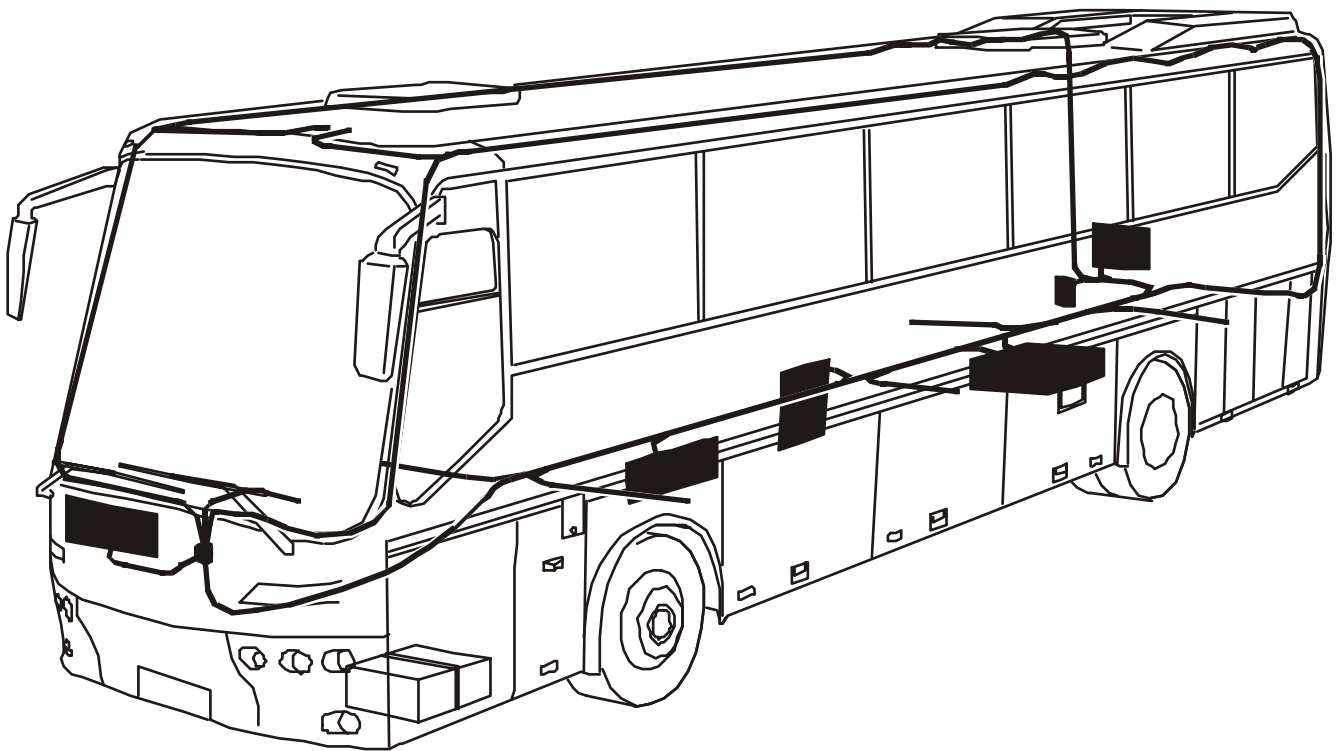


# ELECTRICAL SYSTEM

## Workshop Manual



M10292

*Futura*

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Article: electrical system

Version: 1.0/01-2003

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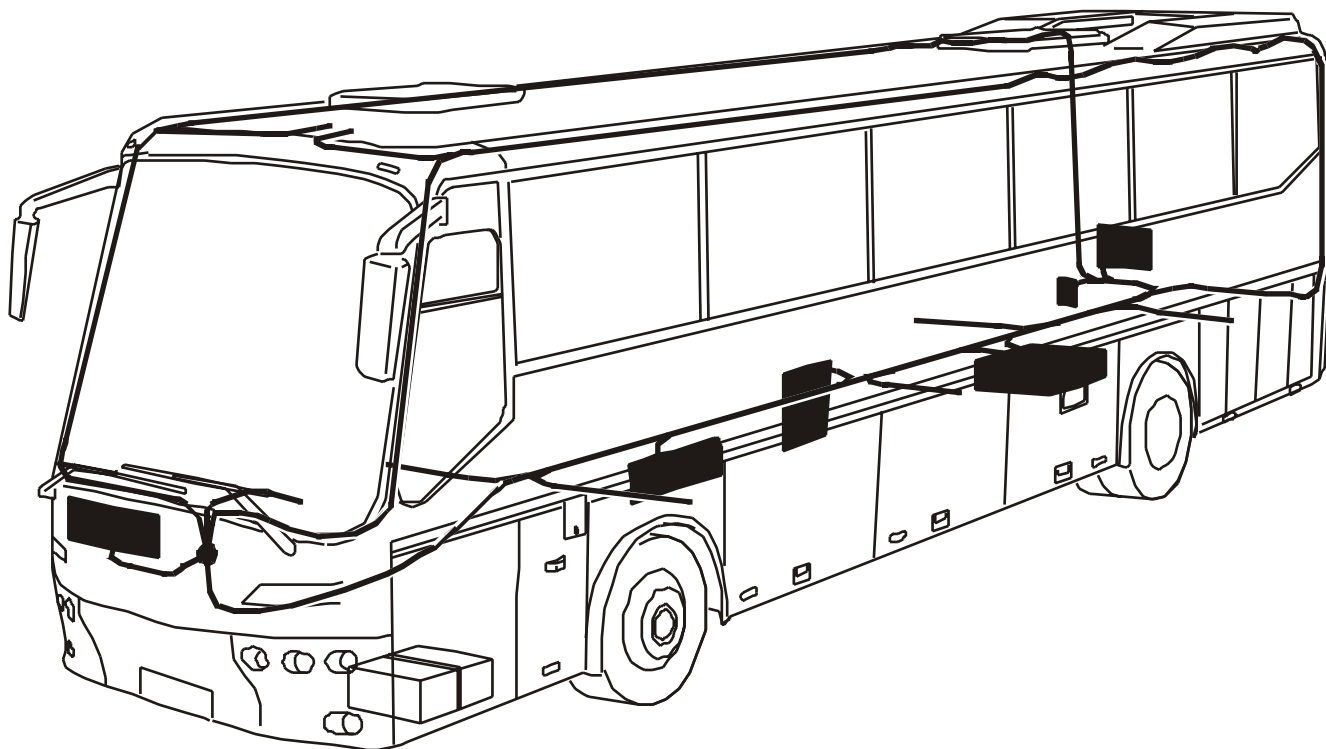


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# 1. Introduction



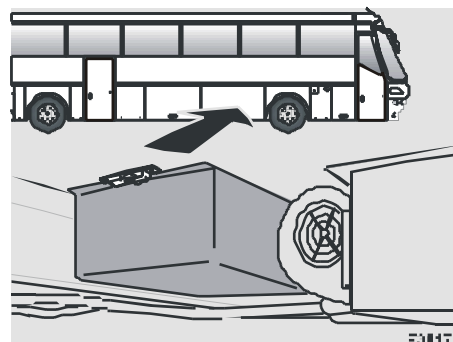
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This workshop manual has been developed with the greatest possible care by Autobusfabriek BOVA b.v. It is intended as a source of information during faultfinding and provides guidelines with regard to the replacement of parts.

Autobusfabriek BOVA b.v. however is not liable for any damage and/or costs arising from wrong or lacking data. Therefore, no rights can be derived from the workshop manual. Adjusting and test data may change due to technical developments and changing work methods. We, therefore, advise you to leave repairs to authorised BOVA dealers, whose practical and theoretical knowledge of the BOVA product is kept up to date by regular refresher courses.

A warranty, laid down in the locally valid sales and delivery conditions, applies to the repairs carried out by BOVA dealers. This warranty does not apply any longer when repairs have been carried out by personnel which has not been trained by BOVA. Thus damage resulting from this and damage caused by the use of non-original parts will not be covered by our warranty.

This is a general description of the coach electrical system which is used in the BOVA Futura. For specific information of the electrical system of your coach please use the binder with electrical diagrams provided at your coach. In the figure below you see the location of the storage box where the binder with electrical diagrams is in.



As from introduction of the euro III engines the powertrain of the Futura's use CAN communication. CAN means Controller Area Network.

