flat commutator with 3 segments and the two-piece silver plated brushes ensure optimal commutation; the built-in spark suppressor (VDR) also increases the collector life considerably.
The motor has a nickel-plated, deep drawn, steel housing.

The frequency tachogenerator has a gearwheel rotor (72 teeth) which is mounted on the protruding spindle of the motor. The stator consists of a deep drawn steel housing, a magnet strip of plastic-bonded ceramic material which has been magnetized with 72 pole pairs, and a coil.
The alternating flux, which arises by rotation of the gearwheel in the magnetic field, is enclosed by the coil in which the tachogenerator voltage is generated.
The frequency of this tachogenerator voltage is determined by the speed of the motor and the number of pole pairs of the tachogenerator.

## TECHNICAL DATA

Dimensions in mm




The direction of rotation is given in connection with the polarity.

| | |
|---|---|
| Weight | 100 g |

The values given below apply to an ambient temperature of 22 ± 5 °C, an atmospheric pressure of 860 to 1060 mbar and a relative humidity of 45 to 75%.

**Direct current motor**

| | |
|---|---|
| Nominal voltage (d.c.) | 7 V |
| Nominal torque | 1 mNm |
| Speed at nominal load | 2000 ± 350 rev/min |
| at no load | 2500 ± 350 rev/min |
| Current at nominal load | max. 65 mA |
| at no load | max. 22 mA |
| Starting torque | min. 4,75 mNm |
| Input power | max. 0,45 W |
| Specific input current | 38,7 to 43,7 mA/mNm |
| Rotor resistance | 27 Ω ± 10% |
| Rotor moment of inertia | 11 gcm$^2$ |
| Bearings | slide bearings |
| Maximum radial force, 4 mm from bearing | 1,5 N |
| Maximum axial force | 0,1 N |
| Maximum axial play | 0,6 mm |
| Housing material | steel, deep drawn |
| finish | nickel plated |

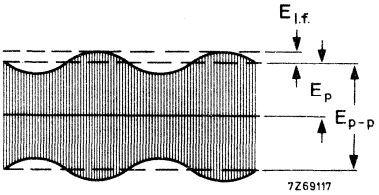
Limiting conditions

The following maximum values indicate those circumstances under which the motor can run continuously without being damaged, but under these circumstances the motor life is greatly reduced.

| | |
|---|---|
| Maximum voltage (d.c.) | 10 V |
| Maximum permissible load | 1,8 mNm |
| Maximum permissible input current | 150 mA |
| Maximum speed | 3000 rev/min |
| Maximum output power | 0,5 W |

**Tachogenerator**

| | |
|---|---|
| Number of pole pairs | 72 |
| Generated voltage, peak to peak value, at 2000 rev/min ($E_{p-p}$) | ≥ 1535 mV |
| Amplitude variation for 1 rev ($\frac{E_{l.f.}}{E_p}$ x 100%) | ≤ 15% |

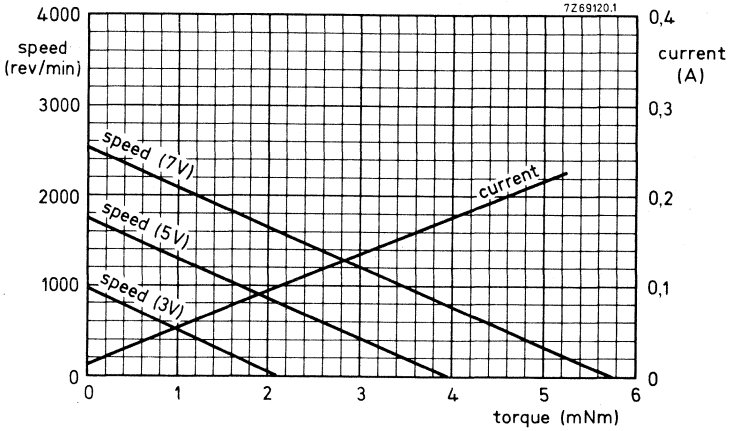



| | |
|---|---|
| Frequency | $\frac{n.72}{60}$ Hz (n = number of rev/min) |
| Frequency wobble at 3000 Hz | ≤ 0,1% 1) |
| Temperature coefficient of the generated voltage | −0,2%/°C |
| Resistance | 930 Ω ± 10% |
| Inductance | 700 mH ± 15% |
| Housing, material | steel, deep drawn |
| finish | nickel plated |

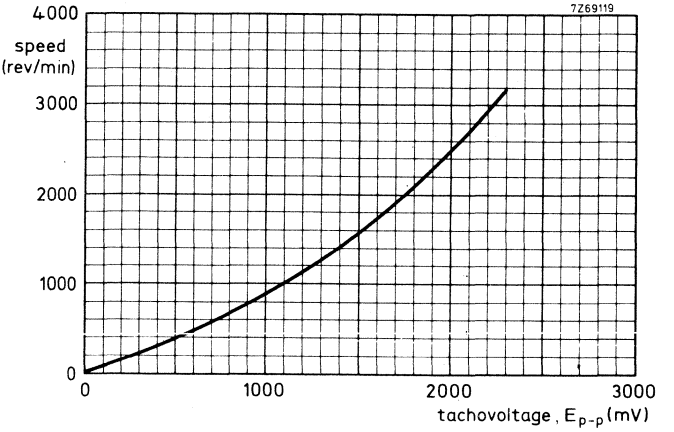
**General**

| | |
|---|---|
| Direction of rotation | reversible |
| Ambient temperature range | −10 to +50 °C |

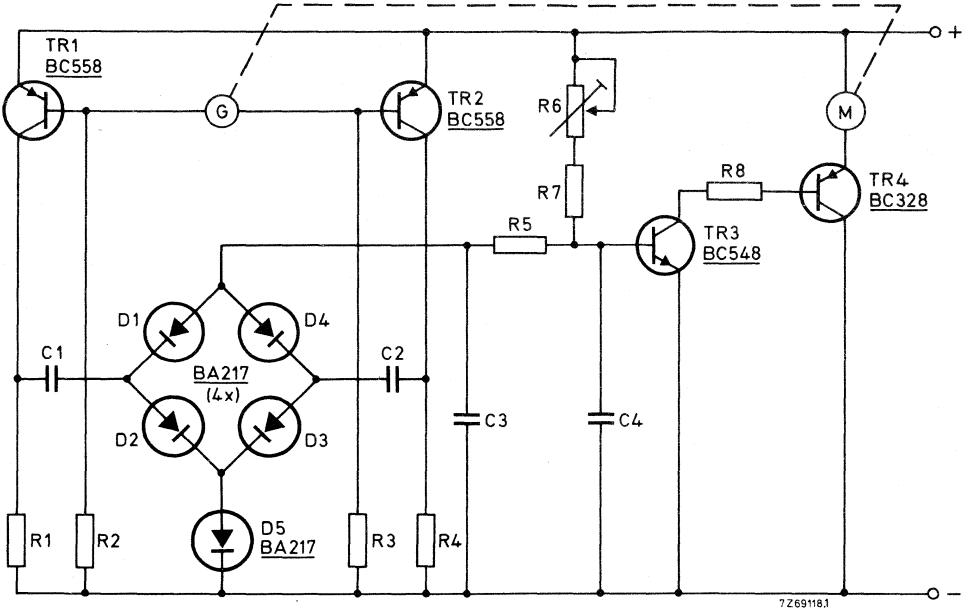
1) Measured with EMT measuring instrument type 420 A, position linear.




Typical motor curves




Typical tachogenerator curves




Example of an electronic speed control system

# DIRECT CURRENT MOTORS

## ironless rotor type

| QUICK REFERENCE DATA | | |
|---|---|---|
| | 9904 120 10601 | 9904 120 10803 |
| Nominal voltage (d.c.) | 12 V | 24 V |
| Nominal speed | 2815 rev/min | 2815 rev/min |
| Nominal torque | 10 mNm | 10 mNm |

### APPLICATION

These motors have been designed for applications which require high acceleration, high efficiency and smooth running (no magnetic holding-torque).

Examples:

- hi-fi reel-to-reel recorders (capstan and reel drive);
- hi-fi cassette recorders (reel drive);
- video recorders (capstan, reel and drum drive);
- digital cassette and cartridge recorders;
- card readers;
- printers (paper transport and head positioner);
- recording measuring instruments.

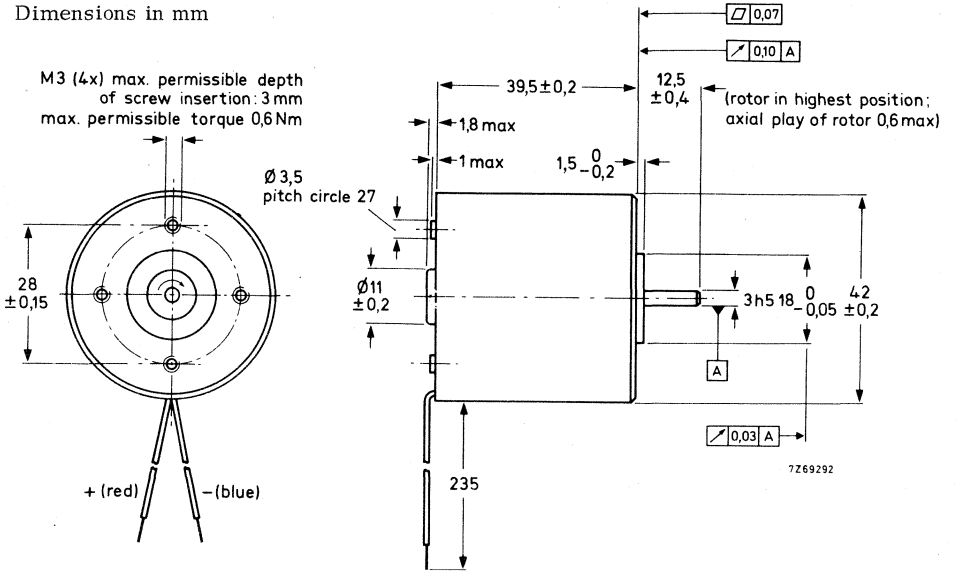
### DESCRIPTION

The motor owes its special characteristics to the following design:

- ironless rotor with oblique winding;
- the low moment of inertia and the high starting torque yield a motor constant of no more than 19,6 ms;
- a gold-plated commutator with 9 segments and three-piece silver-plated brushes ensure optimal commutation, thus making the motor suitable for accurate electronic control and optimal functioning as a servo motor or tachogenerator;
- the powerful cylindrical steel permanent magnet, around which the rotor rotates, makes for high efficiency;
- the above mentioned commutator/brush construction together with the sintered slide bearings ensures a long life, smooth running and low noise level.

## TECHNICAL DATA

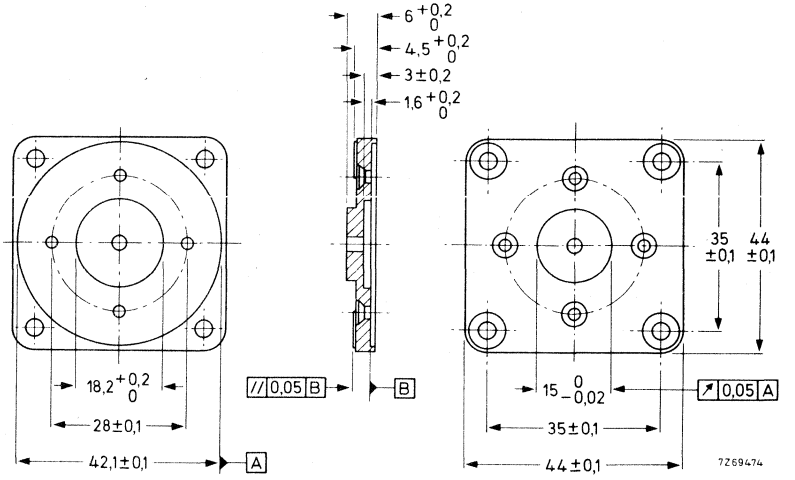
Dimensions in mm




The direction of rotation is given in connection with the polarity.

Weight approx. 230 g

→ Note - A square flange (figure below), which can be fitted to the motor, can be supplied under catalogue number 4322 010 66090.



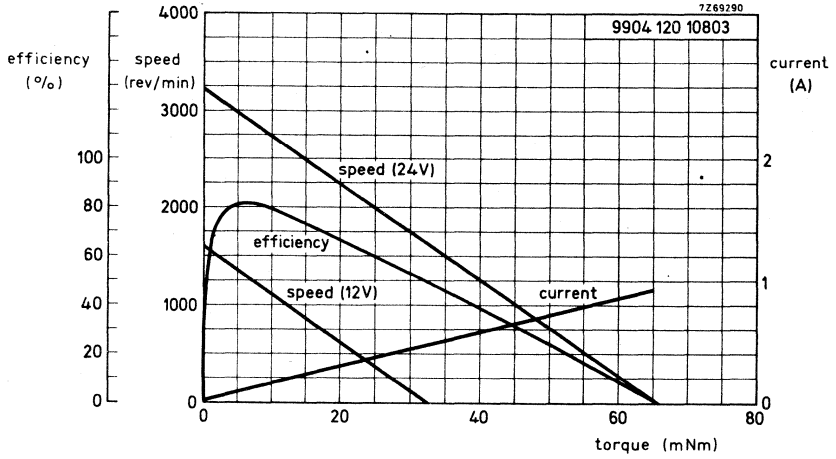
The values given below apply at an ambient temperature of 22 ± 5 °C, an atmospheric pressure of 860 to 1060 mbar and a relative humidity of 45 to 75%.

| | 9904 120 10601 | 9904 120 10803 | |
|---|---|---|---|
| Nominal voltage (d.c.) | 12 V | 24 V | |
| Nominal torque | 10 mNm | 10 mNm | |
| Speed at nominal load<br>at no load | 2815 ± 385 rev/min<br>3310 ± 475 rev/min | 2815 ± 385 rev/min<br>3310 ± 475 rev/min | ←<br>← |
| Current at nominal load<br>at no load | max. 365 mA<br>max. 30 mA | max. 180 mA<br>max. 15 mA | ← |
| Starting torque | 70 ± 17 mNm | 70 ± 15 mNm | ← |
| Input power | max. 4,35 W | max. 4,35 W | ← |
| Specific input current | 25,1 to 33,2 mA/mNm | 12,5 to 16,6 mA/mNm | ← |
| Induced voltage | 3,15 to 4,18 mV per rev/min | 6,31 to 8,36 mV per rev/min | ← |
| Rotor resistance | 6,13 Ω ± 10% | 24,5 Ω ± 10% | |
| Direction of rotation | reversible | reversible | |
| Ambient temperature range | −5 to + 70 °C | −5 to + 70 °C | |
| Rotor moment of inertia | 39,2 gcm$^2$ | 39,2 gcm$^2$ | ← |
| Motor constant | typ. 19,6 ms | typ. 19,6 ms | ← |
| Bearings | slide bearings | slide bearings | |
| Maximum radial force,<br>8 mm from bearing | 5 N | 5 N | |
| Maximum axial force | 0,5 N | 0,5 N | |
| Maximum axial play | 0,6 mm | 0,6 mm | |
| Housing material | sintered iron | sintered iron | |

