Electrical, Computer & Energy Engineering
UNIVERSITY OF COLORADO BOULDER

ECEN 5053-003 Homework Assignment

Course Name: Embedding Sensors and Actuators
Corresponding Module: C2M5
Week Number: 8
Module Name: Stepper Motors
Student Name: **Rushi James Macwan**

Note: Correct answer is in Blue Font

Homework is worth 100 points.

Part 1: Each question is worth 10 points.

A. What happens to a stepper motor if the coil windings are energized and an external torque tries to rotate the motor?

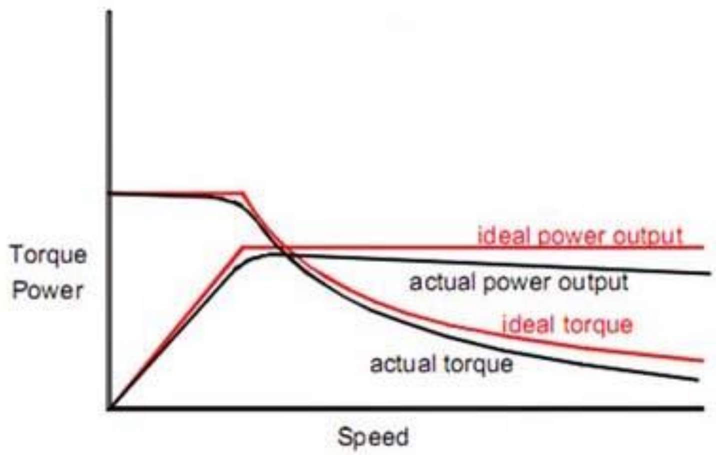
Sol.

If the coil windings of a stepper motor are energized and if an external torque tries to rotate the motor, the rotor will oppose the external torque. This is because when the coil windings are energized, it creates an electromagnetic field with a north and a south pole. The stator carries the magnetic field generated by the coil windings which causes the rotor to align itself with the magnetic field such that unlike poles face each other since unlike poles attract each other. Thus, the magnetic poles generated on the stator locks the rotor in position since it has a north and a south pole that is attracted to the opposite poles of the stator.

This locked rotor thus will oppose the external torque that is applied to the motor and it will resist any movement of the motor shaft.

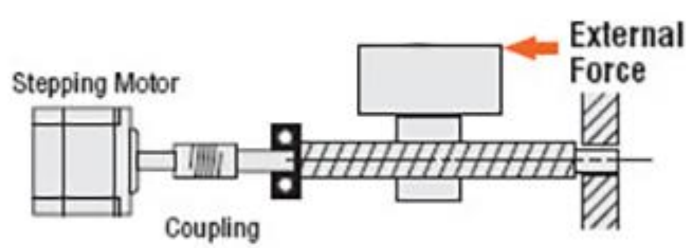
To be more precise, in this problem, it has not been specified which stepper motor is considered: variable reluctance, permanent magnet or hybrid motor. However, assuming it's a hybrid stepper motor, it exhibits a *holding torque*. This means that when the windings are energized but the rotor is stationary, the motor can hold the load in place. But a stepper motor can also hold a load in place when there is no current applied to the windings (for example, in a power-off condition). This is commonly known as the *detent torque or residual torque*.

Because detent torque has to be overcome in order for the motor to move, it reduces the ideal torque that the motor can produce when it's running. Overcoming the detent torque requires more power from the motor, and the amount of power needed is proportional to speed. So the faster the motor turns, the greater the effect that detent torque will have on the motor's actual torque output.



Detent torque reduces both the ideal power and ideal torque that the motor could produce, with the effect becoming larger as speed increases.

A stepper motor's holding torque is the amount of torque needed in order to move the motor one full step when the windings are energized but the rotor is stationary. Holding torque is one of the primary benefits that stepper motors offer versus servo motors and makes steppers a good choice for cases where a load needs to be held in place.

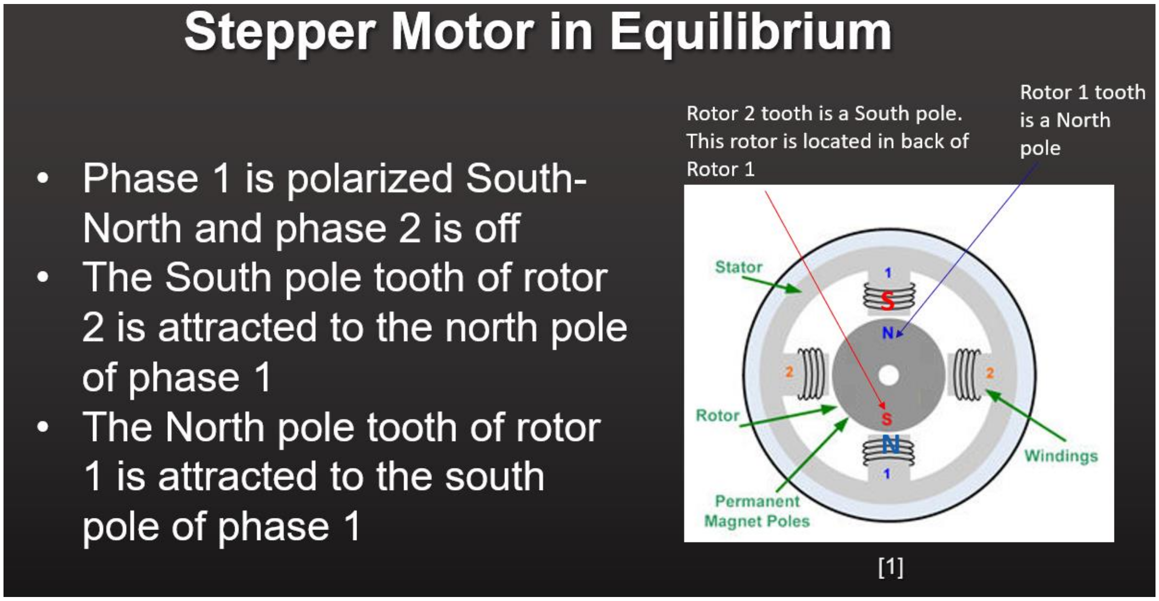


Holding torque is typically higher than running torque, and is limited primarily by the maximum current that the motor can withstand. From a practical standpoint, holding torque is the sum of the magnetic force exerted by the coils to hold the motor's current position, plus the detent torque. Once the motor is moving, the torque available at low speeds equals the holding torque minus two times the detent torque (because the motor has to work against the detent torque).

Thus, to summarize, the external torque needs to overcome the holding torque and the detent torque in order to give some movement to the motor shaft.

Courtesy: Reference Links: [1] [2] [3] [4] [5] [6]

B. In the slide deck C2M4V4 we discussed a simplified demonstration of how two stator phases are energized and de-energized in a set sequence to make the motor rotate 90° clockwise in four steps during one full rotation clockwise. See this slide below for an example of how this was done.



