User's guide for DT-C005

Stepper Motors

EXOTEST® EDUCATION

Document No. 00308616-v1

1. RESOURCES FILE

1.1 STEPPER MOTORS

1.1.1 Principle of operation of the stepper motor

Stepper motors receive an ordered sequence of square-wave signals or pulses and convert them into a rotational mechanical movement made up of a series of increments called “steps” or “½ steps”.
For the four-pole motors described below, one full step corresponds to a 90° rotation of the motor’s shaft (or rotor). Similarly, a ½ step corresponds to the rotor moving through an angle of 45°.

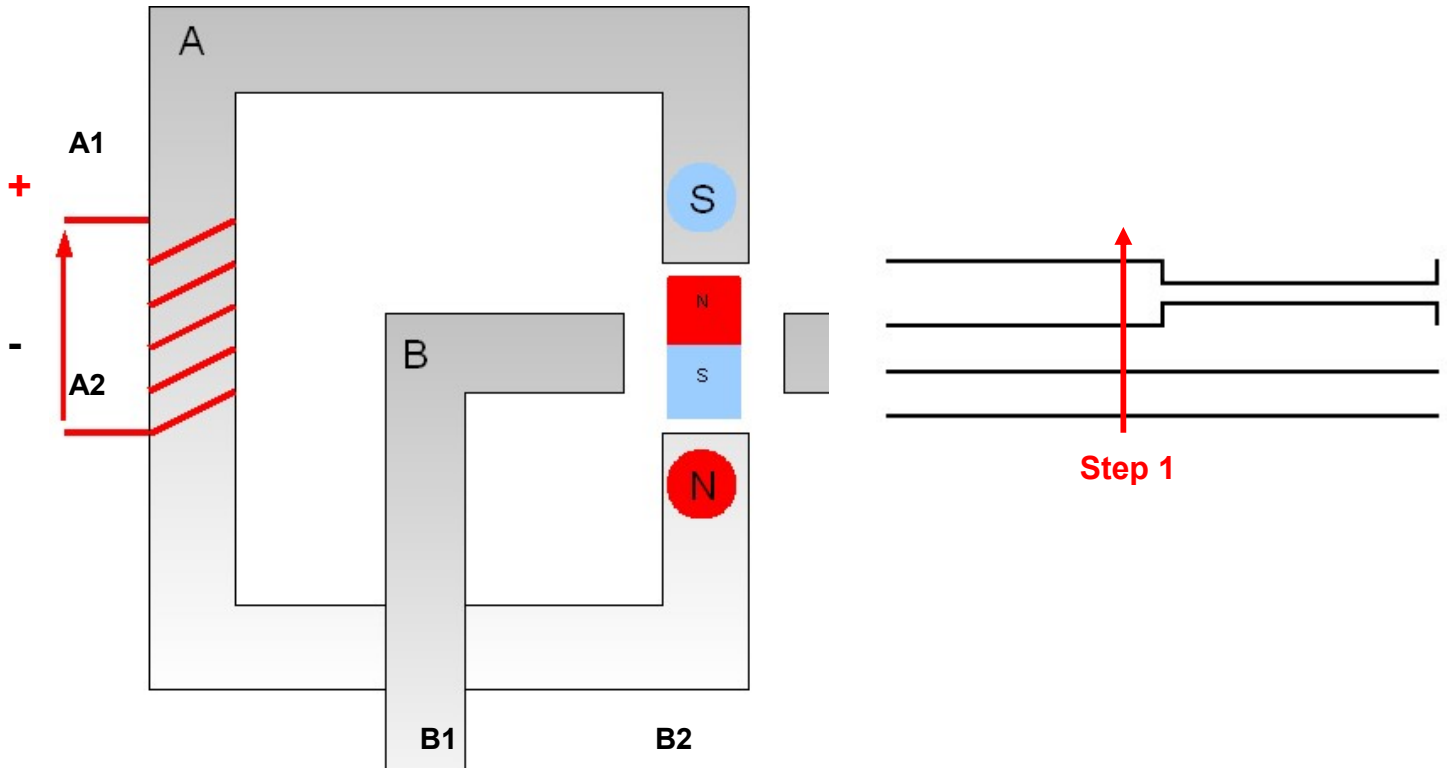
1.1.2 Stepper motor technology

A. Bipolar motor

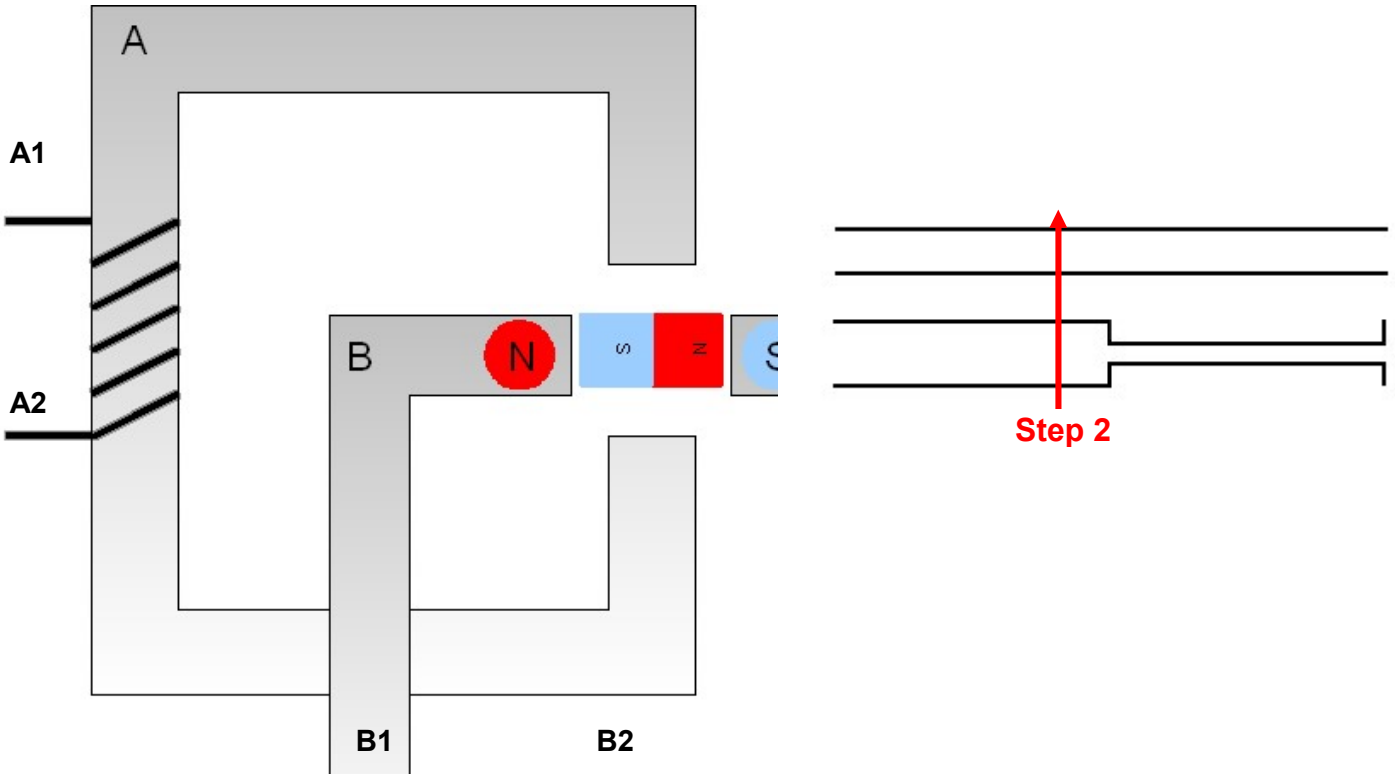
The permanent magnet which forms the rotor rotates under the effect of the magnetic fields generated by the windings on the stator poles. The direction of rotation is determined by the nature of the alternating sequence used to energise the windings.

Explanation of the operation of the motor to produce a sequence of full steps

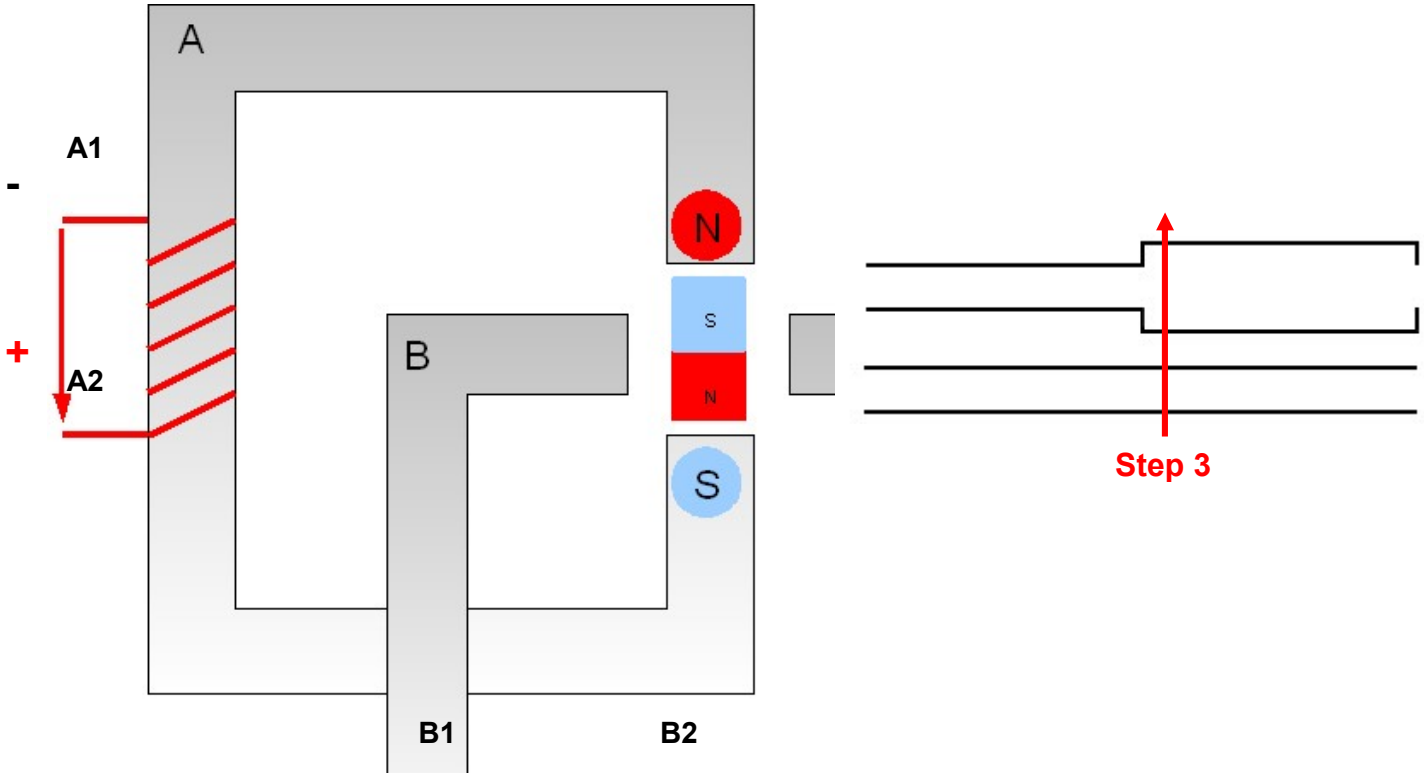
Step 1:



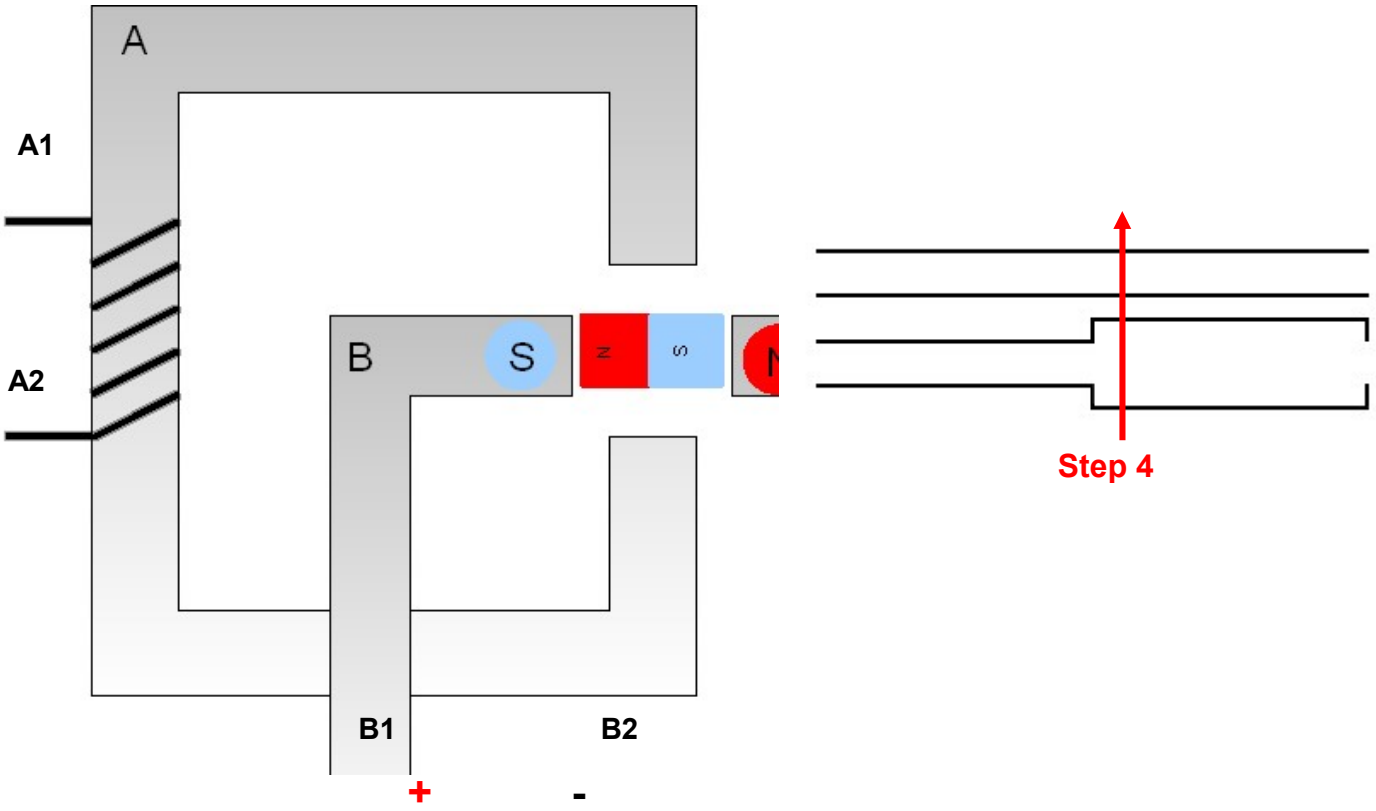
Step 2:



Step 3:



Step 4:



Summary of the various positions

Pulse	Winding A1	Winding A2	Winding B1	Winding B2
P1	+	-		
P2			-	+
P3	-	+		
P4			+	-

The diagrams above show the various possible positions of the rotor of a 4-pole stepper motor with two windings when operated to produce full steps.

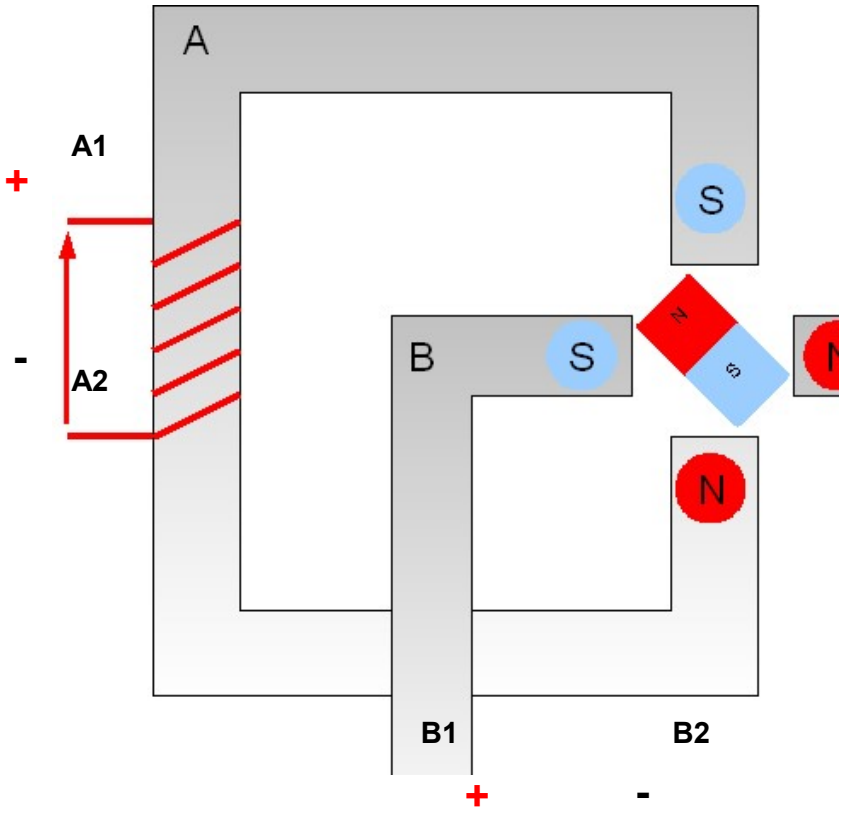
The rotor increments from one step to the next, with each step corresponding to a rotation of 90° aligned on one pair of stator poles.

