## 2-phase and 5-phase stepper motors in comparison

If, in the search for a drive solution, the choice falls on a stepper motor, the question subsequently arises as to 2-phase or 5-phase technology. Oriental Motor offers motors and drivers for both areas. For this reason, the basic differences in terms of resolution, vibration, torque, accuracy and synchronicity of the stator magnetic field and rotor will be discussed here.

### Difference between 2-phase and 5-phase

There are two main differences, the first is mechanical. A stepper motor basically consists of a stator and a rotor. The rotor, in turn, is made up of three components: Two rotor segments and a permanent magnet. In a 2-phase motor, the stator consists of
8 magnetic poles with small teeth, whereas in a 5-phase motor it consists of
10 magnetic poles. The poles in the stator are each provided with a winding.

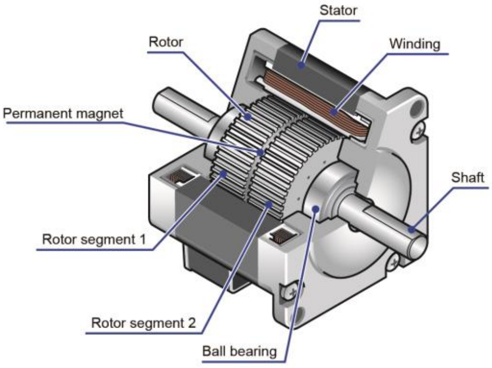



Fig. 1: Stator, rotor, permanent magnet and winding are the most important components of a stepper motor.

The second difference is the number of phases. A 2-phase motor has two phases, an "A" phase and a "B" phase, while a 5-phase motor has five phases. Essentially, the number of phases refers to the different pole combinations of the stator, whose windings have current flowing through them to create interactions with the rotor using the rotating field.

So how do these differences affect performance? The performance of a stepper motor is influenced by a number of factors. There are several ways to drive a stepper motor, and the mode of operation has a major impact on motor performance. Wave drive, full step, half step and micro step are the most common drive methods and each offers very different performance. Without considering the different drive methods, the most important performance parameters for 2-phase and 5-phase stepper motors are listed below.

### Resolution

Structurally, the 5-phase stepper motor does not differ significantly from the 2-phase motor. The rotor has 50 teeth on both motors. The difference is that the 5-phase motor has 10 poles (2 per phase), so the rotor only needs to move 1/10 of a stator tooth pitch to align with the next phase. With the 2-phase motor, the rotor has to move 1/4 of a stator tooth pitch to align with the next phase (8 poles, 4 per phase).

This means that the 2-phase motor requires 200 steps (1.8° per step) for each revolution, whereas the 5-phase motor requires 500 steps (0.72° per step). The higher resolution of the 5-phase motor is therefore design-related. In conjunction with a microstep driver, the 5-phase motor can execute steps of up to 0.00288°, although the positioning and repetition accuracy still depends on the mechanical accuracy of the motor. This is ±0.05° for both motors.

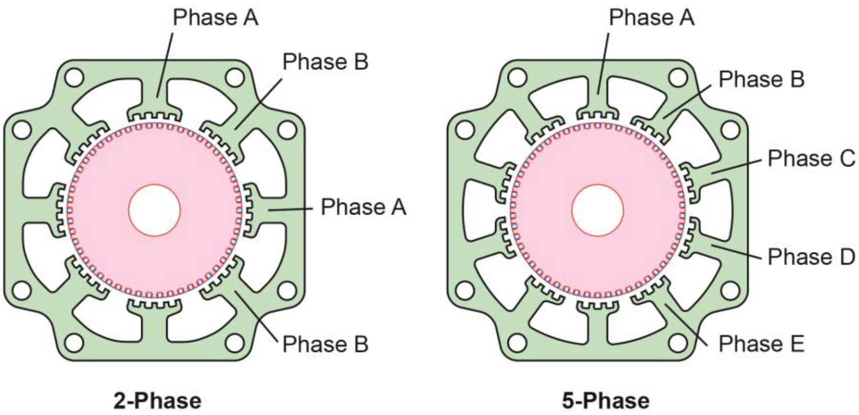



Fig. 2: The larger number of magnetic poles in the 5-phase stepper motor ensures a smaller step angle of 0.72°.

## Vibration

Due to the smaller step angle of 0.72° compared to 1.8°, the vibration of a 5-phase motor is considerably lower than that of a 2-phase motor. Figure 3 shows the vibrations in comparison, the difference is clearly visible. The diagrams represent measured values for the vibration characteristics in microstep operation with 5,000 steps per revolution. For the measurement, a generator was coupled to a motor with a double shaft. The motor vibration is represented graphically by the voltage generated: The more the motor vibrates, the greater the voltage generated.