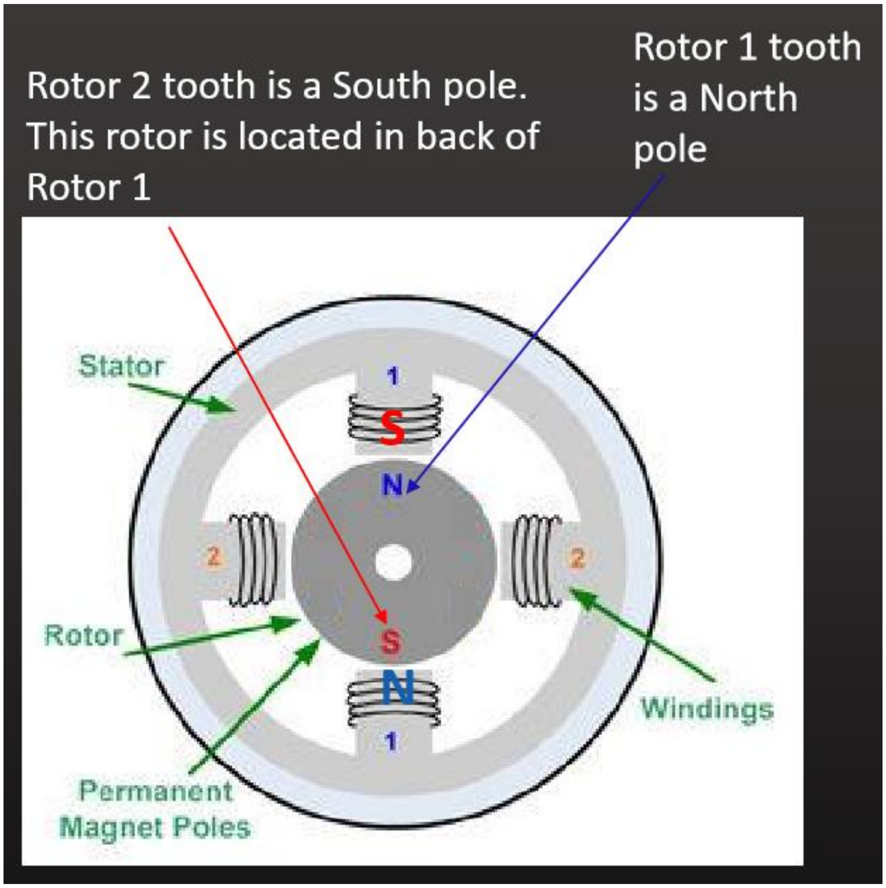
What sequence of energizing and de-energizing the stator phases would you use to make the motor rotate 90° ***counterclockwise*** in four steps during one full rotation counterclockwise? Start your sequence with the image in the slide above. Use diagrams to illustrate your sequence. Feel free to mark up our class slides, as a method of creating illustrations.

Sol.

Below is the sequence of energizing and de-energizing the stator phases so that the motor rotates 90° ***counterclockwise*** in four steps during one full rotation counterclockwise.

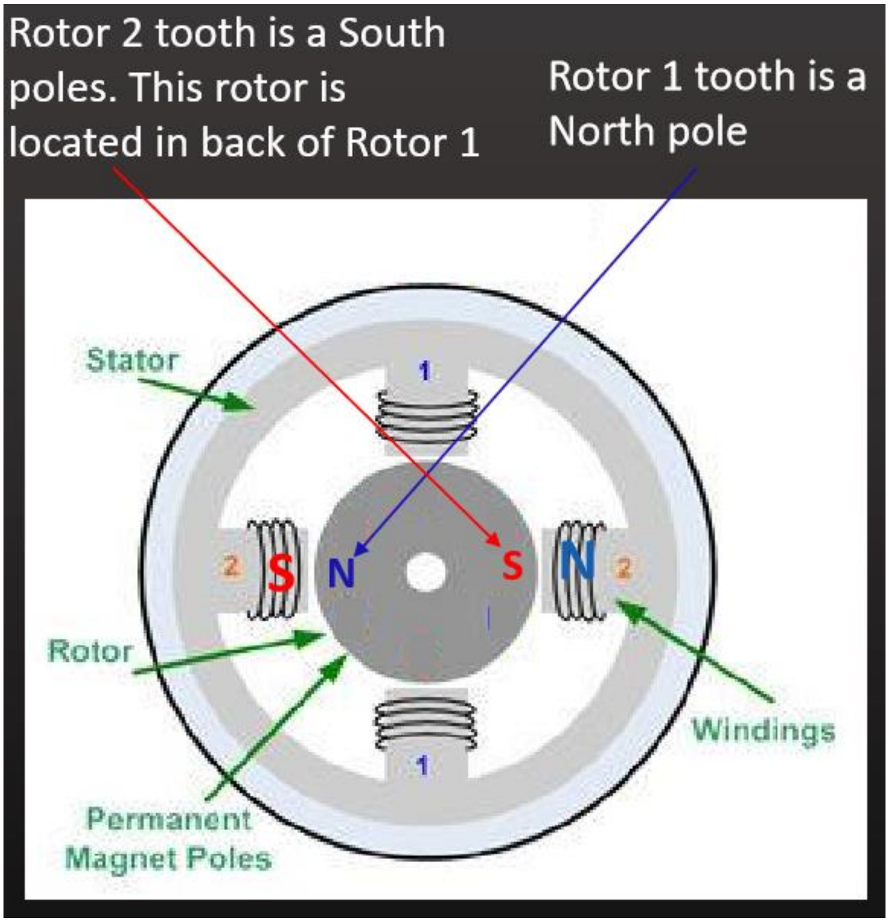
Step – 1: Starting phase – stepper motor is in equilibrium

- In this step, the stepper motor is in equilibrium. Initially, as per the class slide, the phase 1 of the Stator is polarized South-North and phase 2 is off.
- The South pole tooth of rotor 2 is attracted to the north pole of phase 1.
- The North pole tooth of the rotor 1 is attracted to the south pole of phase 1.



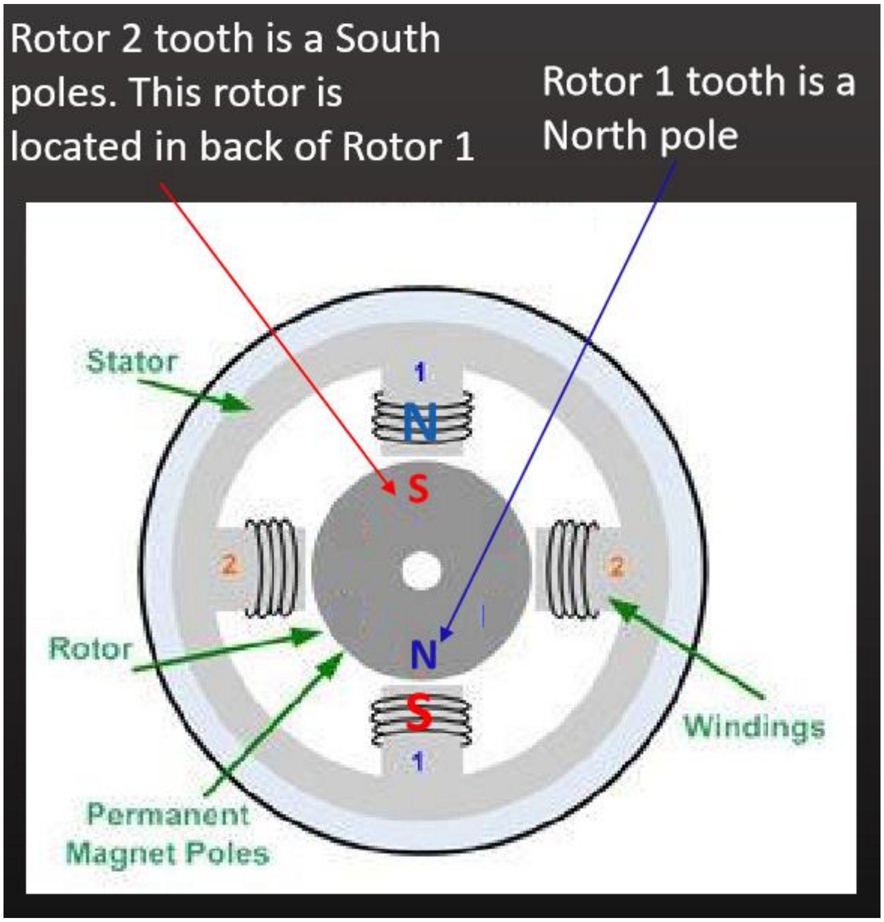
Step – 2: Phase 1 de-energized and Phase 2 energized South-North

- In this step, to make the motor rotate in the counter-clockwise direction and by 90°, the phase-1 of the stator is later de-energized and the phase-2 of the stator is energized South-North so that the rotor moves counter-clockwise by 90°.
- Doing that will make the South pole tooth of rotor 2 get attracted to the North pole of the phase 2.
- Similarly, the North pole tooth of the rotor 1 will get attracted to the South pole of phase 2.
- Thus, rotating 90° counter-clockwise will allow the rotor to gain equilibrium with stator phase 2.
- The next screenshot shows the motor's first new equilibrium position.



