Document No. 00309101-v1

User's guide for MT-BVR

BENCHTOP LEARNING MODEL: ROBOTIZED MANUAL GEARBOX

EXOTEST® EDUCATION

1. THE "SENSODRIVE" GEARBOX

The (*SensoDrive*) robotized manual gearbox combines the advantages of a traditional manual gearbox with those of an automatic gearbox. The driver can choose between two driving modes.

- "Automatic" mode provides an auto-adaptive transmission which uses a set of algorithms (known as "patterns") to optimize gear-shift management based on driving conditions and the driver's requirements.

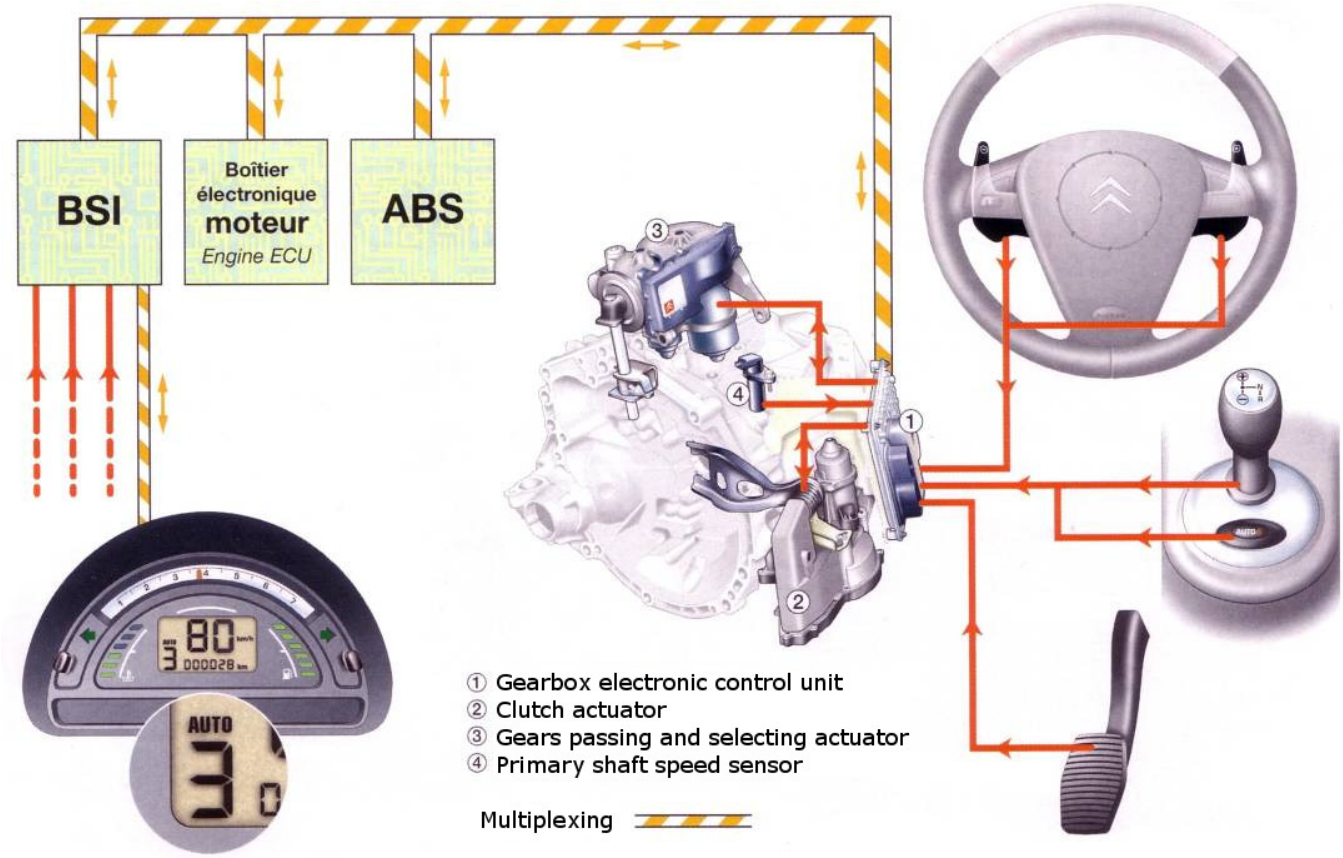
- "Manual" mode gives the driver the driving experience delivered by a conventional manual transmission, but without having to press the clutch.

Via a dedicated control unit and two electrical actuators (gear selection/gear change and clutch control) the robotized manual gearbox (RMG) controls the gearbox by mechanical means.

This electronic management of an automated mechanical system reduces fuel consumption compared to a conventional mechanical gearbox and enhances the driving experience. The add-on cost incurred by this system is less than the add-on cost of an automatic gearbox.

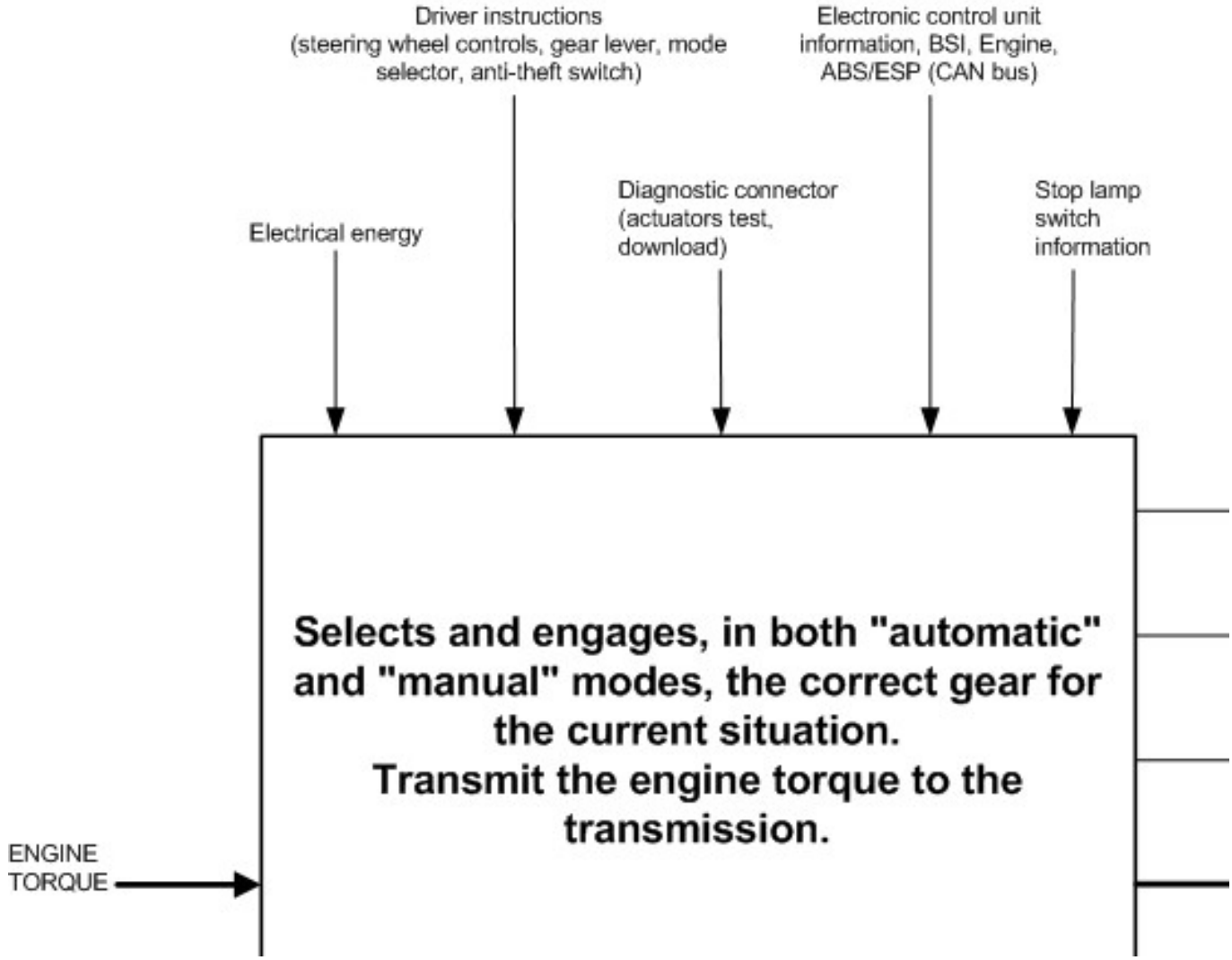
The robotized (or clutchless) manual gearbox is presented as an improvement on the conventional manual transmission system which eliminates some components - such as the clutch pedal and the mechanical link (e.g. mechanical gearstick and cable) with the gearbox. The driver can thus upshift and downshift with minimal effort from the driver.

The driver does not have to ease off the gas pedal when s/he wants to change gear. The engine speed is controlled by the ECU based on signals sent by the gearbox control unit.



1.1. GENERAL OPERATION

1.1.1. Level A-0



The general operation of the “SensoDrive” system is very similar to that of automatic gearboxes fitted with an epicyclic gear train and torque converter. However, the technology used is radically different. Indeed, the core of the system is a traditional manual gearbox coupled with a traditional clutch.

Advantages of a manual gearbox over an automatic gearbox:

- Better fuel efficiency.
- Lower production cost.
- Maintenance-free gearbox, lubricated for life.

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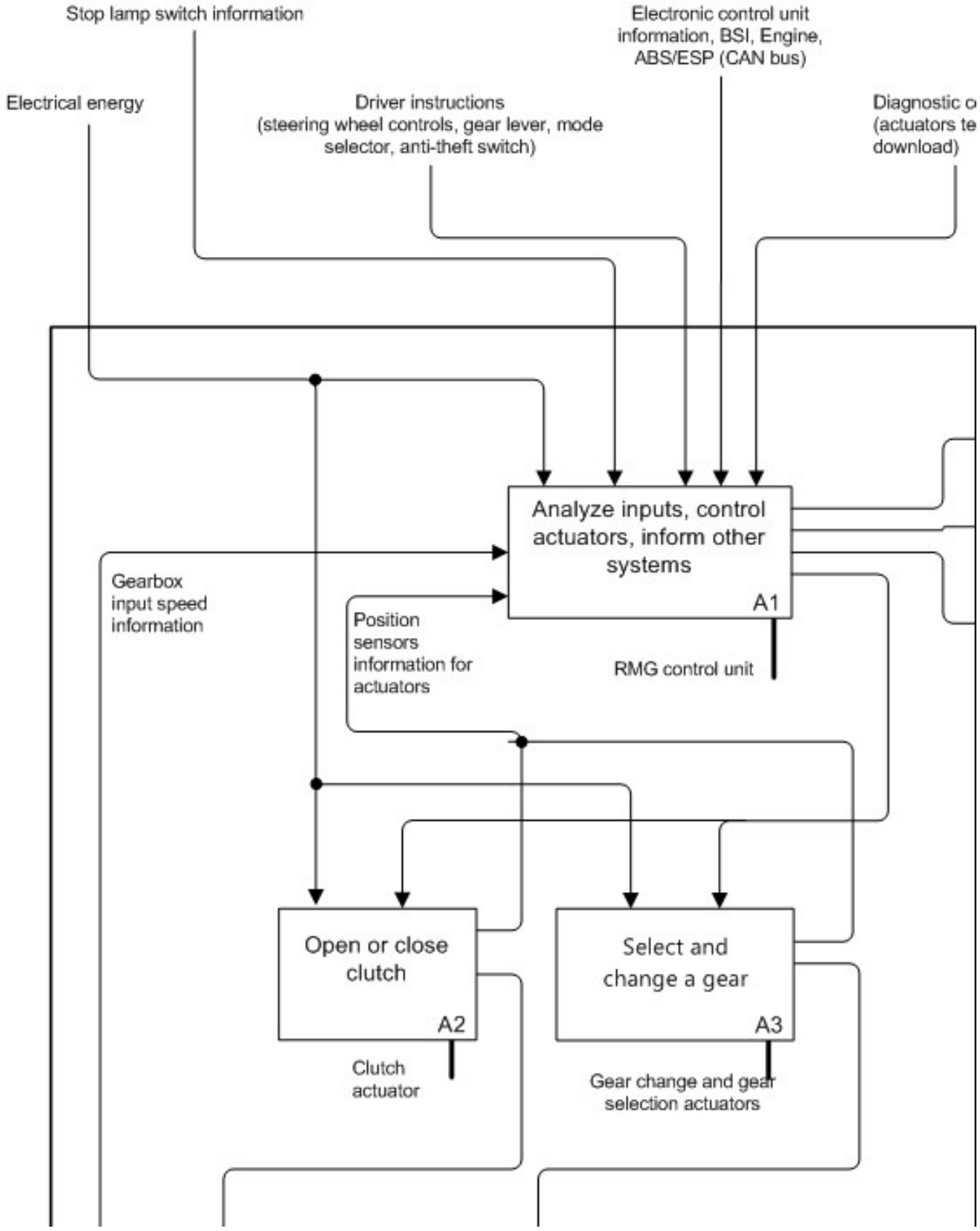
1.1.2. Level A0

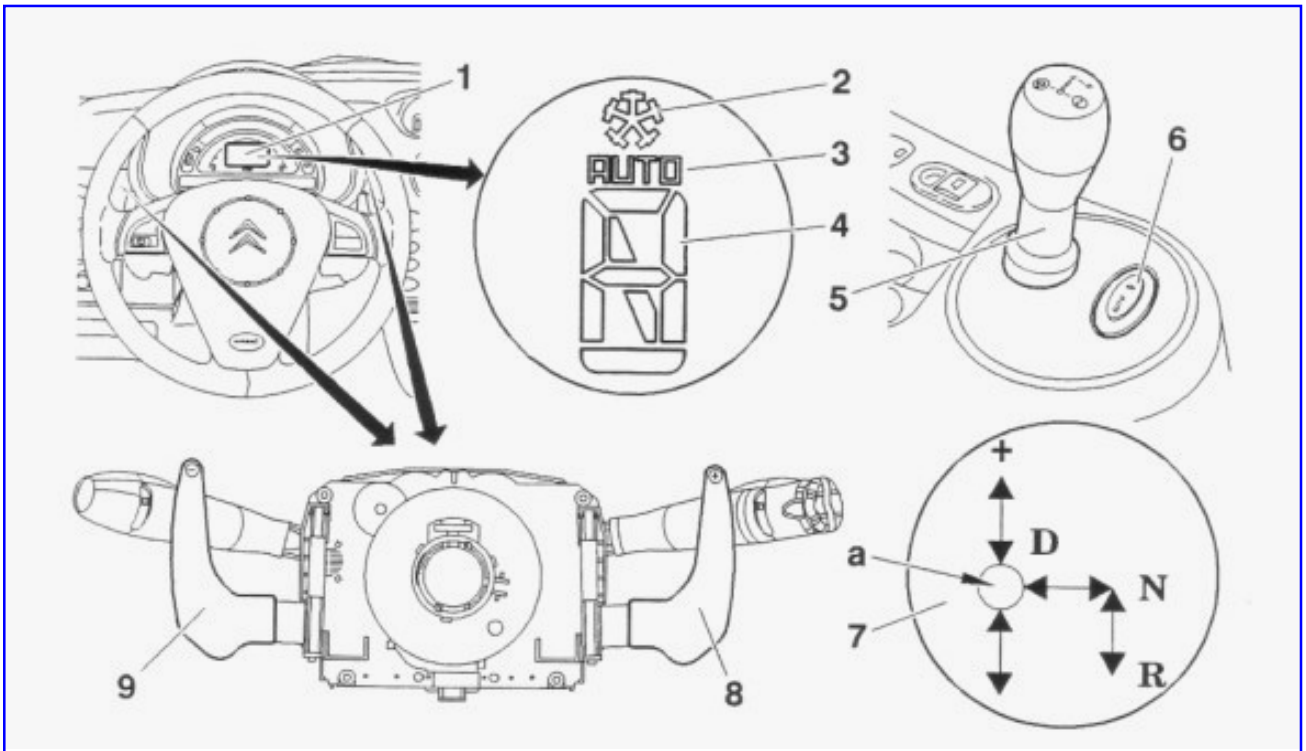

Stop lamp switch information
Electronic control unit information, BSI, Engine, ABS/ESP (CAN bus)
Electrical energy
Driver instructions (steering wheel controls, gear lever, mode selector, anti-theft switch)
Diagnostic c (actuators te download)
Analyze inputs, control actuators, inform other systems
A1
Gearbox input speed information
Position sensors information for actuators
RMG control unit
Open or close clutch
A2
Clutch actuator
Select and change a gear
A3
Gear change and gear selection actuators

1.2. SPECIFIC COMPONENTS

The SensoDrive gearbox differs from a traditional manual gearbox in the following respects:

- There is no mechanical link between the driver and the clutch: **no pedal or cable.**
- There is no mechanical link between the driver and the gearbox: **no gearshift linkage.**
- The driver must press the brake pedal when starting the engine.

The robotized manual gearbox (RMG) comprises the elements shown in the diagram below:



1. Instrument cluster
2. Snow mode indicator
3. Auto mode indicator
4. Alphanumeric gear indicator
5. Gear lever
6. Mode selector
7. Gear selection pictogram
8. Upshift gear control on right-hand side of steering wheel (+)
9. Downshift gear control on left-hand side of steering wheel (-)

1.2.1. Gear lever

The driver uses the gear lever to indicate when s/he wants to change gear. The driver changes up or down sequentially by pushing this lever forwards or back. The driver can also select neutral (N) and engage reverse gear (R).

Characteristics:

- The gear lever is an electrical rather than a mechanical device, and the movement required to achieve a gear shift is small.
- The gear lever will always return to the same stable position when released, i.e. its central position.
- Moving the lever to the (+) position engages a higher gear.
- Moving the lever to the (-) position changes down a gear.
- Moving the lever to the (N) position puts the engine in neutral.
- Moving the lever to the (R) position engages reverse gear.

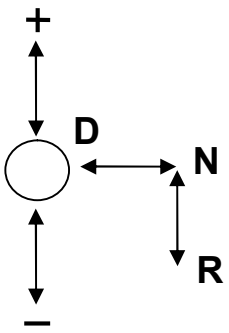
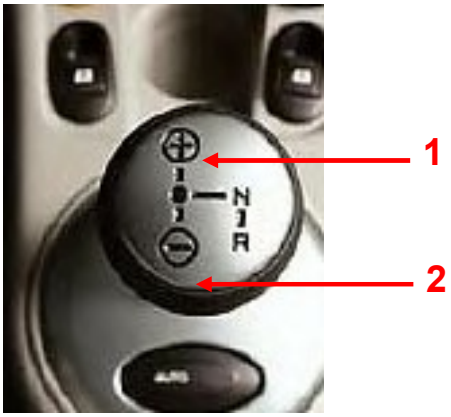


Illustration of the various possible gear lever positions



1. **Gear lever**
2. **Mode selector**

1.2.2. Mode selector

This stable fleeting contact “push” switch enables or disables automatic mode. It is back-lit and when it is pressed to select automatic mode the word "AUTO” is displayed on the instrument cluster.

The driver can switch from one mode to another simply by pressing this button. Pulling on one of the paddles or moving the gear lever forwards or back (+ or –) forces the mode to change to manual with the gearbox operating in the current gear (1, 2, 3, 4 or 5).

