a closer look

Brushless motors

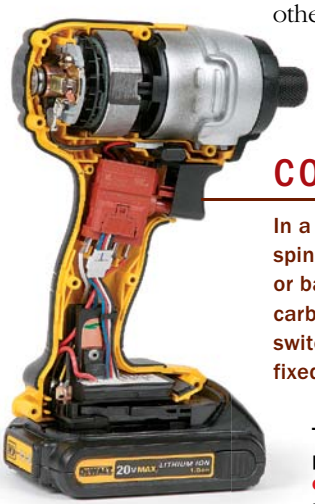
NEW MOTOR TECHNOLOGY IS SPURRING OTHER CHANGES TO POWER TOOLS

BY MARK SCHOFIELD

Electric motors have to be one of the most reliable machines ever made. A few years ago, I picked up an old metal jigsaw at a tag sale. The owner apologized that it hadn't been used since her husband had passed away 30 years earlier. I plugged it in and away it went, just like new. So why would anyone want to replace this tried-and-tested motor with one that's more complicated and costs more to make? In a word, efficiency.

In his test of impact drivers (see pp. 42–45), Eric Constans compared nearly identical brushed and brushless models to see if the brushless type deserved the marketing hype. He found that brushless drills do indeed run longer than brushed-motor drills on a single battery charge (but the difference isn't quite as big as advertised).

While working with Constans on his article, I talked to a lot of engineers at various power-tool companies and realized that the introduction of brushless motors is connected to two other changes in tool technology. Lithium-ion batteries are also evolving, as are the electronics that govern the trigger, motor, and battery.



Electric motors are simple

One reason electric motors are so reliable is that they are pretty simple. The force behind all electric motors—both brushed and brushless—is the attraction between two sets of magnets. In a normal brushed motor, fixed magnets surround spinning electromagnets. The electromagnets receive power by means of carbon brushes that rub against a segmented cylinder called a commutator. Carbon, in the form of graphite, is used because it conducts electricity well, yet slides easily over the commutator. However, graphite is relatively soft so the brushes wear out over time and need to be replaced.

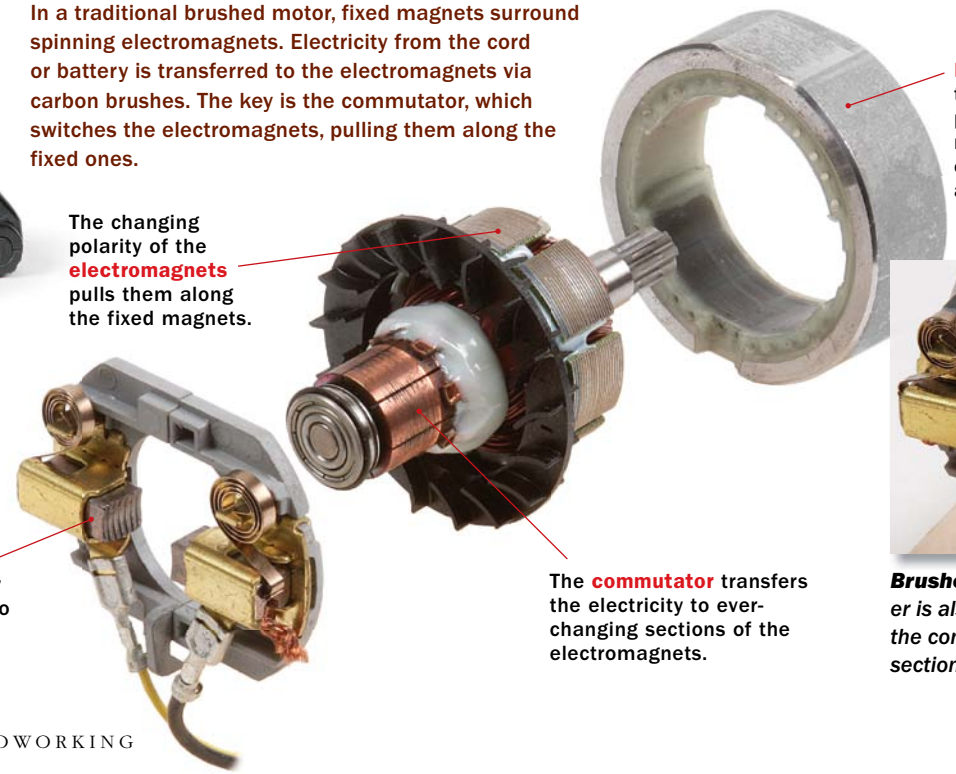
Other drawbacks of brushes are the drag they create and the sparking caused as they cross from one segment of the commutator to another. Both reduce the efficiency of the motor.

