Electric Motors Q&A

A first acquaintance

All electric motors turn and can therefore be used to move something. However, each type of motor has its own characteristics, so it's helpful to choose a motor type and drive arrangement that match the sort of motion you need.

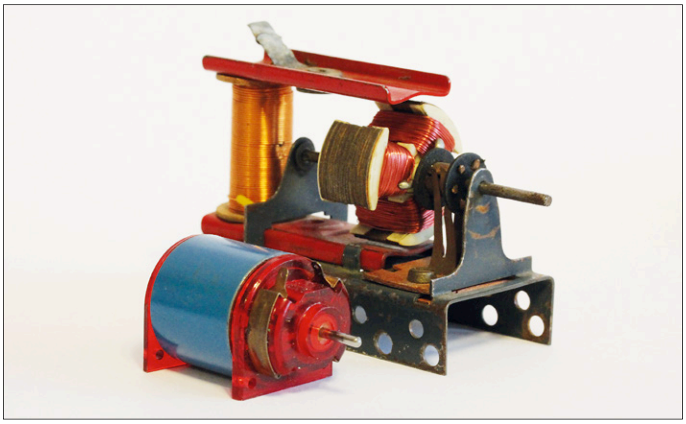

Figure 1. "My first motor" (or two): starting with the basics. The one with the blue housing is a DC motor; the one on the right can run on DC or AC, so it can be connected directly to a model train transformer.

By **Ties Wijffels** (Netherlands)

Q *Let's start with the supply voltage. Should it be DC or AC?*

A The motive force behind every electric motor (**Figure 1**) is magnetism: a magnetic field drives another magnetic field. In order to produce motion, one of these magnetic fields must be constantly changing. This is always achieved by using an electromagnet. The static field can be produced by a permanent magnet, a second electromagnet, or a short-circuited winding on the rotor.
In a DC motor the rotor windings are switched by a commutator, which is a sort of changeover switch mounted on the rotor. However, that can also be done by electronic circuitry. With stepper motors the windings are also switched electronically, but with external circuitry, and the brushless motors commonly used in model aircraft have electronic commutation. AC motors usually work with a rotating magnetic field produced either by the AC line voltage at 50 or 60 Hz, or by a voltage generated by a frequency converter. However, AC motors can also be equipped with a commutator and carbon brushes.

Q *What's the best way to keep it simple?*

A The most common type of motor is the DC motor (**Figure 2**). Most relatively small DC motors have a permanent-magnet stator and a rotor made from soft iron with windings which are supplied with current through carbon brushes and a commutator.
A nice feature of DC motors is that the speed is nearly proportional to the applied supply voltage.
Although DC motors are specified for a particular speed at a particular supply voltage, that is not a hard specification. You can easily use a higher voltage for a higher speed or a lower voltage for a lower speed.

Q *How do I connect a DC motor to my circuit?*

A The control voltage for a DC motor is usually a PWM signal, which means that the voltage is applied to the motor in the form of a series of pulses and the mechanical inertia of the motor converts them into a steady speed.
If the PWM frequency is too high, you can run into problems with the inductance of the motor. For that reason you should choose either a low PWM frequency (at most a few hundred Hertz) or a very high PWM frequency (20 kHz or higher).
The switching transistor should be selected according to the desired switching frequency and the expected motor current. Small motors operating at low PWM frequencies can be driven by a simple transistor or power transistor. Darlington transistors are a good choice for higher motor currents.
Power MOSFETs are almost always used for real high-power applications. The very low on-state resistance and high drain current capacity of power MOSFETs (more than 100 A is by no means unusual) result in much less power dissipation with power MOSFETs than with bipolar transistors.
It's important to always use a freewheeling diode. When the current is switched off, the rotor inductance produces a voltage spike that must be diverted to the positive supply voltage rail.

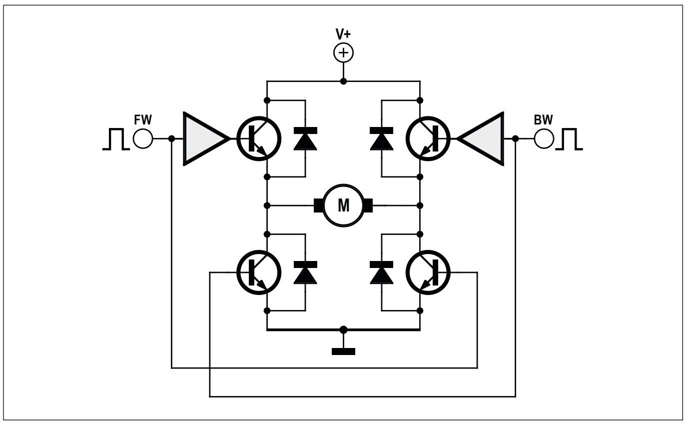

Figure 3. With an H-bridge you can run a DC motor in either direction.