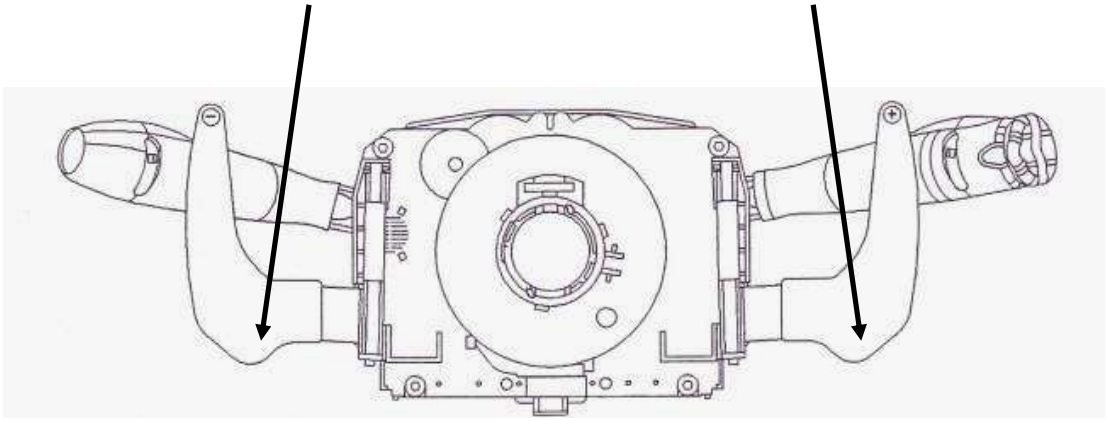
When the engine is started, the first mode is always automatic mode.

1.2.3. Gearshift controls behind the steering wheel (paddles)

The gearshift paddles are located behind the steering wheel. The driver does not have to take his or her hands off the wheel to change gear: this means the driver can drive more safely in emergency situations or when racing.

– gear control
Request a lower gear

+ gear control
Request a higher gear

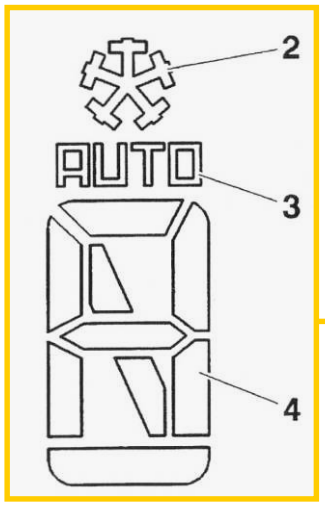


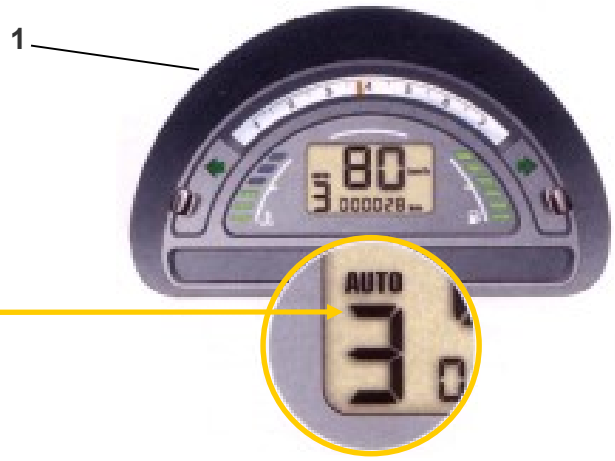
Characteristics of the paddles behind the steering wheel:

- The driver changes gear by pulling the paddle towards him/herself.
- The left-hand paddle (-) is used to change down a gear
- The right-hand paddle (+) is used to change up a gear
- The paddles are integrated into the control unit (switching module) behind the steering wheel, COM2000 (which has a conventionally-wired link with the RMG control unit)
- The paddles cannot be used to select neutral (N) or reverse (R).

1.2.4. Instrument cluster and display unit

The dashboard display cluster consists of a matrix of alphanumeric characters and standard pictograms:





1. Instrument cluster
2. Snow mode indicator
3. Auto mode indicator
4. Display of the selected gear

Unlike a traditional manual gearbox, the position of the gear lever does not indicate the selected gear; for this reason a dashboard display is provided which indicates the current gear whenever it is possible to change a gear.

The display indicates:

- The current mode:

AUTO for “automatic”, nothing for “manual” and the  symbol for “snow mode”.

- The gear selected: 1, 2, 3, 4, 5, N or R

The display switches on as soon as a door is opened and remains On when the Built-in Systems Interface switches to standby/sleep mode (since a gear can be engaged or disengaged even when the ignition key is not set to “On”).

1.3. OPERATION

1.3.1. Unlocking the central door locking, opening the driver's door

Opening the driver's door or unlocking the central door locking system triggers a rapid initialization of the gearbox actuators (clutch actuator, gear change and gear selection actuators). If no gear is selected (position N) the clutch is disengaged (open position). When the driver's door is opened, the instrument cluster switches on and indicates the selected gear and the current mode. Gears 1, 2, N and R may be engaged when the instrument cluster is On.

When the ignition key is set to "On", the gearbox mode systematically sets itself to "automatic".

1.3.2. Actuator initialization

The gearbox control unit must initialize the actuators (clutch actuator, gearbox actuators) in the following cases:

- Disconnection of the battery before the instrument cluster has switched off.
- Disconnection of the battery before the gearbox control unit has switched to standby/sleep mode (4 minutes after the instrument cluster has switched off).
- Any failure to learn information or if learnt information is not stored in the gearbox control unit.

When the ignition key is turned to start, with the brake pedal pressed (the conditions necessary for starting up the engine) the gearbox control unit initializes the clutch fork (fork movements) and initializes the position of the gear lever and paddles.

Caution: Starting the engine is inhibited while the system is running actuator position initialization operations.

The time needed to initialize the position of the actuators varies from 10 seconds to 1 minute.

1.3.3. Start-up safety features

The engine cannot be started unless the driver presses on the brake pedal. This requirement ensures that the driver is present before transmitting power to the road wheels, and prevents the vehicle from lurching forwards or back when a gear is engaged.

The engine can be started up with a gear engaged (1, 2 or R) so long as the brake pedal is pressed. The action of pressing the brake disengages the clutch. To move forwards (or back), the driver simply releases the brake pedal and presses on the gas pedal.

Pressing the brake pedal is also necessary to start-up the engine in neutral ("N" position).

1.3.4. Operation in automatic mode

Gear changes between 1st and 5th gear are performed automatically (with no driver input) The behavior of the gearbox control unit is linked to the the driver's driving style: from very calm to very sporty. If the gas pedal is fully depressed, the control unit immediately adopts "KD" (Kick-down) mode.

In Kick-down, the control unit delays the point at which the engine changes up, or drops down a gear if certain conditions apply.

Any driver input which is incompatible with the current engine speed or the vehicle's speed is ignored.

The driver can switch at any time to manual mode simply by pressing the mode select button or by using the gear lever or the paddles behind the steering wheel.

1.3.5. Operation in manual mode

The driver changes gear using the gear lever or the paddles behind the steering wheel.

First gear can only be engaged if the engine speed is close to idle. The brake pedal must be pressed and the vehicle must be stationary before reverse gear can be engaged. The paddles behind the steering wheel do not let the driver select neutral ("N") or reverse ("R"); the gear lever must be used.

The driver can skip a gear when changing up or down by pressing twice on the (+) or (-) controls. Between any two (+) or (-) gear shift commands, the gear lever must return to its central position or, if the paddles are used, the paddle must be released.

The driver can select automatic mode at any time, even when the vehicle is moving.

Any driver input which is incompatible with the current engine speed or the vehicle's speed is ignored.

1.3.6. Operation in "snow" mode

Snow mode is selected automatically whenever any wheel spinning or skidding is detected (ABS/ESP control unit information)

Whenever wheel spinning/skidding is detected, the gearbox control unit obliges the vehicle to start up in 2nd gear, and prohibits the selection of 1st gear. The interval between gear change points is larger than in the other modes, which ensures "a gentler ride" (no sudden variation in torque at the road wheels).

Snow mode is deselected as soon as wheel spinning/skidding is no longer detected.

1.3.7. Clutch protection functions

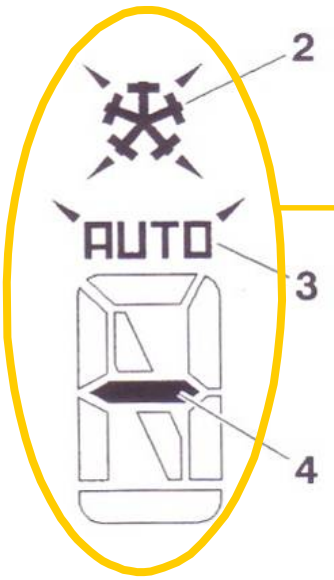
The gearbox control unit continuously estimates the temperature of the clutch's friction plate.

With the vehicle on an uphill slope, and with a gear engaged, the driver can hold the vehicle's position by pressing on the gas pedal. In this situation the clutch will gradually heat up.

If the clutch becomes too hot, the gearbox control unit initiates a series of clutch disengage-engage cycles which rocks the vehicle backwards and forwards to warn the driver of the clutch temperature issue. If no action is taken the engine will ultimately stall.

1.3.8. Fault indication

The simultaneously flashing of the "auto" and "snowflake" pictograms indicates a malfunction. Additionally, the alphanumeric display displays a single horizontal line.



2 Snowflake mode pictogram flashing
3 Automatic mode pictogram flashing
4 "-" shown on alphanumeric display

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1.4. GEARSHIFT PATTERNS

In each mode (automatic, manual, snow and degraded), the decision to change gear is made by the control unit based on a set of curves called “gearshift patterns”.

Each gearshift pattern consists of a number of gearshift thresholds (upshift and downshift), and “Kick down” points.

The gearbox’s operating point is defined by the throttle position, road speed and the load carried by the vehicle.

The control unit uses 9 gearshift patterns:

- 6 auto-adapting patterns (reference patterns),
- 1 pattern specific to the snow program,
- 1 warming-up pattern (for staring in cold conditions)
- 1 pattern specific to degraded modes

1.4.1. Auto-adapting patterns (reference patterns)

The control unit modifies the points at which it changes gear based on a number of factors: driving style, road characteristics (grip and gradient (or road profile)) and engine status (load, engine speed and temperature).

There are six auto-adapting patterns, called reference patterns, which are:

Driver patterns:

- **L1** – Economy pattern (fuel saving is prioritized),
- **L2** – Medium pattern (slightly more sporty than the economy pattern),
- **L3** – Sport pattern (racing-type driving),

Vehicle loading patterns:

- **L4** – Braking pattern 1 (pattern applicable to light vehicle loading and gentle gradients),
- **L5** – Braking pattern 2 (pattern for heavy vehicle loading and steep gradients),
- **L6** - Downhill pattern (pattern for downhill driving, using engine braking).

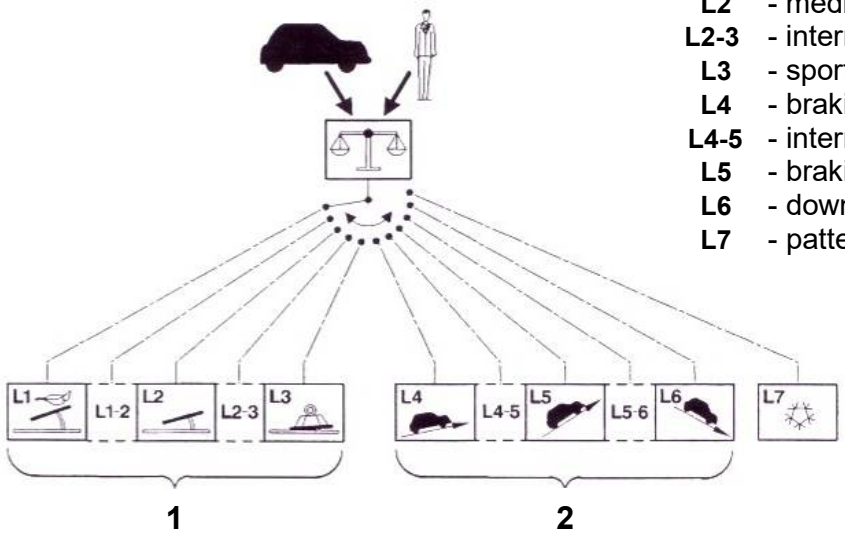
Patterns L1 to L7 (**L7** – is a pattern specific for the snow program) are stored in the control unit (reference patterns).

There are also a number of intermediate patterns (L1-2, L2-3, L4-5, L5-6) which are calculated dynamically by the gearbox control unit based on the reference patterns.

Consequently, to adapt the behavior of the gearbox to the driver’s inputs, the control unit chooses the most suitable reference pattern from the various “driver” and “vehicle loading” patterns. It then calculates, based on the selected reference pattern, the intermediate pattern which is best suited to all the current conditions.

This choice is made based on average values and on the last few minutes of operation. This choice may be corrected at any time: the control unit uses an infinite number of gearshift patterns.

1 - "driver" patterns
2 - "vehicle loading" patterns

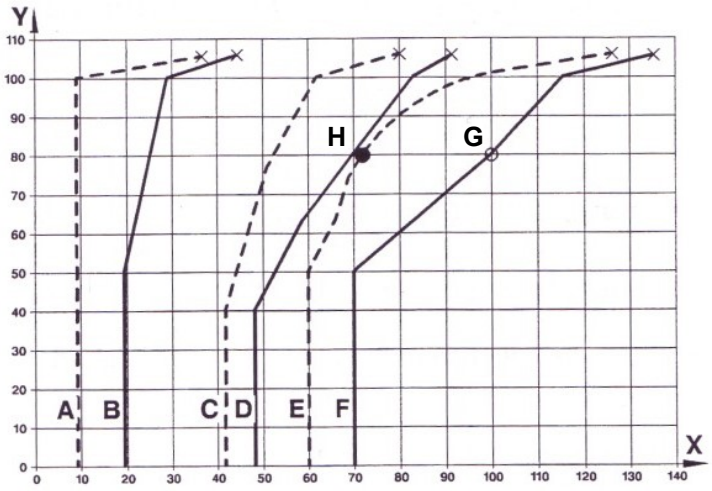


L1 - economy pattern
L1-2 - intermediate pattern (economy – medium)
L2 - medium
L2-3 - intermediate pattern (medium – sport)
L3 - sport pattern
L4 - braking pattern 1
L4-5 - intermediate pattern (braking 1 – braking 2)
L5 - braking pattern 2
L6 - downhill
L7 - pattern specific to snow mode

Examples of gearshift patterns.

X - vehicle speed (km/h)
Y - gas pedal position (as a % of fully depressed)
A - gearshift curve for 2nd gear to 1st
B - gearshift curve for 1st gear to 2nd
C - gearshift curve for 3rd gear to 2nd
D - gearshift curve for 2nd gear to 3rd
E - gearshift curve for 4th gear to 3rd
F - gearshift curve for 3rd gear to 4th

○ **G** - operating point in example **1**
● **H** - operating point in example **2**
× - kick-down point



Example 1 (vehicle accelerating)

- The gas pedal is pressed to 80% of full travel,
- The vehicle is in 3rd gear,
- The upshift occurs as soon as the vehicle reaches a speed of 100 km/h.

Example 2 (vehicle decelerating)

- The gas pedal is pressed to 80% of full travel,
- The vehicle is in 4th gear,
- The downshift occurs as soon as the vehicle's speed drops below 72 km/h.

1.4.2. Specific patterns

Warming-up pattern:

This pattern is activated when the engine is cold, and continues for a preset period of time, which varies as a function of the engine specification, and is then deactivated once this period of time has elapsed.

Snow pattern:

The ESP (Electronic Stability Program) control unit informs the gearbox control unit of any wheelspin. On reception of this information, the gearbox control unit automatically selects the “snow” pattern.

For vehicles fitted with ABS only, the ABS control unit tells the RMG control unit how fast each wheel is rotating. The RMG control unit identifies any wheel spinning or skidding based on these relative wheel speeds and selects the “snow” pattern if appropriate. As soon as the wheels stop spinning/skidding, the control unit re-selects the pattern which was active before the wheels span/skidded.

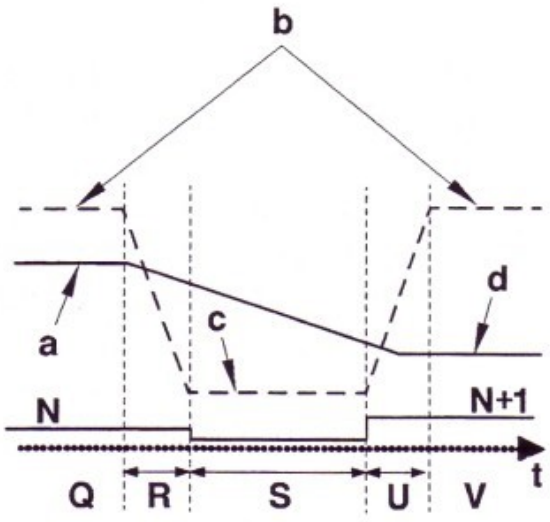
However, the “snow” pattern offers a number of special features:

- 1st gear cannot be selected (the vehicle starts in 2nd gear),
- the interval between gear change points is larger, which ensures a “more gentle” driving style (no sudden variation in torque at the wheels).
- “Kick down” does not trigger a downshift unless the vehicle speed is less than 15 km/h,
- when braking, downshifting is forced by the gearbox control unit.

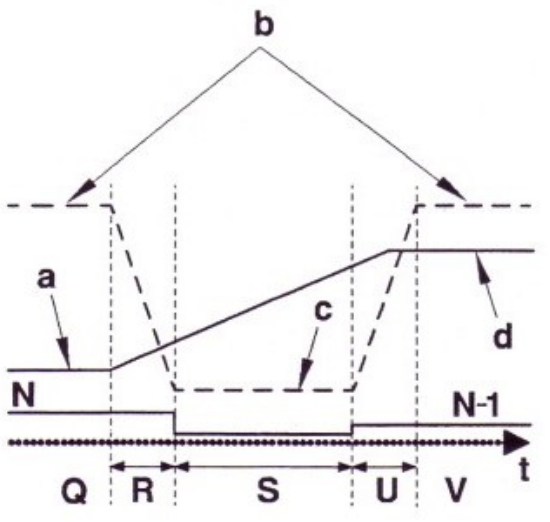
1.5. THE GEARSHIFT PROCESS

The phases in the gearshift process are identical in the two main operating modes (automatic and manual).

Downshift example, vehicle accelerating:



Upshift example:



- The driver may be aware of the change of gear process during the R, S and U phases.

The gearbox control unit sends the “changing gear” signal and “stop any change in air con compressor status” signal (to prevent any disruption occurring when changing gear). The clutch is engaged **(b)** and

the driver's input (indicated via the gas pedal) is ignored. The gearbox control unit sends the "gear engaged" signal to the built-in systems interface (BSI) so that the selected gear can be displayed on the instrument cluster.

*Disengaging clutch phase **(R)**:*

The gearbox control unit gradually disengages the clutch and sends the maximum torque value allowed by the gearbox to the ECU. The maximum torque which the gearbox can handle is continuously readjusted by the RMG control unit as a function of the degree of disengagement of the clutch. When it receives an instruction from the RMG control unit, the ECU reduces the engine torque until it reaches a value of 0 Nm at the end of the clutch disengaging phase.

*Engine speed regulation phase, controlled by the gearbox control unit **(S)**:*

To stop the engine speed racing (due to the clutch being disengaged **(c)**), the RMG control unit requests engine speed regulation and sends the setpoint engine speed value. During this phase, the RMG control unit controls the ECU using a setpoint engine speed value. The setpoint engine speed value is adjusted continuously so as to gradually obtain the speed which corresponds to the selected gear **(d)**. The RMG control unit sends an instruction to the gear change actuator.