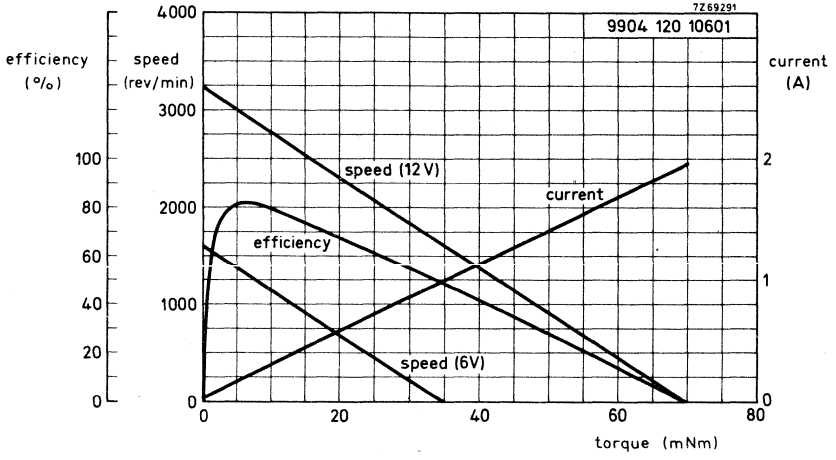
Limiting conditions

The following maximum values indicate those circumstances under which the motor can run continuously without being damaged, but under these circumstances the motor life is greatly reduced.

| | 9904 120 10601 | 9904 120 10803 |
|---|---|---|
| Maximum voltage (d.c.) | 15 V | 30 V |
| Maximum permissible load | 20 mNm | 20 mNm |
| Max. permissible current | 550 mA | 275 mA |
| Maximum speed | 4000 rev/min | 4000 rev/min |
| Maximum output power | 5 W | 5 W |
| Locked rotor | max. 2 min at 12 V | max. 2 min at 24 V |




Typical curves at 24 V and 12 V, $T_{amb}$ = 20 °C




Typical curves at 12 V and 6 V, $T_{amb}$ = 20 °C

# DIRECT CURRENT MOTOR
## with frequency tachogenerator

| QUICK REFERENCE DATA | | | |
|---|---|---|---|
| Motor | | Tachogenerator | |
| Nominal voltage (d.c.) | 24 V | Number of pole pairs | 72 |
| Nominal speed | 2800 rev/min | Generated voltage at 2000 rev/min | 1535 mV |
| Nominal torque | 10 mNm | Frequency wobble at 3000 Hz | ≤ 0,1% |

### APPLICATION

This motor-tachogenerator combination has been designed for applications which require a direct current drive system the speed of which can be controlled in a very accurate and reliable way, and where high acceleration, high efficiency and smooth running are preferred.
Examples:
- hi-fi reel-to-reel recorders (capstan drive);
- video recorders (capstan, reel and drum drive);
- digital cassette and cartridge recorders;
- card readers;
- recording measuring instruments.

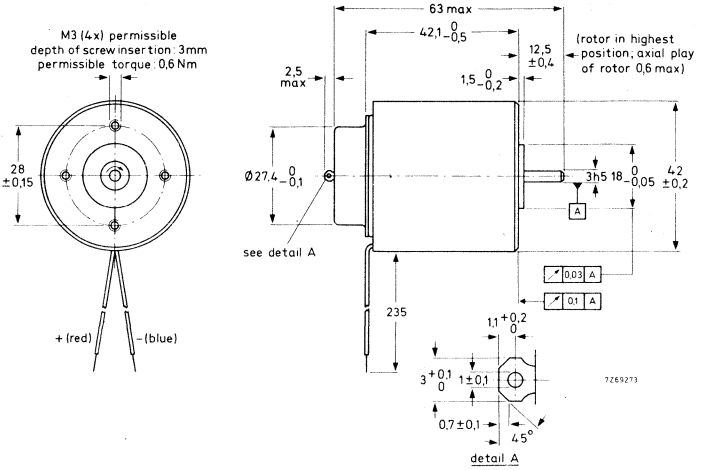
### DESCRIPTION

The motor has an ironless rotor with oblique winding. The low moment of inertia (38 $gcm^2$), and the high starting torque (69 mNm) yield a motor constant of no more than 19 ms.
A gold-plated commutator with 9 segments and three-piece silver-plated brushes ensure optimal commutation, thus making the motor suitable for accurate electronic control and optimal functioning as a servo motor or tachogenerator.
The powerful cylindrical steel permanent magnet, around which the rotor rotates, makes for high efficiency.
The above mentioned commutator/brush construction together with the sintered slide bearings ensures a long life, smooth running and low noise level.

The frequency tachogenerator has a gearwheel rotor (72 teeth) which is mounted on the protruding spindle of the motor. The stator consists of a deep drawn steel housing, a magnet strip of plastic-bonded ceramic material which has been magnetized with 72 pole pairs and a coil.
The alternating flux, which arises by rotation of the gearwheel in the magnetic field, is enclosed by the coil in which the tachogenerator voltage is generated.
The frequency of this tachogenerator voltage is determined by the speed of the motor and the number of pole pairs of the tachogenerator.

## TECHNICAL DATA

Dimensions in mm




The direction of rotation is given in connection with the polarity.

| | |
|---|---|
| Weight | approx. 250 g |

The values given below apply to an ambient temperature of 22 ± 5 °C, an atmospheric pressure of 860 to 1060 mbar and a relative humidity of 45 to 75%.

### Direct current motor

| | |
|---|---|
| Nominal voltage (d.c.) | 24 V |
| Nominal torque | 10 mNm |
| Speed | |
| at nominal load | 2800 ± 350 rev/min |
| at no load | 3300 ± 400 rev/min |
| Current | |
| at nominal load | max. 175 mA |
| at no load | max. 15 mA |
| Starting torque | 69 ± 15,5 mNm |
| Input power | max. 4,2 W |
| Specific input current | 12,5 to 16 mA/mNm |
| Rotor resistance | 24,5 Ω ± 10% |
| Rotor moment of inertia | 38 gcm$^2$ |
| Motor constant, typical | 19 ms |
| Bearings | slide bearings |
| Maximum radial force, 8 mm from bearing | 5 N |
| Maximum axial force | 0,5 N |
| Maximum axial play | 0,6 mm |
| Housing material | sintered iron |

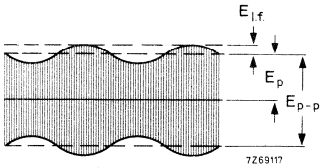
Limiting conditions

The following maximum values indicate those circumstances under which the motor can run continuously without being damaged, but under these circumstances the motor life is greatly reduced.

| | |
|---|---|
| Maximum voltage (d.c.) | 30 V |
| Maximum permissible load | 20 mNm |
| Maximum permissible input current | 275 mA |
| Maximum speed | 4000 rev/min |
| Maximum output power | 5 W |
| Locked rotor | max. 2 min at 24 V |

**Tachogenerator**

| | |
|---|---|
| Number of pole pairs | 72 |
| Generated voltage, peak to peak value, at 2000 rev/min ($E_{p-p}$) | ≥ 1535 mV |
| Amplitude variation for 1 rev ($\frac{E_{l.f.}}{E_p} \times 100\%$) | ≤ 15% |

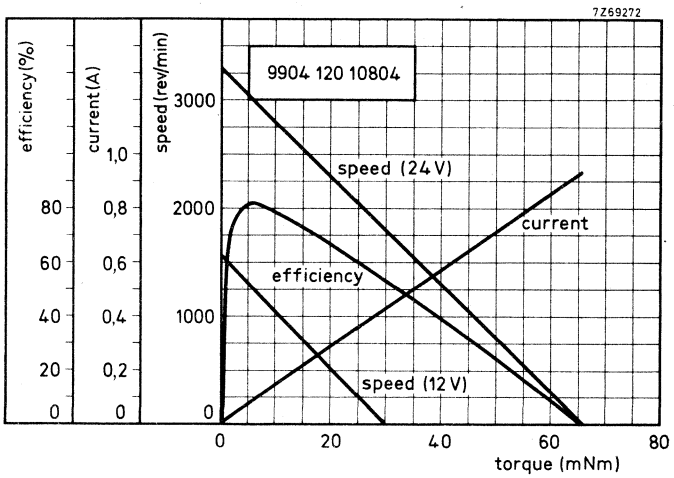



| | |
|---|---|
| Frequency | $\frac{n.72}{60}$ Hz (n = number of rev/min) |
| Frequency wobble at 3000 Hz | ≤ 0,1% [1]) |
| Temperature coefficient of the generated voltage | −0,2%/°C |
| Resistance | 930 Ω ± 10% |
| Inductance | 700 mH ± 15% |
| Housing, material | steel, deep drawn |
| finish | nickel plated |

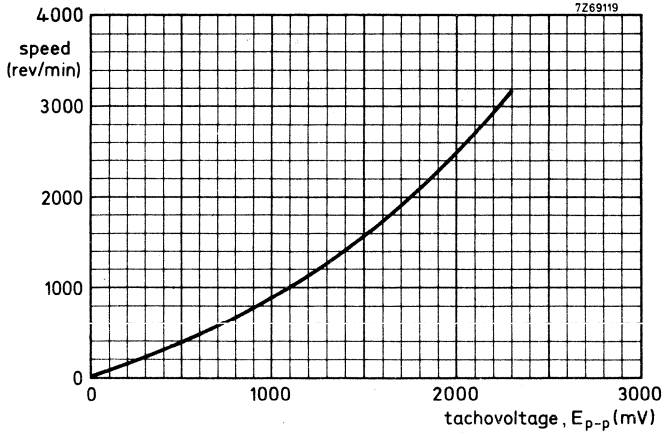
**General**

| | |
|---|---|
| Direction of rotation | reversible |
| Ambient temperature range | −5 to +70 °C |

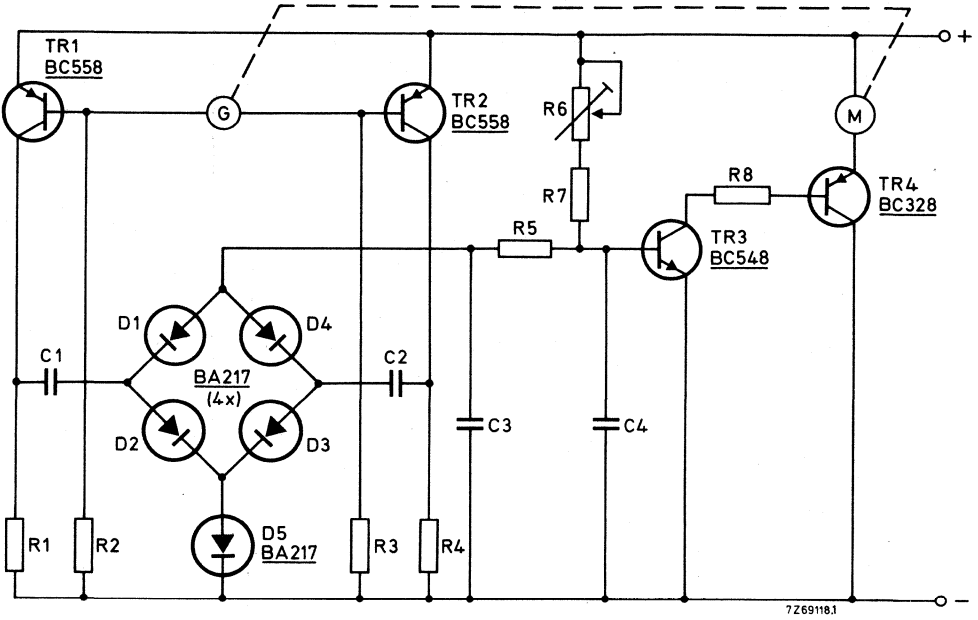
[1]) Measured with EMT measuring instrument type 420 A, position linear.




Typical motor curves




Typical tachogenerator curves




Example of an electronic speed control system

# DIRECT CURRENT MOTOR

## ironless rotor type

| QUICK REFERENCE DATA | |
|---|---|
| Nominal voltage | 12 V d.c. |
| Speed | 3900 rev/min |
| Input power | max. 3,6 W |
| Torque | 5 mNm |

### APPLICATION

This motor has been designed for applications which require high acceleration, high efficiency, smooth running (no magnetic holding-torque).

Examples:
- digital cassette recorders (reel and capstan drive)
- recording measuring instruments (chart and pen drive)
- calculating machines
- process control systems (servo motor or tachogenerator)
- professional film cameras
- dictating machines.

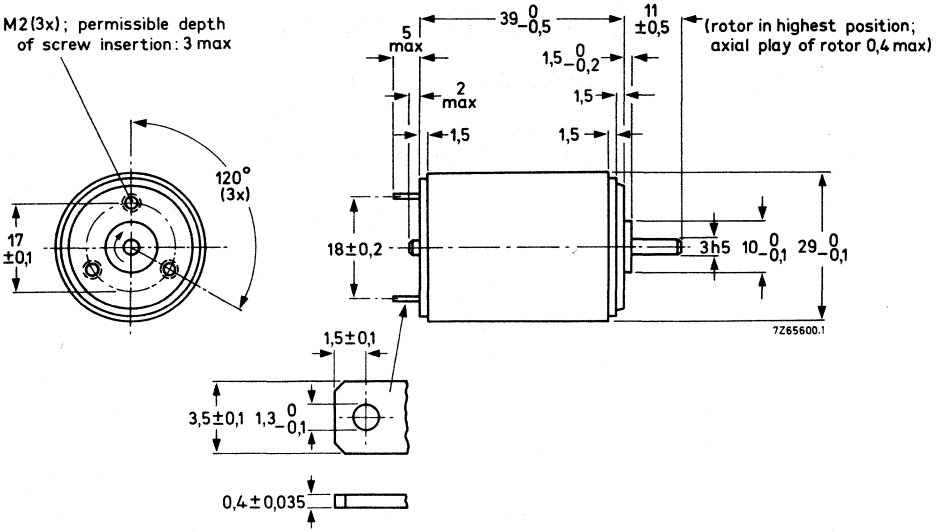
### DESCRIPTION

The motor owes its special characteristics to the following design:

- ironless rotor with oblique winding;
  The low moment of inertia (9 $gcm^2$), and the high starting torque (23 mNm), yield a motor constant of no more than 23 ms;
- a gold-plated commutator with 9 segments and silver-plated brushes of four parts ensure optimal commutation, thus making the motor suitable for accurate electronic control and optimal functioning as a servo motor or tachogenerator;
- the powerful cylindrical steel permanent magnet, around which the rotor rotates, makes for high efficiency;
- the above mentioned commutator/brush construction together with the sintered slide bearings ensures a long life, smooth running and low noise level.

