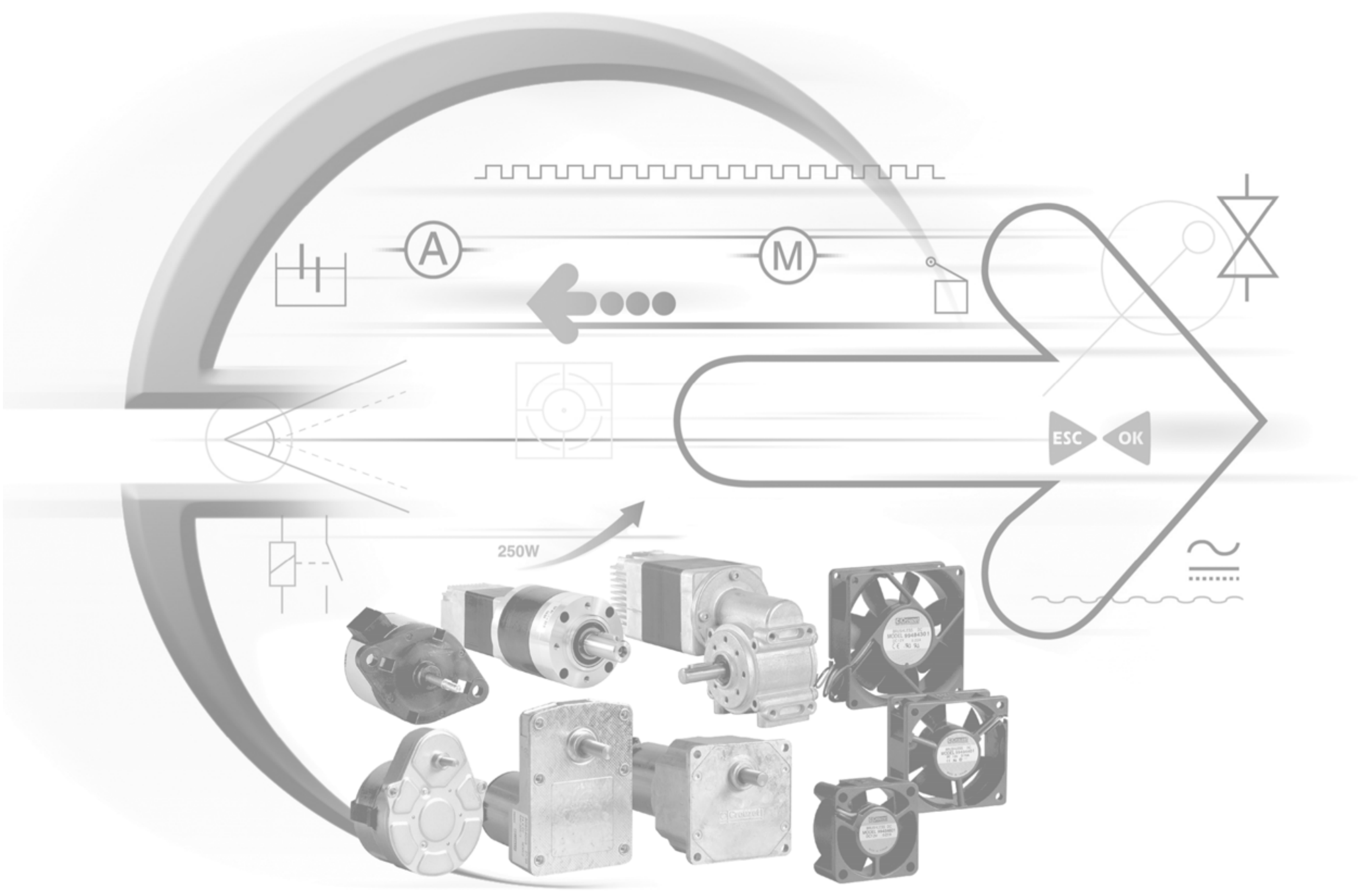


4

Crouzet Motor

Technology Guides

DC motor technology guide

1 - Why choose a DC motor?

Many applications call for a high start-up torque. The DC motor, by its very nature, has a high torque vs. falling speed characteristic and this enables it to deal with high starting torques and to absorb sudden rises in load easily. The speed of the motor adjusts to the load. Furthermore, the DC motor is an ideal way of achieving the miniaturization designers are constantly seeking because the efficiency it gives is high compared with other designs.

2 - Design of Crouzet DC motors

2.1 Safety

Crouzet DC motors are designed and manufactured for integration into equipment or machines which meet, for example, the requirements of the machinery standard :
EN 60335-1 (IEC 335-1, "Safety of domestic electrical appliances").
Integration of Crouzet DC motors into equipment or machines should, as a rule, take the following motor characteristics into account :

- no ground connection
- so-called "principal insulation" motors (single insulation)

- protection index : IP00 to IP40
- insulation classes : A to F

} (see the catalogue page details for individual motor types)

EC LOW VOLTAGE DIRECTIVE 73/23/EEC OF 19/02/73 :
Crouzet DC motors and geared motors are not covered by this directive (LVD 73/23/EEC applies to voltages greater than 75 VDC).

2.2 Electromagnetic compatibility (EMC)

Crouzet Ltd can provide the EMC characteristics of the various types of product on request.

EC DIRECTIVE 89/336/EEC OF 03/05/89, "ELECTROMAGNETIC COMPATIBILITY" :
DC motors and geared motors are considered as components meant for integration into other equipment and therefore fall outside its field of application. However, these products are designed in compliance with EMC characteristics and consequently can be incorporated in equipment having to comply with the EMC directive.

3 - How to select from the Crouzet range

The motor unit is selected according to the required output power.

Depending on the required speed, a direct motor or a geared motor is selected.

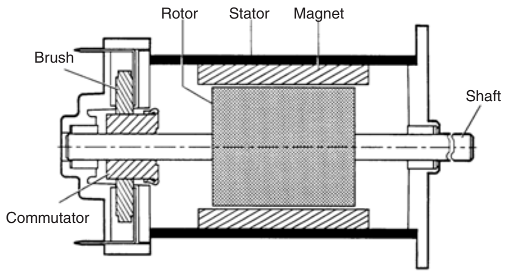
Speeds 1,000 to 5,000 rpm ➔ Direct motor
Speeds below 500 rpm ➔ Geared motor

The gearbox is selected depending on the maximum required torque and the duty cycle.

4 - Definition of the DC motor

This motor follows linear laws of operation and because of this it is easier to fully exploit its characteristics compared to synchronous or asynchronous motors.

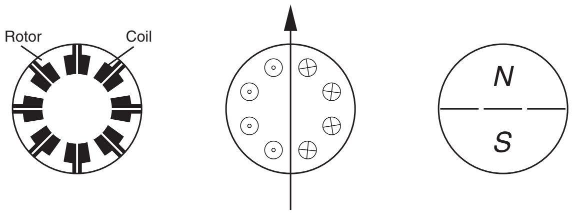
Composition of a DC motor



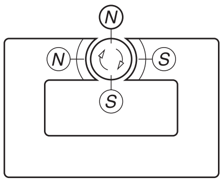
The stator is formed by a metal carcass and one or more magnets that create a permanent magnetic field inside the stator. At the rear of the stator are the brush mountings and the brush gear which provide electrical contact with the rotor.
The rotor is itself formed by a metal carcass carrying coils which are interconnected at the commutator at the rear of the rotor.
The commutator and brush assembly then select the coil through which the electric current passes in the opposite direction.

Principle of operation

Whatever the complexity of the rotor coil windings, once they are energized, they may be represented in the form of a ferromagnetic cylinder with a solenoid wrapped around it.
The wire of the solenoid is in practice the wire bundle located in each groove of the rotor. The rotor, when energized, then acts as an electromagnet, the magnetic field following the axis separating the wires of the solenoid in the direction of the current which flows through them.



The motor, therefore, consists of fixed permanent magnets (the stator) a moving magnet (the rotor) and a metal carcass to concentrate the flux (the motor body).