*Engaging clutch phase **(U)**:*

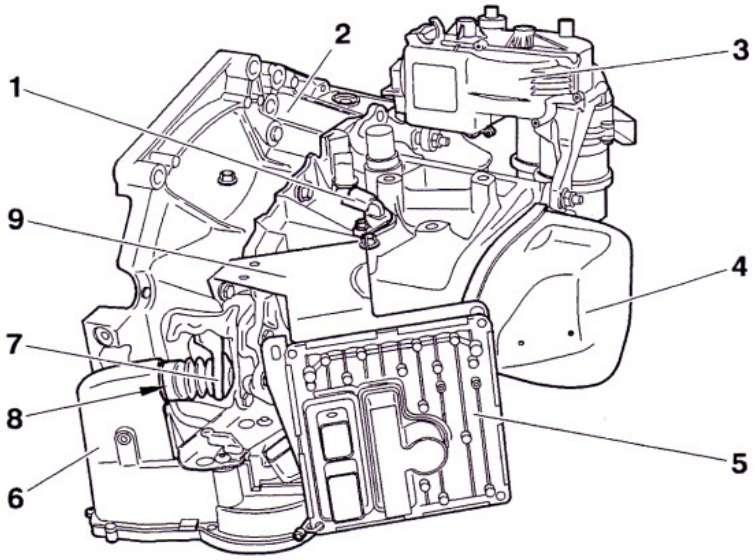
The gear change actuator has engaged the requested gear. The gearbox control unit orders a gradually engaging of the clutch and sends the maximum torque value allowed by the gearbox to the ECU. The maximum torque which the gearbox can handle is continuously readjusted by the RMG control unit as a function of the degree of engagement of the clutch. When it receives an instruction from the RMG control unit, the ECU gradually increases the engine torque until it reaches a torque value corresponding to the driver's input (indicated via the gas pedal). The engine speed is adjusted to the vehicle's road speed and to the gear engaged.

*End of gear changing **(V)**:*

The gearshift process has ended. The clutch is engaged and the driver's input (indicated via the gas pedal) is once again considered.

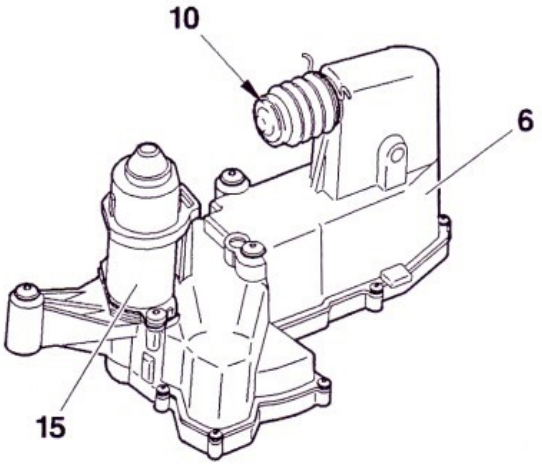
2. MECHANICAL COMPONENTS

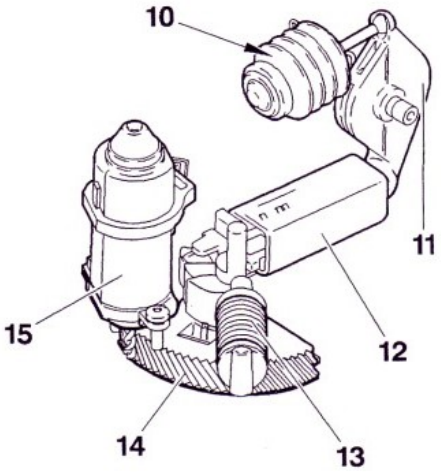
2.1. DESCRIPTION



1. **G**earbox input speed sensor
2. **C**lutch casing
3. **G**earbox actuator
4. **C**asing for 5th gear
5. **RMG** control unit
6. **C**lutch actuator
7. **C**lutch fork
8. **P**ush rod
9. **S**upport bracket for clutch actuator

2.2. CLUTCH ACTUATOR (1665)





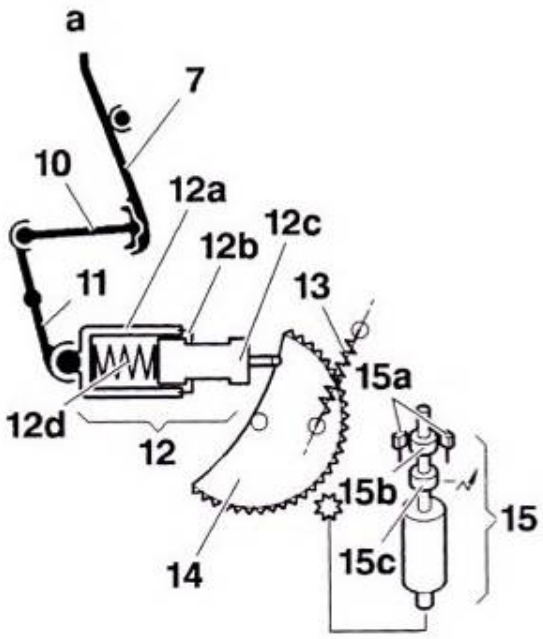
6. Clutch actuator
10. Push rod
11. Connecting link
12. Clutch wear compensation system
13. Force compensation spring
14. Toothed half-disk
15. Electric motor with two integrated position sensors

The clutch actuator engages and disengages the clutch. It is fitted with an automatic wear compensation device.

The gearbox control unit energizes the electric motor **(15)**. The energized electric motor then drives the toothed half-disk **(14)**. The rotation of the toothed half-disk immobilizes the wear compensation system (the system **(12b)** locks together parts **(12a)** and **(12c)**) and actuates the connecting link **(11)**. As a result of the movement of the linkage, the clutch fork **(7)** acts on the clutch release bearing and disengages the clutch. Note that when the toothed sector **(14)** approaches the end of its travel, the force compensation spring **(13)** assists the electric motor **(15)**.

Simplified diagram of the clutch actuator:

- **a.** Clutch release bearing
- **7.** Clutch fork
- **10.** Push rod
- **11.** Connecting rod
- **12.** Clutch wear compensation system
- **12a.** Sleeve
- **12b.** Locking system
- **12c.** Piston
- **12d.** Spring which applies force to the clutch release bearing
- **13.** Force compensation spring
- **14.** Toothed half-disk
- **15.** Electric motor
- **15a.** Position sensor (Hall-effect sensor)
- **15b.** Notched ring (magnetic field)
- **15c.** Electric motor's commutator

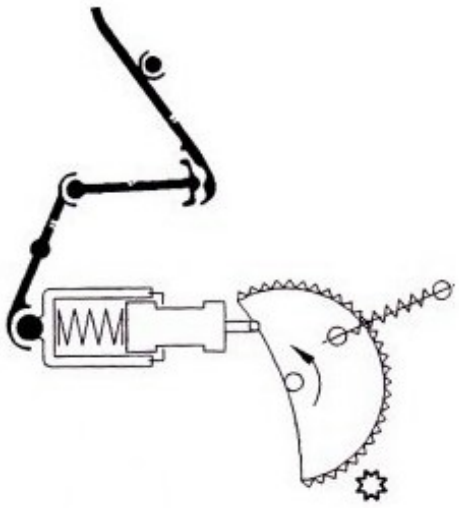


2.2.1. Operation

The clutch actuator obtains two stable mechanical positions:

- Clutch disengaged
- Clutch engaged

A. *Clutch disengaged*



*Description of the disengaging of the clutch **(A)**:*

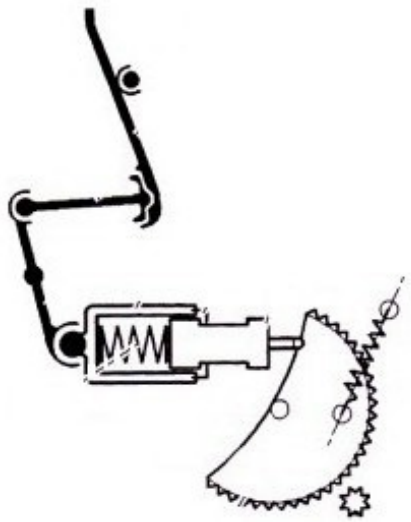
Once the clutch has disengaged, the power supply to the electric is switched off.

The clutch travel is always the same (about 20 mm), irrespective of the degree of clutch plate wear.

*Description of the engaging of the clutch **(B)**:*

The gearbox control unit reverses the polarity of the power supply to the electric motor **(15)**. The toothed half-disk is returned to its initial position. When the clutch is engaged (closed), the fork no longer exerts any force on the wear compensation system **(12)** which unlocks and can be compressed.

B. *Clutch engaged*



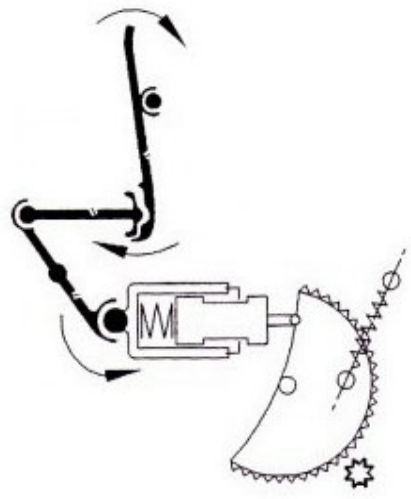
2.2.2. Clutch wear compensation system (C)

The wear compensation system locks systematically (when a disengage request is made) as soon as the toothed half-disk **(14)** is driven by the electric motor **(15)**. The wear compensation system unlocks during a clutch engaging phase. The spring **(12d)** exerts a force on the clutch release bearing. Clutch wear is taken up by the compression of the wear compensation system **(12)**.

When the clutch disk wears, the clutch mechanism acts on the fork **(7)** and on the push rod **(10)**. The clutch fork pushes on the push rod and the spring **(12d)** compresses. In this case, the compensation system shortens.

The wear compensation system is at its longest when the clutch is new and at its shortest when the clutch is worn.

C. *Clutch wear compensation*



2.2.3. Specific features of the control of the electric motor

The clutch actuator is controlled directly by the RMG control unit. The driver module within the RMG control unit which provides this function:

- powers the electric motor, and can reverse the polarity to change the direction of rotation,
- can vary the speed of rotation of the electric motor,
- measures the electric current drawn by the electric motor.

Two position sensors integrated into the electric motor provide the gearbox control unit with information about:

- the displacement of the clutch fork,
- the speed of displacement of the clutch fork.

To enable it to operate, the gearbox control unit must store information about:

- the clutch fork's total travel,
- the clutch's bite point.

The data is stored on completion of a learning procedure activated by a diagnostic tool.

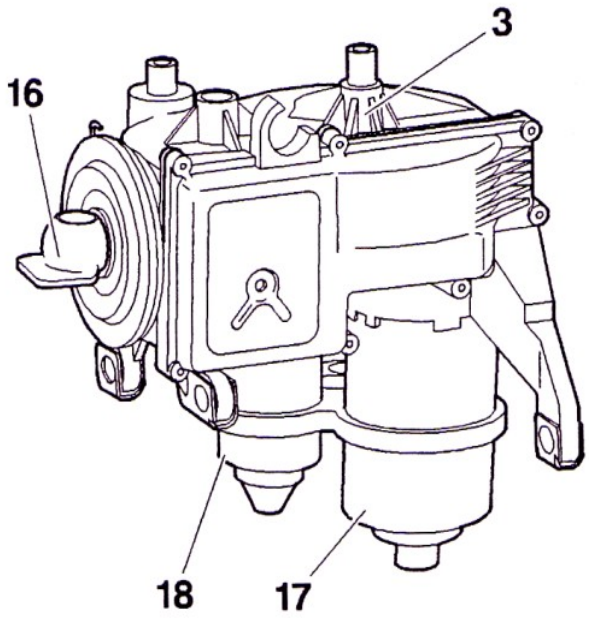
2.3. GEARBOX ACTUATOR (1663, 1664)

The gearbox actuator engages each gear by making a gearshift arm perform a combination of translational and rotational movements.

To generate these movements, the gearbox actuator is equipped with:

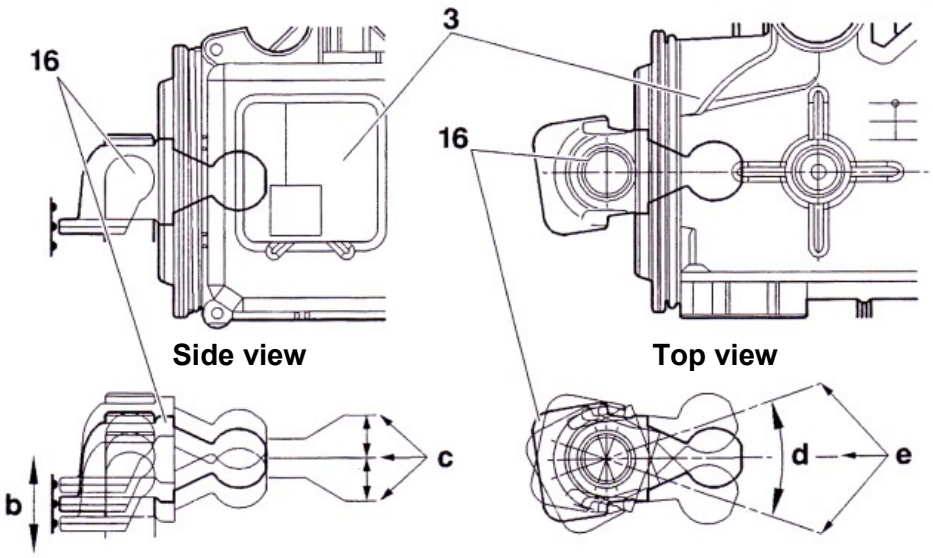
- two electric motors with integrated position sensors,
- a reduction gearing and cranks,

3. Gearbox actuator
16. Gearshift arm
17. Electric motor powering the gear change actuator (1663)
18. Electric motor powering the gear selection actuator (1664)



2.3.1. Operation

The gearbox actuator is in fact a system which comprises two actuators: a gear change actuator and a gear selection actuator. To control each of these actuators, the gearbox control unit uses two position sensors **(15a)**. These sensors are the same type as those fitted to the clutch actuator's electric motor and are mounted such that they face a magnetic notched ring on the electric motor's rotor. They supply a square-wave signal to the gearbox control unit when the electric motor rotates.



3. Gearbox actuator
16. Gearshift arm on gearbox
b. Axis of movement (spindle) for the gearshift arm (selection)
c. The three positions of the gearshift arm are about 5 to 7 mm apart
d. Angle of rotation of the gearshift arm
e. The three angular positions of the gearshift arm are about 17° to 20° apart.

To engage a gear, the gear selection actuator raises or lowers the gearshift arm along the gear selection spindle (**b**, gear selection phase). The gear change actuator then rotates the gearshift arm on its spindle (**d**, gear change phase). The electric motors never operate simultaneously.

The gearbox control unit's driver module:

- controls the operation of the electric motor (in both directions of rotation),
- can vary the speed of rotation of the electric motor,
- measures the electric current drawn by the electric motor.

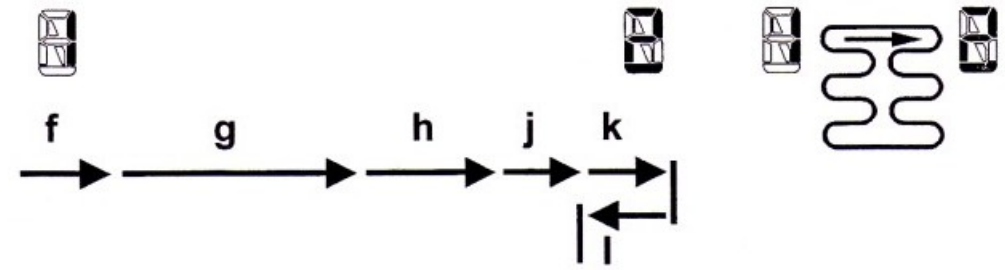
Two position sensors integrated into the electric motor provide the RMG control unit with information about:

- the displacement of the gearshift arm,
- the speed of displacement of the gearshift arm.

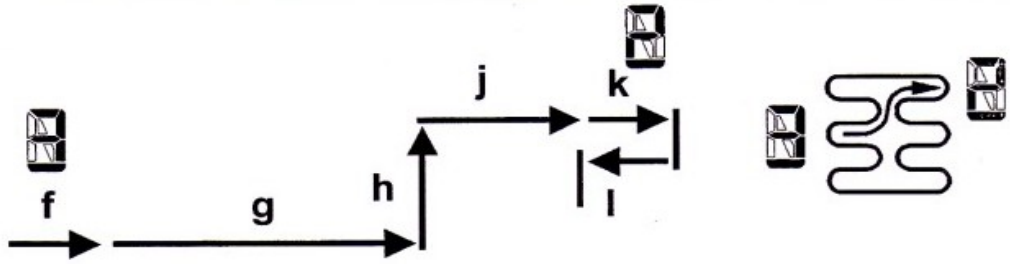
Each gear change involves a number of phases:

Depending on the phase in the gearshift process, the control unit controls the gearbox actuator differently:

From 1st gear to 2nd

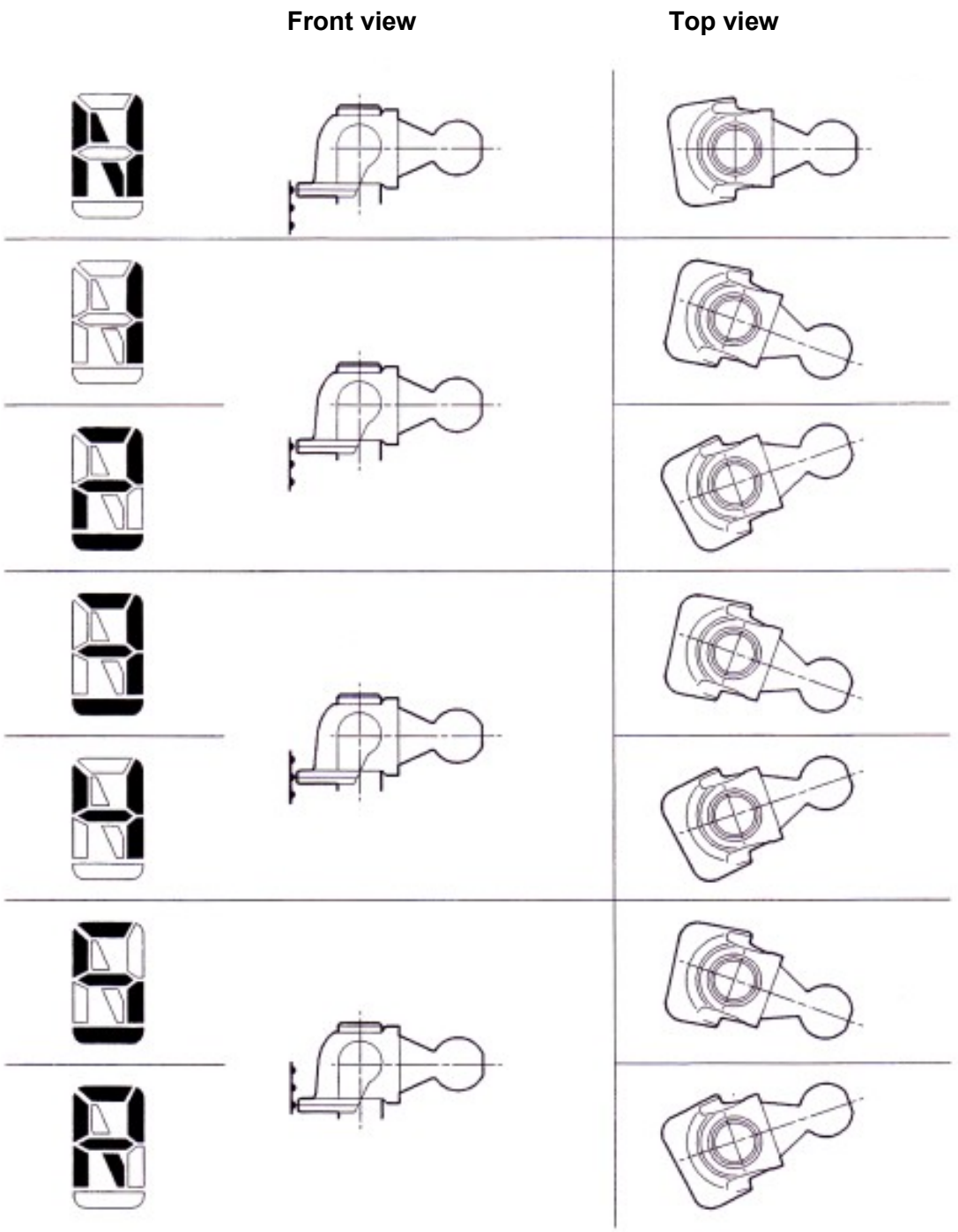


From 3rd gear to 2nd



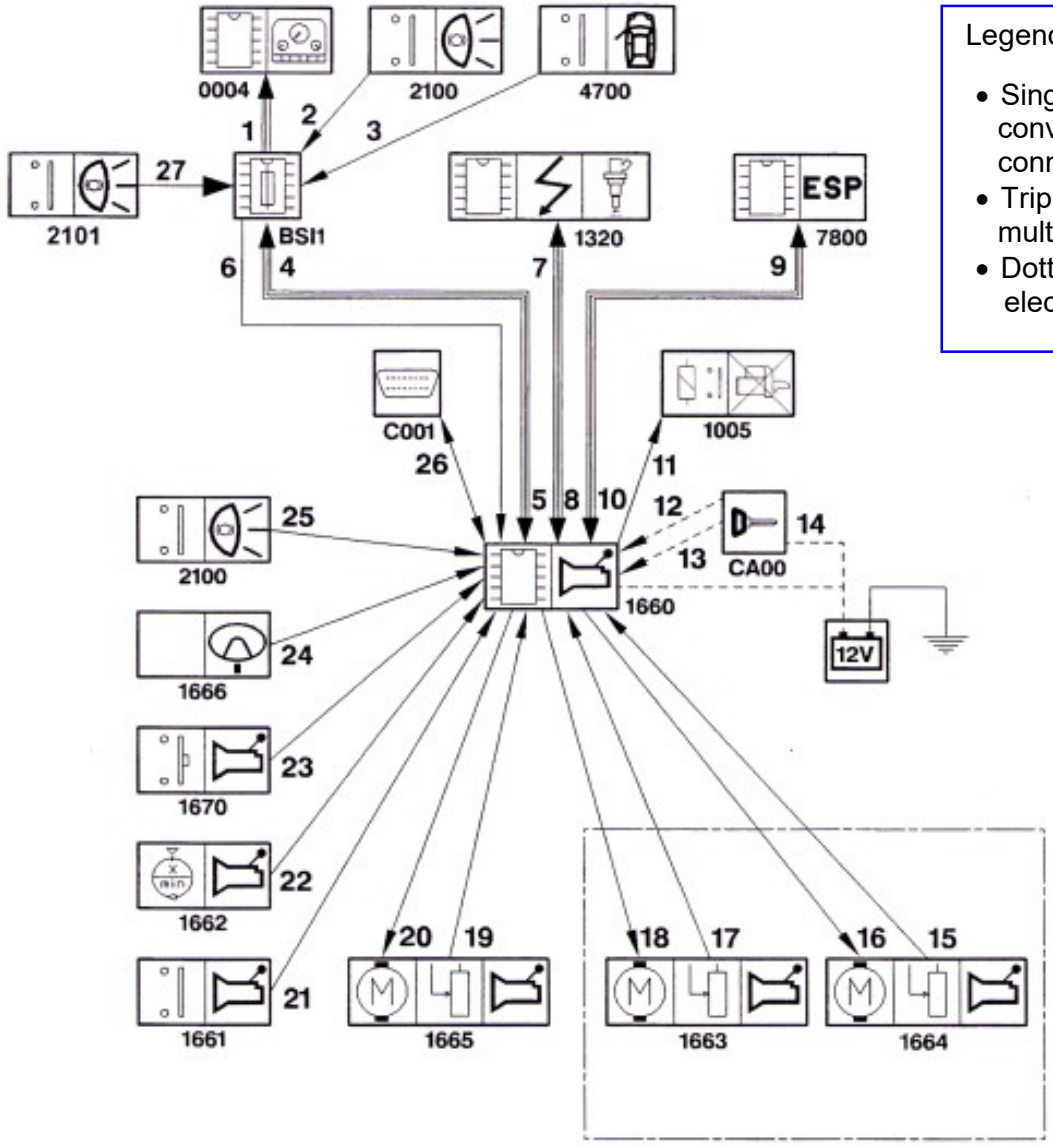
PHASE	ACTION
f	Preloading
g	Disengaging the gear
h	Synchronization
j	Engaging the gear
k	Engaging the gear (the purpose of phase **(k)** is to confirm the engagement action)
l	Draw back (the purpose of phase **(l)** is to avoid excessively wearing the gear teeth)

2.3.2. Position of the gearshift arm for each engaged gear



3. ELECTRICAL COMPONENTS

3.1. BLOCK DIAGRAM



Legend:

- Single-line arrow: conventionally-wired connection
- Triple-line arrow: multiplexed connection
- Dotted-line arrow: electrical power supply

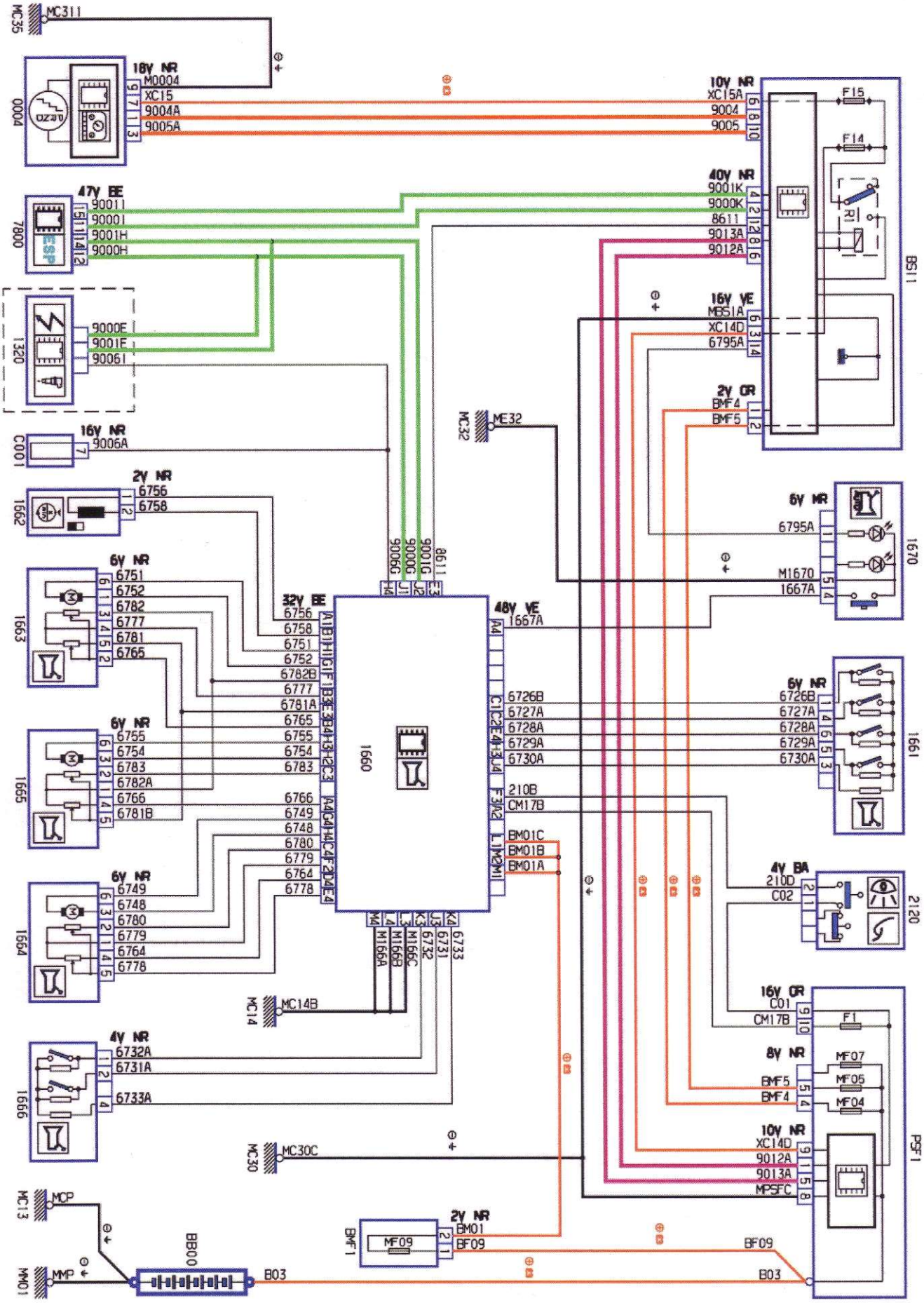
COMPONENT REF.	DESIGNATION
CA00	Anti-theft switch
C001	Diagnostics connector
BSI	Built-in Systems Interface
0004	Instrument cluster display
1005	Starter inhibitor relay
1320	Petrol injection control unit

COMPONENT REF.	DESIGNATION
1660	Gearbox (RMG) control unit
1661	Gear lever
1662	Gearbox input speed sensor
1663	Gear change actuator
1664	Gear selection actuator
1664, 1663	Gearbox actuator
1665	Clutch actuator
1666	Paddles behind the steering wheel
1670	Mode selector
2100	Stop lamp switch (“make” or normally-open contact)
2101	Stop lamp switch (“break” or normally-closed contact)
4700	Door lock switch
7800	ESP or ABS control unit

LINK No.	SIGNAL	NATURE OF THE SIGNAL
1	Selected mode information (automatic or manual) Gearbox fault information/Engaged gear information	VAN
2	Foot brake information (“break” or “normally-closed” type stop lamp switch)	Conv. wired
3	Open driver’s door information	Conv. wired
4	Gear engaged information Selected mode fault information (automatic or manual) Gearbox fault information	CAN
5	Foot brake switch fault information	CAN
6	Wake-up for gearbox control unit	Conv. wired
7	Request engine speed regulation information Engine speed setpoint information Request to reduce torque information/Gear engaged information Maximum torque permitted by gearbox information Prohibition on changing A/C compressor status information	CAN
8	Engine torque information/Engine speed information Engine coolant temperature information Throttle position information/Idle speed regulation instruction information Torque requested by driver information Actual engine torque information/Resisting torque information	CAN

LINK No.	SIGNAL	NATURE OF THE SIGNAL
9	Gear change underway information	CAN
10	Vehicle speed information/ABS or ESP regulation underway information Gear change authorization information ESP or ABS control unit fault information	CAN
11	Control of the starter inhibitor relay	Conv. wired
12	+DEM (start) power supply	Conv. wired
13	+ after ignition to “On” power supply	Conv. wired
14	+ 12 V power supply	Conv. wired
15	Gear selection actuator position	Conv. wired
16	Gear selection actuator control	Conv. wired
17	Gear change actuator position	Conv. wired
18	Gear change actuator control	Conv. wired
19	Clutch actuator position	Conv. wired
20	Clutch actuator control	Conv. wired
21	Gear lever position	Conv. wired
22	Gearbox input speed/RMG input speed sensor	Conv. wired
23	Manual/automatic mode	Conv. wired
24	Position of gear control behind steering wheel	Conv. wired
25	Braking information (“make” or normally-open type stop lamp switch)	Conv. wired
26	Reading faults /Reading parameters/Actuator test/Downloading	Conv, wired (diagnostics line)
27	Redundant brake information	Conv. wired

3.2. WIRING DIAGRAM



3.3. GEARBOX CONTROL UNIT

To change gear, the gearbox control unit electrically controls the actuators (clutch actuator, gearbox actuator). It manages the gear changes and the auto-adaptation of the modes (manual and automatic). The control unit also stores the (learned) actuator characteristics and sends information to the instrument cluster. It dialogs with the other control units via the CAN network, runs auto-diagnostics and can operate in emergency modes (whereby vehicle mobility is prioritized).

The control unit acquires information from the following devices:

- mode selector,
- gear lever,
- gear change controls (paddles) behind the steering wheel,
- stop lamp switch,
- clutch actuator position sensors,
- gear selection actuator position sensors,
- gear change actuator position sensors,
- gearbox input speed sensor.

The gearbox control unit **(1660)** dialogs on the CAN with the ECU **(1320)**, the ESP or ABS control unit **(7800)** and the built-in systems interface **(BSI1)**.

As a result of the dialog between the gearbox control unit and the ECU, gear changes can take place without the driver having to release pressure on the gas pedal (in both manual and automatic modes). It also reduces the torque during the gearshift and thus enhances the mechanical protection of the engine and gearbox. This link between the control units enhances the control of engine speed during gearshifts and improves the driving experience.

The gearbox control unit utilizes all the information available to control the starter inhibitor relay, the clutch actuator and the gearbox actuator.

The actuators are controlled by the gearbox control unit via driver modules integrated into this control unit.

3.3.1. Characteristics and assignation of the connectors

The gearbox control unit has a blue 32-channel connector and a green 48-channel connector.

Updates for the control unit’s software can be downloaded.

Channel assignation for the green 48-channel connector

Channel No.	Assignation
A1 – B1	(not used)
C1	**Input:** A1 signal, gear lever
D1 – H1	(not used)
J1	Dialog line: CAN H network
K1	(not used)
L1	Permanent + 12V **power supply**
M1	Permanent + 12V V **power supply**
A2	+APC information
B2	(not used)
C2	**Input:** A2 signal, gear lever
D2 – H2	(not used)
J2	Dialog line: CAN L network
K2 – L2	(not used)
M2	**Permanent** + 12V power supply
A3	(not used)
B3	**Output:** starter inhibitor relay
C3 – D3	(not used)
E3	**Input:** driver's door open information
F3	**Input:** stop lamp switch
G3	(not used)
H3	**Input:** A4 signal, gear lever
J3	**Input:** gear control on left-hand side of steering wheel
K3	**Input:** gear control on right-hand side of steering wheel
L3	**Ground** for power supplies
M3	(not used)
A4	**Input:** mode selector information
B4 – C4	(not used)
D4	**Input:** +DEM (start)
E4	**Input:** A3 signal, gear selector
F4 – G4	(not used)
H4	Line K diagnostics
J4	**Ground:** gear lever
K4	**Ground:** gear controls behind steering wheel
L4	**Ground** for power supplies
M4	**Ground** for power supplies

Channel assignation for the blue 32-channel connector

Channel No.	Assignation
A1	**Input:** gearbox input speed sensor (+)
B1	**Input:** gearbox input speed sensor (-)
C1 – E1	(not used)
F1	**Ground:** clutch actuator sensor – gear change actuator
G1	**Output:** gear change actuator motor (-)
H1	**Output:** gear change actuator motor (+)
A2 – E2	(not used)
F2	**Ground:** gear selection actuator sensor
G2	(not used)
H2	**Output:** clutch motor control (+)
A3	(not used)
B3	**Input:** gear change motor position sensor
C3	**Input:** clutch motor position sensor
D3	(not used)
E3	+5V **power supply** – clutch actuator position sensor – gear change actuator
F3 – G3	(not used)
H3	**Output:** clutch motor control (-)
A4	**Input:** clutch actuator position switch
B4	**Input:** gear change actuator position sensor
C4	**Input:** gear selection actuator position sensor
D4	**Input:** gear selection actuator position sensor
E4	+5V **power supply** – gear selection actuator position sensor
F4	(not used)
G4	**Output:** gear selection actuator motor control (-)
H4	**Output:** gear selection actuator motor control (+)

The gearbox control unit is mounted on the clutch actuator support bracket.

3.4. CONTROL UNIT-RELATED ELEMENTS

3.4.1. Battery (BB00)

The battery's level of charge needs to be at the correct level to ensure the correct operation of the robotized manual gearbox. The control unit records a fault when the battery voltage drops below 8 V, or rises above 16 V.

3.4.2. Starter inhibitor relay (1005)

The starter inhibitor relay lets the gearbox control unit prevent the operation of the starter motor.

The RMG control unit controls this relay (to let the starter operate) if the ignition is set to the +DEM (start) position when the position of the actuators is compatible with starting the engine, and when the driver presses on the brake pedal.

The starter inhibitor relay is mounted in front of the front, left-hand wheel arch (behind the left-hand headlight).

Characteristics of the relay:

Control: gearbox control unit
Type: binary (on-off) control, using the ground
Connector: 9 black channels
Connector channel assignation:

Channel No.	Assignation
1	(not used)
2	**Output:** starter power supply
3	(not used)
4	+ 12 V **power supply** (fuse box module)
5	+DEM (starter) **power supply**
6	(not used)
7	(not used)
8	(not used)
9	Gearbox control unit **ground**

3.4.3. RMG input speed sensor

This sensor provides the RMG control unit with information about the speed of the gearbox input shaft. This information lets the control unit determine the clutch slippage (i.e. the difference between the engine speed and the rotational speed of the input shaft), and the clutch's bite point. It is also used in the control of the clutch actuator and of the timing of the end of synchronization of a gear.

The sensor consists of a magnetic core and a winding. The information supplied to the RMG control unit is an a.c. voltage whose frequeny varies as a function of the rotational speed of the gearbox input shaft.

Characteristics of the gearbox input sensor:

Resistance between channels 1 and 2: approximately 800 ohms

Signal emitted: an a.c. voltage of variable frequency

Channel assignation for the 2-channel connector:

CHANNEL No.	DESIGNATION
1	Positive signal
2	Negative signal

The gearbox input speed sensor is mounted such that it faces the teeth of the second-gear gearwheel on the input shaft

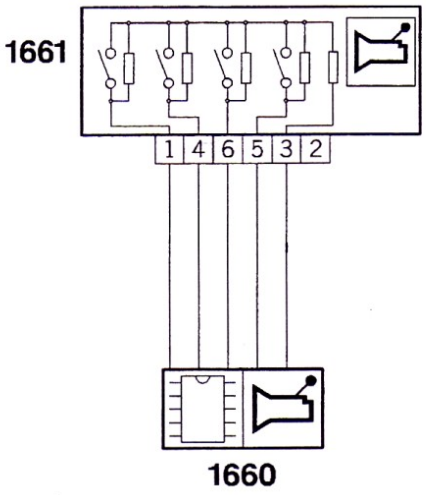
3.4.4. Gear lever

The RMG control unit receives information about the position of the gear lever via four conventionally-wired signals.

The control unit supplies the lever with power and checks the validity of the information received by ensuring that the signals are consistent with each other (diagnostics).

1661 – gear lever

1660 – gearbox control unit



Channel assignation for the 6-channel connector:

CHANNEL No.	DESIGNATION
1	A1 signal
2	(not used)
3	Electronic ground
4	A2 signal
5	A4 signal
6	A3 signal

Moving the gear lever to a new position changes the state of one or more signals.

Gear lever position	Voltage between channel 3 and channel 1 Max./min.	Voltage between channel 3 and channel 4 Max./min.	Voltage between channel 3 and channel 6 Max./min.	Voltage between channel 3 and channel 5 Max./min.
Central	4.1V / 2.4V	4.1V / 2.4V	4.1V / 2.4V	4.1V / 2.4V
+	2.4V / 0.6V	2.4V / 0.6V	4.1V / 2.4V	4.1V / 2.4V
-	2.4V / 0.6V	4.1V / 2.4V	2.4V / 0.6V	4.1V / 2.4V
N	2.4V / 0.6V	4.1V / 2.4V	4.1V / 2.4V	2.4V / 0.6V
R	4.1V / 2.4V	4.1V / 2.4V	2.4V / 0.6V	2.4V / 0.6V

3.4.5. Gear control paddles behind the steering wheel

The RMG control unit receives information about the position of the gear control paddles behind the steering wheel via two conventionally-wired links.

The paddles are mounted on the switching module behind the steering wheel **(COM2000)**.

Characteristics:

Power supply: RMG control unit.

