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Product Manual

42BYGH40(M)-160-4A NEMA 17 Bipolar 26.8:1

Planetary Gearbox Stepper

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Planetary Gearbox Stepper

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Introduction

This NEMA-17 motor has an integrated Planetary gearbox with a 26 $^{103}/_{121}$:1 ratio.

The gearbox on this motor is geared low, theoretically generating over 77 Kg-cm of torque. In practice, the maximum torque is limited by the physical strength of the gearbox, which is rated to 30 Kg-cm continuous, and 50 Kg-cm for momentary loads. If this motor is stalled at full power, the gearbox will most likely be destroyed.

This motor is a bipolar-hybrid and must be driven by a chopper drive controller such as the 1063 - PhidgetStepper Bipolar 1-Motor.

On a 1063, maximum speed is a little under 23 RPM. At the output of the gearbox, the step angle is a little under 0.07 degree.

Product Specifications

Gear Box	
Housing Material	Metal
Backlash at No-Load	≤1°
Bearing at Output	Ball
Permissible Overhung Load	≤10kg
Permissible Thrust Load	≤5kg
Max Radial Play	≤0.05m
Max Thrust Play	≤0.3m
Gear Type	Planetary
Gear Box length	38mm
Gearbox Diameter	36mm
Reduction Ratio[4]	$26\,^{103}/_{121}$: 1
Number of Gear Trains	2
Transmission Efficiency	90%
Max Permissible Torque that gearbox can sustain	30 kg.cm
Momentary Permissible Torque	50 kg.cm
Maximum Speed	22.88 RPM
Step Angle	0.067 °/step

Motor	
Coil Type	Bipolar-Hybrid
Motor Size	42x42mm
Body Length	40mm
Step Angle	0.18 °/step
Phase Current	1.6A
Phase Voltage	2.78V
Phase Resistance	1.73 Ohm
Phase Inductance	3.2mH
Number of Leads	4
Shaft	Single
Shaft Size	8mm
Holding Torque	3600 g.cm
Max Motor Speed (with 1063 controller)	614 RPM
Operating Temperature	-20 to +50°C

Controlling your Stepper Motor

The following information has been derived from using the 3318 - "Bipolar-Hybrid-Chopper Drive" stepper motor connected to a 1063 - PhidgetStepper Bipolar 1-Motor controller.

Setting the Current Limit

The amount of current available to the motor is controlled from software through the Current Limit property. The 1063 uses sophisticated control techniques to ensure the current through the motor never exceeds the Current Limit. Since many stepper motors have a very low coil resistance, the current through the coils cannot "self-regulate" to a safe level on their own. They require the sophisticated control techniques of a Chopper Drive, which is used in the 1063 PhidgetStepper controller. As a result, the maximum current allowed should be explicitly set.

Under some circumstances, the motor will not allow the full current limit through - typically, when the motor is moving quickly and it is lightly loaded. When the motor is turning, the current flowing through the motor is roughly proportional to the torque exerted - if the load doesn't present a resistance to the torque available, the motor accepts less current. This is a good thing - nothing to be worried about.

There are many factors that influence what the current limit should be set to. These include the acceleration and speed of the stepper, the supply voltage, applied torque, motor inductance, and coil resistance. Although it is theoretically possible to model a system accurately enough to calculate the current limit, in reality you can use a few simple rules, and you play with it until it works.

Here are some hints and graphs to help you understand how to set the current limit for your application. We have run a series of tests on this motor to show how Current Limit affects the motor performance. In the tests, we choose a supply voltage (12V, 16V, 24V, 30V), and an acceleration - 100% of the 1063 Maximum Acceleration for this motor. At a range of Current Limits, we find the maximum speed the motor can reliably reach, accelerating from zero. The Speed (Full Steps per second) of the test is limited by the maximum speed of the 1063.

