The advantages of stepper motor

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

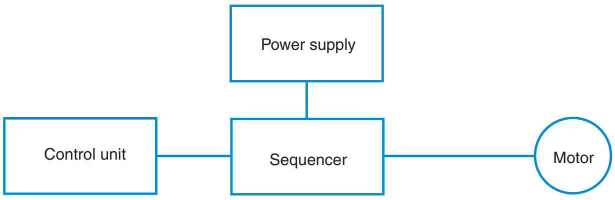
The basic advantage of a stepper motor is that it can operate within an open loop, that is to say that in normal operating conditions, for n impulses one obtains n steps.

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.

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.

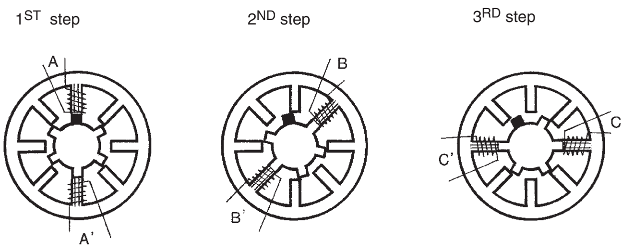


➜ The variable reluctance stepper motor

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

Constitution :

- A stator with teeth
- A rotor with teeth

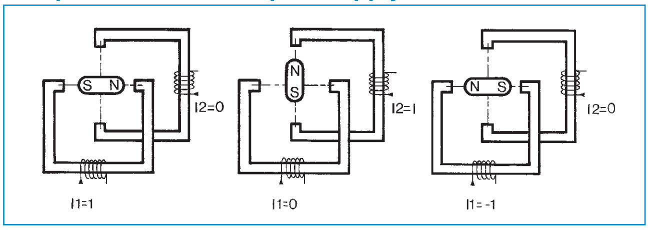


➜ The permanent magnet stepper motor

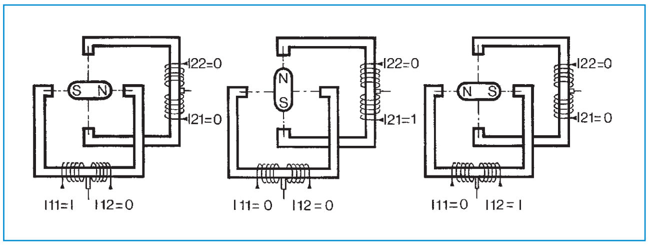
Constitution :

- A stator with teeth
- A magnetised rotor

➜ 2-phase motor - two-pole supply



➜ 4-phase motor - single-pole supply



Different types of energisation

➜ 2 phases

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

➜ 4 phases

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

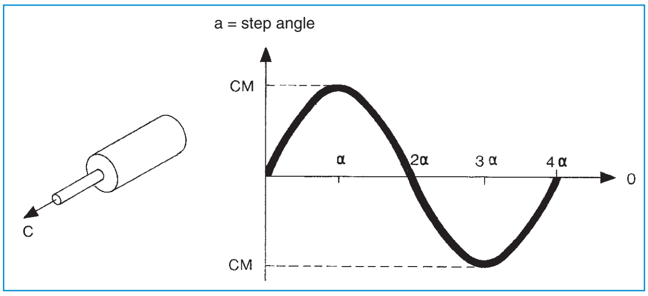
Static characteristics

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



➜ 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 energised 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-energised.

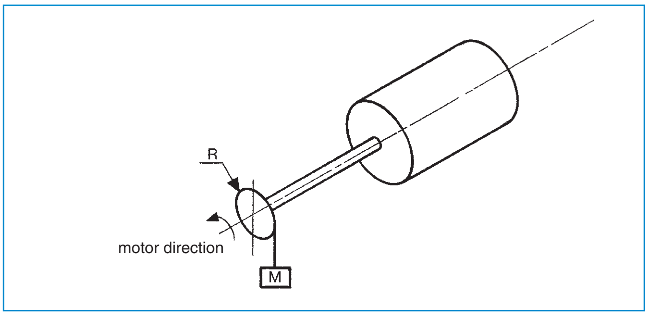
Dynamic characteristics

➜ 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:

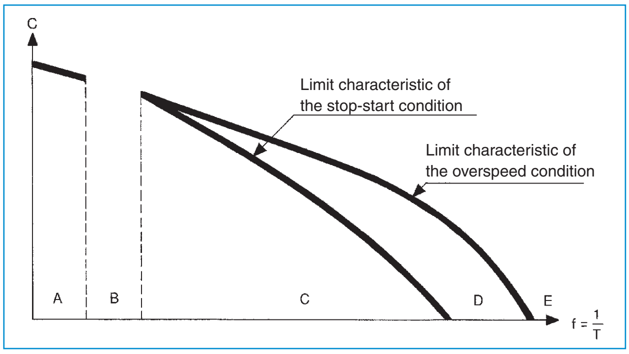
Inertia of the rotor.

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 synchronisation : 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	Ω	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 energised)

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

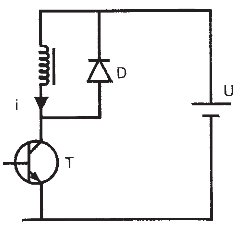
Power supplies

➜ Notation

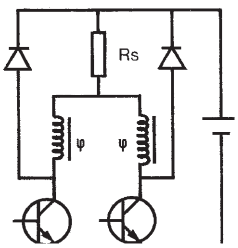
One phase of the motor has a resistance R and an inductance L

➜ Constant voltage supply

without a series resistor



with a series resistor



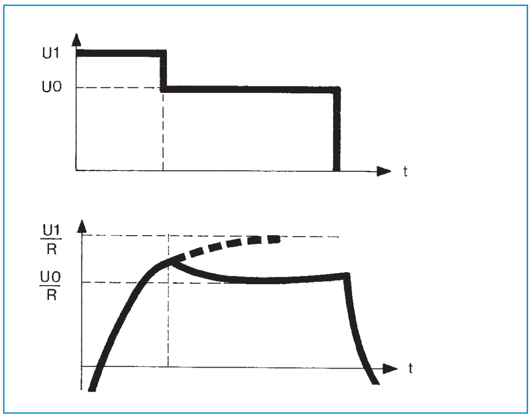
The use of a series resistor necessitates the increase of the supply voltage from :

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

➜ Two-level voltrage supply

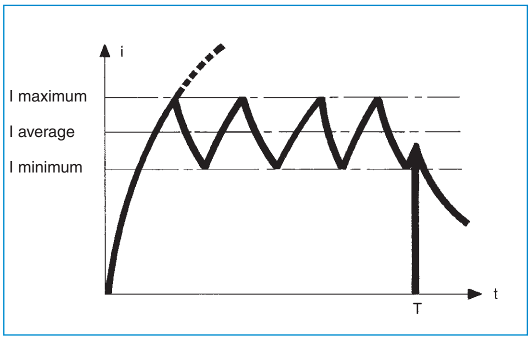
All the improvements are based on increasing the ramp at the source of the current in the (R-L) circuit.

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



Comparisons

➜ Energisation «one phase at a time» «two phases at a time»

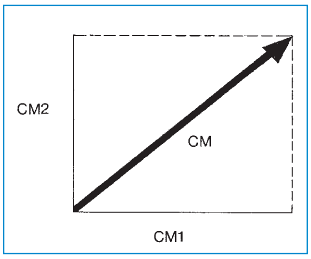
Comparison at the same absorbed power

	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

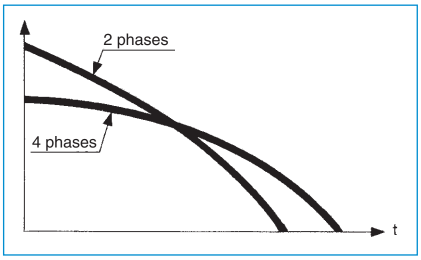
Cm2 = Holding torque produced by phase 2 supplied by I



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

Approvals

➜ Permanent magnet stepper motors

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

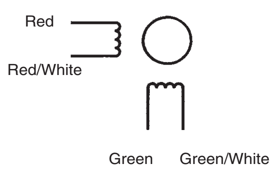
➜ Hybrid stepper motors

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

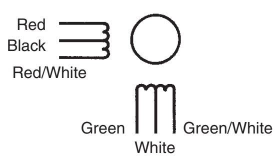
➜ Other hybrid steppers versions

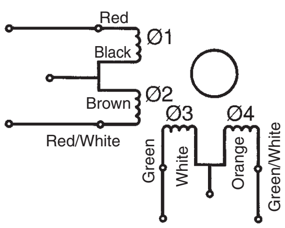
Certain hybrid motors can be supplied in 2 phase (4 leads) or 4 phase (8 leads). The motors are marked as follow.

