Making Sense of Motors

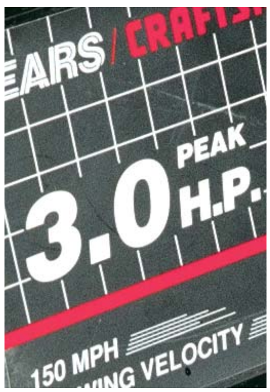
How to cut through the horsepower hype and compare power tools

BY MARTIN SEIFERT

Motorized tools often come with fabulous claims of high horsepower ratings. For example, in my shop I have a vacuum, a router and an air compressor with labels boasting outputs of 3 hp, 3.5 hp and 5 hp, respectively. They are all intended to plug into the same 115-volt, 15-amp residential outlet.

Well, if I jammed the circuit breaker so that it wouldn't trip, maybe I could get that kind of horsepower out of these tools before they went up in smoke. When you see the terms "maximum" or "peak" horsepower, watch out. Horsepower claims couched in those terms aren't complete lies, but they're not always useful for evaluating true power.

Woodworking machines aren't meant to be run like dragsters, pushed to within a couple of rpm of meltdown. They're built to operate at steady cruising speeds with



Hyping horsepower. *The term "peak horsepower" is not as meaningful as "continuous horsepower," a truer measure of a tool's performance. When assessing motors, look at the small print and compare amp ratings.*

occasional bursts of power. When shopping for motorized tools, I look at the fine print on motor labels and do a little math.

Many things affect power output

An electric motor is a device that converts electrical energy into motion. The amount of current pumped into that motor determines, in part, how much horsepower it puts out. A horsepower is a unit of power that's defined as 746 watts. A watt is also a measurement of power; the electric meter on your house tabulates how many watts of power you consume every minute of every day.

The power that comes into your house is parceled out in amps and volts. Think of amps as the volume of current and volts as the pressure. One amp under the pressure of 1 volt equals $\frac{1}{746}$ hp. That brings us to the simple equation for figuring out horsepower: (amps × volts) ÷ 746 = hp.

If that's all there were to it, figuring out a motor's horsepower would be simple. But two other things affect the equation: power factor (pf) and efficiency (eff), things that have to do with how a motor is built and how much of the current goes directly

What to look for in a universal motor

There are a few easy-to-spot qualities to seek out in a universal motor, the type usually found on portable and benchtop tools such as drills, routers and sanders. (Bigger induction motors, like those found on stationary tools such as saws, grinders and planers, are mostly enclosed and can't be evaluated as easily.) The first step is to bring along a few tools when shopping, such as a screwdriver and penlight.

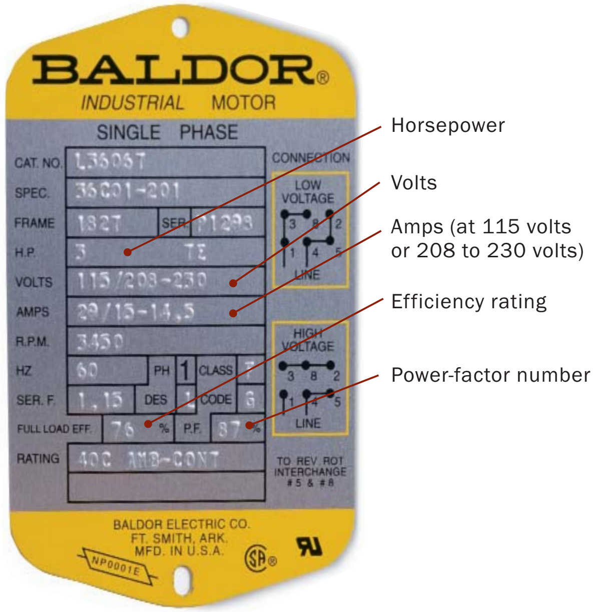
I am not shy about taking a new router off the shelf and unscrewing the brush cover to take a peek inside. A good-quality commutator on a tool that's been broken in should be brown (like an old penny) and smooth, which means the brushes are leaving a nice, thin film of material behind. If the copper is very shiny or grooved, the brushes are stripping away metal. (A new commutator that hasn't been used will be the color of shiny copper.)