Channel assignation for the four-channel connector:

Channel No.	Assignation
1	Signal, **-** control
2	Signal, **+** control
3	(not used)
4	Electronic ground

The control unit checks the validity of the information received by checking that the signals are consistent with each other (diagnostic function).

Every time a paddle is actuated, the state of one or more signals is changed:

Paddle position		Voltage between ground and channel 2 Max./min.	Voltage between ground and channel 1 Max./min.
+ control released	**–** control released	4.1V / 2.4V	4.1V / 2.4V
+ control released	**–** control activated	2.4V / 0.6V	4.1V / 2.4V
+ control activated	**–** control released	4.1V / 2.4V	2.4V / 0.6V
+ control activated	**–** control activated	2.4V / 0.6V	2.4V / 0.6V

3.4.6. Mode selector

When the engine's ignition switch is switched to "On", the gearbox systematically sets itself to "automatic" mode. The mode selector transmits the driver's choice to the RMG control unit. The mode is selected by grounding the channel corresponding to the driver's choice.

The control line is only grounded for the period of time during which the corresponding button is pressed (manual control).

Channel assignation for the 6-channel connector:

CHANNEL No.	DESIGNATION
1	+ 12 V power supply: mode selector illumination (BSI)
2	+ 12 V power supply: auto indicator (BSI)
3	(not used)
4	Signal (to RMG control unit)
5	ground
6	(not used)

The built-in systems interface **(BSI1)** illuminates the "auto" indicating light as soon as the mode selector is pressed, as well as the illumination of the mode selector (**+** position lights).

3.4.7. Driver's door open information

This information is supplied by the built-in system interface **(BSI1)**. It wakes up the RMG control unit when the central door locking is opened or when the driver's door is opened. It also engages neutral as soon as the driver's door is opened (for safety reasons).

3.4.8. Stop lamp switch

The stop lamp switch is a binary (On-Off) contact (used to ground one of the control unit's inputs). It allows the engine to be started-up when the brake pedal is pressed (this is a start-up safety feature). This switch also initiates the downshift control function when the brake pedal is pressed, and initiates the function which reduces the transmission drive force when stopping (via a slow-down instruction).

This normally-open ("make") switch is linked directly to the RMG control unit (via a conventionally-wired link). The BSI receives the same information from the second stop lamp switch and sends it to the RMG control unit via the CAN. The two items of information are then compared.

4. USING THE MT-BVR MODEL

4.1. INSTRUCTION MANUAL

Environment

The MT-BVR model must be used in a dry place away from dust, steam and combustion fumes.
The model requires approximately 400 to 500 lux of lighting. It may be placed in a practical exercise room. Its operating noise level does not exceed 70 decibels.

Starting up the MT-BVR model:

- Check that the battery disconnect switch is open, in a horizontal position (in this position, the red handle may be removed);
- Keep the ignition key in the "Off" position and connect the model to the 230 V mains using the cable wound onto a reel at the rear of the MT-BVR (cable length: 7 meters)
- Close the battery disconnect switch (turns its red handle to the vertical position, and such that the handle cannot be removed), then use the ignition key to switch "On", just like a normal vehicle: turn to the "On" position, then to "Start"…

Calibration and maintenance of the MT-BVR model

Calibrating: factory setting.
Maintenance frequency: none.
Cleaning: use a clean and soft cloth and a window-cleaning product.

If you have to change the battery, replace it with an equivalent battery in terms of size, power, etc. Dispose of the old battery by recycling it in compliance with the requirements applicable in your region.

Number of workstations

The MT-BVR is considered to be a single work station.

Lockout/Tagout procedure

Turn the ignition key to the 0 position ("Off").
Check that the battery disconnect switch is open, in a horizontal position (the red handle may be removed).
Disconnect the 230 V mains connection and wind up the power cable onto the cable reel inside the model.
Check that there is no current by turning the ignition switch to "Start" – if nothing happens, then there is no current.
Remove the ignition key and the battery disconnect switch's handle, and place them in a lockable cabinet.
Store model MT-BVR in a secure room while out of use.

Residual risk

The inside of the MT-BVR should only be accessed (after removing the panel) by certified and authorized persons.

Transporting model MT-BVR

The model must be switched off and disconnected before transport.
Ensure that nothing is left on the model.
A minimum of two people are required to move the model.

Caution: the casters cannot negotiate anything higher than very low steps.

4.2. DESCRIPTION OF THE MODEL

Model **MT-BVR** is a learning aid used to study the “SensoDrive” system fitted to Citroën C3 cars.

The various component elements are mounted on and inside an aluminum frame which runs on casters:

Components identical to those fitted to the road vehicle:

- C3 SensoDrive Robotized Manual Gearbox (RMG)
- C3 flywheel and clutch
- Clutch actuator
- Gear selection and gear change actuator
- RMG control unit
- EOBD II diagnostic connector
- Dashboard (C3 instrument cluster)
- Gear lever and mode selector (push button)
- 12 V batter (mounted inside the aluminum frame)

The components operate under conditions which replicate those on the vehicle.

Elements specific to the model:

- A 12 V charger connected to the battery supplied (protected by a 50-A fuse)
- A 7-metre cable reel for connection to a 230 V mains supply
- An electric motor controlled by an electronic variable speed driver (which provides mechanical power to the RMG)
- A breakout box fitted with protective fuses and terminal connectors for the inputs/outputs to/from the RMG control unit
- A control panel (ignition key, “gas pedal” (accelerator knob), brakes, speed information, etc.)

4.2.1. Power supply to the model, internal view

Emergency stop button:
Press in the event of an emergency, rotate through ¼ of a turn to unlock after waiting for a minimum of 20 seconds.

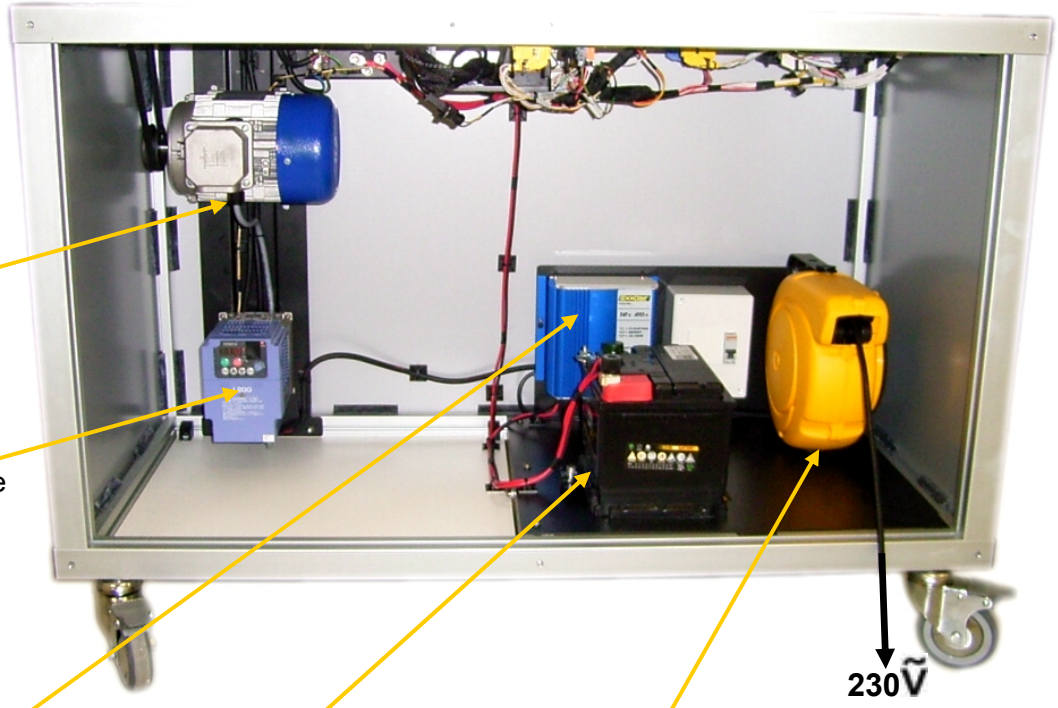
This button disconnects the 220 V power supply to the variable speed drive (stops the "engine")

¼-turn, handle-operated battery disconnect switch (handle can be removed when horizontal = disconnects the "ignition").

Disconnects the 12 V supply to the model (total switch-off)

The inside of the model can only be accessed after removing the protective panel.

Authorized persons only may open the model to perform maintenance operations.



Electric motor

Variable speed drive

Battery charger

Battery

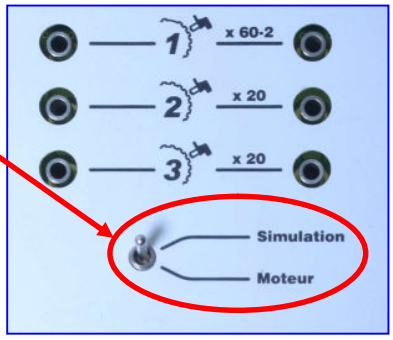
Extension cable on reel for connection to 230V 50-60 Hz mains with ground.

4.2.2. Procedure for switching on the MT-BVR model

- Always connect the model to the 230 V mains (without which the RMG will not be driven and the battery will discharge quickly…)

- Set the battery disconnect switch to its vertical position (circuit closed, contact made).

- Use the ignition key as you would on a vehicle: switch to “On” then to “Start” and return to “On”. Depending on the position selected with the switch towards the top of the control panel, the model can be operated in two different ways:



  - **Simulation:** The electric motor does not drive the RMG, the speeds and gears are simulated, the actuators function normally … In this mode, the emergency stop can be pushed in to prevent unnecessarily supplying power to the electric motor’s variable speed drive.

  - **Motor:** The electric motor drives the RMG which operates normally, but at lower speeds compared with those normally encountered on a vehicle (the actual RMG output speed does not correspond to that displayed on the instrument cluster).
    The measurements made by sensors 1, 2 and 3 (see photo above) are recorded in this mode: actual signals from the sensors present on the RMG.

- At the end of the session, switch the key to “Off” to switch off the model.

- Wait for 4 minutes before disconnecting the 12 V supply to the model (battery disconnect switch); the RMG has a long ‘power latch’.

- If the MT-BVR model is left connected to the 230 V mains to maintain the battery charge, it is advisable to press the "emergency stop" button since this disconnects the power supply to the electric motor's variable speed drive.

Important comments:

  - If the user does not wait for at least 4 minute after switching the ignition to “Off” and disconnecting the 12 V power supply, then when the ignition is switched to "On" again the RMG control unit will run an actuator learning cycle which lasts for about 1 minute. To start this procedure, the ignition must be set to “On” and the brake pedal must be pressed.

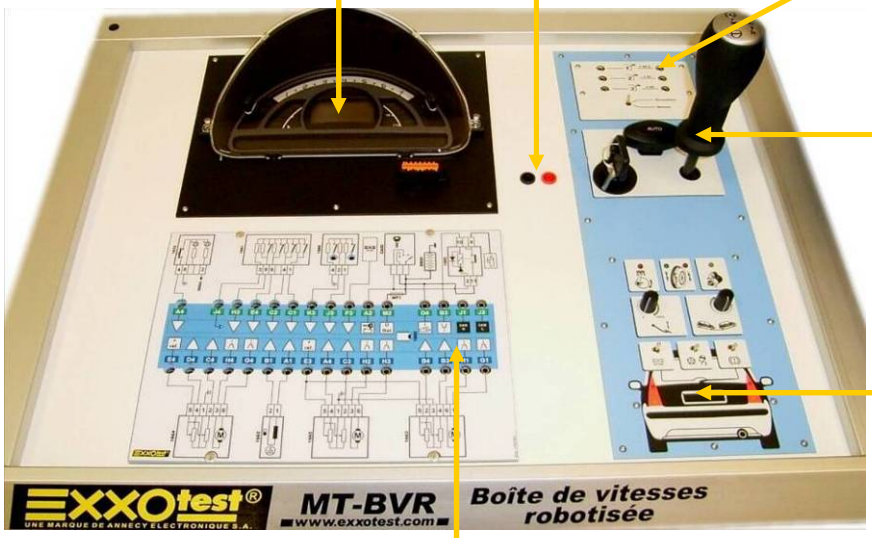
  - The emergency stop is fitted with a timer – if it is pressed and then immediately released the power supply will not be instantly restored. The user must wait for 20 seconds until the power is restored.

4.2.3. Components, controls, measurements and faults

- RMG display
- Vehicle speed display (simulated)
- Rev counter (simulated)
- Diagnostic connector

Battery terminals: power supply for diagnostic and measuring equipment

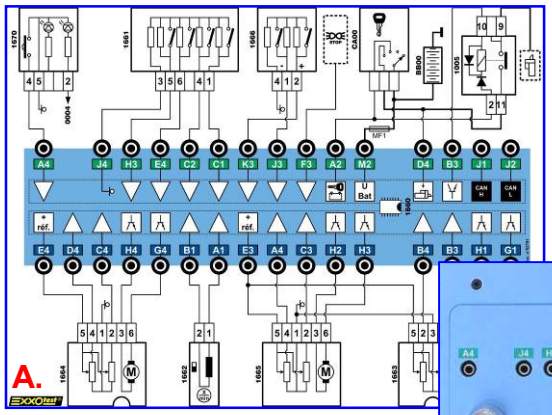
Speed sensor terminals:
1) Engine speed
2) RMG input speed
3) RMG output speed



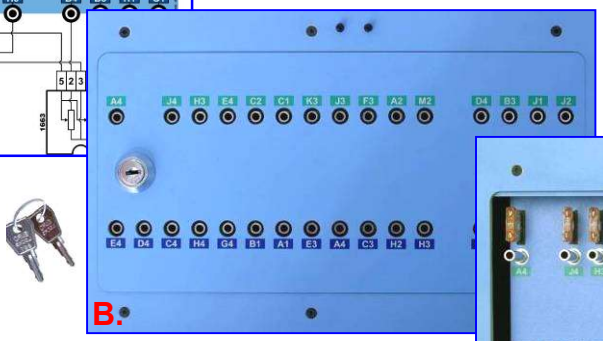
- Gear lever
- Mode selector
- Ignition key

- Indicator lights for engine running, clutch status, starter control.
- "Gas pedal" control
- Road profile
- Brake control

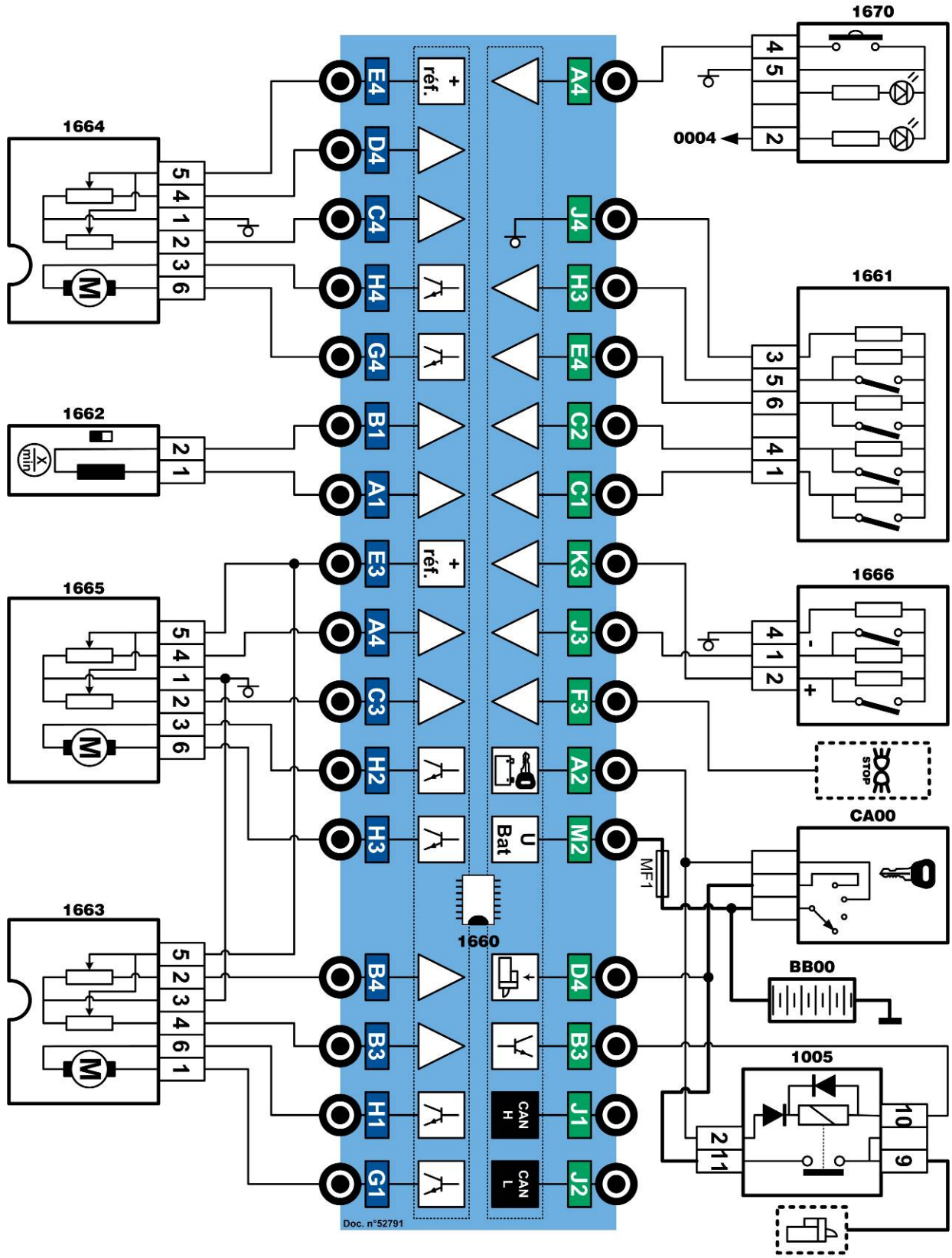
Inputs/outputs diagram for the RMG control unit with measurement terminals and breakout box



The control unit diagram is flexible and removable (**A.**).
Once removed, all that remains identify the terminals are the colors and channel numbers (**B.**).
The rigid cover can, in turn, be removed (using its key).
Under this cover, fuses can be fitted to create faults (**C.**)



