User's guide for MT-DAE

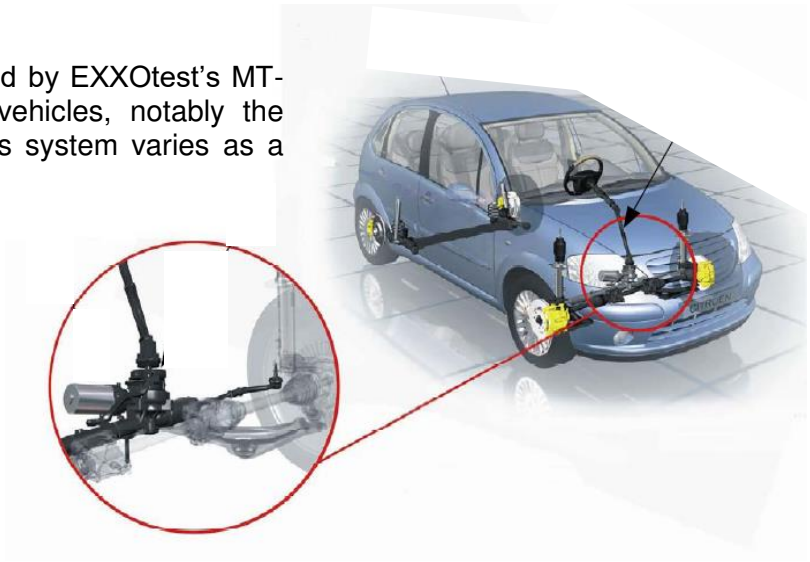
LEARNING MODEL: ELECTRIC POWER STEERING

EXOTEST® EDUCATION

Document No. 309407-v2

1. RESOURCES FILE

1.1. PRESENTATION

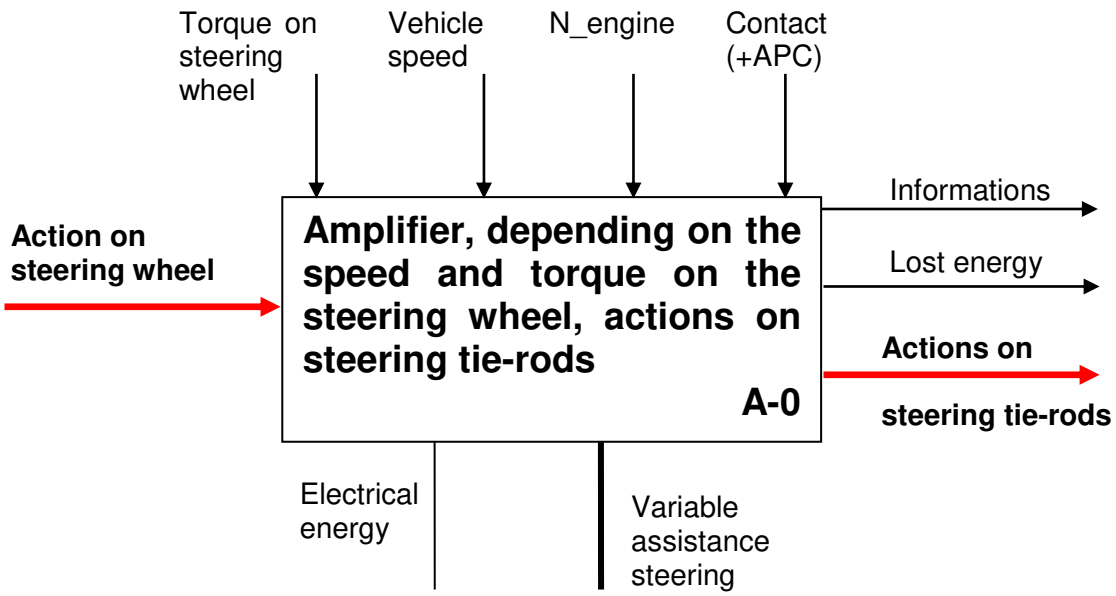


The electric power steering system simulated by EXXOtest's MT-DAE model is currently fitted to several vehicles, notably the Citroen C3. The assistance provided by this system varies as a function of road speed.

Unlike hydraulic power steering systems, power is only consumed when assistance is demanded: i.e. when the driver turns the steering wheel. This results in a power saving compared with hydraulic power steering systems. No direct interaction with the vehicle's engine is required since the electric power steering draws current from the alternator (when the engine is running).

Moreover, this system eliminates any risks associated with leaking hydraulic hoses and offers greater reliability since the mechanisms used are simpler. The basic mechanics of the system are essentially the same as for traditional steering (rack-and-pinion system).

1.2. OVERVIEW OF SYSTEM OPERATION



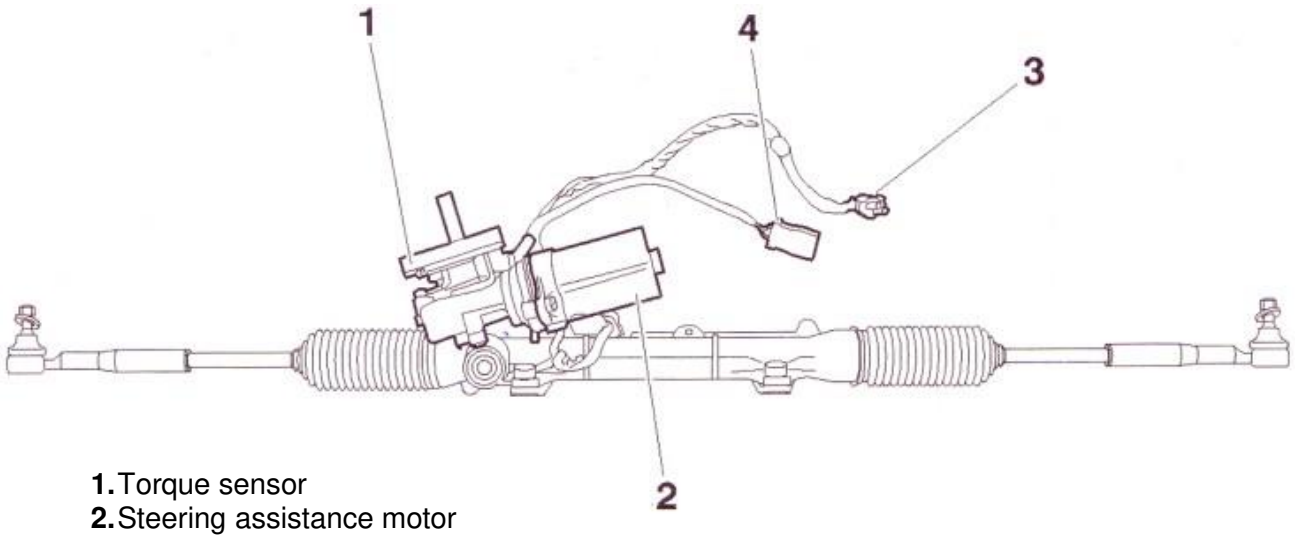
1.2.1. Principle of operation

- When the driver turns the steering wheel, electric power steering provides an assistive torque to help to steer the wheels.
- This assistive torque is provided by an electric motor. The torque is applied to the rack-and-pinion system via a motor and reducing gear assembly. It supplements the torque applied by the driver to the steering wheel.
- The force exerted by the driver on the steering wheel is transmitted to the steering rack. This input torque is measured by a torque sensor and a corresponding electrical signal is generated and sent to the electric power steering (EPS) control unit.
- The electric motor is called the steering assistance motor. The power which the control unit requests to drive the motor is dependent on two variables: the torque applied to the steering wheel and the vehicle's speed.

Vehicle's speed	Level of assistance	Comments
Speed less than 7 km/h (parking, manoeuvring)	Maximum	The EPS control unit controls the assistance motor based on the signal from the torque sensor only.
Speed between 8 and 152 km/h	Variable	The EPS control unit controls the assistance motor based on both the signal from the torque sensor and the vehicle's speed.
Speed greater than 152 km/h	Small, almost zero	The assistance motor is no longer supplied with power and is disengaged from the steering column.

1.2.2. Component elements

The electric power steering system consists of a conventional manual steering system fitted with the following:



1. Torque sensor
2. Steering assistance motor
3. Power supply connector for assistance motor
4. Signal from torque sensor connector

1.3. DESCRIPTION OF THE COMPONENTS

1.3.1. Torque sensor

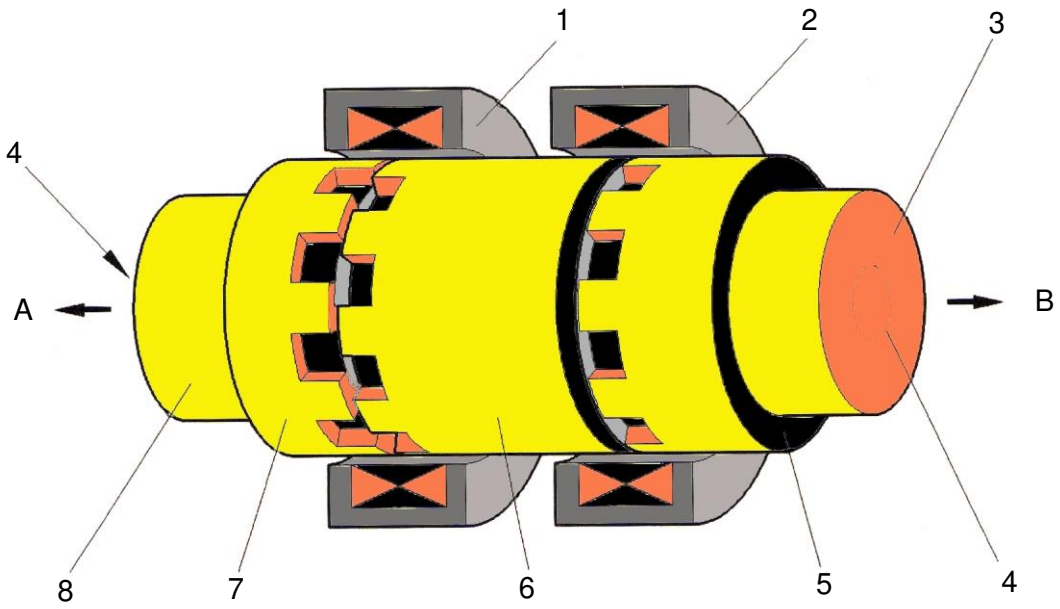
The torque sensor continuously measures the torque which the driver applies to the steering wheel.
The torque sensor detects and measures: the direction of rotation of the steering wheel and the torque applied by the driver.

The electronics integrated into the EPS control unit prevents any assistance torque being provided in a direction which opposes the direction of rotation of the steering wheel and disables all assistance when there is no input on the steering wheel.
This steering system does not require input from a steering wheel angle sensor.

Mounting position

The torque sensor is mounted on the pinion shaft, between the input shaft (steering column and steering wheel side) and the output shaft (rack-and-pinion side)

Description



A: Rack-and-pinion side **B:** Steering wheel side

1: Measuring coil which whose position is fixed in relation to the steering column
2: Reference measuring coil whose position is fixed in relation to the steering column
3: Input shaft on steering wheel side
4: Torsion bar between the input and output shafts
5 and **6:** Detection collar forming one piece with the input shaft
7: Detection ring forming one piece with the output shaft
8: Output shaft on rack side

This sensor is an eddy current torque meter which measures the angle of twist.
A series of notches around the periphery of each detection collar are arranged such that, when torsion is applied, the notches shift position in relation to each other.