3317 / 3318 / 3319 - 16V
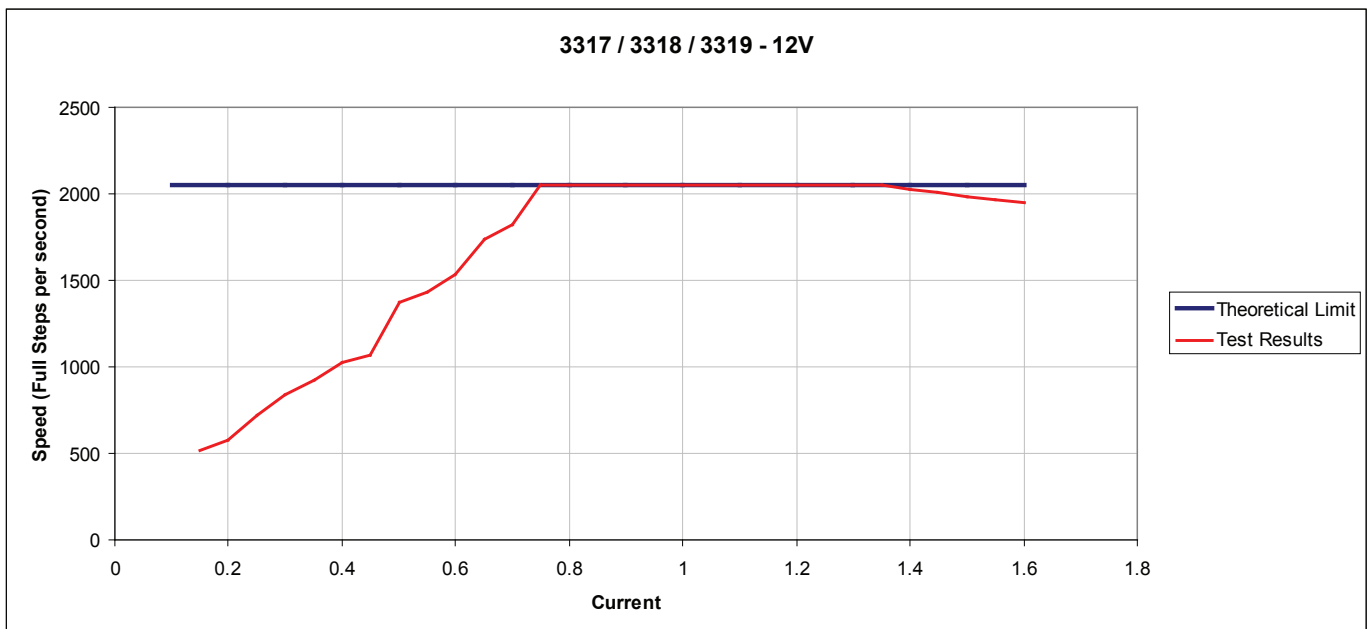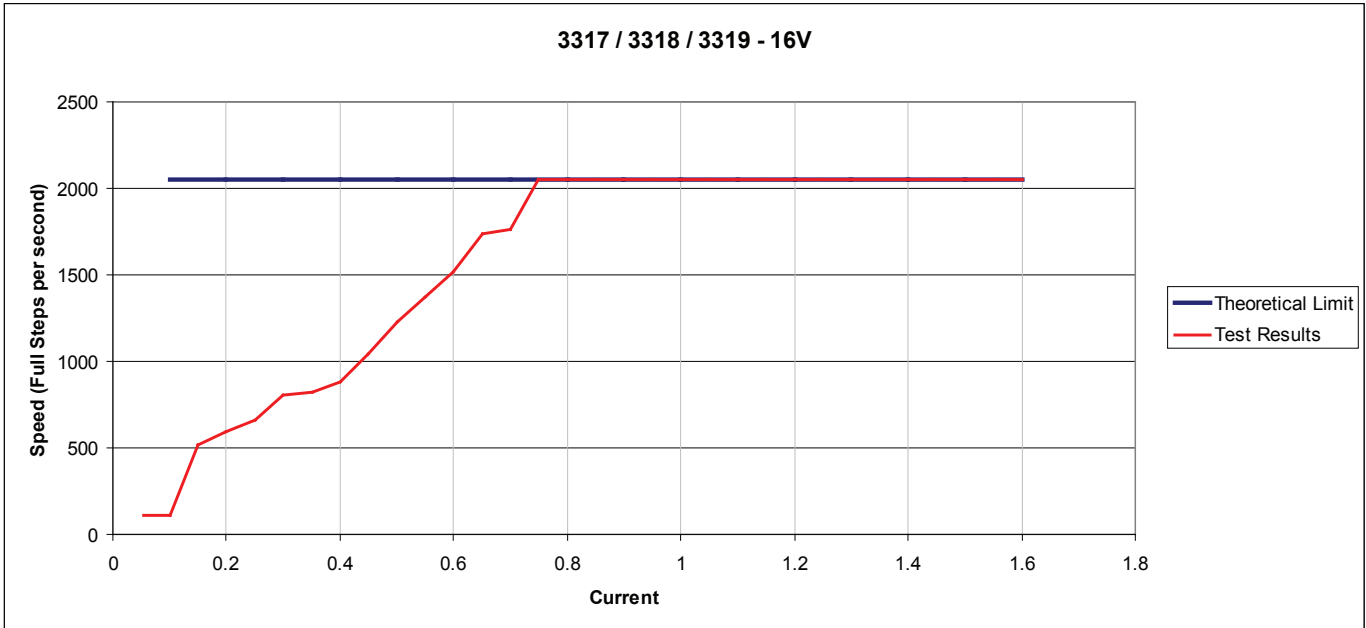
On these graphs, the red line (Test Results) shows the maximum speed at each current limit. Starting from 0 Current Limit, you can see the maximum speed achievable rapidly increases as more current is available to accelerate the internal mass of the motor, and overcome friction losses. Eventually, increasing the current limit does not produce higher speed, and particularly at 12V, begins to decrease the speed. The motors used on the 3317 / 3318 / 3319 are capable of very high speed, faster than the 1063 can drive them, so this effect is not apparent at 16V, 24V, and 30V.

