

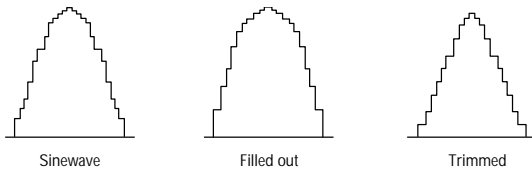
## Microstepping Drives

As we mentioned earlier, subdivision of the basic motor step is possible by proportioning the current in the two motor windings. This produces a series of intermediate step positions between the one-phase-on points. It is clearly desirable that these intermediate positions are equally spaced and produce approximately equal torque when the motor is running.

Accurate microstepping places increased demands on the accuracy of current control in the drive, particularly at low current levels. A small phase imbalance that may be barely detectable in a half-step drive can produce unacceptable positioning errors in a microstep system. Pulse-width modulation is frequently used to achieve higher accuracy than can be achieved using a simple threshold system.

The phase currents necessary to produce the intermediate steps follow an approximately sinusoidal profile as shown in Fig. 2.12. However the same profile will not give the optimum response with all motors. Some will work well with a sinusoidal shape, whereas others need a more filled-out or trimmed-down shape (Fig. 2.12). So a microstep drive intended to operate with a variety of motors needs to have provision for adjusting the current profile. The intermediate current levels are usually stored as data in an EPROM, with some means of selecting alternative data sets to give different profiles. The change in profile may be thought of in terms of adding or subtracting a third-harmonic component to or from the basic sine wave.

Fig. 2.12 Microstep current profile



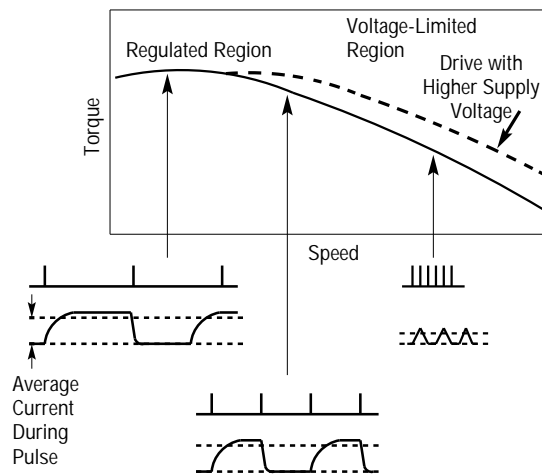
In the case of high-resolution microstep drives producing 10,000 steps per rev or more, the best performance will only be obtained with a particular type of motor. This is one in which the stator teeth are on a 7.5° pitch, giving 48 equal pitches in 360°. In most hybrid steppers, the stator teeth have the same pitch as the rotor teeth, giving equal increments of 7.2°. This latter arrangement tends to give superior torque output, but is less satisfactory as a microstepper since the magnetic poles are "harder" – there is no progressive transfer of tooth alignment from one pole to the next. In fact, with this type of motor, it can be quite difficult to find a current profile that gives good static positioning combined with smooth low-speed rotation. An alternative to producing a 7.5°-pitch stator is to incorporate a slight skew in the rotor teeth. This produces a similar effect and has the benefit of using standard 7.2° laminations throughout. Skewing is also used in DC brush motors as a means of improving smoothness.

Due to this dependence on motor type for performance, it is usual for high-resolution microstep systems to be supplied as a matched motor-drive package.

## The Stepper Torque/Speed Curve

We have seen that motor inductance is the factor that opposes rapid changes of current and therefore makes it more difficult to drive a stepper at high speeds. Looking at the torque-speed curve in Fig. 2.13, we can see what is going on. At low speeds, the current has plenty of time to reach the required level and so the average current in the motor is very close to the regulated value from the drive. Changing the regulated current setting or changing to a drive with a different current rating will affect the available torque accordingly.

