19MCT204- Electrical Drives and Control

RELUCTANCE MOTOR

Variable Reluctance Motor

Variable reluctance (VR) motors have a plain iron rotor and operate based on the principle that minimum reluctance occurs with minimum gap, hence the rotor points are attracted toward the stator magnet poles.

The stepper motor like variable reluctance is the basic type of motor and it is used for the past many years. As the name suggests, the rotor's angular position mainly depends on the magnetic circuit's reluctance that can be formed among the teeth of the stator as well as a rotor.

Hybrid Synchronous Motor

Hybrid stepper motors are named because they use a combination of permanent magnet (PM) and variable reluctance (VR) techniques to achieve maximum power in small package sizes.

The most popular type of motor is the hybrid stepper motor because it gives a good performance as compared with a permanent magnet rotor in terms of speed, step resolution, and holding torque. But, this type of stepper motor is expensive as compared with permanent magnet stepper motors. This motor combines the features of both the permanent magnet and variable reluctance stepper motors. These motors are used where less stepping angle is required like 1.5, 1.8 & 2.5 degrees.

How to Select a Stepper Motor?

Before selecting a stepper motor for your requirement, it is very significant to examine the torque-speed curve of the motor. So this information is available from the designer of the motor, and it is a graphical symbol of the torque of the motor at a specified speed. The motor's torque-speed curve should match closely the necessities of the application; or else, the expected system performance cannot be obtained.

Types of Wiring

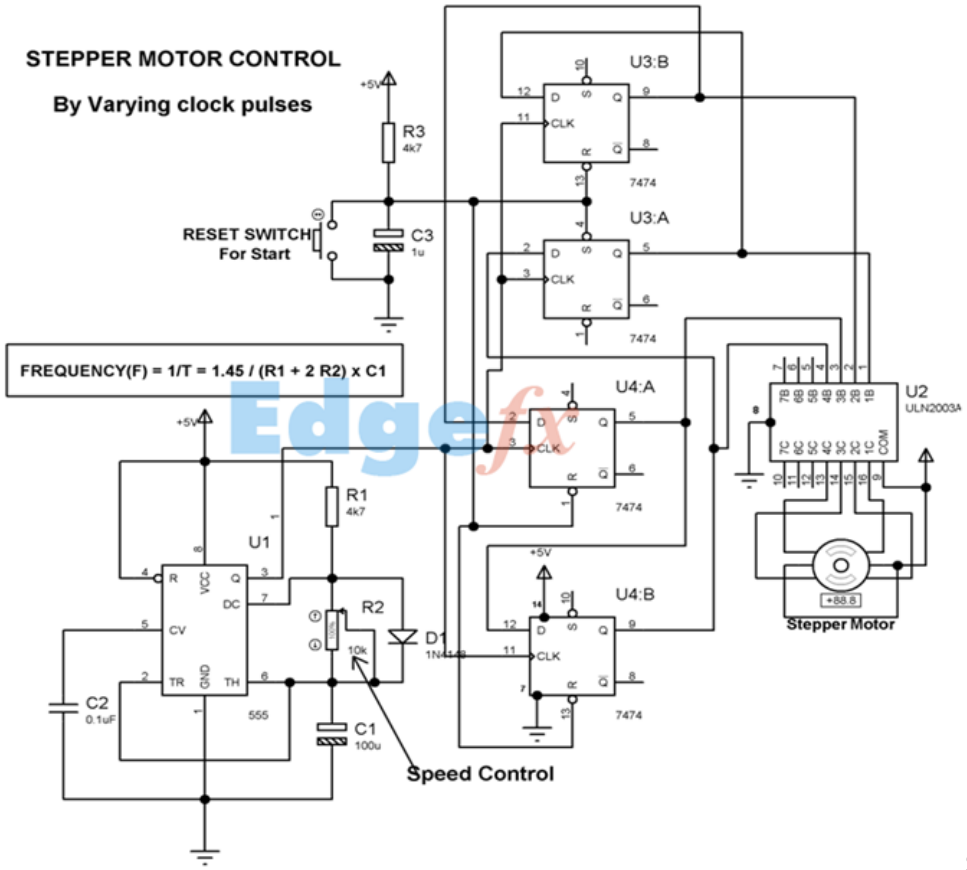
The stepper motors are generally two-phase motors like unipolar otherwise bipolar. For each phase in a unipolar motor, there are two windings. Here, center-tapped is a common one lead in between two windings toward a pole. The unipolar motor has 5 to 8 leads.

In the construction, where the common of two poles are divided however center-tapped, this stepper motor includes six leads. If the two-pole center taps are short inside, then this motor includes five leads. Unipolar with 8 leads will facilitate both series & parallel connection while the motor with five lead or six lead has stator coil's series connection. The operation of the unipolar motor can be simplified because while operating them, there is no requirement of reversing the flow of current within the driving circuit which are known as bifilar motors.

In a bipolar stepper motor, for each pole, there is a single winding. The direction of supply needs to change through the driving circuit so that it will become complex so these motors are called unifilar motors.