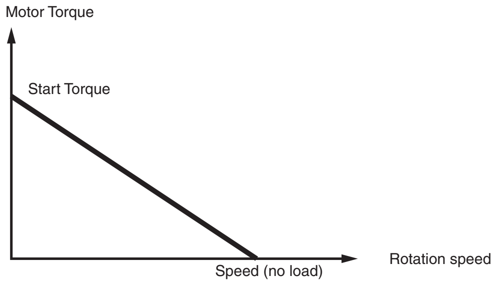
By the attraction of opposite poles and repulsion of like poles, a torque then acts on the rotor and makes it turn. This torque is at a maximum when the axis between the poles of the rotor is perpendicular to the axis of the poles of the stator.
As soon the rotor begins to turn, the fixed brushes make and break contact with the rotating commutator segments in turn.
The rotor coils are then energized and de-energized in such a way that as the rotor turns, the axis of a new pole of the rotor is always perpendicular to that of the stator. Because of the way the commutator is arranged, the rotor is in constant motion, no matter what its position.
Fluctuation of the resultant torque is reduced by increasing the number of commutator segments, thereby giving smoother rotation.
By reversing the power supply to the motor, the current in the rotor coils, and therefore the north and south poles, is reversed. The torque which acts on the rotor is thus reversed and the motor changes its direction of rotation. By its very nature, the DC motor is a motor with a reversible direction of rotation.

DC motor technology guide

Torque and speed of rotation

The torque generated by the motor, and its speed of rotation, are dependent on each other.

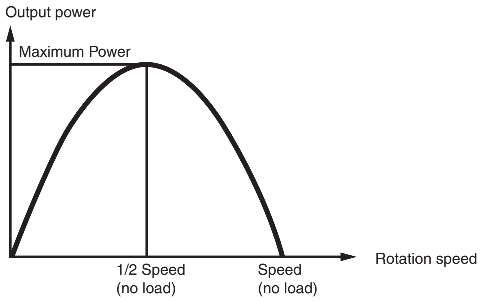
This is a basic characteristic of the motor ; it is a linear relationship and is used to calculate the no-load speed and the start-up torque of the motor.



The curve for the output power of the motor is deduced from the graph of torque versus speed.

$$Pu(W) = \frac{2p}{60} \times C\ (N.m) \times N\ (rpm)$$

Output power	Motor torque	Speed of rotation



The torque vs. speed and output power curves depend on the supply voltage to the motor.
The supply voltage to the motor assumes continuous running of the motor at an ambient temperature of 20˚C in nominal operational conditions.

It is possible to supply the motor with a different voltage (normally between -50% and + 100% of the recommended supply voltage).
If a lower voltage is used compared to the recommended supply the motor will be less powerful.
If a higher voltage is used, the motor will have a higher output power but will run hotter (intermittent operation is recommended).

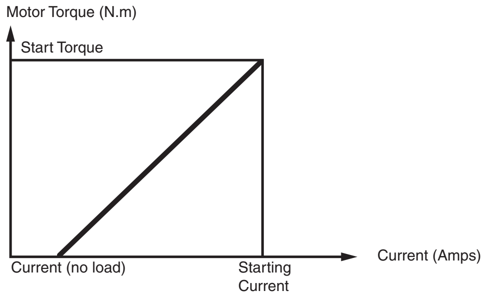
For variations in supply voltage between approximately - 25% to + 50%, the new torque vs. speed graph will remain parallel to the previous one. Its start-up torque and no-load speed will vary by the same percentage (n%) as the variation in supply voltage. The maximum output power is multiplied by $(1 + n\%)^2$.

Example : For a 20% increase in supply voltage

➤ Start-up torque increases by 20% (x 1.2)
➤ No-load speed increases by 20% (x 1.2)
➤ Output power increases by 44% (x 1.44)

Torque and supply current

This is the second important characteristic of a DC motor.
It is linear and is used to calculate the no-load current and the current with the rotor stationary (start-up current).



The graph for this relationship does not vary with the supply voltage of the motor. The end of the curve is extended in accordance with the torque and the start-up current.
The gradient of this curve is called the "torque constant" of the motor.

$$Kc = \frac{Cd}{Id\text{-}Io}$$

This torque constant is such that :

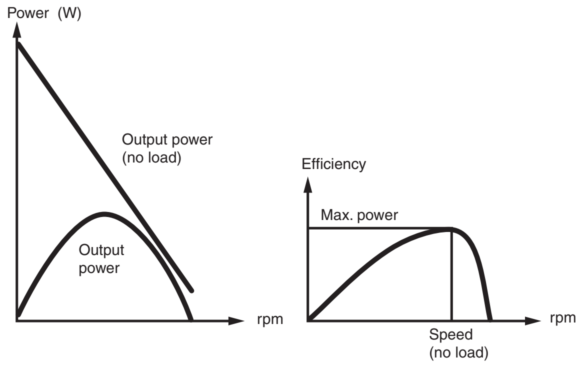
$$C = Kc\ (I - Io)$$

The "rotational friction torque" is Kc Io.
The torque is therefore expressed as follows :

$$C = Kc\ \ I - Cf \quad \text{with} \quad Cf = Kc\ Io$$

Kc = Torque constant (Nm/A)
C = Torque (Nm)
Cd = Start-up Torque (Nm)
Cf = Rotational friction torque (Nm)
I = Current (A)
Io = No-load current (A)
Id = Start-up current (A)

The graph of torque vs. current and torque vs. speed is used to determine the absorbed power as a function of the speed of rotation of the motor.



Efficiency

The efficiency of a motor is equal to the mechanical output power that it can deliver, divided by the power which it absorbs.
The output power and the absorbed power vary in relation to the speed of rotation, therefore the efficiency is also a function of the speed of the motor.
Maximum efficiency is obtained with a given rotational speed greater than 50% of no-load speed.

Temperature rise

The temperature rise of a motor is due to the difference between the absorbed power and the output power of the motor. This difference is the power loss.
Temperature rise is also related to the fact that power loss, in the form of heat from the motor, is not rapidly absorbed by the ambient air (thermal resistance). The thermal resistance of the motor can be greatly reduced by ventilation.

Important

The nominal operating characteristics correspond to the voltage-torque-speed characteristics required for continuous operation at an ambient temperature of 20˚ C. Only intermittent duty is possible outside these operating conditions : without exception, all checks concerning extreme operating conditions must be performed in the actual customer application conditions in order to ensure safe operation.

5 - Motor and gearbox combinations

DC motors are constructed to operate continuously within a range of speeds near their no-load speed. This range of speeds is generally too high for most applications. In order to reduce this speed, a full range of geared motors is available, each with a series of gear ratios to suit most speed requirements.
The complete range is suitable for a wide variety of applications.

Gearbox characteristics

Our gearboxes have been designed for optimum performance and for maximum life under normal operating conditions.

Their main characteristic is the capacity to withstand **maximum design torque with continuous duty**.

The range of gearboxes shown in this catalogue can operate with maximum torque of **0.5 to 6 N.m** for long time periods. All values previously stated are for standard products in normal operating conditions, as specified.

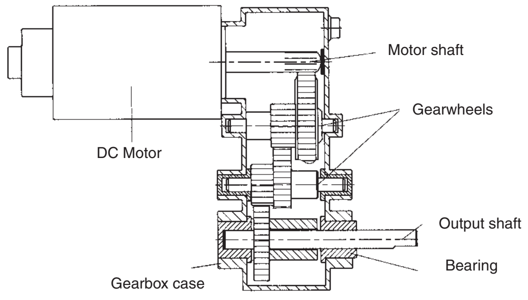
In certain cases, these values may be increased if a shorter life is required.

Please consult our Sales Office for further information.

Every gearbox has a torque limit, which is
the breaking torque

If this torque is applied to the gearbox, it will cause severe damage.