Fig 2.13 Regulated and voltage-limited regions of the torque-speed curve



As speed increases, the time taken for the current to rise becomes a significant proportion of the interval between step pulses. This reduces the average current level, so the torque starts to fall off. As speed increases further, the interval between step pulses does not allow the current time to reach a level where the chopping action can begin. Under these conditions, the final value of current depends only on the supply voltage. If the voltage is increased, the current will increase more rapidly and hence will achieve a higher value in the available time. So this region of the curve is described as "voltage limited", as a change in the drive current setting would have no effect. We can conclude that at low speeds the torque depends on the drive current setting, whereas at high speeds it depends on the drive supply voltage. It is clear that high-speed performance is not affected by the drive current setting. Reducing the current simply "flattens out" the torque curve without restricting the ability to run at high speeds. When performance is limited by the available high-speed torque, there is much to be said for running at the lowest current that gives an adequate torque margin. In general, dissipation in motor and drive is reduced and low-speed performance in particular will be smoother with less audible noise.

With a bipolar drive, alternative possibilities exist for the motor connections as shown in Fig. 2.14. An 8-lead motor can be connected with the two halves of each winding either in series or in parallel. With a 6-lead motor, either one half-winding or both half-windings may be connected in series. The alternative connection schemes produce different torque-speed characteristics and also affect the motor's current rating.

Fig. 2.14 Series & parallel connections

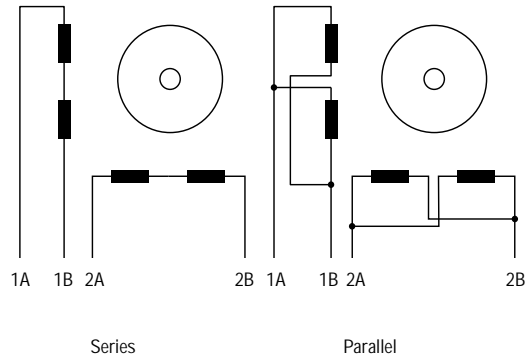
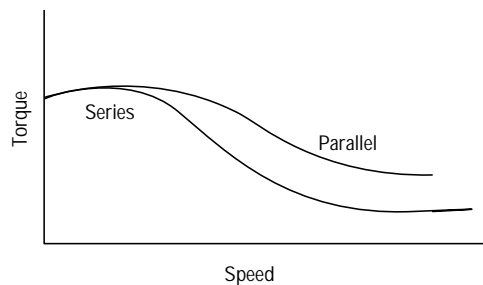


Fig. 2.15 Series & parallel torque/speed curves



Compared with using one half-winding only, connecting both halves in series requires the drive current to flow through twice as many turns. For the same current, this doubles the "amp-turns" and produces a corresponding increase in torque. In practice, the torque increase is seldom as high as 100% due to the non-linearity of the magnetic material. Equally, the same torque will be produced at half the drive current when the windings are in series.

However, having doubled the effective number of turns in the winding means that we have also increased the inductance by a factor of 4. This causes the torque to drop off much more rapidly as speed is increased, and as a result, the series mode is most useful at low speeds. The maximum shaft power obtainable in series is typically half that available in parallel (using the same current setting on the drive).

Connecting the two half-windings of an 8-lead motor in parallel allows the current to divide itself between the two coils. It does not change the effective number of turns and the inductance therefore remains the same. So at a given drive current, the torque characteristic will be the same for two half-windings in parallel as for one of the windings on its own. For this reason, "parallel" in the context of a 6-lead motor refers to the use of one half-winding only.

As has already been mentioned, the current rating of a step motor is determined by the allowable temperature rise. Unless the motor manufacturer's data states otherwise, the rating is a "unipolar" value and assumes both phases of the motor are energized simultaneously. So a current rating of 5A means that the motor will accept 5A flowing in each half-winding.

When the windings of an 8-lead motor are connected in parallel, half of the total resistance is produced. For the same power dissipation in the motor, the current may now be increased by 40%. Therefore, the 5A motor will accept 7A with the windings in parallel, giving a significant increase in available torque. Conversely, connecting the windings in series will double the total resistance and the current rating is reduced by a factor of 1.4, giving a safe current of 3.5A for our 5A-motor in series.

As a general rule, parallel is the preferred connection method as it produces a flatter torque curve and greater shaft power (Fig. 2.15). Series is useful when high torque is required at low speeds, and it allows the motor to produce full torque from a lower-current drive. Care should be taken to avoid overheating the motor in series since its current rating is lower in this mode. Series configurations also carry a greater likelihood of resonance due to the high torque produced in the low-speed region.