In this manual we will try to explain the setup of the various electrical systems step by step. Furthermore we will try to add some basics of electric systems, like:

- Basics of electrics
- Controller Area Network (CAN)
- Fault tracing



## 2. Safety instructions

### 2.1 General

- When working on a BOVA coach always act according the safety instructions of the specific system.
- Only technicians trained and authorised by Bova are allowed to work on Bova products.
- Work carried out by non-authorised persons is dangerous and will affect the warranty.
- Always use durable tools and approved special tools.
- Always keep the workspace clean.
- Always guard personal safety.
- Always switch off the main switch and disconnect the battery clamps when working on parts of the electrical system.
- Protect the vehicle from rolling.

### 2.2 Specific

- Be alert to keep safe from moving parts.
- Protect the engine from starting.
- Only disconnect connectors if the battery clamps are disconnected.
- Never do ohm measurements on ECU's.
- Never do ohm measurements on wiring connected to ECU's or on wiring when the battery clamps are connected.
- Use testing tools approved by BOVA or a led tester or a multimeter in order to test the electrical system.



**Never use a test light with an ordinary bulb because that will damage the ECU's**



## 3. Environmental information

### 3.1 General

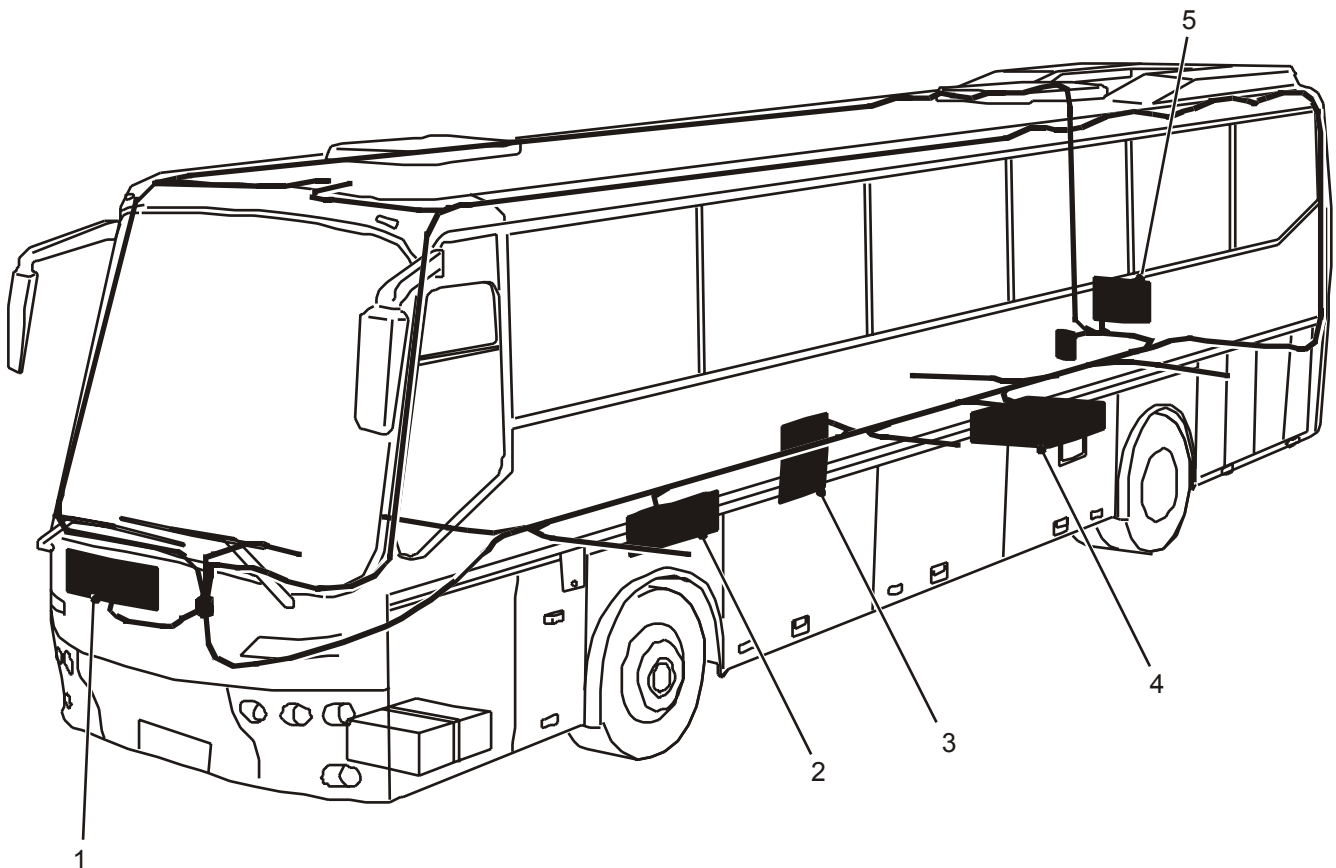
- Always follow local environmental regulations.

### 3.2 Specific

- Always read and follow the instructions on products used while cleaning or maintaining.
- Dispose of waste according to local environmental regulations.

## 4. System description

### 4.1 General



- 1 Front electro box
- 2 Electro panel luggage compartment
- 3 Electro panel toilet/kitchen

- 4 Central electro panel
- 5 Rear electro box

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The electrical system can be divided into an ordinary electrical system and a CAN (Controller Area Network) system.

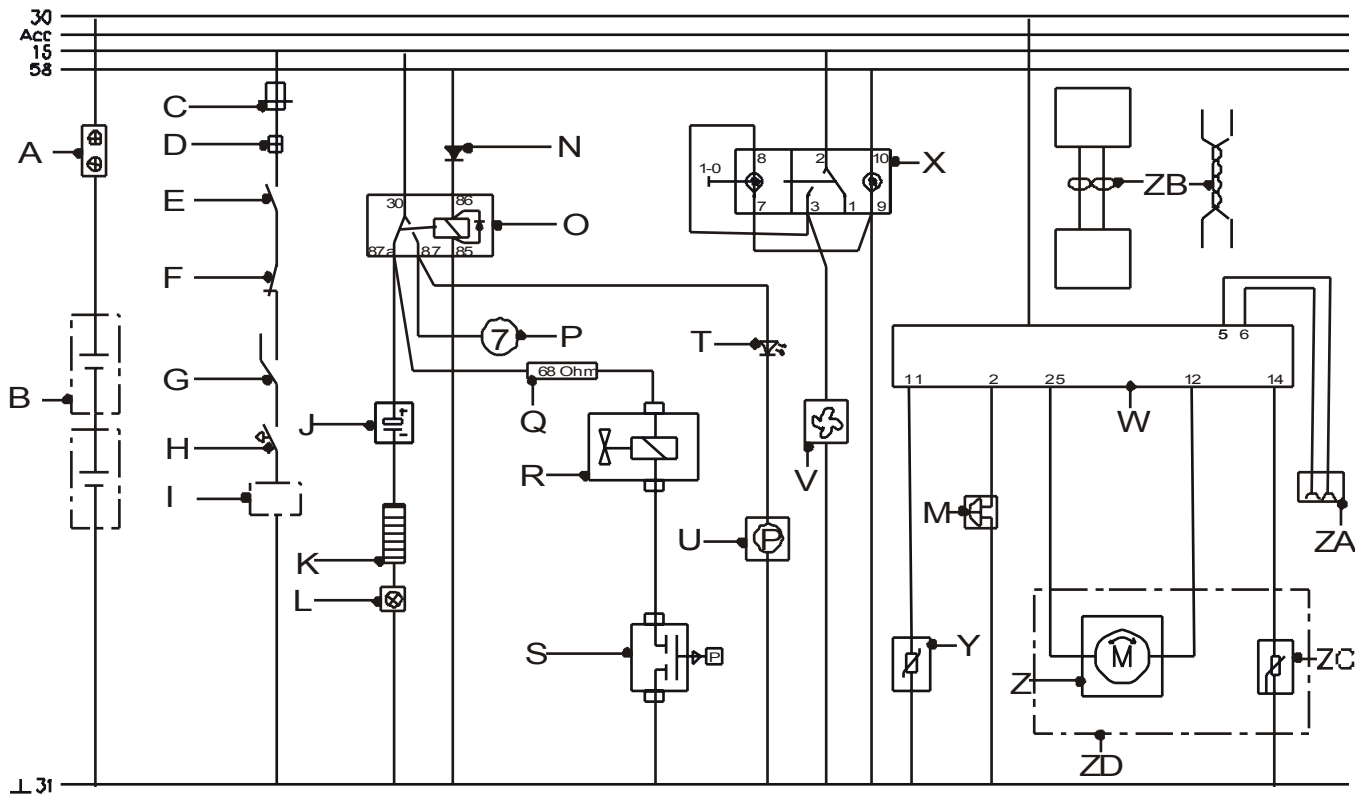
The main parts of the ordinary electrical system are located in the five electro boxes and the dashboard.

