TASK 1

The **unipolar stepper motor** has a step angle of $7.5°$ and we drive it by a full stepper microcontroller. The motor must rotate $360°$.

a) Calculate the number of steps required for a complete $360°$ rotation.

b) Define the step sequence for the full step mode.

Solution:

The step angle of the motor is given as 7.5°. To find the number of steps required to complete a 360° rotation, we use the following formula:

$$N = \frac{360°}{\frac{7.5°}{step}} = 48\, steps$$

In a unipolar stepper motor, the full-step mode typically involves energizing two coils at a time to achieve maximum torque. Here is the step sequence for a 4-phase unipolar stepper motor in full-step mode:

- Energize coils A and B.
- Energize coils B and C.
- Energize coils C and D.
- Energize coils D and A.

The sequence repeats to continue rotation. Assuming the coils are labelled as A, B, C, and D, the step sequence in terms of coil activation would be:

- Step 1: A+, B-
- Step 2: B+, C-
- Step 3: C+, D-
- Step 4: D+, A-

TASK 2

The **bipolar stepper motor** has a step angle of $1.8°$ and we drive it by a half-stepping microcontroller. The motor must rotate $90°$ clockwise.

a) Calculate the number of steps required for a $90°$ rotation.

b) Determine the step sequence for the half-stepping mode.

Solution:

The step angle of the motor is given as 1.8°. When driving the motor in half-stepping mode, the effective step angle is halved. Therefore, the half-step angle is:

$$Half - step\ angle = \frac{1.8°}{2} = 0.9°$$

To find the number of half-steps required to rotate 90°, we use the following formula:

$$Number\ of\ half - steps = \frac{90°}{Half - step\ angle} = \frac{90°}{0.9°} = 100$$

Therefore, 100 half-steps are required for a 90° rotation.

In a bipolar stepper motor, the half-stepping mode involves alternating between full steps (where two coils are energized) and half steps (where only one coil is energized). Here is a typical sequence for a 4-wire bipolar stepper motor (coils labelled A, A', B, and B'):

- Energize coil A
- Energize coils A and B
- Energize coil B
- Energize coils B and A'
- Energize coil A'
- Energize coils A' and B'
- Energize coil B'
- Energize coils B' and A

This sequence repeats to continue rotation. Here is the detailed step sequence:

- Step 1: A+ (coil A energized)
- Step 2: A+ and B+ (coils A and B energized)

- Step 3: B+ (coil B energized)
- Step 4: B+ and A- (coils B and A' energized)
- Step 5: A- (coil A' energized)
- Step 6: A- and B- (coils A' and B' energized)
- Step 7: B- (coil B' energized)
- Step 8: B- and A+ (coils B' and A energized)

TASK 3

We drive a bipolar stepper motor with a step angle of $1.8°$ by a microcontroller with a micro stepping function. We use 16 micro steps per full step. We want to rotate the motor by $180°$.

a) Calculate the number of micro steps required to turn the motor $180°$

b) Determine the micro stepping resolution (in degrees)

Solution:

First, calculate the number of full steps required to turn the motor 180°:

$$Number\ of\ full\ steps = \frac{180°}{1.8°} = 100$$

Since there are 16 micro steps per full step, the number of micro steps required for 180° rotation is:

$$\begin{aligned} Number\ of\ micro\ steps &= Number\ of\ full\ steps\ \cdot\ Micro\ steps\ per\ full\ step \\ &= 100\ \cdot\ 16 = 1600 \end{aligned}$$

So, 1600 micro steps are required to turn the motor 180°.

Micro stepping resolution refers to the angle covered by one micro step. To calculate this, we divide the full step angle by the number of micro steps per full step:

$$Micro\ stepping\ resolution = \frac{Full\ step\ angle}{Micro\ steps\ per\ full} = \frac{1.8°}{16} = 0.1125°$$

Therefore, the micro stepping resolution is 0.1125° per micro step.

TASK 4

We connect a stepper motor with a step angle of $1.8°$ to a gearbox with a reduction ratio of 4:1. We drive the motor by a half-stepping microcontroller. The output shaft of the reducer must rotate $360°$.

a) Calculate the number of half steps required for the output shaft to rotate $360°$.

b) Determine the equivalent pitch angle on the output shaft.

Solution:

First, determine the effective step angle when using half-stepping:

$$Half - step\ angle = \frac{Full\ step\ angle}{2} = \frac{1.8°}{2} = 0.9°$$

Next, calculate the number of half steps required for the motor to rotate one full turn (360°):

$$Number\ of\ half\ steps\ for\ 360° = \frac{360°}{0.9°} = 400$$

With the gearbox reduction ratio of 4:1, the motor needs to make four full rotations to achieve one full rotation of the output shaft. Therefore, the number of half steps required for the output shaft to rotate 360°:

$$Number\ of\ half\ steps\ for\ the\ output\ shaft\ to\ rotate\ 360° = 400 \cdot 4 = 1600$$

Therefore, 1600 half steps are required for the output shaft to rotate 360°.

Now, calculate the equivalent pitch angle:

$$Pitch\ angle = \frac{360°}{Number\ of\ half\ steps} = \frac{360°}{1600} = 0.225°$$

Therefore, the equivalent pitch angle on the output shaft is 0.225° per half step.

TASK 5

The bipolar stepper motor has a step angle of $1.8°$ and we drive it by a microcontroller. The motor is equipped with a quadrature encoder that provides 1000 pulses per revolution (PPR) for position feedback. The motor must rotate $720°$.

a) Calculate the number of encoder steps and pulses required for a $720°$ rotation.

b) Determine the resolution of the encoder in degrees.

