Instrumental Technique – Stepper Motor

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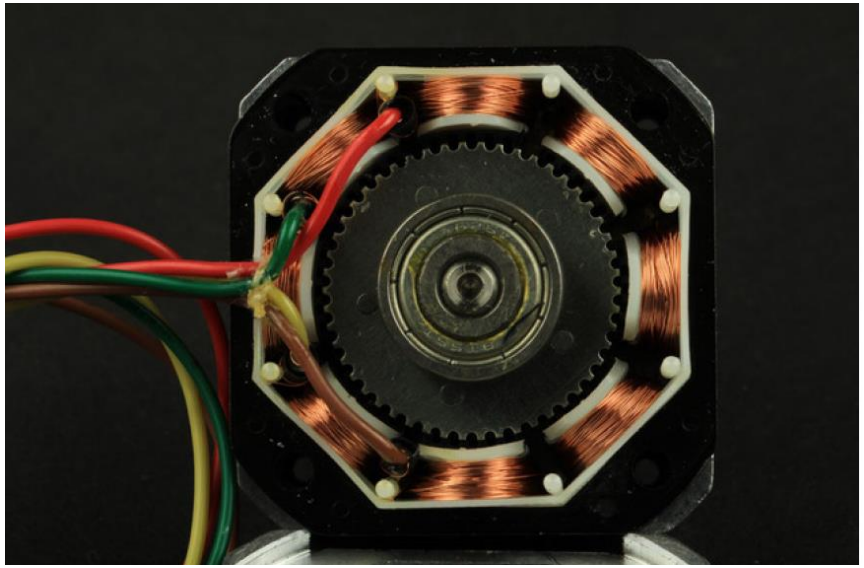
Stepper motors

- Stepper motors are DC motors that move in discrete steps. They have multiple coils that are organized in groups called "phases".
- By energizing each phase in sequence, the motor will rotate, one step at a time. With a computer controlled stepping you can achieve very precise positioning and/or speed control.
- For this reason, stepper motors are the motor of choice for many precision motion control applications. Stepper motors come in many different sizes and styles and electrical characteristics.



Stepper Motor Types

There are three basic stepper motor types.

- Variable-reluctance
- Permanent-magnet
- Hybrid

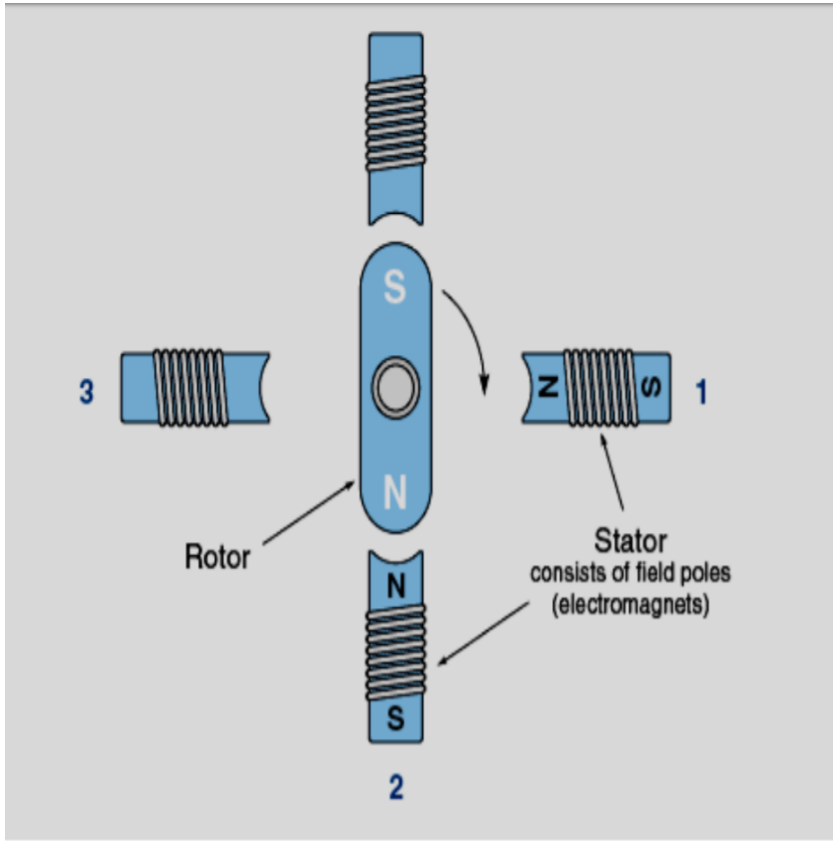
The permanent-magnet (PM) stepper motor:

- It uses a permanent magnet for the rotor. The field consists of four poles (electromagnets).