Gearbox construction



Selection of a geared motor

A geared motor is selected according to the required usable power output.

$$P_{usable} = \frac{2\pi}{60} . C . n$$

W Nm rpm

A geared motor must have usable power equal to or greater than the power required to rotate the load. It is selected by checking that the point corresponding to the required operating conditions (torque and speed output) is higher than the nominal torque versus speed curve of the geared motor.
The required torque output of a geared motor must be within its maximum recommended torque for continuous duty.

Selecting the reduction gear ratio

Two selection criteria may be applied.

- The first criterion concerns the required speed output of the reduction gear only. It is adequate for most applications and is easy to apply. Given that :

$$R = \frac{N1}{Nb}$$

N1 = required speed of geared motor
Nb = basic nominal speed of motor

- The second criterion concerns the required usable power output of the motor. The rotational speed of the motor is given by :

$$N = 1/2\left(No + \sqrt{No^2 - \frac{4P}{A}}\right) \text{ with } A = \frac{\pi Cd}{30No}$$

N = speed of motor (rpm)
No = no-load speed of motor (rpm)
P = required output power (W)
Cd = start-up torque of motor (Nm)

This gives the equation : $R = \frac{N1}{N}$

In order to avoid using numbers less than 1 where the reduction ratio is concerned, the value 1/R is employed.
Due to the fact that it is always a reduction gear and not a "multiplier" gear, there should be no ambiguity concerning the number used.

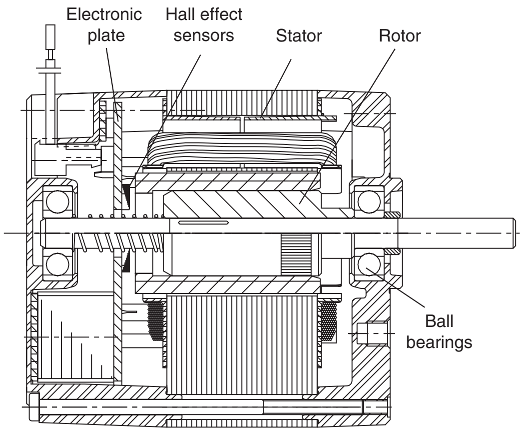
$$1/R = \frac{Nb}{N1} \text{ or } 1/R = \frac{N}{N1}$$

Brushless DC motors and Motomate technology guide

Principle

1.1.Composition of the driving part:

Brushless motors comprise 3 main elements:



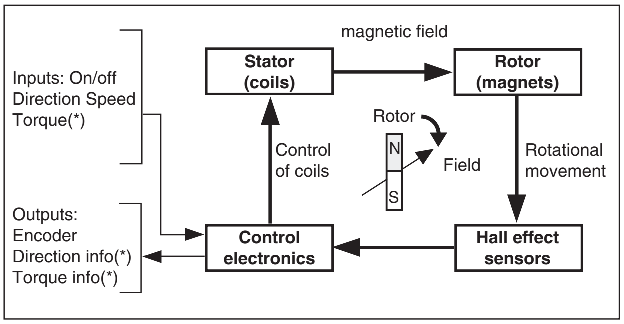
- A fixed part, the stator, which has three groups of coils, called the three phases of the motor. These coils operate as electromagnets and generate various orientations of magnetic field regularly distributed around the central shaft of the motor.

- A rotating part, the rotor, which has permanent magnets. Like the needle of a compass, these magnets permanently drive the rotor to try to align itself with the magnetic field of the stator. For optimum service life of the motor, the rotor is mounted on ball bearings.

- Three "Hall effect" magnetic sensors. These sensors provide information on the position of the rotor magnets at all times.

1.2. The integrated control electronics:

Crouzet brushless motors incorporate their control electronics as standard. The control electronics control the phases of the motor, regulate the speed and incorporate the encoder function.



- The control electronics determine the position of the rotor using the Hall effect sensors.The electronics deduce from the sensors the orientation to give to the magnetic field of the stator. During rotation, they control the three coils to regularly adjust the orientation of the field to the position of the rotor, in order to drive it in the direction chosen by the user.

- By modulating the current in the coils, the electronics can accelerate or slow down the motor and thus regulate its speed.They can also orientate the magnetic field in order to brake the movement of the rotor to bring it to a standstill.

- By limiting the current in the coils, the electronics can also limit the torque of the motor, and activate the corresponding output.

- The electronics also generate the outputs of the built-in encoder using the Hall effect sensors.

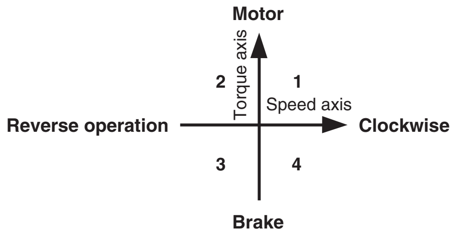
Speed regulation

2.1.What is 4-quadrant regulation?

The four zones of a torque/speed diagram are known as ‘quadrants’:

- A positive speed represents clockwise rotation, and a negative speed counter-clockwise

- A positive torque represents motor operation, and a negative torque brake operation.



1-quadrant regulation operates in a single direction of rotation, with no possibility of braking. In the event of overspeed, the regulator cuts off the current until the motor is braked by the load.

The principle is identical for 2-quadrant regulation, but in both directions of rotation.This operating mode is offered as an option on Crouzet brushless motors, when required by a specific application.

4-quadrant regulation also operates in both directions of rotation, but also allows braking. In the event of overspeed, the motor is involved in the braking and the system quickly loses speed.

All Crouzet brushless motors have 4-quadrant regulation as standard.

2.2. Braking:

Braking means absorbing the energy of the mechanical system.There are several different types of braking, depending on the use made of this absorbed energy:

Regenerative braking converts the energy of the system into electrical current, which will be directed to the motor power supply. Apart from batteries, most commercially available power supplies do not accept this type of current feedback (they are known as ‘non-reversible’). It is therefore necessary to ensure that the directed current can be consumed by another device, without which the power supply may be damaged.This braking mode is offered as an option on Crouzet brushless motors, but must be used with caution.

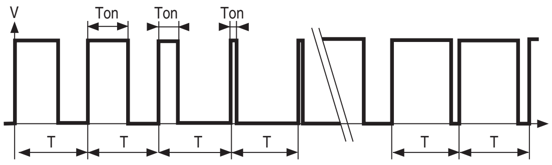
Crouzet brushless motors have braking ‘without energy rejection’ as standard. This means that on braking the kinetic energy of the system is converted into heat inside the motor itself, with no feedback to the power supply.This is the most suitable type of braking for most applications.

However, if there is prolonged braking, the heat that is generated may trip the thermal protection of the motor. For high inertia applications, or operation as a generator, PLEASE CONSULT CROUZET. Depending on the circumstances, our specialists will advise you to select either 2-quadrant regulation, or braking with energy rejection.

2.3. Control by PWM

PWM (Pulse Width Modulation) control is a method of indicating the speed setpoint to the motor. A PWM control motor should be chosen in the following cases:

- Control by CROUZET Millenium II logic controllers (see MOTOMATE information)
- Control by PLC with PWM outputs
- Control by digital control system



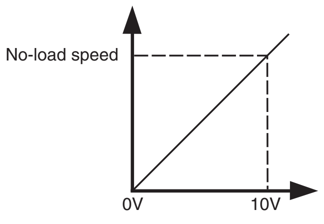
PWM control consists of pulse trains of fixed frequency (Period "T") but variable width ("Ton" period of the pulse). The speed setpoint depends on the Ton/T ratio. However it is independent of the voltage or frequency of the pulses, within the limits of the stated specifications.

