BY BARRY WIXEY

Universal electric motors

The ubiquitous universal motor. *Universal motors are found on almost all handheld power tools because of their high power-to-weight ratio, their compact size, and the ease of controlling their speed.*

Universal electric motors are used to power portable power tools as well as shop vacuums and small stationary and benchtop tools. Compared with the induction electric motors found on large stationary tools (see *FWW* #167, pp. 96-98), universal motors tend to be lighter and less expensive. They also are noisier, run faster, and wear out quicker, but with some routine maintenance, you can keep them humming.

How universal motors work

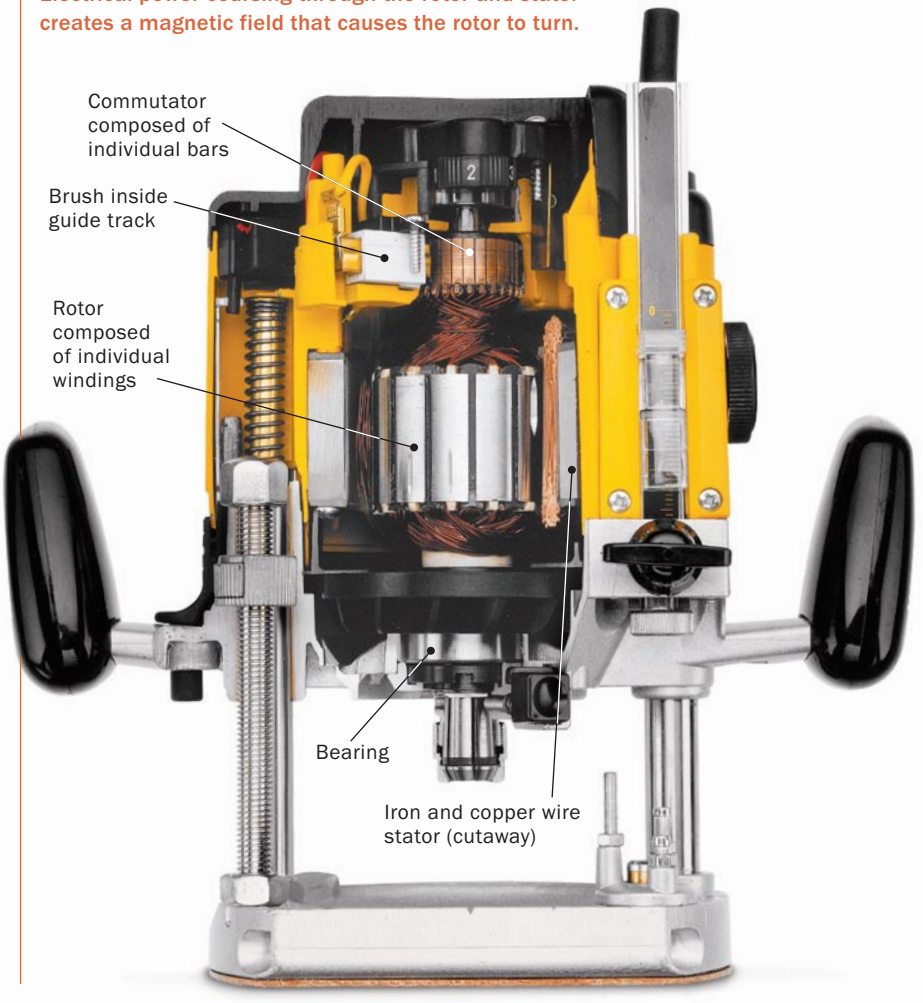
Universal motors consist of a rotor surrounded by a stator, both made from copper wire and iron. The rotor contains a number of separate coils or windings of copper wire, and the ends of these windings are attached to the bars on the commutator. Electrical power is fed to the rotor via this commutator and two carbon brushes, and to the stator through conventional wires.

When current flows through the stator, it becomes an electromagnet. When power is applied to a bar on the commutator through the brushes, that particular winding causes the rotor to become an electromagnet, too, whose north and south poles are nearly aligned with the north and south poles of the stator. The north pole of the stator repels the north pole of the rotor, which causes the rotor to rotate. This in turn lines up a new set of bars and brushes, which move the magnetic fields back to their previous positions, and the poles are repelled over and over again, keeping the motor turning.