3317 / 3318 / 3319 - 24V
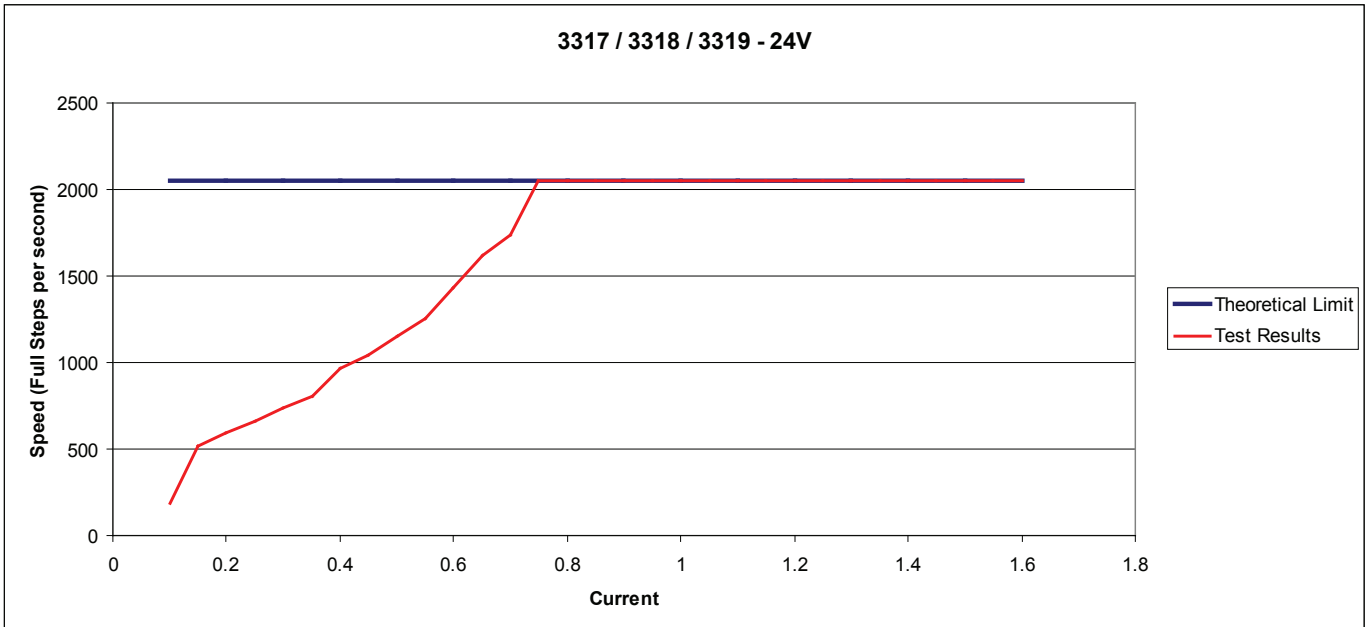
The Theoretical Limit shows the limitation on speed imposed by the inductance of the motor coils at a given supply voltage. In your application, attempting to operate the motor above the Theoretical Limit will create unreliable motor behaviour, and certainly will not result in more power, speed or torque. The only way to operate above the Theoretical Limit is to increase the Supply Voltage to the 1063. Since the 3317 / 3318 / 3319 have very low inductance, this effect is not visible within the speed range possible with the 1063.