Ton/T = 0%	Speed setpoint = 0
Ton/T = 100%	Speed setpoint = No-load speed of the motor
Ton/T = 50%	Speed setpoint = No-load speed of the motor/2

2.4. Control by 0-10V

0-10V voltage control is the other method of indicating the speed setpoint to the motor. A 0-10V input motor should be chosen in the following cases:

- Control by potentiometer
- Control by PLC with analogue converter outputs
- Control by analogue control system



In this type of control, the speed setpoint depends on the voltage U at the speed setpoint input:

U = 0	Speed setpoint = 0
U = 10V	Speed setpoint = No-load speed of the motor
U = 5V	Speed setpoint = No-load speed of the motor/2

Torque limiting (*)

3.1. Operation

Torque limiting is used to deliberately check the motor at certain moments in the operation of a system:

- If there is a risk of encountering an end stop or jamming, to prevent damage to the system

- To maintain a force when the system is at an end stop

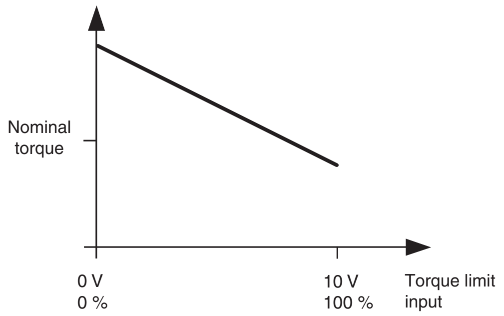
- To control the tension of an element located between two moving motor

3.2. Torque limiting input (*)

This input can be controlled in 0-10V and in PWM, whatever type of speed control is selected (Input impedance 16 k ohms. Minimum PWM voltage 12 volts.)
Frequency range 150 Hz - 1 kHz

- When the input is at 0 or not connected, the motor delivers up to 140% of its nominal torque

- When the input is at maximum (100% PWM or 10V), the motor delivers around 30% of its nominal torque



When the torque limit is reached, the motor does not follow its speed setpoint, but maintains a constant torque equal to this limit, as long as its speed remains below the setpoint.

3.3. Limit reached alert output (*)

This output is at logic state 1 when the torque limit is reached.
IMPORTANT:This output is PNP type.Consult the wiring diagrams and the precautions for use of this output in the motor specifications.

Built-in protection

4.1. 30 watt motors

If the motor locks when it is controlled, a protection system cuts off the power after a few seconds.
The motor can only restart when the On input changes to 0 then 1.

4.2. 80 watt motors

A temperature sensor incorporated in the motor switches the motor to safety mode when the temperature exceeds a value which may damage it. When the trigger temperature is reached, the power is cut off, which causes the motor to stop.
It can only restart when the temperature has fallen below the restart temperature and the On input has changed to 0 then 1.

Direction and on/off controls

Input logic table

On	Direction	Speed	Action
0	X	X	Braking and stop
1	X	0	Braking and stop
1	1	V	Clockwise direction at speed V
1	0	V	Anti-clockwise direction at speed V

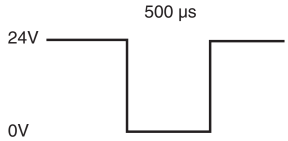
On and Direction inputs:
- Input impedance: 60 Ω
- Logic state 0: < 2V
- Logic state 1: > 4V

Built-in encoder

The built-in encoder supplies fixed width pulses each time a Hall effect sensor switches. These pulses can be counted to ascertain the speed and position of the motor, or filtered to obtain an analogue signal proportional to the speed.

The additional direction of rotation (*) output is used to determine the direction of count of the pulses.

IMPORTANT: These outputs are NPN or PNP type depending on the version. Consult the wiring diagrams and the precautions for use ofthese outputs in the motor specifications.



Safety

Crouzet BRUSHLESS DC motors are designed and manufactured to be integrated into appliances or machines which meet, for example, the specifications of the machine standard: EN 60335-1 (IEC 335-1, “Safety of household and similar electrical appliances”). The integration of Crouzet DC motors into appliances or machines should generally take account of the following motor characteristics:

- no earth connection
- “simple isolation” motors
- protection index: IP54
- insulation system class: B (120 ˚C)
- Vibration: EN 60068.2.6:5G from 55 Hz to 500 Hz/0.35 mm peak to peak from 10 Hz to 55 Hz
- Shock: IEC 60068.2.27: 1/2 sine 50G for 11 ms

European low voltage directive 73/23/EEC of 19/02/73:
Crouzet DC motors and geared motors are outside the scope of this directive (LVD 73/23/EEC applies to voltages over 75 volts DC).

IMPORTANT

• Product operation:

To ensure correct operation of Brushless actuators, it is advisable to take account of all the necessary installation and wiring precautions.

• Product characteristics:

The stated nominal operating characteristics correspond to the voltage-torque-speed characteristics which permit continuous operation, at an ambient temperature of 40 ˚C. Above these operating conditions, only intermittent duty cycles will be possible: without exception, where extreme conditions prevail, all checks should be performed by the customer in the real-life context of the application to ensure safe operation.
->For operation in non-nominal conditions, please consult us

• Product usage:

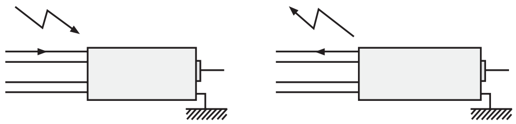
If these products are being used in very specific operating conditions:

- food and beverage (eg:non-continuous, rectified)
- ambient atmosphere (extreme temperatures and vibrations, significant relative humidity, explosive or confined atmosphere, etc)
->other (use as load, sudden stalling, severe operating cycle,etc), please consult us.

EMC Compatibility

On request, Crouzet will provide the EMC characteristics of the various types of product.
European directive 89/336/EEC of 03/05/89, “electromagnetic compatibility”:
DC motors and geared motors which are components designed for professionals to be incorporated in more complex devices, and not for endusers, are excluded from the scope of this directive.
However, conscious of the potential customer difficulties concerning problems connected with electromagnetic compatibility, Crouzet has designed its products to meet the requirements of the standards: for example EN 55011 Gr.1 class B (medical) and also EN 55022, class B (data processing) in terms of emitted electromagnetic interference, in addition to standards connected with immunity:
IEC 1000- 4 -2/3/4/5/6/8

• Wiring precautions



For EMC conformity:

- The motor should be connected to earth via its front flange.
- The length of the wires is 0.5 m max.(*) Note: Functions marked with an asterisk are only available on the 80 watt versions. If they are required on 30 watt motors, please consult Crouzet.

• Electromagnetic compatibility:

Emission

• Conducted emissions:	EN 55022/11G1 class B
• Radiated emissions:	EN 55022/11G1 class B

Immunity

• Electrostatic discharges:	EN 61000-4-2 Level 3
• Electromagnetic fields:	EN 61000-4-3 level 3
• Pulse trains:	EN 61000-4-4 level 3
• Shock waves:	EN 61000-4-5 level 2
• Radio frequency:	EN 61000-4-6 level 3
• Magnetic field:	EN 61000-4-8 level 4
• Voltage dips:	EN 61000-4-29

(*) Note: Functions marked with an asterisk are only available on the 80 watt versions. If they are required on 30 watt motors, please consult Crouzet

Synchronous motor technology guide

1 - Why choose a synchronous motor?

To produce a certain number of movements within a well defined time period - in this case, the motor is used as a time base.
To produce a rotation movement requiring relatively low torque at reasonable cost.

2 - How to select from the Crouzet range

The Crouzet synchronous range consists of the following motor types :

1 Single direction

Either :
- clockwise (CW or SA)
- or counter-clockwise (ACL or SI)

(We will see below how to ensure the correct direction of rotation).
In special applications it is possible to dispense with the anti-return totally (SAR version). In this case, the motor may rotate in a clockwise direction.

2 Reversible

The motor rotates in either a clockwise or an counter-clockwise direction. The direction of rotation is controlled by a capacitor.

3 - Definition of a synchronous motor

This motor is characterised by a constant speed of rotation which is independent of the load but linked to the supply frequency.

A synchronous motor maintains its speed of rotation until an overload occurs.

When overload occurs, the motor loses synchronisation, ie. it stops and develops an oscillation (vibration).

Speed of rotation

This basic characteristic can be calculated as below :

$$\text{Speed (in rpm)} = \frac{60 \times f\,(\text{en Hz})}{P}$$

f Hz : The frequency of the AC voltage through the coil.