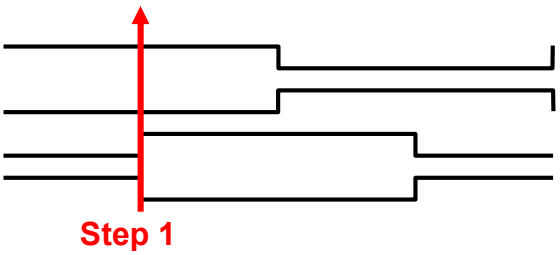
The stator windings are energised in sequence either in one direction or in the other.

However, it is also possible to operate this same motor at a higher torque.

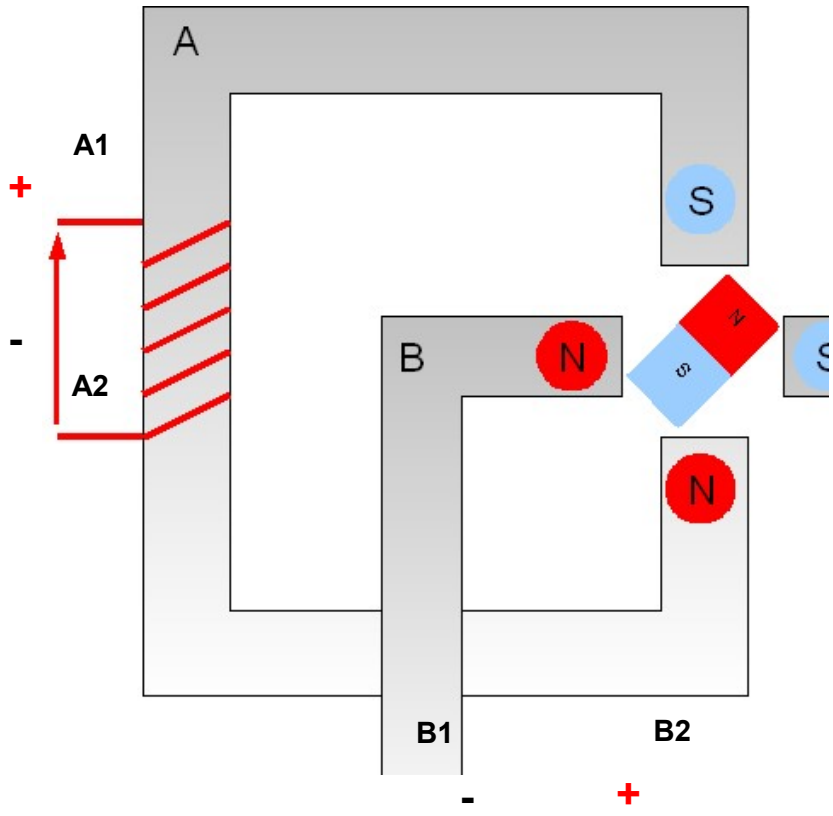
Explanation of the high-torque operation of the motor to produce a sequence of full steps

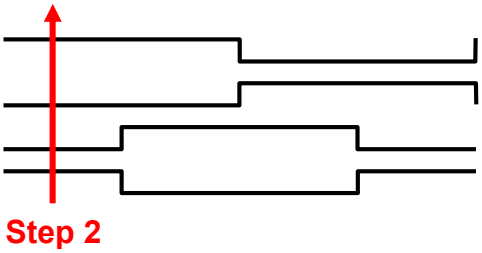
Step 1:



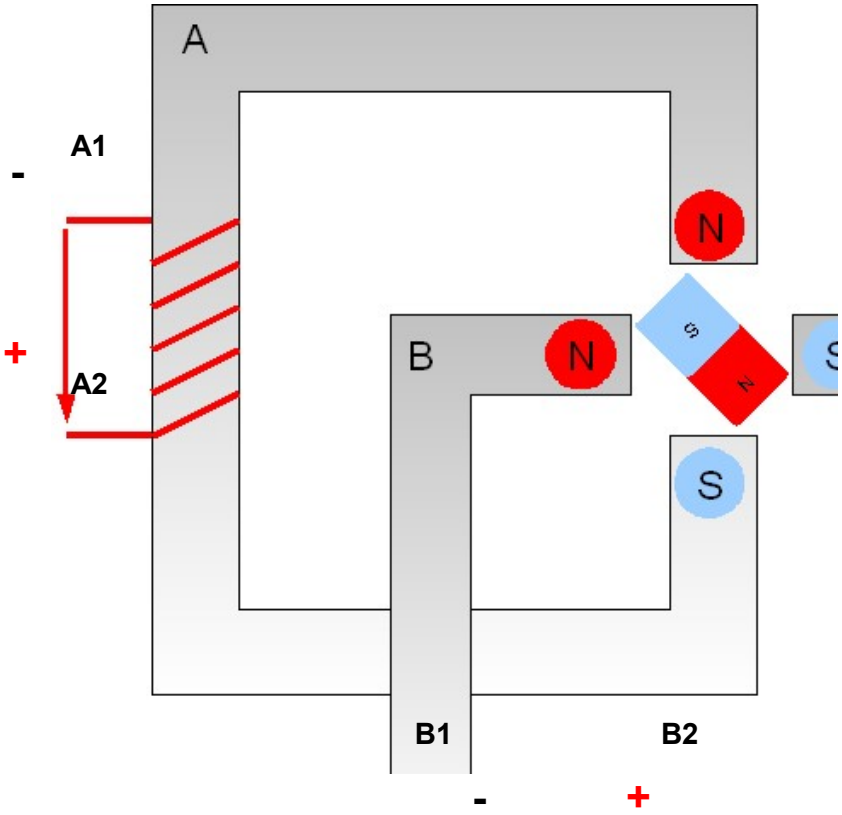


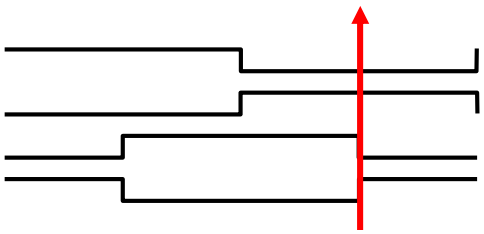
Step 2:





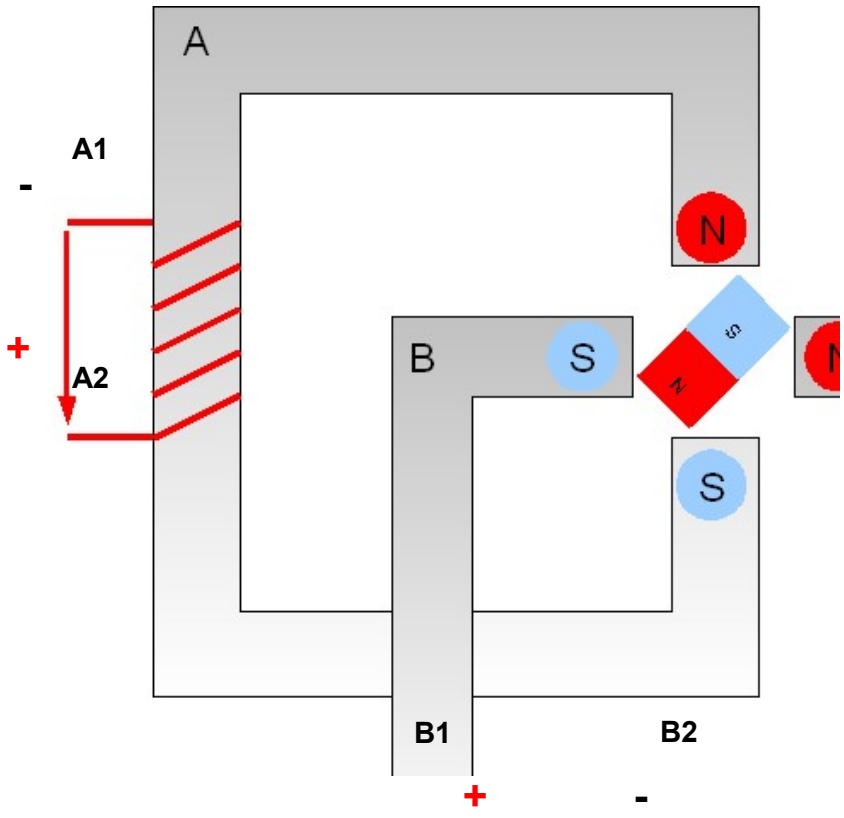
Step 3:





Step 3

Step 4:



Summary of the various positions

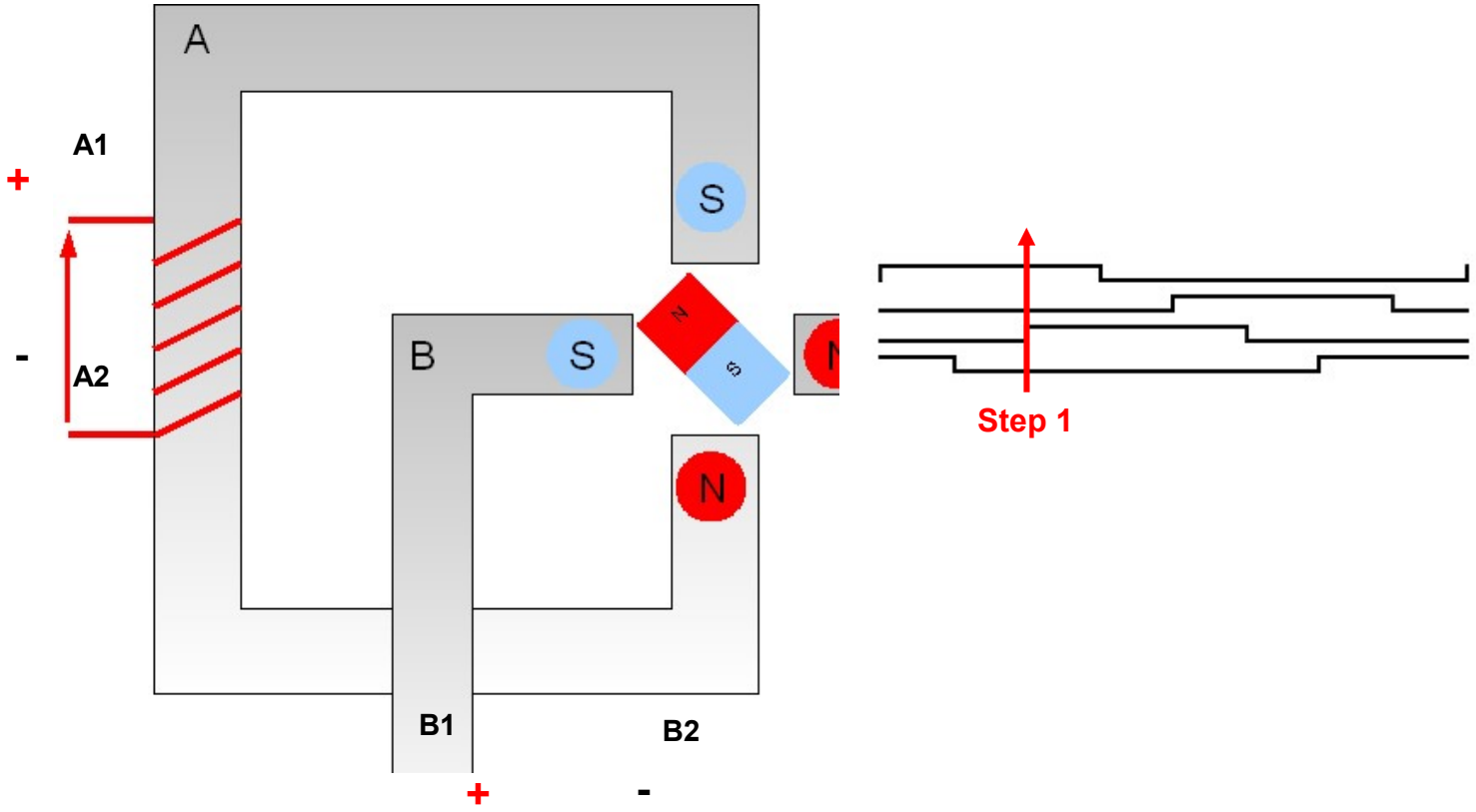
Pulse	Winding A1	Winding A2	Winding B1	Winding B2
P1	+	-	+	-
P2	+	-	-	+
P3	-	+	-	+
P4	-	+	+	-

The diagrams above show the various possible positions of the rotor of a 4-pole stepper motor with two windings when operated at maximum torque to produce full steps.
The rotor increments from one step to the next, with each step corresponding to a rotation of 90° aligned at the midway point between two pairs of stator poles.
The stator windings are always energised in sequence either in one direction or in the other.

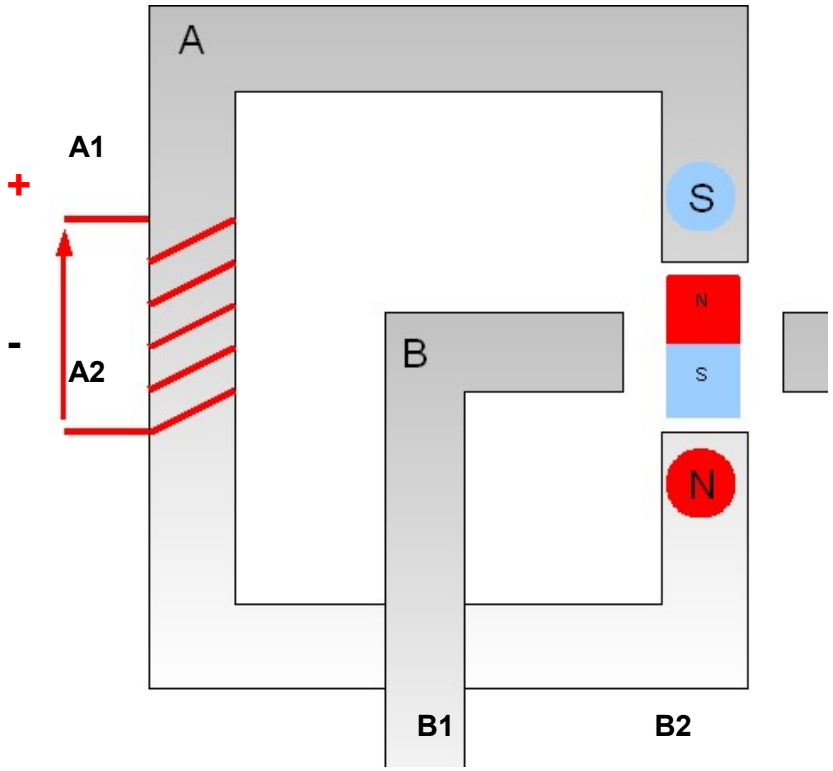
However, it is also possible to operate this same motor to produce half-steps by combining the two control methods described above.

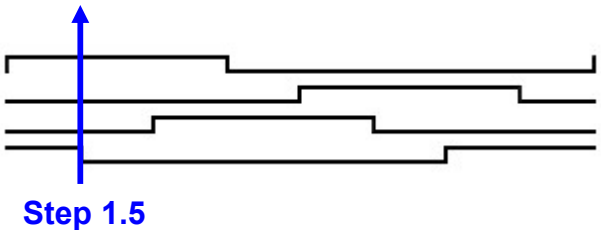
Explanation of the operation of the stepper motor to produce a sequence of ½ steps

Step 1:

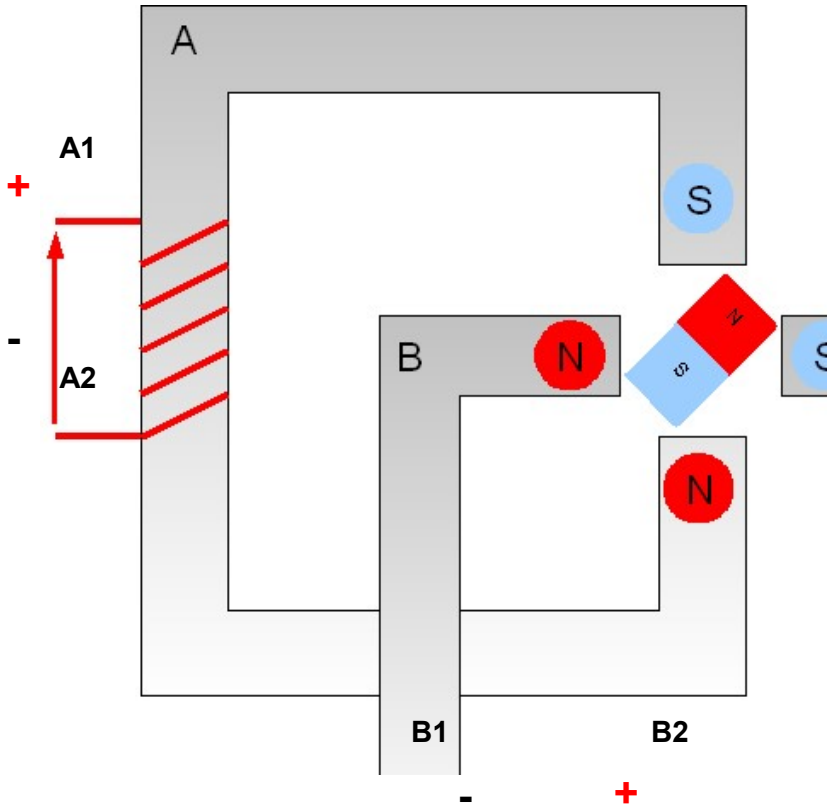


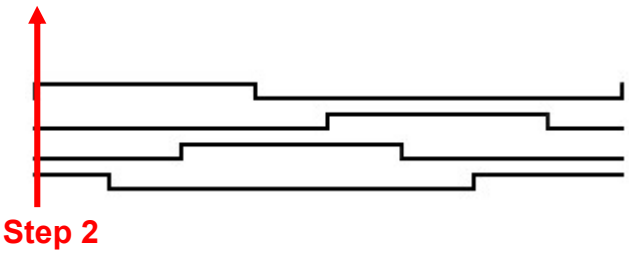
Step 1.5:



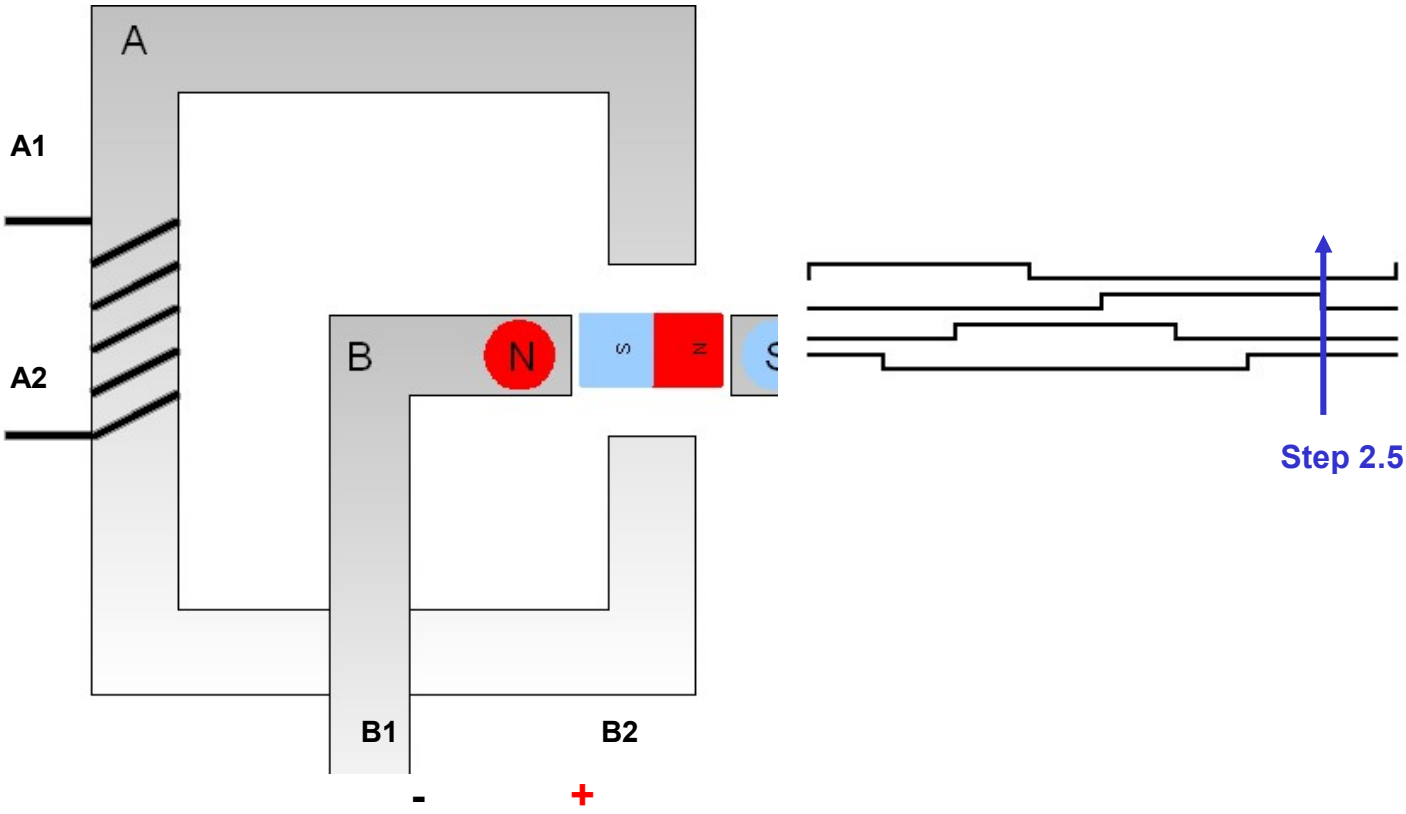


Step 2:

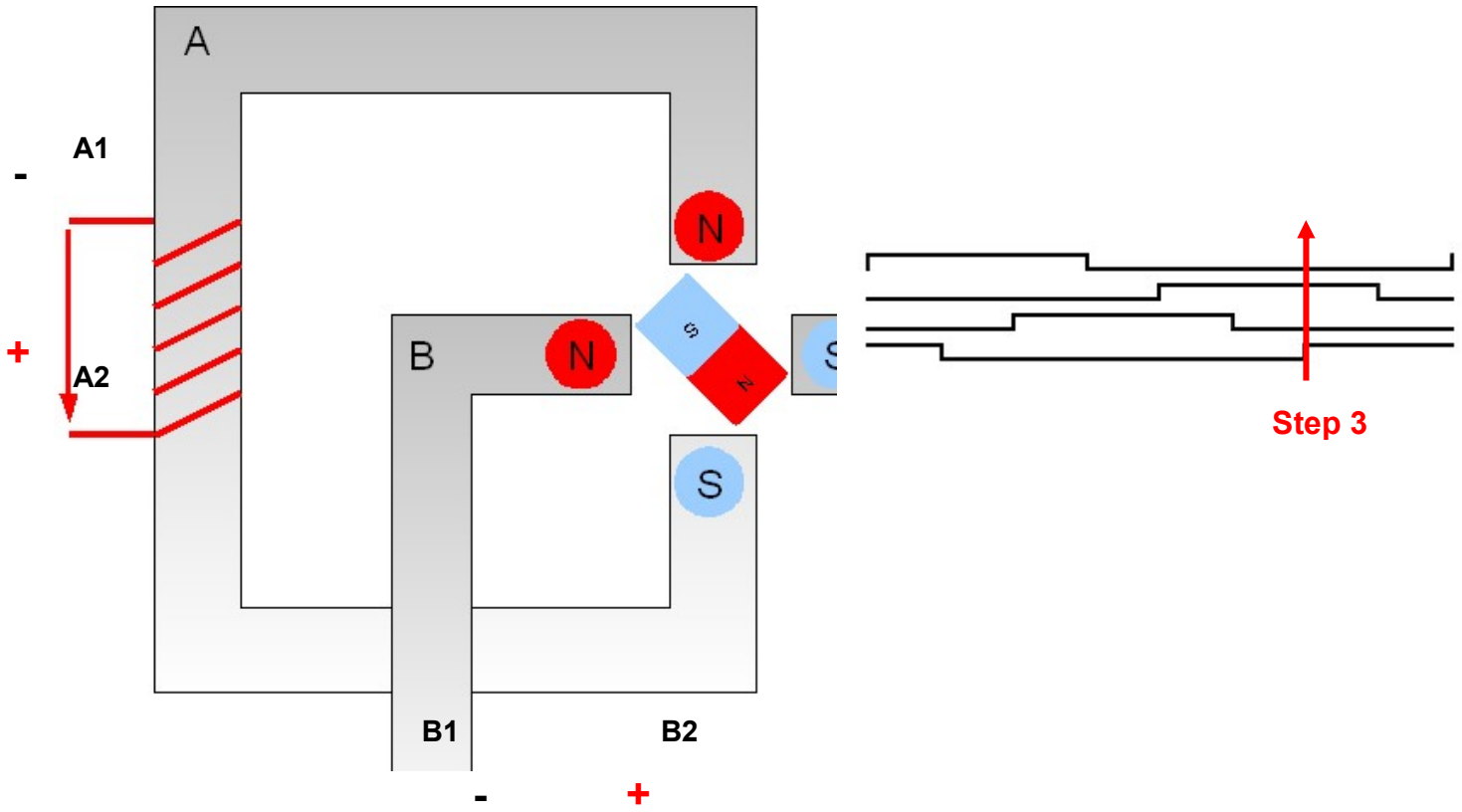




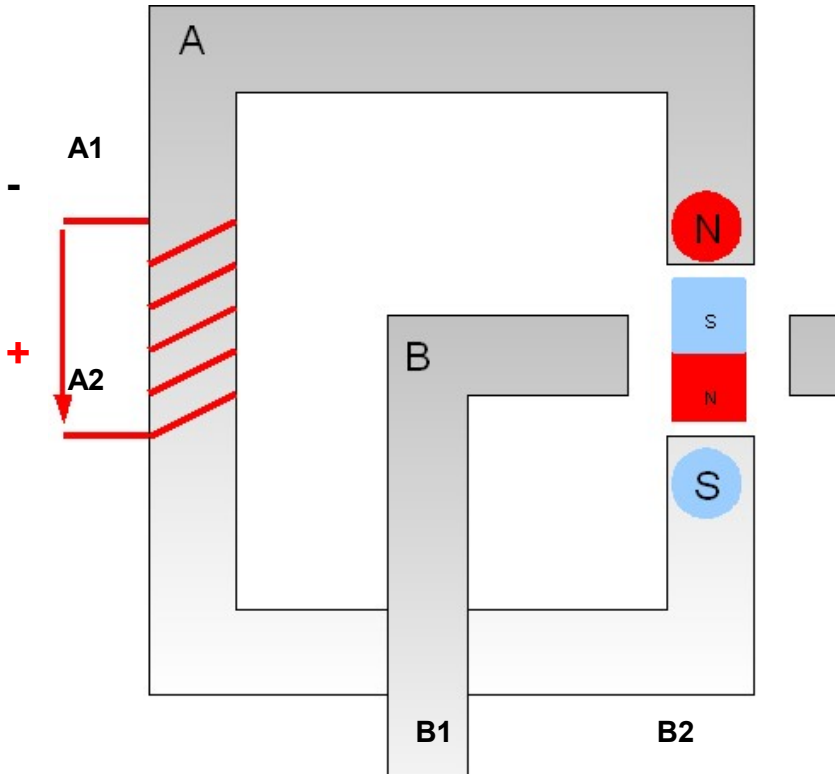
Step 2.5:

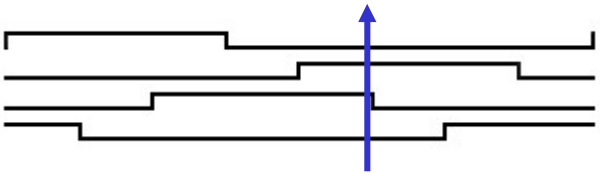


Step 3:



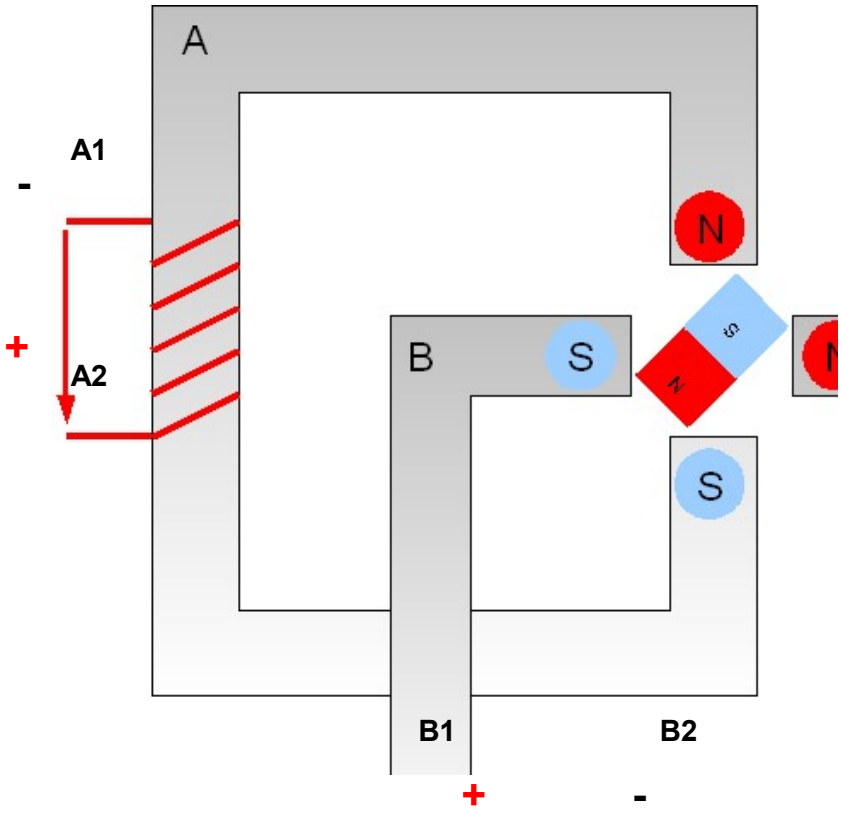
Step 3.5:

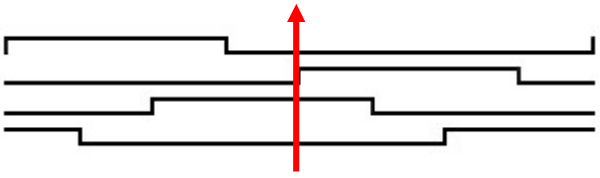




Step 3.5

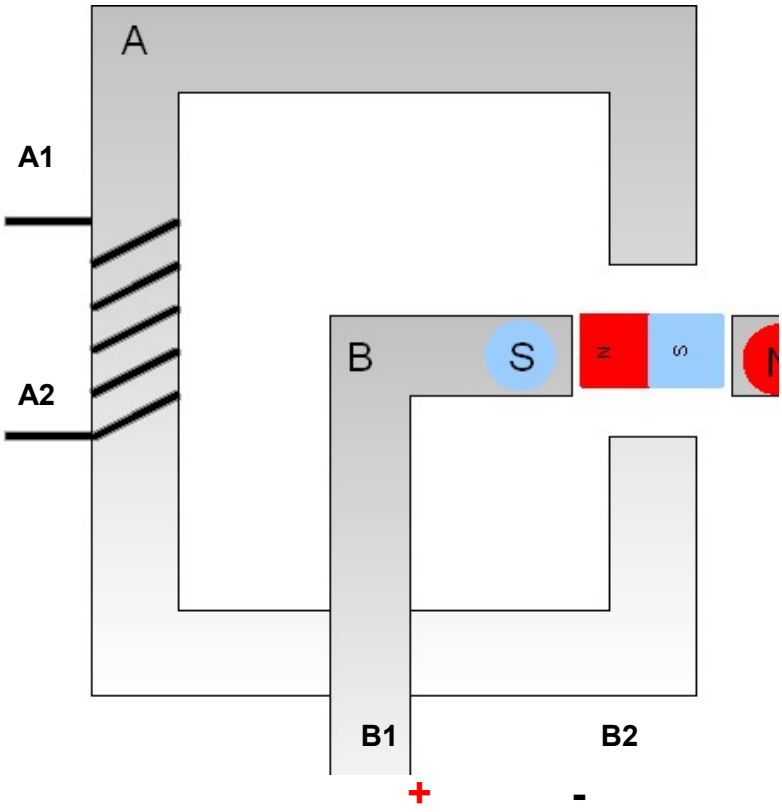
Step 4:

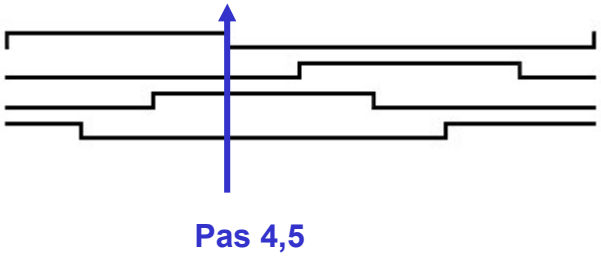




Pas 4

Step 4.5:





Pas 4,5

Summary of the various positions

Pulse	Winding A1	Winding A2	Winding B1	Winding B2
P1	+	-	+	-
P1.5	+	-		
P2	+	-	-	+
P2.5			-	+
P3	-	+	-	+
P3.5	-	+		
P4	-	+	+	-
P4.5			+	-

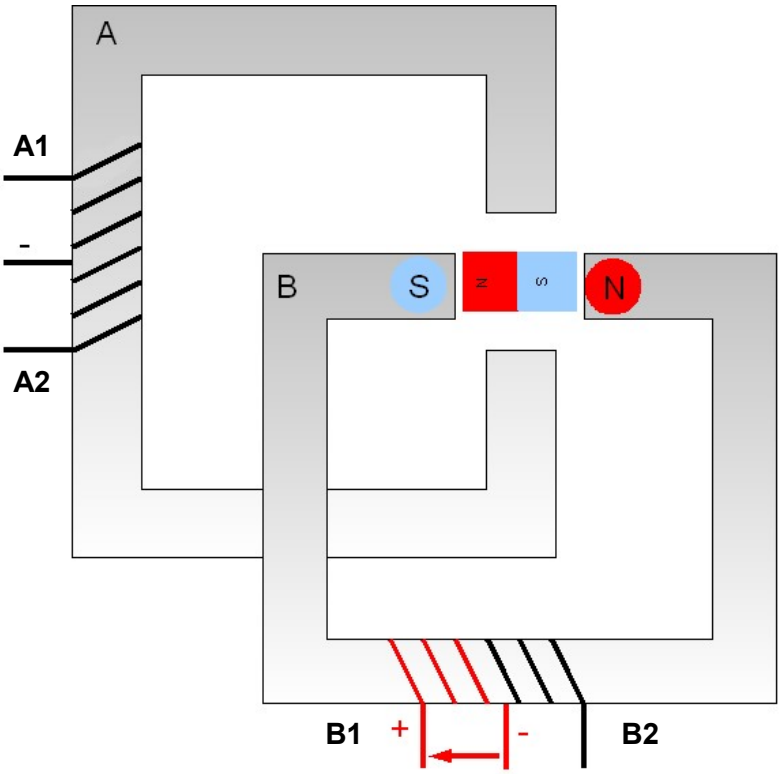
The combination of the standard control and high-torque control methods doubles the number of steps without making any change to the motor technology.
Each step position is offset by 45° compared to the adjoining positions.