The effect of this shift in notch position between adjoining collars is to change the inductance in the two coils.

The signal processing electronics are located near to the coils.

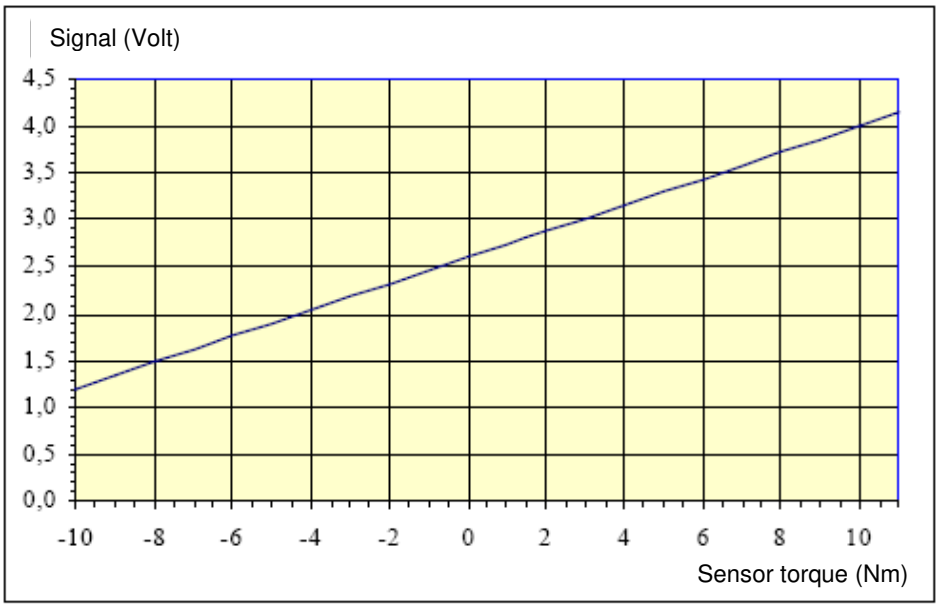
The torsion sensor has three subassemblies:

- The mechanical subassembly consists of a torsion bar. The angular shift between the input shaft and the output shaft is proportional to the torque applied by the driver. The limit of this angular offset is **+/- 4.5°.**

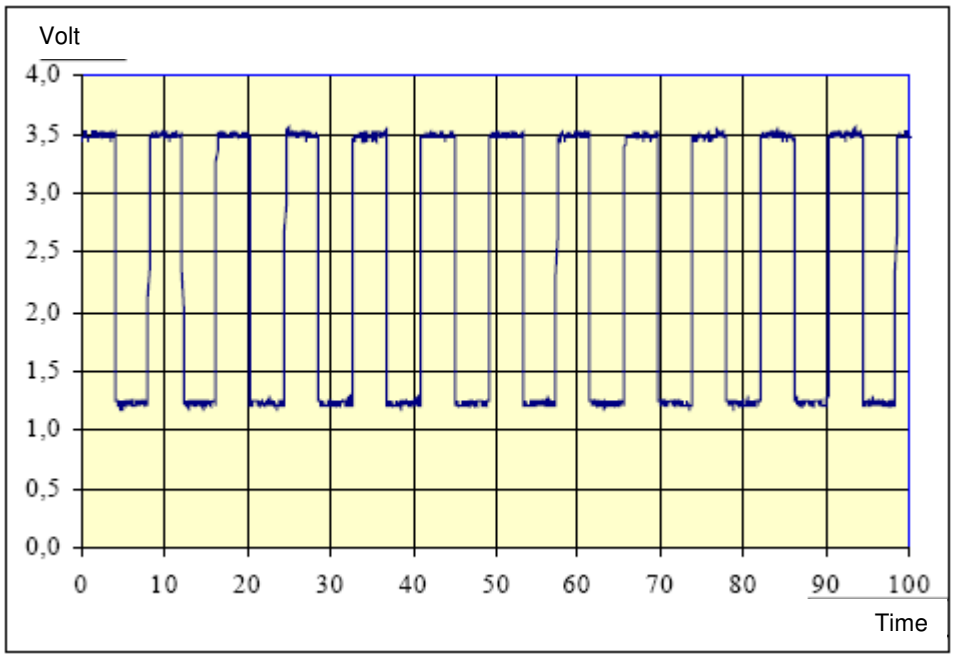
- The electromagnetic components provide information about the angular deviation of the detection collars (component 7 in the diagram compared with component 6) and consequently of the input shaft compared with the output shaft.

- The sensor's electronics which transform this angular position information into torque information based on the principle that the angular deformation of the torsion bar is proportional to the steering torque.

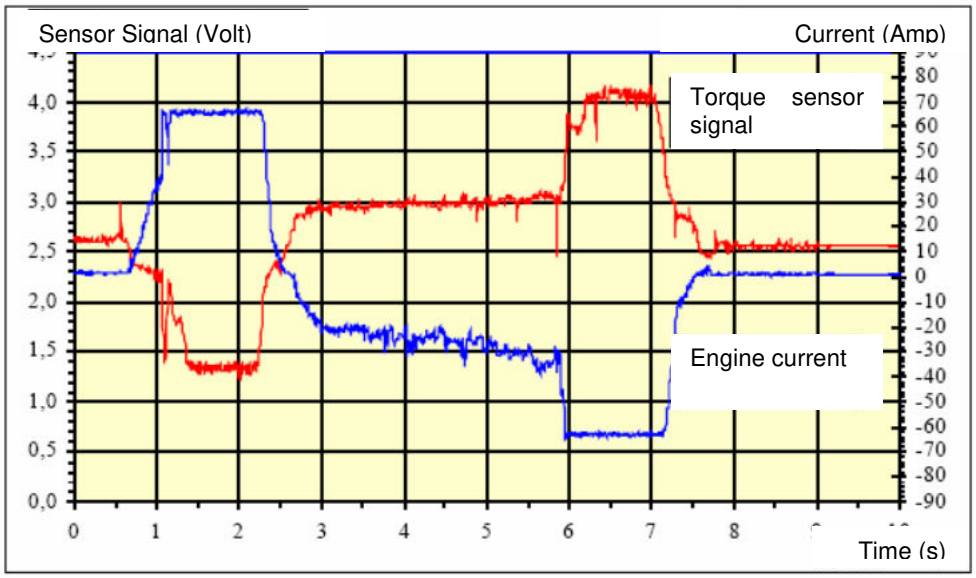
The torque sensor has a second detection stage. A reference coil, whose inductance is not changed by the angular deviation of the first set of detection collars.
It sends a reference electrical signal, irrespective of the environmental conditions (e.g. temperature).



Signal sent by the torque sensor to the control unit



Reference signal for the torque sensor generated by the control unit



Actual signal generated by an actuation

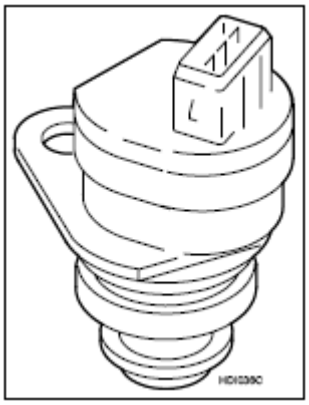
ACTUATION WHICH PRODUCED THE ABOVE SIGNAL

Start with the steering wheel in its straight-ahead position, then rotate for a right turn to full lock, then rotate for a left turn to full lock then return to the straight-ahead position.

1.3.2. Vehicle speed sensor

On some versions of the electric power steering system, a speed sensor provides the control unit with information about the vehicle's speed.

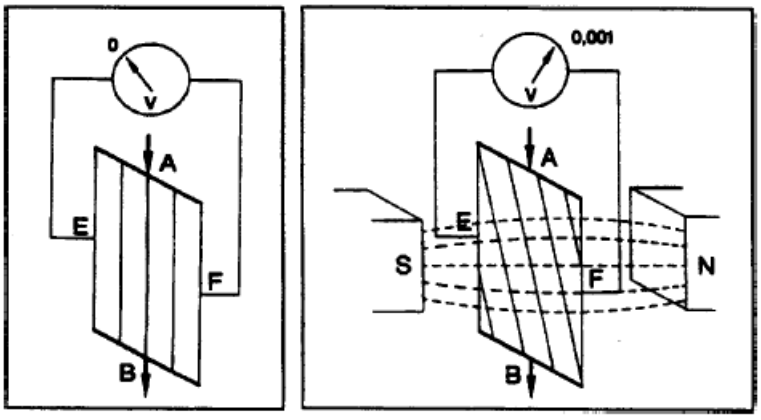
If the vehicle is fitted with ABS, this information is transmitted directly by this system on the multiplexed bus (there is no speed sensor).



Function

It is a Hall-effect sensor. It produces 5 signal "spikes" per meter and 8 signal "spikes" per rotation. The vehicle speed sensor provides an electrical signal whose frequency is proportional to the speed of rotation of the gearbox's secondary shaft, thus to the vehicle's speed. It is mounted on the gearbox.

The Hall effect

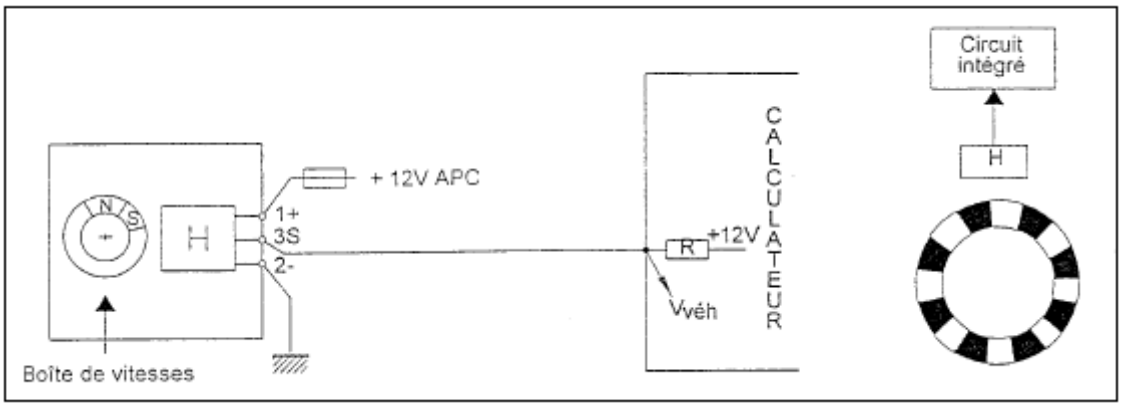


The key component of this system is an extremely thin, 1.2-mm square plate through which a current passes from point A to point B.

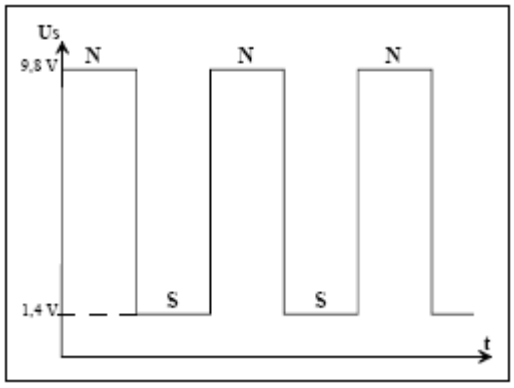
When a magnetic field SN is applied perpendicular to the plate, a very weak Hall voltage (0.001 V) can be measured between points E and F. This voltage is generated as a result of the current lines A B being deviated by the magnetic field. No voltage is measured if the magnetic field is absent.