Figure 2. DC motors: big and small.

Figure 4. A brushless DC motor and motor controller.

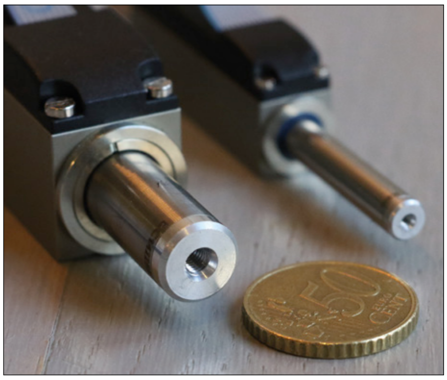

Figure 5. Encoders: you can also make your own.

Q *How can I control the direction of rotation of the motor (clockwise or counterclockwise)?*

A If you want to have a DC motor rotate clockwise instead of counterclockwise, you have to change the polarity of the supply voltage. That can be done with a changeover switch if the direction only has to be changed occasionally. If the direction has to be changed frequently, for example in a servo system, you need an H-bridge output stage with four transistors in an H configuration, where only two diagonally opposite transistors are conducting at any given time (**Figure 3**). Freewheeling diodes are also necessary with H-bridge circuits (four in that case).

Q *What if I want to use a brushless motor to avoid wear?*

A Then you can use the type of motor often used in model building, which has three connecting leads (**Figure 4**). These motors are actually equivalent to brushless AC motors, but with the rotating stator field generated externally. If you want to use one of these brushless motors, it's a good idea to buy a ready-made controller. The controller is driven by a pulse signal with a range of 1 ms (stopped) to 2 ms (full speed). The frequency of the control pulses can vary, but 50 Hz is almost always a good choice. The direction of rotation can be changed by swapping two of the three phases. If you want to be able constantly change direction, you can use a controller with a zero midpoint (1 ms = reverse, 1.5 ms = stop, 2 ms = forward).

Q *Okay, now we have motion, but what if I want to position something precisely?*

A Positioning can be done in different ways. You can use a normal motor (DC or AC) with position feedback from an encoder or a potentiometer. Potentiometers are used in servos, such as the servos commonly used in model building. It's not surprising that the popular Arduino family has a separate servo library. However, for positioning tasks the usual choice is a stepper motor.

Q *Can stepper motors be operated with a different supply voltage, the same as DC motors?*

A Although stepper motors operate on the same basic principle as DC motors, the situation is more complicated due to the different application area. A DC motor runs when a supply voltage is applied and stands still when no voltage is applied. A stepper motor stands still most of the time, but it needs a supply voltage to maintain its position. The stator resistance of a stepper motor is relatively high to limit the current when the motor is standing still. That is different from DC motors, where the rotor resistance is kept as low as possible for efficiency reasons. If you raise the supply voltage of a stepper motor, heat dissipation may become a problem, especially at standstill. For that reason you should stick to the specified supply voltage.

Q *Do stepper motors also have drawbacks?*

A The most commonly encountered problem with stepper motors is losing steps when the stepping rate is too high or the load is too heavy. When that occurs, the positioning is no longer accurate. Another frequent issue is resonance at low stepping rates, which causes audible humming. What's worse is that resonance can destroy drive trains. For that reason speed reduction with gears, which always have a certain amount of play, should not be used. Toothed belt drive is a better solution.

Q *Is there an alternative to stepper motors?*

A The nice thing about stepper motors is that you do not need feedback for positioning. If you opt for explicit feedback, for example with an encoder on the motor shaft, then you can basically use any type of motor for positioning (**Figure 5**).

Q *Aren't encoders awfully expensive?*

A They don't have to be. If you do not need very high precision, it is certainly possible to make your own encoder using a light-barrier sensor and a simple encoder wheel, or a vane or spot on the rotating shaft.

(160219)

Web Links

https://en.wikipedia.org/wiki/DC_motor

https://en.wikipedia.org/wiki/AC_motor

https://en.wikipedia.org/wiki/Stepper_motor