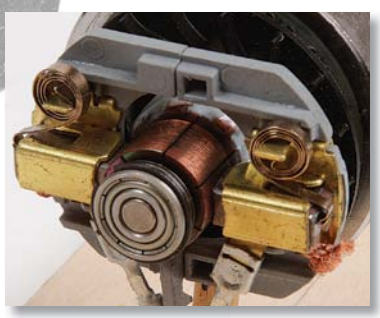
How brushless is different

In a brushless motor, the positions of the magnets are reversed, with fixed electromagnets surrounding conventional magnets. Because the electromagnets don't move, the power can be supplied directly without the use of brushes. There is no friction or arcing, so the motor is more efficient. What

CONVENTIONAL MOTOR

In a traditional brushed motor, fixed magnets surround spinning electromagnets. Electricity from the cord or battery is transferred to the electromagnets via carbon brushes. The key is the commutator, which switches the electromagnets, pulling them along the fixed ones.





Brushes rub. *This creates drag. Power is also lost in the form of sparks as the contact point switches from one section of the commutator to the next.*

Photos: staff

makes the motor more complicated, and adds to the cost, is a microcontroller that reverses the direction of the current every fraction of a second.

Although first invented in the 1960s, brushless motors didn't become commercially viable until the 1990s with the growth of sophisticated and cheap electronic controls. If you're a fan of radio-controlled cars, you'll already appreciate brushless motors for their compact size, their lack of friction at high rpm, and the greater battery range they can accommodate. Cooling fans in computers almost all use brushless motors because they run cooler and the lack of sparking means no electronic interference.

The delay in getting brushless motors into woodworking tools has been a combination of scaling up their size, dealing with the high peak loads these tools need to handle, and seeing if the market will pay more for a tool, particularly in a depressed economy.

A friend to lithium-ion

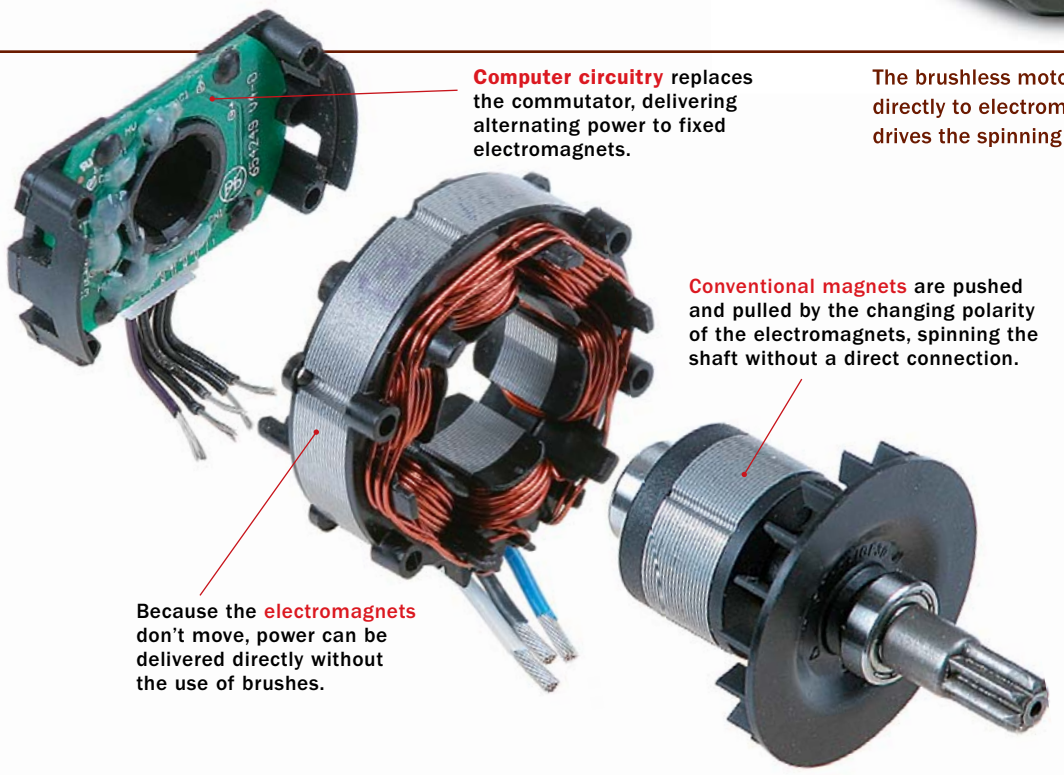
The brushless motor's microcontroller can be programmed to react to changes in speed and load by changing the timing of those current reversals. It turns out that this electronic control is also vital for getting the best out of lithium-ion batteries.