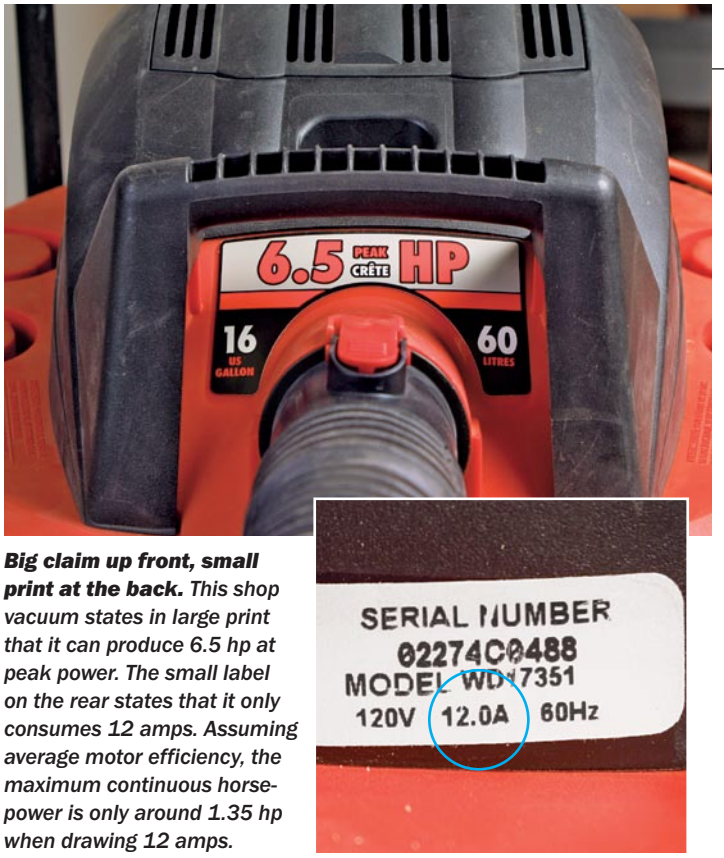
The speed of a universal motor is controlled in two different ways. Cheaper tools use a rheostat

THE PARTS OF A UNIVERSAL MOTOR

Electrical power coursing through the rotor and stator creates a magnetic field that causes the rotor to turn.



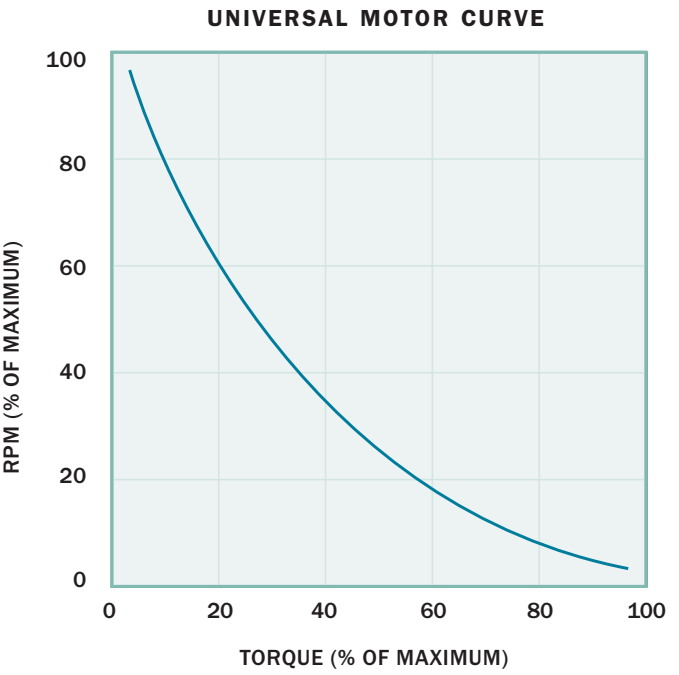
Photos, except where noted: Mark Schofield; this page (bottom): Courtesy of DeWalt



Big claim up front, small print at the back. *This shop vacuum states in large print that it can produce 6.5 hp at peak power. The small label on the rear states that it only consumes 12 amps. Assuming average motor efficiency, the maximum continuous horsepower is only around 1.35 hp when drawing 12 amps.*

Understanding power

Universal motors without electronic speed control will slow down as the load, or torque, increases. Eventually, the motor stalls at near-maximum torque.



(like a light dimmer) to reduce the voltage supplied to the motor and hence to slow it down. This system will not maintain the motor's speed when it is under load and is likely to be found on such items as inexpensive drills.

Some products use a constant motor-feedback system that either measures or calculates the motor speed and adjusts the voltage accordingly to try to maintain that speed. This type of system commonly is found in high-end routers.

What to look for in a motor

Manufacturers test universal motors to determine a specific amount of useful life. This testing usually consists of a mixture of mild use, heavy use, and stalls. It is not uncommon for the minimum life expectancy of upper-end professional tools to be 500 hours or more, whereas the minimum life span of some low-end consumer tools may be less than 100 hours. How do you determine which tool has the better motor?

Peeking through the cooling grills on most power tools allows you to see how many bars there are on the commutator. As a general rule, the greater the number of bars, the greater the life expectancy of the motor. Also examine the size of the contact area between the brush and commutator: The larger the area the better. Most important, check the amp rating of the tool. A higher-rated motor is designed to take heavier use.

Consider amps and watts, not horsepower—Like most people, you probably are confused by the outrageous power claims on some products. I have seen routers rated at 3.5 hp and wet/dry vacuums boasting more than 6 hp.