P : The number of pole pairs in the motor
(1 pair = 1 North Pole + 1 South Pole).

Therefore the speed of rotation of a synchronous motor is defined by its construction.

Example :

A motor equipped with 5 pole pairs would give :

$$V = \frac{60 \times 50}{5} = 600 \text{ rpm using a 50 Hz supply}$$

and

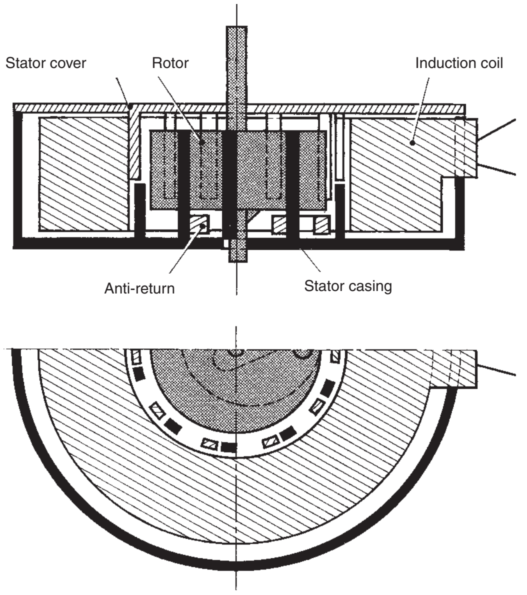
$$V = \frac{60 \times 60}{5} = 720 \text{ rpm using US supply (60 Hz)}$$

Construction of a permanent magnet synchronous motor

Single direction

Technology

Casing poles S.N.S.N.S.N



Cover poles N.S.N.S.N.S

Our single direction motors are only available with a mechanical anti-return. This assembly offers the double advantage of being a relatively simple technical design while offering good performance.

The permanent magnet rotor has at its periphery a number of alternating NORTH and SOUTH poles equal to the number of poles on the stator. The latter, energized by a single coil connected to an AC supply, produces a magnetic asymmetry which positions the rotor when stopped in such a way that it is attracted by an oscillating torque when the current is switched on.

This start-up condition would cause the motor to turn in either direction if a mechanical device called an "anti-return" did not define and impose the direction of rotation.

Principle of operation

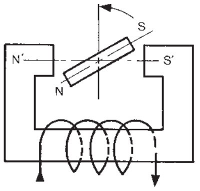


Figure 1

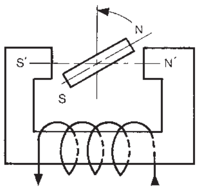


Figure 2

The principle assumes an electro-magnet : a permanent NS magnet rotates around axis O in the air-gap of the electro-magnet, perpendicular to the lines of magnetic force.

Let us suppose that this moving permanent magnet reaches the position marked in figure 1. If the relative positions of the electro-magnet poles are as shown in this figure, the magnet will be repelled and tend to oscillate around an equilibrium position at 180˚ to direction S'N'.

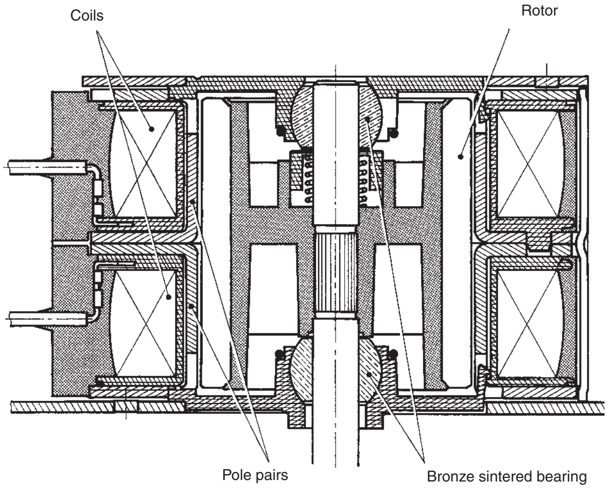
When the permanent magnet is just past this position (figure 2) and the polarity of the electro-magnet is reversed, the magnet will be repelled and return to its previous position, and so on.

By energizing the electro-magnet with an AC current of frequency f, the magnet will turn at a speed of f revolutions per second.

In these circumstances, a motor can start up in either direction. To determine a particular direction, a mechanical device (anti-return) is placed on the rotor to ensure that the motor operates only in the direction required. There are several types of anti-return device which are differentiated by the degree of the reverse rotation angle within which the rotor can move.

Reversible
(Also called reversible synchronous motors)

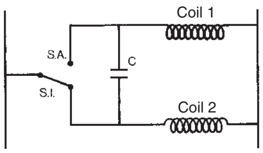
Technology



Synchronous motors with a single-phase AC voltage and a permanent magnet must have, for reverse operation, at least 2 stators and 2 coils. Reverse operation can be achieved electrically using a single-pole switch.

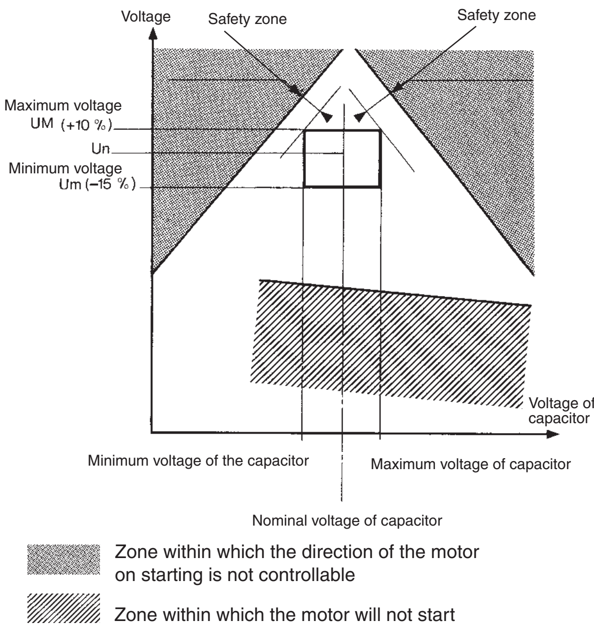
A capacitor is used on reversible synchronous motors with 2 coils to produce an electrical dephasing of 90˚ between the 2 coils. This creates a circular revolving magnetic field. Component precision assures a perfectly circular field and ensures silent motor operation.

Wiring diagram for capacitor



The capacitor specification must be appropriate to each type of motor and to the supply voltage. An incorrect capacitor may distort the magnetic field and have detrimental effects on the reliability of the start-up of the motor as well as on operational quality.

The curve (motor reversing curve) below shows the limits within which the motor will always start in relation to variation in supply voltage and the capacitor values.



The zone within which the motor operates, ie. the area around the nominal voltage of the capacitor, must be completely controlled by the manufacturer.

Operating within this zone guarantees starting and operating in the direction selected by the user.

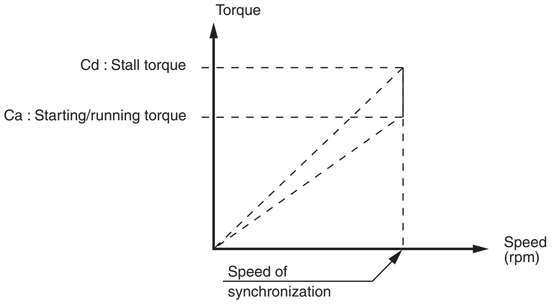
As the diagram shows, we build our motors so that the operating zone is as far as possible from the critical zones, whatever the nature of the torque.

Boosted winding

Our experience in this area allows us, in certain cases and depending on the precise specification, to operate outside this zone to produce a higher torque and increase performance by between 30 and 80%. Please consult us.

Motor torque

2 types of torque can be distinguished.



Starting/running torque (or synchronization torque)

This is the torque that a synchronous motor can develop both at start-up and at synchronization speed.

N.B :
In all technical data concerning geared motors in this catalogue, the torque/speed curves indicate the value of the starting/running torque for all the gearbox output speeds.