3317 / 3318 / 3319 - 30V
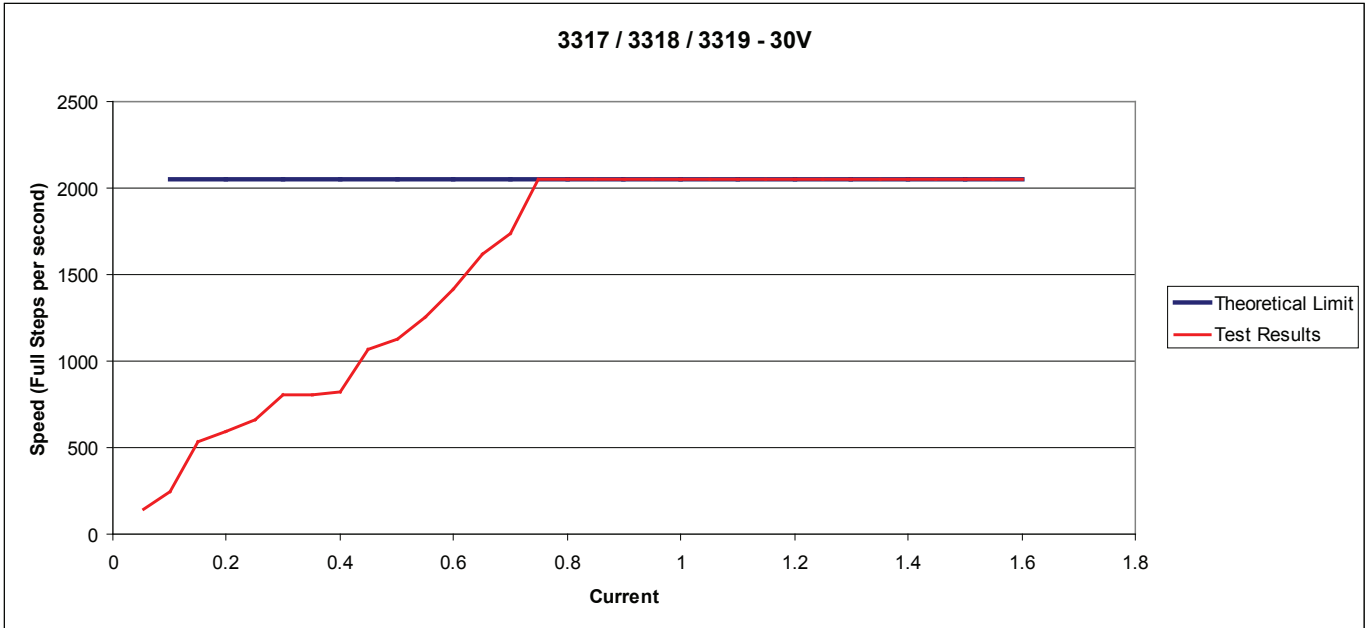
Setting Current Limit for your application is a balancing act. By increasing the current limit, more torque is available, but far more power will be consumed when the motor is turning very slowly or stopped. When setting a high acceleration, more power (therefore current) is required to accelerate the motor and it's load. Selecting the current limit is often done dynamically in the actual application - set the current limit very low, and run the system, increasing the Current Limit if it stalls. After a set up has been determined that is reliable, increase the current limit by another 25% to give some margin.

Increasing the power supply voltage will increase the theoretical limit, and cause motors with high inductance to perform much better, but will make the motor vibrate more when it is turning.

When the current limit is set low and the acceleration is high, the motor will not be able to provide enough power to accelerate itself and the load it's driving. The motor also has to overcome friction losses within the system, and do work on the load - for example, lifting a weight. By increasing the current limit, more current and power is made available to accelerate and maintain maximum speeds. This can be seen on any of the graphs in the initial steep ramp of the Test Results. As the current limit increases, the motor is able to achieve higher speeds.

Setting the Acceleration

The acceleration of a stepper motor is an important consideration when driving a load. Setting the acceleration too high can result in the motor stalling, especially with a heavy load.

Using the 1063 - PhidgetStepper Bipolar 1-Motor

The PhidgetStepper Bipolar is most effective when used with stepper motors designed to be driven with a chopper drive stepper controller. These motors are often large, with a rectangular industrial appearance. The specifications of these motors are often confusing and may seem contradictory. Our users are often confused attempting to relate the specifications of their motor to the capabilities of the 1063. If you are in doubt if your motor will work with the 1063, call us.

