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THE BENEFITS OF BRUSHLESS MOTORS, WITH THE APPLICATION SIMPLICITY OF BRUSHED MOTORS

Surprisingly, the brushed electric motor and the incandescent bulb have many things in common: both were invented and optimized in the 19th century, their ease of use has made them ubiquitous companions of our everyday life throughout the 20th century and they are now both falling victim to regulations emphasizing energy efficiency in the 21st.

But while the incandescent lightbulb has largely disappeared, brushed motors are only slowly being replaced by their more efficient brushless variants. This is partly for cost reasons, but also because significant technical challenges remain when implementing brushless motor systems. Semiconductor technology has helped the cheap but inefficient incandescent lightbulb disappear and will likely do the same with the brushed motor.

Electric motors are present everywhere, but unlike lightbulbs, they are less obvious. Whenever something inanimate moves, most likely it is being powered by an electric motor. These motors run our refrigerators, dishwashers, and washing machines at home. They open doors, move elevators, escalators and trains as we make our way to work. They brew our coffee, cool our computers and run the air conditioning at work. In modern cars 20 to 50 electric motors are employed to power a variety of functions from adjusting the mirrors, headlights and seats, pumping fuel, water and windshield fluid, as well as assisting with braking and steering. As the electric vehicle becomes more prevalent, electric motors will take over moving the car itself.

The motor of choice for most of these applications over the last century has been the brushed motor because it is beautifully simple to use. Like the lightbulb, it works as soon as it is switched on - reverse the voltage across its terminals and the motor will reverse direction. Vary that voltage and the speed changes. This simplicity is possible because a mechanical switch (the commutator) inside the motor keeps it rotating. The commutator consists of a revolving segmented assembly that connects to the rotating motor coils; and sliding contacts (brushes) that conduct the current from the fixed motor case to connecting segments. As the motor coil assembly rotates, the coil terminals slide past the brushes, directing current through the coils in such a way as to maintain rotation.

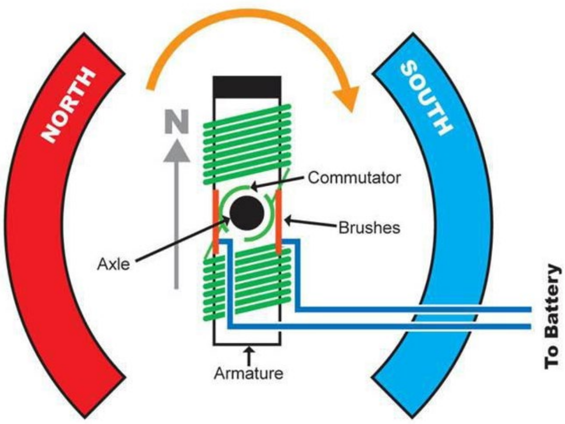

Figure 1 *Schematic of a brushed motor*

While the commutator makes brushed motors easy to use, it is also the main source of its problems. The commutator (usually, mainly copper) is subject to mechanical wear and tear, limiting the lifetime of the motor. The brushes (normally carbon) wear out generating dust which reduces motor performance. In addition, when the motor current switches from coil to coil along the slip rings, electric arcs form. Such brush arcing generates ozone, as well as causing acoustic noise and EMI, with all of its associated potential for interference. In dusty or combustible environments, brush arcing can be very hazardous as it can start fires and even cause explosions. The commutator, with its mechanical brushes, also limits the electric efficiency of the motor up to a maximum of 70%; whereas a motor without brushes can achieve efficiencies of up to 90% (as Nicola Tesla showed back in the late 19th century). If brushless motors are more efficient, more reliable and more environmentally friendly than brushed motors, why are brushed motors still so common today?

As with the incandescent bulb and the LED light, replacing something cheap and simple with something more complex and expensive usually requires some initial regulator pressure from government until mass production brings the price down. International energy efficiency standards (such as Energy Star in North America and Ecodesign in the European Union) are forcing companies to comply. In addition, consumers have become increasingly concerned about the environment and energy conservation and are now more willing to spend money on energy efficient products, either for conscientious reasons, or to lower their utility bills. As a result, energy efficiency, apart from being a purely a legislative requirement, is also being seen as a way for engineers to set their products apart from those of the competition. Likewise, in the automotive sphere, car manufacturers

have been required to improve fuel economy by ever tightening CO2 emission standards. This can be achieved in many creative ways, but a sustainable approach is to replace the drive, in systems that were traditionally mechanically connected to the combustion engine, with electric motors. The latter can be better optimized for the task at hand and run only when necessary. A good example is the power steering system, which has to provide maximum steering support during parking with an idling engine. When the power steering system was still linked to the engine it wasted a lot of power on the highway when steering is minimal, as a result the power steering system in the car became one of the first applications to use a brushless motor. Increasingly, as regulations tighten, brushless motors are being designed into hydraulic pumps for brake support, engine cooling fans, fuel pumps, oil/water pumps, etc.