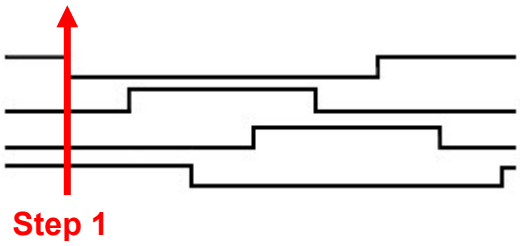
B. Unipolar motor

The principle of operation of the unipolar motor is similar to that of the bipolar motor, except that each of the two windings has a permanent centre tap which is made common.

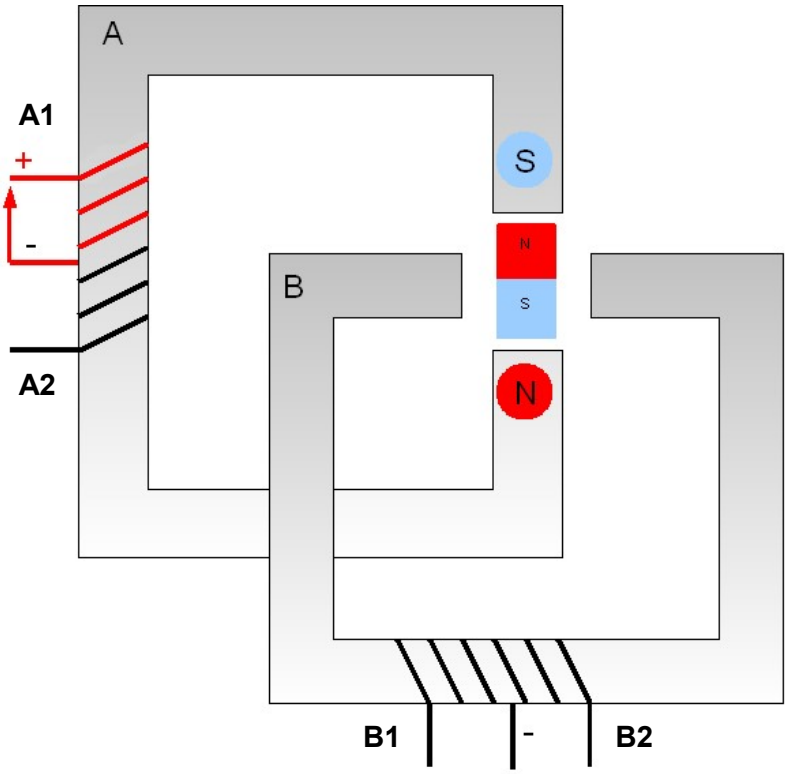
Explanation of the operation of the motor to produce a sequence of full steps

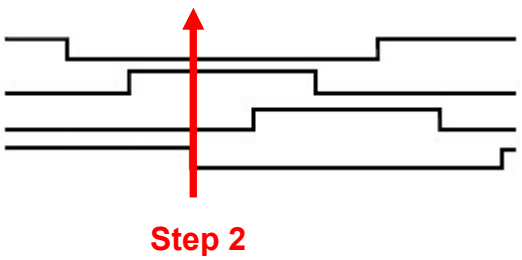
Step 1:



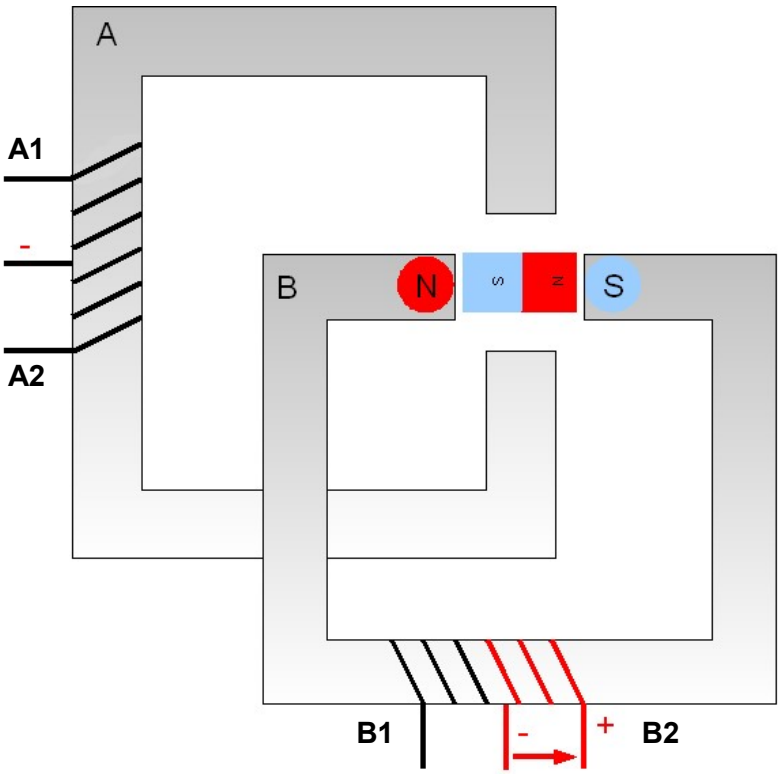


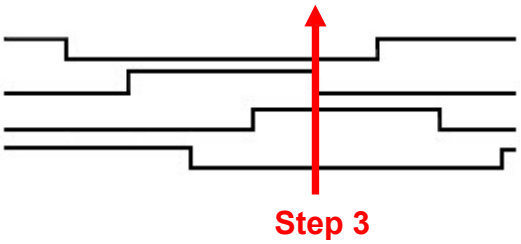
Step 2:



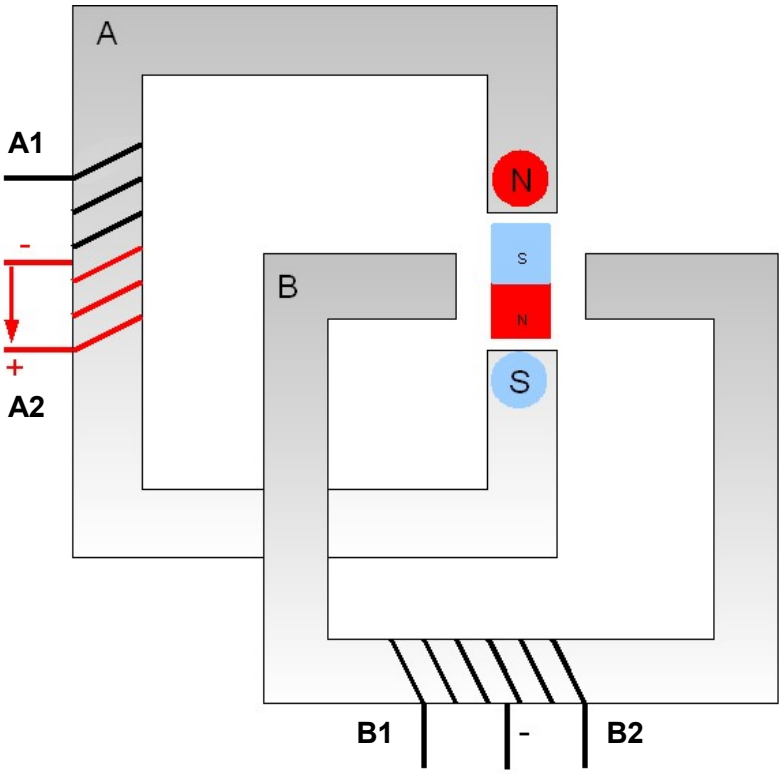


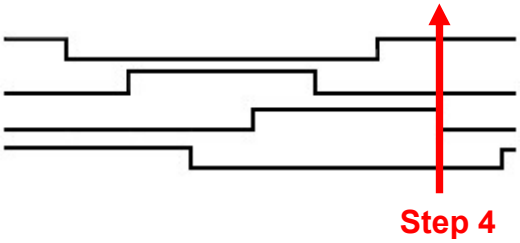
Step 3:





Step 4:





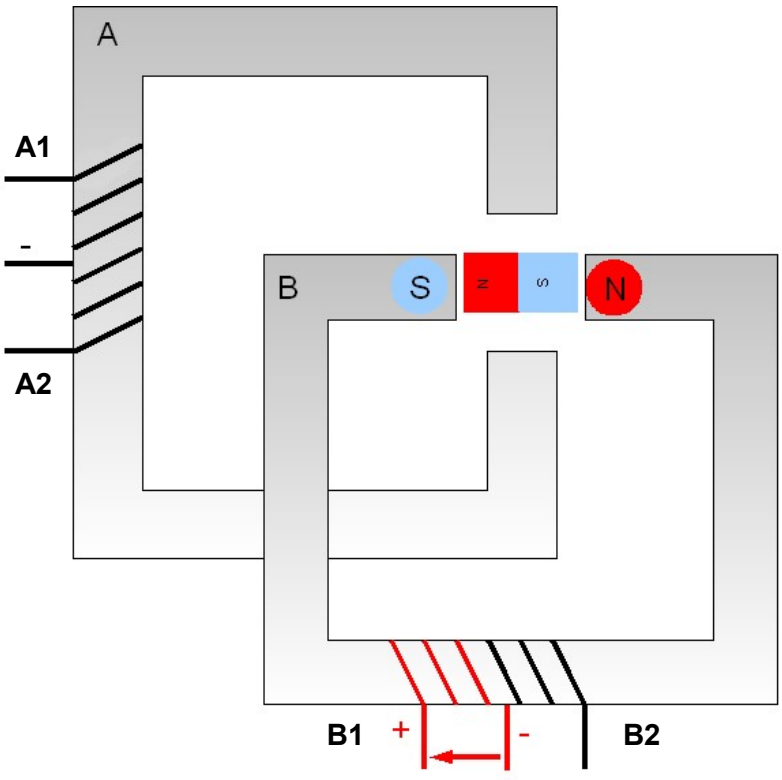
Summary of the various positions

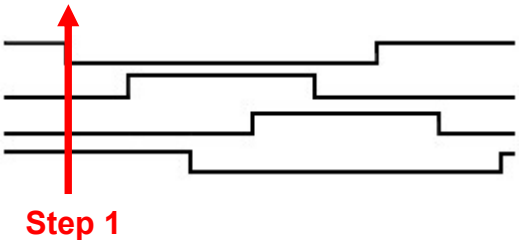
Pulse	Winding A1	Winding A2	Winding B1	Winding B2
P1			+	-
P2	+	-		
P3			-	+
P4	-	+		

The diagrams above show the various possible positions of the rotor of a 4-pole unipolar stepper motor when operated to produce full steps. One of the two windings is not energised at any one time. When the next pair of stator poles in the sequence is energised the rotor rotates through 90° from the previous step position.
The stator windings are grounded via a transistor.
However, it is also possible to operate this same motor to produce half-steps.

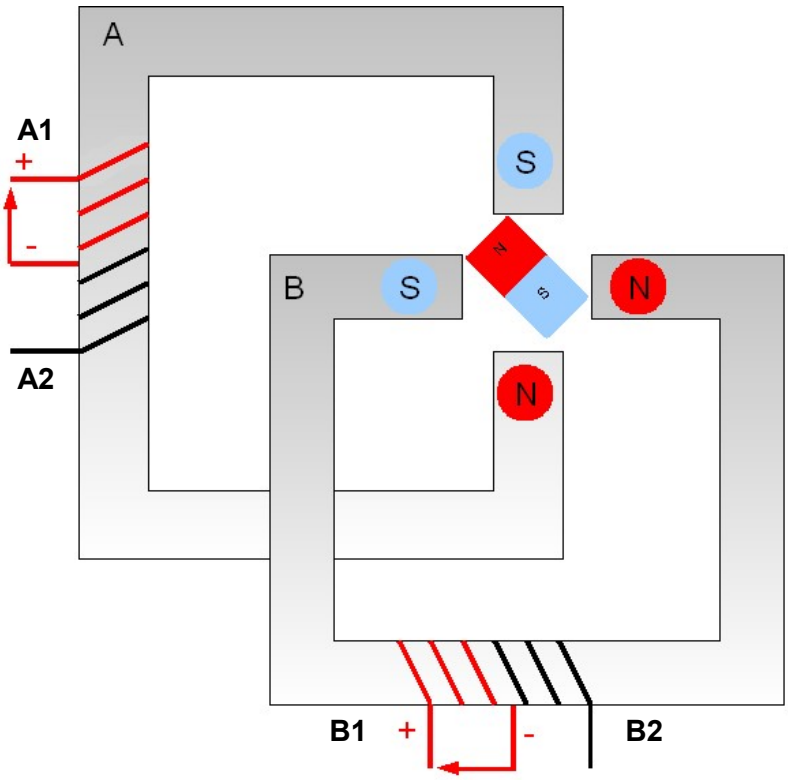
Explanation of the operation of the motor to produce a sequence of ½ steps

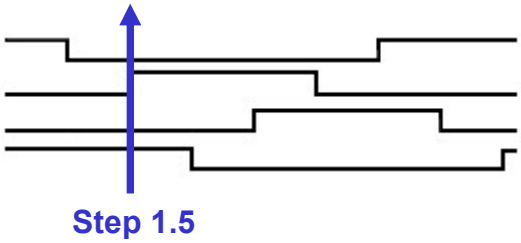
Step 1:



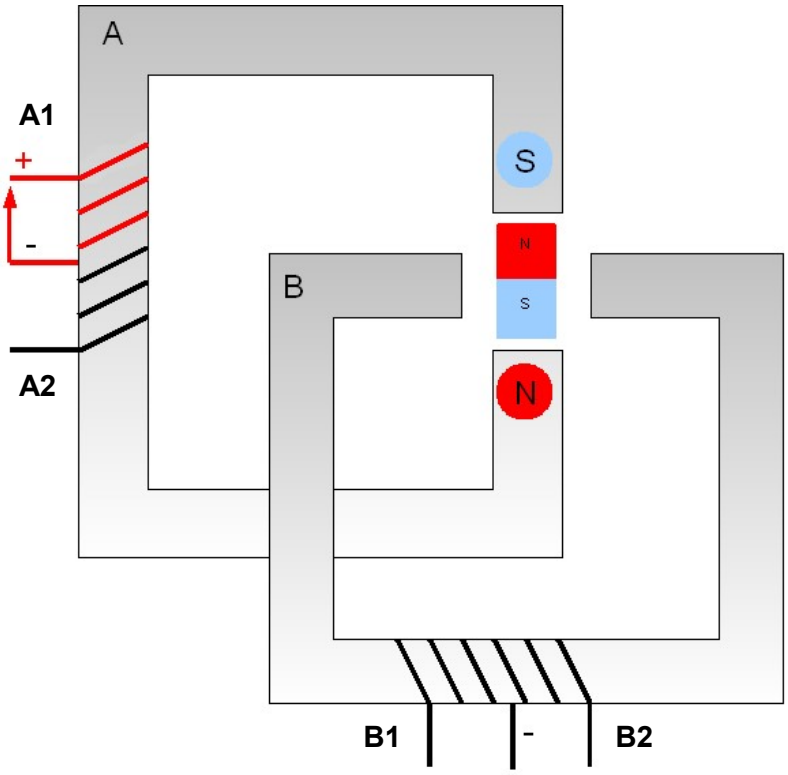


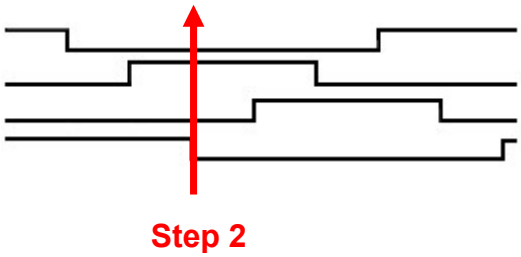
Step 1.5:



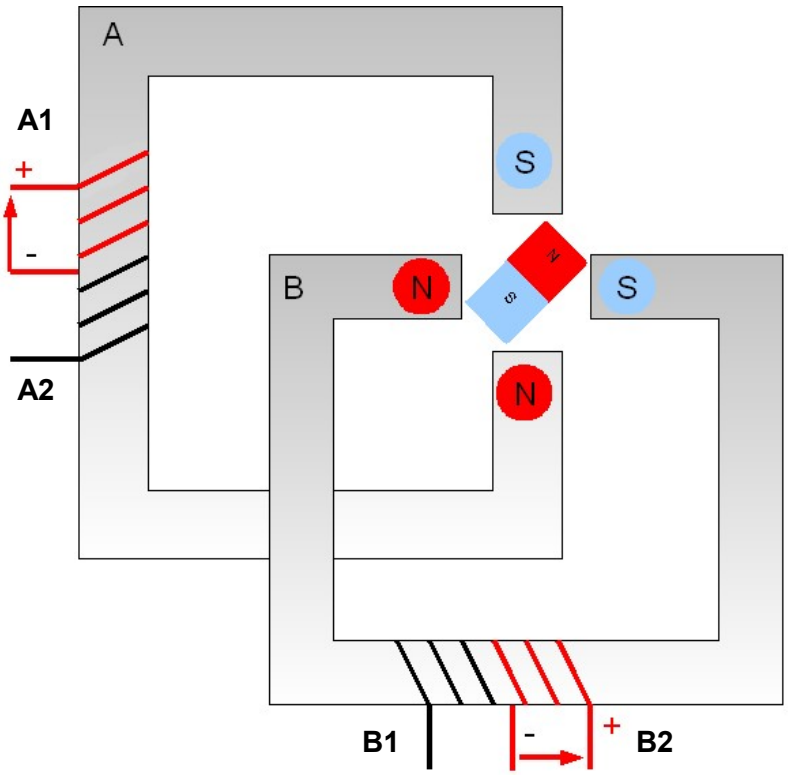


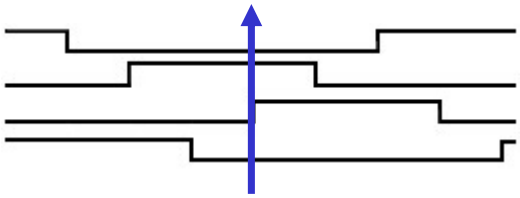
Step 2:





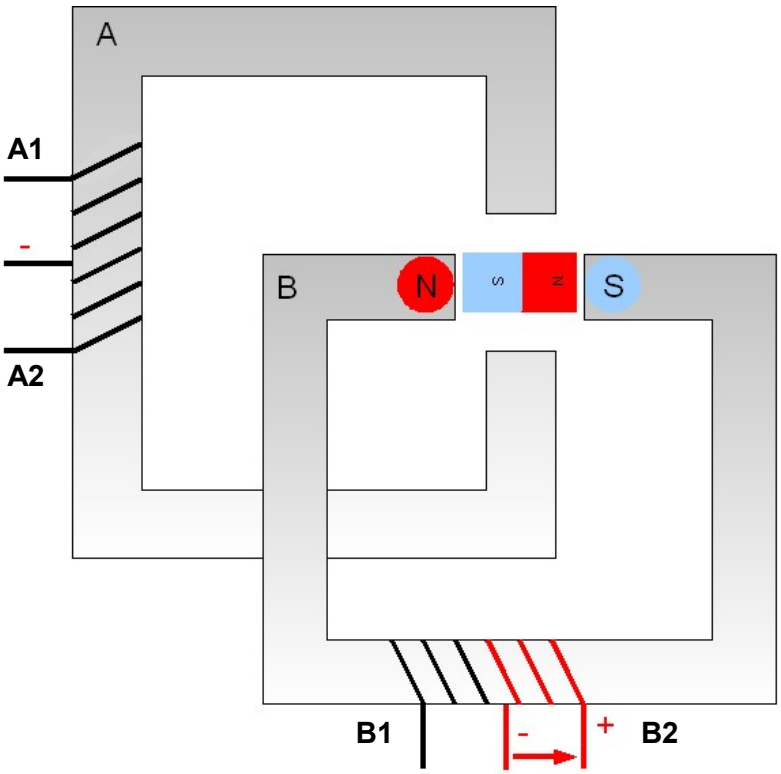
Step 2.5:

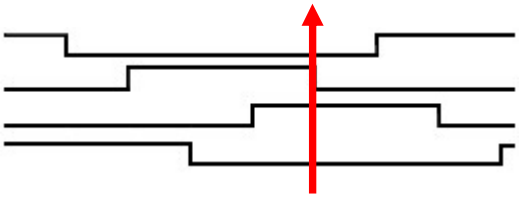




Step 2.5

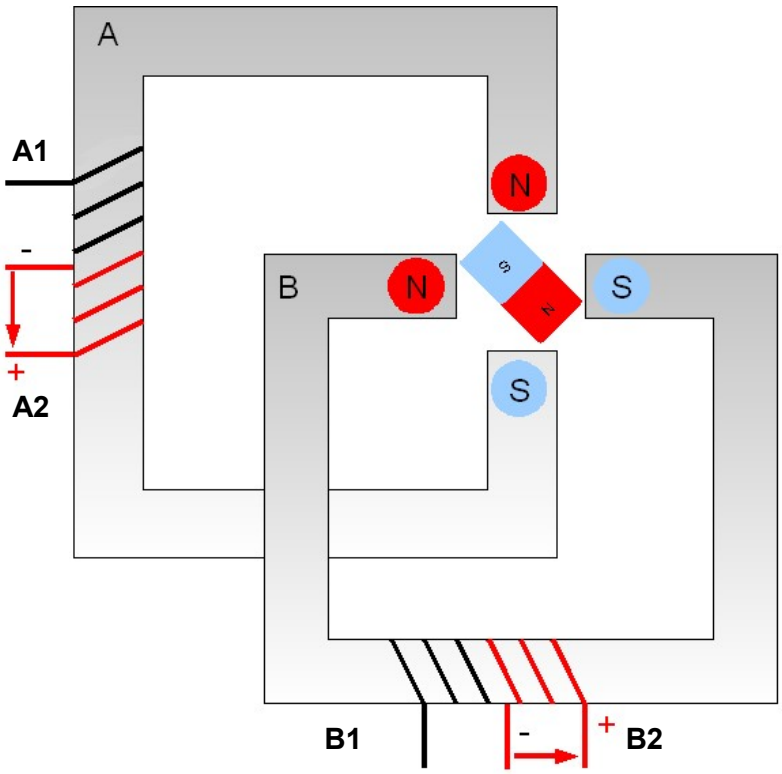
Step 3:

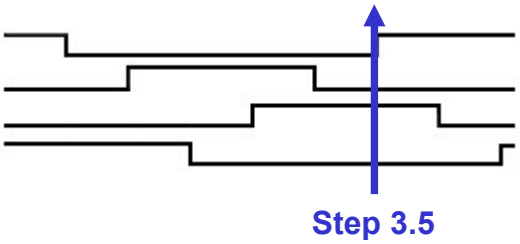




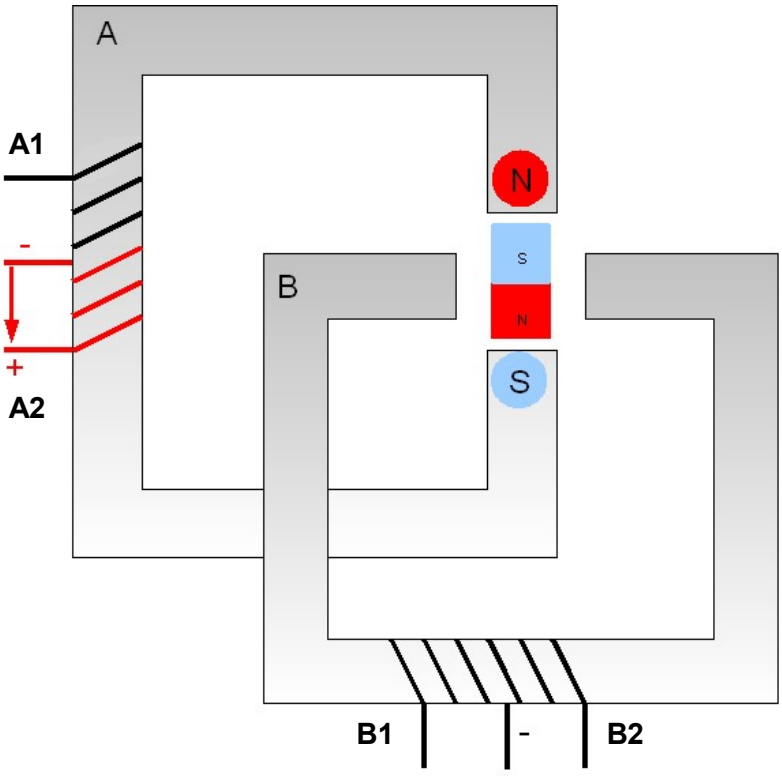
Step 3

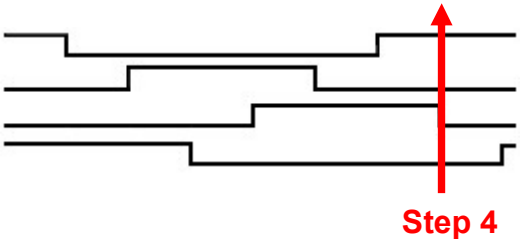
Step 3.5:



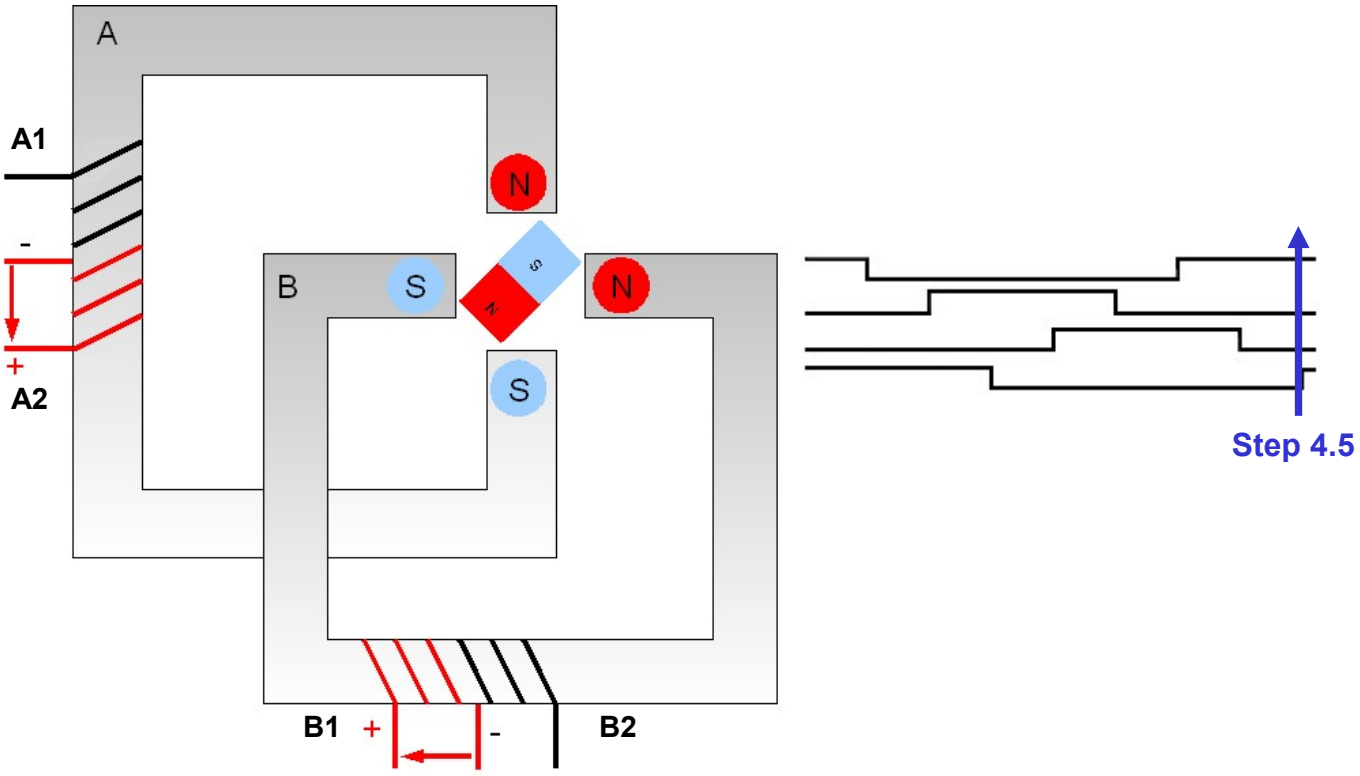


Step 4:





Step 4.5:



Summary of the various positions

Pulse	Winding A1	Winding A2	Winding B1	Winding B2
P1			+	-
P1.5	+	-	+	-
P2	+	-		
P2.5	+	-	-	+
P3			-	+
P3.5	-	+	-	+
P4	-	+		
P4.5	-	+	+	-

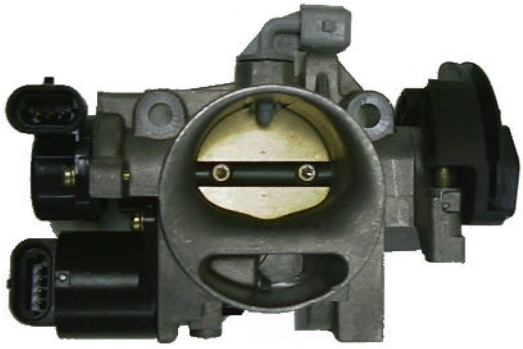
The way in which the stator is energised is very different from that described above.
In addition to the full-step control described above for the unipolar motor, the intermediate 45° positions midway between the poles, i.e. the half-steps, are produced by energising the two stator windings simultaneously.
This method doubles the number of rotor positions without making any change to the motor technology.

An alternative approach to increasing the number of rotor positions is to increase the number of rotor and/or stator poles.

1.2 STEPPER MOTOR OPERATION OF AN IDLE AIR CONTROL VALVE

1.2.1 Equipment

This valve is fitted to the (non-motorised) throttle body on petrol engines.



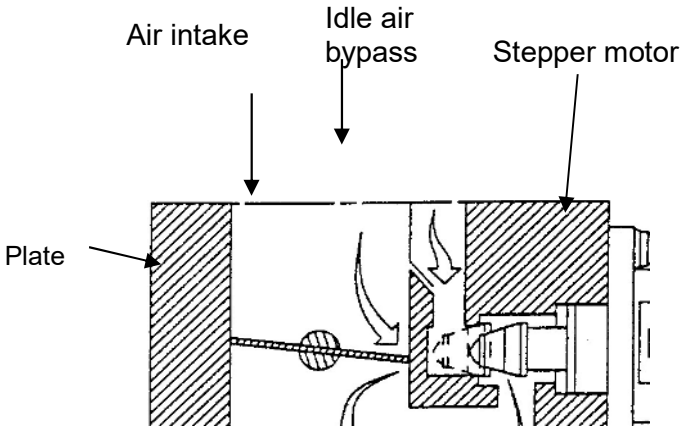
1.2.2 Purpose

The function of this actuator is to regulate the flow of air needed to run the engine at idle. It opens and closes an air bypass passage in the throttle body, and is controlled by the ECU. The idle speed is no longer adjusted manually, but is specified as one or more setpoint values stored in the ECU.

1.2.3 Description

The motor rotates a worm gear which converts the rotational movement into the translational movement of a pintle which regulates the amount of air which can flow through the bypass passage.

Illustration of the idle air control valve



A square-wave signal is sent to this motor's windings. The speed of operation of the motor depends on the frequency of the pulses and the direction depends on the control sequence.

1.2.4 Electrical features

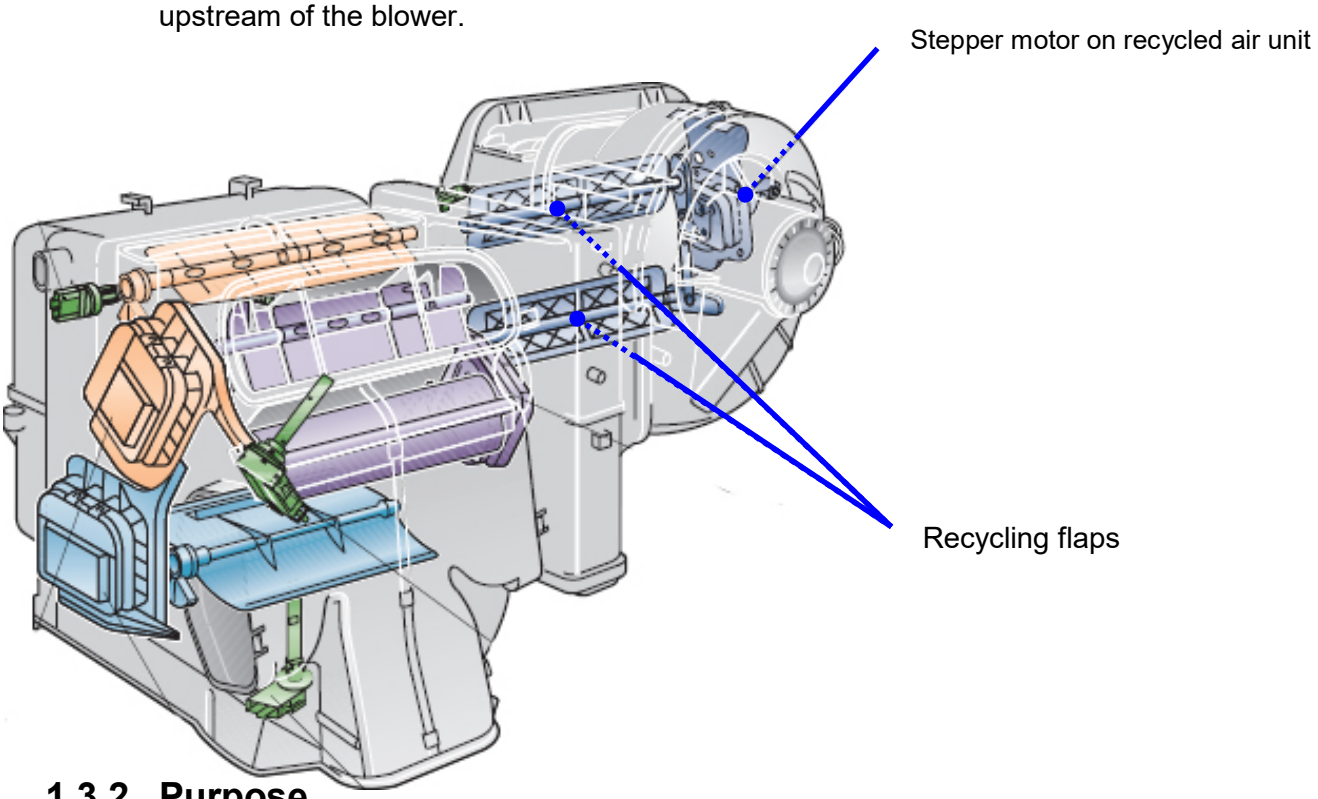
Allocation of the connector's channels

Channel number	Signal
A	Winding1
B	Winding2
C	Winding2
D	Winding1

1.3 STEPPER MOTOR OPERATING AN AIR RECYCLING UNIT

1.3.1 Equipment

The stepper motor which controls the air recycling unit is located on the heating unit, upstream of the blower.