- The motor works in the following manner: Assume the rotor is in the position shown with the south end up. When field coil 1 is energized, the south end of the rotor is attracted to coil 1 and moves toward it. Then field coil 1 is de-energized, and coil 2 is energized. The rotor pulls itself into alignment with coil 2.

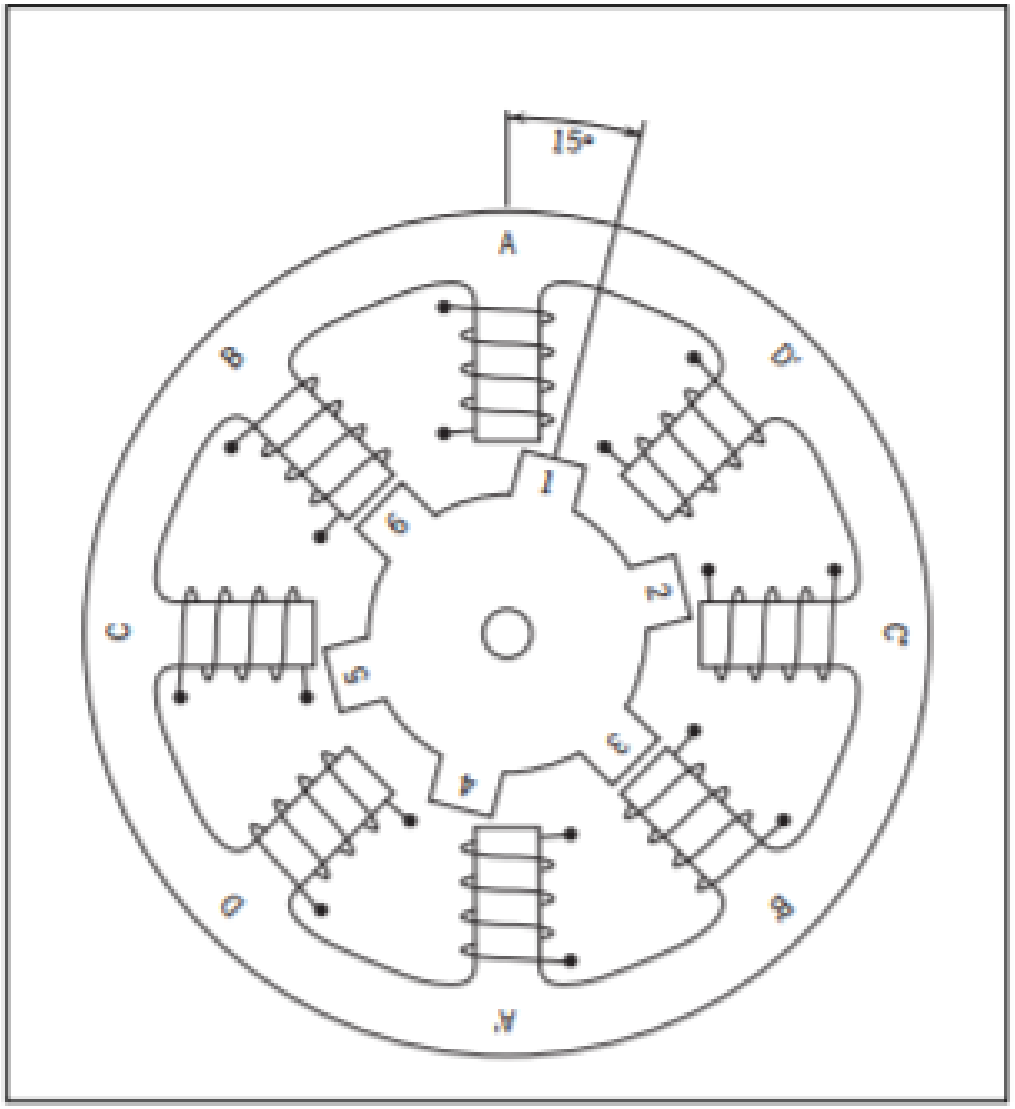
- Thus, the rotor turns in 90° steps for each successive excitation of the field coils.

- The motor can be made to reverse by inverting the sequence.