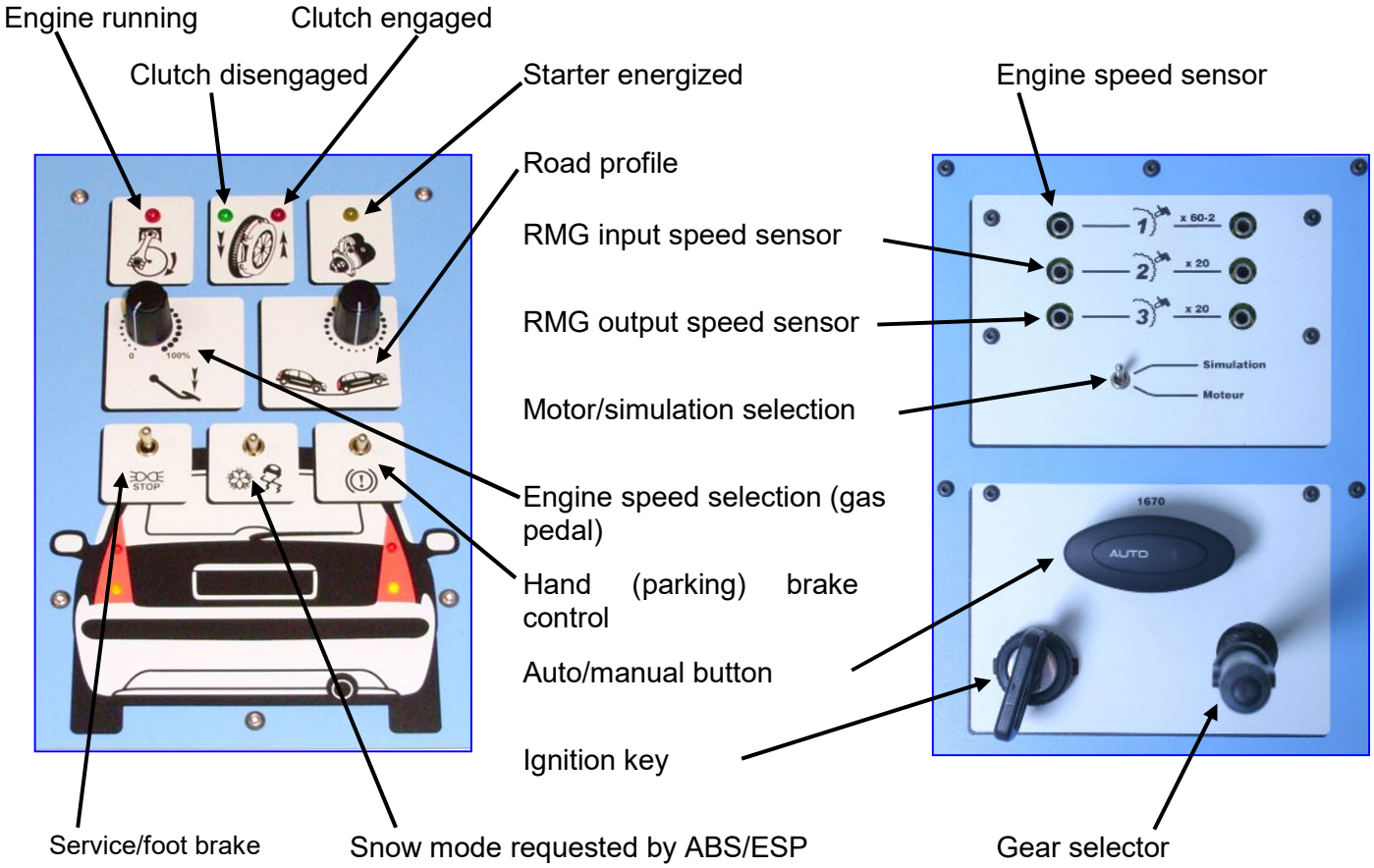
Front face of the model:



Parts list:

MANUFACTURER'S REF	COMPONENT
BB00	BATTERY
CA00	ANTI-THEFT SWITCH
0004	CLUSTER DISPLAY
1005	STARTER INHIBITOR RELAY
1660	RMG CONTROL UNIT
1661	GEAR LEVER
1662	RMG INPUT SPEED SENSOR
1663	GEAR CHANGE ACTUATOR
1664	GEAR SELECTION ACTUATOR
1665	CLUTCH ACTUATOR
1666	CONTROL PADDLES BEHIND THE STEERING WHEEL
1670	RMG AUTO MODE SWITCH

Engine speed control and measurement part:



5. DIAGNOSTICS AND WORKING ON THE MT-BVR

5.1. MISCELLANEOUS OPERATIONS

When the ignition key is turned to “ON”, and with the brake pedal pressed, the RMG control unit:

- initializes the position of the clutch fork (movement of the clutch fork)
- initializes the position of the gearshift arm (movement of the gearshift arm).

The engine cannot be started while the control unit is running actuator position initialization operations. The time needed to initialize the position of the actuators varies from between 10 seconds and 1 minute.

5.1.1. Description

To enable it to operate, the RMG control unit needs to know and store the characteristics of the gearbox (clutch and gearbox actuators). This data is stored once the RMG control unit has finished running one or more “learning programs” activated by the diagnostic tool.

The learning programs let the RMG control unit:

- measure and record the characteristics of the various system components,
- initialize the system.

The following procedures require the use of the diagnostic tool:

- learning program for the clutch actuator,
- learning program for the gearbox actuator,
- reading and writing to the usage counters,
- disassembling the gearbox actuator,
- securing the gearbox actuator in position during assembly.

5.1.2. Removal and refitting of parts

Element removed/refitted	Operation performed	Observations
Removal/refitting of the RMG control unit	Turn the ignition key to “Off” Wait for the cluster display to switch off Disconnect the cable from the battery’s negative terminal	
Removal of the clutch actuator	Remove the clutch actuator	
Refitting of the clutch actuator	After refitting the clutch actuator, run the **learning program**	Run duration of the learning program: about 12 seconds
Removal of the gearbox actuator	Before removing the actuator, perform a **“removal of the gearbox actuator”** operation using the manufacturer’s tool	

Element removed/refitted	Operation performed	Observations
Refitting of the gearbox actuator	After fitting the gearbox actuator, run the **learning programs**	Run duration of the learning program: about 12 minutes
Refitting of a badly disassembled gearbox actuator	Before fitting the actuator, run a "**securing the actuator in position"** operation After fitting the actuator, run the learning programs	Duration of the securing operation (Run duration of the learning program: about 12 minutes)
Removal of the gearbox	This operation requires the removal of the clutch actuator, gearbox actuator and RMG control unit	
Refitting of the gearbox	The actuators must be reassembled on the gearbox Refit the clutch actuator Refit the gearbox actuator Run the **"learning sequences"** (an automatic sequencing of all the learning programs)	The learning programs for the clutch actuator **MUST** be performed before running the learning programs for the gearbox actuator (Run duration of the learning programs: about 13 minutes)
Removal/refitting of the gear change controls behind the steering wheel	None	
Removal/refitting of the gear lever	None	

5.1.3. Description of the learning programs for the clutch actuator

Learning the end-of-travel positions

The RMG control unit learns the end-of-travel positions of the clutch actuator so that it can store the total travel of the clutch fork.

A number of conditions must be in place when performing this learning operation:

- the engine must not be running,
- the vehicle must be stationary on horizontal ground,
- the ignition key must be set to "ON"

When instructed by the diagnostic tool, the control unit opens (disengages) or closes (engages) the clutch.

If the learning operation fails, a fault code is generated in the RMG control unit's memory.

Learning the position of the bite point

The clutch's bite point is the position of the clutch fork at which the gearbox's input shaft first starts to be driven.

A number of conditions must be in place when performing this learning operation:

- the engine must be running at idle,
- the vehicle must be stationary on horizontal ground,
- the gearbox must be in neutral "N",
- the handbrake must be on.

When instructed by the diagnostic tool, the RMG control unit performs a succession of partial clutch opening and closing operations. It detects, based on information from the gearbox input speed sensor, the rotational speed of the input shaft.

After replacing a clutch, run this learning program on the clutch actuator on completion of a road test.

5.1.4. Description of the learning program for the gearbox actuator

The learning program for the gearbox actuator lets the gearbox control unit stores the characteristics of the gearbox's internal control components. Note that the "gearbox actuator" is in fact an assembly comprising two actuators: the gear change actuator and the gear selection actuator. It also lets the RMG control unit store the position of the gearbox actuator.

Note: always run the learning programs for the clutch actuator before running learning programs on the gearbox actuator.

A number of conditions must be in place when running this learning program:

- the engine must not be running,
- the handbrake must be off,
- the vehicle must be stationary on horizontal ground,
- the battery's voltage must be 12 V or higher.

A drop in battery voltage to below 10.5 V during the learning operation generates a failure.

The gearbox control unit generates a series of sudden movements to determine the position of each gear and the shape of the gear grid.

To store the learnt information definitively, the following operations must be performed:

- turn the ignition key to "Off",
- wait for the cluster display to switch off,
- wait for 4 minutes before turning the ignition key back to "On".

If the learning operation fails, a fault code is generated in the RMG control unit's memory.

5.1.5. Disassembling the gearbox actuator

The RMG control unit is able to move the gearshift arm (by controlling it via the gear change actuator and the gear selection actuator) into the position it needs to occupy for disassembly (refer to the corresponding operation).

This operation must be performed with the actuators mounted on the gearbox.

When the dialog with the diagnostic tool has finished, the gearshift arm is maintained and immobilized in its disassembly position.

Note: check the position of the gearshift arm before commencing any disassembly work.

If the actuator had previously been removed incorrectly without first being secured, then immobilize it in its assembly position using the “secure gearbox actuator in assembly position” function (see below).

Securing the gearbox actuator in its assembly position

Note: this function should only be used after the actuator has been disassembled.

This function is used to immobilize the gearbox actuator in its assembly position. To perform this securing operation, the actuator must be disassembled and must be turned upside down, with the securing lugs facing upwards.

5.1.6. Replacing a RMG control unit

Never swap the RMG control units between two vehicles. If necessary, run all the learning programs for each control unit.

Failure to comply with the instructions can result in the malfunction of the gearbox, or even the destruction of the actuators.

There is no telecoding to be performed on a new control unit.

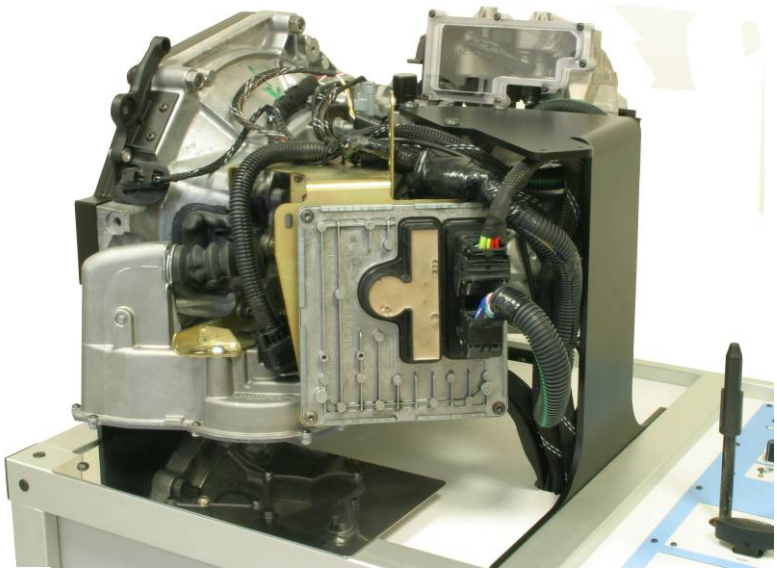
6. PRACTICAL EXERCISES ON MODEL MT-BVR

OBJECTIVES

- To analyze the operation of the robotized manual gearbox.
- To identify the various components of the robotized manual gearbox.
- To record various signals relating to the operation of the robotized manual gearbox.
- To identify the multiplexed networks involved in the operation of the robotized manual gearbox.
- To identify the nature of the information exchanged over the multiplexed network.

EQUIPMENT USED

- Robotized Manual Gearbox model
- Oscilloscope
- Multimeter
- USB 1 CAN, 3 VAN unit with software (e.g. USB-MUX-C3VL with AMUX-CC3V cable + MUXTRACE software)
- Manufacturer's diagnostic tool (e.g. LEXIA)



6.1. UNDERSTANDING THE SYSTEM

1) What does the abbreviation RMG stand for?

RMG stands for Robotized Manual Gearbox

2) What is the main difference between a conventional manual gearbox and an RMG?

The RMG uses two actuators, powered by electric motors and managed by a dedicated control unit, to mechanically control the gearbox and clutch.

3) The RMG is presented as an improved version of the conventional mechanical gearbox. What elements of the conventional system have been eliminated?

The eliminated elements are the clutch pedal and the mechanical link (including cable) between the gear lever and the gearbox.

4) What RMG-related elements are present in the passenger cell?

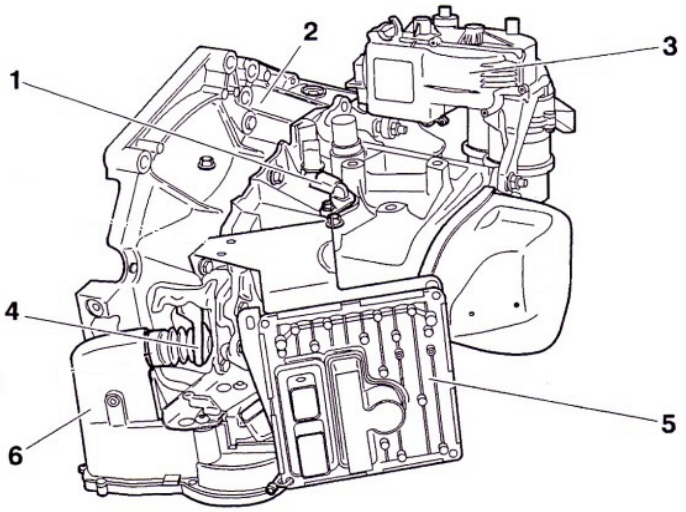
- Instrument cluster display.
- Gear lever.
- Mode selector.
- Gear control paddles behind the steering wheel.

5) The engine of vehicles fitted with a robotized manual gearbox will only start if the driver is pressing on the brake pedal, true or false?

True, the engine will not start unless the brake pedal is depressed.

6) Complete the table below with reference to the drawing.

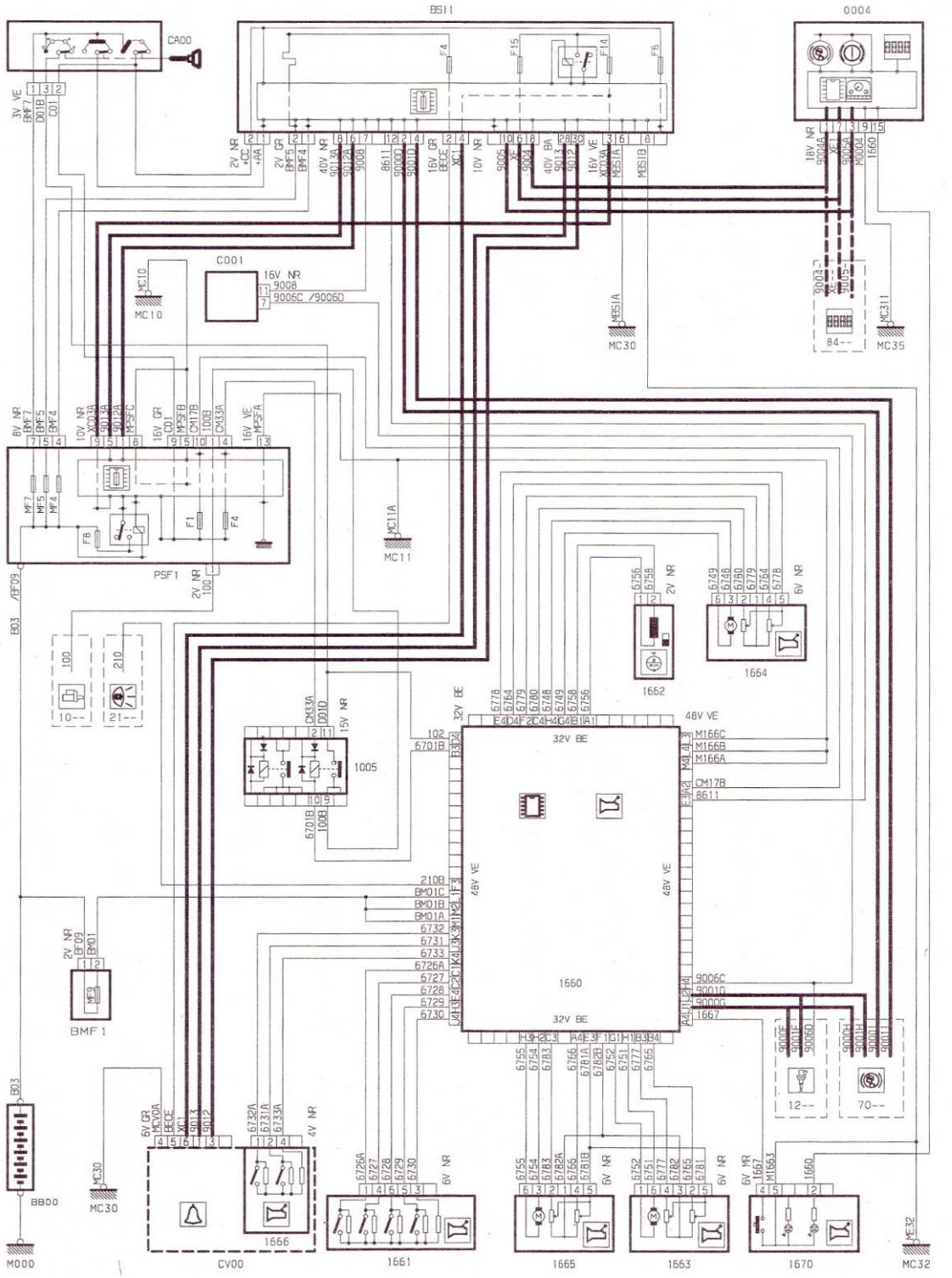
N	Name of component
1	Input shaft speed sensor
2	Clutch housing
3	Gear change and gear selection actuators
4	Clutch fork
5	Robotized manual gearbox control unit
6	Clutch actuator



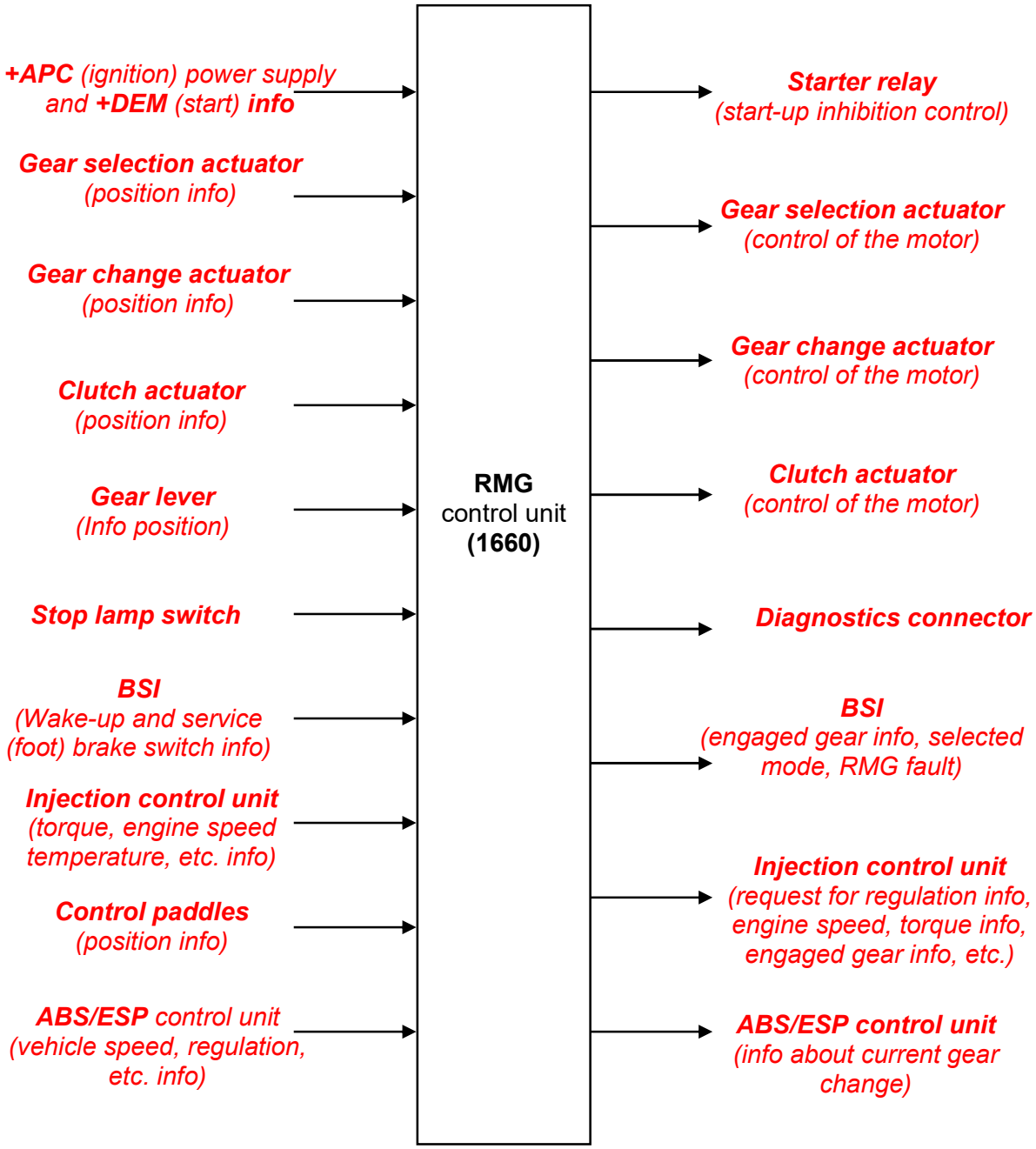
6.2. IDENTIFICATION OF THE ELEMENTS

1) On the wiring diagram:

- Color in the actuators in red
- Color in the sensors in green
- Color in the following control units in blue / BSI1 / PSF1 / INJECTION / ABS / INSTRUMENT CLUSTER



2) Complete the inputs to and outputs from the RMG control unit.