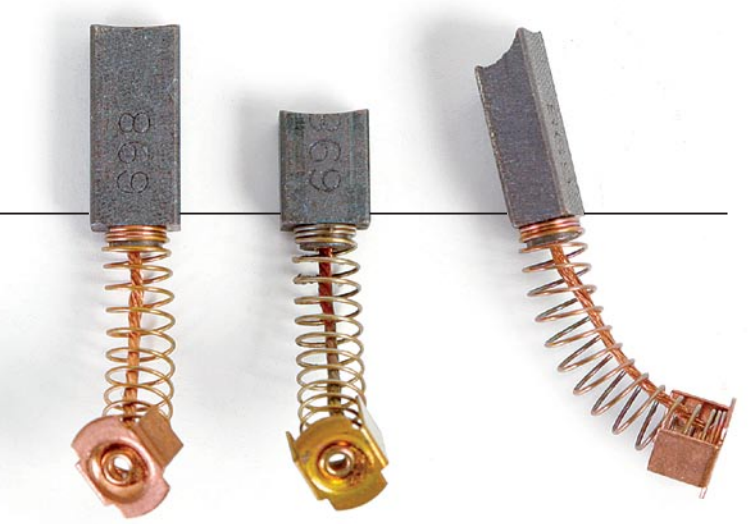
But the horsepower ratings start to fall apart when you do the math and consider all of the variables. A standard household outlet is rated for 15 amps at 120 volts; 15x120 = 1,800 watts; and 1 hp = 746 watts, so 1,800/746 = 2.41 hp. To muddy the waters even more, this 2.41-hp rating assumes the motor is 100% efficient. Motor efficiency is the amount of mechanical power out to electrical power in. In universal motors this efficiency is in the neighborhood of 65% to 75% when the motor is near its peak load. So assuming 70% efficiency in the example above, the output could be only 1.7 hp, with the balance of the power going to waste, mostly as heat.

So how can a 120v tool be rated any higher than around 1.7 hp? What you are witnessing here is a rating game reflecting a tool's peak power, not its continuous power. This game was started many years ago by a well-known major tool brand and has been adopted by some other power-tool companies over the years.

When approving a power tool, scientists at Underwriters Laboratories (UL) do not even consider horsepower as a means to rate the power of tools. The only power ratings they use are either amps or watts to measure a tool running continuously without failure. If a

Motor maintenance

Periodically remove the plastic caps and pull the carbon brushes out of the motor. Check if they have chipped or worn down below the recommended minimum length.



The good, the bad, and the ugly. *The brush on the left is new. The center brush has worn down and should be replaced. The one on the right has cracked and will cause excessive sparking in the motor.*

File to fit. *The brushes should slide into the housing easily so that the spring can keep the brushes in good contact with the commutator. If the fit is tight, smooth the edges of the brush with a fine file.*

power-tool company puts an amp rating or a watt rating on a tool that is UL approved, you can be assured that it can put out that much power continuously. The horsepower claims that a company makes can be derived by any test method the company chooses to adopt. The bottom line: When comparing power between different tools, it is best to look at the amp or watt rating.

Motor life—use and abuse

As mentioned before, no motor is 100% efficient, because the harder you push a motor, the more heat the motor produces. Compounding this is the basic nature of a universal motor. The torque versus rpm curve (see the graph on p. 20) shows that as the torque is increased by forcing a tool to take a bigger or faster cut, the rpm drops until the motor stalls. As the speed decreases, so does the fan speed and consequently the airflow needed to cool the harder-working motor.

If the temperature of the motor's copper wires gets too high, the varnish insulation can burn off, cause the wires to short out, and even eventually melt the copper.

An occasional stall where the power is removed immediately or the circuit breaker trips will not harm the motor or reduce its life. However, allowing a circular saw with no overload protection to stall repeatedly as you rip that oak beam will gradually raise the internal temperature to burnout levels. It's all about keeping the motor cool.

Maintenance for universal motors

If the air vents and the inside of the motor become packed with sawdust, excessive heat can develop quickly, even if you run a tool below its designed capacity. Dust also can clog the track that the brushes slide in so that the springs can't push the brushes properly against the commutator. This lack of contact causes arcing (sparks between the brushes and commutator) that can overheat the windings and destroy the commutator. Therefore, your most regular maintenance should be to remove any dust in your power tools with a vacuum.

Even when the brushes are making perfect contact, both they and the commutator will wear away gradually. On most universal motors you will be lucky to get 100 hours out of a set of brushes, but they can be replaced a number of times. Check the brushes regularly and compare their length to that specified when your manual says it is time to replace them.

This information should be helpful the next time you purchase a power tool. Check the motor specifications carefully so you are sure of the real power you are buying, and then take a look at the tool's overall construction. With proper use and regular maintenance, motors will give many years of trouble-free performance. □