How the sensor works

When the pole wheel (made up of successive segments of north and south poles) rotates, a series of north and south poles pass in front of the Hall plate. The voltage generated across the plate thus alternates as the current direction changes with each new pole.
The sensor's integrated circuit amplifies the square-wave signal produced, whose high value corresponds to one current direction across the plate and whose low value corresponds to the reverse direction of current through the plate, induced by the polarity of the pole passing in front of it.

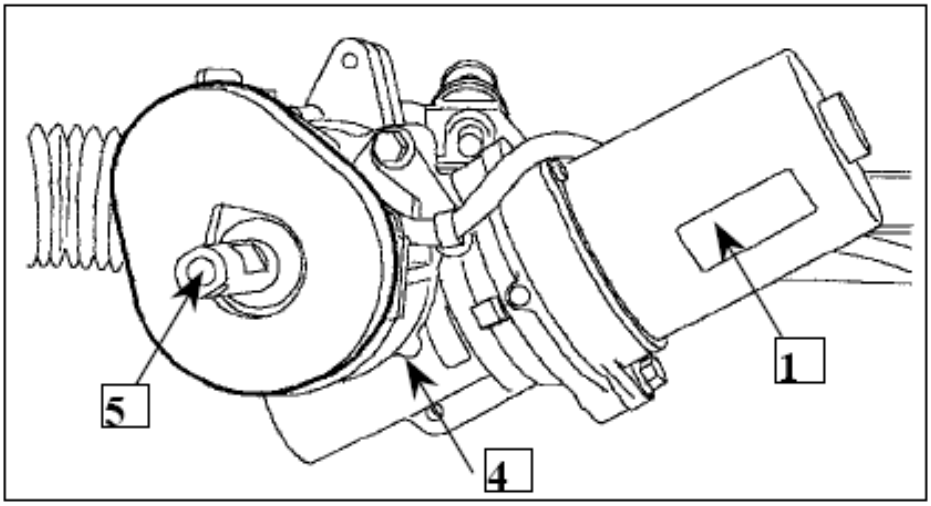


Example of the signal produced by the sensor



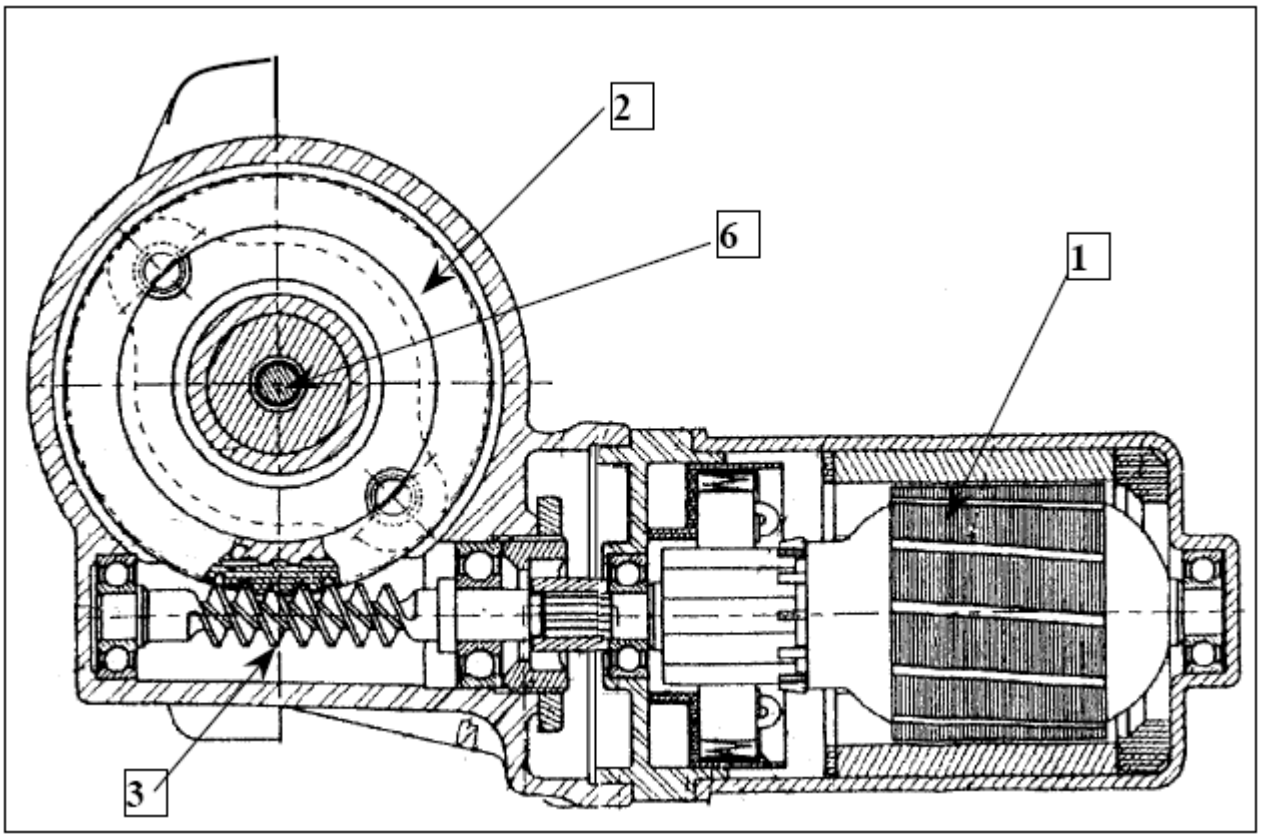
This is the signal received by the injection & ignition control unit; it is measured at terminal 3 of the vehicle speed sensor's connector.

1.3.3. Motor and reducing gear assembly



	Designation
1	Assistance motor
2	Reducing worm wheel
3	Worm screw
4	Reducing gear assy
5	To steering wheel
6	Output shaft

Internal view of the assembly



The reducing gear consists of a worm wheel and a worm screw.

- The worm wheel forms one piece with the steering column
- The worm screw is driven by the steering assistance motor's shaft

The reducing gear ratio is: 1/15

The steering assistance motor is a brushed d.c. motor.
There are two types of electric motor, differentiated by their power:

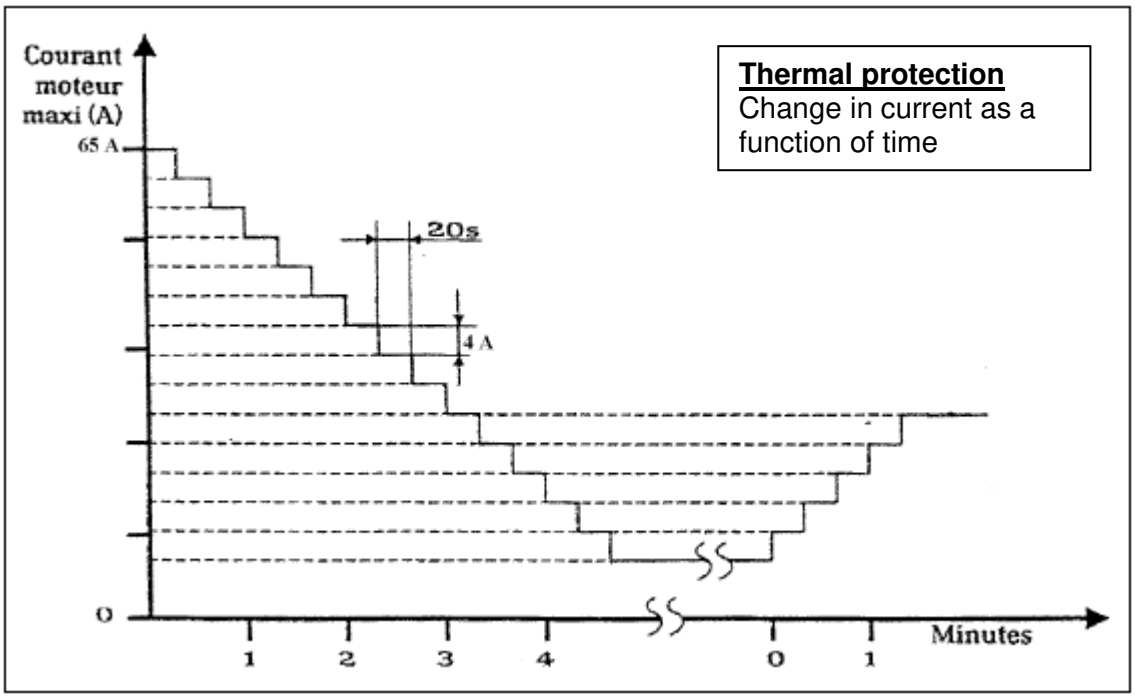
- 60 amperes for light vehicles
- 65 amperes for heavier vehicles fitted, for example, with an option such as air conditioning or an automatic transmission

The motor cannot operate unless:

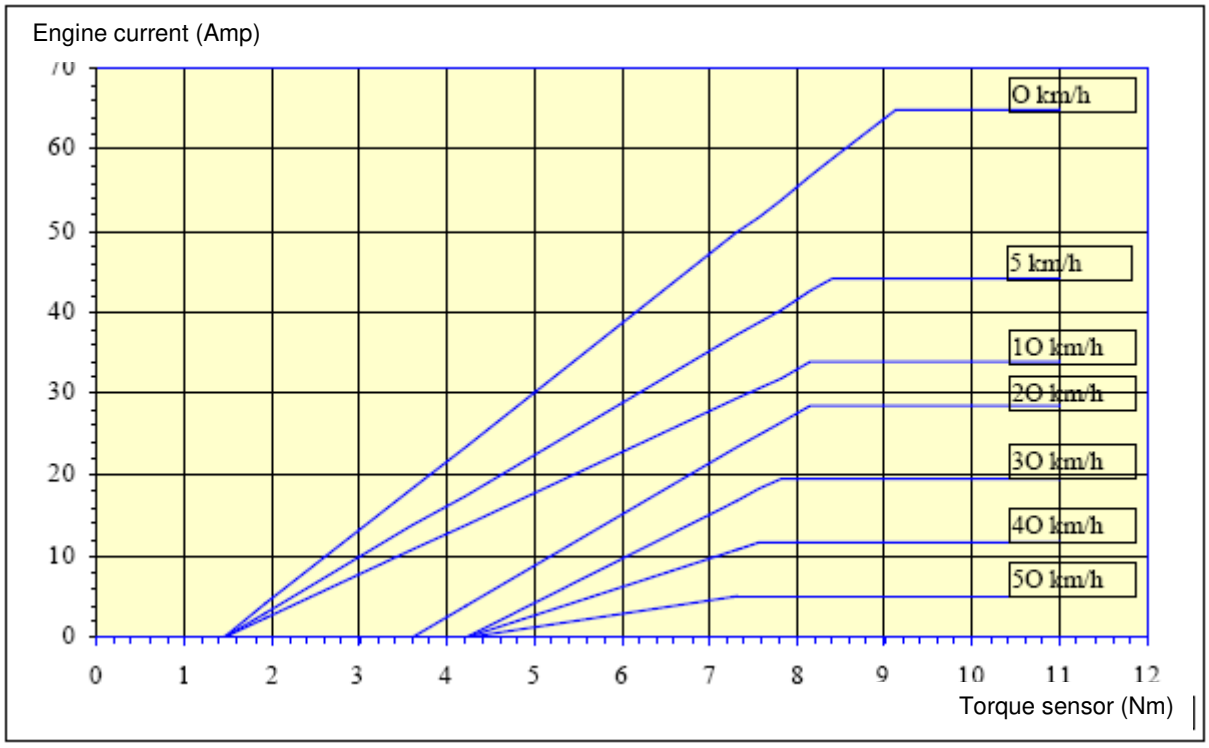
- The battery's voltage is 9 V or higher.
- The engine speed is faster than 285 rpm

Thermal protection

The control unit gradually cuts back on the assistance (by reducing the maximum current) if the vehicle is steered heavily for a long period (e.g. turning from one full-lock position to the other several times in a row) to stop the assistance motor overheating and to avoid any risk of damaging or degrading the motor or control unit.
The current is gradually restored as the system cools.