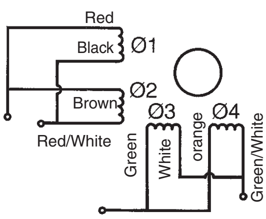
A - Connections in series



B - Connections in parallel







Notes

In this catalogue, 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.

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 3/15speed available.

➜ Specific requirements

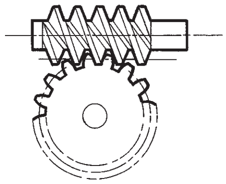
Elements to provide to define a motor correctly if you do not find the product you need in the catalogue:

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.

Wheel/screw system

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



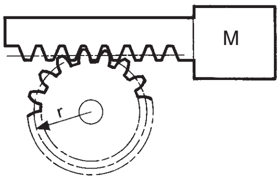
J_v = Inertia considered as a cylinder of a diameter equal to the initial diameter.

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

R = Reduction ratio

Rack and pinion

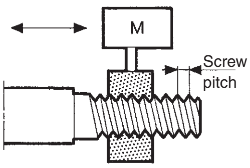
$$J = Mr^2 + \frac{mr^2}{2}$$



M = Mass to be moved
m = Mass of pinion

Threaded screw system

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



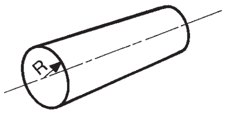
M = Mass to be moved
m = Mass of the screw
r = Average radius of screw

Inertia

Calculation of inertias applied to motor

➜ Cylinder

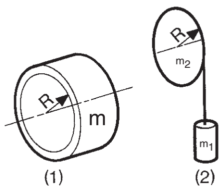
$$J = \frac{mR^2}{2}$$



➜ Wheel - Weight/pulley

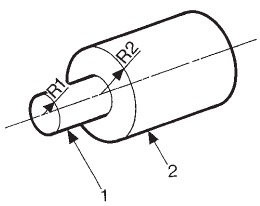
$$J = mR^2$$

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



➜ Coaxial cylinders (tenons)

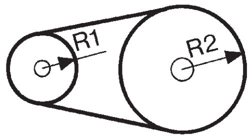
$$J = \frac{M_1 R_1^2}{2} + \frac{M_2 R_2^2}{2}$$



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

Transmission by belt (or chain)

$$J = \frac{M_1 + 2m + M^2}{2} R1^2$$

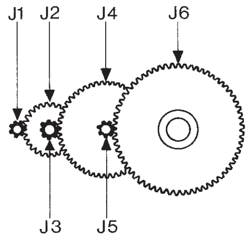


M1 = Mass of motor pulley
M2 = Mass of drawn pulley

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

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

J_c = Load inertia carried at the gearbox output shaft
J_r = Gearbox inertia
R = Gearbox ratio

➜ NB:

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

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

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

Torque conversion chart

	Nm	cm kg	cm N	m Nm	cm gr	in.oz	lb.Ft
1b.Ft	1.383	=13.83	=138.3	=1383	=13830	=192	=1
in.oz	0.00072	=0.0723	=0.723	=7.23	=72.3	=1	=0.0052
cm gr	0.0001	=0.001	=0.01	=0,1	=1	=0,0.139	=0.0000723
m Nm	0.001	=0.01	=0.1	=1	=10	=0.139	=0.000723
cm N	0.01	=0.1	=1	=10	=100	=1.39	=0.00723
cm kg	0.1	=1	=10	=100	=1000	=13.9	=0.0723
Nm	1	=10<					