## TECHNICAL DATA

Dimensions in mm




The direction of rotation is given in connection with the polarity indicated on the terminals.

| | |
|---|---|
| Weight | approx. 100 g |

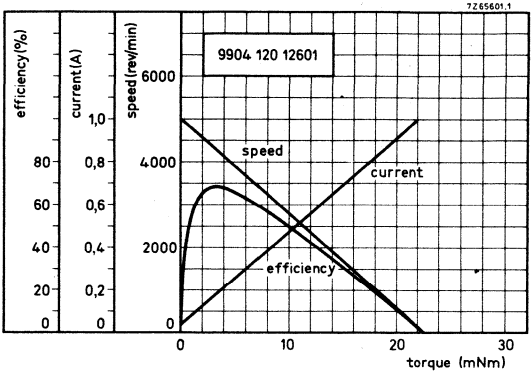
The values given below apply to an ambient temperature of 22 ± 5 °C, an atmospheric pressure of 860-1060 mbar and a relative humidity of 45-75 %.

| | |
|---|---|
| Voltage | 12 V d.c. |
| Torque | 5 mNm |
| Speed | |
| at nominal load | 3900 ± 525 rev/min |
| at no load | 5125 ± 675 rev/min |
| Current | |
| at nominal load | 260 ± 40 mA |
| at no load | max. 45 mA |
| Starting torque | 23 ± 6 mNm |
| Input power | max. 3,6 W |
| Specific input current | 40 to 50,5 mA/mNm |
| Induced voltage | 2,03 to 2,57 mV per rev/min |
| Rotor resistance | 11,8 Ω ± 10% |
| Direction of rotation | reversible |
| Ambient temperature range | -5 to +70 °C |
| Rotor moment of inertia | 9 gcm$^2$ |
| Motor constant | 23 ms (typical value) |
| Bearings | slide bearings |
| Maximum radial force, 10 mm from bearing | 3,4 N |
| Maximum axial force | 0,5 N |
| Maximum axial play of rotor | 0,4 mm |
| Housing material | steel |

Limiting conditions

The following maximum values indicate those circumstances under which the motor can run continuously without being damaged, but under these circumstances the motor life is greatly reduced.

| | |
|---|---|
| Maximum voltage (d.c.) | 16 V |
| Maximum permissible load | 6,5 mNm |
| Maximum permissible input current | 375 mA |
| Maximum speed | 6000 rev/min |
| Maximum output power | 3 W |
| Locked rotor | max. 2 min at 12 V |




Typical curves at 12 V, $T_{amb}$ = 20 °C

Note - This motor, provided with a frequency tachogenerator, can be supplied on request.

# DIRECT CURRENT MOTORS
## with reduction

| QUICK REFERENCE DATA | | | | | |
|---|---|---|---|---|---|
| catalogue numbers | | | | | |
| nominal voltage 6 V d.c. | nominal voltage 12 V d.c. | nominal voltage 24 V d.c. | reduction ratio | speed (rev/min) | torque (mNm) |
| 9904 120 52402 | 9904 120 52602 | 9904 120 52702 | 9 : 1 | 330 | 25 |
| 9904 120 52405 | 9904 120 52605 | 9904 120 52705 | 50 : 1 | 60 | 150 |
| 9904 120 52407 | 9904 120 52607 | 9904 120 52707 | 150,4 : 1 | 23 | 150 |
| 9904 120 52409 | 9904 120 52609 | 9904 120 52709 | 451,25 : 1 | 8,2 | 150 |

### APPLICATION

These small d.c. motors with integrated gearboxes have been designed for applications which require a driving system of good quality and a long life.

Application examples are :
- rotating warning lights e.g. on cars
- positioning of searchlights e.g. on cars
- headlamp wipers on cars
- automation systems
- high quality toys

### DESCRIPTION

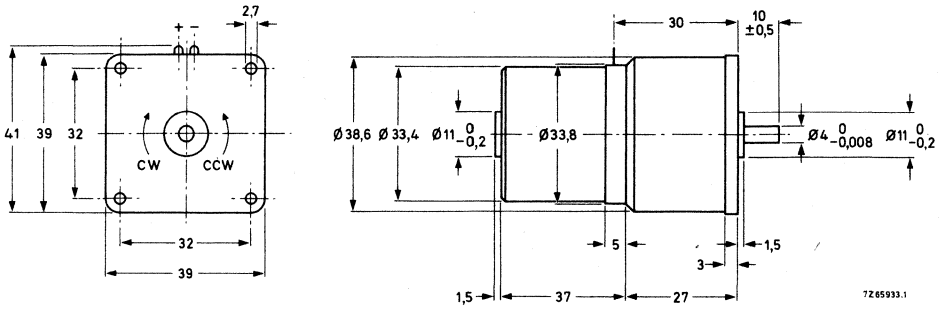
The motor has been provided with a permanent-magnet stator system. A reduction gear-box has been built in with gearwheels made of polyacetal resin ; various reductions are available.
The use of special brushes, a flat commutator and a built-in spark suppressor (voltage dependent resistor) guarantee a long life and a low interference level. The new stator magnet material and the special rotor construction give the motor a high efficiency.
The grey injection-moulded housing of polyacetal resin is highly resistant to chemicals and corrosion.

### MOUNTING

Mounting the motor is easy since it is provided with a flange having four holes.
Four screws M 2,5 and washers can be used.

**TECHNICAL DATA**

Dimensions (mm)




The direction of rotation is given in connection with the polarity (see table next page)

| | |
|---|---|
| Ambient temperature range | -20 to +60 °C |
| Bearings | bronze, self lubricating |
| Maximum axial play | 0,5 mm |
| Housing, material<br>colour | polyacetal resin<br>grey |
| Gears, material | polyacetal resin |
| Weight | 125 g approx. |

The values given below apply to an ambient temperature of 22 ± 5 °C, an atmospheric pressure of 860 - 1060 mbar and a relative humidity of 45 to 75%.

| catalogue number 9904 120 52... | 402 | 602 | 702 | 405 | 605 | 705 | 407 | 607 | 707 | 409 | 609 | 709 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| reduction ratio | 9 : 1 | | | 50 : 1 | | | 150, 4 : 1 | | | 451, 25 : 1 | | | |

Nominal values

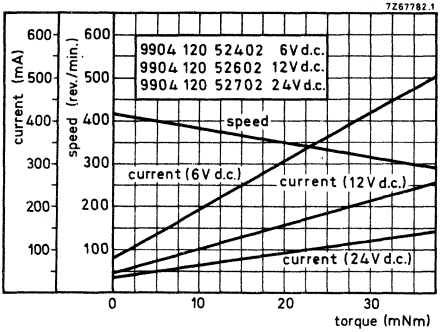
| voltage | 6 | 12 | 24 | 6 | 12 | 24 | 6 | 12 | 24 | 6 | 12 | 24 | V d.c. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| torque | 25 | | | 150 | | | 150 | | | 150 | | | mNm |
| speed at nom. load<br>at no load | 330<br>415 | | | 60<br>78 | | | 23<br>26 | | | 8, 2<br>8, 5 | | | rev/ min |
| current at nom. load<br>at no load | 360<br>80 | 185<br>45 | 105<br>35 | 360<br>80 | 185<br>45 | 105<br>35 | 180<br>75 | 100<br>40 | 60<br>35 | 110<br>70 | 60<br>40 | 45<br>35 | mA<br>mA |
| input power | 2, 1 | 2, 2 | 2, 5 | 2,1 | 2, 2 | 2, 5 | 1, 1 | 1, 2 | 1, 4 | 0, 7 | 0, 7 | 1, 1 | W |
| direction of rotation (see also dim. drawing) | CW | | | CW | | | CCW | | | CW | | | |
| max. radial force on the bearings | 2 | | | 6 | | | 8 | | | 10 | | | N |
| max. axial force | 2 | | | 6 | | | 8 | | | 10 | | | N |

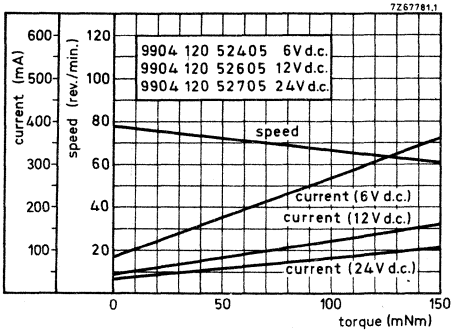
Limiting conditions *)

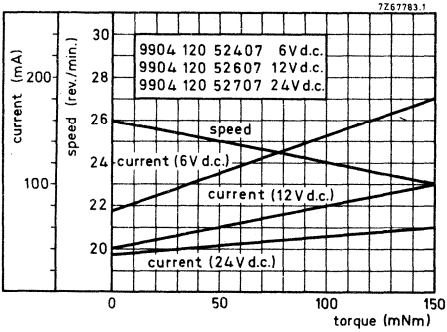
| max. voltage | 9 | 18 | 28 | 9 | 18 | 28 | 9 | 18 | 28 | 9 | 18 | 28 | V d.c. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| max. perm. load | 37, 5 | | | 150 | | | 150 | | | 150 | | | mNm |

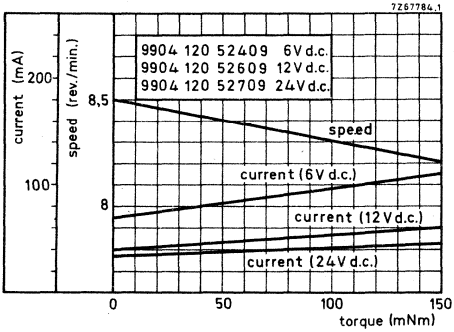
*) These maximum values should never be exceeded.

The curves are measured on an arbitrary motor.



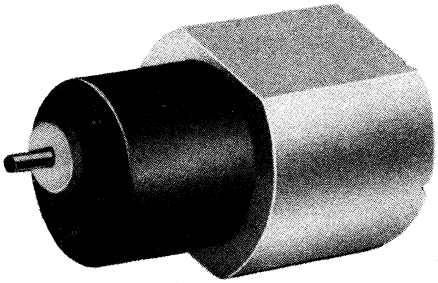



# DIRECT CURRENT MOTORS
## with reduction

70.612H1



| QUICK REFERENCE DATA | | | | | |
|---|---|---|---|---|---|
| catalogue number | nominal voltage (V d.c.) | reduction ratio | speed (rev/min) | input power (W) | torque (mNm) |
| 9904 120 53101 | 3 | 27 : 1 | 96 | 0,45 | 15 |
| 9904 120 53102 *) | 3 | 15,8 : 1 | 162 | 0,45 | 9 ← |
| 9904 120 53103 *) | 3 | 10 : 1 | 258 | 0,45 | 5,5 ← |
| 9904 120 53104 *) | 3 | 1,6 : 1 | 1600 | 0,45 | 1,1 ← |

### APPLICATION

These small d.c. motors with reduction have been mainly designed for servo purposes in professional and industrial applications, which require high reliability and smooth running.

Examples:
- film cameras (film drive and zoom lens drive);
- slide projectors;
- portable recording instruments (chart drive and pen drive);
- instruments for automation.

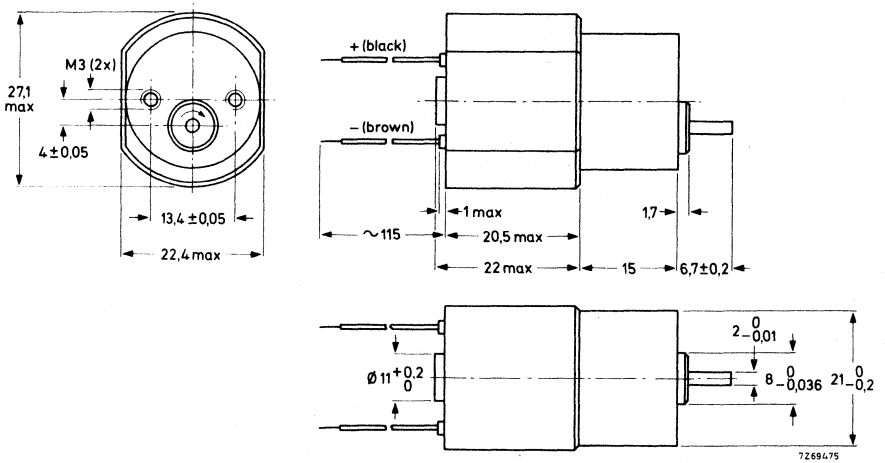
*) The smallest order quantity is 500.
A few samples are available on request.

## DESCRIPTION

The motors have been provided with a housing of sintered iron.
A reduction of the motor speed has been obtained by means of a high-precision reduction gear, mounted in a steel housing, which is fitted to the motor.
The special construction of a flat collector, a light brush construction and a built-in spark suppressor (VDR) guarantee smooth running.
The motors are suitable for use with an electronic remote control unit.
They can be used in tropical environments.

## TECHNICAL DATA

Dimensions in mm




The direction of rotation is given in connection with the polarity.

Weight approx. 65 g

The values given below apply to an ambient temperature of 22±5°C, an atmospheric pressure of 860 - 1060 mbar and a relative humidity of 45 - 75%.

Nominal values

| Catalogue number 9904 120 ..... | 53101 | 53102 | 53103 | 53104 | |
|---|---|---|---|---|---|
| Reduction ratio | 27 : 1 | 15.8 : 1 | 10 : 1 | 1.6 : 1 | |
| Voltage | 3 | 3 | 3 | 3 | V d.c. |
| Torque | 15 | 9 | 5.5 | 1.1 | mNm |
| Speed at nominal load | 96 ± 12 | 162 ± 20 | 258 ± 31 | 1600 ± 180 | rev/min |
| at no load | 110 ± 12 | 190 ± 20 | 298 ± 31 | 1870 ± 200 | rev/min |
| Current at nominal load | ≤ 0.15 | ≤ 0.15 | ≤ 0.15 | ≤ 0.15 | A |
| at no load | ≤ 0.05 | ≤ 0.05 | ≤ 0.05 | ≤ 0.05 | A |
| Starting voltage at no load | < 1 | < 1 | < 1 | < 1 | V d.c. |
| Starting torque | ≥ 75 | ≥ 45 | ≥ 28.5 | ≥ 5.5 | mNm |
| Input power | ≤ 0.45 | ≤ 0.45 | ≤ 0.45 | ≤ 0.45 | W |
| Maximum radial force on the bearings | 2 | 2 | 2 | 1 | N |

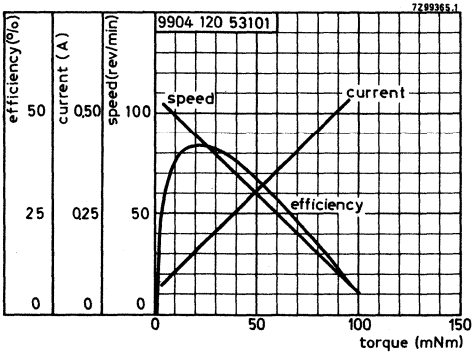
| | |
|---|---|
| Induced voltage at 3000 rev/min (rotor speed) | between 2.6 and 3.1 V |
| Rotor resistance measured statically with brushes | 4.5 Ω ± 10% |
| Direction of rotation | clockwise, see dimensional drawing |
| Ambient temperature range | −10 to +50 °C |
| Maximum axial force | 1 N |
| Maximum axial play | 0.2 mm |
| Rotor inertia | 4 gcm$^2$ |
| Housing, material of motor | sintered iron |
| material of gearbox | steel |

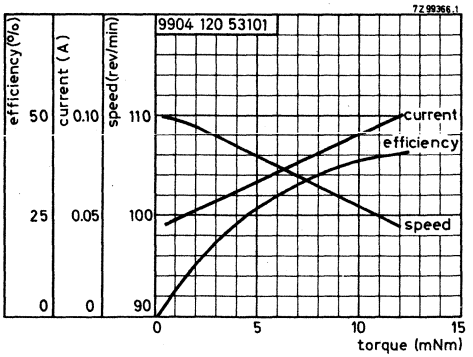
Limiting conditions

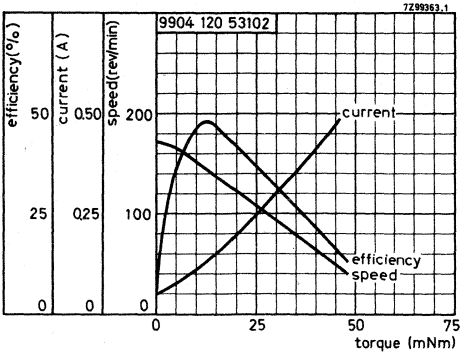
The following maximum values should never be exceeded.