When lithium-ion batteries were introduced into woodworking tools, they were hailed as a breakthrough. Seven years later, several tool companies admit that early versions of the batteries left a lot to be desired and that customers ended up finding faults that should have been uncovered in the lab. I'm not the only woodworker annoyed to find that my battery suddenly couldn't be charged. As

The battery has a chip, too. *Lithium-ion batteries have a computer circuit board that controls the draw, preventing the cells from being over-taxed and permanently damaged.*

BRUSHLESS TECHNOLOGY

The brushless motor is the best of all worlds. Electricity is delivered directly to electromagnets with no power loss, while magnetism drives the spinning shaft with no friction.



Computer circuitry replaces the commutator, delivering alternating power to fixed electromagnets.

Conventional magnets are pushed and pulled by the changing polarity of the electromagnets, spinning the shaft without a direct connection.

Because the **electromagnets** don't move, power can be delivered directly without the use of brushes.

No touching parts. *The shaft on a brushless motor spins more freely, unhindered by the drag of brushes.*

one engineer said, "It's a finicky technology and lithium-ion has to be managed far more than NiCd [nickel-cadmium]".

All lithium-ion batteries require some kind of computer chip in the battery itself or in the tool's switch to monitor the draw from the battery. Without this electronic control, you could burn out the battery in seconds and it might even catch fire.

The fact that both the brushless motor and the battery require electronic control has spurred manufacturers to create far more sophisticated circuits that optimize the draw from the battery, the output of the motor, and the overall run time. These changes should also increase the lifespan of the battery.

Beyond cordless? *Manufacturers' initial forays into brushless motor technology have been confined mainly to cordless tools. So far the only other brushless woodworking power tools have been Festool's high-end offerings and Porter-Cable's low-profile sander.*

It makes more sense to put brushless motors in cordless tools where their efficiency will directly result in longer run time.

Why impact drivers are leading the way

All that said, with the exception of Festool, manufacturers have been fairly slow to introduce brushless technology into woodworking. A few years ago, Porter-Cable introduced a low-profile, 5-in.-dia. random-orbit sander. The shape of the brushless motor allowed the sander to be much shorter and more stable than other sanders. However, the brushless motor's efficiency wasn't really a factor because the sander was corded.

Since then almost all the other brushless tools have been cordless drills, and in particular, impact drivers. It makes sense to put brushless motors in cordless tools where their efficiency will directly result in longer run time. Impact drivers are an even better fit. First, according to manufacturers, they have been the fastest-growing segment of the drill market over the last five years. Second, they are popular in Japan where a lot of development work on brushless motors was done. And finally, the way impact motors work means that they automatically limit peak draw from the battery at around 50 amps, while a conventional drill can pull over 200 amps. This means the electronic control of battery power doesn't have to be quite as sophisticated on an impact driver.

Manufacturers were coy about what other tools might receive brushless motors. They are waiting to see how well the drills are received, how price-sensitive the market is, and how the construction sector recovers. I would expect to see brushless motors in a wider range of drills over the next year or so, but the brushless, corded router could be a few years off. In the meantime I recommend the current brushless drills, particularly if you draw down a battery or more a day. However, look for the longest warranty you can find on both tool and battery. □

Eric Constans, chair of mechanical engineering at Rowan University, Glassboro, N.J., helped with this article. Mark Schofield is the former managing editor.

HEAD-TO-HEAD COMPARISON

While testing brushless impact drivers for a separate article (see pp. 42–45), we also tested the conventional brushed models of the same tools where available. The brushless motors offered distinct advantages in both run time and torque.

TYPE	BRUSHED IMPACT DRIVERS	BRUSHLESS IMPACT DRIVERS
AVG. SCREWS PER AMP-HR.	90.5	110.2
AVG. PEAK TORQUE (IN.-LB.)	1,080	1,200
AVG. SUSTAINED TORQUE (IN.-LB.)	45.78	56.91