Stepper Motor Control by Varying Clock Pulses

Stepper motor control circuit is a simple and low-cost circuit, mainly used in low power applications. The circuit is shown in the figure, which consists of 555 timers IC as a stable multi-vibrator. The frequency is calculated by using the given relationship. Frequency = 1/T = 1.45/(RA + 2RB)C Where RA = RB = R2 = R3 = 4.7 kilo-ohm and C = C2 = 100 µF.



Stepper Motor Control by Varying Clock Pulses

The output of the timer is used as a clock for two 7474 dual 'D' flip-flops (U4 and U3) configured as a ring counter. When power is initially switched on, only the first flip-flop is set (i.e. Q output at pin 5 of U3 will be at logic '1') and the other three flip-flops are reset (i.e. the output of Q is at logic 0). On receipt of a clock pulse, the logic '1' output of the first flip-flop gets shifted to the second flip-flop (pin 9 of U3).

Thus, logic 1 output keeps shifting circularly with every clock pulse. Q outputs of all the four flip-flops are amplified by Darling-ton transistor arrays inside ULN2003 (U2) and connected to the stepper motor windings orange, brown, yellow, black to 16, 15,14, 13 of ULN2003 and the red to +ve supply.

The common point of the winding is connected to the +12V DC supply, which is also connected to pin 9 of ULN2003. The color code used for the windings is may vary from make to make. When the power is switched on, the control signal connected to the SET pin of the first flip-flop and CLR pins of the other three flip-flops goes active 'low' (because of the power-on-reset circuit formed by the R1-C1 combination) to set the first flip-flop and reset the remaining three flip-flops.

On reset, Q1 of IC3 goes 'high' while all other Q outputs go 'low'. An external reset can be activated by pressing the reset switch. By pressing the reset switch, you can

stop the stepper motor. The motor again starts rotating in the same direction by releasing the reset switch.

Difference between Stepper Motor and Servo Motor

Servo motors are suitable for high torque & speed applications whereas the stepper motor is less expensive so they are used where the high holding torque, acceleration with low-to-medium, the open otherwise closed-loop operation flexibility is required. The difference between the stepper motor and servo motor includes the following.

Stepper Motor	**Servo Motor**
The motor which moves in discrete steps is known as the stepper motor.	A servo motor is one kind of closed-loop motor that is connected to an encoder to provide speed feedback & position.
Stepper motor is used where control, as well as precision, are main priorities	Servo motor is used where the speed is the main priority
The overall pole count of the stepper motor ranges from 50 to 100	The overall pole count of servo motor ranges from 4to 12
In a closed-loop system, these motors move with a consistent pulse	These motors need an encoder to change pulses to control the position.
Torque is high in less speed	Torque is low in high speed
Positioning time is faster throughout short strokes	Positioning time is faster throughout long strokes
High-tolerance movement of inertia	Low-tolerance movement of inertia
This motor is suitable for low rigidity mechanisms like pulley and belt	Not suitable for less-rigidity mechanism

Responsiveness is high	Responsiveness is low
These are used for fluctuating loads	These are not used for fluctuating loads
The adjustment of gain/tuning is not required	The adjustment of gain/tuning is required

Stepper Motor vs DC Motor

Both the stepper and dc motors are used in different industrial applications but the main differences between these two motors are a little bit confusing. Here, we are listing some common characteristics between these two designs. Each characteristic is discussed below.

Characteristics	**Stepper Motor**	**DC Motor**
Control Characteristics	Simple and uses microcontroller	Simple and no extras required
Speed Range	Low from 200 to 2000 RPMs	Moderate
Reliability	High	Moderate
Efficiency	Low	High
Torque or Speed Characteristics	Highest Torque at Fewer Speeds	High Torque at Fewer Speeds
Cost	Low	Low

Parameters of Stepper Motor

The stepper motor parameters mainly include step angle, steps for each revolution, steps for each second, and RPM.

Step Angle

The step angle of the stepper motor can be defined as the angle at which the motor's rotor turns once a single pulse is given to the stator's input. The resolution of the motor can be defined as the number of steps of the motor and the number of revolutions of the rotor.

Resolution = Number of Steps/Number of Revolution of the Rotor

The motor's arrangement can be decided through the step-angle & it is expressed within degrees. The resolution of a motor (the step number) is the no. of steps which make within a single revolution of the rotor. When the step-angle of the motor is small then the resolution is high for the arrangement of this motor.

The exactness of the arrangements of the objects through this motor mainly depends on the resolution. Once the resolution is high then the accuracy will be low.

Some accuracy motors can create 1000 steps within a single revolution including 0.36 degrees of step-angle. A typical motor includes 1.8 degrees of step angle with 200 steps for each revolution. The different step angles such as 15 degrees, 45 degrees, and 90 degrees are very common in normal motors. The number of angles can change from two to six and a small step angle can be attained through slotted pole parts.