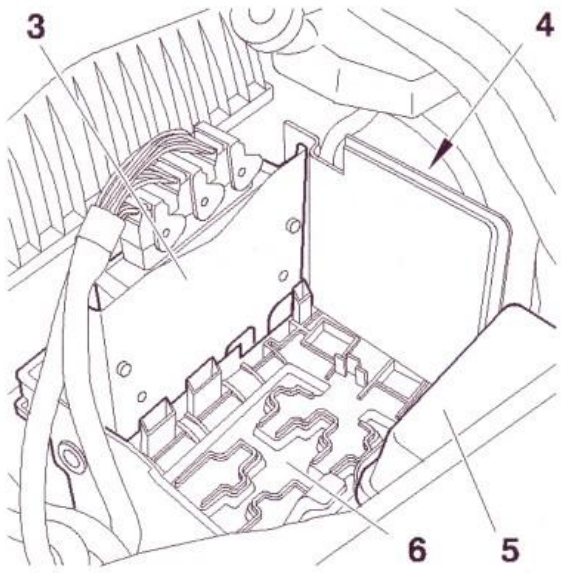
The power interface is controlled by a voltage chopper which regulates the mean value of the current which the motor can draw.



1.3.4. Electric power steering (EPS) control unit

The EPS control unit is fitted in the engine compartment.

E.g. for a Citroen C3:



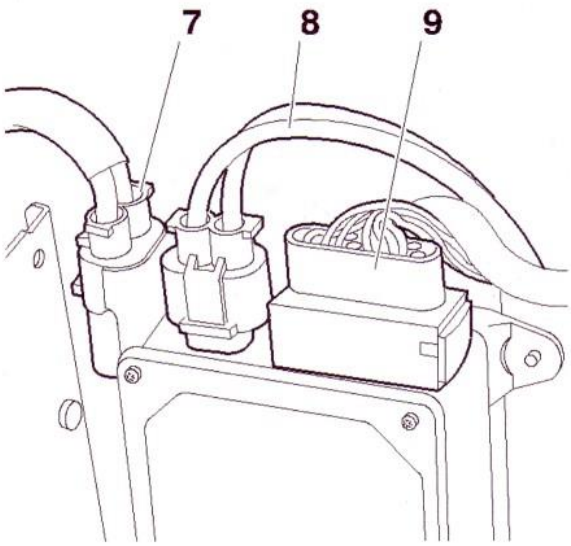
3 – Injection & ignition control unit

4 – EPS control unit

5 – Fuse box in engine compartment (BSM)

6 – Battery compartment

The EPS control unit is connected via 3 cable harnesses:



7 – Power supply for steering assistance motor: 2-channel connector

8 – Power supply for EPS control unit from the battery: 2-channel connector

9 – 9-channel connector, comprising: 4 wires carrying information from the torque sensor, 1 wire carrying the system temperature signal, 2 twisted wires (CAN bus), 1 wire for +APC and the diagnostics line.

1.3.5. Degraded modes

The EPS control unit is set up with a strategy for managing system failures:

- Within the steering system (torque sensor fault, loss of an electric circuit)
- External to the steering system (incorrect CAN communication, invalid vehicle speed information)

The EPS control unit switches to degraded mode if one or more fault codes are generated.

There are two degraded modes:

- Baseline assistance (assistance greatly reduced)
- Total loss of assistance

Fault	Degraded mode
Faulty communication with the CAN bus	Baseline assistance
Invalid or inconsistent vehicle speed Vehicle speed greater than 250 km/h No vehicle speed information	Baseline assistance
Engine speed Engine speed higher than 7000 rpm	Baseline assistance
Defective torque sensor	Total loss of assistance
Battery voltage less than 7.7 Volts	Total loss of assistance
Assistance motor seized	Total loss of assistance
Wiring problem	If the wiring fault is detected before starting the engine, the power steering does not operate

1.3.6. Assignation of the control unit's channels

Channel	Assignation
15 V BLACK CONNECTOR	
1	Secondary torque info
2	Torque sensor (ground)
3	Torque sensor (+5V)
4	-
5	Power supply after ignition switched to "On", protected by fuse F4
6	Multiplexed line on CAN bus
7, 8, 9	-
10	Primary torque info
12	Diagnostics info
13	Torque sensor temperature info
14	Multiplexed line on CAN bus
15	-
2 V BLACK CONNECTOR	
1	Ground
2	Power supply from battery protected by fuse MF8
2 V BLUE CONNECTOR	
1	Steering assistance motor control
2	Steering assistance motor control

2. USER FILE

2.1. INTENDED USE

This equipment has been designed to let trainees learn about the operation of an electric power steering system developed by the PSA PEUGEOT CITROEN group.

It shows how the equipment is put together, presents a number of components used on production vehicles and lets the trainee access the messages exchanged between the control unit, sensors and actuators.

It can also show how the system behaves when faults occur. The range of diagnostic possibilities is thus very broad.

2.2. USING THE MODEL

2.2.1. Initial state

Position the model in a clear area within the workshop, reasonably close to an electrical power outlet.

Apply the brake to each of the 4 casters

Plug the power cable into a 230 V mains supply

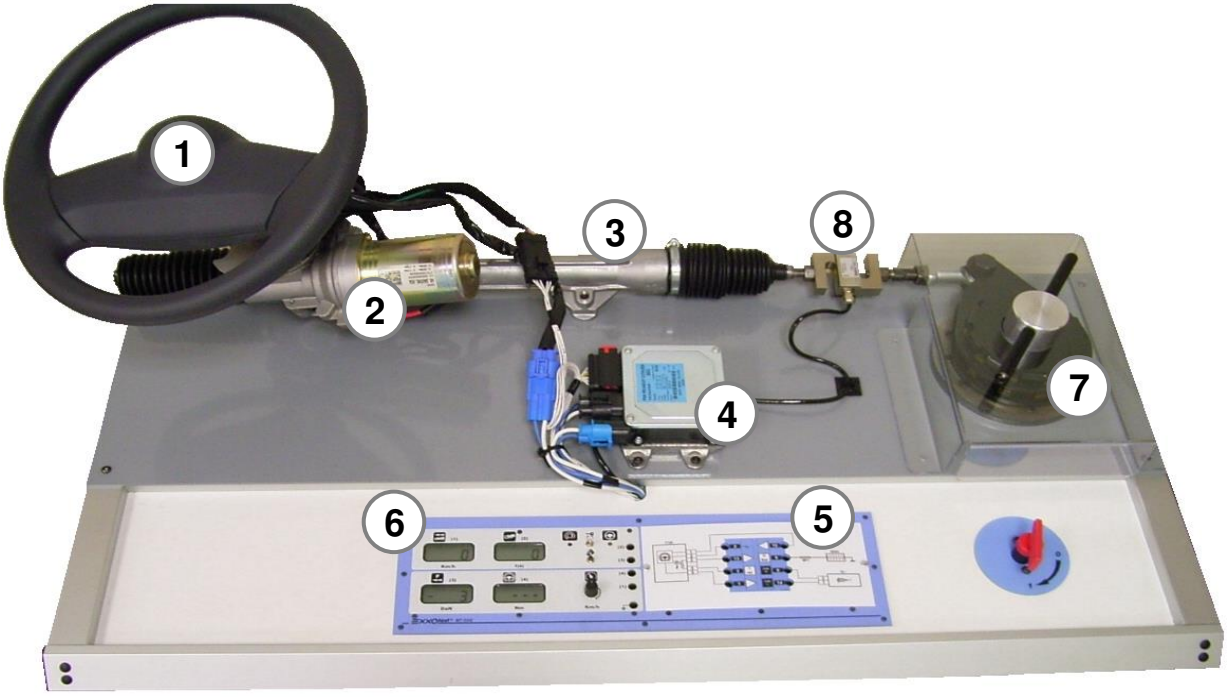
The components are supplied with power by a battery which is permanently connected to a charger which is in turn connected to the mains (230 V); this arrangement maintains a constant nominal voltage even during prolonged use.

2.2.2. Switching on

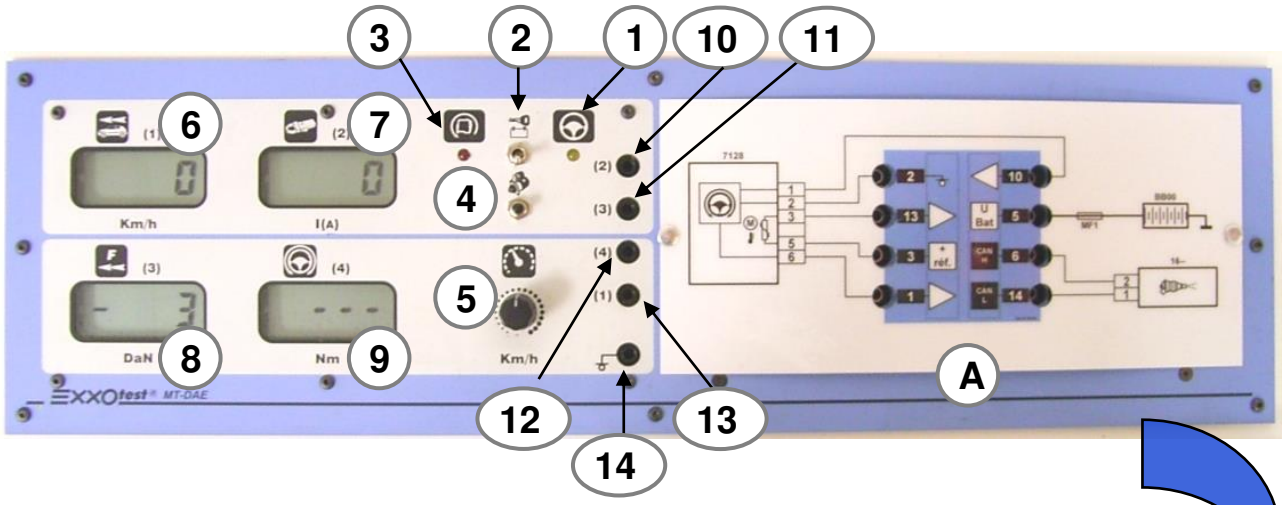
The model is switched on using the red key.
The power steering is only active when the engine is running. To simulate the + DEM information (engine running) press on the switch (4) to start up the engine.