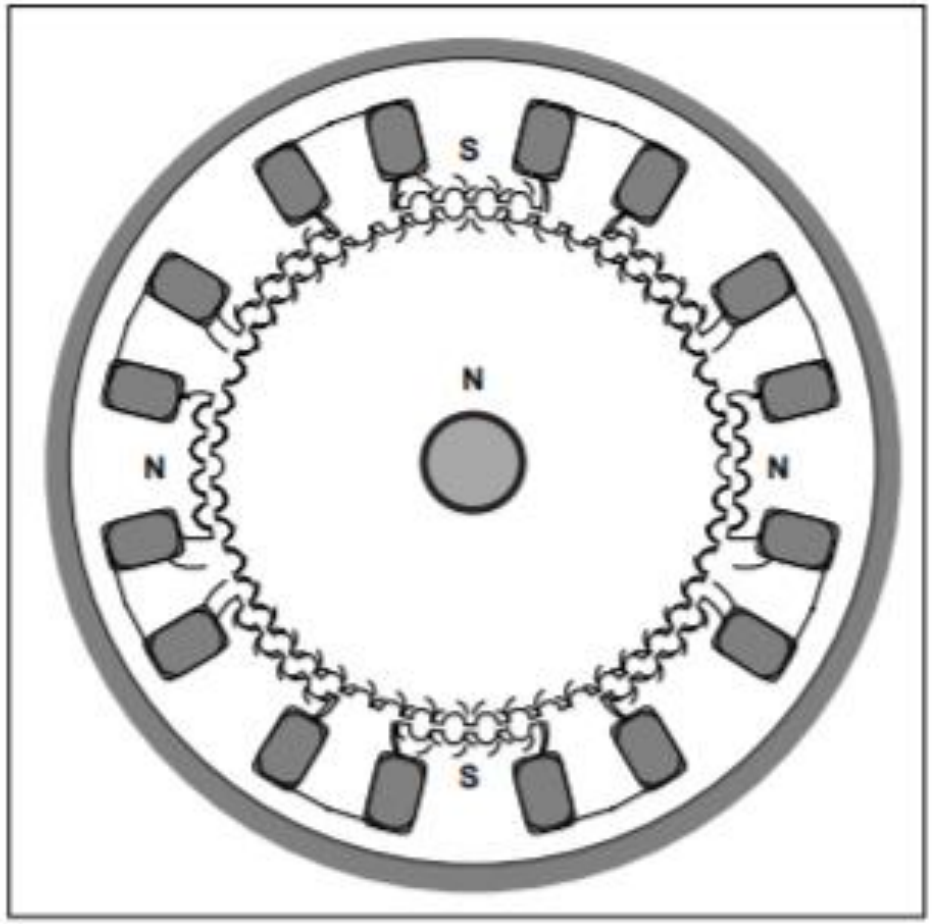
Variable-reluctance (VR)

- This type of stepper motor has been around for a long time. It is probably the easiest to understand from a structural point of view. Figure shows a cross section of a typical V.R. stepper motor.
- This type of motor consists of a soft iron multi-toothed rotor and a wound stator.
- When the stator windings are energized with DC current the poles become magnetized.
- Rotation occurs when the rotor teeth are attracted to the energized stator poles.



Hybrid Stepper Motor

- The hybrid stepper motor combines the best features of both the PM and VR type stepper motors.
- The rotor is multi-toothed like the VR motor and contains an axially magnetized concentric magnet around its shaft.
- The teeth on the rotor provide an even better path which helps guide the magnetic flux to preferred locations in the air gap.
- This further increases the detent, holding and dynamic torque characteristics of the motor when compared with both the VR and PM types