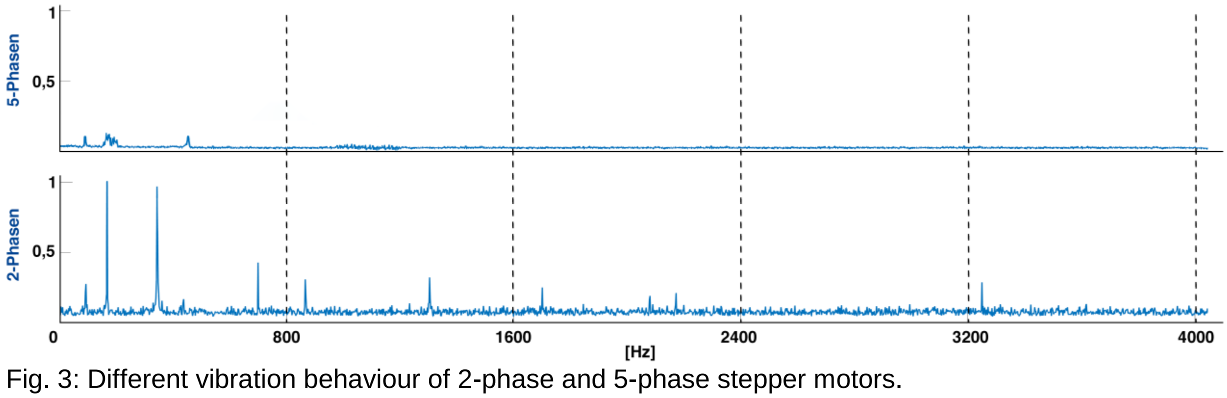



Fig. 3: Different vibration behaviour of 2-phase and 5-phase stepper motors.

## Torque

While the output torque of a 2-phase stepper motor hardly differs from that of a 5-phase motor, the latter has more "usable" torque. This is mainly due to the lower torque ripple that can be observed in both motors due to their principle.

Half-step or micro-step operation of a 5-phase stepper motor increases the maximum usable torque by up to 10 %, as more phases are excited simultaneously. 2-phase motors lose up to 40 % of torque in half-step and micro-step operation, but many 2-phase drivers compensate for this by adjusting the opposite torque vector.

Each phase of the motor contributes to the total output torque of the motor with the sinusoidal torque shift curve (Fig. 4). The difference between the peak and the trough (in the area of the peaks) is called torque ripple. The torque ripple causes vibrations, i.e. the greater the difference, the greater the vibrations.

Since more phases contribute to the total torque of the motor, the torque ripple in a 5-phase motor is significantly lower than in a 2-phase motor. The difference between peak and valley can be as high as 29 %, while it is only about 5 % for a 5-phase motor. Since torque ripple contributes directly to vibration, the 5-phase motor runs more quietly than the 2-phase motor.

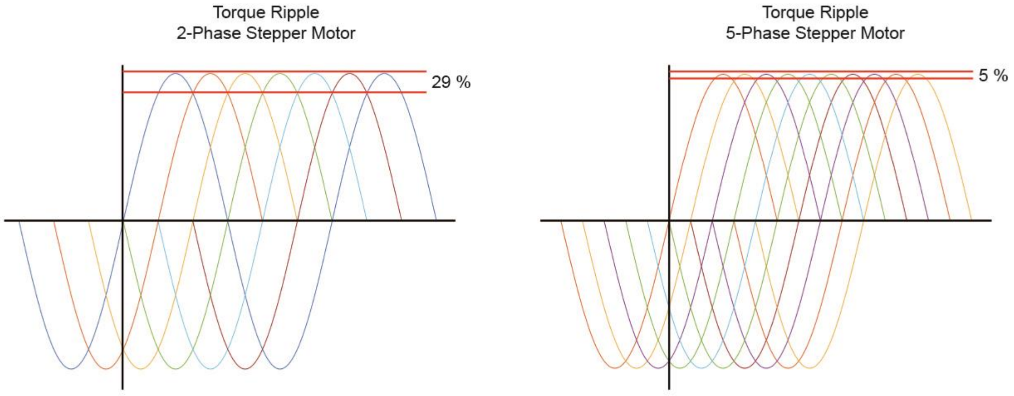



Fig. 4: Lower torque ripple in the 5-phase stepper motor ensures lower vibrations.

## Accuracy

With regard to accuracy, electrical and mechanical factors play a role. Errors due to electrical deviations are caused by the phases not being balanced. For example, if a motor is rated at 10 W with ±10 % deviation, one phase may contribute 9.2 W, the other 10.6 W. This difference would cause the rotor to align more with one phase during operation.

In the case of errors caused by mechanical deviations, the tooth configuration is crucial. Although the teeth of a motor should be square by design, the stamping process and tool age can cause some of the teeth or parts of the teeth to be rounded. Instead of the magnetic flux passing directionally, rounded teeth can contribute to parasitic leakage. These component specifications therefore contribute to the accuracy of the motor.

In full step operation, a 2-phase motor repeats its state at every fourth step, a 5-phase motor at every tenth step. Any electrical error caused by electrical imbalances of the phases is compensated accordingly with the 2-phase motor at every fourth step and with the 5-phase motor at every tenth step, so that theoretically only a mechanical error remains.