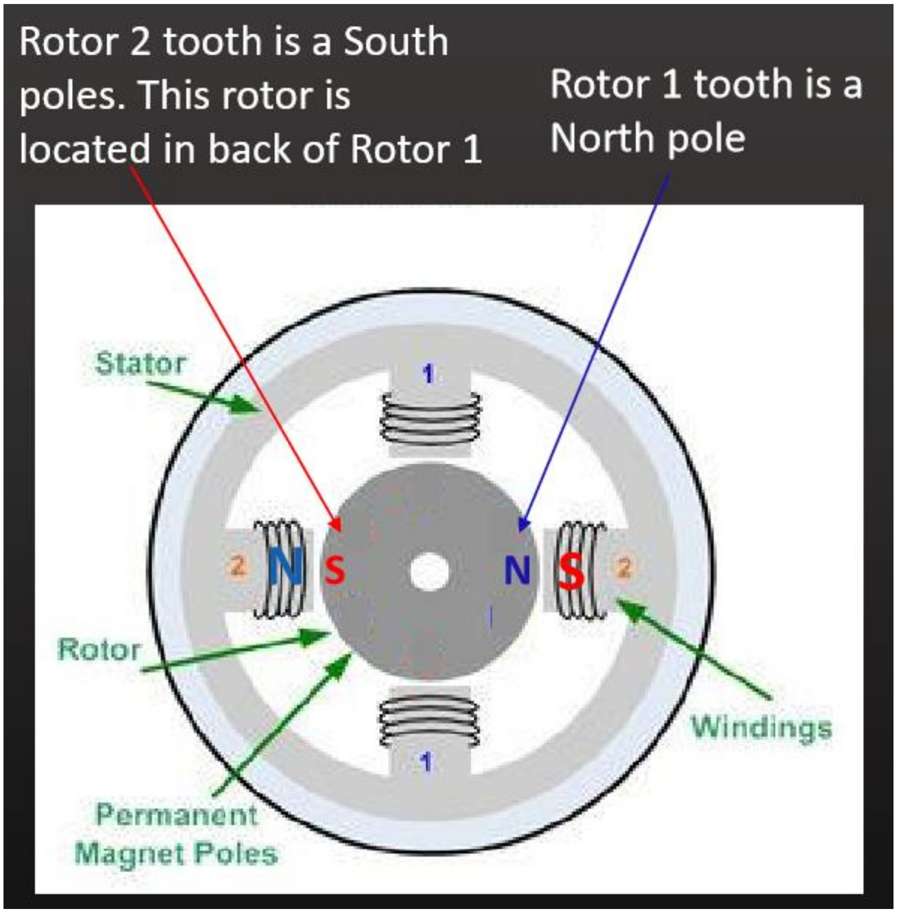
Step – 3: Phase 2 de-energized and Phase 1 energized North-South

- In this step, to make the motor rotate once again in the counter-clockwise direction and by 90°, the phase-2 of the stator is later de-energized and the phase-1 of the stator is energized North-South so that the rotor moves counter-clockwise by 90°.
- Doing that will make the South pole tooth of rotor 2 get attracted to the North pole of the phase 1.
- Similarly, the North pole tooth of the rotor 1 will get attracted to the South pole of phase 1.
- Thus, rotating 90° counter-clockwise will allow the rotor to gain equilibrium with stator phase 1.
- The next screenshot shows the motor's second new equilibrium position.



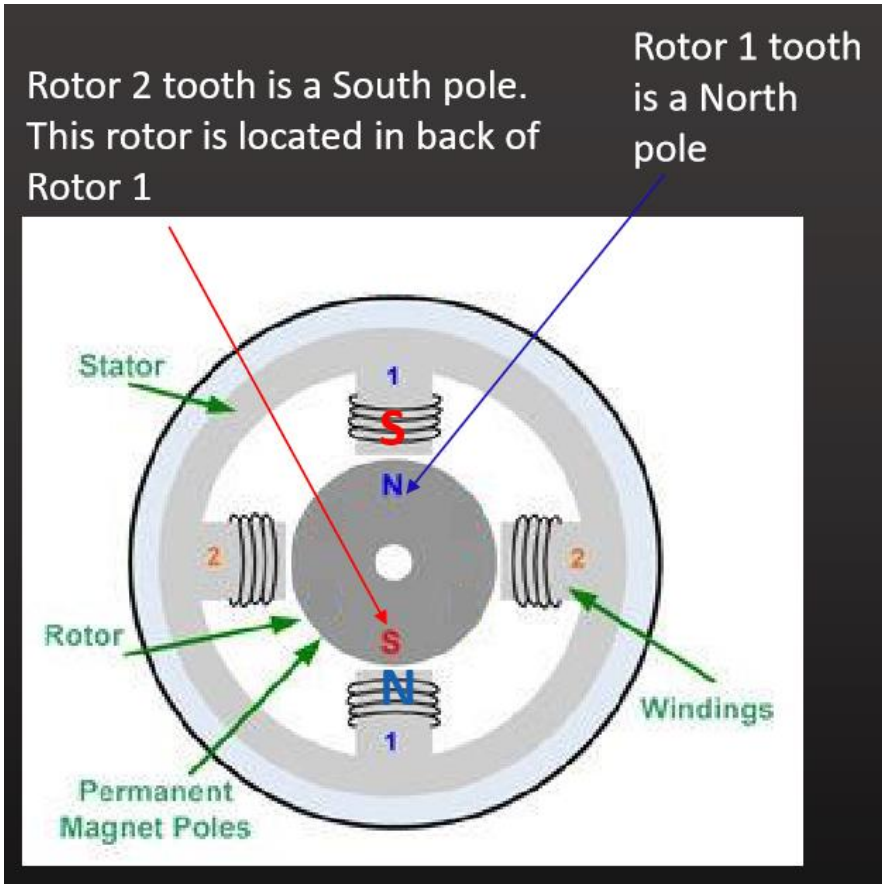
Step – 4: Phase 1 de-energized and Phase 2 energized North-South

- In this step, to make the motor rotate once again in the counter-clockwise direction and by 90°, the phase-1 of the stator is later de-energized and the phase-2 of the stator is energized North-South so that the rotor moves counter-clockwise by 90°.
- Doing that will make the South pole tooth of rotor 2 get attracted to the North pole of the phase 2.
- Similarly, the North pole tooth of the rotor 1 will get attracted to the South pole of phase 2.
- Thus, rotating 90° counter-clockwise will allow the rotor to gain equilibrium with stator phase 2.
- The next screenshot shows the motor's third new equilibrium position.



Step – 5: Phase 2 de-energized and Phase 1 energized South-North

- In this step, to make the motor rotate once again in the counter-clockwise direction and by 90°, the phase-2 of the stator is later de-energized and the phase-1 of the stator is energized South-North so that the rotor moves counter-clockwise by 90°.
- Doing that will make the South pole tooth of rotor 2 get attracted to the North pole of the phase 1.
- Similarly, the North pole tooth of the rotor 1 will get attracted to the South pole of phase 1.
- Thus, rotating 90° counter-clockwise will allow the rotor to gain equilibrium with stator phase 1.
- The next screenshot shows the motor's fourth new equilibrium position which is when the motor shaft completes one complete revolution of 360°. The fourth equilibrium position will be the same as what it were when the motor shaft began rotating.



C. Your stepper motor is rated at 2 amps supply current per phase. There are two phases in the stepper motor. During full stepping what is the total motor current drawn:

Sol. $\boxed{\textbf{2.828 A}}$

During full-stepping, both the phases of the stator will be energized simultaneously during each step for the stepper motor to run. Furthermore, the said stepper motor is rated at 2 A supply current per phase. Therefore, during the full-stepping mode, both the phases are energized together and both of them will draw currents and therefore the total current will be equal to the vector summation of the currents drawn by each phase.

This is because during every step, the stator phase will change its polarity from N-S to S-N and vice-versa. Thus, we need to take the vector summation of the currents drawn by each phase in order to find the total current during full-stepping operation.

Thus, *at full-stepping, the said stepper motor will draw a total current of*
= SQRT((2^2) + (2^2))
= SQRT (4 + 4)
= SQRT (8)
= ***2.828 A***

Courtesy: Reference Links: [1] [2] and the Reference Document: Designing and Manufacturing Miniature Stepper Motors by Lin Engineering provided on Canvas

D. Your stepper motor is rated at 2 amps supply current per phase. There are two phases in the stepper motor. During half stepping what is the total motor current drawn?