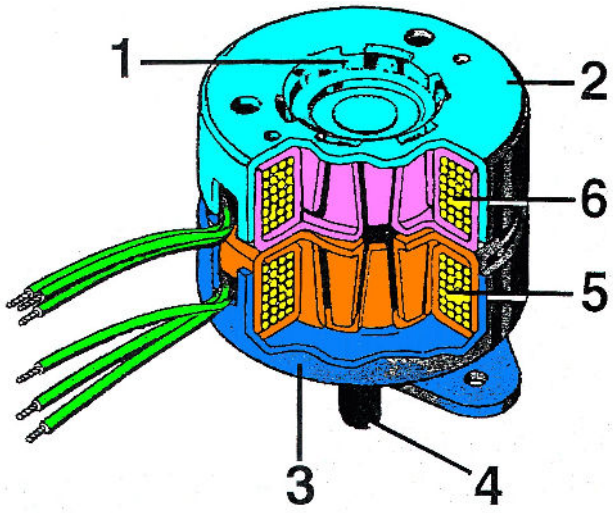
1.3.2 Purpose

This motor actuates one or two flaps, depending on the configuration, which isolates the passenger cell air from the outside air.
In automatic mode, the system may run a partial recirculation phase. Its role is to heat the passenger cell more effectively or alternatively to cool it down rapidly. This phase involves mixing some of the passenger cell air with some outside air.

1.3.3 Description

1- Rotor
2- Stator A
3- Stator B
4- Rotor spindle
5- Winding B
6- Winding A

The stepper motor has two windings, A and B, each of which is wound around a stator which usually has six pairs of poles (north and south).



Like the idle air control valve actuator, a square-wave signal is sent to this motor's windings. The speed of operation of the motor depends on the frequency of the pulses and the direction depends on the sequence.

The difference is that it is possible to double the number of the steps by grounding the windings' centre taps.

Unlike the idle air control valve actuator, the worm gear has a mechanical stop fitted at its maximum position.

1.3.4 Electrical features

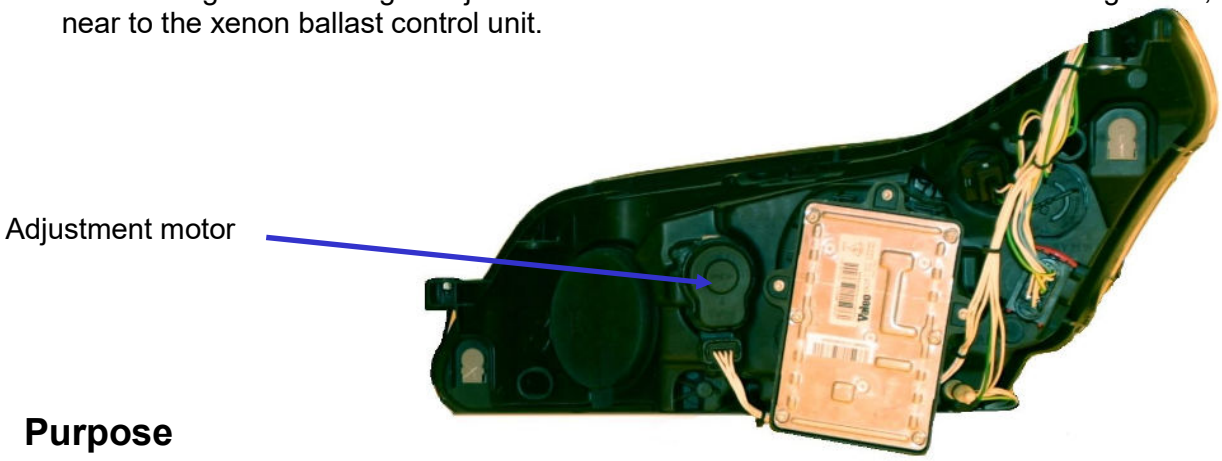
Allocation of the connector's channels

Channel number	Signal
1	Winding1
2	Ground
3	Winding 2
4	Winding 3
6	Winding 4

1.4 HEADLIGHT BEAM HEIGHT ADJUSTMENT MOTOR

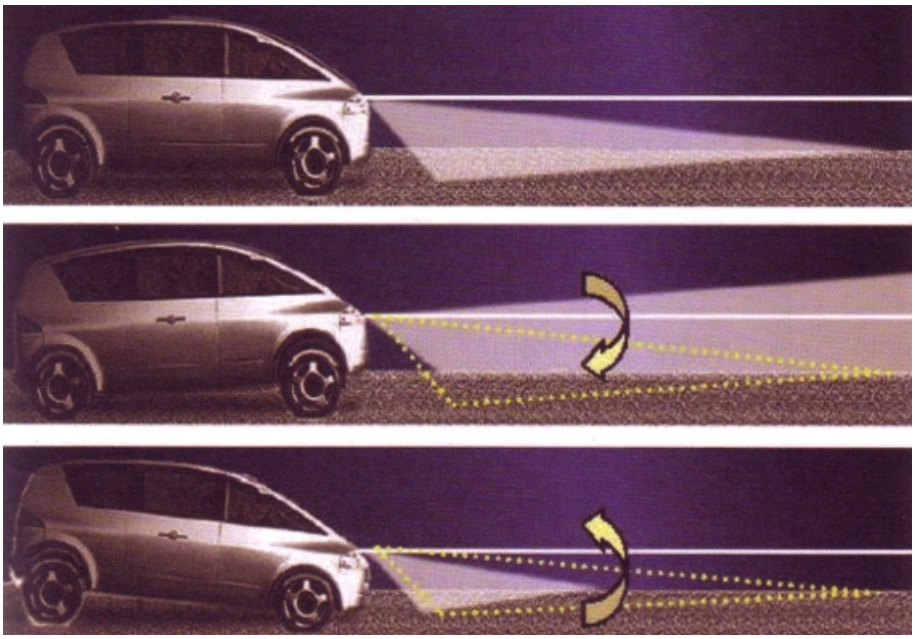
1.4.1 Equipment

The headlight beam height adjustment motor is fitted at the rear of the headlight unit, near to the xenon ballast control unit.



1.4.2 Purpose

This motor accurately adjusts the height of the headlight beam. The aim is to keep the beam angle constant with respect to the horizontal, regardless of variations in the nose-down/nose-up attitude of the vehicle.



Beam correctly set
→ At setpoint value

Beam too high
- Acceleration
- Loaded at rear

→ Beam is dipped

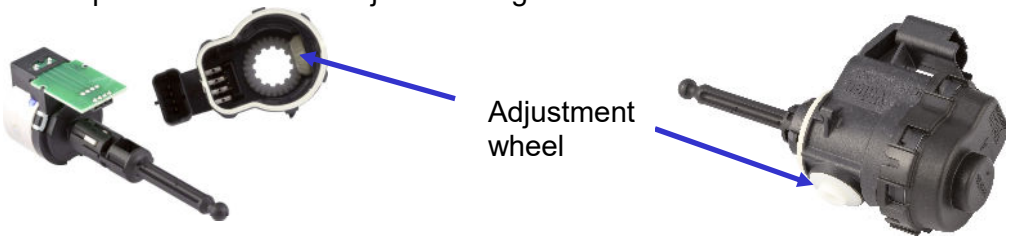
Beam too low
- Braking

→ Beam is raised

1.4.3 Description

The motor rotates a worm gear, fitted with a fixed-position stop, which converts the rotational movement into a translational movement to adjust the up/down aim of the headlight.
The end-of-travel stop protects the headlight from being damaged.

The setpoint value can be adjusted using the mechanism located underneath the motor.



1.4.4 Electrical features

Allocation of the connector's channels

Channel number	Signal
1	Winding 1
2	Winding 2
3	Winding 2
4	Winding 1

Caution: This motor draws between 3.5 and 4 amps.

2. USER FILE

2.1 Installing and starting up benchtop learning module DT-C005

Use the 12 V, 1 A power supply provided. Connect up the 230 V mains supply (check the position of the power supply switch on the rear of the power supply).
Connect the ground and the +ve on the power supply to module DT-C004 using the cables provided.
Switch on the power supply. Then wire up the module.
The moving components are the idle air control valve actuator, the air recycling unit's geared motor and the headlight beam height adjustment motor.
Comment: a protective device with a buzzer lets you know if the power supply voltage is greater than 12 V, or if the plus and minus have been inversed.

2.2 Environment

Module DT-C005 is designed for benchtop use.
It must be installed in a dry place away from dust, steam and combustion fumes.
The module requires approximately 400–500 lux of light
The module may be placed in a practical exercise room. Its operating noise level does not exceed 70 decibels.
The module is protected against potential user error.

2.3 Calibrating and maintaining module DT-C005

Calibrating: set in the factory.
Maintenance frequency: none.
Cleaning: use a clean and very soft cloth and a window-cleaning product.

2.4 Number of work stations and position of user

Module DT-C005 is considered to be a single work station.
The module user will remain seated throughout the practical exercise.

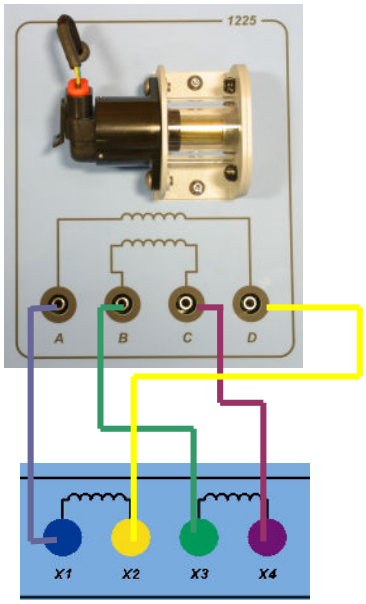
2.5 Lockout/Tagout procedure

Switch off the fixed power supply by setting the switch to 0
Unplug the mains 230 V connector.
Remove all the banana plug cables from the module.
Store module DT-C005 in a secure room while out of use.

The module should only be opened by certified and authorised persons

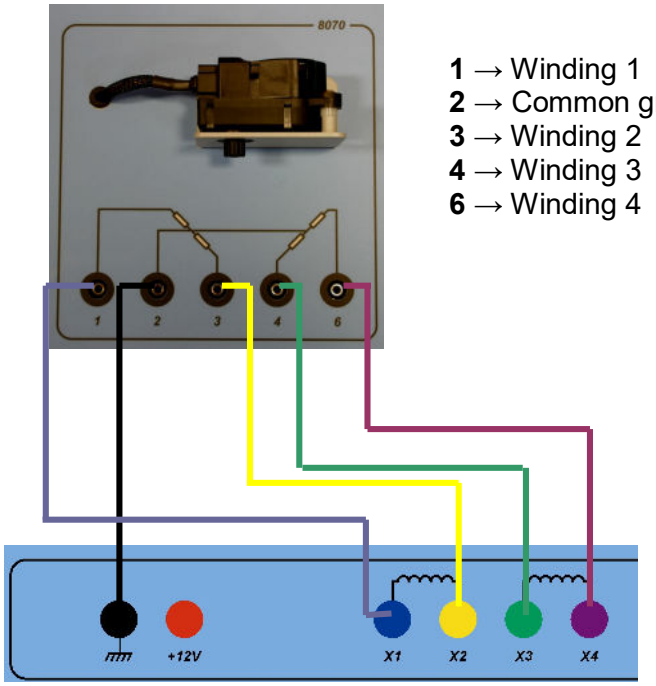
2.6 Details of front face and wiring

Idle air control valve actuator:



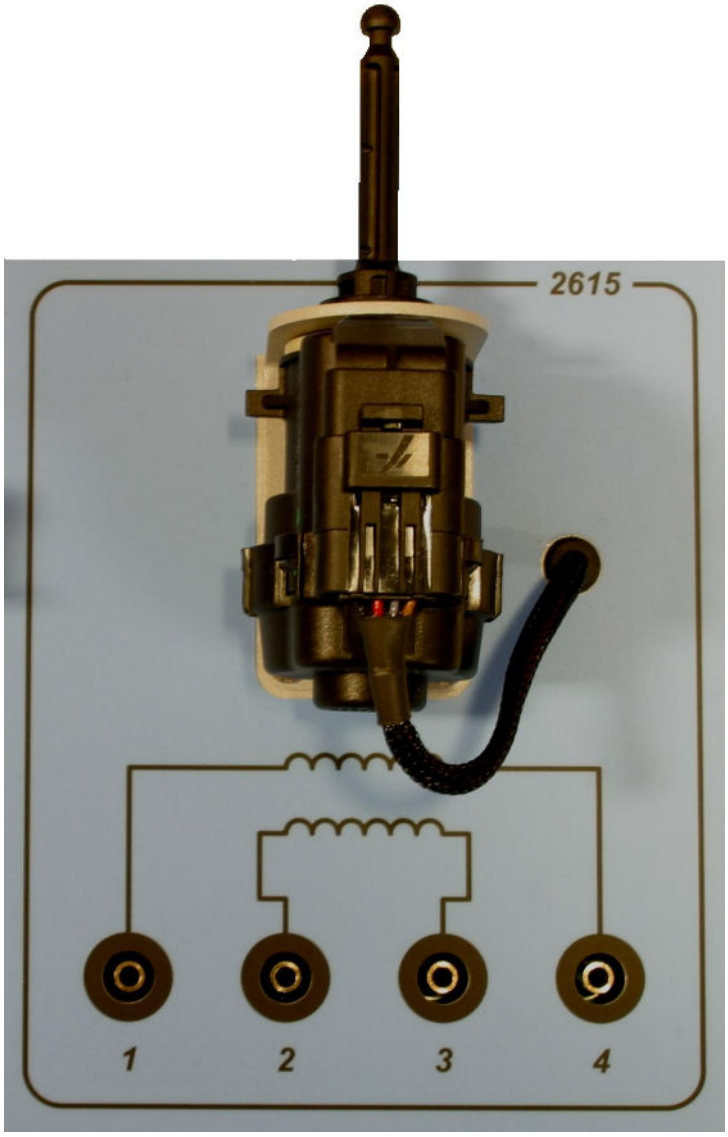
A → Winding 1
B → Winding 2
C → Winding 2
D → Winding 1

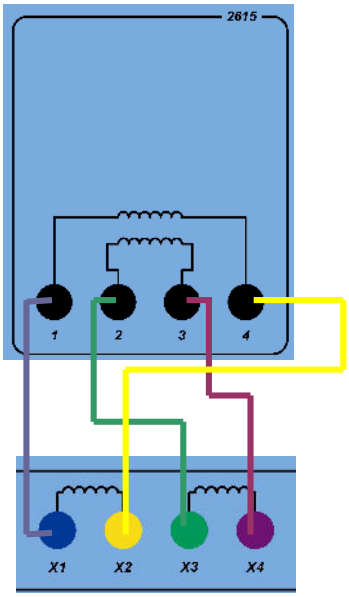
AIR RECYCLING MOTOR



1 → Winding 1
2 → Common ground
3 → Winding 2
4 → Winding 3
6 → Winding 4

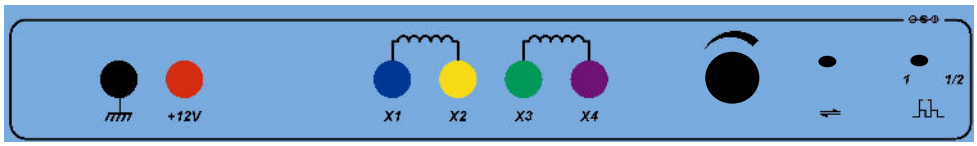
Headlight beam height adjustment motor





- **1** → Winding 1
- **2** → Winding 2
- **3** → Winding 2
- **4** → Winding 1

Control zone:



- ⏚ → Ground-controlled step-by-step actuation
- +12V → +12 V step-by-step energisation control power
- X1 and X2 → Control 1
- X3 and X4 → Control 2
- ◠ → Speed variator
- ⇄ → Change of direction
- ⎍ → Change from full-step increments to half-step increments

3. PRACTICAL EXERCISES

3.1 Stepper motors

A. What are the main characteristics of a stepper motor?

The stepper motor produces stable speeds of rotation and precise positioning.
The torque from these motors is high even when the speed is low. It is an ideal actuation device for applications which require a long service life even under difficult operating conditions.

B. Mention some applications for stepper motors in a vehicle?

- in the climate control system - actuating mixing and recycling flaps,
- in the air intake system (the idle air control valve actuator)
- in the headlight beam height adjustment system,
- speedo needle actuation,
- …

C. What types of stepper motor are used in automotive applications?

Two types of stepper motor are used:

- unipolar motors,
- bipolar motors.

D. How are these two motors different?

The only difference is in how the stator windings are wired up.
In the bipolar motor, the polarities at the two winding terminals are reversed.
The unipolar motor has a common tap at the centre of each winding and the polarity of the poles is reversed by alternately passing current in different directions through the two halves.