Stall torque (or desynchronization torque)

This is the torque limit at which a synchronous motor loses its synchronization.

4 - Motor and gearbox combination

The motor output shaft turns at a defined speed as in paragraph 3.1. This speed is generally too high for the majority of applications.

To reduce this speed we provide users with a complete range of gearboxes, each equipped with a series of ratios.

As a result, the motors can be used for numerous functions.

Gearbox characteristics

Each gearbox has been designed for a certain workload. We have defined its potential and its limits for optimum mechanical life.

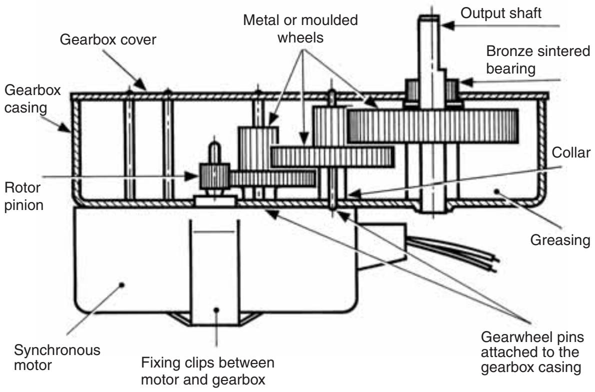
The principal characteristic is its capacity to absorb a maximum torque in continuous operation.

The range of gearboxes in this catalogue can be used for maximum torques of between 0.5 and 6 N.m for long mechanical lives. The values given are for standard products used in the normal operating conditions specified.

In certain cases, these values can be increased if the required life is reduced. Special cases are dealt with by our design staff.
Each gearbox nevertheless has a limit which is the Breakdown torque

This torque, applied to the gearbox, can cause its destruction when first used.

Gearbox construction



Selecting a geared motor

Selection is made in relation to the prospective workload.

Before making a selection, it should be remembered that the motor absorbs a certain amount of power, the absorbed power and it cannot deliver more than a fraction of this power : the maximum is defined as the usable power or the mechanical power.

Usable power links 2 factors.

torque and speed

$$P = C \times \omega$$

Usable power expressed in Watts	Maximum torque expressed in N.m	Angular speed of the output shaft expressed in radians per second

Analysis of this formula clearly shows the function of the gearbox.

It reduces speed and increases torque since the usable power produced by the motor is recovered by the gearbox (within the limits of normal efficiency of course).

The torque requirement thus serves to define the gearbox (characterised by its maximum torque) and the choice of motor depends on the speed at which the torque is required.

The usable power should be borne in mind in all cases, as it is the basic parameter when choosing a motor.

5 - Additional information

Temperature rise

Permanent magnet motors generally have relatively low efficiency and some of the lost energy is converted into a rise in the temperature of the motor.

We consider that this rise in temperature reaches its maximum level after 2 hours of continuous operation.

To calculate the rise, we use the method known as resistance variation.

$$\Delta T = \frac{\Delta R}{R}(234.5 + Ta) - (T1 - Ta)$$

R = Coil resistance at ambient temperature before applying voltage to the motor (expressed in Ohms - Ω).

R' = Resistance of the same coil after 2 hours of continuous motor operation.

ΔR = R' - R = Increase in coil resistance.

T1 = Ambient temperature at the end of the test (in degrees KELVIN).

Ta = Ambient temperature at the beginning of the test.

Dielectric strength

All our products are tested to current standards.

Insulation resistance

This is greater than or equal to 75,000MΩ measured using a 500 VDC current in conditions of ambient temperature and humidity.

Safety

Crouzet synchronous motors are designed and manufactured for integration into equipment or machines meeting, for example, the requirements of the Machinery standard : EN 60335-1 (IEC 335-1) : Safety of domestic electrical appliances.
Integration of Crouzet synchronous motors into appliances or machines should, as a rule, take into account the following motor characteristics :
- no earth connection,
- so-called "principal insulation" motors (single insulation)
- protection index : IP40
- insulation class : B.

6 - Standards and approvals

Our motors are in general designed to conform to international recommendations (IEC), American standards (UL - CSA) and/or European standards (EN).

Proof of compliance with these standards and recommendations is demonstrated by an approval (a mark or certificate of conformity granted by an accredited body) or the manufacturer's declaration of conformity (drafted in accordance with ISO/IEC 22 guidelines).

7 - Rules and regulations

EC directives

Our motors are compatible with European Community directives (Low voltage 73/23 > 50 VAC) and in particular the aspects of electrical safety referred to in the above standard EN 60335 (domestic electrical appliances).

The "CE" mark on all our products is proof of this conformity.

Moreover, our products are particularly suited, for example, to applications concerning both office equipment and medical equipment covered by standards EN 60601 and EN 60950 respectively.

Environmental protection

The modern concept of protection of the environment is an integral part of our motors, from product design through to packaging.

8 - Electromagnetic compatibility

(EC Directive 89/336/EEC dated 03/05/89)

Both asynchronous and synchronous motors and geared motors designed for integration into more complex equipment by professionals, rather than end users, are excluded from the areas of application of this directive.

Crouzet will however be pleased to provide the EMC characteristics of its products on request.

Stepper motor technology guide

It is useful to examine the principal characteristics of stepper motors and evaluate their advantages

Characteristics	Advantages
No brushes	No wear, therefore long operating life
Open loop operation	No need for encoder or emulator (cost reduction)
Several step angles available	Provides optimum characteristics for the resolution of speed/load.
Direct motor drive from a digital signal	Easy integration into a complex system

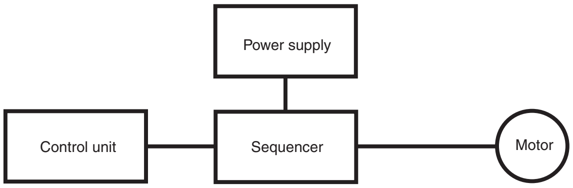
The basic advantage of a stepper motor is that it can operate within an open loop, that is to say that in normal operating conditions, for n impulses one obtains n steps.

Stepper motors are found in numerous applications such as : photocopiers, typewriters, bank printers, computer peripherals, x-y plotters, instrumentation, medical pumps, drip feeders, vending machines, gaming machines, automobiles, heating and ventilation and process control.

1 - Principles of stepper motors

The operation of a stepper motor requires the presence of the following elements :

- A control unit (a micro-processor for example) which supplies impulses the frequency of which is proportional to the speed of the motor. This applies equally to both directions of rotation.
- A sequencer which will direct the impulses to the various motor coils.
- A power supply.

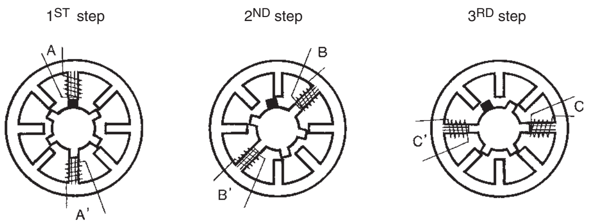


The variable reluctance stepper motor

This type of motor functions according to the Law of maximum flux.