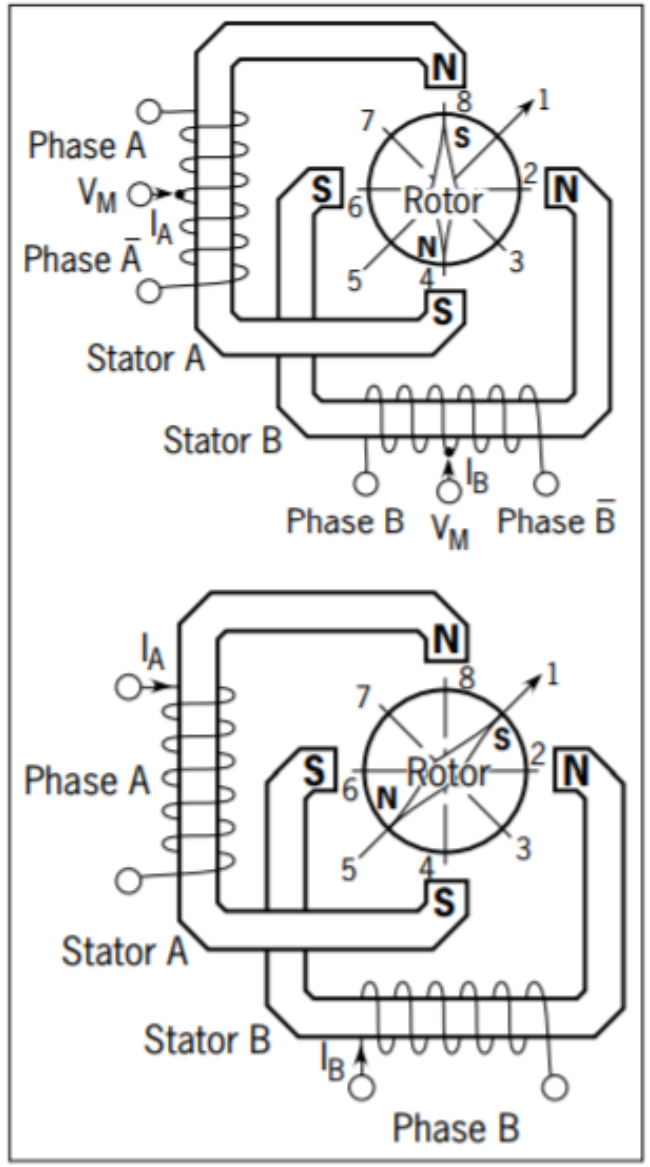
Stepping Modes:

The following are the most common drive modes.

- Wave Drive (1 phase on)
- Full Step Drive (2 phases on)
- Half Step Drive (1 & 2 phases on)
- Microstepping (Continuously varying motor currents)

Wave Drive

- In Wave Drive only one winding is energized at any given time.
- The stator is energized according to the sequence A → B → A' → B' and the rotor steps from position 8 → 2 → 4 → 6.
- For unipolar and bipolar wound motors with the same winding parameters this excitation mode would result in the same mechanical position.
- The disadvantage of this drive mode is that in the unipolar wound motor you are only using 25% and in the bipolar motor only 50% of the total motor winding at any given time.
- This means that you are not getting the maximum torque output from the motor



Full Step Drive

- In Full Step Drive you are energizing two phases at any given time.
- The stator is energized according to the sequence AB → A'B → A'B' → AB' and the rotor steps from position 1 → 3 → 5 → 7 .
- Full step mode results in the same angular movement as 1 phase on drive but the mechanical position is offset by one half of a full step.
- The torque output of the unipolar wound motor is lower than the bipolar motor (for motors with the same winding parameters) since the unipolar motor uses only 50% of the available winding while the bipolar motor uses the entire winding.

Half Step Drive

- Half Step Drive combines both wave and full step (1&2 phases on) drive modes.

- Every second step only one phase is energized and during the other steps one phase on each stator.

- The stator is energized according to the sequence AB → B → A'B → A' → A'B' → B' → AB' → A and the rotor steps from position 1 → 2 → 3 → 4 → 5 → 6 → 7 → 8. This results in angular movements that are half of those in 1- or 2-phases-on drive modes.

- Half stepping can reduce a phenomena referred to as resonance which can be experienced in 1- or 2- phases-on drive modes.

Microstepping Drive

- In Microstepping Drive the currents in the windings are continuously varying to be able to break up one full step into many smaller discrete steps.

- Benefit of microstepping (for delicate systems) is that it reduces the vibrational “shock” of taking a full step—that is, taking multiple microsteps creates a more “fluid” motion.

What are stepper motors good for?

- Positioning – Since steppers move in precise repeatable steps, they excel in applications requiring precise positioning such as 3D printers, CNC, Camera platforms and X,Y Plotters. Some disk drives also use stepper motors to position the read/write head.

- Speed Control – Precise increments of movement also allow for excellent control of rotational speed for process automation and robotics.

- Low Speed Torque - Normal DC motors don't have very much torque at low speeds. A Stepper motor has maximum torque at low speeds, so they are a good choice for applications requiring low speed with high precision.

Disadvantages

1. Resonances can occur if not properly controlled.
2. Not easy to operate at extremely high speeds.

Thank you