E. What is the basic principle of operation of a stepper motor?

It converts an ordered sequence of square-wave signals into a rotating mechanical movement.

3.2 Bipolar motors

A. On the module, which device (or devices) is(are) a bipolar type motor?

The idle air control valve actuator and the headlight beam height adjuster are bipolar motors.

B. What are the operating characteristics of this type of motor?

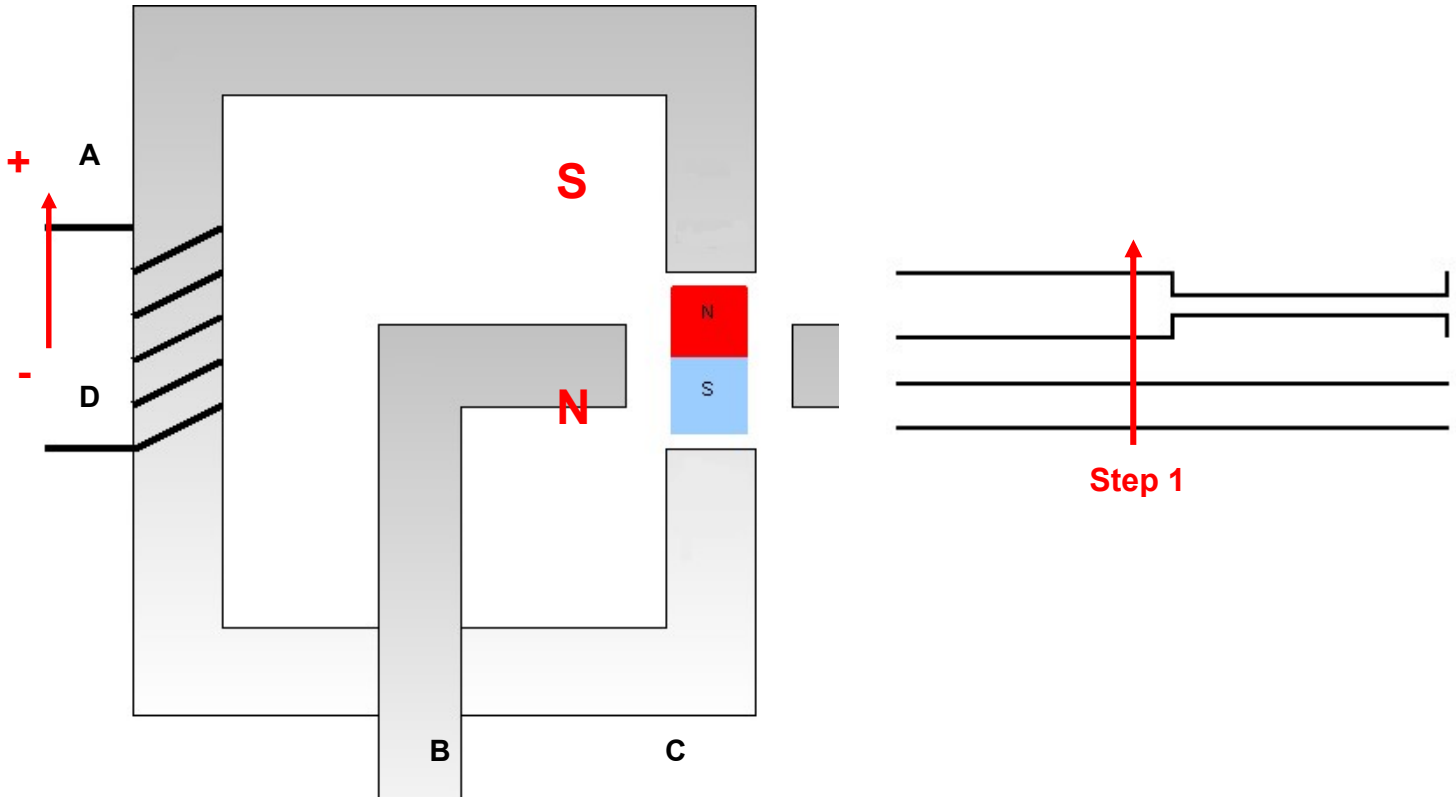
Bipolar motors have two wound stators and a permanent magnet (the rotor).
Depending on the polarity of the energisation of the windings, the rotor rotates to a position under the effect of the magnetic fields generated in the stator by the windings
The direction of rotation of the rotor is determined by the sequence used to energise these windings.
The speed is proportional to the frequency.

C. How are the windings energised to produce rotation with one full step at a time?

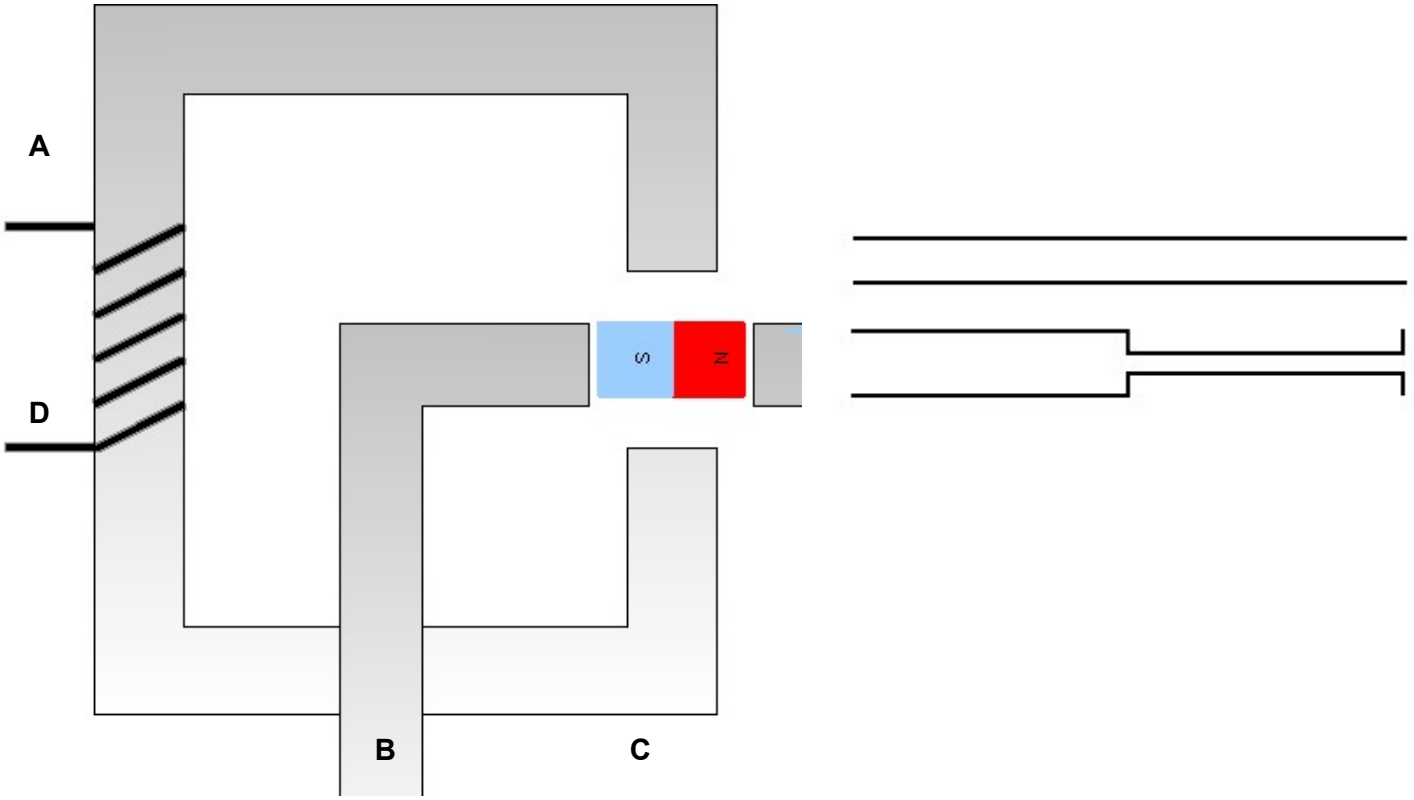
In full-step mode, each winding is energised independently of the other. Their polarities are alternated to generate the rotational movement.

D. By referring to the signal timing chart, show on the diagram how the stator windings are being supplied with power and indicate on the timing chart, using an arrow, the current position in time for the step shown.

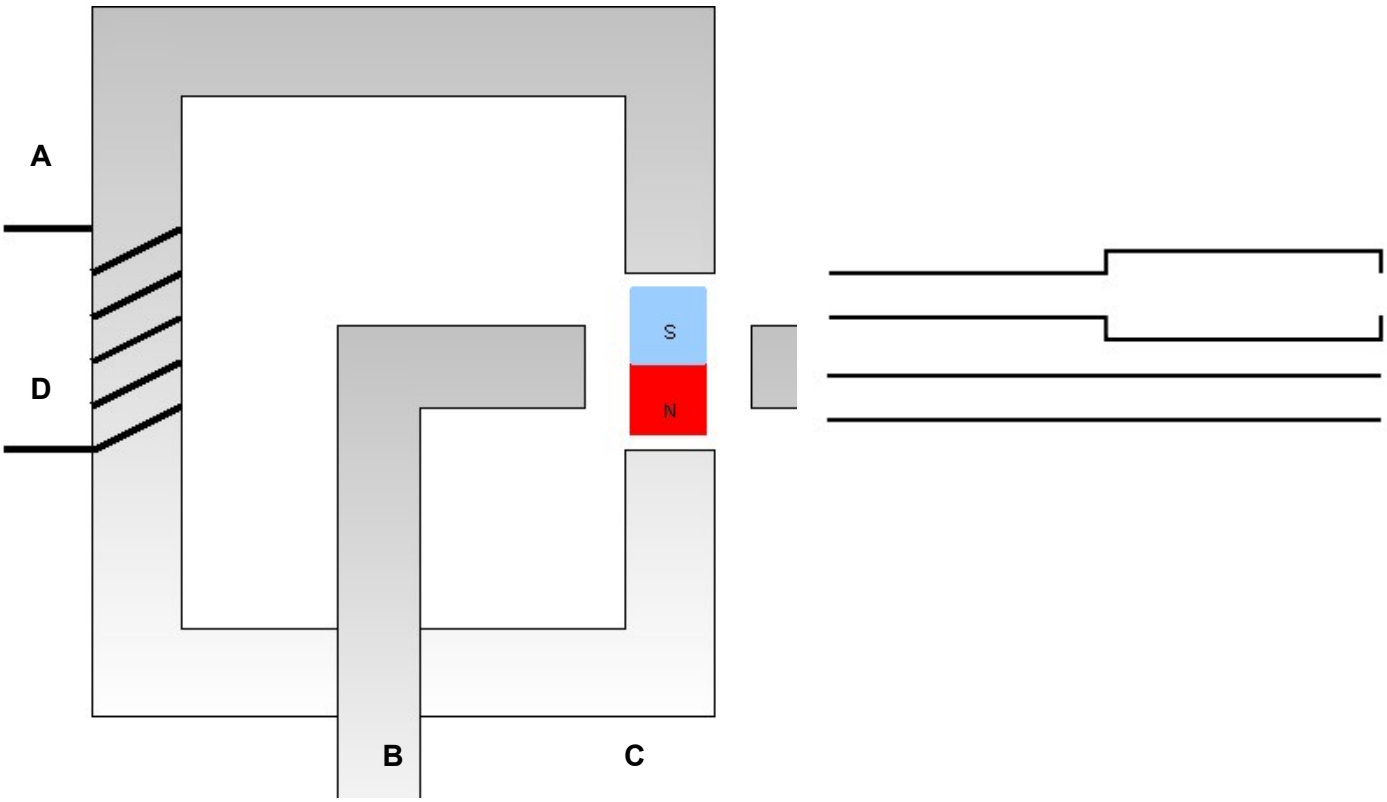
For step 1:



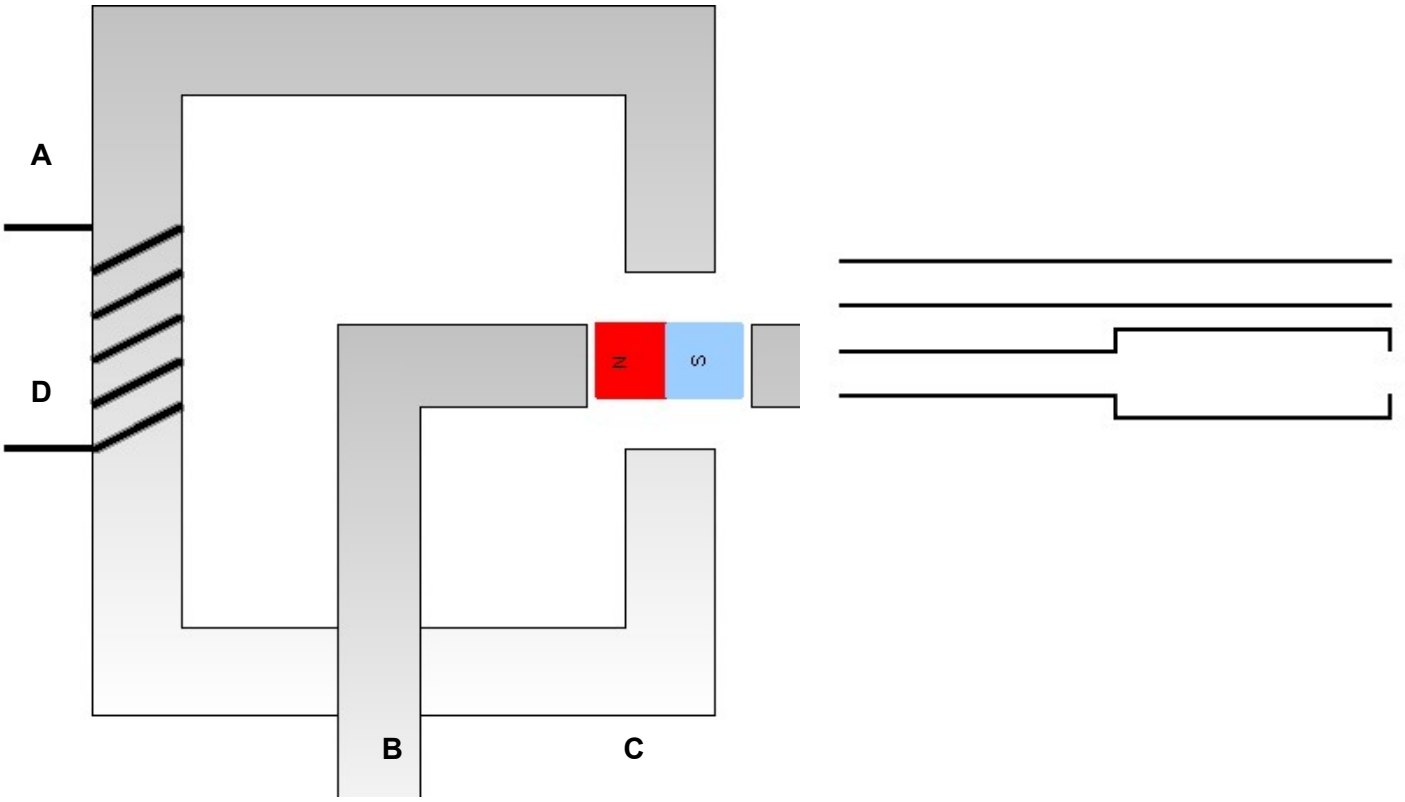
For step 2:



For step 3:



For step 4:



E. How are ½ steps produced?

Unlike full-step mode, the two windings are energised at the same time. The rotor then moves to an intermediate position midway between the two pairs of poles.

F. Complete the summary table to show how the windings are energised to produce half-step increments.

Pulse	Input A	Input D	Input B	Input C
P1	+	-		
P1.5	+	-	-	+
P2			-	+
P2.5	-	+	-	+
P3	-	+		
P3.5	-	+	+	-
P4			+	-
P4.5	+	-	+	-

3.3 Air recycling motor

A. What type of stepper motor is used in this application?

The air recycling motor is a unipolar stepper motor.

B. What are the operating characteristics of this type of motor?

Unipolar motors have two wound stators and a permanent magnet (the rotor), just like bipolar stepper motors

However, the windings have a common and fixed centre tap which effectively doubles the number of windings.

Depending on the polarity of the energisation of the windings, the rotor rotates to a position under the effect of the magnetic fields generated in the stator by the windings.

The direction of rotation of the rotor is determined by the sequence used to energise these windings.