At low speeds, less than 1024 1/16th steps per second, the 1063 uses a microstepping scheme to allow precise control of the current to each coil, and therefore the position of the stepper. It's important to note that many steppers are not designed to be microstepped precisely, and will not accurately produce the expected angle.

At higher speeds, the 1063 switches to a full stepping mode. The 1063 will automatically switch back to microstepping when approaching the target position.

To avoid the use of floating point in the APIs, the position, velocity and acceleration parameters are expressed in microsteps (1/16th steps), instead of full steps. If your application wants to move the motor by 1 full step, you change the position by 16.

API Variables used to control your motor

To use a stepper motor, first select (in software) which motor the PhidgetStepperBipolar should affect. Step position, maximum velocity, acceleration ramping, and torque/current can be controlled for each motor in both directions:

- Step position is controlled in a graduating scale dependant upon the speed of the motor

  - Up to 1016 1/16th steps/second, shaft angle is affected in 1/16th step increments

  - 1024 1/16th steps/second and higher, shaft angle is affected in full step increments

  - The position property always contains a count of 1/16th steps

  - Maximum velocity is controlled in 1/16th steps/second up to 32768 1/16th steps/second

  - Acceleration/deceleration is controlled in 1/16th steps/second^2 up to 1020000 1/16th steps/second^2

  - Current limit is varied between 0 and ~2.5A and is directly proportional to the maximum current through the motor up to 2.5 Amps

Continuous Rotation

A stepper motor can be caused to rotate continuously by simply setting the motor position property to an extremely large number of steps. The valid range of values for the motor position property is large enough to be able to cause the motor to continuously turn at maximum velocity for 194 days.

Disabling the motor or reducing current when the motor is not moving

When the stepper motor has rotated the requested number of steps, and is stopped, the coils will remain energized to hold it in position. This is necessary to allow the motor to support a load on its shaft without rotating to an unknown position.

Holding torque is the amount of torque required to rotate the motor 'against it's will' when the full rated current is flowing through the coils. If current consumption / heating is a problem, and full holding torque is not required,

the Current Limit can be decreased in software when the motor is not moving. Holding torque will decrease linearly with the Current Limit.

There is also a small resistance to movement within the motor even when there is no current, called Detent Torque. This may be sufficient to prevent rotation in your application, particularly if the stepper has a gearbox on it.

If the motor is not supporting a load or is not required to maintain a specific angle, it is recommended to set the Enable property to false. This will allow the motor shaft to rotate freely, but the present angle may be lost if forces on the motor-shaft are greater than can be resisted by the detent torque of the unpowered motor.

Starting the motor

When the steppers are first engaged from software, the stepper motor may not be at the same state as the default output state of the controller. This will cause the stepper to 'snap' to the position asserted by the controller - potentially moving by 2 full steps.

High Precision Applications

Stepper motor precision is limited by the manufacturing process used to build them. Errors in the rotor and coils will cause some degree of inaccuracy. In our experience, inexpensive stepper motors will often have positioning errors approaching a half-step.

Controlling Steppers - Open and Closed Loop

Because stepper motors do not have the inherent ability to sense their actual shaft position, they are considered open loop systems. This means that the value contained in the current position property is merely a count of the number of steps that have occurred towards the target value; it can not be relied upon as a measure of the actual shaft angle, as external forces may also be affecting the motor.

There are several ways of overcoming this drawback. The simplest is to allow the motor load to depress a limit switch located at a known position. This can be used to fire an event in software to recalibrate the shaft position values. A more elegant solution might involve the mounting of an optical encoder on the shaft and the development of a control system.

Formulas

Output Speed = MotorSpeed / GearboxRatio

Maximum Output Speed = Maximum Motor RPM / GearboxRatio
$$= 614.4 / (26 + (103 / 121))$$
$$= 22.8816251 \text{ RPM}$$

Output Torque = MotorHoldingTorque x GearboxRatio X GearboxEfficiency
$$= 3.6 * (26 + (103 / 121)) * 0.8$$
$$= 77.3315702 \text{ Kg-cm}$$

Note: In practice, the maximum torque is limited by the physical strength of the gearbox, which is rated to 30 Kg-cm continuous, and 50 Kg-cm for momentary loads. If this motor is stalled at full power, the gearbox will most likely be destroyed.