Another sign of quality is the number of segments in a commutator (see the photos

Photos: Anatole Burkin

DECIPHERING CONTINUOUS HORSEPOWER

The nameplate on an industrial motor, such as this 3-hp Baldor, gives you all the information you need to figure out continuous horsepower. Not all manufacturers provide this information.



$$\frac{\text{amps} \times \text{volts} \times \text{power factor (pf)} \times \text{efficiency (eff)}}{746} = \text{continuous horsepower}$$

$$\frac{29 \text{ amps} \times 115 \text{ volts} \times 0.87 \text{ pf} \times 0.76 \text{ eff}}{746} = 3 \text{ hp in the example above}$$

into creating motion. Power-factor and efficiency ratings—both of which reduce horsepower output—vary among motors, and they're not things most tool sellers publicize. Power-factor and efficiency losses of between 10% and 30% are pretty common. A company's technical-support department may be able to tell you what the power-factor and efficiency ratings are for any given product if you really want to know.

You can trust amperage ratings

Look at any motor's nameplate, and you'll see two essential numbers: amps and voltage (see the photo above). And assuming that the motor has an Underwriters Laboratory (UL) label, it has been tested to run safely at the rated voltage and amperage without turning to toast (for some tips on evaluating a motor, see the story below). Because voltage can vary slightly, most tools will run fine between 110 volts and 120 volts. But for consistency's sake, I'm going to assume a voltage of 115 when making comparisons.

Horsepower claims aren't regulated like amperage ratings, and manufacturers can make a lot of interesting claims. Take that 3.5-hp router I own. It's rated for 13 amps. Let's do the math:

(13 amps × 115 volts) ÷ 746 = 2 hp.

Power-factor and efficiency losses will bring that number down to around 1.5 hp, which is the most continuous horsepower you can expect from any tool that plugs into a 115-volt, 15-amp circuit. The equation for calculating continuous horsepower goes like this:

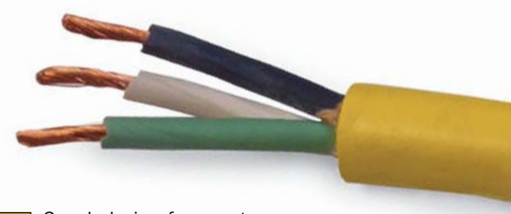
(volts × amps × pf × eff) ÷ 746 = hp.

Yes, many motors will survive a surge in amperage under heavy load and produce

WIRE COMES IN DIFFERENT GAUGES

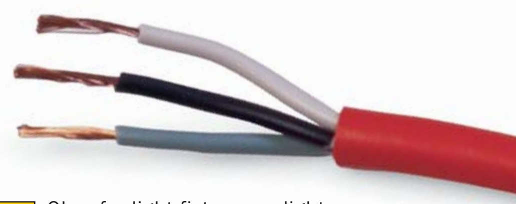
The lower the number, the fatter the wire. High-amp tools require a thick wire. As the length of a cord increases, so must the wire gauge. Check a tool's instruction manual for specific guidelines.

10 ga. Best for large stationary machines



12 ga. Good choice for most portable power tools

14 ga. Short runs okay for small- to medium-sized tools



16 ga. Okay for light fixtures or light-duty tools

at right). While looking through the brush-access port of a well-made tool, there should be three segments of a commutator visible. That means each brush is in contact with at least

continued on the next page

A COMMUTATOR TELLS A LOT ABOUT A MOTOR.
A universal motor, as found on most portable power tools and many benchtop machines, has a commutator, the copper bars at the base of the shaft. A good commutator should be a dull copper color and contain many segments, like the one on the left. The commutator on the right has fewer segments, the sign of a lower-quality tool.

Quick checkup for power tools

Testing the current draw (amps) of a motorized tool is a good way to spot problems. And it takes only a few minutes using an ammeter. When I'm shopping for used tools, I take the ammeter with me and test tools on the spot. I also test new tools after bringing them home from the store to make sure they're working properly—or as advertised.