Constitution :

- A stator with teeth
- A rotor with teeth

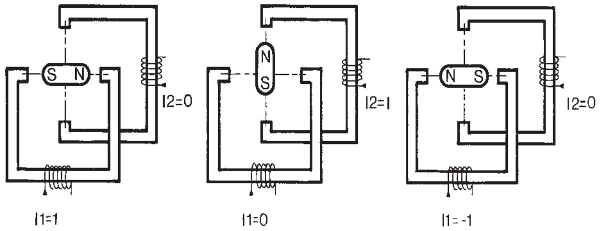


The permanent magnet stepper motor

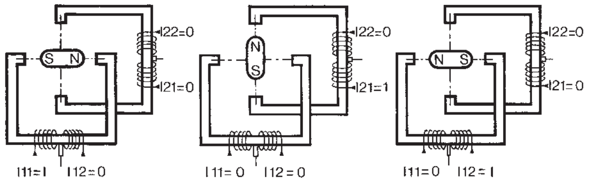
Constitution :

- A stator with teeth
- A magnetized rotor

2-phase motor - two-pole supply



4-phase motor - single-pole supply



2 - Different types of energization

2 phases

	I1	I2	j
1 phase on	I	0	0
	0	I	90
	-I	0	180
	0	-I	270
2 phases on	I	I	45
	-I	I	135
	-I	-I	225
	I	-I	315
1/2 step	I	0	0
	I	I	45
	0	I	90
	-I	I	135
	-I	0	180
	-I	-I	225
	0	-I	270
	I	-I	315

4 phases

	I11	I12	I21	I22	j
1 phase on	I	0	0	0	0
	0	0	I	0	90
	0	I	0	0	180
	0	0	0	I	270
2 phases on	I	0	I	0	45
	0	I	I	0	135
	0	I	0	I	225
	I	0	0	I	315
1/2 step	I	0	0	0	0
	I	0	I	0	45
	0	0	I	0	90
	0	I	I	0	135
	0	I	0	0	180
	0	I	0	I	225
	0	0	0	I	270
	I	0	0	I	315

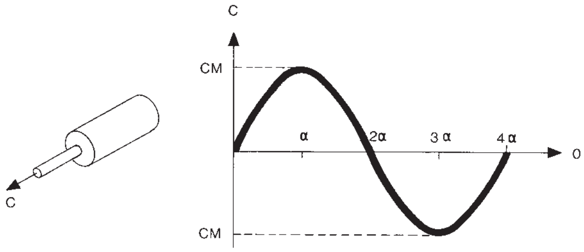
3 - Static characteristics

Current per phase

This is the current rating per phase at zero frequency (motor stopped) which produces the maximum permitted temperature rise for the motor in operation. This current is measured when power & voltage are constant.

Static holding torque

With the motor energized, the static holding torque is the torque which must be applied via the motor shaft to induce continuous rotation.



= step angle

Holding torque (Cm)

The holding torque is the minimum torque which needs to be applied to the rotor for it to turn, measurement being made with the "motor energized two phases at a time" at zero frequency.

Detent torque

This torque has the same definition as the holding torque but with the motor de-energized.

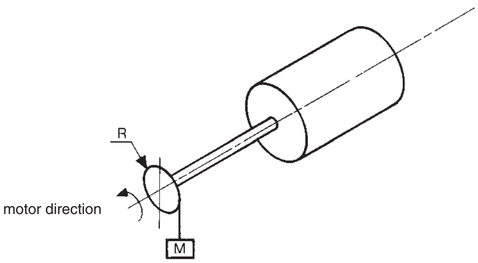
4 - Dynamic characteristics

Elementary movement

There are 4 types of constraints which can influence a motor :

The inertial load JL

This factor only affects the motor during acceleration or deceleration, and also influences the resonant frequency. If JL is the result of the load inertia (directly applied to the motor shaft) the equivalent torque caused by this inertia is a function of the transmission system (see later section concerning mechanical aspects).



The antagonistic torque MR

This is the torque which opposes the general rotation of the motor.
A pulley and weight system best exemplifies this torque.

The resistive torque caused by viscous friction

This is proportional to the speed. By definition, this friction represents the result of the actions of a liquid or a gas on a solid which moves though liquid or gas. Cars and aircraft are good examples of this.

The resistive torque caused by dry friction

This is always against the direction of movement. By definition, this friction represents the result of actions applied on a solid moving against another solid.

Example of the paper feed on a printer.

Inertias :

J pinions + J gears + J rollers. These inertias must be applied to the motor shaft.

Antagonistic torque :

This is the weight of the paper. It is not significant compared to the dry friction torque.

Viscous friction torque :

This torque caused by the displacement of the roller in air is negligible.

Dry friction torque :

This is the torque caused by the friction of the different shafts (gears and rollers) on their bearings.

Up to now, we have mentioned the external constraints but there are constraints caused by inertia, viscous friction and dry friction inside the motor.

Inertia :

Inertia of the rotor.

Viscous friction :

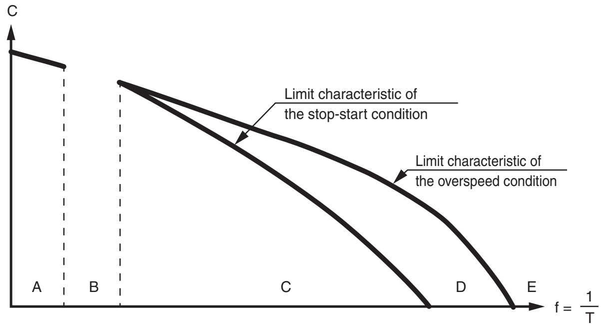
- Friction of the rotor in the air.
- Resistive torque caused by resulting air flow of which the effect is the equivalent of viscous torque.

Dry friction :

For a given system, the variation of the antagonistic torque and the frequency of the drive impulses determine the dynamic characteristics of the motor.

Dynamic torques

For a given system, the variation of the antagonistic torque and the frequency of the drive impulses determine the dynamic characteristics of the motor, for one power value.



Zone A

Operation possible but risk of excessive noise generation due to motor shocks.

Zone B

Risk of loss of synchronization : low frequency resonance.

Zone C

Stop-start zone.

Starting and stopping of the motor in this zone without loss of step.

Zone D

Overspeed zone.

Operation possible if the stopping and starting occur in zone C.

Zone E

Operation impossible.

Remarks on a given specification

For a given type of motor and number of phases several coil types are available. They have been developed in order to adapt the motor to each type of electronic control.

For example :
a low resistance is required for a DC supply and a higher resistance will be appropriate for a constant voltage supply. However, all the coil types are roughly equivalent from the point of view of power absorbed, ampere/revolution and the (L/R) time constant (static).

These motors will have about the same performance for a given type of electronic control.

Example motor 82 910 - 2 phases.

		82 910 001	82 910 005	82 910 022
R		9	12.9	66
L	H	12	15	68
N tr		320	373	762
I e	A	0.52	0.44	0.19
NI A.tr		166.4	164	145
P	W	4.9	5	4.8
Z=L/R	ms	1.3	1.15	1

Step precision

Condition : (full stepping with 2 phases energized)

The external loads are nil, the current is at its nominal value.
Measurement is made on all the steps and for a complete rotation.

Definition

Positioning precision
This is the variance with the theoretical equilibrium position.

Step precision

This is the variance of the movement angle (step)

Influence of the inertia of the load

Fo - Maximum frequency of stopping-starting with no load inertia
JR - Inertia of the rotor
JL - Inertia of the load

Note :

The above formula is determined using the approximation JL ~ JR

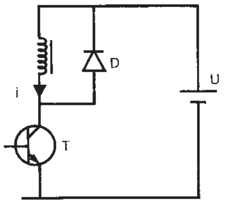
5 - Power supplies

Notation

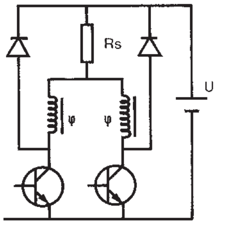
One phase of the motor has a resistance R and an inductance L

Constant voltage supply

without a series resistor



with a series resistor

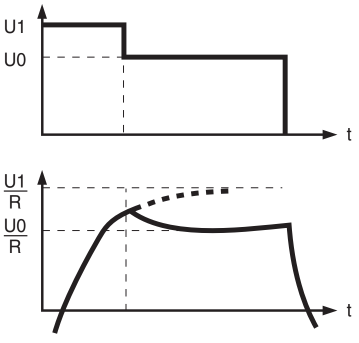


The use of a series resistor necessitates the increase of the supply voltage from :

U to $\frac{R + Ro}{R}$ U in order to maintain the same absorbed power to the motor.