Sol. **2.414 A**

During half-stepping, for 50% of the total time of motor operation, only half of the phases of the given stepper motor will be energized and for the remaining 50% of the time, all the phases of the given motor will be energized. Since, the said stepper motor has only two phases, in our case, to calculate the total current drawn by the motor, for 50% of the time only one phase will be energized and for the remaining 50% of the time both the phases will be energized. Furthermore, the said stepper motor is rated at 2 A supply current per phase. Therefore, at half-stepping, we can calculate the total current drawn by the motor using vector summation for both the cases and then taking the average of the vector summation for the both the cases (both phases on for 50% of time and only one phase on for 50% of time).

This is because during every step, the stator phase will change its polarity from N-S to S-N and vice-versa. Thus, we need to take the vector summation of the currents drawn by each phase in order to find the total current during full-stepping operation.

Thus, *at half-stepping, the said stepper motor will draw a total current of*
= (SQRT((2^2) + (2^2)) + SQRT ((2^2) + (0^2))) / 2
= (SQRT (8) + SQRT (4)) / 2
= (2.828 + 2) / 2
= **2.414 A**

Courtesy: Reference Links: [1] [2] and the Reference Document: Designing and Manufacturing Miniature Stepper Motors by Lin Engineering provided on Canvas

E. Just like AC motors, stepper motors have a variety of terminology for their torque output. Answer the following questions about their torque output?

E.1 What is the detent torque and why is it useful when stopping the stepper motor?

Sol.

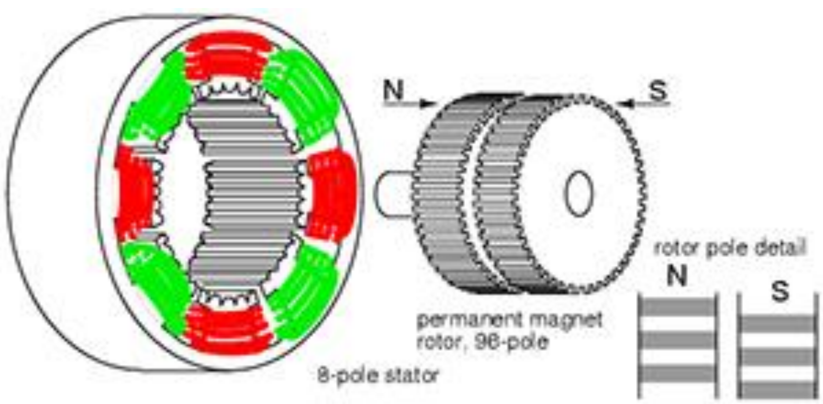
Detent torque

Detent torque – The torque required to rotate the motor’s shaft while the windings are not energized.

Unlike variable reluctance motors, permanent magnet and hybrid motors cog when they are turned by hand while not powered. This is because the permanent magnets in these motors attract the stator poles even when there is no power. This magnetic detent or residual holding torque is desirable in some applications.

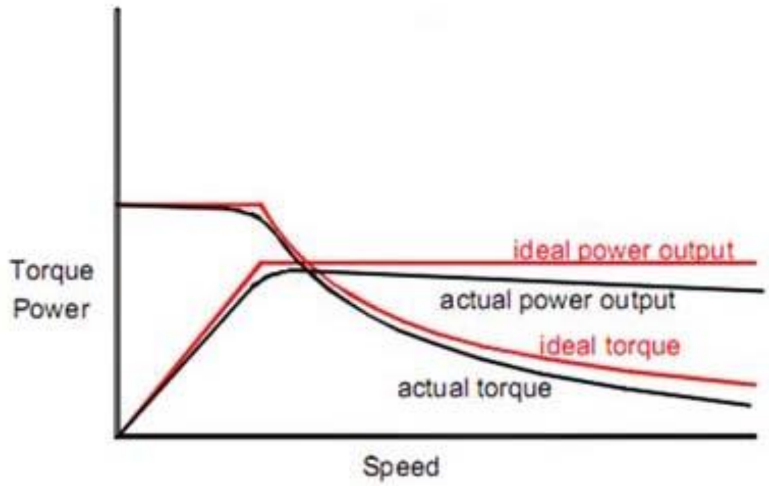
Stated another way, detent torque is the amount of torque the motor produces when the windings are not energized. The effect of detent torque can be felt when moving the motor shaft by hand, in the form of torque pulsations or cogging.

Of the three types of stepper motors—variable reluctance, permanent magnet, and hybrid—only variable reluctance motors do not exhibit detent torque. This is due to the difference in construction between variable reluctance motors versus permanent magnet and hybrid designs. Both permanent magnet and hybrid stepper motors use a permanent magnet rotor, which is attracted to the poles of the stator even when there is no power to the stator windings. Variable reluctance motors, on the other hand, use a passive (non-magnetized) rotor made of soft iron; therefore, there is no attraction between the rotor and the stator when the stator windings are not energized. Hybrid stepper motors incorporate teeth on the surface of the rotor, so they are able to better manage the magnetic flux between the stator and rotor, which gives them higher holding, dynamic, and detent torque values than permanent magnet steppers.



Teeth around the perimeter of a hybrid stepper motor's permanent magnet rotor give it higher holding, running, and detent torque than other types of steppers.

Because detent torque has to be overcome in order for the motor to move, it reduces the ideal torque that the motor can produce when it's running. Overcoming the detent torque requires more power from the motor, and the amount of power needed is proportional to speed. So the faster the motor turns, the greater the effect that detent torque will have on the motor's actual torque output.



Detent torque reduces both the ideal power and ideal torque that the motor could produce, with the effect becoming larger as speed increases.

On the other hand, detent torque can be beneficial when stopping the motor. The momentum of the moving rotor is countered by the detent torque and the friction in the rotating components. Therefore, a higher detent torque will help the motor to stop more quickly. The detent torque typically ranges from 5 to 20% of the holding torque.

Courtesy: Reference Links: [1] [2] [3] [4]

E.2 Which type of stepper motor does not exhibit detent torque?

Sol. **Variable Reluctance Motor**

Detent torque is the amount of torque the motor produces when the windings are not energized. The effect of detent torque can be felt when moving the motor shaft by hand, in the form of torque pulsations or cogging.

Of the three types of stepper motors—variable reluctance, permanent magnet, and hybrid—***only variable reluctance motors do not exhibit detent torque***. This is due to the difference in construction between variable reluctance motors versus permanent magnet and hybrid designs. Both permanent magnet and hybrid stepper motors use a permanent magnet rotor, which is attracted to the poles of the stator even when there is no power to the stator windings.

Variable reluctance motors, on the other hand, use a passive (non-magnetized) rotor made of soft iron; therefore, there is no attraction between the rotor and the stator when the stator windings are not energized.

Courtesy: Reference Links: [1]

E.3 Quantitatively, how does detent torque relate to holding torque in a stepper motor that exhibits detent torque?

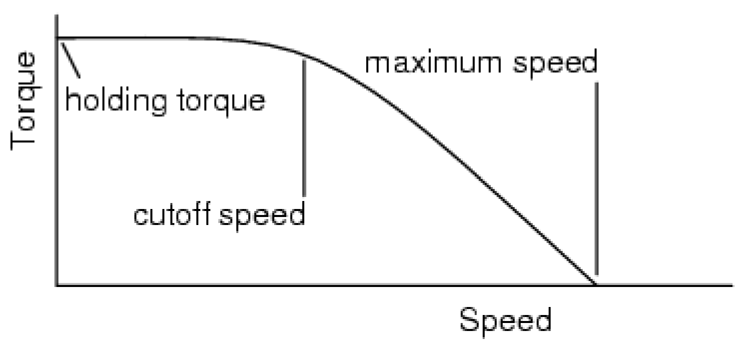
Sol.

A stepper motor's holding torque is the amount of torque needed in order to move the motor one full step when the windings are energized but the rotor is stationary. Holding torque is one of the primary benefits that stepper motors offer versus servo motors and makes steppers a good choice for cases where a load needs to be held in place. Holding torque is typically higher than running torque, and is limited primarily by the maximum current that the motor can withstand.