Solution:

First, determine the number of full steps required for the motor to rotate 720°:

$$Number\ of\ full\ steps = \frac{720°}{1.8°} = 400$$

Next, calculate the number of revolutions required for a 720° rotation:

$$Number\ of\ revolutions = \frac{720°}{360°} = 2$$

Since the encoder provides 1000 pulses per revolution, the total number of pulses for two revolutions (720°) is:

$$Number\ of\ pulses = 2 \cdot 1000 = 2000$$

Therefore, 2000 encoder pulses are required for a 720° rotation.

The resolution of the encoder is the angle that corresponds to one pulse from the encoder. Since the encoder provides 1000 pulses per revolution (360°), the resolution can be calculated as:

$$Encoder\ resolution = \frac{360°}{PPR} = \frac{360°}{1000} = 0.36°$$

Therefore, the resolution of the encoder is 0.36° per pulse.

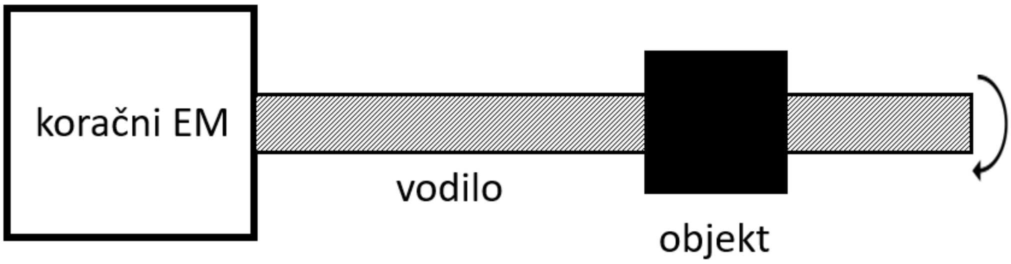
TASK 6

There is a threaded linear guide on the axis of the stepper motor with a quarter micro-stepping.

How many micro steps are needed to move the object on the guide by $1\ cm$, if the number of steps of the electric motor for 1 revolution is equal to 100, and the number of revolutions of the electric motor to move the object by $1\ cm$ is 5? How many full steps would be required for the same effect?

What should be the clock rate of the microcontroller that controls the motor if we want the object to move at a speed of $5\ cm/s$?

Circuit:



Data:

$N = 100$

$micro - stepping = ¼$

$revs/cm = 5$

$S_{\mu}, S, f = ?$

Solution:

In quarter micro-stepping, each full step is divided into 4 micro steps.

Therefore, the motor performs $100 \cdot 4 = 400$ micro steps per revolution.

Since it takes five revolutions to move 1 cm, the total number of micro steps needed is $400 \cdot 5 = 2000$ micro steps.

Given that one full step equals four micro steps, the total number of full steps required to move 1 cm can be calculated as $\frac{2000}{4} = 500$ full steps.

To move the object at a speed of 5 cm/s, the motor must complete enough micro steps for 5 cm within one second.

The total number of micro steps for 5 cm is $2000 \cdot 5 = 10000$.

Therefore, the clock rate of the microcontroller should be set to generate 10000 pulses per second to achieve this speed.

TASK 7

We connect the stepper motor to a voltage of $12\ V$. At this voltage, a current of $0.4\ A$ flows through each coil (phase) (stationary state). The inductance of the coil is $37\ mH$. We use full step stepping, the angle of one motor step is $1.8°$. There is a guide on the axis of the motor, which must rotate 5 revolutions for $1\ cm$ of movement, and the desired speed of movement of the linear guide is $0.5\ cm/s$.

Determine:

- the number of steps required for 1 turn,
- the time required for 1 step,
- rotation frequency of the electric motor,
- maximum power consumed by the electric motor,
- microcontroller frequency (clock).

Data:

$U = 12\ V$

$I_L = 0.4\ V$

$L = 37\ mH$

$\varphi = 1.8°$

$revs/cm = 5$

$v = 0.5\ cm/s$

$S, t, \omega_M, P_{MAX}, f_{MC} = ?$

Solution:

Each full step rotates the motor by 1.8°.

$$Steps\ per\ revolution = \frac{360°}{1.8°} = 200$$

To calculate time required for one step, first calculate the total number of steps required to move 0.5 cm:

- 5 revolutions = 1 cm of movement
- Desired speed: 0.5 cm/s, so the motor needs to make 2.5 revolutions per second to achieve this speed.

$$Total\ steps\ per\ second = 2.5\ revolutions\ per\ second \cdot 200\ steps\ per\ revolution$$
$$= 500\ steps\ per\ second$$

The time required for one step is the reciprocal of the steps per second:

$$Time\ per\ step = \frac{1}{Steps\ per\ second} = \frac{1}{500\ steps\ per\ second} = 0.002\ seconds$$
$$= 2\ ms$$

The rotation frequency is the number of revolutions per second:

$$Rotation\ frequency = 2.5\ revolutions\ per\ second$$

Maximum power consumed can be calculated using the power formula for resistive loads:

$$P = U \cdot I$$

For each coil:

$$P_{coil} = 12\,V \cdot 0.4\,A = 4.8\,W$$

Since the motor has two coils:

$$P_{total} = 2 \cdot P_{coil} = 2 \cdot 4.8\,W = 9.6\,W$$

The microcontroller needs to provide 500 steps per second to achieve the desired movement speed:

$$Microcontroller\ frequency = 500\ steps\ per\ second$$