2.2.3. Composition

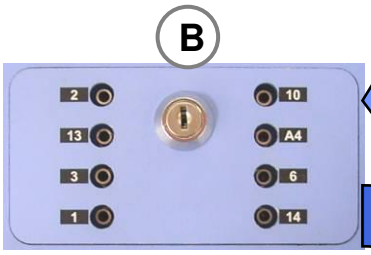
All the relevant elements present on the vehicle are provided on the model.



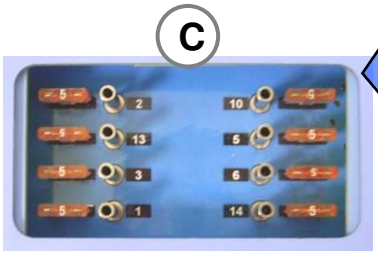
No.	Item name	Function
1	Steering wheel	Steers the vehicle.
2	Electric motor	Provides additional torque to assist the driver.
3	Steering rack	Transforms the rotational motion of the steering wheel into a translational motion.
4	Control unit	Controls the motor based on pre-programmed algorithms.
5	Terminal board	For making electrical measurements at the control unit's terminals.
6	Control panel	Provides the information required by the user.
7	Mechanical resistance	Simulates the resistance of the wheels on the ground.
8	Force sensor	Indicates the force exerted by the rack



A Removable face with symbols and manufacturer's references



B Measurement terminals and references



C Protection fuses, option to generate faults

No.	Item name	Function
1	Diagnostics light	Tells the user that there is a fault.
2	Ignition switch	Simulates the + APC (“ON”) position.
3	Engine running indicator light	Tells the user that the engine is running.
4	Engine “Start” switch	Simulates the “Start” position of the ignition key.
5	Vehicle speed potentiometer	Simulates the vehicle’s speed.
6	Speed display	Tells the user what vehicle speed is being simulated.
7	Current display	Indicates to the user how much current is being consumed by the electric motor.
8	Force display	Indicates to the user how much force is being applied to the rack.
9	Torque display	Indicates to the user how much torque is being generated by the user turning the steering wheel.
10	Voltage proportional to motor current (image of the current)	Lets the user measure the power consumed by the assistance motor, indicated as a voltage (via the use of the REFLET data acquisition software)
11	Voltage proportional to force on rack	Lets the user measure the force applied by the assistance motor, indicated as a voltage (via the use of the REFLET data acquisition software)
12	Voltage proportional to steering wheel torque	Lets the user measure the torque applied by the user, indicated as a voltage (via the use of the REFLET data acquisition software)
13	Voltage proportional to vehicle speed	Lets the user measure the vehicle’s speed, indicated as a voltage (via the use of the REFLET data acquisition software)
14	Analog ground of control unit	Ground (REFLET)

3. EXERCISE FILE

3.1. PRACTICAL EXERCISES No. 1

3.1.1. Meaning of the symbols

CAUTION! This symbol draws attention to an important point.

When you see this symbol, you must ask the trainer to watch or supervise in person the tasks indicated
.

When you see this symbol, your response to the questions must involve highlighting with different colours or drawing
.

When you see this symbol, you must complete a table or perform calculations
.

3.1.2. Preparatory work

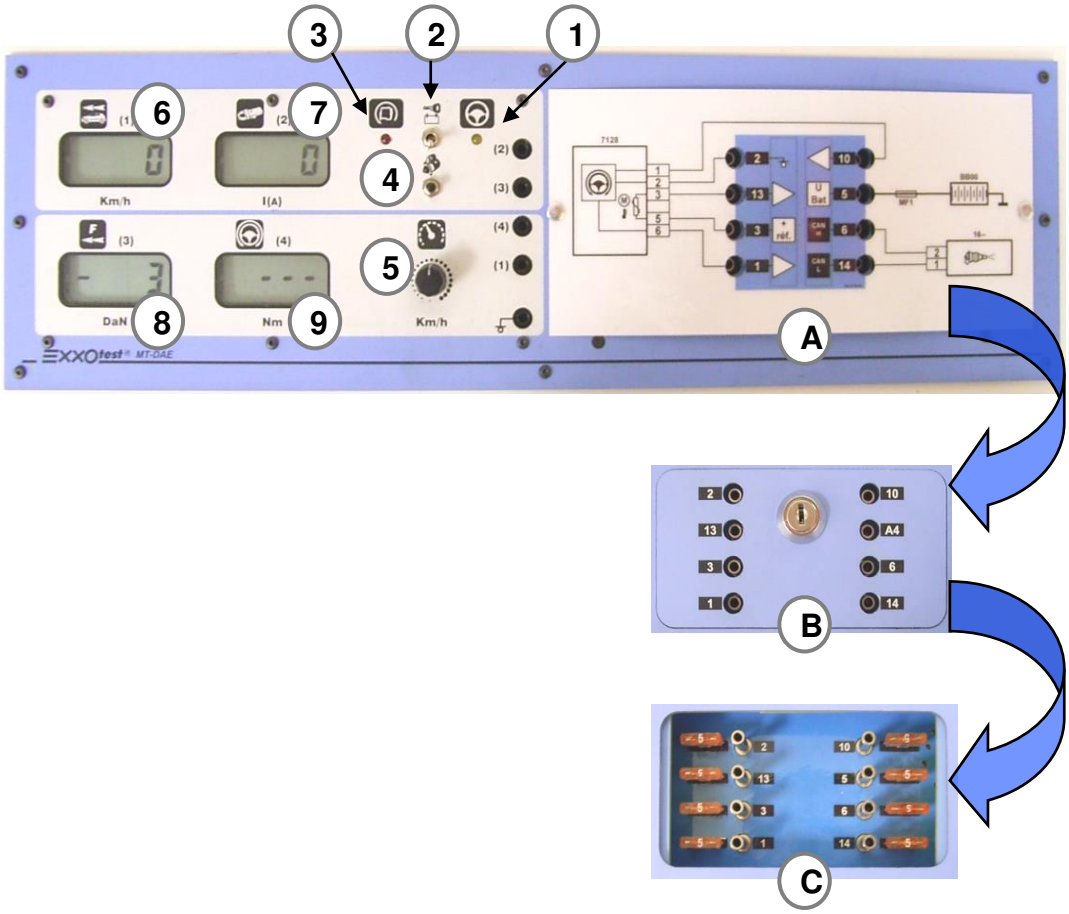
By referring to the exercise file, prepare the workstation in accordance with the instructions relating to safety.

☞Call the trainer

1. **Name the various elements numbered in the figure below in the table**

No.	Name of component	Function
1		
2		
3		
4		
5		
6		
7		
8		

2. Name the various elements numbered in the figure below in the table

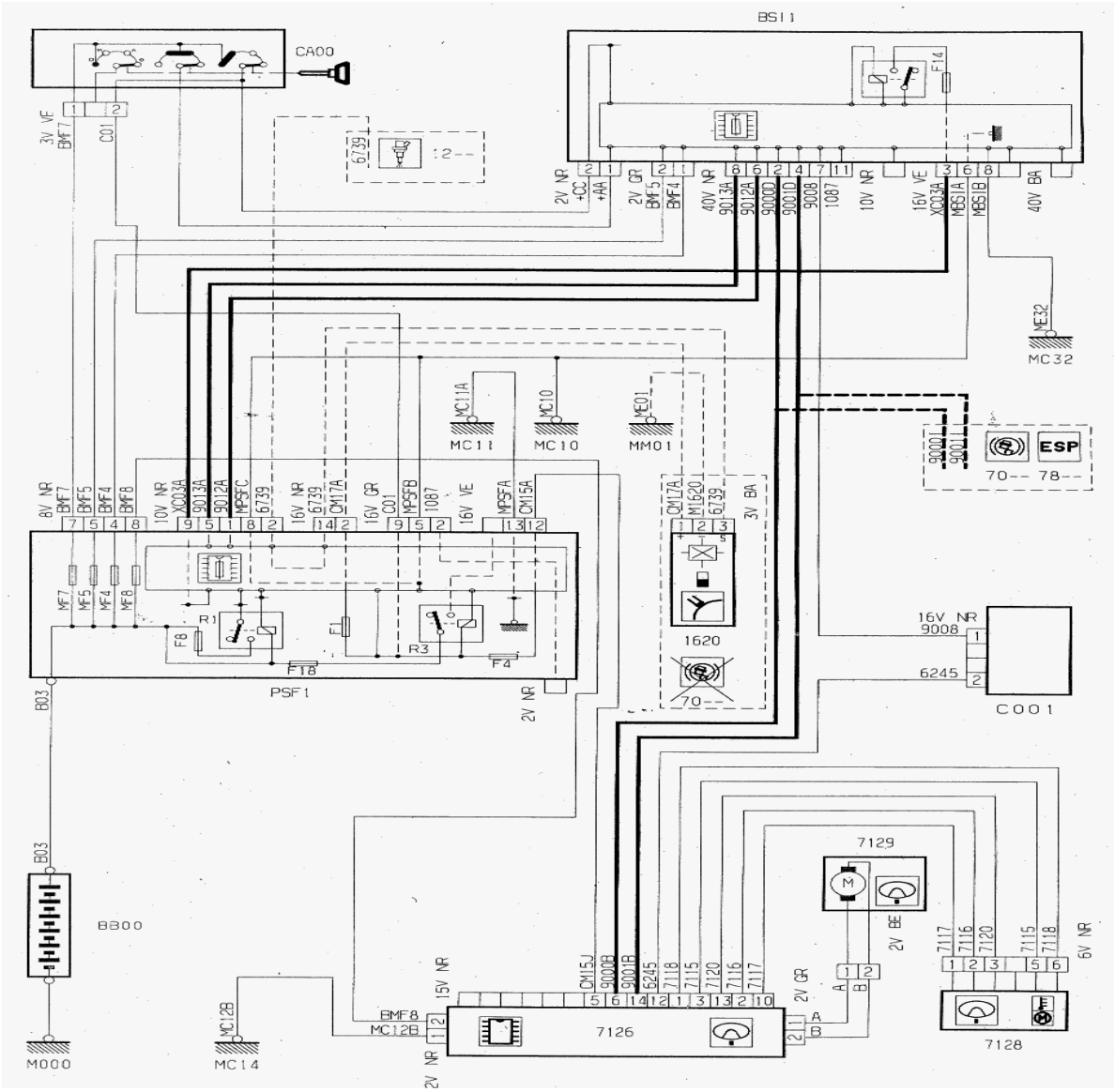


No.	Item name	Function
1		
2		
3		
4		
5		
6		
7		
8		
9		
A		
B		
C		

3. **By referring to the wiring diagram and to the resources file, complete the table below.**

Name of the component	Manufacturer's code on the diagram	Function
	7128	
Speed sensor		
	7126	
Electric motor		
	BB00	

4. **On the wiring diagram, indicate in red pen the power supply to the control unit and in blue its ground.**



☞Call the trainer

5. **On the Citroen C3 vehicle provided, identify the various visible components, then complete the diagram below.**

Reference	Name	Function
1		
2		
3		
4		

Returning to the model, plug its power cable into the mains (in accordance with the safety instructions detailed in the resources file) and screw down the handle on the mechanical resistance so that the force applied by the rack is 330 DaN.