From a practical standpoint, holding torque is the sum of the magnetic force exerted by the coils to hold the motor's current position, plus the detent torque.

Once the motor is moving, the torque available at low speeds equals the holding torque minus two times the detent torque (because the motor has to work against the detent torque).

An energized, holding stepper has a relatively high *holding torque* rating. There is less torque available for a running motor, decreasing to zero at some high speed. This speed is frequently not attainable due to mechanical resonance of the motor load combination.



Stepper speed characteristics

Courtesy: Reference Links: [1] [2]

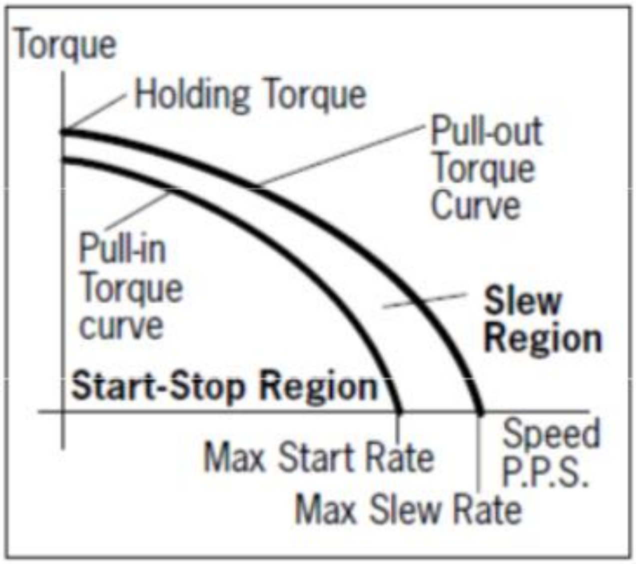
E.4 What is pull-in torque curve, and why is it important?

Sol.

Pull-in torque – The torque against which a motor can accelerate from a standing start without missing any steps, when driven at a constant stepping rate.

The pull-in curve defines an area referred to as the start stop region. This is the maximum frequency at which the motor can start/stop instantaneously, with a load applied, without loss of synchronism.

The Speed-Torque graph indicates the characteristic relationship between the speed and torque when the stepping motor is driven. The torque vs speed characteristics are the key to selecting the right motor and drive method for a specific application. These characteristics are dependent upon (change with) the motor, excitation mode and type of driver or drive method. On the graph, the horizontal axis is the speed at the motor's output shaft while the vertical axis is the torque.



The dynamic torques, pull-in and pull-out, are a function of step rate. These torques are important for determining whether or not a stepping motor will "slip" when operating in a particular application. A "slip" refers to the motor not moving when it should or moving when it should not (overrunning a stop). In either case, the result is the controller will no longer know the position of the motor. Open loop positioning fails in this case. The motor must be adequately sized to prevent this from happening or a closed loop feedback system employed.

The pull-in torque offered by a stepping motor depends strongly on the moment of inertia of any load rigidly attached to the motor. This makes this torque figure somewhat problematic because the moment of inertia of the rig used to measure this torque is rarely stated in manufacturer's data sheets and is rarely equal to the moment of inertia of the load actually driven in the application.

Courtesy: Reference Links: [1] [2] [3]

E.5 What is the major advantage and disadvantage of using microstepping vs. full stepping in driving a stepper motor?

Sol.

<u>Advantages:</u>

Microstepping increases the position resolution and smoothness of conventional hybrid step motors. This is done with electronic control in the drive circuits. The drive subdivides each full step electronically into a large number of smaller steps. For example, a microstepping drive that subdivides each full step of a 200-step/rev motor into 125 microsteps produces 25,000 steps/rev (200 X 125 = 25,000).

Motors and drives must provide high positional resolution in applications such as semiconductor fabrication. A 25,000 step/rev system attached to a 10-pitch leadscrew on an *X-Y* table can position a silicon wafer to one part in 250,000/in. This high positional resolution often eliminates gearboxes (and gear backlash) or other mechanical reducers otherwise needed to place wire bonds or test probes on exposed IC wafers. But many applications that do not need high resolution can also benefit from microstepping.

The biggest advantage of microstepping is smooth operation and the elimination of resonance over its entire speed range, typically 0 to 3,000 rpm. Micro stepping is used to achieve increased step resolution and smoother transitions between steps. In most applications, micro stepping increases system performance while limiting noise and resonance problems. Smooth operation permits full torque utilization and freedom from rattling and mechanical wear. Also, half stepping or micro stepping usually reduces resonance problems.

<u>Disadvantages:</u>

The previous discussion assumed an ideal two winding stepping motor. There are several factors that affect the linearity of micro stepping in real motors. ***The first limitation is static friction in the system.***

FIGURE 10: TORQUE VS. ANGULAR POSITION FOR AN IDEAL TWO WINDING MOTOR

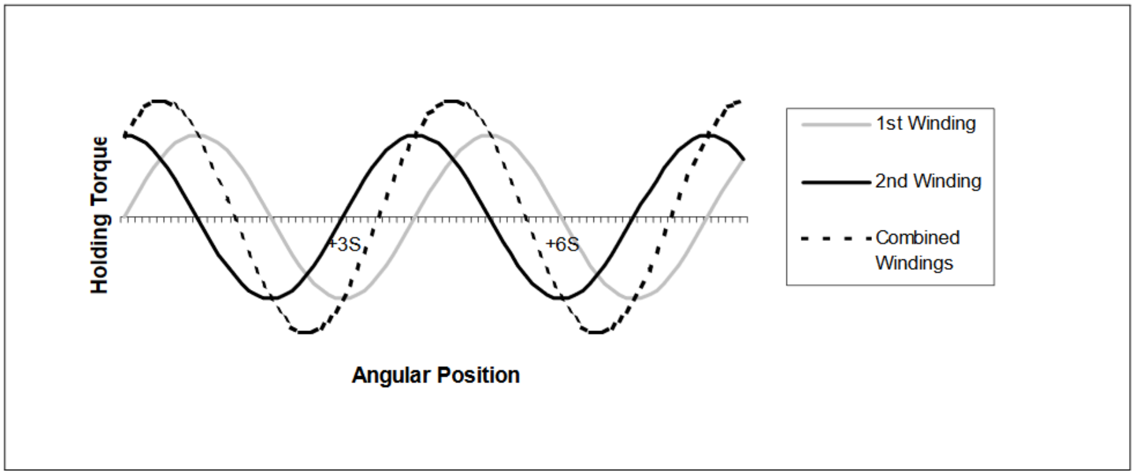


Figure 10 shows a graph of torque verses position of the motor shaft.

