Electrical Tech Note — 321
Biosystems & Agricultural Engineering Department
Michigan State University

Stepper Motor Principles

A form of synchronous motor where the rotor is made to turn a fixed number of degrees and hold that position until directed to move to a different position. The rotor can be directed to move in either direction. The amount of rotor turn is precise and feedback is not required provided the motor is matched to the application. If the load torque is excessive and speed of movement is too high, the stepper motor may not be capable of keeping up with the commands and steps can be skipped resulting in loss of precision. Applications range from disc drives in a computer to industrial robots on an assembly line.

How a Stepper Motor Works: The rotor of a stepper motor works on the principle that if a magnetic core can be physically changed in shape or position, a magnetic flux will force the core material to align itself to form a magnetic flux circuit of minimum reluctance. This is how a solenoid works to align a cylindrical core in the center of a coil, or to pull a movable portion of the magnetic core closed. Figure 521.1 shows a steel core that can rotate inside a stator winding. When either direct current is passed through the winding a magnetic flux is established in the motor that is fixed and does not move. If the steel core is not exactly aligned with the magnetic field, it will be forced to rotate until it is aligned. When the core is aligned with the magnetic flux the reluctance of the core will be at a minimum.

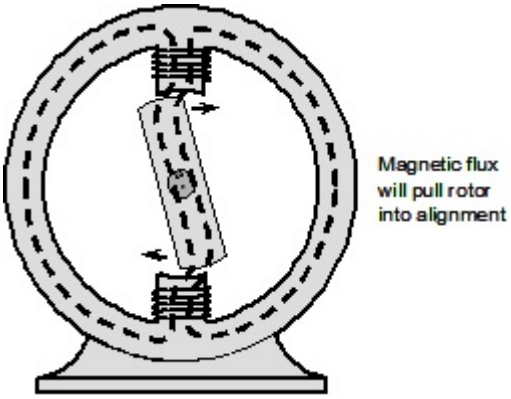

Figure 321.1 When a magnetic field is created the cord will rotate into a position where the reluctance of the magnetic core is a minimum.

In the case of a stepper motor a steel rotor is constructed with teeth around the outer circumference and the ends of the electromagnet poles in the stator also have teeth. This is illustrated in Figure 521.2. The teeth on the rotor circumference are misaligned with the teeth on every stator electromagnet core but one. This misalignment is arranged in a predetermined pattern. An electromagnet is energized where the stator teeth and rotor teeth are misaligned. The magnetic flux will move the rotor a small angle so the stator and rotor teeth are aligned. This will cause the next electromagnetic pole teeth and rotor teeth to move out of alignment.

By energizing that electromagnet the rotor will move another small increment. By energizing that electromagnet the rotor will move another small increment. By energizing the stator electromagnets in a particular rotational sequence for a given number of pulses, the rotor will turn a precise number of degrees.

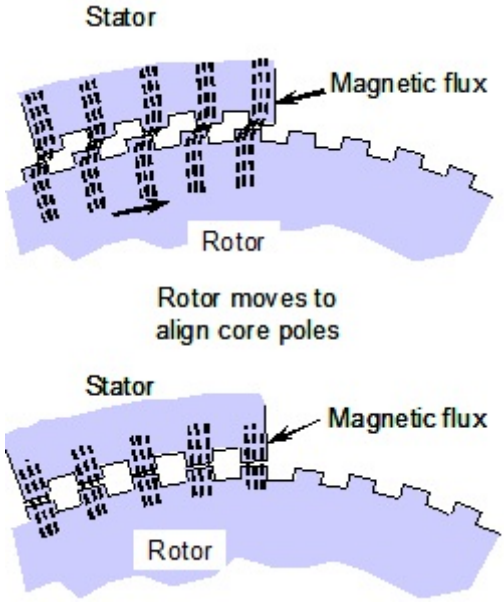

Figure 321.2 When a stator coil is energized, the rotor will move to align the stator pole and rotor teeth to achieve minimum reluctance of the magnetic circuit.

A typical stepper motor will have several coils arranged around the stator with current supplied to the coils in a desired sequence for a predetermined duration to move a lever or some other mechanism to an exact location. If the system is designed properly, exact movement can be achieved without feedback to the controller. A typical stepper motor arrangement is shown in Figure 321.3.

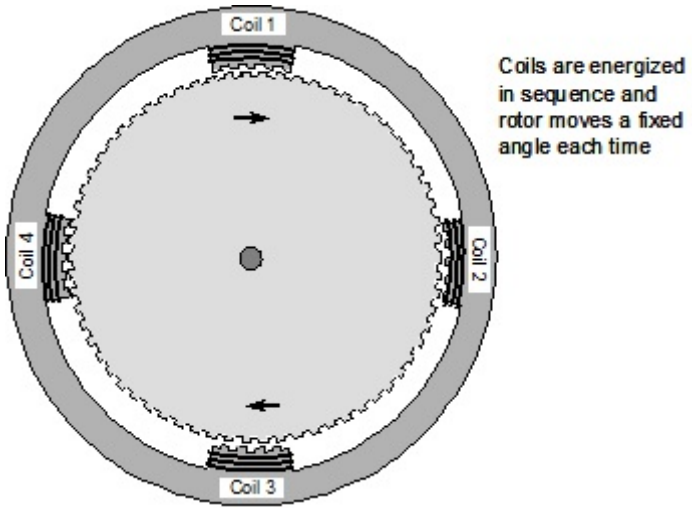

Figure 321.3 Several coils are arranged in the stator of the stepper motor and energized

in a desired sequence to achieve exact movement of the rotor.