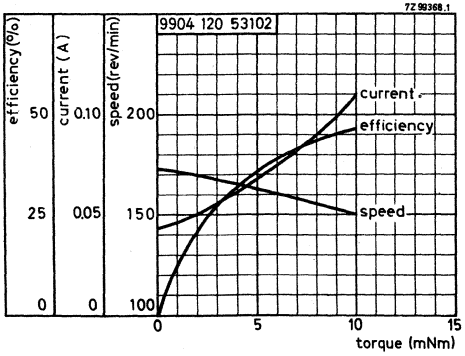
| Catalogue number 9904 120 ..... | 53101 | 53102 | 53103 | 53104 | |
|---|---|---|---|---|---|
| Maximum voltage | 5 | 5 | 5 | 5 | V d.c. |
| Maximum permissible load | 47 | 28 | 17.5 | 3.5 | mNm |
| Maximum permissible input current | 0.35 | 0.35 | 0.35 | 0.35 | A |
| Maximum speed | 130 | 220 | 350 | 2200 | rev/min |
| Maximum output | 0.6 | 0.6 | 0.6 | 0.7 | W |

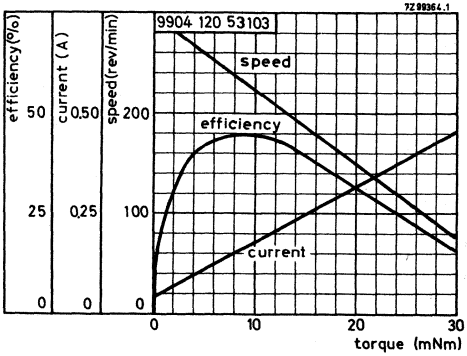
Note – The gears of the gearbox can easily withstand a load of 100 mNm on the outgoing spindle.

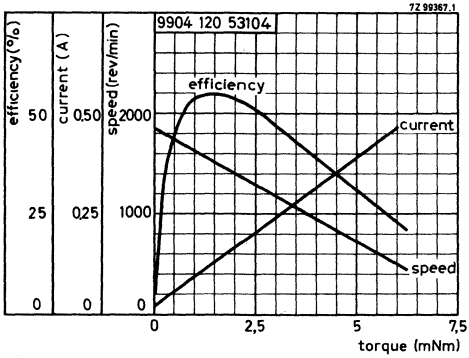



7Z99363.1
9904 120 53102
efficiency(%)
current (A)
speed(rev/min)
50
25
0
0.50
0.25
0
200
100
0
current
efficiency
speed
0
25
50
75
torque (mNm)


7Z99368.1
9904 120 53102
efficiency(%)
current (A)
speed(rev/min)
50
25
0
0.10
0.05
0
200
150
100
current
efficiency
speed
0
5
10
15
torque (mNm)




## MOUNTING

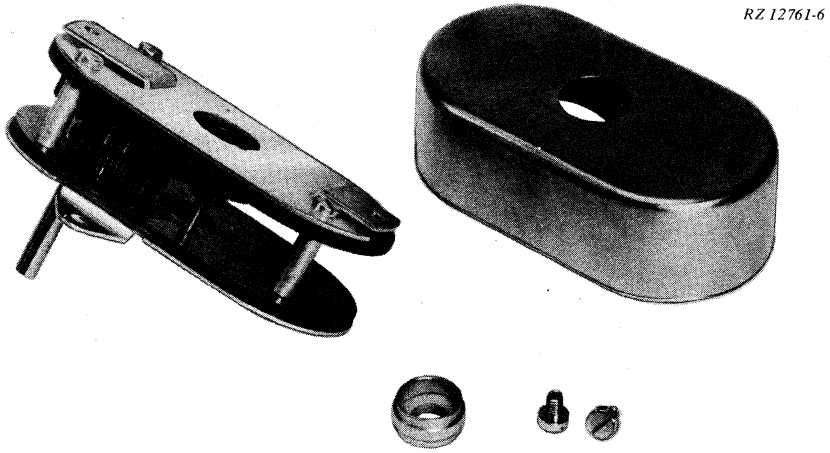
The motors can be fixed by means of two screws M3 in the mounting holes of the gearbox.
The bearing of the outcoming spindle can also be used as a centring piece.

## REMARK

A circuit diagram of an electronic 4-speed control unit can be supplied on request.

# Accessories

# GEARBOXES
## for small synchronous motors



RZ 12761-6

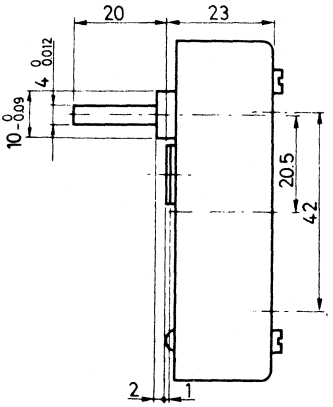
**GENERAL**

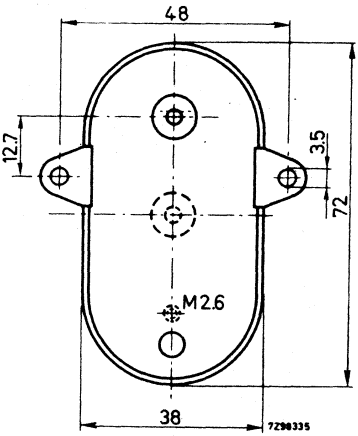
The reduction gearboxes of the 9904 130 01... series have been designed for use with the synchronous motors, provided with a pinion. They are supplied separately but can easily be mounted to any of these motors.

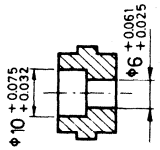
To attach the motor to the gearbox, place the reversible centring bush in position so that it fits the centring rim on the motor casing, and fasten the motor by means of the two screws in the gearbox cover. For fastening the motors 9904 110 05... and 9904 111 07.. the gearbox is provided with two threaded holes M2,6.

Many different gear ratios can be built into the same metal casing; there are 19 standard gear ratios. ←
The gearboxes are meant for small series and professional applications with versatility as the main property. As a rule small quantities can be supplied from stock.

For all data necessary for selecting the appropriate gearbox from the series, see the survey at the end of this section.




centring bush

## TECHNICAL DATA

| | |
|---|---|
| Maximum permissible load | 200 mNm |
| Maximum permissible radial force | 10 N |
| Maximum permissible axial force | 2 N |

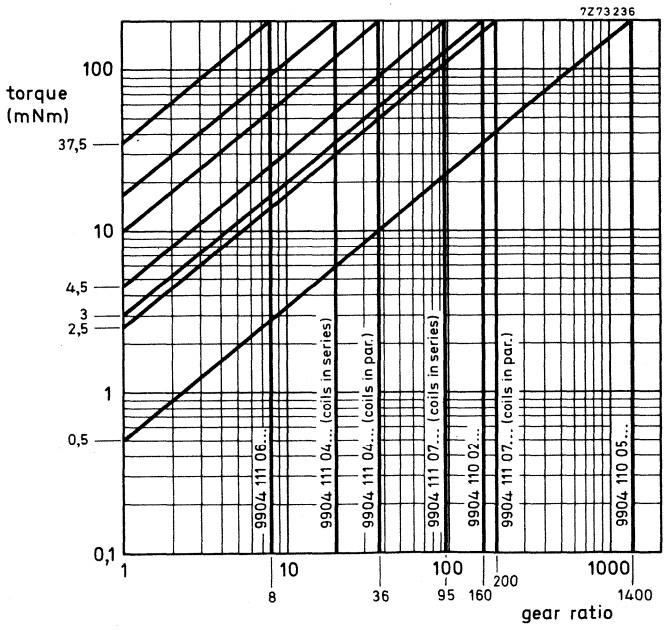
Gearbox - performance graph

By using a gearbox with a large gearing - down ratio it will be possible to obtain a torque at the outgoing spindle of the gearbox which surpasses the maximum permissible load on the gearbox of 200 mNm. The gearbox - performance graph therefore shows 200 mNm as the torque limit.

The graph can be used either for finding the maximum obtainable torque value of a given motor + gearbox, or the proper motor - gearbox combination for obtaining a given torque.

a. Motor 9904 110 05...; required gearing - down ratio 36 : 1.
The graph shows the maximum obtainable torque to be 10 mNm. Gearbox efficiency has been taken into account.

b. Desired torque value 10 mNm, required gearing - down ratio 36 : 1.
The graph shows that the motor with the catalogue number 9904 110 05... does the job.



**SURVEY**

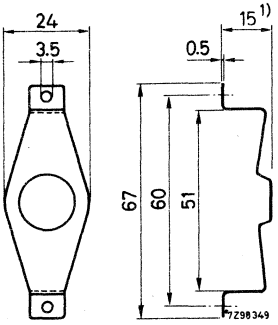
| gear ratio | number of revolutions of outgoing spindle when coupled to a motor operating from | | direction of rotation of outgoing spindle compared to motor spindle [1] | efficiency | catalogue number |
|---|---|---|---|---|---|
| | 50 Hz mains | 60 Hz mains | | | |
| 25:6 | 60 rev/min | 72 rev/min | same | 0,64 | 9904 130 01001 |
| 25:4 | 40 rev/min | 48 rev/min | same | 0,64 | 01003 |
| 25:3 | 30 rev/min | 36 rev/min | same | 0,64 | 01004 |
| 10:1 | 25 rev/min | 30 rev/min | same | 0,64 | 01005 |
| 25:2 | 20 rev/min | 24 rev/min | same | 0,64 | 01006 |
| 50:3 | 15 rev/min | 18 rev/min | opposite | 0,51 | 01008 |
| 20:1 | 12,5 rev/min | 15 rev/min | same | 0,64 | 01009 |
| 25:1 | 10 rev/min | 12 rev/min | opposite | 0,51 | 01011 |
| 100:3 | 7,5 rev/min | 9 rev/min | opposite | 0,51 | 01014 |
| 125:3 | 6 rev/min | 7,2 rev/min | opposite | 0,51 | 01016 |
| 50:1 | 5 rev/min | 6 rev/min | opposite | 0,51 | 01017 |
| 125:2 | 4 rev/min | 4,8 rev/min | opposite | 0,51 | 01019 |
| → 250:3 | 3 rev/min | 3,6 rev/min | same | 0,41 | 01021 |
| 125:1 | 2 rev/min | 2,4 rev/min | opposite | 0,51 | 01023 |
| 250:1 | 1 rev/min | 1,2 rev/min | same | 0,41 | 01027 |
| 500:1 | 30 rev/h | 36 rev/h | same | 0,41 | 01034 |
| → 750:1 | 20 rev/h | 24 rev/h | opposite | 0,33 | 01037 |
| 1250:1 | 12 rev/h | 14,4 rev/h | opposite | 0,33 | 01041 |
| 15000:1 | 1 rev/h | 1,2 rev/h | opposite | 0,21 | 01062 |

[1]) When the direction of rotation of the outgoing spindle is not the one which is desired a motor with the reverse direction of rotation should be chosen.

# MOUNTING BRACKET

## for small synchronous motors 9904 110 02...

A special bracket, catalogue number 9904 131 01001 has been made available for mounting the unidirectional motors of the series 9904 110 02... to some piece of equipment, which may be a gearbox.



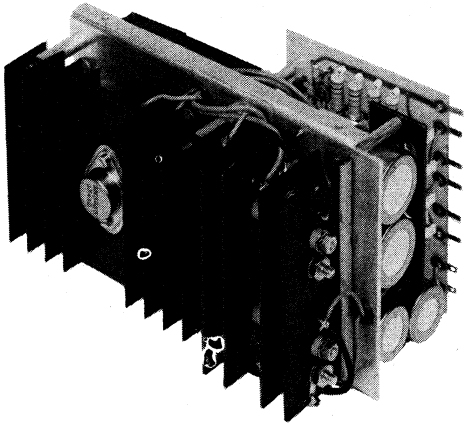

1) In mounted position.

# POWER SUPPLY UNIT

## for bipolar constant current drive

| QUICK REFERENCE DATA | |
|---|---|
| Input voltage | 220 V, 50 to 60 Hz |
| Output voltages | +5 V<br>+60 V |

750528-15-01



### APPLICATION

The power supply unit has been designed to supply the required voltages and currents for the BCCD unit, catalogue number 4322 027 90070, and to fulfil additional requirements for this unit.

### DESCRIPTION

The unit mainly consists of a transformer and a rectifier. The mains voltage of 220 V is transformed into two voltages which, after being rectified, are matched to the BCCD unit supply requirements (5 V and 60 V). Provision is made in the unit so that the 60 V supply becomes available later than the 5 V supply when the unit is switched on. When the unit is switched off, by means of an external double-pole double-throw switch, electrolytic capacitors in the unit are discharged so that the 5 V supply maintains its voltage till the 60 V supply has dropped below 30 V.