FIGURE 12: STATIC FRICTION IMPOSED ON TORQUE VS ANGULAR POSITION

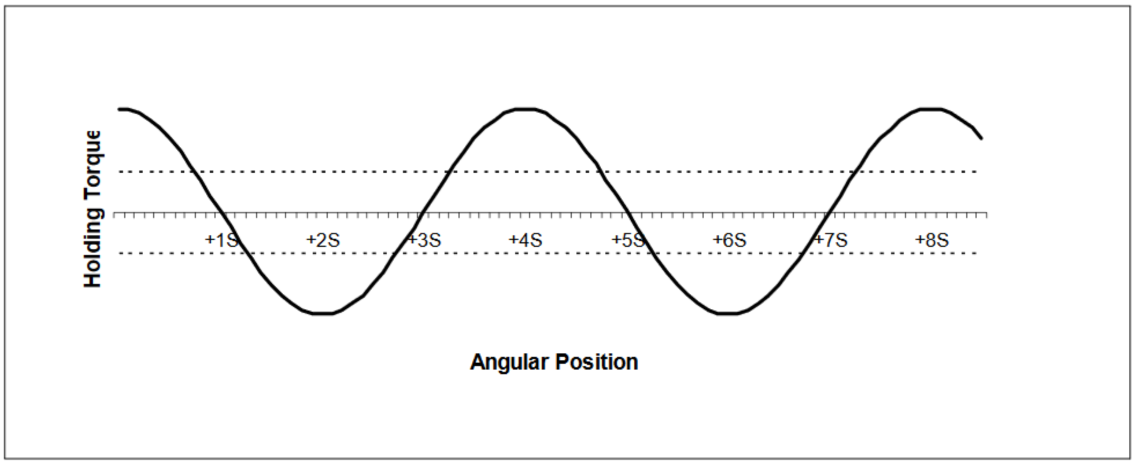
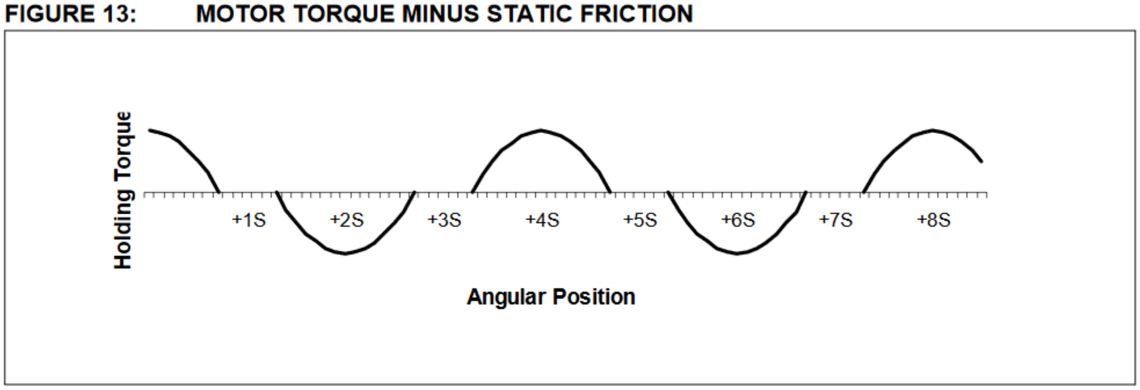


Figure 12 shows this same graph (for one winding) with the dotted lines representing the effect static friction has on the system. Redrawing the graph in Figure 12 to show only the available torque for a single winding results in the graph shown in Figure 13.

FIGURE 13: MOTOR TORQUE MINUS STATIC FRICTION



The resulting dead zone between the zones of available torque shows that the magnitude of torque overall is less than the ideal case.

In theory, microstepping is quite simple, and theoretically, the technique solves all resonance, vibration and noise problems in a stepper motor system.

In reality, a lot of different phenomena arise which set limits for the system performance. Some are related to the driver and others to the motor. If a high-precision controller/driver combination such as PBM 3960 and PBL 3771 or equivalent are used, then the errors associated with the driver are negligible when compared with those associated with most available motors.

Courtesy: Reference Links: [1] [2] [3 - the Reference Document: Designing and Manufacturing Miniature Stepper Motors by Lin Engineering provided on Canvas] [4] [5] [6]

F. A stepper motor has the following attributes:

Rotation angle of the motor output shaft, Θ =	90	dgrees
Number of pulses, A =	50	pulses
Pulse speed, f =	100	Hz

What is the speed of the motor output shaft as measured in RPM?

Sol. **30 RPM**

Based on the referenced document, the speed of the motor output shaft can be calculated by primarily calculating the value of the step angle.

The formula to calculate the step angle is as under:

$$\theta = \theta s \times A \quad \begin{cases} \theta \ : \text{Rotation angle of the motor output shaft [deg]} \\ \theta s : \text{Step angle [deg/step]} \\ A \ : \text{Pulse number [pulses]} \end{cases}$$

Thus, the step angle value (deg/step) would be:

= Rotation angle of the motor output shaft (deg) / Number of pulses (pulses)
= 90 / 50 (deg/step)
= 1.8 degree / step

Now, the speed of the rotation is proportional to the speed of the pulses. The relationship of the pulse speed (Hz) and motor speed (r/min) is expressed as follows:

$$N = \frac{\theta s}{360} \times f \times 60 \quad \left\{ \begin{array}{ll} N & : \text{Speed of the motor output shaft [r/min]} \\ \theta s & : \text{Step angle [deg/step]} \\ f & : \text{Pulse speed [Hz]} \\ & \quad \text{(Number of pulses input per second)} \end{array} \right.$$

Therefore, the speed of the motor output shaft (r/min) as measured in RPM:

N = (1.8 / 360) x 100 x 60 = **30 RPM**

Therefore, the value of the speed of the motor output shaft is 30 RPM.

Courtesy: Reference Links: [1]

G. The angle between rotor teeth of permanent magnet stepper motor is 3.6° and there are five stator phases in this motor. What is the step angle in this motor?

Sol. **0.72°**

To calculate the value of the step angle for the said stepper motor, we first need to calculate the value of the steps per revolution.

Thus,
Steps per revolution = Number of rotor teeth x Number of stator phases …. [1]

In our case, the angle between rotor teeth of permanent magnet stepper motor is 3.6° and therefore,

The number of rotor teeth

= 360° / 3.6° = 100

Thus, the rotor in our case, has 100 teeth.

Now, it is given that there are five stator phases in the stepper motor. Therefore, the steps per revolution using the equation [1] is:

Steps per revolution = 100 x 5 = 500 steps/rev

Now, the step angle can found using the below given equation:

Step angle = 360 / Steps per revolution …. [2]

Thus, the step angle in our case = 360/500 = **0.72°**

Courtesy: Reference Links: [1]

H. What will be the maximum starting frequency of the stepper motor under load under this situation?

Maximum starting frequency of motor, f_s =	100	Hz
Moment of inertia of rotor, J_o =	1.4	$Kg\text{-}cm^2$
Moment of inertia of load, J_L =	6	$Kg\text{-}cm^2$

Sol. **43.495 Hz**

This problem can be solved using the below given equation as explained in the referenced document:

$$f = \frac{f_s}{\sqrt{1 + \frac{J_L}{J_o}}} \text{ [Hz]}$$

f_s : Maximum starting frequency of motor [Hz]
f : Maximum starting frequency where inertial load is present [Hz]
J_o : Moment of inertia of rotor [kg·m² (oz-in²)]
J_L : Moment of inertia of load [kg·m² (oz-in²)]

Based on the above equation, *the maximum starting frequency* of the said stepper motor *under load under the given situation* can be given as below using the above equation:

= 100 / SQRT(1 + (6/1.4))
= 100 / SQRT (5.285)
= 100 / 2.29
= **43.495 Hz**

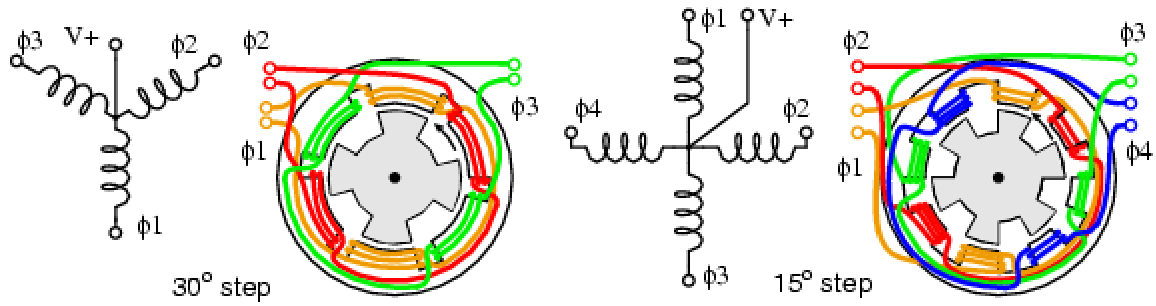
Courtesy: Reference Link: [1]

I. Describe how a variable reluctance stepper motor works. What is the big limitation of this type of stepper motor?

Sol.

Variable reluctance stepper motor:

A *variable reluctance stepper motor* relies upon magnetic flux seeking the lowest reluctance path through a magnetic circuit. This means that an irregularly shaped soft magnetic rotor will move to complete a magnetic circuit, minimizing the length of any high reluctance air gap. The stator typically has three windings distributed between pole pairs , the rotor four salient poles, yielding a 30º step angle.(Figure below) A de-energized stepper with no detent torque when hand rotated is identifiable as a variable reluctance type stepper.