Gearbox Step Angle = MotorStepAngle / GearboxRatio
$$= 1.8 / (26 + 103 / 121)$$
$$= 0.0670360111 \text{ °}$$

Maximum Motor Speed = (Maxstepspersecond *60) /(360 / 1.8)
$$= (2048 * 60) / (360 / 1.8)$$
$$= 614.4 \text{ RPM}$$

Glossary of Terms

Motor Terms

Backlash
The amount of clearance between mated gear teeth. Theoretically, the backlash should be "the smaller the better," but in actual practice, some backlash must be allowed to prevent jamming.

Coil Resistance
The electrical resistance (to direct current) of the wiring within the motor. The resistance causes some of the energy being applied to the motor to be converted into hear. Some motors and motor controllers rely solely on the electrical resistance to regulate the current flowing through the motor. The Unipolar Motors we sell, and the 1062 PhidgetStepper Unipolar rely on this inexpensive, but inefficient technique. Other motors will have very low resistance, increasing their efficiency, but requiring very sophisticated control techniques because the resistance cannot regulate the current to a safe level on its own. The 1063 PhidgetStepper Bipolar controller and our Bipolar motors use this technique, otherwise known as Chopper Drive.

Holding Torque
The amount of torque needed to rotate the shaft of the stepper motor while the controller attempts to hold the position, using the maximum current allowed for the motor. Holding Torque is the sum of the force that the electrical coils exert to hold the current position, and the Detent Torque, which is the natural resistance of the motor to rotation. Once the motor begins to rotate, the torque it can exert (at least at low speeds) is Holding Torque minus Detent Torque. As the motor speed increases, torque begins to decrease. If the power supply voltage is low, or the inductance of the motor is high, the torque will fall more rapidly.

Motor Inductance
Stepper motors are built with a specific coil inductance. A high inductance motor will provide a greater amount of torque at low speeds and lower torque at higher speeds.

Overhung Load (OHL)
Load applied by the application on the output shaft of the gear head. This load is often produced if pulleys are mounted directly on the shaft, pulling sideways on it. When the OHL exceeds a safe value, the bearings can fail, or the shaft can break from bending fatigue.

Rated Current
Maximum current that can be applied to the motor. Current generates heat within the motor, and exceeding the regulated current will cause the motor to overheat. If the motor is operated in a hot environment, or is enclosed, it can overheat at reduced currents.

Step Angle
The change in angle when the motor moves forward or backward by one full step. Stepper Motors (2-phase) are controlled by two sine waves of current – one sine wave into each coil. One of the sine waves permanently lags behind the other by 90 degrees. The motion of the motor is locked to these waves – as the rise and fall, the motor moves with them. A full step is when the sine waves advance by 90 degrees. The sine waves can be varied by less than 90 degrees – this is known as micro-stepping. Because of effects like Detent Torque, the motor position is not as accurate for micro-steps as for full steps.

Step Accuracy
Depending on the motor and how it is loaded down, the step positions will vary slightly. Fortunately, this variance doesn't accumulate – so if you move the motor by one step or one million steps, the angle that the motor stops at will have the same error.

Thrust load
A load applied directly in line with the output shaft of the gearbox. Avoid thrust as much as possible. If thrust load is unavoidable, keep it to no more than the permissible value.

Gearbox Terms

Gear Ratio

The gearbox accepts the power (think of power as a torque that rotates) from the motor, reducing the speed (exactly) by a given ratio, while increasing the torque (roughly) by the same ratio – a ratio of the gear head with which the gear head reduces the motor speed. E.g., if a motor has a speed of 500RPM and the reduction ratio is 100:1, the speed of the gear head is 500/100 = 5RPM. This is the actual reduction ratio. The calculated speed from the gear head should be based on this ratio.

Gearbox Step Angle

A full step of the motor will result in the gearbox making a smaller step. The angle of this step is the step angle of the motor divided by the gearbox reduction ratio.

Gearbox Output Torque

The gearbox takes the torque from the output shaft of the motor, reducing the speed and increasing the torque. The gearbox, depending on its efficiency, converts some of the torque of the motor into heat, and it is lost. SO, the Gearbox Output Torque is the motor output torque multiplied by the reduction ratio multiplied by the efficiency of the gearbox.

Gear Trains

Planetary gearheads use multiple gear sets to achieve large gear reductions. Each gear set makes the gearbox longer, and reduces the efficiency.