## MECHANICAL DATA

Dimensions (mm)

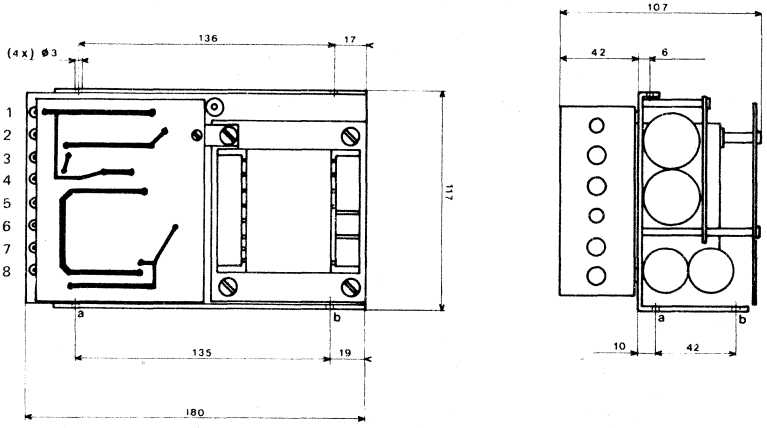



Fig. 1

Connections

The connections are given in the connection diagrams of the bipolar constant current drive 4322 027 90070.

Mounting

The unit has four holes of 3 mm for mounting. The holes are indicated in Fig. 1.

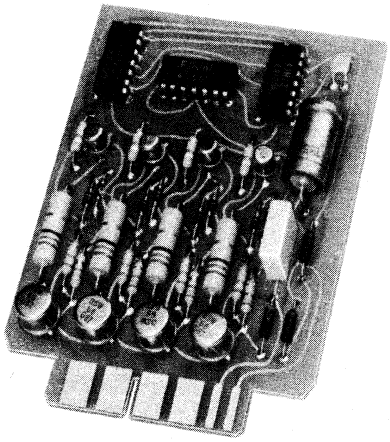
**NOTE**

Data sheet with complete information will be issued shortly.

# ELECTRONIC SWITCH

## for 4-phase unipolar stepper motors

RZ26753-1



### APPLICATION

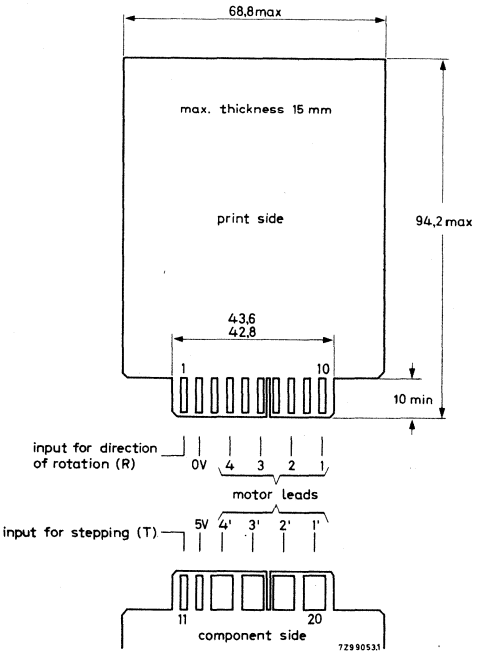
The electronic switch changes a train of input pulses into a sequential pulse output which provides the required pulse pattern for driving 4-phase unipolar stepper motors.

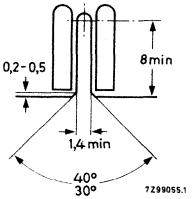
### DESCRIPTION

The electronic switch is essentially a reversible ring counter, each of its 4 outputs being followed by an output stage. The ring counter is built up with IC s of the GFB family which need a supply voltage of 5 V. For this reason the whole unit has been designed for this voltage. The unit has two inputs : the first one receives the order for the rotor to perform the step, the second one determines the direction of rotation by means of a d.c. level. The output stages are equipped with silicon transistors developed for switching inductive loads. All components are mounted on a double-sided printed-wiring board that mates with a printed-wiring connector with two rows of 10 contacts and a contact pitch of 0,156 inch.

## TECHNICAL DATA

Dimensions (mm) and terminal location




Detailed view of the slot

Weight 40 g

Ambient temperature range

| | |
|---|---|
| operating | 0 to + 70 °C |
| storage | −40 to + 70 °C |

Power supply

| | |
|---|---|
| voltage ($V_b$) | + 5 V ± 5% |
| current (at $V_b$ = 5 V) | 230 mA ± 10% |

Input data

Direction of rotation

The level of $V_R$ may change state only when the input pulse for stepping is LOW.

| | |
|---|---|
| $V_R$, HIGH (clockwise) | ≥ 2,0 V, ≤ 5 V |
| LOW (counter-clockwise) | ≥ 0 V, ≤ 0,8 V |
| $V_R$, limiting value *) | max. 5,5 V |
| $I_R$, at $V_R$ HIGH | max. 0,12 mA |
| $-I_R$, at $V_R$ LOW | max. 4,8 mA |
| $-I_R$, limiting value *) | 20 mA |

Stepping

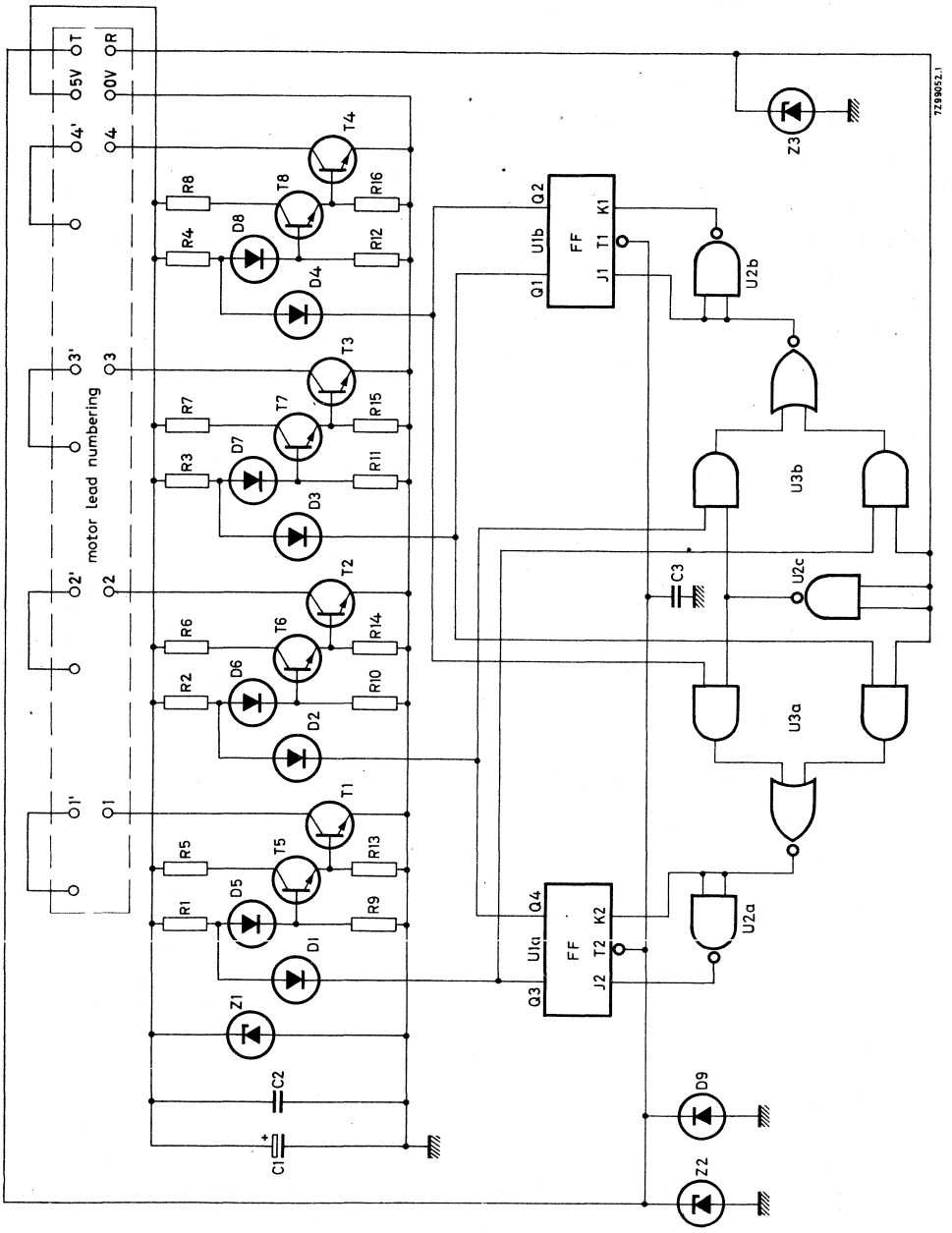
| | |
|---|---|
| $V_T$, HIGH | ≥ 2,0 V, ≤ 5 V |
| LOW | ≥ 0 V, ≤ 0,8 V |
| $V_T$, limiting value *) | max. 5,5 V |
| $I_T$, at $V_T$ HIGH | max. 0,25 mA |
| $-I_T$, at $V_T$ LOW | max. 6,4 mA |
| $-I_T$, limiting value *) | 20 mA |
| Pulse width, $V_T$ HIGH | min. 100 ns |
| Pulse frequency | max. 25 kHz |

Output data

| | |
|---|---|
| Permissible voltage (at each output) | max. 100 V |
| Permissible current (per output) | max. 600 mA |
| Saturation voltage ($V_{CE}$) | max. 500 mV |

*) In accordance with the Absolute Maximum Rating System as defined in IEC publication 134.

Circuit diagram

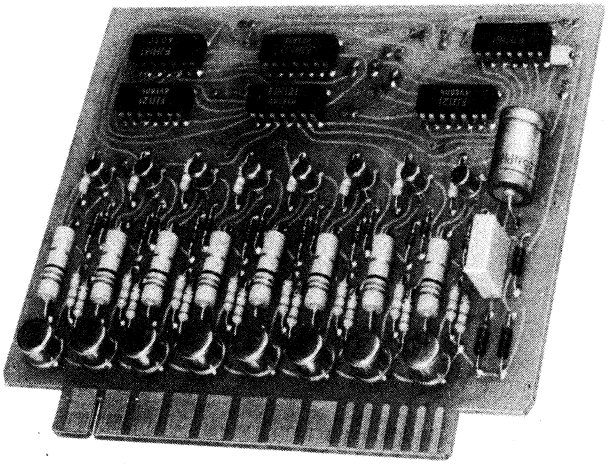


Parts list

| component | description | value | tolerance |
|---|---|---|---|
| C1 | capacitor | 125 µF, 10 V | −10/+50% |
| C2 | capacitor | 0,1 µF | 10% |
| C3 | capacitor | 1 nF | 10% |
| D1 -D8 | diode | BAX13 | |
| D9 | diode | AAZ18 | |
| U1 | integrated circuit | GFB7473D | |
| U2 | integrated circuit | GFB7400D | |
| U3 | integrated circuit | GFB7451D | |
| R1 -R4 | carbon resistor | 390 Ω, 0,2 W | 5% |
| R5 -R8 | carbon resistor | 51 Ω, 0,7 W | 5% |
| R9 -R12 | carbon resistor | 6,8 kΩ, 0,2 W | 5% |
| R13-R16 | carbon resistor | 180 Ω, 0,2 W | 5% |
| T1 -T4 | transistor | BSW66 | |
| T5 -T8 | transistor | BC107 | |
| Z1 | voltage regulator diode | BZY88-C5V6 | |
| Z2 -Z3 | voltage regulator diode | BZY88-C5V1 | |

# ELECTRONIC SWITCH

## for 8-phase unipolar stepper motors



*RZ 26753-2*

### APPLICATION

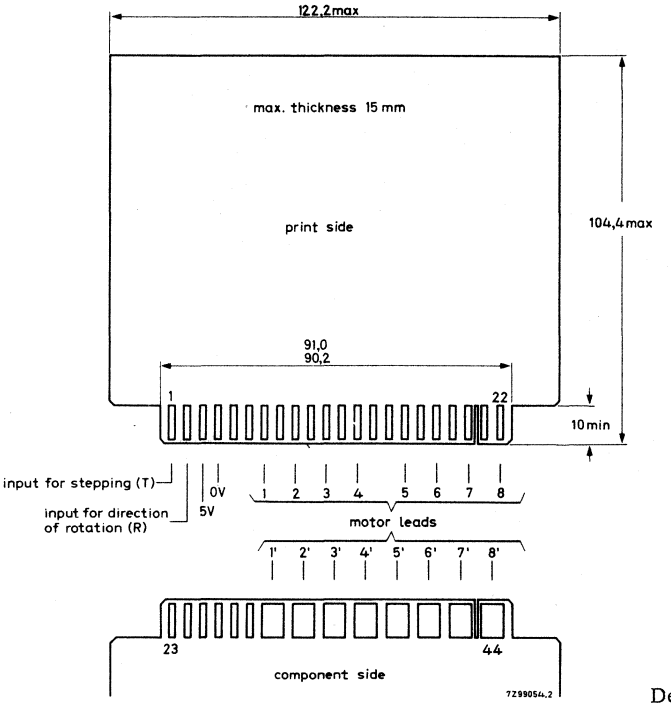
The electronic switch changes a train of input pulses into a sequential pulse output which provides the required pulse pattern for driving 8-phase unipolar stepper motors.

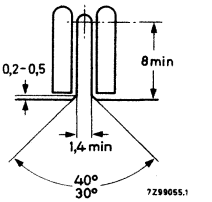
### DESCRIPTION

The electronic switch is essentially a reversible ring counter, each of its 8 outputs being followed by an output stage. The ring counter is built up with IC s of the GFB family which need a supply voltage of 5 V. For this reason the whole unit has been designed for this voltage. The unit has two inputs: the first one receives the order for the rotor to perform the step, the second one determines the direction of rotation by means of a d.c. level. The output stages are equipped with silicon transistors developed for switching inductive loads. All components are mounted on a double-sided printed-wiring board that mates with printed-wiring connector with two rows of 22 contacts and a contact pitch of 0,156 inch.