The main parts of the CAN system are located in the engine compartment (UPEC), the central electro panel (ABS, EST 42 and CXB) and in the dashboard (MTCO tachometer).

With help of the electrical diagrams provided with your coach you can check the various systems.

All electrical diagrams are drawn to a fixed standard. Sometimes the electrical diagrams of one system are drawn on several pages. If you lay all pages side by side, you will have the complete diagram of that specific system. There is a register to every diagram in a number of languages. The numbers in the electrical diagram correspond with the numbers in the register.

## 4.1.1 Electrical diagrams



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- |                                    |  |
|------------------------------------|--|
| <b>A</b> Connection block          | <b>P</b> Reference to another diagram          |
| <b>B</b> Battery                   | <b>Q</b> Resistor                              |
| <b>C</b> Fuse                      | <b>R</b> Electro magnetic valve                |
| <b>D</b> Connectors                | <b>S</b> Pressure switch (1-0, means on/off)   |
| <b>E</b> Make contact              | <b>T</b> Led                                   |
| <b>F</b> Break contact             | <b>U</b> Pump                                  |
| <b>G</b> Make and/or break contact | <b>V</b> Fan                                   |
| <b>H</b> Spring return contact     | <b>W</b> Control unit                          |
| <b>I</b> Device                    | <b>X</b> Switch                                |
| <b>J</b> Capacitor                 | <b>Y</b> Temperature sensor                    |
| <b>K</b> Heating element           | <b>Z</b> Regulating motor                      |
| <b>L</b> Lamp                      | <b>ZA</b> Diagnose connector                   |
| <b>M</b> Buzzer                    | <b>ZB</b> Twisted wire                         |
| <b>N</b> Diode                     | <b>ZC</b> Position sensor                      |
| <b>O</b> Relay                     | <b>ZD</b> Frame means that it is one component |

### Explanation of the electrical diagram

The lines on top of the diagram are the + lines.  
The line at the bottom of the diagram is the earth line.

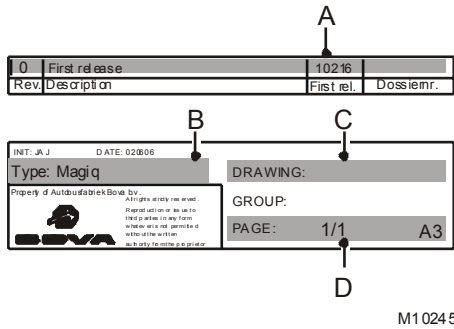
- 30 = Constant power supply.
- Acc = Power supply with main switch on.
- 15 = Power supply with ignition on.

- 58 = Power supply with lamps on.
- 31 = earth.

All diagrams are drawn in the power off situation. This means that electrical power is not present, and that airpressure is not present.

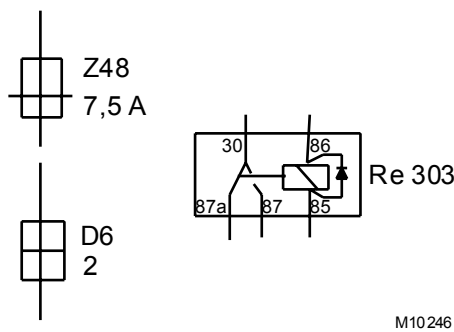
### Coding of the electrical diagrams

At the bottom of an electrical diagram you can find at the left side the subject for which this diagram is valid. At the right side there are two frames, side by side. In the figure below they are drawn below each other.



- A** Chassis number when the drawing is released or changed
- B** Type of vehicle
- C** Drawing number
- D** Number of pages

In the electrical diagram there are connectors, fuses and relays with a code to it.



- Z48** Fuse code Z48 tells you where to find this fuse.  
 Fuse 1 - 199 in the front electro box  
 Fuse 200 - 269 in the central electro panel  
 Fuse 270 - 299 in the electro panel toilet/kitchen (if there is no toilet or a "floor mounted toilet" these fuses are also in the central electro panel)  
 Fuse 300 - 332 in the electro panel in the luggage compartment  
 Fuse 350 - 400 in the rear electro box
- 7,5 A** Tells you what the value of the fuse is in Ampere.
- D6** Connector code where D tells you something about the location in the vehicle, which will be explained later on in this manual.
- 2** Connector code where 2 tells you which contact of the connector.

- Re 303** Relay code Re 303 tells you where to find this relay.  
 Relay 1 - 199 in the front electro box  
 Relay 200 - 269 in the central electro panel  
 Relay 270 - 299 in the electro panel toilet/kitchen (if there is no toilet or a "floor mounted toilet" these relays are also in the central electro panel)  
 Relay 300 in the electro panel in the luggage compartment  
 Relay 301 - 330 in the rear electro box

### Abbreviations

In the electrical diagrams we also use abbreviations like:

Sk	Switches
Cl	Control light
Br	Diode block
Dm	Diode matrix
Di	Diode
W	Resistor
P	Capacity

### Fuses and relays

All fuses and relays are located in the 5 electro boxes. In every electro box there is a fuse and relay list for that specific box. On that list there is a drawing for the positions of the fuses and relays completed with a register with a definition of the functions in the language of the country where the coach is registered.



**In the storage box in the luggage compartment there is a binder with all fuse and relay lists and electrical diagrams for that coach in five languages.**

### Colour code of the fuses

BOVA uses ATO plug fuses. All fuses have a specific colour and on every fuse the value in Ampere is mentioned.

Colour	Value
Black	1A
Grey	2A
Purple	3A
Pink	4A
Light brown	5A
Dark brown	7,5A
Red	10A
Blue	15A
Yellow	20A
Transparent	25A
Green	30A

### Colour code of the wires

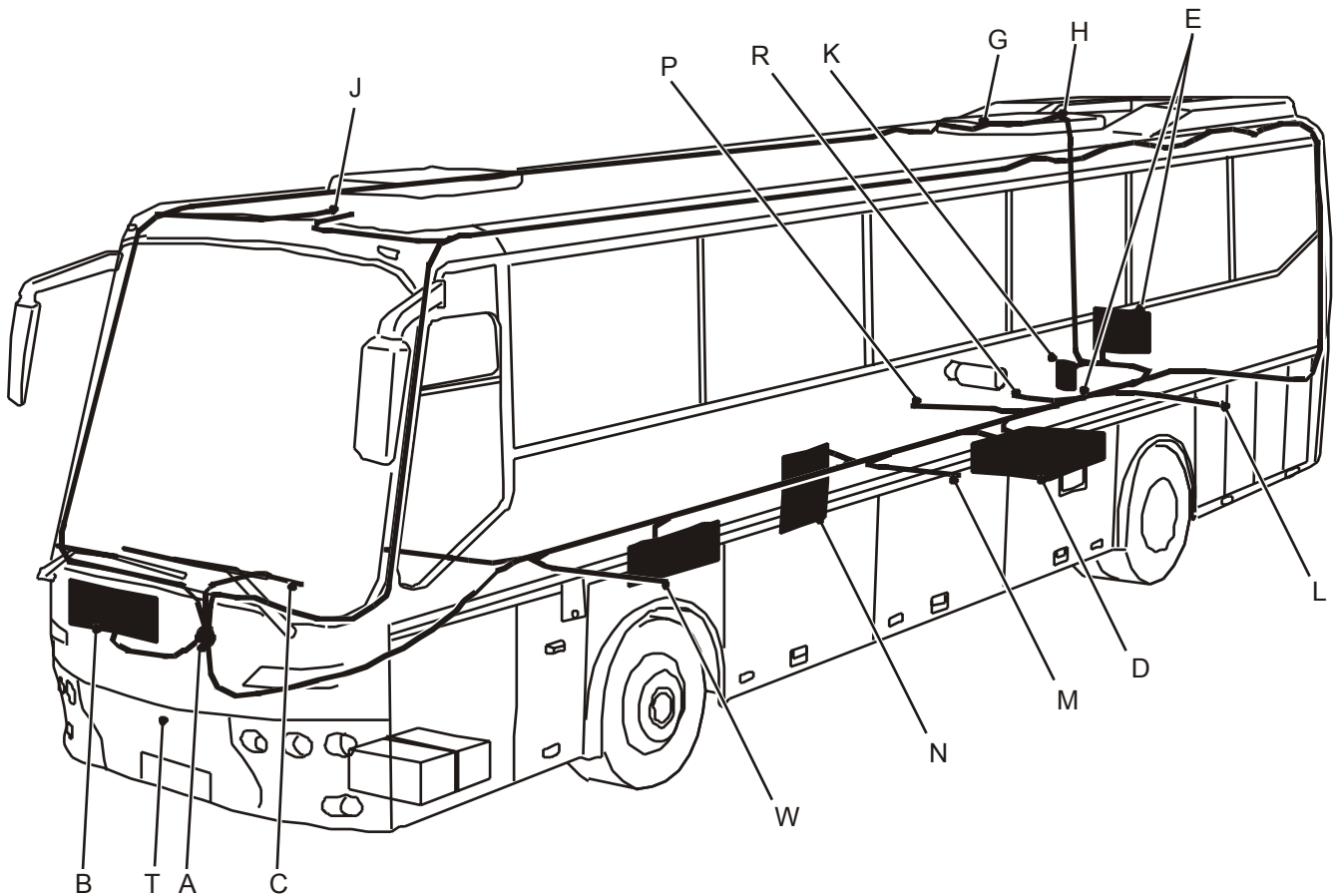
Every wire in the diagram has a colour code:

- RD = Red
- WT = White
- BN = Brown
- GN = Green
- GS = Grey
- GL = Yellow
- OE = Orange
- ZT = Black
- BW = Blue
- PS = Purple
- RE = Pink

Wires can have these colours or a combination of 2 of these colours. The colour is also shown in the electrical diagram, next to the wire. The electrical diagram gives the code one time per wire. For example, a wire carries the code GL/GS. This means that the wire is Yellow and Grey. At some wires you can find a code: For example PS2, which means the colour is Purple and the diameter of the wire is 2 mm<sup>2</sup>.

1 mm<sup>2</sup> is the standard and is therefore not mentioned.

## 4.1.2 Connector locations

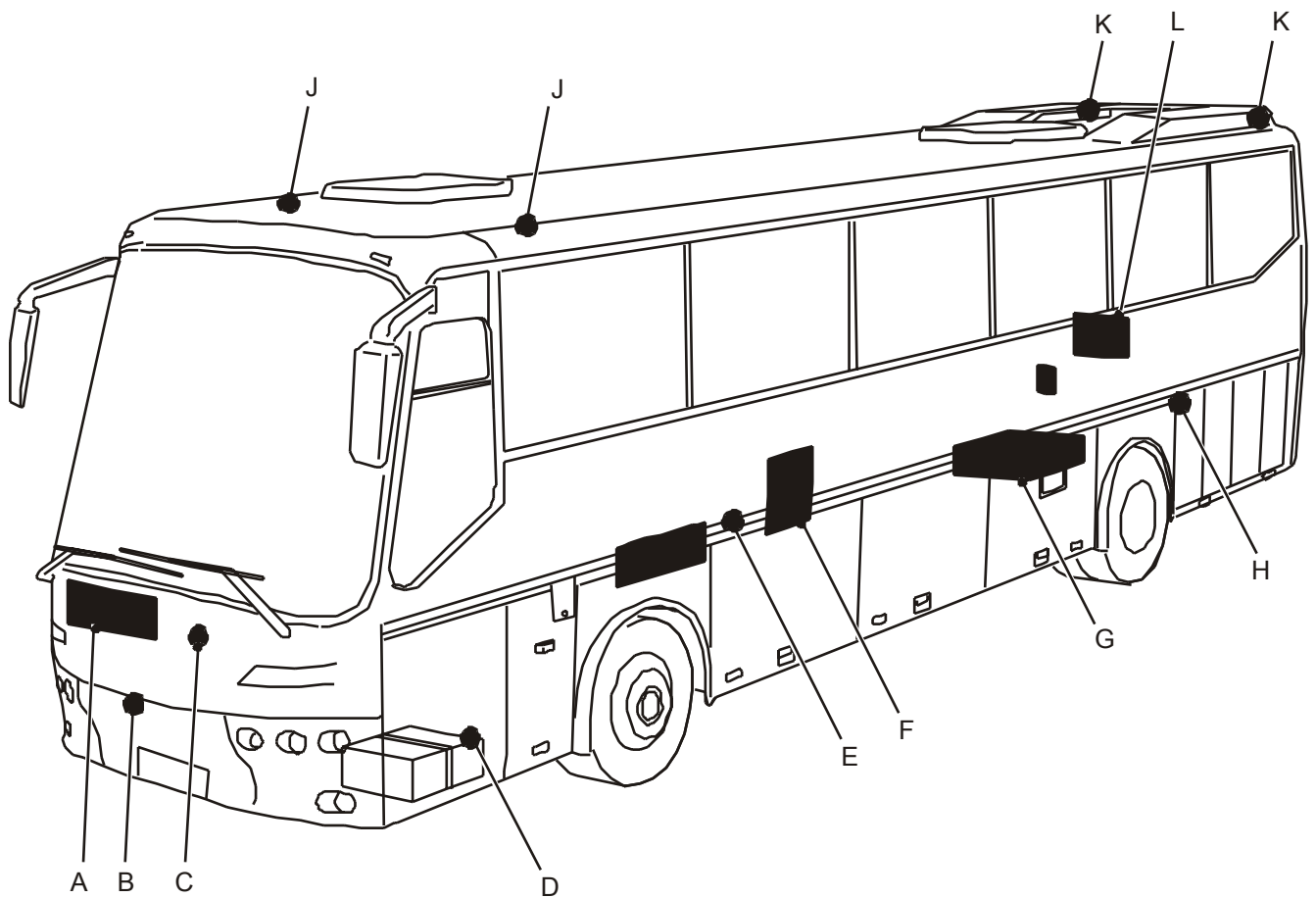


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- |   |   |
|---|---|
| <b>A</b> Behind the middle dashboard section in front of the vehicle                  | <b>K</b> In the box at the airco compressor                       |
| <b>B</b> In the front electro box   | <b>L</b> At the cooling fan                                       |
| <b>C</b> In the dashboard in front of the driver                                      | <b>M</b> In the main luggage compartment                          |
| <b>D</b> In the central electro panel   | <b>N</b> At the electro panel toilet/kitchen and the central door |
| <b>E</b> In the rear electro box and the rear side of the coach and above the gearbox | <b>P</b> In the extra luggage compartment                         |
| <b>G</b> In the roof from the middle to the rear of the coach                         | <b>R</b> Near the gearbox   |
| <b>H</b> At the rear end top of the coach   | <b>T</b> Lower front end  |
| <b>J</b> At the front end top of the coach  | <b>W</b> Near all the wheels                                      |

A character and a number make the connector number. The character indicates the location of the connector in the vehicle. The number in the code is a follow up number, and has no further meaning.