Although replacing conventional brushed electric motors with brushless motors is a fast path to higher efficiency and reliability, while eliminating noise and pollution, the implementation of brushed motors is a significant challenge for engineers. What was previously done mechanically by the commutator must now be done electrically with a three-phase inverter. The inverter needs a gate driver which is usually controlled by a microcontroller implementing complex motor control algorithms. As a result, engineers that develop these applications not only need to be competent in hardware design as well as microcontroller programming, but they also need a thorough understanding of motor physics to design maximum efficiency into the system. Brushed motor application designers do not usually have these skills, so they feel uncomfortable using brushless motors.

What these engineers need is an off-the-shelf solution that does not require in-depth design and programming expertise to get a brushless motor running. The goal is to make brushless motor application development just as straightforward as brushed motor development, so that application engineers can focus their expertise on their application and not on how to make the motor turn. Similar to replacing the incandescent bulb with LED lights, the semiconductor industry can support the shift towards the use of brushless motor deployment by solving the complexities of the motor control systems for their customers. Fortunately there are companies that are beginning to rise to this challenge.

One example is ON Semiconductor, which has used its experience with “easy to use” motor drivers for stereo equipment, disc drives and cooling fans to focus on the development of brushless drivers for industrial and automotive applications. In particular with the highly integrated LV8907, the company has introduced a motor driver IC that makes brushless motors as easy to use as brushed motors, without requiring any software development. The LV8907 can be used for 12V industrial and consumer applications, but is also compatible with automotive requirements and only needs six power switches and a few discrete resistors and capacitors. The IC takes care of start-up, sensor-less commutation and various safety features required for running a brushless motor. After motor and application relevant parameters have been uploaded via SPI interface, all that is necessary to control motor speed is a pulse width modulated (PWM) control signal - just as in brushed motor applications. All relevant parameters can be stored in the device’s embedded non-volatile (OTP) memory and will remain fixed during the lifetime of the application.

While it is possible to use an on-off switch for fixed speed operation, the LV8907’s built in P-I speed control loop combined with a PWM input allows precise regulation of the motor speed during varying supply voltage and load conditions. Integrated protection functions can safeguard the application from over-current, over-voltage and over-temperature, as well as other fault conditions. In the case of a blocked rotor, the LV8907 will stop driving the motor and restart it again after a set interval.

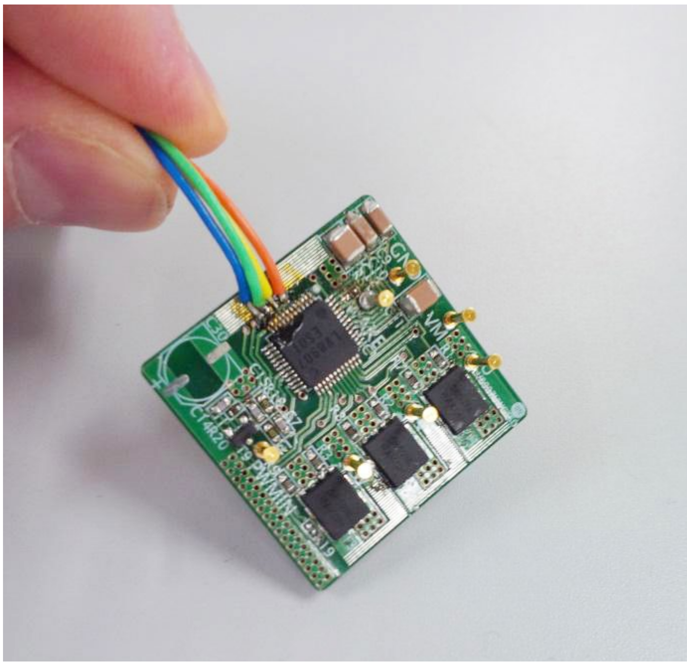

Figure 2 *This brushless motor solution featuring an integrated controller/driver plus three dual FETs.*

The transition from brushed to brushless motors is already underway for efficiency reasons, and tightening government regulations are accelerating this development. However, as there are significant technical challenges involved in this transition, they still present an obstacle to increasing the range of brushless motor applications. Through the introduction of intelligent motor control solutions for brushless motors, the semiconductor industry is offering more and more products that remove these obstacles. Thus brushless motors, like LED lights, are likely to become more widespread to respond to our environmental challenges the brushed motor might soon be as much a relic of the past as the incandescent lightbulb has become.

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