Stepper phase current made easy

It is easier to match stepmotors and drives from different manufacturers if you know what each is saying.

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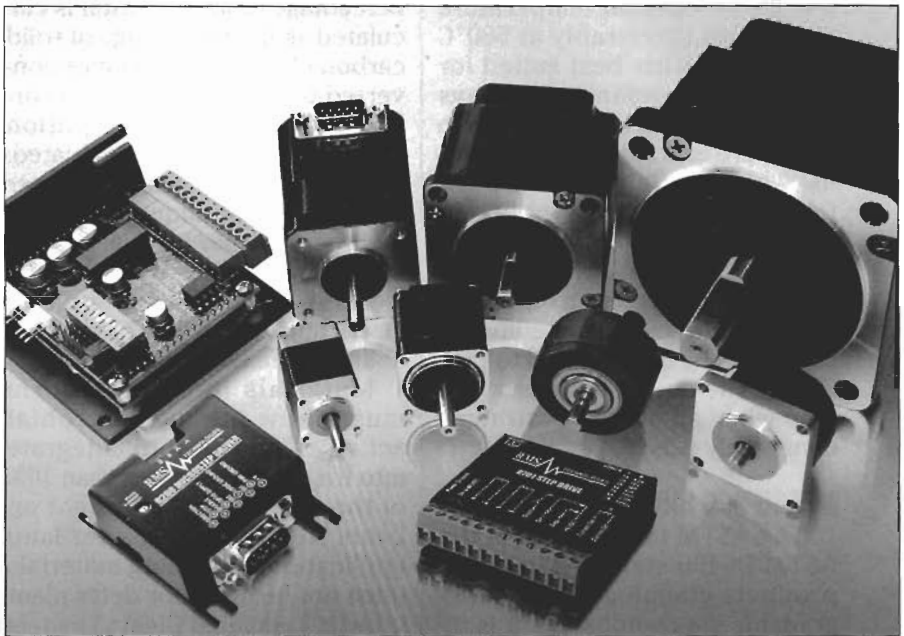

Stepmotors and drives from Lin Engineering.

It's hard to stay up to date when you are floating in a sea of technical jargon. However, it's imperative that engineers know the terminology associated with the areas in which they work. And that's especially true if their assignments take them outside their engineering discipline. For example, a mechanical engineer specifying a stepmotor should understand the associated mechanical and electrical terms.

Stepmotors need the right current if they are to work correctly. Without it, the motors can overheat, miss steps, and even freeze in their tracks. Yet the one electrical specification that most confuses all engineers, from the recent graduate through seasoned veteran, is the rating for stepmotor current. No doubt this happens because stepmotor-current ratings come in many forms such as amps/phase, amps RMS, average current, and even amps peak current.

An understanding of how power is applied to a stepmotor to make it step gives insight into the different current ratings. Most stepmotors have two electrical windings or phases labeled A and B. The phases are placed at a magnetic angle of 90° apart. Current flows through the windings generating a magnetic field that forces the permanent magnet in the rotor to align with the field.

Power for the windings comes from the stepmotor driver. The most common drive technique uses a bipolar, current-controlled method. Bipolar means the driver periodically reverses the polarity of voltage applied to the winding. Current controlled, as its name implies, varies the amount of current the motor sees. When power is first applied, the permanent magnet in the rotor of the stepmotor aligns with the magnetic fields generated by the windings.

To step the motor, current in one phase is turned off. The change in direction of the magnetic field forces the rotor to align with the powered phase. With that, the motor has taken its first step. Power to the first winding is turned back on, but with opposite polarity. This reverses the magnetic field of that phase. The rotor takes its second step to align with the new polarities. The second phase is turned off for the third step, and then its polarity is reversed for the fourth step. Overall, the motor takes eight steps before the polarity sequence repeats.

An obvious problem with this method is that one phase is turned off every other step. The lack of phase current reduces

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motor torque. To compensate for this drop, the driver boosts current in the powered phase. The higher current flow in the powered phase keeps torque the same for all steps.

At first glance, it appears that current through the powered phase should double. Such is not the case, however. When both phases are powered, the rotor locks midway between them. That places the rotor at a 45° magnetic angle to each phase. The strength of the magnetic field felt by the rotor is the *sin* 45° for one phase and *cos* 45° for the other, or only 70.7% of each phase.

When one phase turns off, the rotor aligns with the powered phase. To keep torque the same, the single-powered phase must develop a magnetic field strength of 2 × 70.7%, or 141.4%. The current through the single-powered phase must be 1.414× higher than its value when both phases are powered.

Because current changes with each step of the motor, it's not possible to specify a single value of current when the motor is running. Current ratings in stepmotors stem from the amount of power and, thus, heat that the motor winding can handle. Power, of course, is calculated using the square of the current multiplied by resistance, or $P = I^2R$. Resistance in this case is the resistance of the motor windings. For each motor a value of I is chosen such that I^2R does not exceed the standard power rating of the motor.