### 4.1.3 Earth points

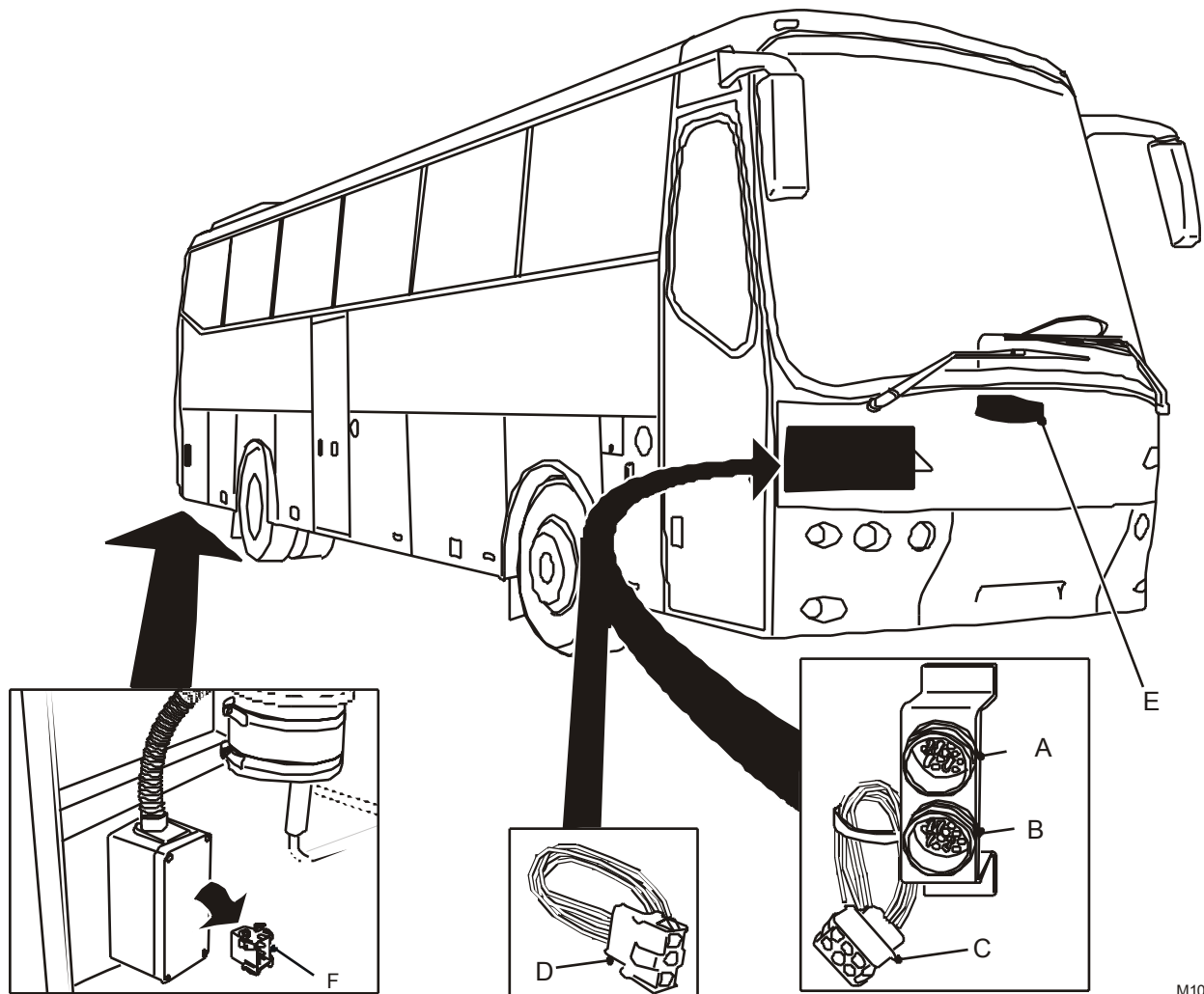


M10296

- |   |   |   |                                 |
|---|---|---|---------------------------------|
| A | Front electro box   | G | Central electro panel           |
| B | Lower front end   | H | Near the condenser of the airco |
| C | Behind the middle dashboard section in front of the vehicle | J | At the top front of the coach   |
| D | Batteries   | K | At the top rear of the coach    |
| E | Frame under aisle   | L | In the rear electro box         |
| F | Electro panel toilet/kitchen                                |   |                                 |

In the coach there are several earth points *without* a specific code. For the location see figure above.

## 4.1.4 Diagnostic connectors



M102.97

- |  |   |
|--|---|
| <p><b>A</b> UPEC (connector B60)</p> <p><b>B</b> CAN extension box (connector B23)<br/>Hydraulic system (connector B23)<br/>ABS/ASR (connector B23)<br/>Futurair (connector B23)</p> | <p><b>C</b> Retarder EST 42 (connector B59)</p> <p><b>D</b> Automatic gearbox 5HP 600 (connector X25 ZF)</p> <p><b>E</b> Tacho</p> <p><b>F</b> Pre-heater</p> |
|--|---|

You can find diagnostic connectors on three places in the coach. In the front electro box you find the diagnostic connectors for UPEC, the hydraulic system, the ABS/ASR system, the Futurair system, the retarder, the CAN extension box and when the vehicle has an automatic gearbox there is also a diagnostic connector for the automatic gearbox. In the pre-heater compartment located in the electro box there is a diagnostic connector for the pre-heater. The diagnostic connector for the tachometer is on the tachometer itself.

### UPEC

Connector B60 is the diagnostic connector for the UPEC system. The diagnostic tool for UPEC is DAF DAVIE XD.



**Using DAF DAVIE XD it is also possible to diagnose the ABS/ASR system and the retarder.**

### CAN Extension Box (CXB)

Connector B23 is the connector for loading software and not for diagnosis.



### **Hydraulic system**

Connector B23 is the diagnostic connector for the hydraulic system. The diagnostic tool for the hydraulic system is named winluft 3 which you can order at our parts department.

### **ABS/ASR system**

Connector B23 is the diagnostic connector for the ABS/ASR system. The diagnostic tool for the ABS/ASR system is the WABCO diagnostic controller (or DAF DAVIE XD in combination with connector B60). The ABS/ASR system also has a blinkcode. For information about that blinkcode you have to contact the service BOVA department or your local WABCO dealer.

### **Futurair**

Connector B23 is the diagnostic connector for the Futurair system and can be done with help of the WABCO diagnostic controller together with a test card which you can order at our parts department (for now only in the German language).



**You can order a translation sheet for the test card from German into English; French; Italian; Swedish and Danish. The order number is: 237144**

### **Retarder (EST 42)**

Connector B59 is the diagnostic connector for the control unit of the retarder. The diagnostic tool for the control unit is ZF Testman (laptop) or Mobidig (or DAF DAVIE XD in combination with connector B60).

### **Automatic gearbox 5 HP 600**

Connector X25 (ZF) is the diagnostic connector for the control unit of the automatic gearbox and is located in the front electro box behind the fuse panel. Diagnosis can be done with help of ZF Testman (laptop) or Mobidig.