6. **For a vehicle speed of 0 km/h, what force must be applied by the "driver"?**

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……
……
……

7. **And similarly for a speed of 100 km/h?**

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8. **And for 180 km/h?**

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9. **What do you notice?**

……
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……

10. **To draw together the various points of this first PE, explain how electric power steering works.**

……
……
……
……
……
……

3.1.3. Summary

1. Presentation

The electric power steering (EPS) system provides speed-dependent, electric-powered assistance to the driver when steering. This type of power steering system offers many benefits:

- A much improved driving experience in both urban and extra-urban environments.
- A non-negligible reduction in fuel consumption of about 0.2 litres per 100 km.
- No requirement for hydraulic fluids for the assistance pump or for hoses to carry the fluids.

2. Principle of operation

When the driver turns the steering wheel, electric power steering provides an assistive torque to help to steer the wheels.

The assistance torque is provided by an electric motor which supplements the torque transmitted from the steering wheel applied by the driver. This driver-induced torque is measured by the torque sensor and sent to the EPS control unit.

The control unit supplies the motor with power as a function of:

- The torque applied to the steering wheel
- The vehicle's speed.

3. Components

The electric power steering system consists of a conventional manual steering system fitted with the following:

- A torque sensor
- An electric assistance motor and its reducing gear
- Two cable harnesses (a signal harness and a power harness)
- A control unit connected to the CAN bus (not shown in the drawing)

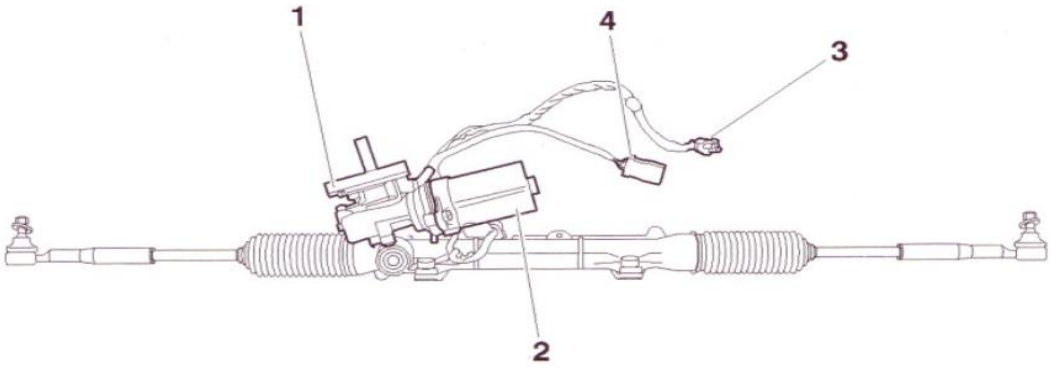


Diagram Ref.	Name of component
1	Torque sensor
2	Steering assistance motor
3	Connector for remote power supply to motor
4	Signal from torque sensor connector

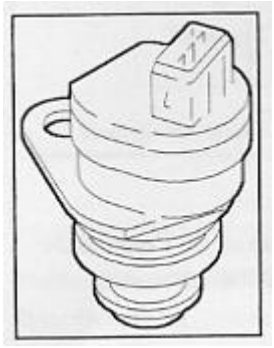
4. Component elements

a) Torque sensor

The torque sensor continuously measures the torque which the driver applies to the steering wheel.

b) Vehicle speed sensor

It provides the electric power steering control unit with information about the vehicle's current speed.



c) Motor and reducing gear assembly

Consists of an electric steering assistance motor coupled to a reducing gear which are linked to the steering rack (the reducing gear multiplies up the force generated by the motor).

The motor cannot operate unless:

- The battery's voltage is 9 V or higher.
- The engine speed is faster than 285 rpm

Thermal protection The control unit gradually cuts back on the assistance (by reducing the maximum current) if the vehicle is steered heavily for a long period (e.g. turning from one full-lock position to the other several times in a row) to stop the assistance motor overheating and to avoid any risk of damaging or degrading the motor or control unit.
The current is gradually restored as the system cools.

d) Electric power steering (EPS) control unit

The EPS control unit receives information from:

- the torque sensor
- the speed sensor
- the temperature sensor

It controls the operation of the electrical motor based on these parameters.

3.2. PRACTICAL EXERCISE No. 2

3.2.1. Meaning of the symbols

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When you see this symbol, you must complete a table or perform calculations.

3.2.2. Preparatory work

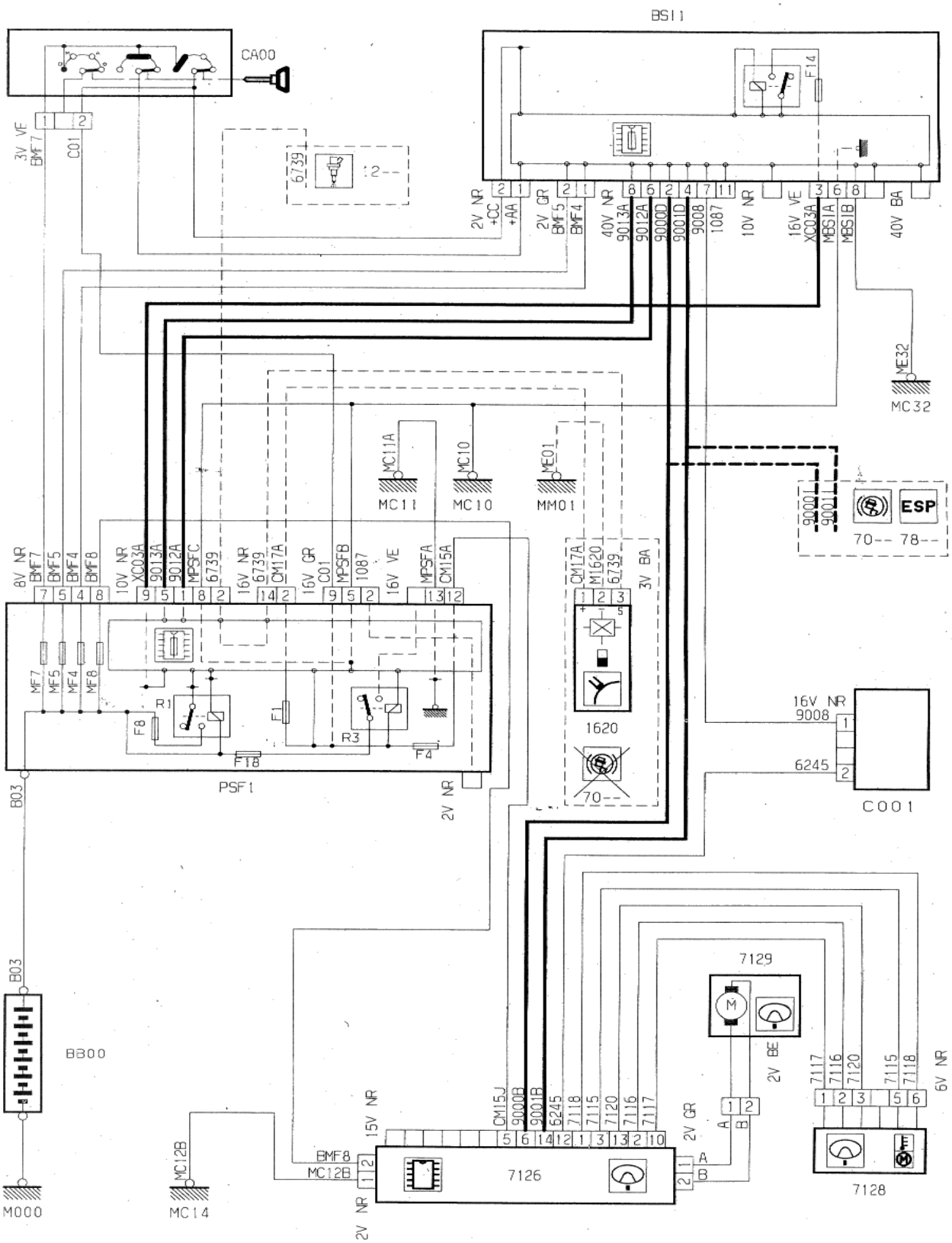
By referring to the exercise file, prepare the workstation in accordance with the instructions relating to safety.

☞Call the trainer

1. **By referring to the wiring diagram and to the resources file, indicate the function of each element**

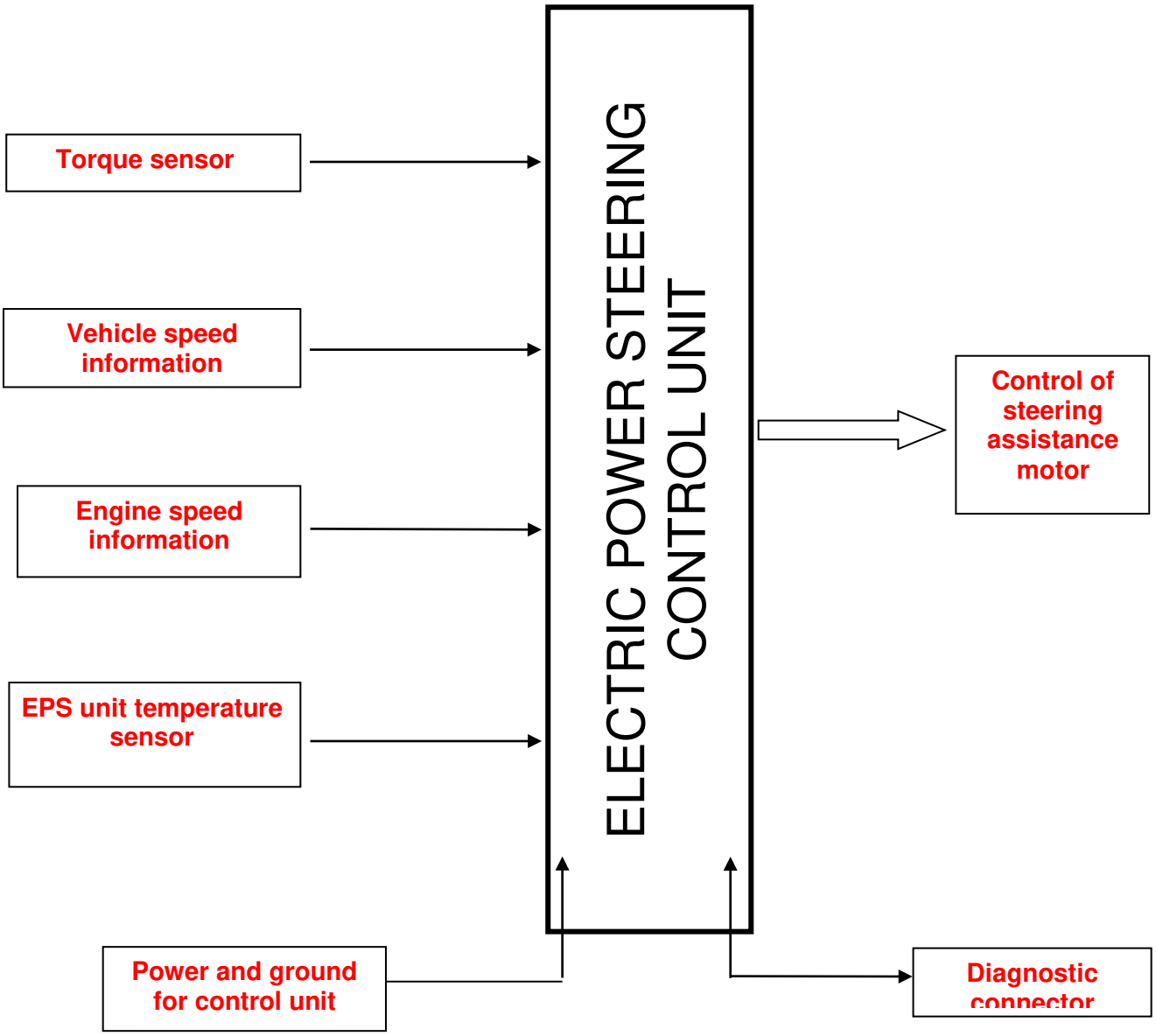
Name of the component	Manufacturer's code on the diagram	Function
	7128	
Speed sensor		
	7126	
Electric motor		
	PSF1	