Because current is constantly changing in an operating motor, a statistical method is used to calculate the current's effect on motor power. As power is a function of current squared, the method used is called the Root Mean Square, or RMS, method. Using this technique, the value of

Rotation/step

This simplified diagram of stepmotor operation shows how the magnet in the rotor aligns with the magnetic field generated by the pole windings. Step 1 shows current in both phases with the rotor aligned between them. The Phase B current is turned off for Step 2. Without the magnetic field from Phase B, the rotor aligns with Phase A producing another step. The polarity of the current applied to Phase B is reversed in Step 3, reversing the magnetic polarity of the Phase B poles. The rotor attempts to align with both poles, stopping between them as shown. Step 4 turns off the current in Phase A, letting the rotor align with the Phase B poles. The changing currents continue four more steps to bring the rotor almost 360° until, at Step 9, current flows match Step 1 and the cycle begins again.

Each step in this example turned the demo rotor 45°. Actual stepmotors have many more poles and turn only a fraction of that distance per step. Most common motors turn only 1.8 or 0.9°/step.

ON: Normal polarity
(–)ON: Reversed polarity

all currents are squared, the average of their squared values found, and then the square root is taken of that average value. The calculation shows that the RMS value of a stepmotor equals the amount of current when both phases have power. Thus, for stepmotors, average current, RMS current, and amps RMS are identical ratings.

Labels on motors and motor data sheets typically list an amps/phase rating. amps/phase specifies how much average current each winding or phase can handle without burning out the motor. It should be obvious that this value is the same as the amps RMS rating.

Peak current or amps peak is the highest current that can flow through the motor. As previously shown, the peak current is 1.41 × amps RMS. Drivers and controller products cannot supply currents higher than their design permits. Therefore, they specify their current rating in terms of its peak value. Recent changes now have some companies adding both amps peak and amps RMS to their driver data sheets to make it easier for engineers to match what the motor can handle.

The key relationship to remember is that amps peak = 1.41 × amps/phase (or amps RMS). Regardless whether you remember the reason behind the 1.41 constant, understanding the relationship between amps peak and amps/phase is crucial because, for most manufacturers, stepmotors only list amps/phase while drives only spec amps peak. Understanding that difference lets you talk the same language to drive and stepmotor makers alike. **MD**

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Calculating the RMS value

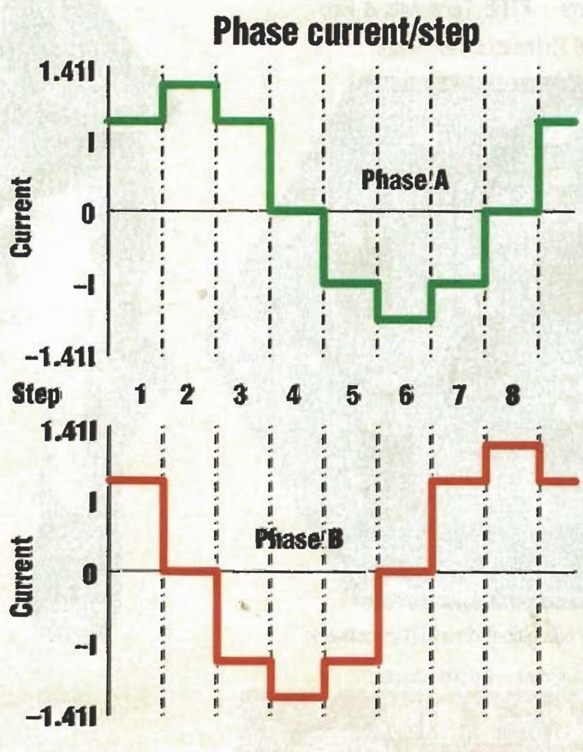
Power dissipation in stepmotors is a function of the square of the phase current times the winding resistance, I^2R. However, phase currents in a turning stepmotor are constantly changing. To determine power dissipation in the motor involves calculating the average power over a specific period of time.

The current pattern repeats every eight steps, so averaging the power level of all eight steps should provide the average power. To find the average power, take the average of the square of the current — a process known as the root-mean-square or RMS value. To help with the calculation, assume the current for each phase is 1 A when both phases are powered, and 1.41 A when only one phase has power.

Calculating the RMS value of current for the eight steps gives:

$$\text{RMS} = \sqrt{1^2 + 1.414^2 + 1^2 + 0^2 + (-1)^2 + (-1.414)^2 + (-1)^2 + 0^2} = 1.0 \text{ A}$$

Notice that the RMS value is the same as when both phases are powered. Thus the amps/phase, amps RMS, and the average current are all the same value, and that the amps peak value is 1.41× higher.



Intensity of current flow changes as a stepmotor rotates. When one phase is off the current through the powered phase must be 1.41× higher to match the torque when both phases are powered.