I prefer Fluke Corp. professional equipment (425-347-6100), but Radio Shack (800-843-7422) sells some less-costly testers that will work, too. To get useful information, you'll need to test tools under a load. It's important that the cutting tool be sharp and that the load be a typical woodworking operation.

For example, to test a drill, I'll chuck in a sharp, large bit and bore into a chunk of wood while a helper observes the meter. The Radio Shack ammeter has a special female plug that a tool plugs into; a male plug from the meter goes into the wall outlet. With other meters you must open your service panel and isolate the hot wire. Either way, turn off other appliances or lights to the circuit being used for the tool test, then record the reading while running the motor at full load.

If the reading varies 10% or less from what's on the nameplate, I'm not worried. I enter that number in the tool's manual for reference. Down the road, if a tool isn't performing well, I'll check it again. If the reading is different, then I know the tool needs servicing. For example, a high reading on the ammeter when a tool is not under load may indicate that a bearing is about to seize.—*M.S.*

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extra horsepower as well as excess heat. But that's like pushing the rpm of your car well into the red zone before shifting gears. You can get away with it for a while but at a cost in longevity.

Robert Carson, the electrical engineer at Delta International, says excessive temperature is the enemy of electric motors. "The bad thing about running hot is that temperature burns up a motor. There's a general rule of thumb: You load the motor up to the amps on the nameplate, and that produces a safe operating temperature. That motor is designed to run 40 years like that. But every time you overheat a motor by 10°, you halve the life of it. On a new tablesaw, if you're ripping thick oak at an overly fast rate and overheating the motor by 10°, your motor is good for 20 years. Do it again, then it's good for 10 years. Do it again, then five years. And so on."

Motors on many newer tablesaws come with thermal overload protection. When the motor overheats, it automatically shuts down and won't start until it cools. This is a good safety feature to look for. But if you have a saw with thermal overload protection and it continually shuts down, chances are you're asking it to do too much. Assuming there's no problem with the tool, the blade and your power supply, you either need to change the way you feed stock or get a more powerful machine.

Other things that affect power output

The actual power output of electrical motors is affected by other factors, including the length of wire from the circuit breaker to the tool, the number of other outlets connected to that line, the type of extension cords used and the condition of outlets, switches and motor bearings. If you have other tools or lights running off the same circuit as a high-amp motor, the motor may not be able to get enough current to reach its full potential.

To give a motor all of the current it needs at full load, do not use an extension cord longer than absolutely needed and use the proper gauge wire recommended by the tool manufacturer. I never use a cord smaller than 12 ga. (the higher the number, the smaller the diameter) for any tools in my shop. A 12-ga. power cord can handle up to 20 amps (for more on wire gauge, see the story on p. 73).

There's another trick to preventing an overload. Whenever possible, I wire my induction motors (the nameplate usually says whether this is an option) for 230 volts (see the left photo on p. 73). The advantage of changing from 115-volt to 230-volt operation is that all else being equal, at twice the voltage the equivalent power tool will run with one half of the current. Because current is what overloads wires, by halving the current I give myself a greater margin. For a given cord length I have one half the problem, or I can go twice as far from my socket with the same tool. Put another way, a contractor-style tablesaw that's rewired for 230 volts may give you the edge to rip a hunk of 8/4 maple without tripping the overload protection or circuit breaker. □

Martin Seifert works in the automation and power plant generation industries and enjoys woodworking in his spare time.

Universal motors (continued)

three sections of the commutator at any given time. On cheaper consumer-grade motors, you'll only see one or two segments in contact with the brushes. More segments means the tool will have a smoother torque output when under load.

Put the tool back together, plug it in and examine the arc around the commutator. On a good-quality motor, the arc will be confined close to the brushes. The arc on a cheaper motor will be blowing out all over the place like a Fourth of July sparkler.

In general, better-quality tools typically come with soft rubber power cords that stay pliable even in cold weather. But there are times when I don't need an industrial-quality power tool, so I'll settle for less. I will replace the power cord, though, if it's made of stiff vinyl. Replacing the cord will make the tool easier to use.—*M.S.*