Lecture 8. Stepper Motors

<u>STEPPER MOTOR</u> – an electromagnetic actuator. It is an incremental drive (digital) actuator and is driven in fixed angular steps.

This mean that a digital signal is used to drive the motor and every time it receives a digital pulse it rotates a specific number of degrees in rotation.

- Each step of rotation is the response of the motor to an input pulse (or digital command).
- Step-wise rotation of the rotor can be synchronized with pulses in a command-pulse train, assuming that no steps are missed, thereby making the motor respond faithfully to the pulse signal in an open-loop manner.
- Stepper motors have emerged as cost-effective alternatives for DC servomotors in high-speed, motion-control applications (except the high torque-speed range) with the improvements in permanent magnets and the incorporation of solid-state circuitry and logic devices in their drive systems.
- Today stepper motors can be found in computer peripherals, machine tools, medical equipment, automotive devices, and small business machines, to name a few applications.

Stepper motors are usually operated in open loop mode.

<u>TYPES OF MOTORS AVAILABALE</u>

Brushed	Most common. Toys, battery powered tools, electric machines. Apply power and go!
Brushless	Less common. Higher efficiency, less friction, less electrical noise. Requires electronic driver
Step Motor	Very common. Requires driver. Very strong when not rotating. Easy to control rotor position
Piezo (ultrasonic)	Relatively new type. Requires driver. No electrical coils. More torque with axial load!
Linear	Same as Brushed or Step but it is 'opened and unrolled' Moves load linearly

DC MOTORS VS. STEPPER MOTORS

- Stepper motors are operated open loop, while most DC motors are operated closed loop.
- Stepper motors are easily controlled with microprocessors, however logic and drive electronics are more complex.
- Stepper motors are brushless and brushes contribute several problems, e.g., wear, sparks, electrical transients.
- DC motors have a continuous displacement and can be accurately positioned, whereas stepper motor motion is incremental and its resolution is limited to the step size.
- Stepper motors can slip if overloaded and the error can go undetected. (A few stepper motors use closed-loop control.)
- Feedback control with DC motors gives a much faster response time compared to stepper motors.

ADVANTAGES OF STEPPER MOTORS

- Position error is noncumulative. A high accuracy of motion is possible, even under open-loop control.
- Large savings in sensor (measurement system) and controller costs are possible when the open-loop mode is used.
- Because of the incremental nature of command and motion, stepper motors are easily adaptable to digital control applications.
- No serious stability problems exist, even under open-loop control.
- Torque capacity and power requirements can be optimized and the response can be controlled by electronic switching.
- Brushless construction has obvious advantages.