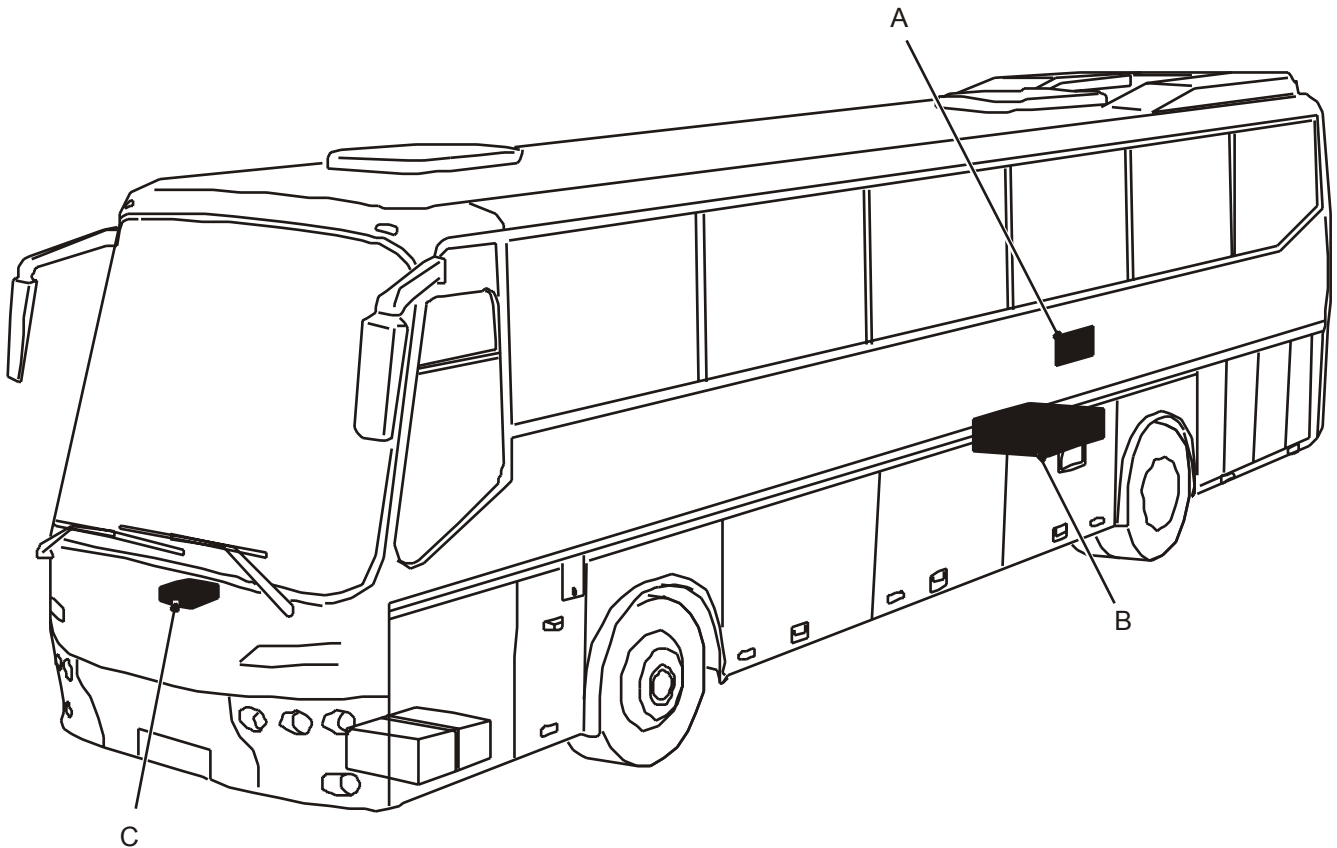
### **Tacho**

Diagnosis of the tacho is only allowed by authorised workshops and can be done on the device it self. There is also a possibility to read faults from the display.

### **Pre-heater**

In the electro box of the pre-heater compartment you can find the diagnostic connector. Diagnosis can be done with help of a laptop and a special program. For information about that diagnostic program you have to contact the BOVA service department or your local Webasto dealer.

## 4.2 CAN system



M102.98

**A** UPEC

**C** MTCO Tacho

**B** ABS/ASR, EST 42 and CXB

### 4.2.1 General

The CAN (Controller Area Network) system is introduced in the Futura in order to:

- Reduce costs
- Reduce weight
- Reduce wiring
- Reduce sensors and actuators
- Increase reliability
- Increase possibility of diagnosis

You can compare the CAN system with a computer network. A CAN system can send electrical signals for several actuators or sensors at the same time through one wire. This is called "multiplexing".

You can divide the system in hardware and software.

The hardware contains of:

- ECU's for UPEC, ABS, EST 42, CXB and MTCO Tacho.

UPEC is located in the engine compartment. ABS/ASR, EST 42 and CXB are located in the central electro panel and the MTCO tacho is located in the dashboard.

The ECU's communicate via CAN (Controller Area Network) lines with each other. Every ECU receives and sends signals from and to the other ECU's by CAN lines. In the ECU's the CAN signals are converted to analog signals and digital signals and vice versa. Every ECU has connection with sensors and actuators. At the command of an ECU the other ECU's can activate the actuators. All ECU's base the command on sensor information and the software which is programmed in each ECU.

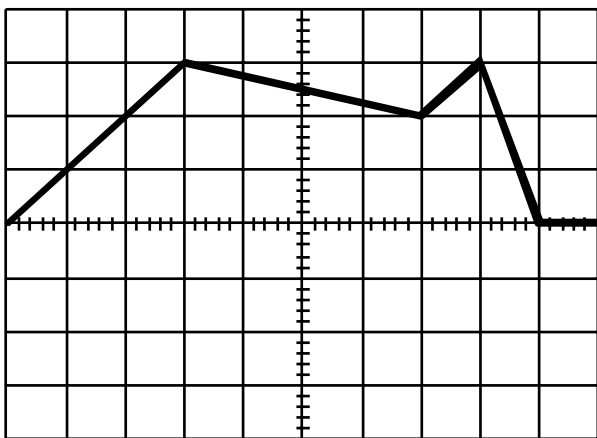
## 4.2.2 Multiplex

### Analog and digital signals

The difference between an analog system and a digital system can be compared to a flood gate. This flood gate can be closed, half open, and completely open. Between opened and closed, the door can take any position. This results in a completely variable waterflow. The flood gate operates as an analog system, or stepless. If the flood gate can only be open or closed, the only way to manage the waterflow is constantly opening and closing the door. If the opening of the flood gate is not stepless, then the flood gate operates as a digital system, or with steps.

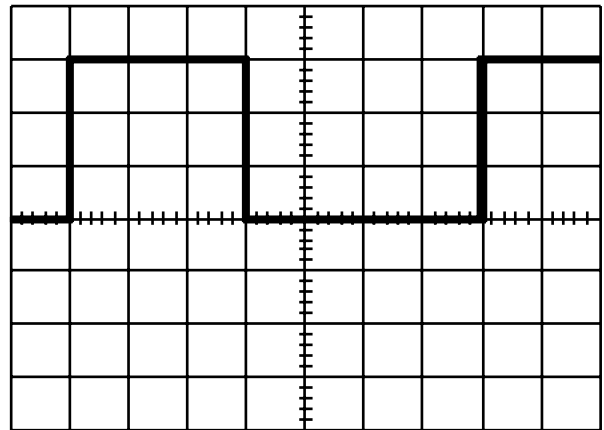
A potentiometer in an electrical system makes the signal analog. For example, you can adjust the light intensity of a lamp, stepless. If, instead of the potentiometer, there is a switch, the lamp can only be on or off. Now the electrical system operates as a digital system. It is possible to simulate the potentiometer with the switch. In order to do this, you have to operate the switch with a high frequency.

If the analog signal is presented on a scope, the signal can look like:



M10265

If the digital signal is presented on a scope, the signal can look like:



M10267

### Binary signals

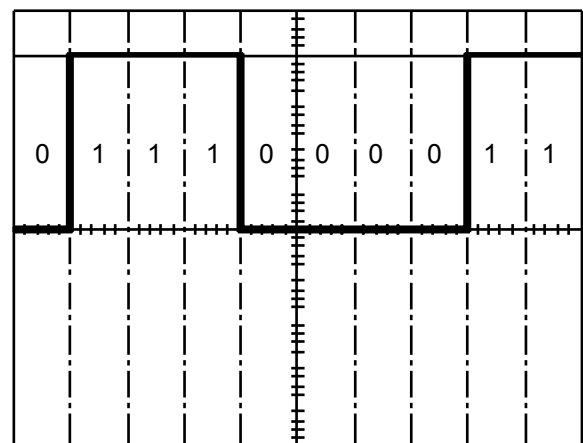
Binary signals are often used in digital signals. Binary is that the signal only can have 2 stable conditions. These stable conditions are voltage and no voltage.

To the conditions voltage and to no voltage the numbers 1 and 0 are awarded. This means:

- 0 = no voltage
- 1 = voltage

If the signal is divided in equal pieces, and the signal is awarded with binary values, the signal will look as in figure M10268. Every piece of this signal is called a bit. Bit means binary digit. The total binary signal is a bit combination. The bit combination of the signal in the picture is:

- 011100011



M10268

A correct binary signal will go on for ever. Other bit combinations can also occur, like:

- 11100011011

The digital system does not know what to do, it does not know where to start. For this reason the agreement is that the bit combination has a predetermined amount of bits. A common bit combination is the 8-bit combination. This 8-bit combination is called a byte, and is often used in computer systems. If a bit combination of 1 bit is agreed, only 2 values can be awarded. Therefore, it is better to have more bits in a bit combination. At this point you can award more functions. If a bit combination of two bits is agreed, the following different bit combinations are possible:

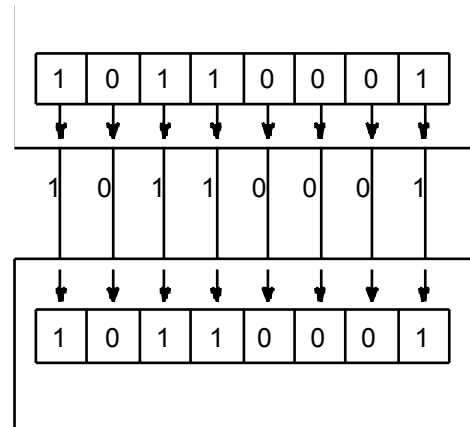
- 00
- 01
- 10
- 11

Now it is possible to award 4 different values. In a bit combination of "n" bits the total amount of values is  $2^n$ . This means that 1 byte has  $2^8 = 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 = 256$  values.

The CAN system is a 16-bit system.