2. <u>On the wiring diagram, indicate in red pen the power supply to the control unit and in blue its ground</u>



☞Call the trainer

3. **Enter the inputs/outputs for the EPS control unit in the boxes below.**



3.2.3. Tasks to be performed

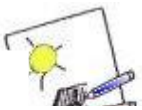
1. **Once the model is connected to the mains, screw down the handle on the mechanical resistance so that the force applied by the rack is 330 daN.**

   a) **On the vehicle, what does this value relate to? How can it be changed?**

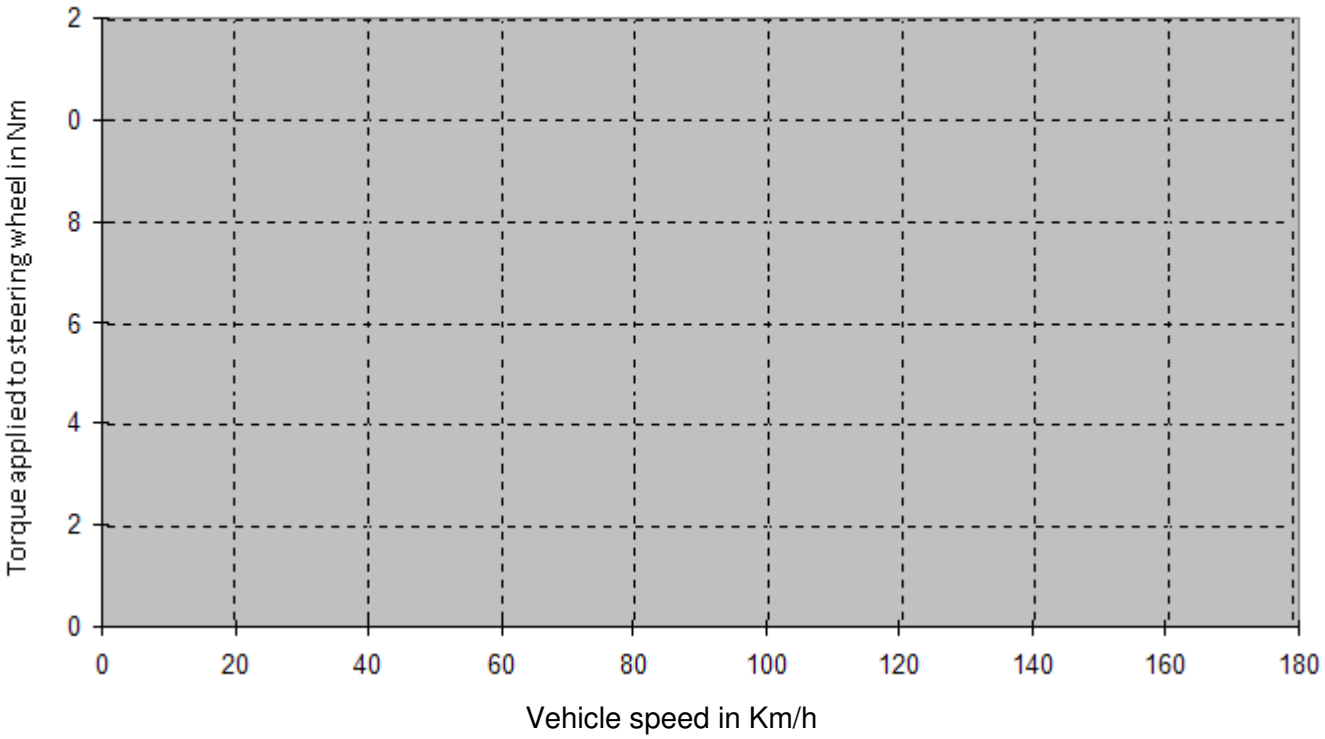
   ……
   ……
   ……
   ……
   ……
   ……

   b) **Complete the table below then plot the corresponding curve.**

Vehicle speed (km/h)	0	20	40	60	80	100	120	140	160	180
Steering wheel torque in Nm										



Steering wheel torque depending on vehicle speed



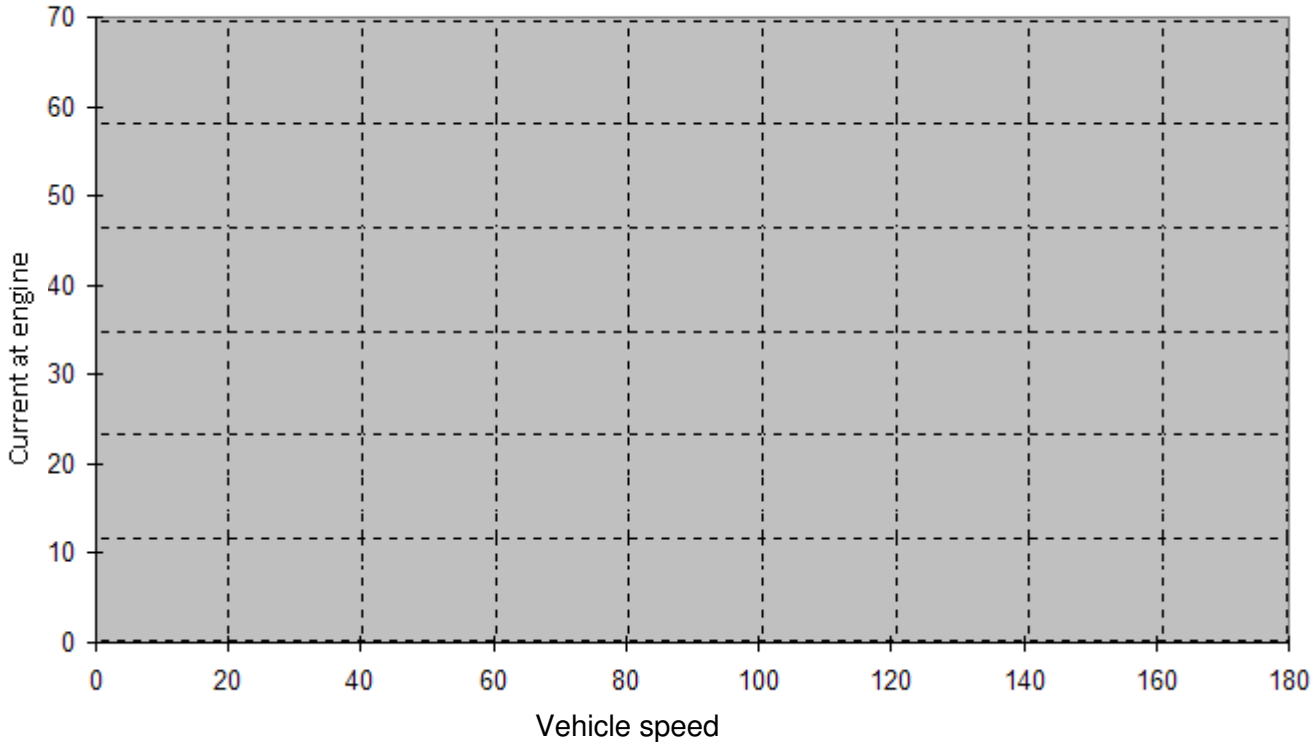
c) **What do you notice?**

.....
.....
.....
.....
.....
.....

d) **Complete the table below then plot the corresponding curve.**

Vehicle speed (km/h)	0	20	40	60	80	100	120	140	160	180
Current in A										

Current depending on vehicle speed



e) What do you notice?

……
……
……
……
……
……

f) What comment can you make about how the current changes as a function of torque?

……
……
……
……
……
……

2. Recording the signal produced by the torque sensor

By referring to the wiring diagram and the channel assignation table (in the resources file):
Identify the torque sensor by drawing a circle around it and then highlight:

- In green, the output signal from the torque sensor
- In red, the power supply
- In blue, its ground

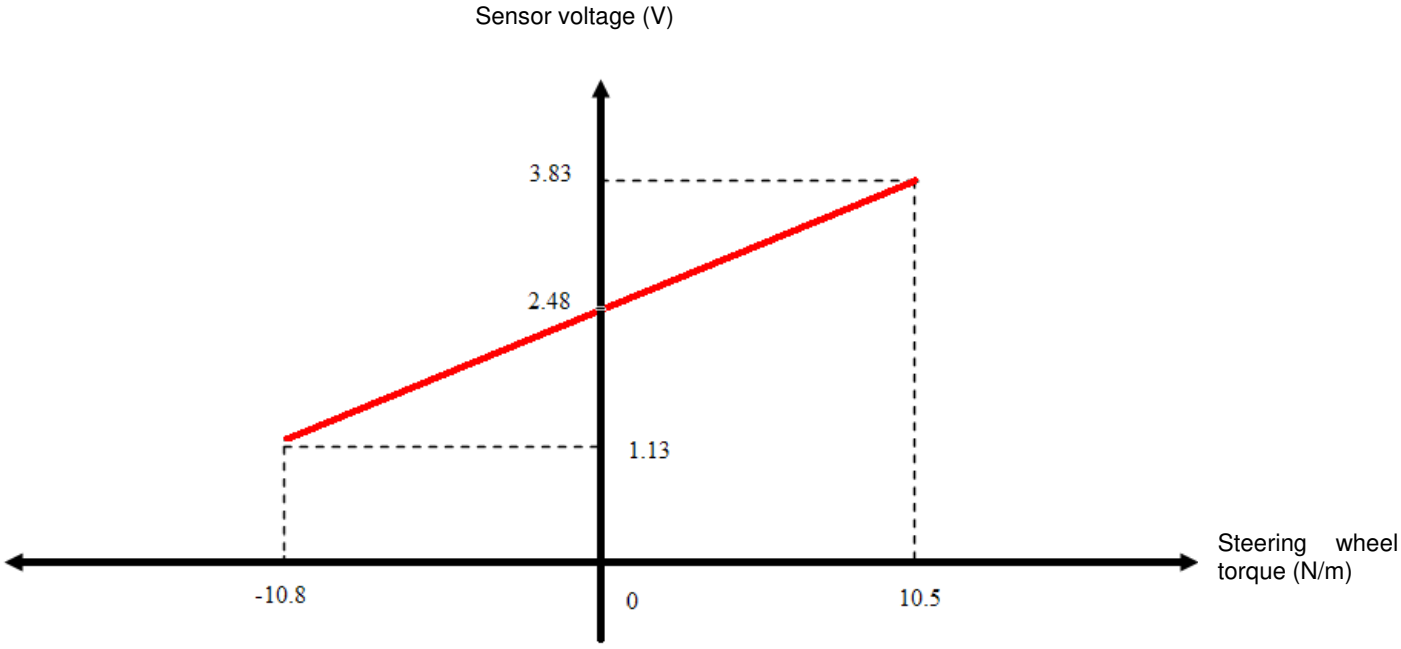
☞Call the trainer

Connect the multimeter to measure the signal.