6.3. GEAR LEVER

1) What is the manufacturer's reference number for the gear lever? (see diagram)

*The gear lever's reference number is **1661.***

2) What does the gear lever do?

The gear lever lets the driver indicate when s/he wants to change gear (upshift or downshift).

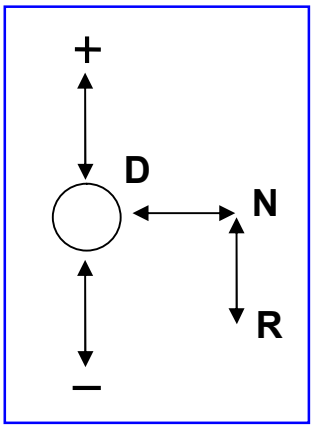
3) Is the link between the gear lever and the gearbox mechanical or electrical?

The gear lever is linked electrically.

4) Is the link between the gear lever and the robotized manual gearbox provided by conventional wiring or by a multiplexed link?

The link is provided by conventional wiring.

5) Indicate on the diagram the possible movements of the gear lever.



6) Measure the values on the terminal board and complete the table below.

Gear lever position	Voltage between channel 3 and channel 1 (in V)	Voltage between channel 3 and channel 4 (in V)	Voltage between channel 3 and channel 5 (in V)	Voltage between channel 3 and channel 6 (in V)
Central	*3.48*	*3.48*	*3.48*	*3.48*
+	*2.47*	*2.47*	*3.73*	*3.73*
-	*2.47*	*3.73*	*3.73*	*2.47*
N	*2.47*	*3.73*	*2.47*	*3.73*
R	*3.73*	*3.73*	*2.47*	*2.47*

6.4. CONTROL PADDLES BEHIND THE STEERING WHEEL

1) What is the manufacturer's reference number for the control paddles behind the steering wheel? (see diagram)

*The reference number for the control paddles behind the steering wheel is **1666***

2) What do these paddles do?

These paddles let the driver indicate when he or she wishes to change gear (+ or -)

3) Can reverse gear (R) and the neutral position (N) be engaged using the paddles behind the steering wheel?

No, the paddles cannot be used to select neutral (N) or reverse (R).

4) Is the link between the paddles and the RMG control unit provide by conventional wires or multiplexed wiring?

The link is provided by conventional wires.

5) On which control unit are the paddles mounted?

The paddles are mounted on the control unit (switching module) behind the steering wheel (COM2000).

6) Measure the values on the terminal board and complete the table below.

Paddle position		**Voltage between ground and channel 1 (in V)**	**Voltage between ground and channel 2 (in V)**
+ control released	**-** control released	3.78	3.78
+ control released	- control activated	4.05	2.40
+ control activated	**-** control released	2.40	4.05
+ control activated	**-** control activated	2.88	2.88

6.5. MODE SELECTOR

1) What is the manufacturer's reference number for the mode selector? (see diagram)

*The reference number for the mode selector is **1670.***

2) How many modes can be selected using this button?

It is used to select between two modes: "automatic" and "manual".

3) While driving in "auto" mode, the driver actuates the gear lever (+, -) or one of the paddles (+, -), what happens?

When the driver actuates the gear lever or one of the paddles, the mode switches to manual and the requested gear change occurs – the driver does not need to press the mode selector button.

4) When the ignition key is switched to "On", what mode does the vehicle start in?

Automatic mode.

5) Explain the difference between "automatic" mode and "manual" mode.

In "automatic" mode, the gear changes are managed automatically, without any input being required from the driver. On the contrary, in "manual" mode, it is the driver who initiates the gear changes using the gear lever or paddles.

6) Can the driver select "automatic" mode at any time, even when the vehicle is moving?

Yes, "automatic" mode can be selected at any time.

7) Is there a "snow" mode? How is it selected? When is it selected?

Yes, there is a "snow" mode. It is selected automatically by the RMG control unit when the wheels slip or skid (information from the ABS/ESP control unit).

8) In snow mode, the RMG control unit forces the vehicle to start in 2nd gear, true or false?

True, the RGB control unit starts the vehicle in 2nd gear when it is in "snow" mode. In this mode, it is not possible to change down to 1st gear.

6.6. INSTRUMENT CLUSTER AND DISPLAY UNIT

1) What is the manufacturer's reference for the instrument cluster? (see diagram)

*The reference number for the instrument cluster is **0004.***

2) What is the role of the display unit in relation to the RMG?

The display unit informs the driver of the gear engaged, and indicates the active mode: "automatic", "manual" or "snow".

3) What sends the gear engaged and active mode information to the instrument cluster's display unit?
(see wiring diagram)

The information is sent by the BSI, which received this information from the RMG.

4) Is this information carried on a wire-based or multiplexed link?

The information is carried on a multiplexed link (VAN comfort network).

6.7. STARTER INHIBITOR RELAY

1) What is the manufacturer's reference number for the starter inhibitor relay? (see diagram)

*The reference number for the starter inhibitor relay is **1005**.*

2) What does this relay do?

The starter inhibitor relay disables the starter motor.

3) What controls this relay?

It is controlled by the RMG control unit.

4) In what circumstances is the relay energized (so as to enable the operation of the starter motor)?

The relay is energized (to enable the starter motor) when the ignition key is set to the + DEM (start) position, when the position of the actuators is compatible with starting the engine, and when the driver is pressing on the brake pedal.

6.8. RMG INPUT SPEED SENSOR

1) What is the manufacturer's reference number for the RMG input speed sensor? (see diagram)

*The reference number for the RMG input speed sensor is **1662**.*

2) What does the RMG input speed sensor do?

The RMG input speed sensor provides the control unit with information about the speed of rotation of the RMG input shaft.

3) What does the RMG control unit calculate using the information provided by this speed sensor?

The RMG control unit calculates the clutch slippage (i.e. the difference between engine rpm and the speed of rotation of the RMG input shaft), and the clutch's bite point.

4) Identify the RMG input speed sensor's terminal numbers from the wiring diagram and use this information to generate a display on an oscilloscope of the sensor's signal.

5) What type of sensor is it? Inductive, Hall-effect or Piezo-resistive?

The RMG input speed sensor is an inductive sensor.

6) Is it a passive or active sensor?

The RMG input speed sensor is an active sensor.

6.9. STOP LAMP SWITCH

1) What is the manufacturer's reference number for the stop lamp switch? (see diagram)

*The reference number for the stop lamp switch is **2100**.*

2) What does the stop lamp switch do in terms of the operation of the RMG?

The stop lamp switch tells the RMG control unit whether or not the brake pedal is pressed, and is used to enable or disable the starting of the engine.

3) Does the stop lamp switch information pass via the BSI or is it sent directly to the RMG control unit? (see wiring diagram)

The information is sent directly to the RMG control unit.

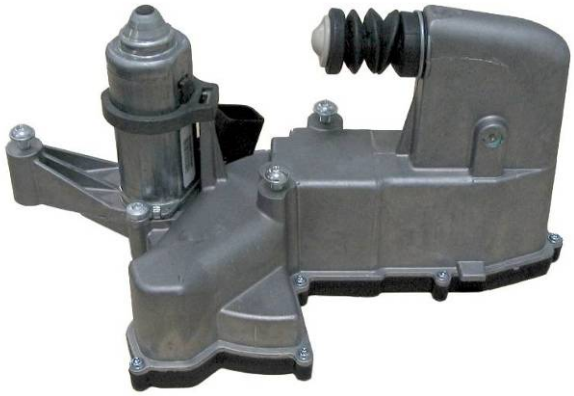
4) Is there a second stop lamp switch, and where is its signal sent?

There is a second stop lamp switch – it sends its signal to the BSI.

5) What is the purpose of the second stop lamp switch?

The BSI sends this information to the RMG control unit, which compares these two bits of information.

6.10. CLUTCH ACTUATOR



1) What is the manufacturer's reference number for the clutch actuator? (see diagram)

*The reference number for the clutch actuator is **1665**.*

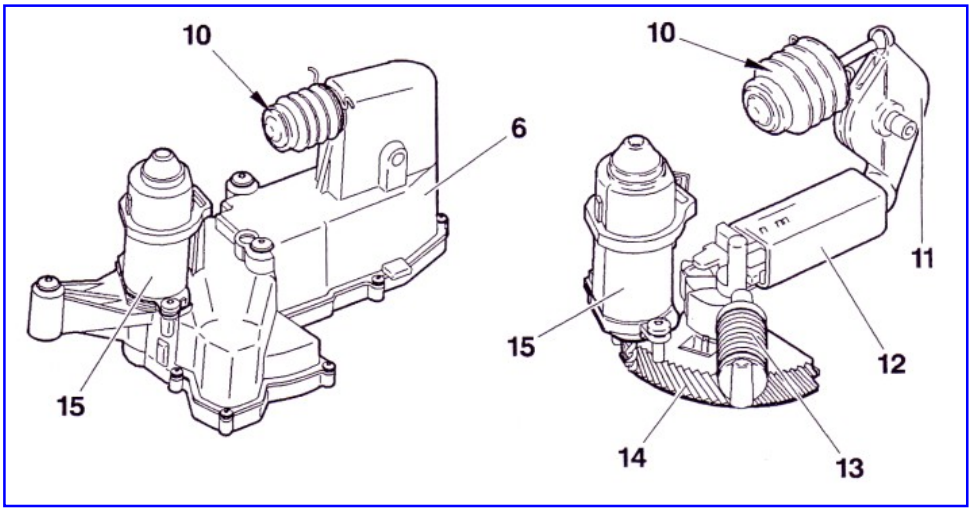
2) What does the clutch actuator do?

The clutch actuator engages (closes) and disengages (opens) the clutch.

3) What conventional elements does the clutch actuator replace?

The clutch actuator replaces all the manual clutch operating components: typically the clutch pedal, cable, etc.

4) Complete the table below:

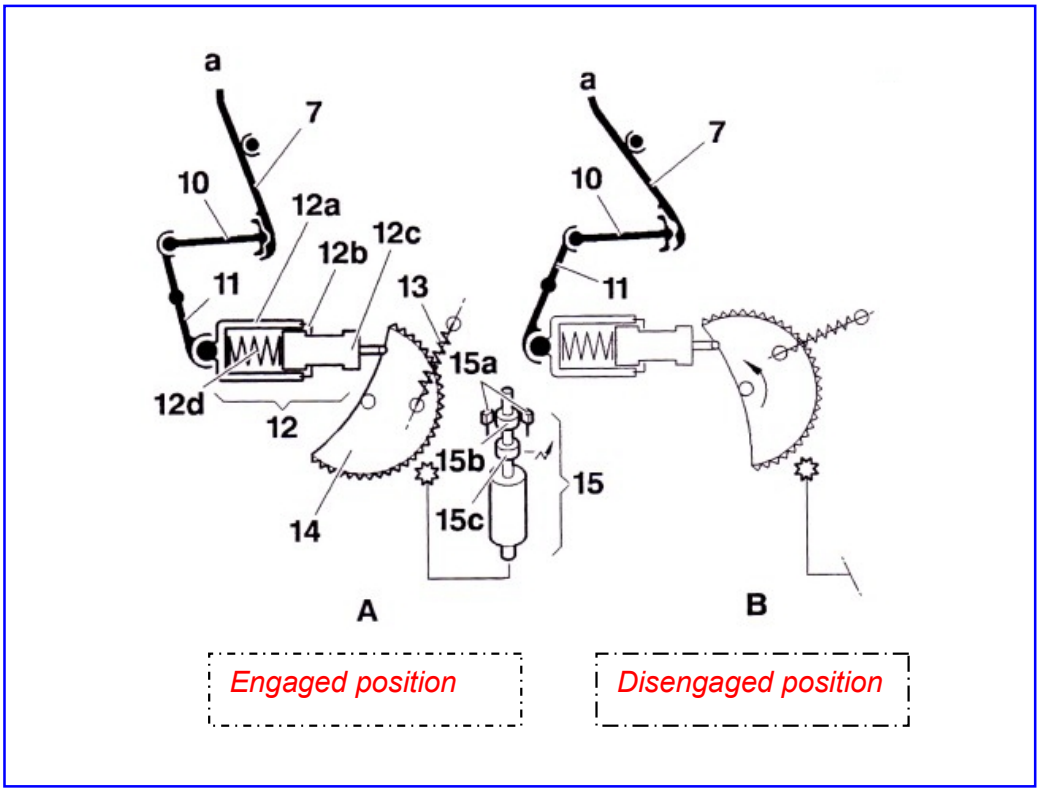


Number	Name of component
6	*Clutch actuator*
10	*Push rod*
11	*Connecting link*
12	*Clutch wear compensation system*
13	*Force compensation spring*
14	*Toothed half-disk*
15	*Electric motor with two integrated position sensors*

5) The clutch actuator is designed to obtain two stable mechanical positions, what are they?

The two positions obtained by the clutch actuator are a disengaged clutch and an engaged clutch.

6) Indicate under A and B the clutch position for the configuration shown, then complete the table.



Number	Name of component
a	*Clutch release bearing*
7	*Clutch fork*
10	*Push rod*
11	*Connecting link*
12	*Clutch wear compensation system*
12a	*Sleeve*
12b	*Locking system*
12c	*Piston*
12d	*Spring which applies force to the clutch release bearing*
13	*Force compensation spring*
14	*Toothed half-disk*
15	*Electric motor*
15a	*Position sensor (Hall-effect sensor)*
15b	*Notched ring (magnetic field)*
15c	*Electric motor's commutator*

7) Describe how the clutch actuator disengages the clutch using the schematic provided for the previous question.

The RMG control unit energizes the electric motor (15). The rotation of the electric motor drives the toothed half-disk (14). The rotation of the toothed half-disk immobilizes the wear compensation system (the system (12b) locks together parts (12a) and (12c) and actuates the connecting link (11). As a result of the movement of the linkage, the clutch fork (7) displaces the clutch release bearing and disengages the clutch.

8) Describe how the clutch actuator engages the clutch.

The RMG control unit reverses the polarity of the power supply to the electric motor (15). The toothed half-disk is returned to its initial position. When the clutch is engaged (closed), the fork no longer exerts any force on the wear compensation system (12), which unlocks and can be compressed.

9) Identify the electric motor's terminal numbers from the wiring diagram and use this information to generate a display on an oscilloscope of the signal which controls the clutch actuator's electric motor. What type of signal is it?

The signal which controls the motor is a square wave with a variable duty cycle.

10) What components control the electric motor? (position sensors, clutch actuator, injection control unit, RMG control unit or BSI.)

The electric motor is controlled by the RMG control unit.

11) The square-wave signal transmitted by the RMG control unit controls the actuation of the electric motor in both directions of rotation. This signal also varies the speed of rotation and is used to measure the current drawn by the electric motor, TRUE or FALSE?

TRUE, by varying the duty cycle of the square-wave signal, this signal can be used to vary the speed of rotation of the motor, and can be used to measure the current drawn.

12) How many position sensors are integrated into the electric motor?

Two.

13) What do these integrated sensors do?

The two position sensors integrated into the electric motor let the RMG control unit measure the displacement and speed of operation of the clutch fork.

14) Identify the two position sensor's terminal numbers from the wiring diagram and use this information to generate a display on an oscilloscope of the signal sent by these two sensors.

14) What type of signal is this?

A square-wave signal.

7) Are these sensors passive or active?

These are Hall-effect sensors: passive sensors.
(They are mounted such that they face a magnetic notched ring on the electric motor's rotor.)

6.11. GEARBOX ACTUATOR

1) What does the gearbox actuator do?

The gearbox actuator engages each gear, replacing the function conventionally performed by the gear stick and linkages.

2) The gearbox actuator consists of two actuators, and thus requires two electric motors, true or false? What are their names?

True. The gearbox actuator comprises a gear selection actuator and a gear change actuator.

3) What is the manufacturer's reference number for the gear change actuator? (see diagram)

*The reference number for the gear change actuator is **1663**.*

4) What is the manufacturer's reference number for the gear selection actuator? (see diagram)

*The reference number for the gear selection actuator is **1664**.*

5) For each actuator, the RMG control unit is linked to two position sensors, just like for the clutch actuator, true or false?

True, each actuator is fitted with two sensors.

6) What functions are performed by these sensors integrated into the electric motors?

The two position sensors integrated into each electric motor provide the RMG control unit with information about the position and speed of operation the gear-shift arm.

7) Identify, from the wiring diagram, the terminal numbers for the two sensors in the electric motor which powers the gear change actuator. Using this information, generate a display on an oscilloscope of the signal from these two sensors.

8) Identify, from the wiring diagram, the terminal numbers for the two sensors in the electric motor which powers the gear selection actuator. Using this information, generate a display on an oscilloscope of the signal from these two sensors.

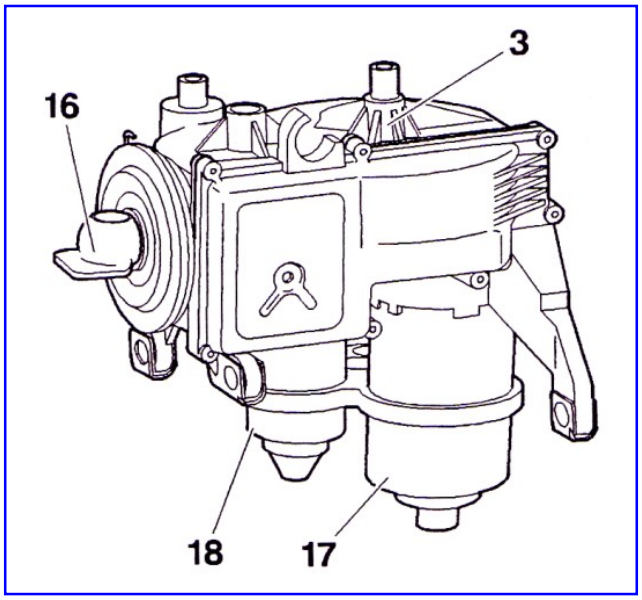
9) What type of signals are these?

They are square-wave signals.

10) Are these sensors passive or active?

They are Hall-effect sensors: passive sensors.
(They are mounted such that they face a magnetic notched ring on the electric motor's rotor.)

11) Complete the table below by referring to the diagram.



Number	Name of component
3	*Gearbox actuator*
16	*Gear-shift arm*
17	*Electric motor powering the gear change actuator* ***(1663)***
18	*Electric motor powering the gear selection actuator (**1664**)*

12) Identify the terminal numbers, from the wiring diagram, for the gear change actuator's electric motor and use this information to generate a display on an oscilloscope of the signal which controls this electric motor. What type of signal is it?

The signal which controls the motor is a square wave with a variable duty cycle.

13) Identify the terminal numbers, from the wiring diagram, for the gear selection actuator's electric motor and use this information to generate a display on an oscilloscope of the signal which controls this electric motor. What type of signal is it?

The signal which controls the motor is a square wave with a variable duty cycle.

14) Which component controls the electric motors which power the gear change and gear selection actuators? (position sensors, clutch actuator, injection control unit, RMG control unit or BSI.)

The electric motors which power the actuators are controlled by the RMG control unit.