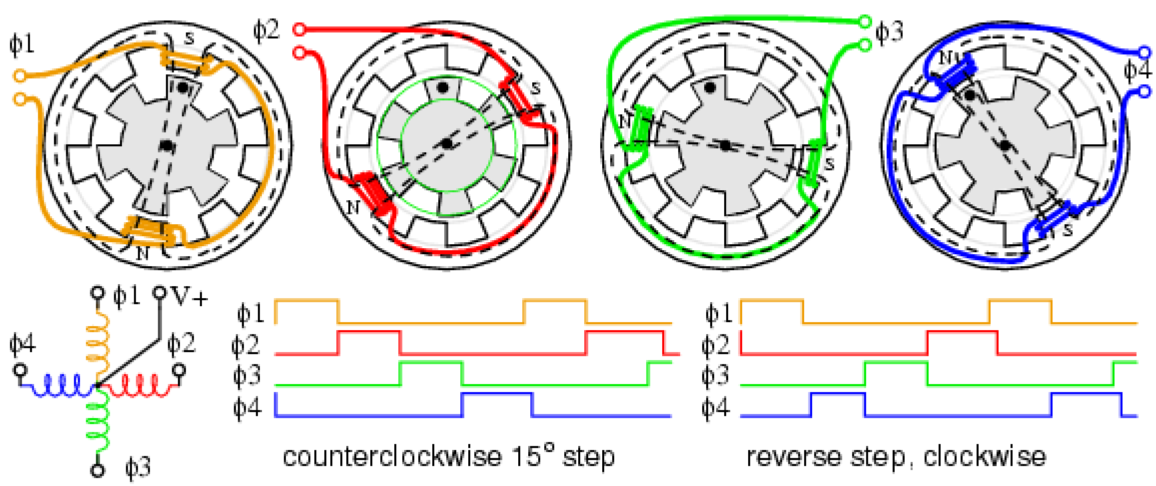


Three phase and four phase variable reluctance stepper motors.

The drive waveforms for the 3-φ stepper can be seen in the “Reluctance motor” section. The drive for a 4-φ stepper is shown in Figure below. Sequentially switching the stator phases produces a rotating magnetic field which the rotor follows. However, due to the lesser number of rotor poles, the rotor moves less than the stator angle for each step. For a variable reluctance stepper motor, the step angle is given by:

$\Theta_S = 360^o/N_S$
$\Theta_R = 360^o/N_R$
$\Theta_{ST} = \Theta_R - \Theta_S$

Where: Θ_S = stator angle, Θ_R = Rotor angle, Θ_{ST} = step angle N_S = number stator poles, N_P = number rotor poles

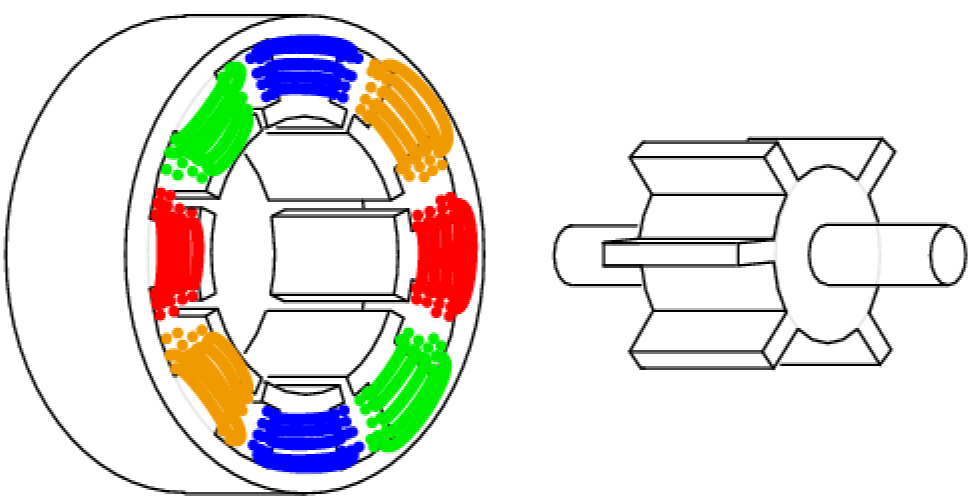


Stepping sequence for variable reluctance stepper.

In Figure above, moving from φ_1 to φ_2, etc., the stator magnetic field rotates clockwise. The rotor moves counterclockwise (CCW). Note what does not happen! The dotted rotor tooth does not move to the next stator tooth. Instead, the φ_2 stator field attracts a different tooth in moving the rotor CCW, which is a smaller angle (15º) than the stator angle of 30º. The rotor tooth angle of 45º enters into the calculation by the above equation. The rotor moved CCW to the next rotor tooth at 45º, but it aligns with a CW by 30º stator tooth. Thus, the actual step angle is the difference between a stator angle of 45º and a rotor angle of 30º. How far would the stepper rotate if the rotor and stator had the same number of teeth? Zero– no notation.

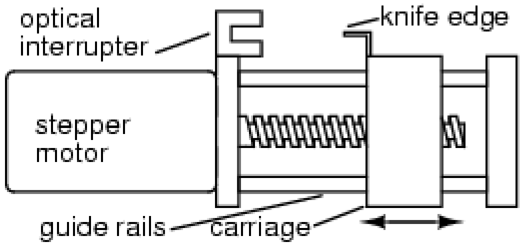
Starting at rest with phase φ_1 energized, three pulses are required (φ_2, φ_3, φ_4) to align the "dotted" rotor tooth to the next CCW stator Tooth, which is 45º. With 3-pulses per stator tooth, and 8-stator teeth, 24-pulses or steps move the rotor through 360º.

By reversing the sequence of pulses, the direction of rotation is reversed above right. The direction, step rate, and number of steps are controlled by a stepper motor controller feeding a driver or amplifier. This could be combined into a single circuit board. The controller could be a microprocessor or a specialized integrated circuit. The driver is not a linear amplifier, but a simple on-off switch capable of high enough current to energize the stepper. In principle, the driver could be a relay or even a toggle switch for each phase. In practice, the driver is either discrete transistor switches or an integrated circuit. Both driver and controller may be combined into a single integrated circuit accepting a direction command and step pulse. It outputs current to the proper phases in sequence.



Variable reluctance stepper motor.

Disassemble a reluctance stepper to view the internal components. Otherwise, we show the internal construction of a variable reluctance stepper motor in Figure above. The rotor has protruding poles so that they may be attracted to the rotating stator field as it is switched. An actual motor, is much longer than our simplified illustration.



Variable reluctance stepper drives lead screw.

The shaft is frequently fitted with a drive screw. (Figure above) This may move the heads of a floppy drive upon command by the floppy drive controller.

Variable reluctance stepper motors are applied when only a moderate level of torque is required and a coarse step angle is adequate. A screw drive, as used in a floppy disk drive is such an application. When the controller powers-up, it does not know the position of the carriage. However, it can drive the carriage toward the optical interrupter, calibrating the position at which the knife edge cuts the interrupter as "home". The controller counts step pulses from this position. As long as the load torque does not exceed the motor torque, the controller will know the carriage position.

Summary: variable reluctance stepper motor

- The rotor is a soft iron cylinder with salient (protruding) poles.
- This is the least complex, most inexpensive stepper motor.
- The only type stepper with no detent torque in hand rotation of a de-energized motor shaft.
- Large step angle
- A lead screw is often mounted to the shaft for linear stepping motion.

The big limitation of a variable reluctance stepper motor:

Of the three types of stepper motors—variable reluctance, permanent magnet, and hybrid—only variable reluctance motors do not exhibit detent torque. This is due to the difference in construction between variable reluctance motors versus permanent magnet and hybrid designs. Both permanent magnet and hybrid stepper motors use a permanent magnet rotor, which is attracted to the poles of the stator even when there is no power to the stator windings. Variable reluctance motors, on the other hand, use a passive (non-magnetized) rotor made of soft iron; therefore, there is no attraction between the rotor and the stator when the stator windings are not energized.