Steps for Each Revolution
The steps for each resolution can be defined as the number of step angles necessary for a total revolution. The formula for this is 360°/Step Angle.

Steps for Each Second
This kind of parameter is mainly used for measuring the number of steps covered within each second.

Revolution per Minute
The RPM is the revolution per minute. It is used to measure the frequency of revolution. So by using this parameter, we can calculate the number of revolutions in a single minute. The main relation between the parameters of the stepper motor is like the following.

Steps for Each Second = Revolution per Minute x Steps per Revolution / 60

Stepper Motor Interfacing with 8051 Microcontroller

Stepper motor interfacing with 8051 is very simple by using three modes like wave drive, full step drive & half step drive by giving the 0 & 1 to the motor's four wires based on which drive mode we have to choose for running this motor.

The remaining two wires must be coupled to a voltage supply. Here the unipolar stepper motor is used where the four ends of the coils are connected to the primary four pins of port-2 in the microcontroller using the ULN2003A.

This microcontroller doesn't supply sufficient current to drive the coils so the current driver IC likes ULN2003A. ULN2003A must be used and it is the collection of 7-pairs of NPN Darlington transistors. The designing of the Darlington pair can be done

through two bipolar transistors which are connected for achieving maximum current amplification.

In ULN2003A driver IC, input pins are 7, output pins are 7, where two pins are for power supply & Ground terminals. Here 4-input & 4-output pins are used. As an alternative to ULN2003A, L293D IC is also used for amplification of current.

You need to observe two common wires & four coil wires very carefully or else the stepper motor will not turn. This can be observed by measuring the resistance through a multimeter but the multimeter won't display any readings among the two phases of wires. Once the common wire & other two wires are in the equal phase then it must show a similar resistance whereas the two coils finish points in the similar phase will demonstrate the double resistance as compared with resistance among common point as well as one endpoint.

Troubleshooting

- Troubleshooting is the process to check the motor status whether the motor is working or not. The following checklist is used to troubleshoot the stepper motor.
- First, verify the connections as well as the code of the circuit.
- If it is ok, next verify that the motor gets proper voltage supply or else it simply vibrate however not revolve.
- If the voltage supply is well, then verify the endpoints of the four coil which is allied to ULN2003A IC.
- First, discover the two general endpoints & fix them to 12v supply, after that fix the residual four wires to IC ULN2003A. Until the stepper motor gets started, attempt all possible combinations. If the connection of this is not proper then this motor will vibrate in place of revolving.

Can Stepper Motors Run Continuously?

Generally, all the motors run or rotate continuously but most of the motors cannot stop while they under power, When you try to restrict the shaft of a motor when it is under power supply then it will burn or break.

Alternatively, stepper motors are designed to make a discrete step, then wait there; again step and stay there. If we want to make the motor stay in a single location for less time before stepping again then it will look like rotating continuously. The power consumption of these motors is high but the power dissipation mainly occurs once the motor is stopped or designed poorly then there is a chance for overheating. Because of this reason, the motor's current supply is frequently decreased once the motor is in a holding position for a longer time.

The main reason is, once the motor is rotating, its input electrical power part can be changed to mechanical power. When the motor is stopped while it is rotating, then all input power can be changed into heat on the inside of the coil.

Advantages

The **advantages of stepper motor** include the following.

- Ruggedness
- Simple construction
- Can work in an open-loop control system
- Maintenance is low
- It works in any situation
- Reliability is high
- The rotation angle of the motor is proportional to the input pulse.
- The motor has full torque at standstill.
- Precise positioning and repeatability of movement since good stepper motors have an accuracy of 3 – 5% of a step and this error is noncumulative from one step to the next.
- Excellent response to starting, stopping, and reversing.
- Very reliable since there are no contact brushes in the motor. Therefore the life of the motor is simply dependant on the life of the bearing.
- The motor's response to digital input pulses provides open-loop control, making the motor simpler and less costly to control.
- It is possible to achieve very low-speed synchronous rotation with a load that is directly coupled to the shaft.
- A wide range of rotational speeds can be realized as the speed is proportional to the frequency of the input pulses.

Disadvantages

The **disadvantages of stepper motor** include the following.

- Efficiency is low
- The Torque of a motor will declines fast with speed
- Accuracy is low
- Feedback is not used for specifying potential missed steps
- Small Torque toward Inertia Ratio
- Extremely Noisy
- If the motor is not controlled properly then resonances can occur
- Operation of this motor is not easy at very high speeds.
- The dedicated control circuit is necessary
- As compared with DC motors, it uses more current

Applications

The **applications of stepper motor** include the following.

1. **Industrial Machines** – Stepper motors are used in automotive gauges and machine tooling automated production equipment.
2. **Security** – new surveillance products for the security industry.
3. **Medical** – Stepper motors are used inside medical scanners, samplers, and also found inside digital dental photography, fluid pumps, respirators, and blood analysis machinery.
4. **Consumer Electronics** – Stepper motors in cameras for automatic digital camera focus and zoom functions.