3. Record from the model the output voltage from the torque sensor and its physical value shown on the display. Using this data, complete the table below.

Action performed on the EPS model	Sensor output voltage	Torque on steering wheel
Apply force to the steering wheel at its full right-lock position	**3.83**	**10.5**
Do not apply any force to the steering wheel	**2.48**	**0**
Apply force to the steering wheel at its full left-lock position	**1.13**	**-10.8**

Complete the graph below with the values recorded above.



What can you say about the operation of the torque sensor based on the data you recorded?

The plot is a straight line; this indicates that the sensor's output voltage is proportional to the torque applied to the steering wheel.
If no force is applied to the steering wheel, the output voltage is stable at 2.5 V; this voltage increases if you turn the steering wheel to the right and reduces if you turn it to the left.

3.2.4. Summary

Refer to page 27, PE No. 1

3.3. PRACTICAL EXERCISE No. 3

3.3.1. Meaning of the symbols

CAUTION! This symbol draws attention to an important point.

When you see this symbol, you must ask the trainer to watch or supervise in person the tasks indicated.

When you see this symbol, your response to the questions must involve highlighting with different colours or drawing.

When you see this symbol, you must complete a table or perform calculations.

Information: "the customer complains that the steering has become too stiff"

1. Identify the vehicle's characteristics

Make of vehicle	……	Registration No.	
Model	……	Engine power	
Date of first registration	……	Fuel used	
Serial No.	……		

Fuel level	Kilometrage	Audio system YES/NO	Date received for work
0 | 1/4 | 1/3 | 1/2 | 1	| | | | | |	| |	……

2. Describe the symptoms observed

- The diagnostic light for Power steering is lit
- The EPS system no longer delivers a comfortable driving experience

3. Study the diagrams needed for the diagnosis

Schematic diagram	Layout diagram	Summary of the system

4. Study the functioning of the circuit suspected to be at fault

Method

- Identify the elements on the diagram.
- Highlight the power supplies (in red) and the grounds (in black) for the electronic control unit
- Highlight in blue the information from any sensors
- Indicate (with a pencil) the current flow when the driver actuates the system.

☞Call the trainer

(Explain the operation of the circuit)

5. What do you think may have caused the malfunction (list all the possible causes)

- Torque sensor.
- Vehicle Speed Information.
- Temperature sensor on the EPS unit
- Speed sensors mounted on the gearbox.
- Management of the EPS control unit
- Interconnections with the injection & ignition and/or ABS control units

(Call the trainer

6. Use the equipment which assists in forming a diagnosis

Method:

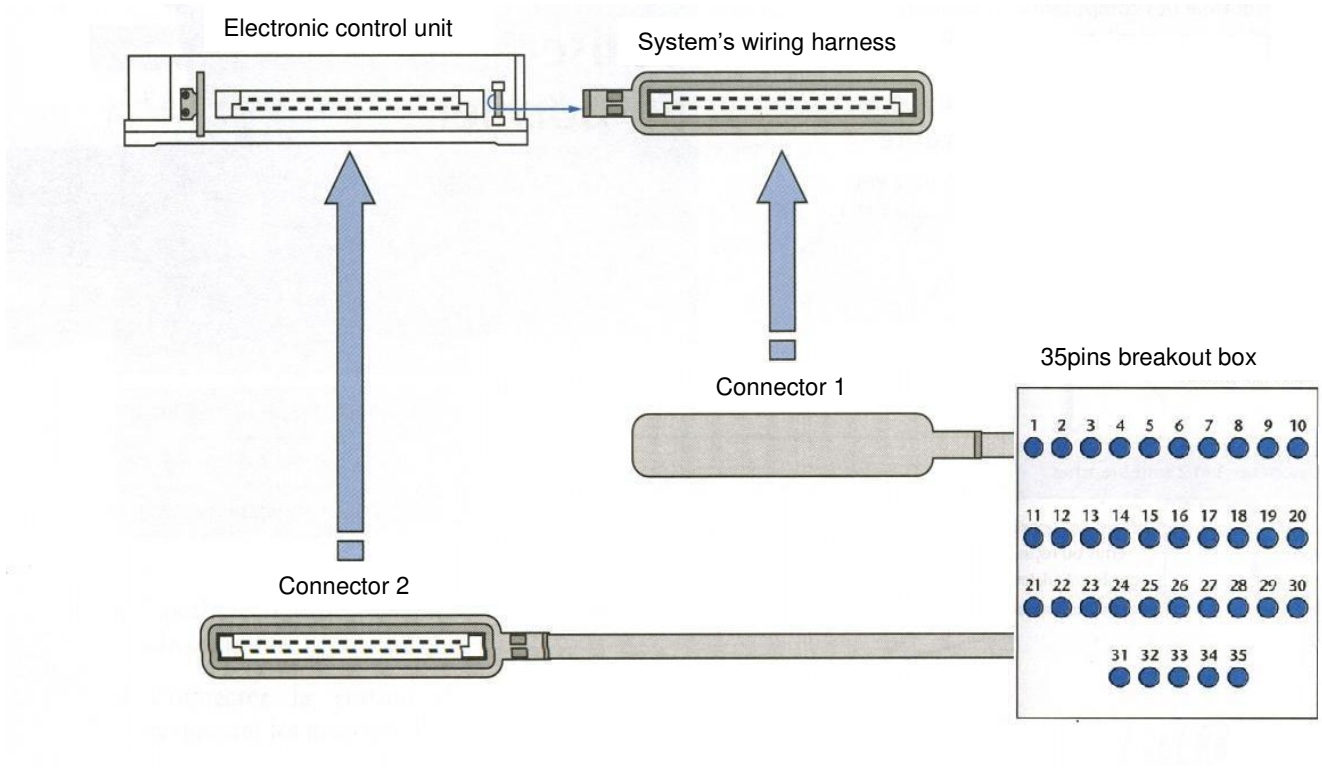
- Locate the vehicle's diagnostic connector
- Connect up the diagnostic station*
- Configure the station
- Follow the procedure specified for the diagnostic tool

7. Interrogate the control unit suspected of being at fault to check for any stored faults and interpret them

Fault code Ref.	Name of the Component or Circuit	Reading of the faults observed
CAN bus fault	Torque sensors	Torque sensor fault

(Call the trainer

8. Checking the elements suspected of being at fault



	TEST			CHECK	
Component to be checked	**Channel No. on terminal board**	**Measurement conditions, ignition key set to "On" or "Off"**	**Expected value**	**Recorded value**	**Ok/Not Ok**
Continuity 1 Power supply to torque sensor		Engine not running Ignition set to "Off"	Audible signal	signal	OK
Continuity 2 Torque sensor ground		Engine switched off Ignition set to "Off"	Audible signal	signal	OK
Continuity 3 Torque sensor signal		Engine switched off Ignition set to "Off"	Audible signal	No signal	Not OK

(Call the trainer

8. What maintenance operations should be performed to fix the system?

Repair or replace the cable loom connected to the power steering torque sensor (wire 6783 BA)

9. What is the point of clearing the faults? (tick the correct answer)

- ☐ There is no point
- ☐ To make the system work better
- ☐ To re-initialise the control unit

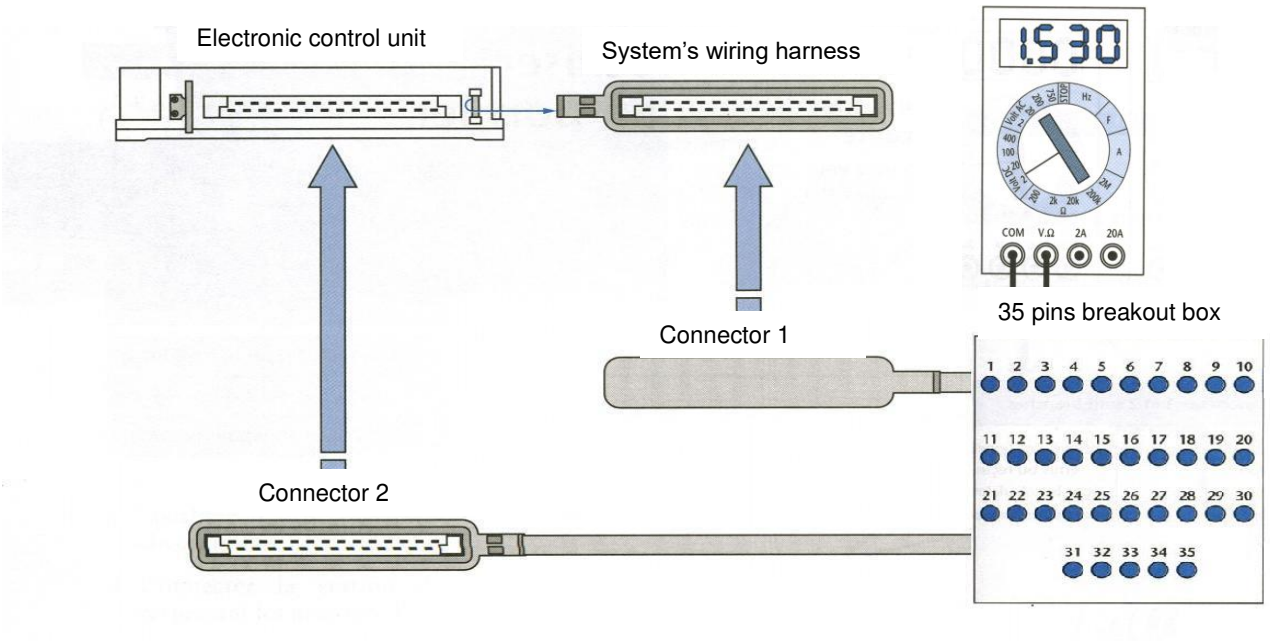
10. Report

Present and explain the work to the customer
Fault investigation Reading the diagnostics Repair/replacement of the torque sensor's cable harness Clearing of the faults

3.3.2. Summary

Using a Terminal Board

To confirm or complete the diagnostic performed by the checking tools, measurements should be made directly on the circuit which serves the defective components.



Using the terminal board, the various possible electrical checks are:

Connector 1 only is connected

Connectors 1 & 2 are connected

- Resistance of the components
- Continuity of the cable harness
- Power supply voltage of the components
- Recording of the signals transmitted or received by the control unit

CE DECLARATION OF CONFORMITY

By this declaration of conformity under the terms of Electromagnetic Compatibility Directive 2004/108/EC:

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

Declares that the following product:

Make	Model	Component
EXXOTEST	**MT-DAE**	**LEARNING MODEL: Electric Power Steering**

I - has been manufactured in accordance with the requirements of the following 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 complies with the requirements of standard:

- EN 61326-1:1997 + A1:1998 + A2:2001
  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 and electronic equipment
- Directive 2002/95/EC of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

Signed in Annecy, France, on 24 July 2007

Stéphane Sorlin, Chairman