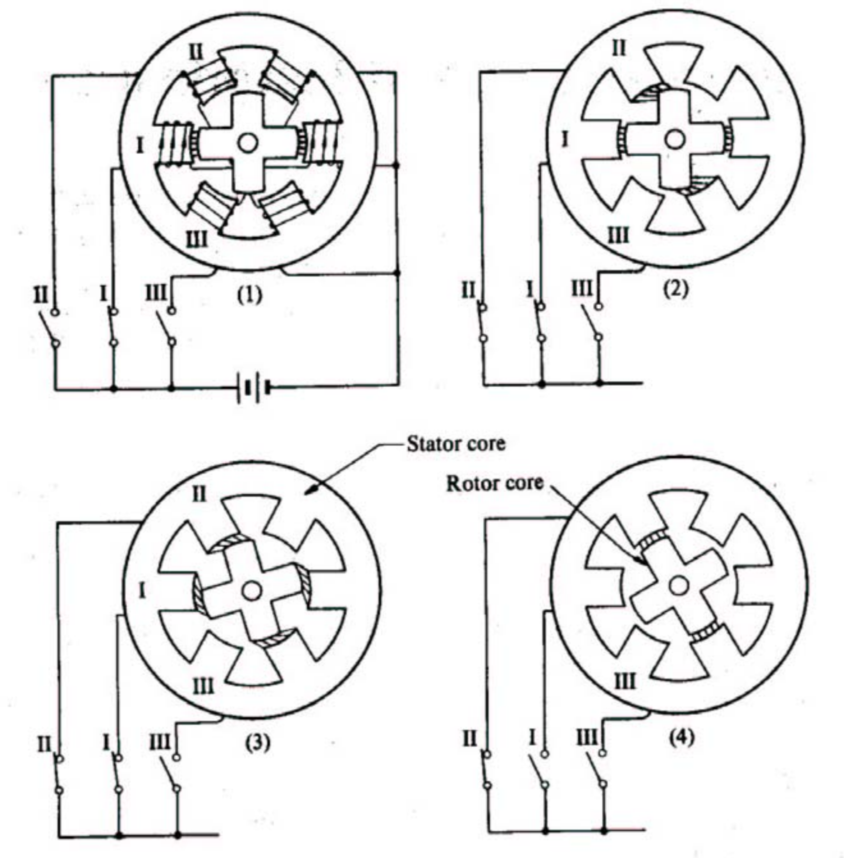
DISADVANTAGES OF STEPPER MOTORS

- They have low torque capacity (typically less than 2,000 oz-in) compared to DC motors.
- They have limited speed (limited by torque capacity and by pulse-missing problems due to faulty switching systems and drive circuits).

•They have high vibration levels due to stepwise motion.

•Large errors and oscillations can result when a pulse is missed under open-loop control.

STEPPER MOTOR BASICS



STEPPER MOTOR STATES FOR MOTION

The above figure is the cross-section view of a single-stack variable-reluctance motor. The stator core is the outer structure and has six poles or teeth. The inner device is called the rotor and has four poles. Both the stator and rotor are made of soft steel. The stator has three sets of windings as shown in the figure. Each set has two coils connected in series. A set of windings is called a "phase". The motor above, using this designation, is a three-phase motor. Current is supplied from the DC power source to the windings via the switches I, II, and, III.

Starting with state (1) in the upper left diagram, note that in state (1), the winding of Phase I is supplied with current through switch I. This is called in technical terms, "phase I is excited". Arrows on the coil windings indicate the magnetic flux, which occurs in the air-gap due to the excitation. In state I, the two stator poles on phase I being excited are in alignment with two of the four rotor teeth. This is an equilibrium state.

Next, switch II is closed to excite phase II in addition to phase I. Magnetic flux is built up at the stator poles of phase II in the manner shown in state (2), the upper right diagram. A counter-clockwise torque is created due to the "tension" in the inclined magnetic flux lines. The rotor will begin to move and achieve state (3), the lower left diagram. In state (3) the rotor has moved 15°.

When switch I is opened to de-energize phase I, the rotor will travel another 15° and reach state (4). The angular position of the rotor can thus be controlled in units of the step angle by a switching process. If the switching is carried out in sequence, the rotor will rotate with a stepped motion; the switching process can also control the average speed.

STEP ANGLE

The step angle, the number of degrees a rotor will turn per step, is calculated as follows:

$$\textbf{Step Angle}\,(\Theta_S) = \frac{360^\circ}{S}$$

$$S = mN_r$$

$$m = \textit{number of phases}$$

$$N_r = \textit{number of rotor teeth}$$

For this motor:

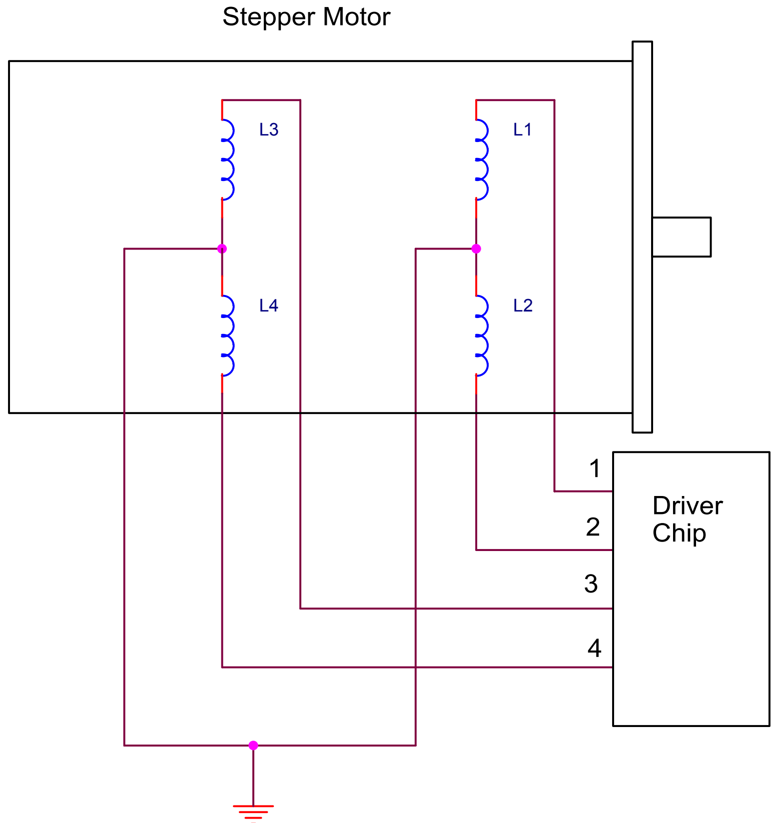
$$m = 3$$

$$N_r = 4$$

$$S = mN_r = 3 \bullet 4 = 12$$

$$\Theta_S = \frac{360^\circ}{12} = 30^\circ \textit{ per step}$$

BASIC WIRING DIAGRAM



TWO PHASE STEPPER-MOTOR WIRING DIAGRAM

The above motor is a two-phase motor. This is sometimes called UNIPOLAR. The two-phase coils are center-tapped and in this case they the center-taps are connected to ground. The coils are wound so that current is reversed when the drive signal is applied to either coil at a time. The north and south poles of the stator phases reverse depending upon whether the drive signal is applied to coil 1 as opposed to coil 2.

STEP SEQUENCING

There are three modes of operation when using a stepper motor. The mode of operation is determined by the step sequence applied. The three step sequences are:

Wave	
Full	H = HIGH = +V
Half Stepping	L = LOW = 0V

WAVE STEPPING

The wave stepping sequence is shown below.

STEP	L1	L2	L3	L4
1	H	L	L	L
2	L	H	L	L
3	L	L	H	L
4	L	L	L	H

Wave stepping has less torque then full stepping. It is the least stable at higher speeds and has low power consumption.

FULL STEPPING

The full stepping sequence is shown below.

STEP	L1	L2	L3	L4
1	H	H	L	L
2	L	H	H	L
3	L	L	H	H
4	H	L	L	H

Full stepping has the lowest resolution and is the strongest at holding its position. Clock-wise and counter clockwise rotation is accomplished by reversing the step sequence.

HALF-STEPPING – A COMBINATION OF WAVE AND FULL STEPPING

The half-step sequence is shown below.

STEP	L1	L2	L3	L4
1	H	L	L	L
2	H	H	L	L
3	L	H	L	L
4	L	H	H	L
5	L	L	H	L
6	L	L	H	H
7	L	L	L	H
8	H	L	L	H

The half-step sequence has the most torque and is the most stable at higher speeds. It also has the highest resolution of the main stepping methods. It is a combination of full and wave stepping.

ADDITIONAL INFORMATION

If the drive chip does not have internal clamp diodes, you need to supply them. The motor can produce >100V due to back EMF.

****************<u>**MAKE SURE ALL GRONDS ARE CONNECTED**</u> ****************

You reverse the motor rotation by reversing the sequence.

In the lab you will use the SAA1042 driver chip. This chip has a pin to control clock-wise (CW) and counter clock-wise (CCW) rotation and to select between full and half-step modes of operation.