## TECHNICAL DATA

Dimensions (mm) and terminal location




Detailed view of the slot

Weight 80 g

Ambient temperature range

| | |
|---|---|
| operating | 0 to +70 °C |
| storage | −40 to +70 °C |

Power supply

| | |
|---|---|
| voltage ($V_b$) | +5 V ± 5% |
| current (at $V_b$ = 5 V) | 440 mA ± 10% |

Input data

Direction of rotation

The level of $V_R$ may change state only when the input pulse for stepping is LOW.

| | |
|---|---|
| $V_R$ , HIGH (clockwise) | ≥ 2,0 V, ≤ 5 V |
| LOW (counter-clockwise) | ≥ 0 V, ≤ 0,8 V |
| $V_R$ , limiting value *) | max. 5,5 V |
| $I_R$ , at $V_R$ HIGH | max. 0,2 mA |
| $-I_R$, at $V_R$ LOW | max. 8 mA |
| $-I_R$, limiting value *) | 20 mA |

Stepping

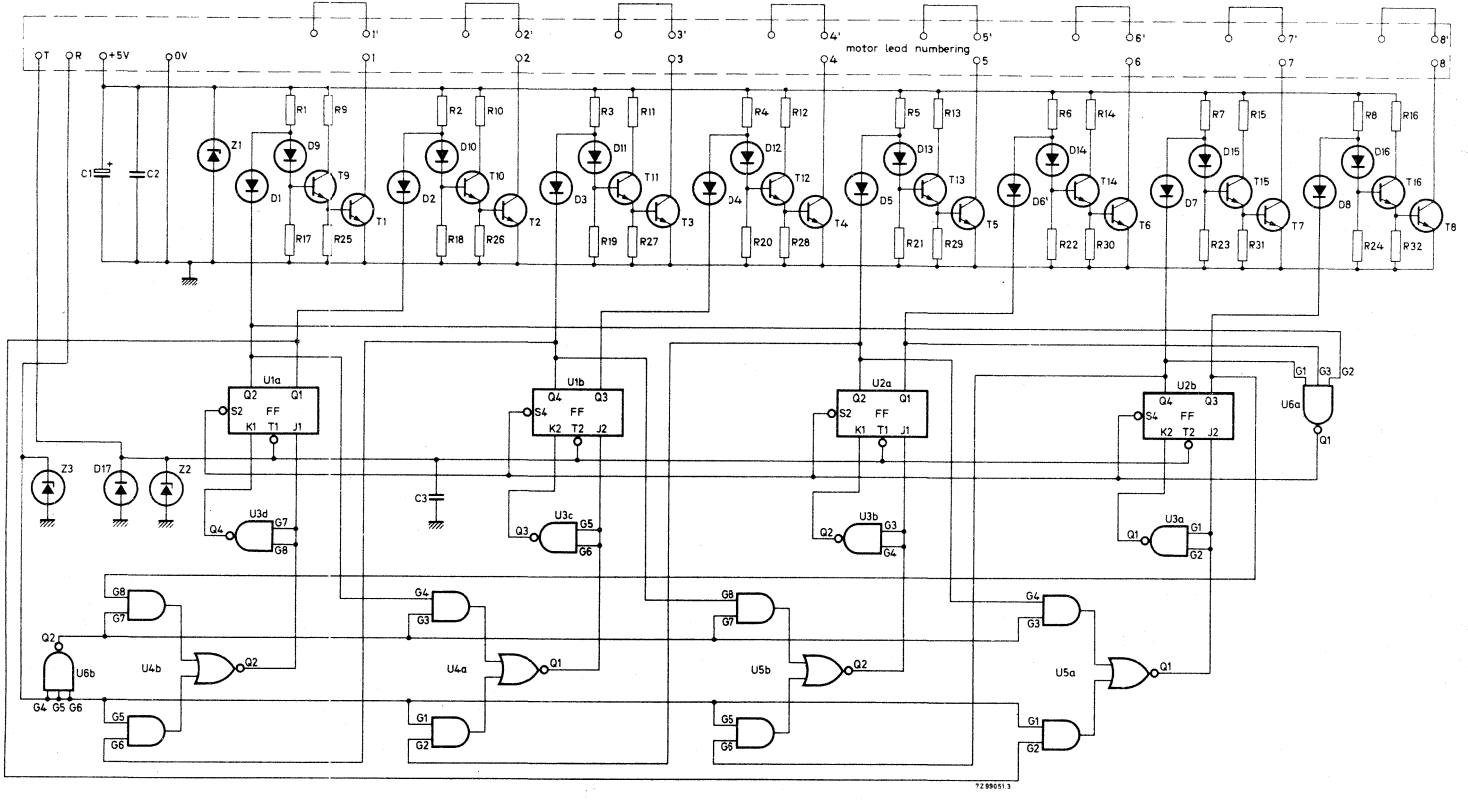
| | |
|---|---|
| $V_T$ , HIGH | ≥ 2,0 V, ≤ 5 V |
| $V_T$ , LOW | ≥ 0 V, ≤ 0,8 V |
| $V_T$ , limiting value *) | max. 5,5 V |
| $I_T$ , at $V_T$ HIGH | max. 0,4 mA |
| $-I_T$, at $V_T$ LOW | max. 12,8 mA |
| $-I_T$, limiting value *) | 20 mA |
| Pulse width, $V_T$ HIGH | min. 100 ns |
| Pulse frequency | max. 25 kHz |

Output data

| | |
|---|---|
| Permissible voltage (at each output) | max. 100 V |
| Permissible current (per output) | max. 600 mA |
| Saturation voltage ($V_{CE}$) | max. 500 mV |

*) In accordance with the Absolute Maximum Rating System as defined in IEC publication 134.

## Circuit diagram



Parts list

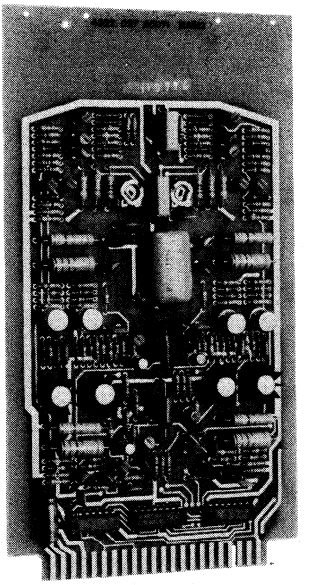
| component | description | value | tolerance |
|---|---|---|---|
| C1 | capacitor | 125 µF, 10 V | −10/+50% |
| C2 | capacitor | 0,1 µF | 10% |
| C3 | capacitor | 1 nF | 10% |
| D1 -D16 | diode | BAX13 | |
| D17 | diode | AAZ18 | |
| U1 | integrated circuit | GFB7473D | |
| U2 | integrated circuit | GFB7473D | |
| U3 | integrated circuit | GFB7400D | |
| U4 | integrated circuit | GFB7451D | |
| U5 | integrated circuit | GFB7451D | |
| U6 | integrated circuit | GFB7410D | |
| R1 -R8 | carbon resistor | 390 Ω, 0,2 W | 5% |
| R9 -R16 | carbon resistor | 51 Ω, 0,7 W | 5% |
| R17-R24 | carbon resistor | 6,8 kΩ, 0,2 W | 5% |
| R25-R32 | carbon resistor | 180 Ω, 0,2 W | 5% |
| T1 -T8 | transistor | BSW66 | |
| T9 -T16 | transistor | BC107 | |
| Z1 | voltage regulator diode | BZY88-C5V6 | |
| Z2 -Z3 | voltage regulator diode | BZY88-C5V1 | |

# BIPOLAR CONSTANT CURRENT DRIVE

## for 2- and 4-phase stepper motors

| QUICK REFERENCE DATA | |
|---|---|
| Supply voltages | 5 V ± 5 %<br>60 V +20/−30 % |
| Output currents | 2 x max. 500 mA |
| Control inputs for direction of rotation and stepping | TTL compatible |

*750527-17-04*



**APPLICATION**

The BCCD unit is designed to drive bipolar stepper motors. It converts the input data into the requisite current reversals through successive stator coils of 2- and 4-phase bipolar motors. Two drive units are needed for 4-phase bipolar motors.

## DESCRIPTION

A simplified circuit diagram is shown in Fig. 1 (the complete circuit diagram is given in Fig. 5). The unit consists of two parts: a logic control circuit and a motor drive circuit. The logic control circuit needs a supply voltage of 5 V and has two inputs: input (T) (Figs 3, 4 and 5) receives the command for the rotor to perform the step, input (R) determines the direction of rotation. The motor drive circuit needs a supply voltage of 60 V and forms the output stages which drive the stator coils of the motor. The maximum current through the stator coils is controlled by a level detector (chopper), see Fig. 1. This ensures that the current through a stator coil reaches its maximum value in the shortest possible time and reduces the power consumption of the overall system. The current remains constant over the greater part of the stepping rate. Consequently the motor temperature increases with the increase of the stepping rate due to the iron losses within the motor.

It should be noted that the bipolar stepper motors in conjunction with the BCCD unit, are not designed for continuous operation in the pull-out range but are intended for applications requiring rapid positioning in which the pull-out operation is limited to a few seconds. Prolonged duty cycles in the pull-out range may result in an unacceptable temperature rise of the motor.

The unit has four different current settings to match the drive current to the application requirements. The torque characteristics in the pull-in and pull-out range will be affected by the current setting, however, the maximum pull-out rate will not be reduced.

All components are mounted on a double-sided printed-wiring board, which mates with printed-wiring connector type F047, having two rows of 22 contacts and a contact pitch of 0,156 inch.

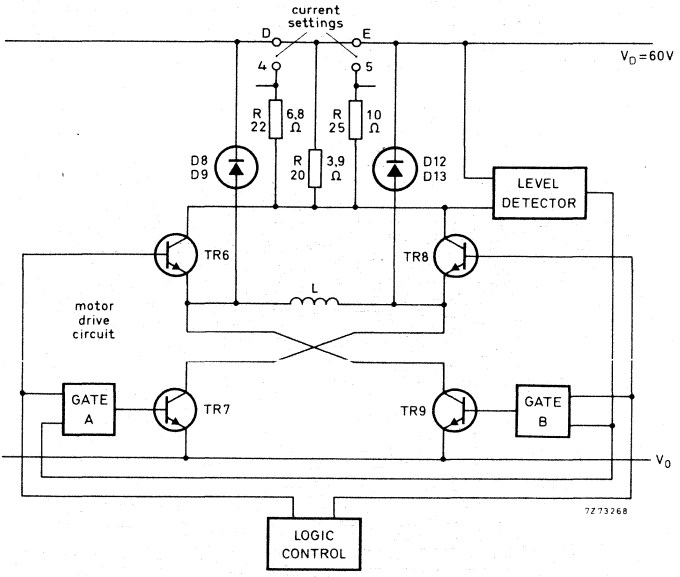
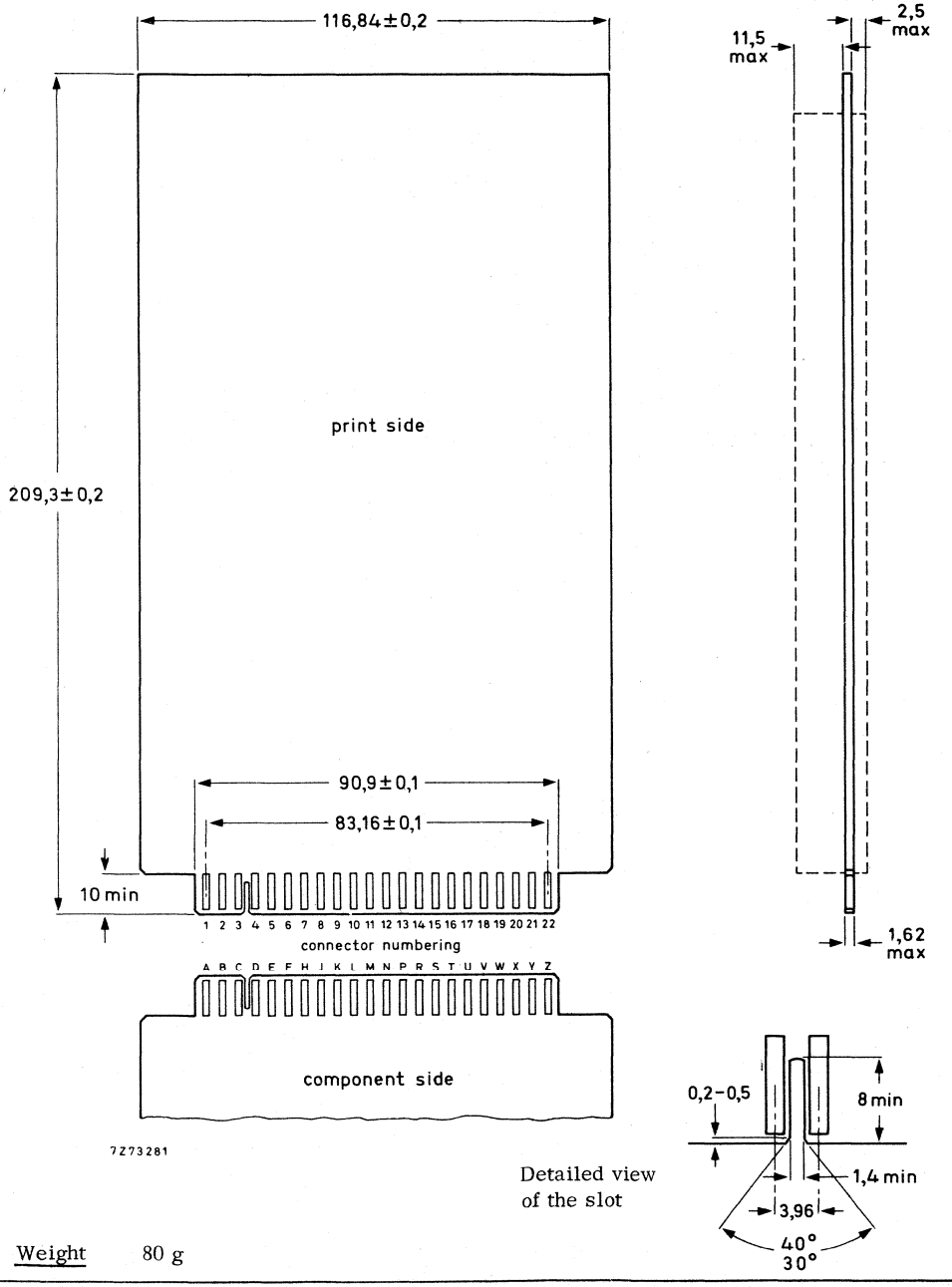



Fig. 1 Basic bipolar constant current drive circuit for one stator coil (L).

## MECHANICAL DATA

Dimensions (mm)




Detailed view of the slot

Weight 80 g

Connections

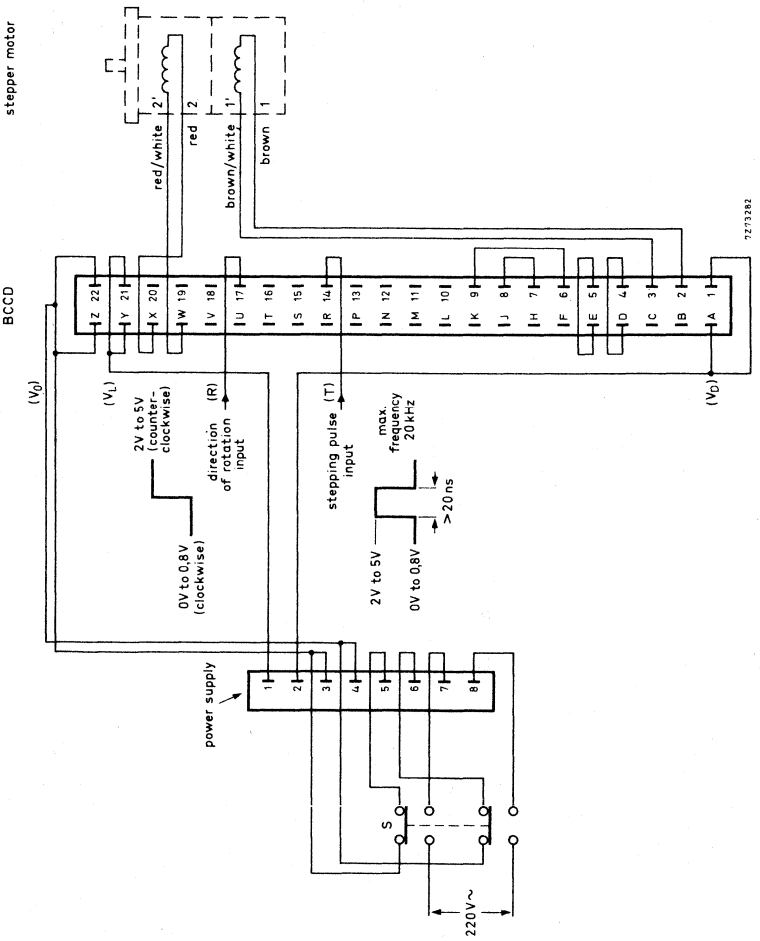



Fig. 3. Connection diagram for a BCCD unit, a 2-phase bipolar motor and power supply unit 9904 132 02001. A double-pole double-throw switch is needed to discharge electrolytic capacitors in the power supply unit when it is switched off.