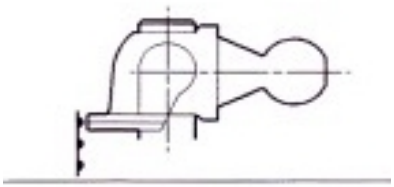
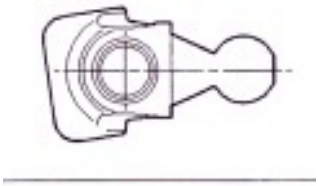
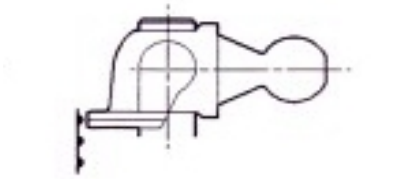
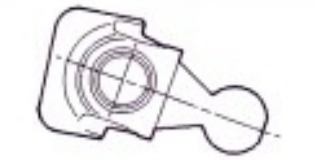
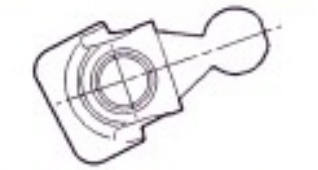
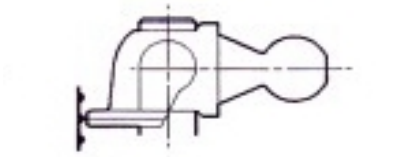
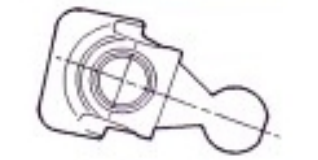
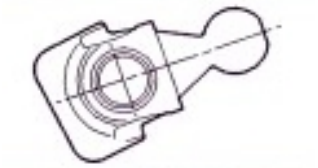
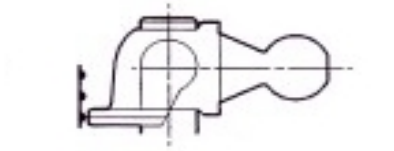
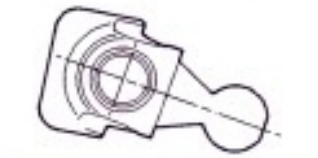
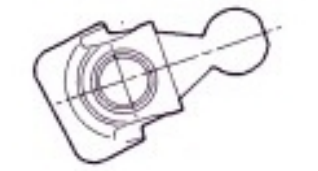
15) The square-wave signal transmitted by the RMG control unit control the electric motor in both directions of rotation. Are they used to vary the speed of rotation of the electric motor and to measure the current drawn?

Yes, by varying the duty cycle of the square-wave signals they can be used to adjust the speed of rotation of the motor. The signals are also used to measure the current drawn by the electric motors.

16) Can these two electric motors operate at the same time?

No, the electric motors never operate simultaneously.

17) Determine the gears selected based on the position of the gear-shift arm on the model, and use this information to complete the table below.

Gear engaged	Front view	Top view
N		
1		
2		
3		
4		
5		
R		

6.12. IDENTIFICATION OF MULTIPLEXED NETWORKS

1) What is multiplexing?

Multiplexing *is a technique which involves sending two or more signals via the same transmission medium (called a "bus").*

2) What do the initials CAN stand for?

Control Area Network.

3) What do the initials VAN stand for?

Vehicle Area Network.

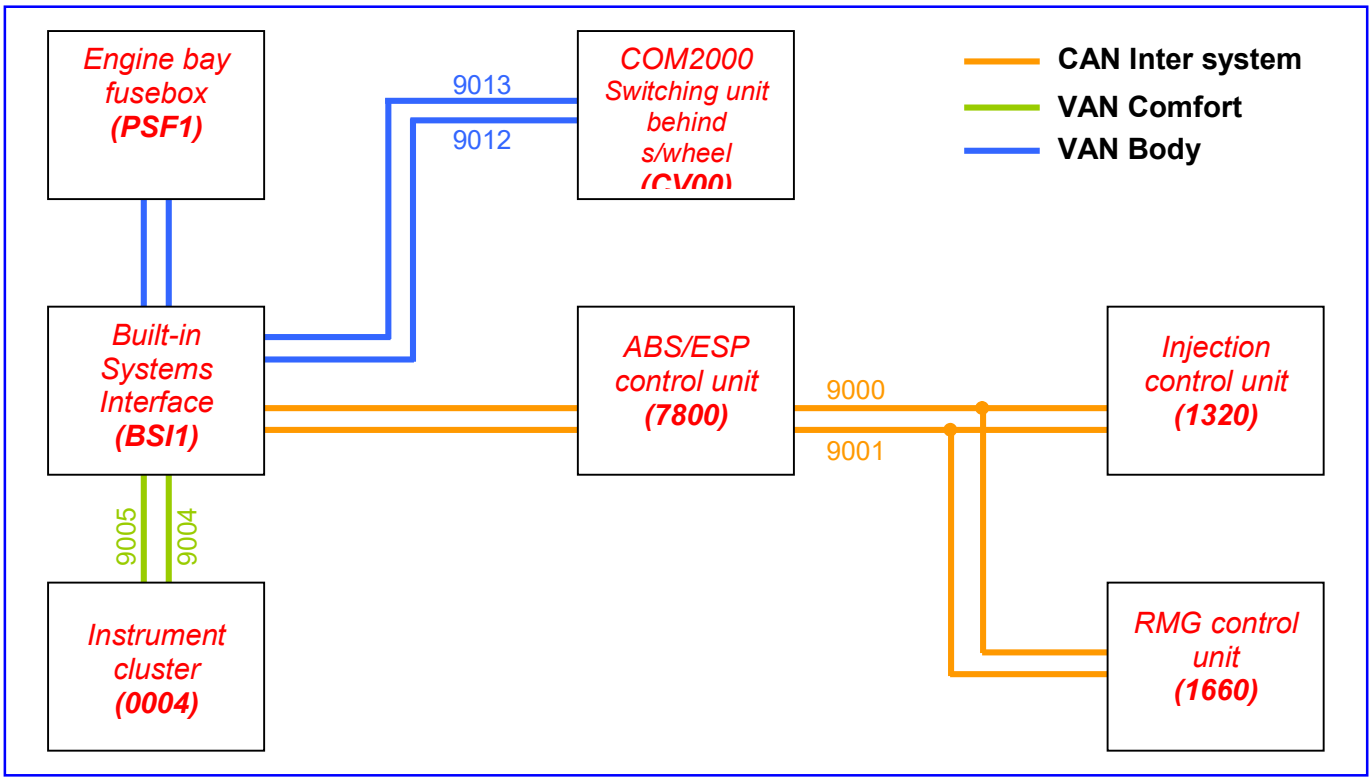
4) Which multiplexed networks are involved in the operation of the RMG system?

The multiplexed networks used are: CAN inter-system, VAN Comfort network and VAN Body network.

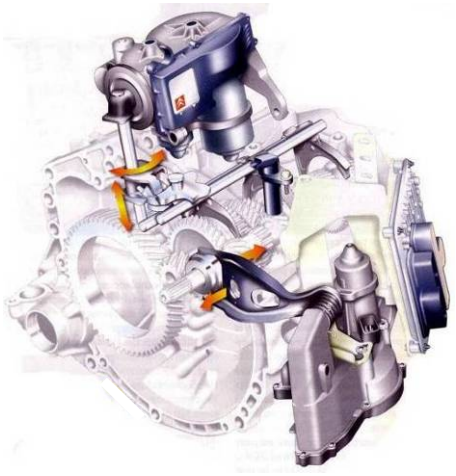
5) By referring to the wiring diagram, list all the control units which communicate via a multiplexed link.

- *Robotized manual gearbox control unit*
- *Injection control unit*
- *ABS/ESP control unit*
- *Built-in Systems Interface (BSI)*
- *Fuse box module (BSM)*
- *Switching unit behind steering wheel (COM2000)*
- *Instrument cluster*

6) Draw the architecture of the RMG system, indicating the control units with their reference codes, the multiplexed networks and the number of wires. (see diagram)



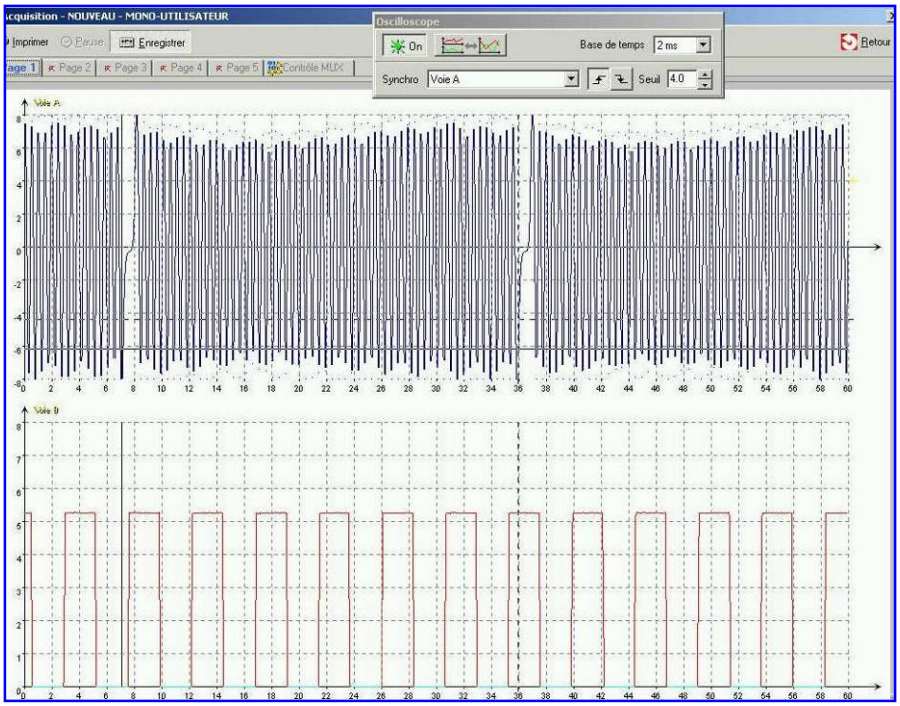
6.13. ROTATIONAL SPEEDS OF SHAFTS AND GEARBOX RATIOS



Calculation of the various gearbox input/output ratios:

- To calculate the ratios for the 6 gears (1, 2, 3, 4, 5, R), you will need to use information from the crankshaft's rotational speed and position sensor, and from the gearbox output speed sensor.

Using the Reflet 2000, record the signals from these two sensors, so as to measure the time taken for one rotation of the shaft, as shown below:



<u>CAUTION:</u>

On the MT-BVR, the gearbox is driven by a 220 V electric motor and consequently the rpm indicated on the instrument cluster does not correspond to the actual gearbox rpm, but to the theoretical rpm which would be recorded in a real vehicle.

The values indicated in the following pages may vary from one version of the model to another, depending on the RMG used: there are <u>several versions</u> with different gear ratios.

6.13.1. Calculating first gear

Conditions:

- RMG in first gear
- vehicle speed: 20 km/h (about 2400 rpm)

1) Measure the time corresponding to one rotation of the crankshaft (i.e. the time between 2 missing teeth), then calculate from this the rotational speed N of the crankshaft in rpm:

   - 1 rotation => 54 ms; 1 min = 60000 ms
   - $N_{Crankshaft}$ = 60000 / 54 = **1111.11 rpm**

2) Measure the time corresponding to one revolution of the RMG output shaft, knowing that the sensor's target has 20 teeth. Calculate from this the actual RMG output speed:

   - 20 teeth => 690.7 ms
   - $N_{RMG\ output}$ = 60000 / 690.7 = **86.87 rpm**

3) From the gearbox input and output speeds, calculate the ratio for first gear. Express the output speed as a percentage of the input speed (i.e. the crankshaft's rotational speed).

   - G1 = $N_{RMG\ output}$ / $N_{Crankshaft}$ = 86.87 / 1111.11 = **0.078**
   - $N_{RMG\ output}$ = **7.8%** $N_{Crankshaft}$

6.13.2. Calculation of second gear

Conditions:

- RMG in second gear
- vehicle speed: 35 km/h (about 2400 rpm)

Repeat the procedure described above and calculate the input and output speeds, the gear ratio and the percentage:

- $N_{Crankshaft}$ = 60000 / 53.7 = **1117.32 rpm**
- $N_{RMG\ output}$ = 60000 / 394 = **152.29 rpm**
- G2 = $N_{RMG\ output}$ / $N_{Crankshaft}$ = **0.136**
- $N_{RMG\ output}$ = **13.6%** $N_{Crankshaft}$

6.13.3. Calculation of third gear

Conditions:

- RMG in third gear
- vehicle speed: 50 km/h (about 2400 rpm)

Repeat the procedure described above and calculate the input and output speeds, the gear ratio and the percentage:

- $N_{Crankshaft}$ = 60000 / 49.5 = **1212.12 rpm**
- $N_{RMG\ output}$ = 60000 / 254 = **236.22 rpm**
- G3 = $N_{RMG\ output}$ / $N_{Crankshaft}$ = **0.195**
- $N_{RMG\ output}$ = **19.5%** $N_{Crankshaft}$

6.13.4. Calculation of fourth gear

Conditions:

- RMG in fourth gear
- vehicle speed: 65 km/h (about 2400 rpm)

Repeat the procedure described above and calculate the input and output speeds, the gear ratio and the percentage:

- $N_{Crankshaft}$ = 60000 / 57 = **1052.63 rpm**;
- $N_{RMG\ output}$ = 60000 / 226,33 = **265.10 rpm**;
- G4 = $N_{RMG\ output}$ / $N_{Crankshaft}$ = **0.252**
- $N_{RMG\ output}$ = **25.2%** $N_{Crankshaft}$

6.13.5. Calculation of fifth gear

Conditions:

- RMG in fifth gear
- vehicle speed: 80 km/h (about 2400 rpm)

Repeat the procedure described above and calculate the input and output speeds, the gear ratio and the percentage:

- $N_{Crankshaft}$ = 60000 / 50.67 = **1184.13 rpm**
- $N_{RMG\ output}$ = 60000 / 162,66 = **368.86 rpm**
- G5 = $N_{RMG\ output}$ / $N_{Crankshaft}$ = **0.311**
- $N_{RMG\ output}$ = **31.1%** $N_{Crankshaft}$

6.13.6. Calculation of reverse gear

The conditions for reverse gear are different so as to avoid an excessively high engine speed:

- RMG for reverse gear
- vehicle speed: 10 km/h (about 1400 rpm)

Repeat the procedure described above and calculate the input and output speeds, the gear ratio and the percentage:

- $N_{Crankshaft}$ = 60000 / 116.33 = **515.77 rpm**
- $N_{RMG\ output}$ = 60000 / 1590 = **37.74 rpm**
- $G_R = N_{RMG\ output} / N_{Crankshaft}$ = **0.073**
- $N_{RMG\ output}$ = **7.3%** $N_{Crankshaft}$

6.13.7. Calculation of the differential gear ratio

The number of teeth on the differential's pinion and ring gear are: 16 x 53. Write down the equation which will let you calculate the differential gear ratio. Calculate this ratio.

- R_{Diff} = Number of drive pinion teeth/Number of driven ring gear teeth
- R_{Diff} = 16 / 53 = **0.302**

6.13.8. Conclusion

Complete the summary table below:

Gear	Ratio of RMG input/output (total gearing)	Differential gear ratio	Gear ratio ($R_{i/o}/R_{Diff}$)
1st	**0.078**	0.302	**0.258**
2nd	**0.136**	0.302	**0.450**
3rd	**0.195**	0.302	**0.646**
4th	**0.252**	0.302	**0.834**
5th	**0.311**	0.302	**1.03**
R	**0.073**	0.302	**0.242**

Refer to the teeth data for RGM gear wheels (1st column of the table). Complete the table by indicating the gear ratio, total gearing and, in the last column, the RMG gear to which the line relates.

Gear wheel tooth numbers	Differential gear ratio	Gear ratio	RMG ratio (total gearing)	RMG gear
41x35	0.302	**1.171**	**0.354**	**5th**
20x39	0.302	**0.513**	**0.155**	**2nd**
37x39	0.302	**0.949**	**0.287**	**4th**
12x30x43	0.302	**0.279**	**0.084**	**R**
12x41	0.302	**0.293**	**0.088**	**1st**
30x41	0.302	**0.732**	**0.221**	**3rd**

Copy into the table below the values obtained previously.

RMG gear	1st	2nd	3rd	4th	5th	R
Total measured ratio	**0.078**	**0.136**	**0.195**	**0.252**	**0.311**	**0.073**
Total calculated ratio	**0.088**	**0.155**	**0.221**	**0.287**	**0.354**	**0.084**

The differences are due to measurement inaccuracy and to the various rounding errors in the calculations.

6.13.9. Application

Consider the following example. A vehicle is running with an engine speed of 3000 rpm and is fitted with 185 / 60 R 15 tires (1 inch = 2.54 cm). Calculate the theoretical road speed of the vehicle for each RMG gear (use the measured gearbox ratios and then the calculated ratio).

Wheel circumference:

Inner rim: 15 x 2.54 = 38.1 cm; Sidewall of tire: 18.5 x 0.6 = 11.1 cm; Total diameter: 38.1 + (2 x 11.1) = 60.3 cm; Wheel circumference: π x 0.603 = **1.894 m**

RMG output speed, in 1st gear: N = 3000 x 0.088 = 264 rpm
Vehicle speed: V_1 = 1.894 x 264 = 500 m/min i.e. 500 x 60 / 1000 = **30 km/h**

RMG gear	1st	2nd	3rd	4th	5th	R
Theoretical road speed using the measured ratio (in km/h)	**26.6**	**46.4**	**66.5**	**85.9**	**106**	**24.9**
Theoretical road speed using the calculated ratio (in km/h)	**30**	**52.8**	**75.3**	**97.8**	**120.7**	**28.6**

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	Name of component
EXXOTEST	**MT-BVR**	**BENCHTOP LEARNING MODEL: Robotized Manual Gearbox**

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.

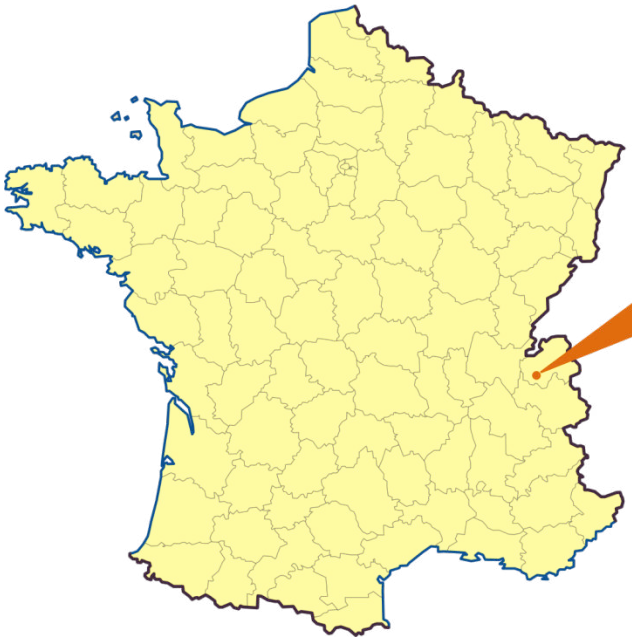
II – has been manufactured in compliance with the requirements of European directives relating to the design of Electrical & Electronic Equipment (EEE) and the management of Waste Electrical & Electronic Equipment (WEEE) in the EU :

- 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 Saint-Jorioz on 24 July 2007

Stéphane Sorlin, Chairman

Latitude: 45° 53' 49" / Longitude: 6° 4' 57"



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S.A.S. with share capital of €276 000 - RC ANNECY 80 B 243 - SIRET 320 140 619 00042 - APE 2651B – VAT No. FR 37 320 140 619
ISO 9001: 2008 FQA No. 4000142 by L.R.Q.A.