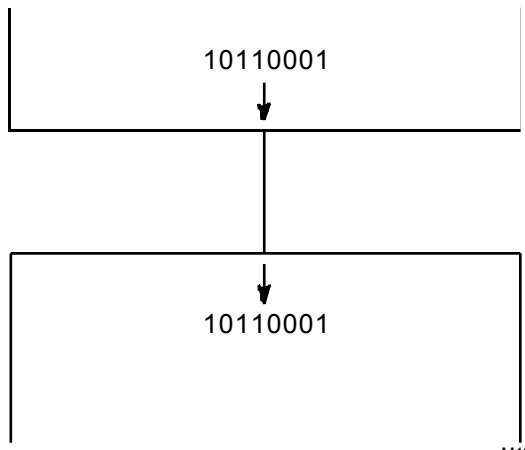
**Parallel and serial communication**

It is possible to send every bit of a bit combination over a separate wire. For an 8-bit system this would look like:



M10269

This method of sending a binary signal is called parallel communication. You can also send the complete byte over 1 single wire. This would look like:



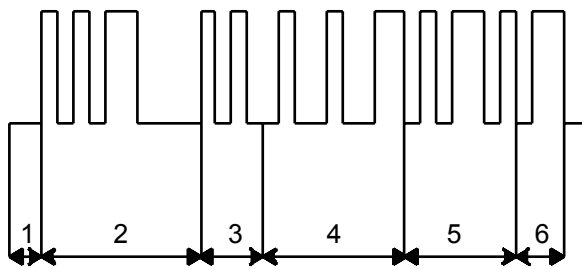
M10270

This method of sending a binary signal is called serial communication.

### The Controller Area Network (CAN) protocol

The CAN is a serial communications protocol. In automotive electronics, engine control units, sensors and so on, are connected using CAN. CAN reduces the amount of wiring in the vehicle body, and is cost effective. Most CAN systems use two twisted wires in order to exchange information between processing units. Every processing unit in the CAN system is capable of sending and of receiving. The system can send information and receive information at the same time. For data transmission, a particular processing unit is not addressed. The content of a message is designated by an identifier unique throughout the network. The identifier defines the content of the message and the priority of the message. This is important for allocation of the CAN wire if several processing units are competing for access to the CAN wire. A frame with data is divided into 6 parts. These parts are:

- Start of frame
- Priority level
- Length of the data
- Data
- Data check
- End of frame

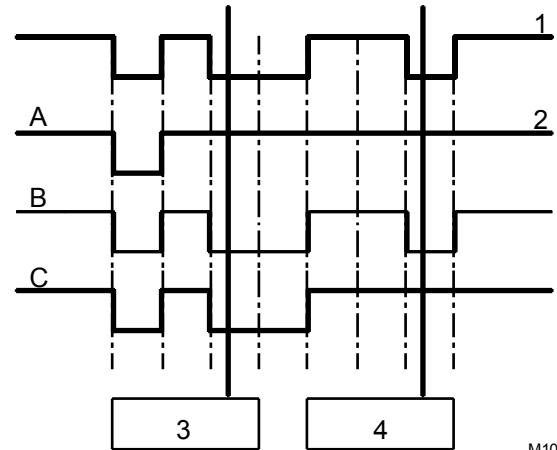


M1 02 71

- 1 Start of frame
- 2 Priority level
- 3 Length of the data
- 4 Data
- 5 Data check
- 6 End of frame

The start of frame signal alerts processing units that there is data coming. In the priority level signal, the sender tells the receiver the importance of the message. In this signal a "0" is dominant and a "1" is recessive. The more "0" there are the higher the priority. Example: 3 processing units send a message at the same time. Processing unit A sends a prioritylevel 0111111 message, processing unit B sends a prioritylevel 0100110 message, and processing unit C sends a prioritylevel 0100111 message. At the third bit,

processing unit A has a "1" in the prioritylevel, processing units B and C have a "0". Processing unit A has the lowest prioritylevel. At the seventh bit processing unit B has a "0" in the prioritylevel whereas processing unit C has a "1". Processing unit B has the highest prioritylevel. At the moment a processing unit has sensed a lower prioritylevel the processing unit stops transmitting.



M10272

- 1 Recessive
- 2 Dominant
- 3 A loses
- 4 C loses

The length of data signal informs the processing unit about how many bits of information to expect.

The data signal contains the actual information that was sent. In order to see if the received signal contains the correct information, the data-check signal is used. The end of frame signal indicates that no more information will be sent in this signal. If a processing unit sends a message to 1 or more processing units, the processing unit passes the data to the CAN bus. The other processing units now become receivers of the data. Each processing unit can determine if the data received is relevant for that processing unit. If the data is relevant, the data will be processed, otherwise, the data will be ignored.

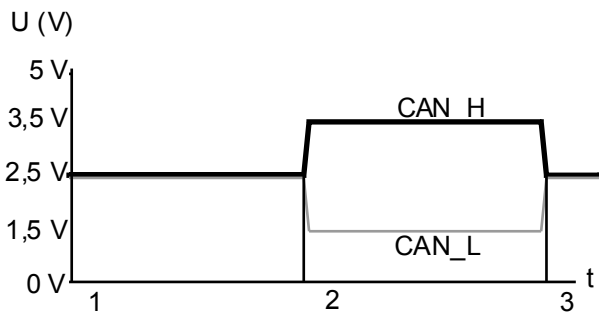
CAN systems most of the time have 2 wires. The first is CAN high (CAN\_H), the other is the CAN low (CAN\_L). The CAN\_H carries a high voltage (2.5 Volt - 5 Volt). The CAN\_L carries a low voltage (0 Volt - 2.5 Volt).

A recessive state (1) on the CAN\_H wire will show a low voltage. On the CAN\_L wire the recessive state will show a high voltage. A dominant state (0) on the CAN\_H wire will show a high voltage. On the CAN\_L wire the dominant state will show a low voltage.

### Voltages on the CAN wires

	Recessive state (1)	Dominant state (0)
CAN_H	low voltage ( $\pm 2.5V$ )	high voltage ( $\pm 3.5V$ )
CAN_L	high voltage ( $\pm 2.5V$ )	low voltage ( $\pm 1.5V$ )

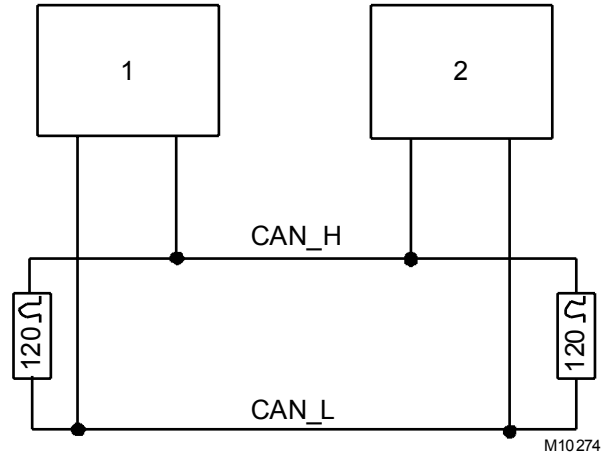
The processing units detect a recessive state if the voltage of CAN\_H is not higher than the voltage of CAN\_L + 0.5 Volt. If the voltage of CAN\_H is higher than CAN\_L + 0.9 Volt, then a dominant state of the vehicle will be detected.



M10273

- 1 Recessive
- 2 Dominant
- 3 Recessive

A resistor connects the CAN\_H wires and the CAN\_L wires. This makes the CAN wiring like a ring. The resistor between CAN\_H and CAN\_L is in order to minimize reflection effects on the vehicle. The CAN system is insensitive to electromagnetic interference because of the twisted wire and also because the CAN system itself measures the difference between CAN\_H and CAN\_L, so when there is an interference on the CAN wires the difference between CAN\_H and CAN\_L is probably still the same.



M10274

- 1 Node 1
- 2 Node n

## 4.3 Fault tracing

### 4.3.1 Way of thinking

Fault tracing is not the use of equipment and information of the system you have. These are just tools to find a fault. Fault tracing in fact is "a way of life".

By thinking systematically or "Thinking as an ECU" in combination with the tools, you will find the cause of the fault. If one of these factors is not present it will be very difficult to find the cause of a fault.

Later on in this manual we will explain the possibilities and the impossibilities of the various tools. At the moment we first try to explain thinking systematically or "Thinking as an ECU".

At thinking systematically, first of all, it is important to know on what principle the system is based (controlling or regulating), and what is the intention of the system (when will what happen).