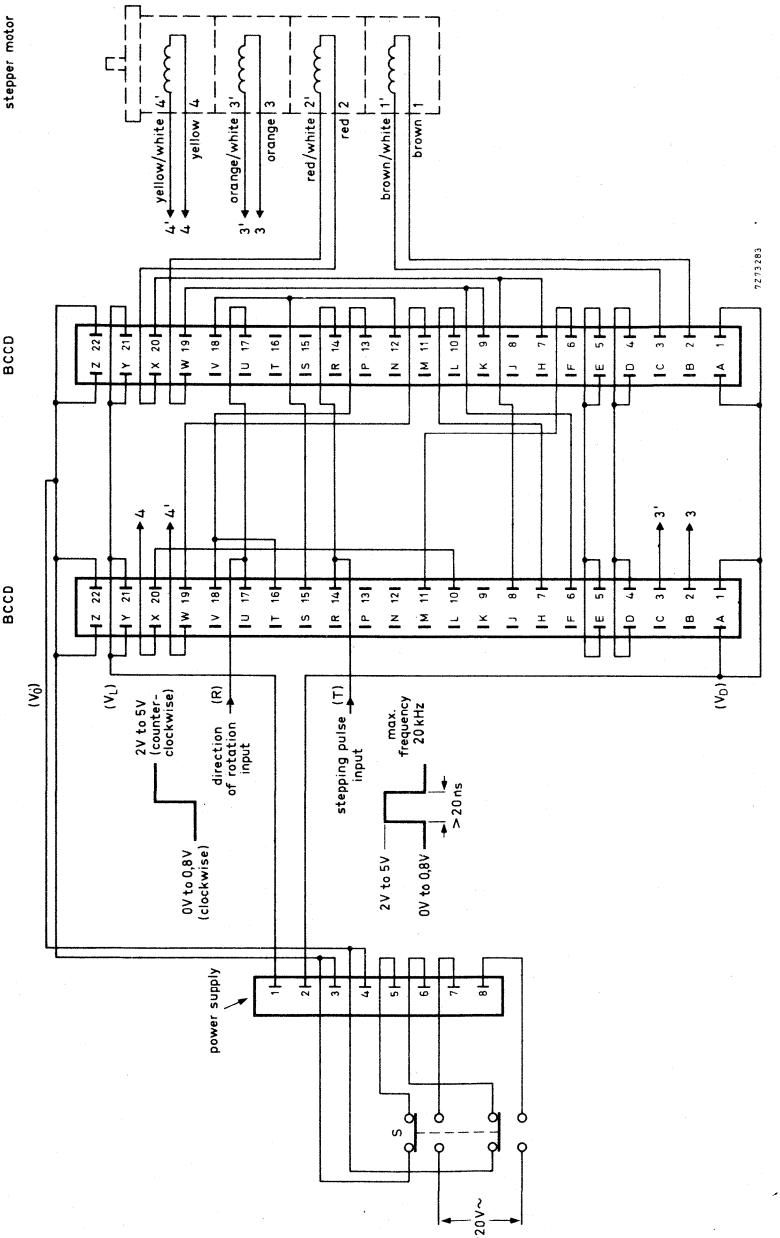



Fig. 4. Connection diagram for two BCCD units, a 4-phase bipolar motor and power supply unit 9904 132 02001. A double-pole double-throw switch is needed to discharge electrolytic capacitors in the power supply unit when it is switched off.

## ELECTRICAL DATA

Input data

Direction of rotation

The level of $V_R$ may change state only when the input pulse for stepping is LOW.

| | |
|---|---|
| $V_R$, HIGH (clockwise) | ≥ 2 V, ≤ 5 V |
| LOW (counter-clockwise) | ≥ 0 V, ≤ 0,8 V |
| $V_R$, limiting values *) | -max. 2 V **) |
| | max. 5,5 V |
| $I_R$, at $V_R$ HIGH, Fig. 3 | max. 0,12 mA |
| Fig. 4 | max. 0,24 mA |
| $-I_R$, at $V_R$ LOW, Fig. 3 | max. 4,8 mA |
| Fig. 4 | max. 9,6 mA |

Stepping

| | |
|---|---|
| $V_T$, HIGH | ≥ 2 V, ≤ 5 V |
| LOW | ≥ 0 V, ≤ 0,8 V |
| $V_T$, limiting values *) | -max. 2 V **) |
| | max. 5,5 V |
| $I_T$, at $V_T$ HIGH, Fig. 3 | max. 0,16 mA |
| Fig. 4 | max. 0,32 mA |
| $-I_T$, at $V_T$ LOW, Fig. 3 | max. 6,4 mA |
| Fig. 4 | max. 12,8 mA |
| Pulse width, $V_T$ HIGH | min. 20 ns |
| Pulse frequency, Fig. 3 | max. 20 kHz |
| Fig. 4 | max. 40 kHz |

*) In accordance with the Absolute Maximum Rating System as defined in IEC publication 134.

**) Pulse duration 20 ns, frequency 5 MHz, source resistance minimum 75 Ω.

Output data

Four drive current settings can be obtained by interconnecting the following connector terminals:

| set current (mA) | power consumption of motor | terminals to be interconnected |
|---|---|---|
| 500 | P nominal | 4 and D |
| | | 5 and E |
| 400 | 2/3 $P_{nom}$ | 4 and D |
| 350 | 1/2 $P_{nom}$ | 5 and E |
| 250 | 1/4 $P_{nom}$ | - |

Interconnection shunts R20 (in Fig. 1) so that the level detector which controls the maximum current chopper operates at a higher current level.

Caution: Two BCCD units are required for 4-phase stepper motors. Be sure that both units are set for the same output current.

The BCCD unit has been developed to drive bipolar stepper motors having coil windings adapted for this form of drive. Do not replace the motor by other electrical components to simulate the load conditions and do not connect other electrical components in series or in parallel with the motor coils. To do so may damage the unit.

Power supply requirements

Logic circuit

| | |
|---|---|
| Voltage $V_L$ | +5 V ±5 % |
| Current $I_L$ (per unit) | 160 mA |

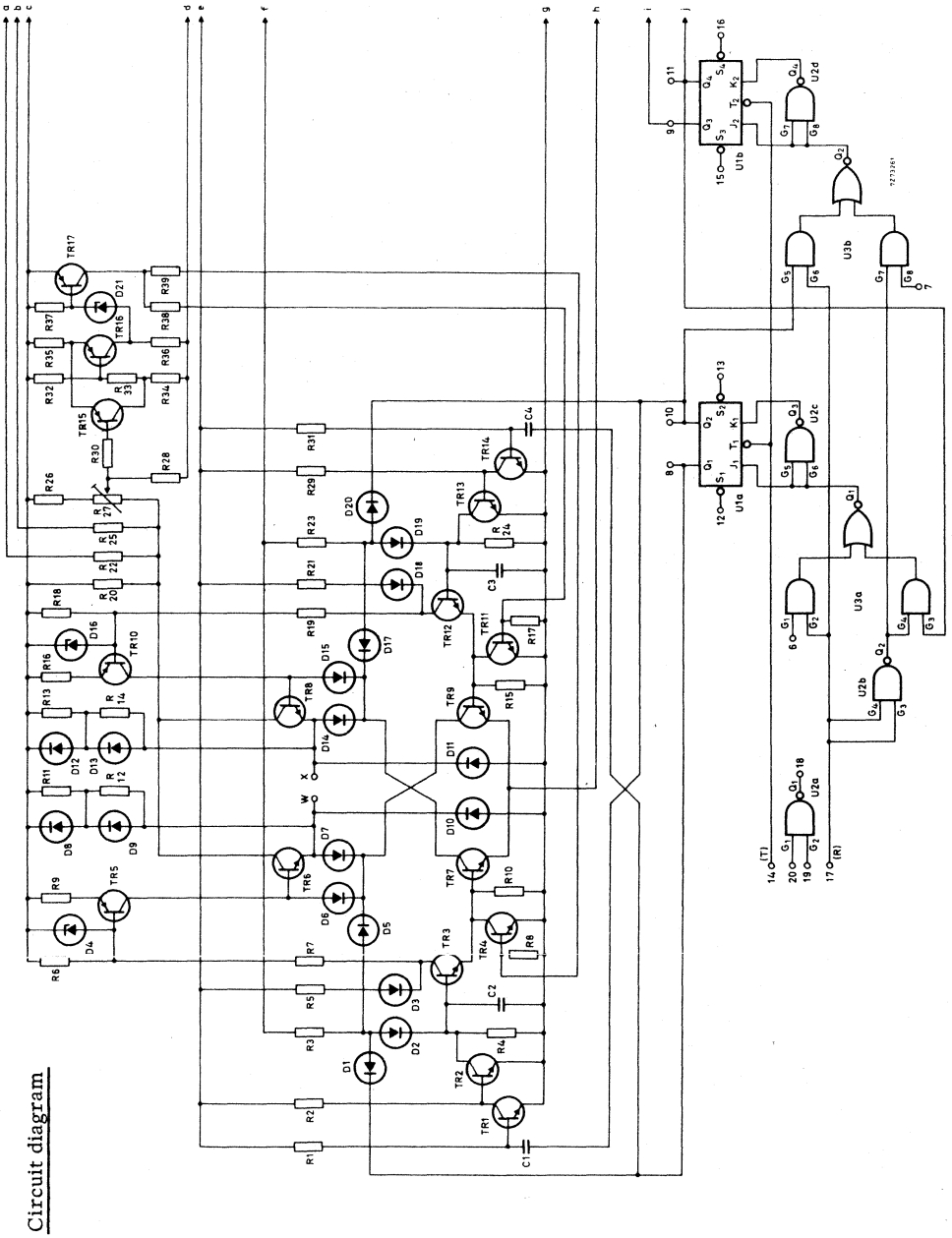
Drive circuit

| | |
|---|---|
| Voltage $V_D$ | 60 V +20/−30 % |
| Current $I_D$ (per unit) | |
| no load | 45 mA |
| full load | 750 mA |

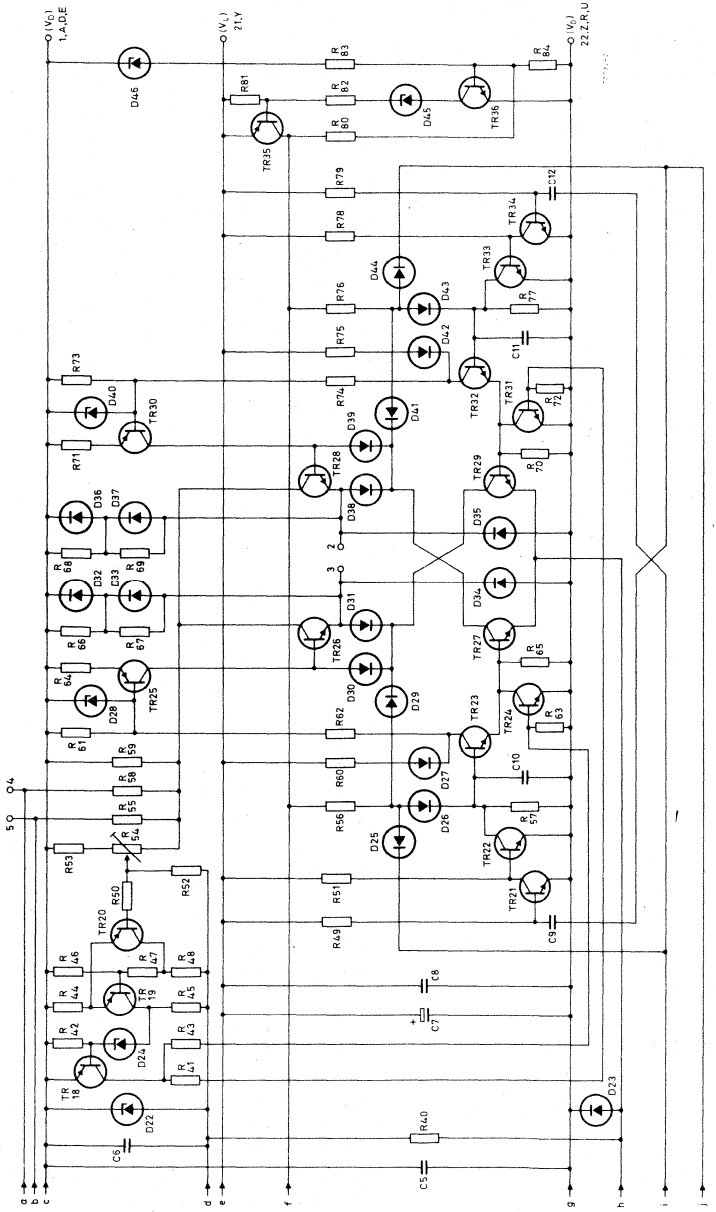
Note: See under Precautions below.