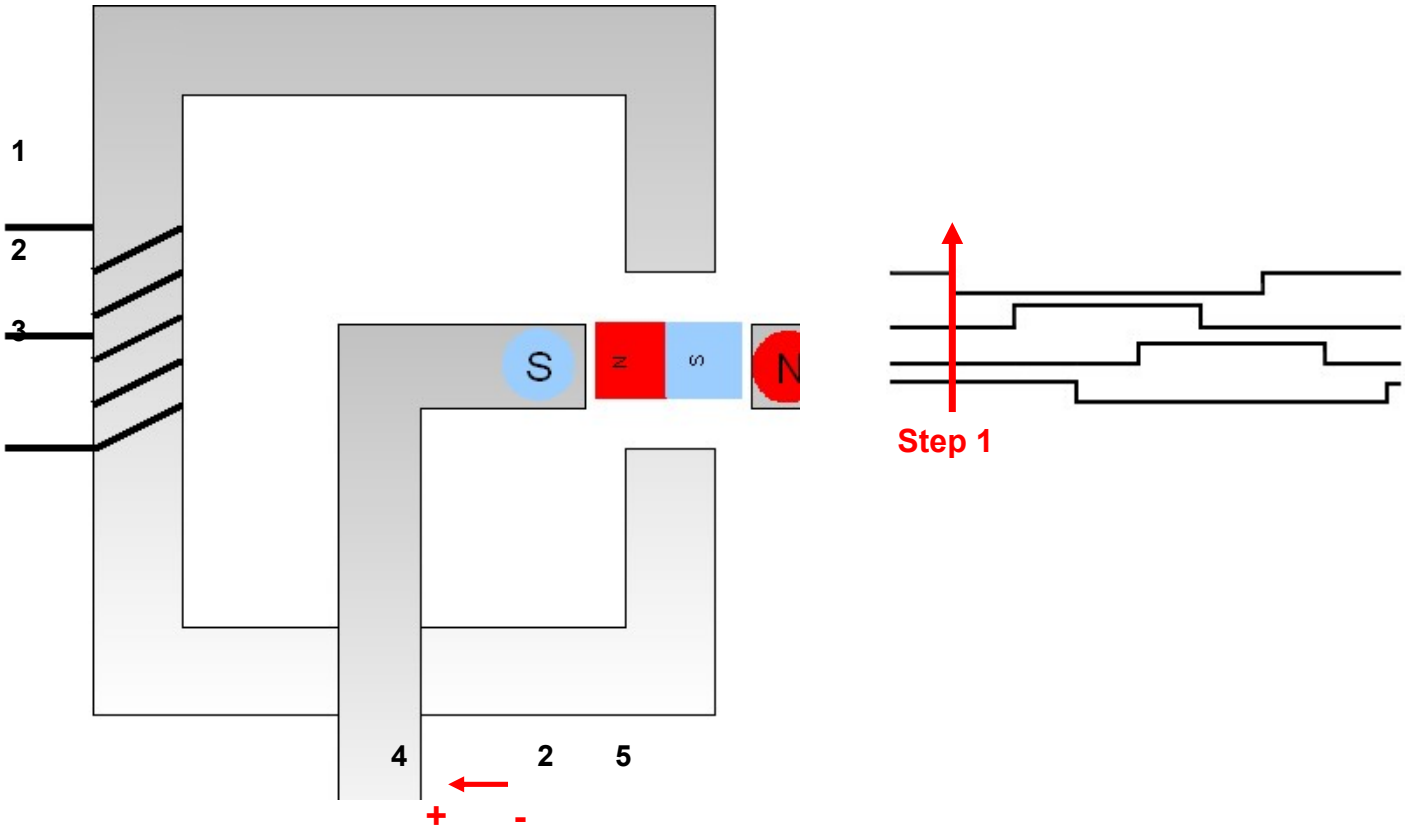
The speed is proportional to the frequency.

C. How are the windings energised to produce rotation with one full step at a time?

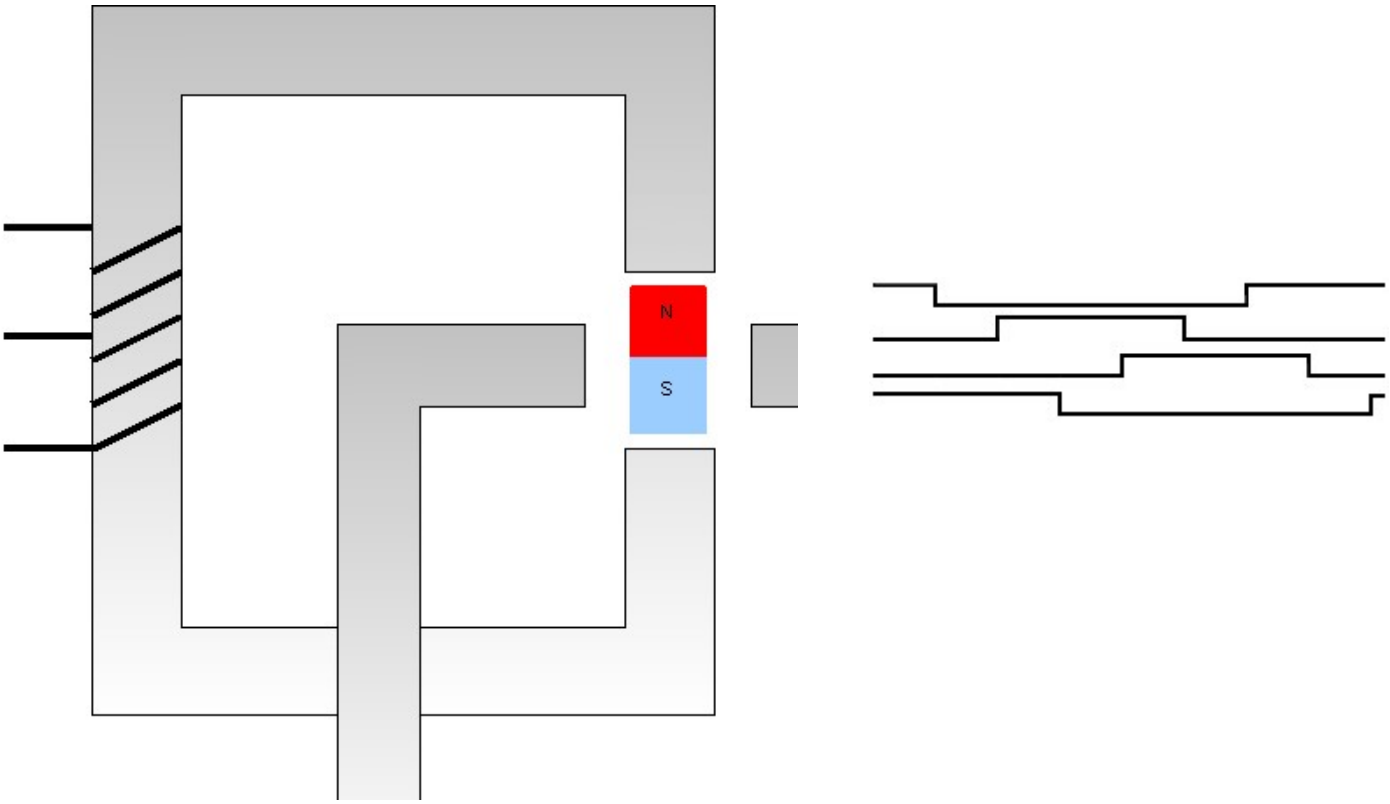
In full-step mode, each winding is energised independently of the other. The polarities of the poles are alternated to generate the rotational movement.

D. By referring to the signal timing chart, show on the diagram how the stator windings are being supplied with power and indicate on the timing chart, using an arrow, the current position in time for the step shown.

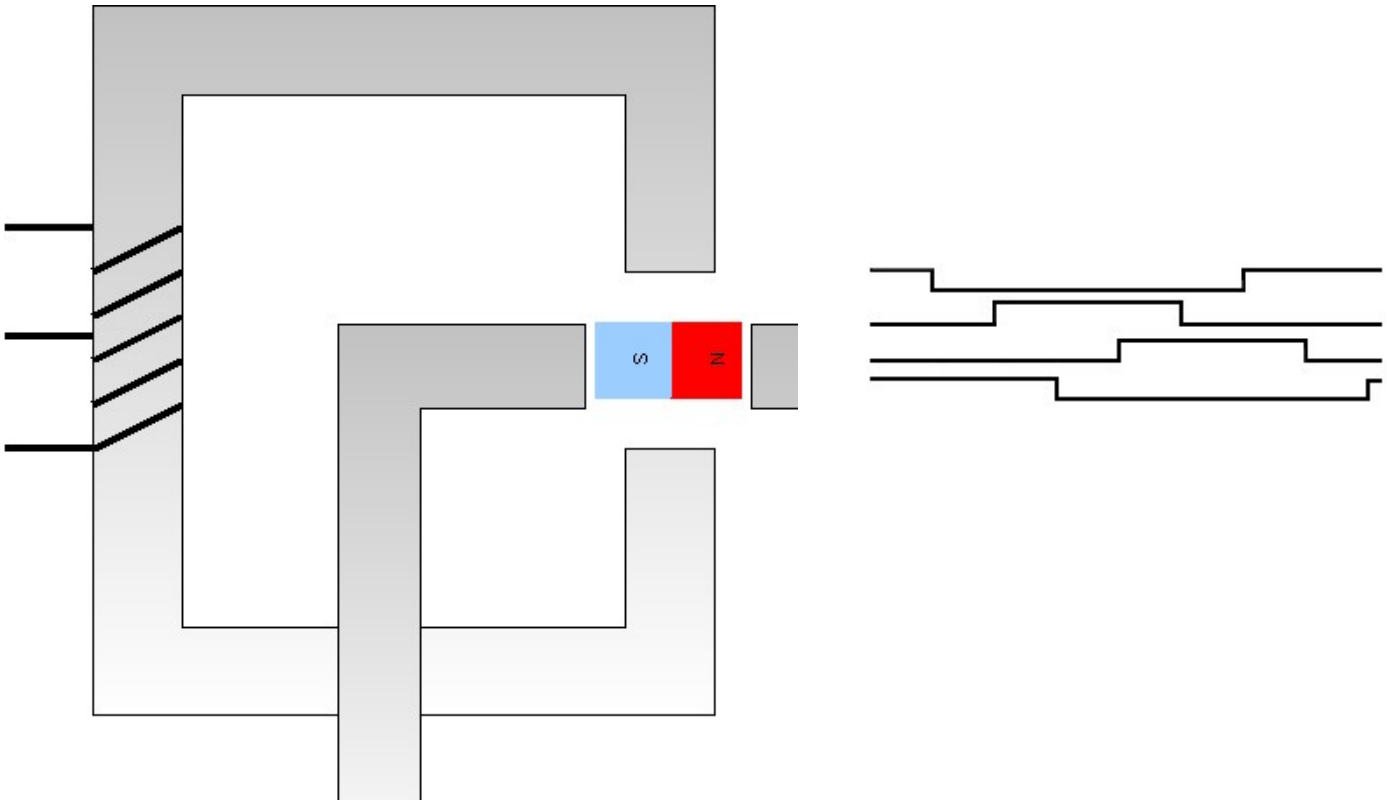
For step 1:



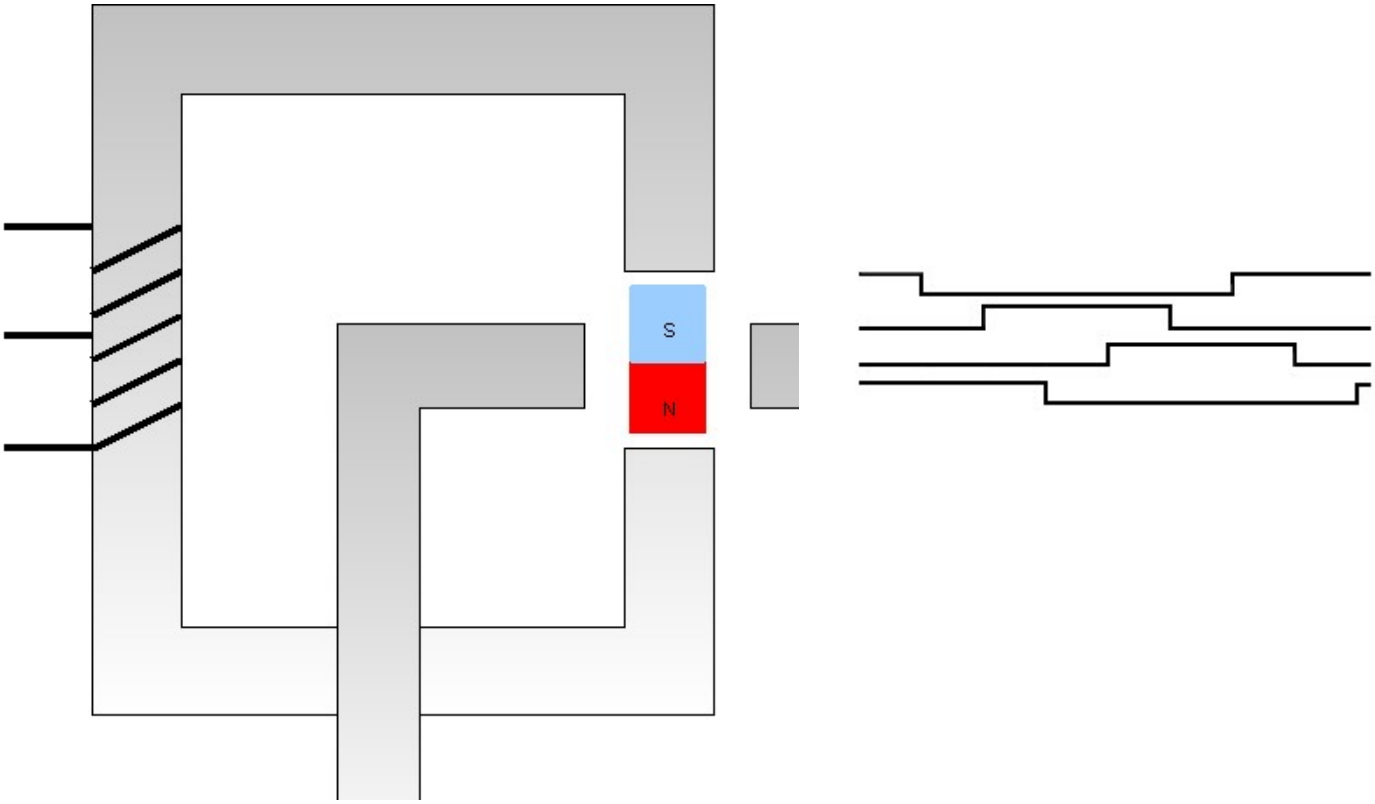
For step 2:



For step 3:



For step 4:



E. How are ½ steps produced?

Unlike full-step mode, the two windings are energised at the same time. The rotor then moves to an intermediate position midway between the two pairs of poles.

F. Complete the summary table to show how the windings are energised to produce half-step increments.

Pulse	Input 1	Input 3	Input 2	Input 4	Input 6
P1			-	+	-
P1.5	+	-	-	+	-
P2	+	-	-		
P2.5	+	-	-	-	+
P3			-	-	+
P3.5	-	+	-	-	+
P4	-	+	-		
P4.5	-	+	-	+	-

CE DECLARATION OF CONFORMITY

Via this declaration of conformity with the requirements stated in directive 2004/108/EC relating to electromagnetic compatibility, the company:

S.A.S. ANNECY ELECTRONIQUE
Parc Altaïs – 1, rue Callisto
F-74650 CHAVANOD

Declares that the product indicated below:

Make	Model	Product name
EXXOTEST	**DT-C005**	**BENCHTOP LEARNING MODULE: Controlling stepper motors**

I - has been manufactured in accordance with the requirements of European directives:

- Low Voltage Directive 2006/95/EC of 12 December 2006
- Machinery Directive 98/37/EC of 22 June 1998
- Electromagnetic Compatibility directive 2004/108/EC of 15 December 2004

and meets the requirements of the following standard:

- NF EN 61326-1 of 07/1997 +A1 of 10/1998 +A2 of 09/2001
  Electrical equipment for measurement, control and laboratory use. EMC requirements.

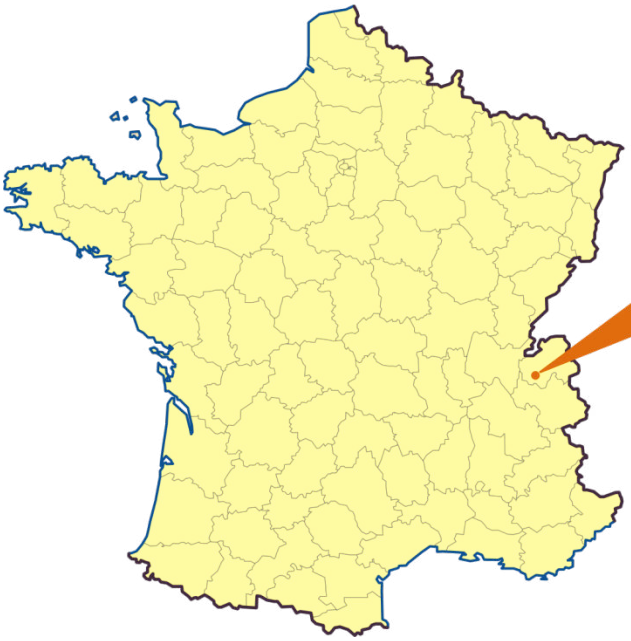
II – has been manufactured in compliance with the requirements of European directives relating to the design of Electrical & Electronic Equipment (EEE) and the management of Waste Electrical & Electronic Equipment (WEEE) in the EU.:

- Directive 2002/96/EC of 27 January 2003 on waste electrical & electronic equipment
- Directive 2011/65/EC of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (ROHS).

Signed in Chavanod, France, on 30 June 2009

Stéphane Sorlin, Chairman

Latitude : 45° 53’ 49” / Longitude : 6° 4’ 57”



Visit our website ***www.exxotest.com***

This document is available in the Download Area.

Sign in!

Notice Originale

Document n° 00308616-v1

ANNECY ELECTRONIQUE, créateur et fabricant de matériel : Exxotest et Navylec.
Parc Altaïs - 1 rue Callisto - F 74650 CHAVANOD - Tel : 33 (0)4 50 02 34 34 - Fax : 33 (0)4 50 68 58 93
S.A.S. au Capital de 276 000€ - RC ANNECY 80 B 243 - SIRET 320 140 619 00042 - APE 2651B - N° TVA FR 37 320 140 619
ISO 9001 : 2008 N° FQA 4000142 par L.R.Q.A.