Moment of inertia

B A	kg-cm^2	g-cm^2	kg-cm-s^2	g-cm-s^2	lb-in^2	oz-in^2	lb-in-s^2	oz-in-s^2	lb-ft^2	lb ft -s^2
kg-cm^2	1	10^3	1.01972 x10^{-3}	1.01972	0.341716	5.46745	8.85073 x10^{-4}	1.41612 x10^2	2.37303 x10^{-3}	7.37561 x10^3
g-cm^2	10^{-3}	1	1.01972 x10^{-6}	1.01972 x10^{-3}	3.41716 x10^{-4}	5.46745 x10^{-3}	8.85073 x10^{-7}	1.41612 x10^{-5}	2.37303 x10^{-6}	7.37561 x10^{-6}
kg-cm-s^2	980.665	980.665 x10^3	1	10^3	335.109	5.36174 x10^3	0.867960	13.8874	2.32714	7.23300 x10^{-2}
g-cm-s^2	0.980665	980.665	10^{-3}	1	0.335109	5.36174	8.67960 x10^{-4}	1.38874 x10^{-2}	2.32714 x10^{-3}	7.23300 x10^{-5}
lb-in^2	2.92641	2.98411 x10^3	2.98411 x10^{-3}	2.98411	1	16	2.59009 x10^{-3}	4.14414 x10^{-2}	6.94444 x10^{-3}	2.15840 x10^{-4}
oz-in^2	0.182901	182.901	1.96507 x10^{-4}	0.186507	0.0625	1	1.61880 x10^{-4}	2.59009 x10^{-3}	4.34028 x10^{-4}	1.34900 x10^2
lb-in-s^2	1.12985 x10^3	1.12985 x10^6	1.15213	1.15213 x10^3	386.088	6.17740 x10^{-3}	1	16	2.68117	8.33333 x10^2
oz-in-s^2	70.6157	70.6157 x10^3	72.0079 x10^{-3}	72.0079	24.1305	386.088	6.25 x10^{-2}	1	0.107573	52.0833 x10
lb-ft^2	421.403	421.403 x10^3	0.429711	429.711	144	2304	0.372972	5.96756	1	3.10810 x10^2
lb ft -s^2	1.35582 x10^4	1.35582 x10^7	13.8255	1.38255 x10^4	4.63305 x10^3	7.41289 x10^4	12	192	32.1740	1

Conversion tables

g		ounces
7.1	1/4	0.008
14.2	1/2	0.017
21.3	3/4	0.025
28.3	**1**	0.035
42.5	**1** 1/2	0.053
56.7	**2**	0.070
70.9	**2** 1/2	0.087
85.0	**3**	0.106
113.0	**4**	0.141
142.0	**5**	0.176
170.0	**6**	0.212
198.0	**7**	0.247
227.0	**8**	0.282
255.0	**9**	0.318
283.0	**10**	0.353
312.0	**11**	0.388
340.0	**12**	0.424
368.0	**13**	0.459
397.0	**14**	0.494
425.0	**15**	0.53
454.0	**16**	0.564

kg		lbs
0.23	1/2	1.10
0.45	**1**	2.20
0.91	**2**	4.41
1.36	**3**	6.61
1.81	**4**	8.82
2.27	**5**	11.0
2.72	**6**	13.2
3.18	**7**	15.4
3.63	**8**	17.6
4.08	**9**	19.8
4.54	**10**	22.0
4.99	**11**	24.2
5.44	**12**	26.4
5.90	**13**	28.6
6.35	**14**	30.8
6.80	**15**	33.1
7.26	**16**	35.2

cmkg		in/ lbs
1.152	**1**	0.870
2.304	**2**	1.739
3.456	**3**	2.609
4.608	**4**	3.478
5.760	**5**	4.348
6.912	**6**	5.218
8.064	**7**	6.087
9.216	**8**	6.957
10.368	**9**	7.826
11.520	**10**	8.696

cmg		in/oz
72	**1**	0.013
144	**2**	0.026
216	**3**	0.039
288	**4**	0.053
360	**5**	0.069
432	**6**	0.078
504	**7**	0.091
574	**8**	0.106
648	**9**	0.120
720	**10**	0.139
1152	**12**	0.212
1440	**20**	0.278
2160	**30**	0.416
2880	**40**	0.555
3600	**50**	0.694