Ambient temperature range

| | |
|---|---|
| Operating | 0 to +70 °C |
| Storage | −40 to +70 °C |



Circuit diagram



Parts list

| | | |
|---|---|---|
| D1, D2, D3, D6, D15, D18, D19, D20, D25, D26, D27, D30, D39, D42, D43, D44 | diode | BAW62 |
| D4, D16, D28, D40 | stabistor | BZX75-C1V4 |
| D5, D17, D29, D41 | diode | BAV19 |
| D7, D14, D31, D38 | diode | BAX18 |
| D8, D9, D12, D13, D32, D33, D36, D37 | diode | BAV10 |
| D10, D11, D34, D35 | diode | BY206 |
| D23 | diode | BV126 |
| D21, D24 | stabistor | BZX79-C4V7 |
| D22 | voltage regulator diode | BZX61-C20 |
| D45 | voltage regulator diode | BZY88-C3V3 |
| D46 | voltage regulator diode | BZX79-C36 |
| TR1, TR2, TR13, TR14, TR21, TR22, TR33, TR34, TR36 | transistor | BC548 |
| TR3, TR12, TR23, TR32 | transistor | BSS38 |
| TR4, TR11, TR24, TR31 | transistor | BSX20 |
| TR5, TR10, TR17, TR18, TR25, TR30 | transistor | BSS68 |
| TR6, TR7, TR8, TR9, TR26, TR27, TR28, TR29 | transistor | BSW66 |
| TR15, TR16, TR19, TR20, TR35 | transistor | BC558 |
| U1 | integrated circuit | GFB7476D |
| U2 | integrated circuit | GFB7400D |
| U3 | integrated circuit | GFB7451D |
| C1, C2, C3, C4 | capacitor 4700 pF, 100 V | |
| C5 | capacitor 0,47 µF, 100 V | |
| C6 | capacitor 0,1 µF, 250 V | |
| C7 | capacitor 15 µF, 10 V | |
| C8 | capacitor 0,1 µF, 250 V | |
| C9, C10, C11, C12 | capacitor 4700 pF, 100 V | |
| R1, R31, R49, R79 | carbon resistor 15 kΩ, 5 %; 0,33 W | |
| R2, R29, R51, R78 | carbon resistor 4,7 kΩ, 5 %; 0,33 W | |
| R3, R23, R56, R76 | carbon resistor 390 Ω, 5 %; 0,33 W | |
| R4, R10, R15, R24, R30, R50, R57, R65, R70, R77 | carbon resistor 1 kΩ, 5 %; 0,33 W | |
| R5, R21, R60, R75 | carbon resistor 39 Ω, 5 %; 0,67 W | |
| R6, R18, R26, R53, R61, R73 | carbon resistor 560 Ω, 5 %; 0,33 W | |
| R7, R19, R62, R74 | carbon resistor 5,6 kΩ, 5 %; 1,15 W | |
| R8, R17, R63, R72, R81 | carbon resistor 560 Ω, 5 %; 0,33 W | |
| R9, R16, R64, R71 | carbon resistor 10 Ω, 5 %; 0,33 W | |
| R11, R12, R13, R14, R66, R67, R68, R69 | carbon resistor 680 kΩ, 5 %; 0,33 W | |
| R20, R59 | carbon resistor 3,9 Ω, 5 %; 0,5 W | |
| R22, R58 | carbon resistor 6,8 Ω, 5 %; 0,5 W | |

| | |
|---|---|
| R25, R55 | carbon resistor 10 Ω, 5 %; 0,5 W |
| R27, R54 | carbon pre-set potentiometer 220 Ω |
| R28, R52 | carbon resistor 39 kΩ, 5 %; 0,33 W |
| R32, R36, R38, R39, R41, R43, R45, R46 | |
| R83 | carbon resistor 10 kΩ, 5 %; 0,33 W |
| R33, R47 | metal film resistor 2,2 kΩ, 2 %; 0,4 W |
| R34, R48 | metal film resistor 6,8 kΩ, 2 %; 0,4 W |
| R35, R44 | carbon resistor 56 Ω, 5 %; 0,33 W |
| R37, R42 | carbon resistor 4,7 kΩ, 5 %; 0,33 W |
| R40, | wirewound resistor 2,2 kΩ, 5 %; 4,2 W |
| R80 | carbon resistor 33 kΩ, 5 %; 0,33 W |
| R82 | carbon resistor 100 Ω, 5 %; 0,33 W |
| R84 | carbon resistor 3,3 kΩ, 5 %; 0,33 W |

## ACCESSORIES

Power supply

A power supply unit designed for the BCCD unit is available under catalogue number 9904 132 02001.

Connector

The BCCD unit fits a printed-wiring connector F047 with 2 x 22 connections which is available in different versions.

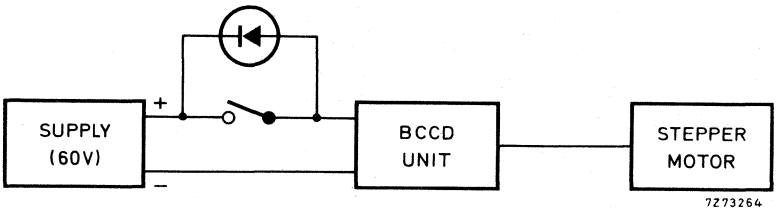
## PRECAUTIONS

To be considered when using a power supply which has not been specifically designed to accomodate the BCCD units.

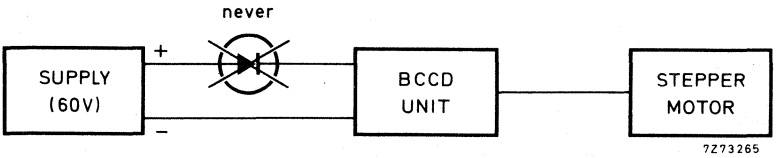
(a) Switching on
$V_L$ must always be switched on FIRST and then $V_D$, because the drive circuit will be damaged if the logic control levels are not available.

Switching off
For the same reason $V_L$ should not be switched off before $V_D$ has dropped below 30 V. This can be achieved by maintaining the logic supply voltage $V_L$ for a short period after the switch-off by means of electrolytic capacitors.

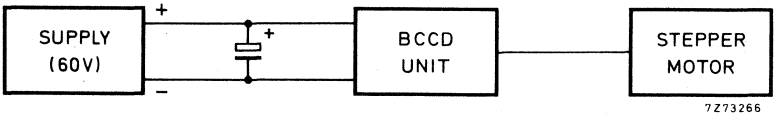
(b) When a bipolar stepper motor operates, magnetic (field) energy is stored in the motor coils. If the 60 V supply is suddenly interrupted, this energy will cause a high voltage peak which will damage some semiconductors in the BCCD unit.
To avoid this, a diode should be connected in parallel with the interruption switch.




(c) For the same reason, it is clear that a diode should not be connected in series with the 60 V supply line.
This method is commonly used as a safeguard against reverse connection of the supply, but here it would result in a damaged BCCD unit.




(d) When use is made of a 60 V stabilized (chopper) supply, an electrolytic capacitor of 1200 μF, 100 V must be connected between the positive and negative supply lines to provide the necessary feedback, thus avoiding damage to the BCCD unit.



# INTEGRATED CIRCUIT

## for driving 4-phase unipolar stepper motors

### APPLICATION

The integrated circuit SAA1027 changes a train of input pulses into a sequential pulse output which provides the required pulse pattern for driving 4-phase unipolar stepper motors.
The unit is intended to drive the following motors:

- 9904 112 04002 (ID 04-Series)
- 9904 112 05001 (ID 05-Series)
- 9904 112 06001 (ID 06-Series)
- 9904 112 07005 (ID 07-Series)
- 9904 112 08001 (ID 08-Series)

For detailed information on the SAA1027 see Data handbook "Semiconductors and integrated circuits", Part 5.

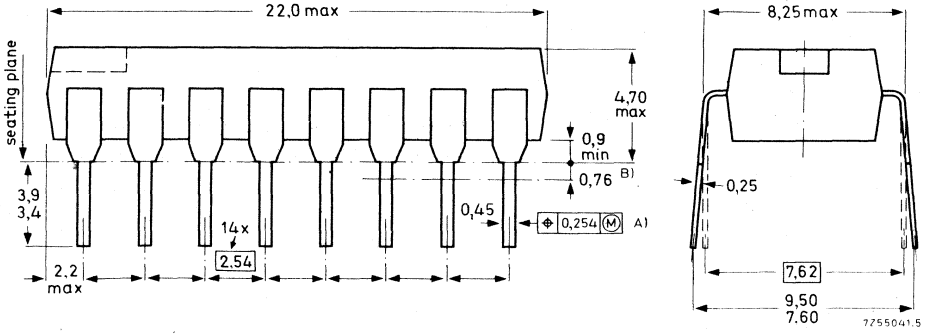
### DESCRIPTION

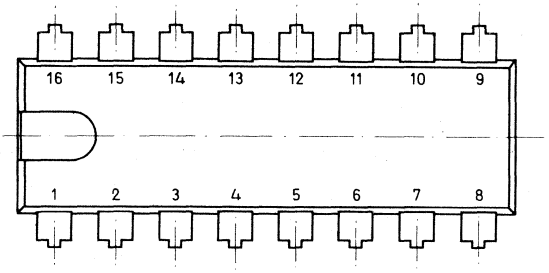
The circuit consists of three input stages, a logic part, and four output stages. The inputs are as follows:
- a trigger input which receives the order for the rotor to perform the step.
- an input which determines the direction of rotation by changing the d.c. level.
- a set input, being an option for setting the logic part at 'zero' before the trigger pulses are applied.

All three inputs are compatible with high noise immunity logic to ensure proper operation, even in noisy environments.
The four output stages can supply 350 mA each. Integrated diodes protect the outputs against transient spikes caused by switching the motor coils.

## MECHANICAL DATA

Dimensions (mm)




A) Centre-lines of all leads are within ± 0,127 mm of the nominal positions shown; in the worst case, the spacing between any two leads may deviate from nominal by ± 0,254 mm.

B) Lead spacing tolerances apply from seating plane to the line indicated.

Soldering

By hand

Apply the soldering iron below the seating plane (or not more than 2 mm above it). If its temperature is below 300 °C it must not be in contact for more than 10 seconds; if between 300 °C and 400 °C, for not more than 5 seconds.

By dip or wave

260 °C is the maximum allowable temperature of the solder; it must not be in contact with the joint for more than 5 seconds. The total contact time of successive solder waves must not exceed 5 seconds.
The device may be mounted up to the seating plane, but the temperature of the plastic body must not exceed the specified storage maximum. If the printed-wiring board has been pre-heated, forced cooling may be necessary immediately after soldering to keep the temperature within the allowable limit.

Repairing soldered joints

The same precautions and limits apply as for hand soldering.

Connections

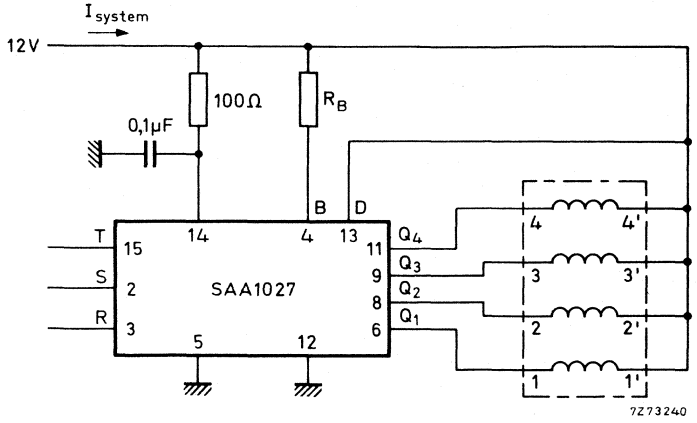



Fig. 2

| motor | $R_B$ | $I_{system}$ |
|---|---|---|
| 9904 112 04002 | 470 Ω, 0,33 W | 300 mA |
| 9904 112 05001 | 220 Ω, 0,67 W | 620 mA |
| 9904 112 06001 | 220 Ω, 0,67 W | 620 mA |
| 9904 112 07005 | 620 Ω, 0,33 W | 200 mA |
| 9904 112 08001 | 220 Ω, 0,67 W | 620 mA |

## ELECTRICAL DATA

Input data

Direction of rotation (pin 3)

| | |
|---|---|
| $V_R$, HIGH (counter-clockwise) | 7,5 to 12 V |
| LOW (clockwise) | 0 to 4,5 V |
| $I_R$, at $V_R$ HIGH | typ. 1 μA |
| $-I_R$, at $V_R$ LOW | typ. 30 μA |

Stepping (pin 15)

| | |
|---|---|
| $V_T$, HIGH | 7,5 to 12 V |
| LOW | 0 to 4,5 V |
| $I_T$, at $V_T$ HIGH | typ. 1 μA |
| $-I_T$, at $V_T$ LOW | typ. 30 μA |

Note: Triggering occurs when T goes from LOW to HIGH.

Set control (pin 2)

| | |
|---|---|
| $V_S$, HIGH | 7,5 to 12 V |
| LOW | 0 to 4,5 V |
| $I_S$ , at $V_S$ HIGH | typ. 1 μA |
| $-I_S$ , at $V_S$ LOW | typ. 30 μA |

Note: When T is HIGH and S is LOW the outputs are: $Q_1$ = LOW, $Q_2$ = HIGH, $Q_3$ = LOW, $Q_4$ = HIGH.

Ambient temperature range

Operating: minimum −20 °C

maximum see Table below

Storage : minimum −40 °C

maximum + 125 °C

Remarks

Four integrated diodes dissipate the energy stored in the motor coils when the outputs Q are being switched.

- The common line of these clamping diodes (pin 13) must therefore have the shortest connection to the common line of the motor windings. Due to this effect, the temperature rise of the IC increases with the increase of the stepping rate of the stepper motor. This reduces the max. permissible ambient temperature in which the IC can operate. To overcome this phenomena, external diodes e.g. BAX12, accross the motor windings are recommended (see Fig. 3 and Table).
- To achieve maximum noise immunity, unused inputs must not be left floating, but should be connected to the voltage level appropriate to the required function.
- When both the IC and the motor are connected to the same supply, a simple RC network must be used in the supply line of the logic part to prevent the logic sequence from being discontinued by transient spikes, caused by the switching of the motor coils. This network is depicted in Fig. 2 (and Fig. 3). The capacitor should be connected as close as possible to pin 14 and 5 (or 12).

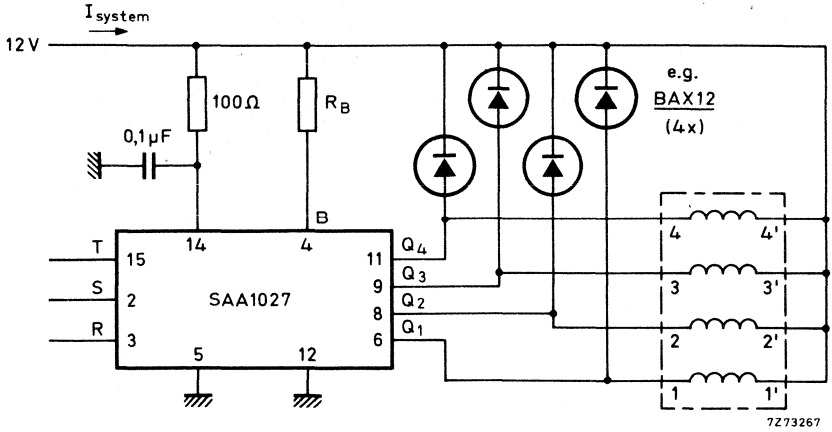



Fig. 3

Table of maximum permissible ambient temperatures.

| motor | without external diodes (°C) | with external diodes (°C) |
|---|---|---|
| 9904 112 04002 | 65 | 90 |
| 9904 112 05001 | 25 | 65 |
| 9904 112 06001 | 25 | 65 |
| 9904 112 07005 | 80 | 100 |
| 9904 112 08001 | 30 | 65 |

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