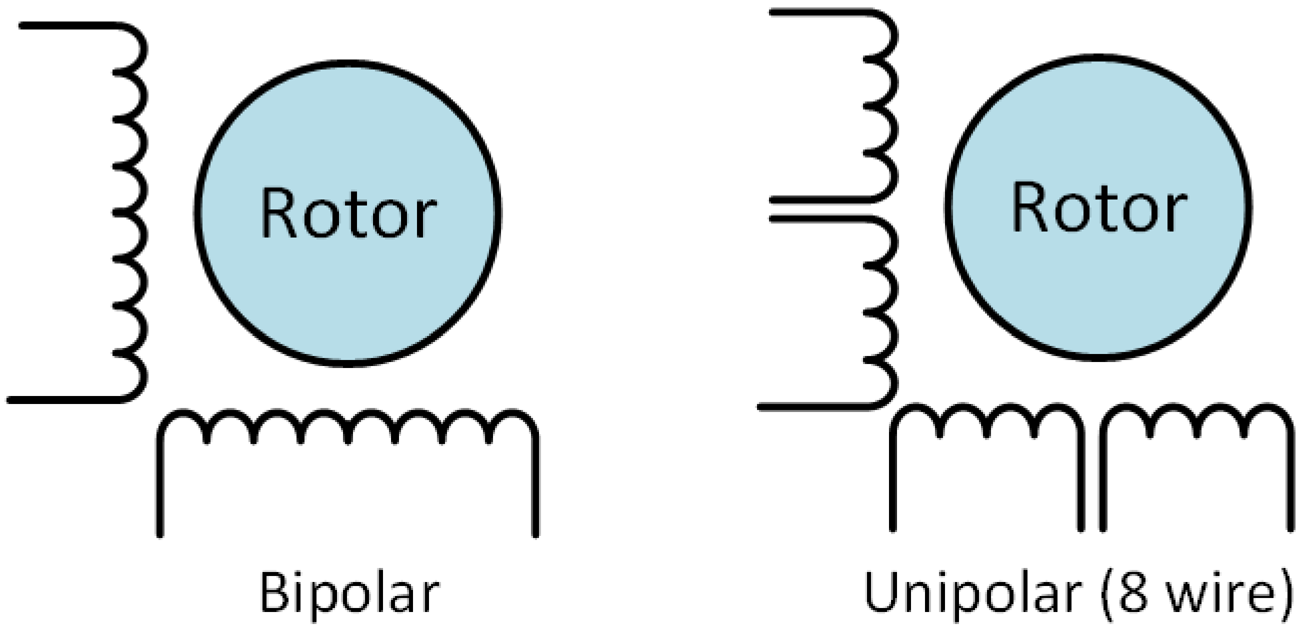
Courtesy: Reference Links: [1] [2] [3]

J. Explain which of the 4-wire, 5-wire, and 6-wire stepper motors can be driven by unipolar, bipolar, or both types of stepper motor drives?

Sol.

Coils and Phases

A stepper motor may have any number of coils. But these are connected in groups called "phases". All the coils in a phase are energized together.



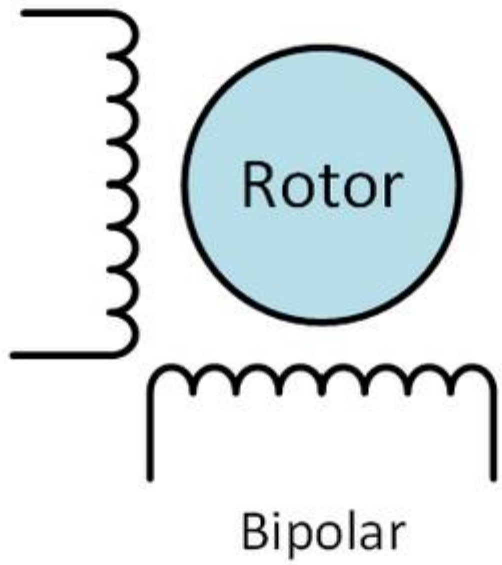
Unipolar vs. Bipolar

Unipolar drivers, always energize the phases in the same way. One lead, the "common" lead, will always be negative. The other lead will always be positive. Unipolar drivers can be implemented with simple transistor circuitry. The disadvantage is that there is less available torque because only half of the coils can be energized at a time.

Bipolar drivers use H-bridge circuitry to actually reverse the current flow through the phases. By energizing the phases with alternating the polarity, all the coils can be put to work turning the motor.

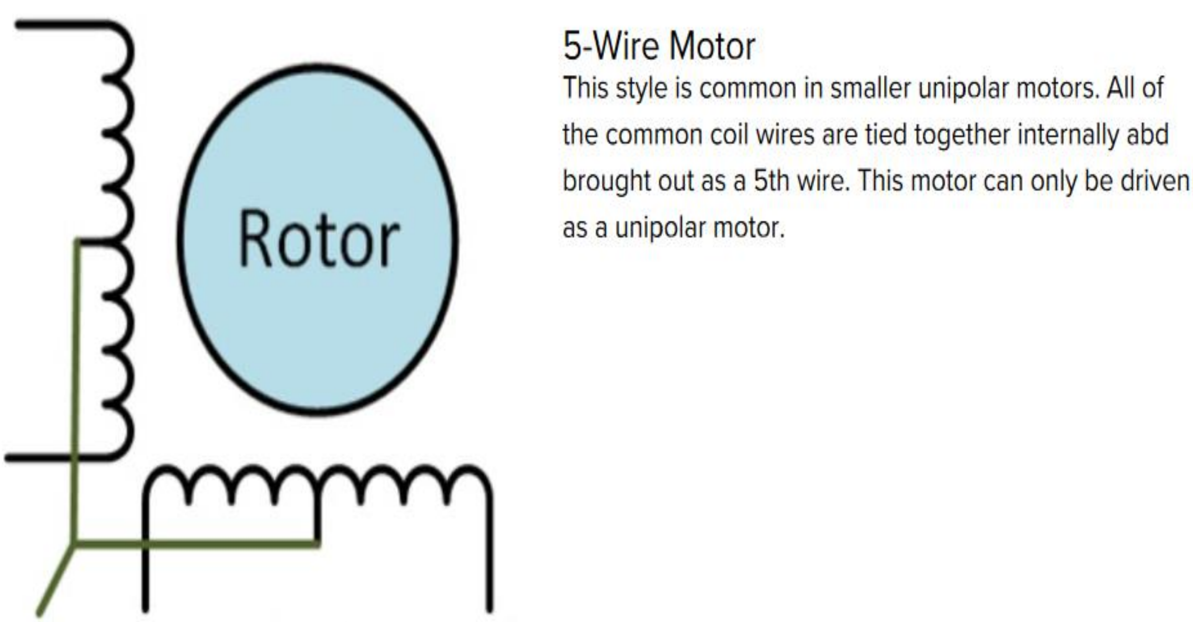
A two phase bipolar motor has 2 groups of coils. A 4 phase unipolar motor has 4.

4-wire stepper motor:

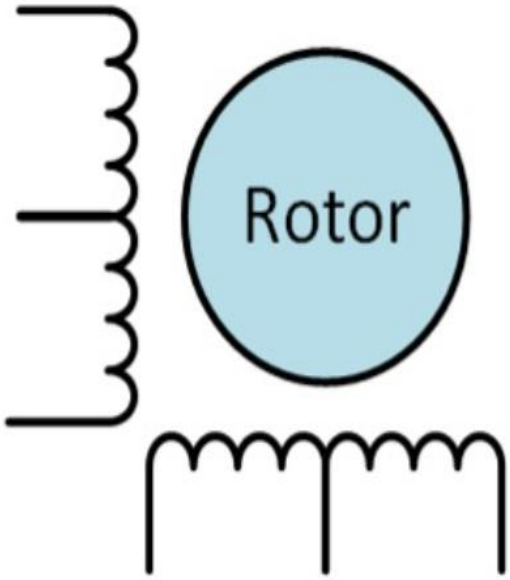


A 2-phase **bipolar** motor will have **4 wires** - 2 for each phase. Some motors come with flexible wiring that allows you to run the motor as either bipolar or unipolar.

5-wire stepper motor:



6-wire stepper motor:



6-Wire Motor

This motor only joins the common wires of 2 paired phases. These two wires can be joined to create a 5-wire unipolar motor.

Or you just can ignore them and treat it like a bipolar motor!

Courtesy: Reference Links: [1] [2]