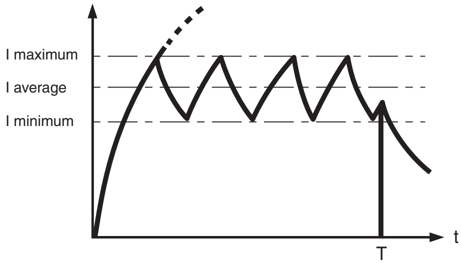
Two-level voltage supply

All the improvements are based on increasing the ramp at the source of the current in the (R-L) circuit.
The first method consists of increasing the total resistance of the circuit.
The second method consists of increasing the supply voltage for a certain time, with the average power dissipated within the motor not producing a temperature rise above that permitted.



Constant current supply

The supply voltage is considerably higher than the nominal RI. The current is regulated by a transistor functioning in digital mode following the given principle of chopper supplies.



6 - Comparisons

Energization "one phase at a time" "two phases at a time"

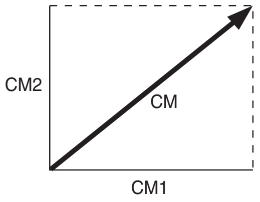
Comparison at the same absorbed power.

	1 phase at a time	2 phases at a time
Power	$P = R(\sqrt{2}I)^2$	$P = 2RI^2$
Current per phase	$\sqrt{2}$ I	I
Holding torque	$\sqrt{2}$	$\sqrt{2}$ Cm

The holding torque is proportional to the current and is linear in the magnetic region.
Beyond this, the phenomenon of saturation renders the holding torque almost independent of the current.

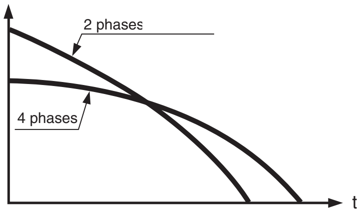
Cm1 = Holding torque produced by phase 1 supplied by I

Cm2 = Holding torque produced by phase 2 supplied by I



Cm = Holding torque of the motor energised "two phases at a time"

Comparison "2 phases" - "4 phases"



Comparison with constant voltage and resistance.

Comparison of the "2 phases" and "4 phases" motor supplied at constant voltage

	2 phases	4 phases
Performance	High in low frequency Low in high frequency	High in low frequency
Motor price	Low	Supplement to cover 6 leads
Electronics	8 transistors	4 transistors

7 - Approvals

Permanent magnet stepper motors

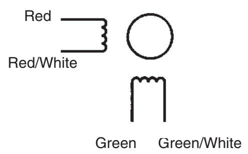
The standard connection leads AWG22 are approved to UL 80˚C, 300V. (AWG24 available on request).

Hybrid stepper motors

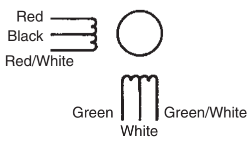
The standard connection leads AWG22 are approved to UL 125˚C, 300V. UL 325 - 6 CSA.

Other hybrid stepper versions

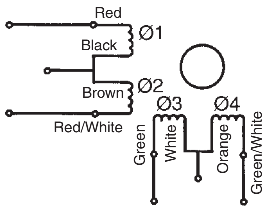
Certain hybrid motors can be supplied in 2 phase (4 leads) or 4 phase (8 leads). The motors are marked as follow.

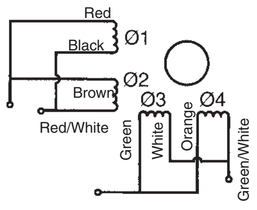


A - Connections in series



B - Connections in parallel





8 - Notes

In this catalog, each motor shown has an 8-digit part number which is a complete definition. To avoid any error, this part number should appear on orders.

For any additional information and to order please contact your sales office.

9 - How to define your requirements

The stepper motor can satisfy numerous applications : to find the right motor for your application, certain points require definition :

Mechanical characteristics

Define clearly your system and your drive layout in order to evaluate the frictions and inertias as they apply to the motor shaft (see appendix covering mechanical aspects).

Define your transmission mode. Determine the usable torque, in dynamic and holding form.

Determine the number of steps to accomplish and the time allocated for this movement.

Select an operating speed.

Select a supply mode (constant voltage, two voltage levels, constant current).

Should the motor selected produce the necessary torque at the required frequency but in the overspeed zone, do not forget to ramp up and down to prevent any loss of step.

Determination of conditions of use : temperature, axial and radial load, operational frequency. In certain cases the use of a gearbox will provide extra torque and speed; for such cases refer to curves in the catalogue to indicate the usable power and 3/15 speed available.

Specific requirements

Elements to provide to define a motor correctly if you do not find the product you need in the catalog:

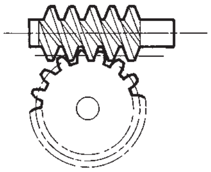
Dimensions, step angle, resistance, number of phases, lead length, type of connector, supply type, operating frequency, required torque, operating cycle.

But if your application requires special shafts or other mechanical or electric adaptations (pinions, connectors etc) our staff are at your disposal (for significant quantities). We point out as well that numerous adaptations exist as standard or semi-standard versions.

4

Wheel/screw system

$$J = J_v + \frac{1}{R^2} J_r$$



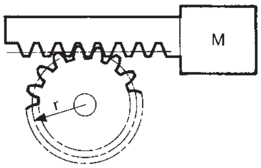
J_v = Inertia considered as a cylinder of a diameter equal to the initial diameter.

Jr = Inertia of the wheel considered as a whole cylinder of a diameter equal to the initial diameter.

R = Reduction ratio

Rack and pinion

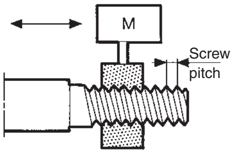
$$J = Mr^2 + \frac{mr^2}{2}$$



M = Mass to be moved
m = Mass of pinion

Threaded screw system

$$J = \frac{MP^2}{4\pi^2} + \frac{mr^2}{2}$$



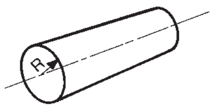
M = Mass to be moved
m = Mass of the screw
r = Average radius of screw

Inertia

Calculation of inertias applied to motor

Cylinder

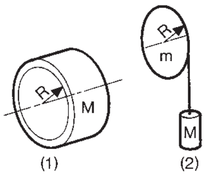
$$J = \frac{MR^2}{2}$$



Wheel - Weight/pulley

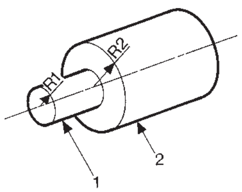
$$J = MR^2$$

$$J = MR^2 + \frac{mR^2}{2}$$



Coaxial cylinders (tenons)

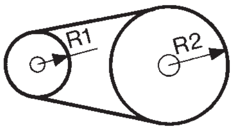
$$J = \frac{M_1R_1^2}{2} + \frac{M_2R_2^2}{2}$$



M1 = Mass of cylinder 1
M2 = Mass of cylinder 2

Transmission by belt (or chain)

$$J = \frac{M_1 + 2m + M^2}{2} R_1^2$$



M1 = Mass of motor pulley
M2 = Mass of drawn pulley

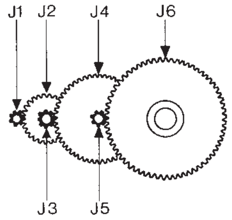
m = Mass of belt

If the drawn pulley also receives the inertia moment Jc of a load then :

$$J = \frac{M_1 + 2m + M_2}{2} R_1^2 + J_c\left(\frac{R_1}{R_2}\right)^2$$

Example of a gearbox

$$J = \frac{1}{R^2} J_c + J_r$$



Jc = Load inertia carried at the gearbox output shaft
Jr = Gearbox inertia
R = Gearbox ratio

NB :
The inertia of a gearbox is calculated stage by stage, each gearwheel being considered as a cylinder.

$$J_r = J_1 + \left(\frac{1}{R_1}\right)^2 (J_2 + J_3) + \left(\frac{1}{R_1}\right)^2 (J_4 + J_5) + \ldots\ldots$$

In practice the calculation of the first two gears, even the first one only, will give a sufficient approximate value.