Errors caused by mechanical deviations are eliminated as soon as the motor has completed a full 360° rotation and the same tooth is back in its original position. This takes place every 200 steps for 2-phase motors, for 5-phase motors every 500 steps.

## Synchronicity of stator magnetic field and rotor

Since the 5-phase stepper motor moves only 0.72° per step, it is almost impossible for the motor to lose a step due to overshoot or undershoot. In rudimentary terms, a motor loses a step or leaves synchronisation if the rotor teeth are not aligned with the corresponding stator teeth. This is caused by the rotor moving too far (overshoot) or too short (undershoot) by more than 3.6°.

## Suitable driver technology

Oriental Motor has developed matching drivers for the 2-phase and 5-phase motors (Fig. 5), which further optimise the overall performance. A new driver technology provides improvements in terms of torque and vibration. The CVD drivers use new field-effect transistors with low losses, which has a direct positive effect on heat generation. Fig. 6 shows the comparison of two motors as a thermographic image, both motors are supplied with a phase current of 1.4 A per phase. While with the predecessor driver the motor temperature increased up to 67.9°C, with the new CVD driver the temperature was only 48.3°C. This difference of 20°C ensures that the motor temperature is not too high. This difference of 20°C ensures a longer service life for all components and reflects the up to 75 % lower power consumption (Fig. 7).

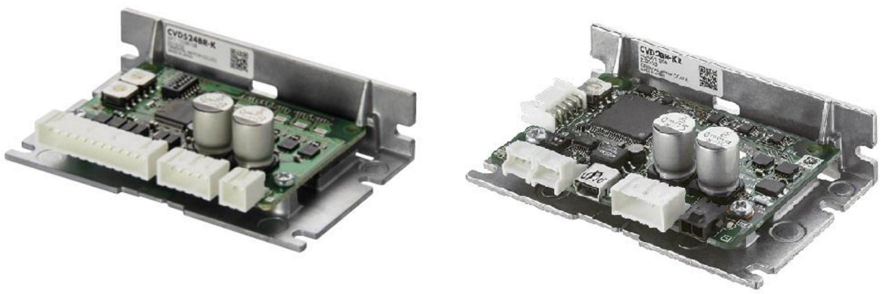
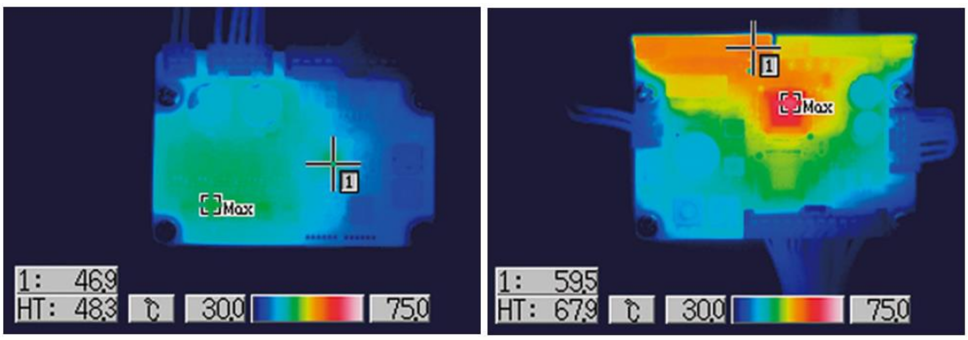


Fig. 5: CVD driver for 2-phase and 5-phase stepper motors, also with RS-485 communication.




5-phase motor with CVD driver | 5-phase motor with conventional driver

Fig. 6: Significantly lower heat generation due to new CVD drivers in the thermographic image.

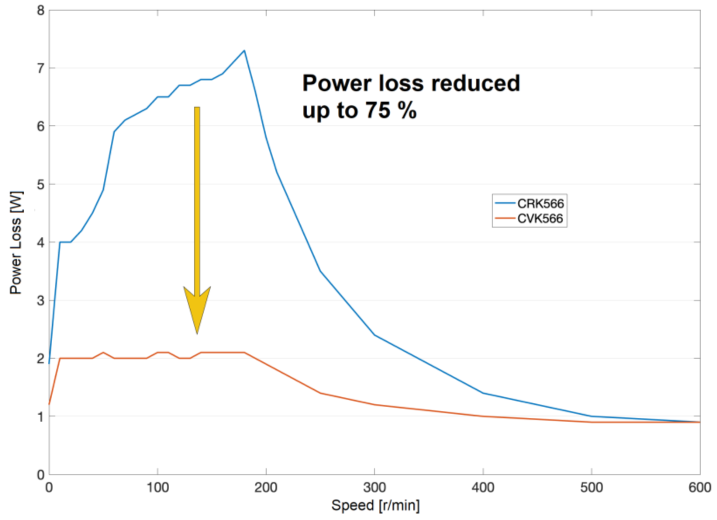



Fig. 7: Up to 75 % less losses through the use of the new CVD driver compared to the conventional driver.

The CVD microstep drivers are available for both 2-phase and 5-phase stepper motors, and in addition to the version for pulse input, there is also one for RS-485 communication.

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