### 4.3.2 Controlling or regulating

When 'controlling' we think of the process without measuring the result (no feedback). This is also called "open loop".

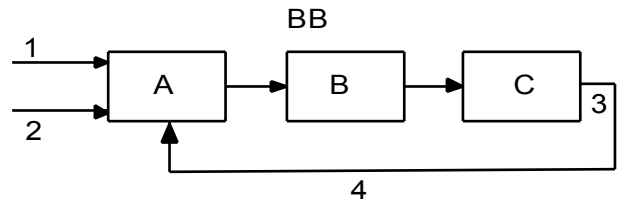
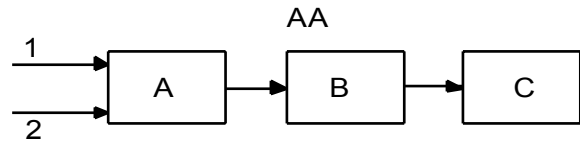
When 'regulating' the result will be measured by a sensor. There will be feedback. This is a so called closed circuit (closed loop).



**It is a fact that all systems (not only electrical systems) function according to one of these two principles.**

Abstractly spoken every action is (mechanical, electrical or natural) the result of controlling or regulating.

Whether it is controlling or regulating, the regulator (ECU) will always try to neutralize the difference between the required-, and the actual value.



M10250

- AA** Principle of controlling
- BB** Principle of regulating
- A** Regulator
- B** Actuator
- C** Process
- 1** Required value
- 2** Actual value
- 3** Sensor
- 4** Feedback

When designing various control systems, one has looked to human acting very precisely. See for your self in the next examples.

#### Controlling

Something simple like a "toilet occupied" light is an example of controlling. At the moment that someone (regulator) closes the toilet (actuator), the "toilet occupied" light has to light (proces). The person in the toilet however does not know whether the light is burning. There is no feedback.

#### Regulating

Now the same example with someone (sensor) that will stay outside to see whether the light is burning (feedback). Someone (regulator) enters the toilet and closes the door (actuator), the "toilet occupied" light has to light (proces). The person who stayed outside (sensor) tells the person on the toilet whether the "toilet occupied" light is burning (feedback).

To stay at the same example, it is of course very important to know when the "toilet occupied" light should burn. For example: when the contact (actuator) is in the lock but the door is open the "toilet occupied" light should not burn when the lock is closed. In other words: it is important to think systematically and to know when what should happen.

### 4.3.3 Thinking systematically

It is important to know in which way the ECU gets all the different data:

- Required value (e.g. software or switch)
- Actual value (sensor)
- Feedback (sensor)

It is important to know how an ECU controls a process:

- Actuator (e.g. switch, injector or stepper motor)


It is important to know when an ECU acts when the required value differs from the actual value:

- Software (conditions, regulation strategy)

For this the ECU has several in-, and outputs, like a human has it's senses (sensors) and organs (actuators).

Above we have seen that controlling or regulating for every ECU in fact the same is, but however the moment of controlling or regulating depends on the software (brains).

By thinking out of the ECU we mean:



**What will the ECU “see”(values of sensors) before it controls something (actuator), and at which conditions will the ECU do this (software).**

As an example in practice we will take the automatically heated mirror which will be controlled by an ECU and which will be operated automatically when the temperature falls under 15°C.

#### Conditions:

- Constant supply present
- Supply via contact switch present
- Earth present
- Ambient temperature below 15°C

#### Sensors:

- Ambient temperature sensor

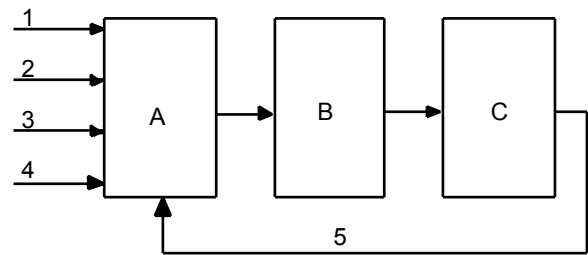
#### Actuators:

- Heating element in mirror

#### Feedback:

- Current measurement on the output of the ECU to the heating element of the mirror

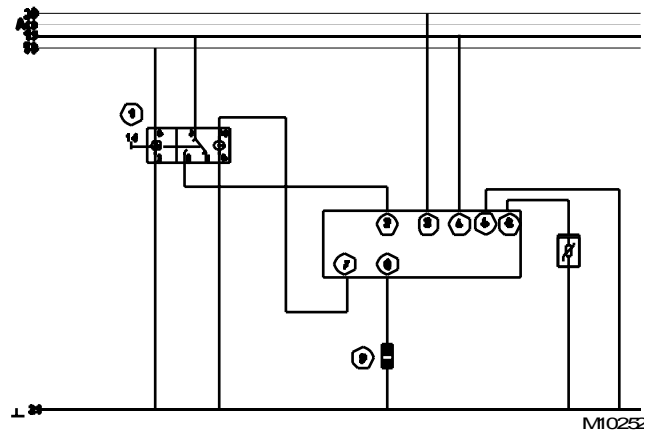
When you compare this with a principle diagram of a regulation, it looks like this:



M 1 0251

- 1 Constant supply
  - 2 Supply via contact switch
  - 3 Earth
  - 4 Ambient temperature (e.g. 10°C)
  - 5 Current measurement on output of ECU
- A ECU (regulation “on” when temp. is < 15°C)  
 B Heating element in mirror  
 C Current through heating element

In an electrical diagram it looks like:



M10252

- 1 Switch mirror heating
- 2 Mirror heating on
- 3 Constant supply ECU
- 4 +15 supply ECU
- 5 Earth supply ECU
- 6 Ambient temperature sensor
- 7 Indication heating on
- 8 Output mirror heating
- 9 Resistor mirror heating



To come back to “thinking out of the ECU” we will prove that in fact it is never difficult to solve a fault in the system

For a start, the software never can be the problem (or there has to be a bug in the program, but in a released system that will seldom or never happen). As software can not be damaged, there are only 2 possibilities left namely: the input or output (or the ECU itself, but that we will see when we checked the next few things).

When you, per example, find out that the mirror heating does not switch on automatically you start to work systematically according the block diagram, see: figure M10251.

- From left to right, or
- From right to left

Either you check from the sensor(s) up to the input(s), or from the output(s) up to the actuator(s) including connection (wiring when it is an electrical system, piping when it is a pneumatic or hydraulic system).

To check this you need tools which we will discuss now.

### 4.3.4 Tools

In the previous chapter we discussed what conditions we need to be able to solve a malfunction with the following tools. In this chapter we discuss the tools themselves and the possibilities and impossibilities of the tools.

By tools we mean (in random order):

- System description
- Electrical diagram
- Workshop manual
- Measurement equipment

#### **System description**

There almost always will be a description of the system you have to deal with. When you are creative you can get a lot of information out of the driver's manual, the maintenance manual, the sales brochure or even out of a general system description in an old school book.

This is important to determine the conditions in which the system functions and to understand the regulation or control.

#### **Electrical diagram**

The electrical diagrams of BOVA are set up according to the "cascade principle from supply to earth" in a way that you can get the following information:

- Type of supply (+30; +15; +58 etc.)
- Type of switch (single; double; spring return; air pressure; etc.)
- Value and number of the fuse (and with help of the fuse list also the location of the fuse)
- Connector number (and with help of the connector overview also the location of the connectors)
- Relay number (and with help of the relay list also the location of the relay)
- Colours of the wires
- Name (and therefore also the purpose) of the actuators and sensors (with help of the number in the diagram you can find it in the register of the diagram)
- If applicable: all used pin numbers of an ECU and also the purpose of this in-, or output.

All this information will give you a complete system overview. Together with the conditions in which the system functions (system description) and the required measuring tools, in most cases, you have enough information to search for a malfunction.

#### **Workshop manual**

The workshop manual contains a summary system description, remove and install instructions and sometimes an electrical (principle) diagram. After all it is a source which you can not ignore in your search for information.

### 4.3.5 Measure

Before we continue describing the tool “measurement equipment”, we first explain the definition of measure. We will also explain briefly the basic principles of measuring.

#### What is measuring

Measuring is comparing a quantity (e.g. voltage) with an arranged unit (e.g. volt) in order to give it a value in numbers, or in other words: how much bigger is the measured value compared to the arranged unit.

In the next table the most important quantities together with their arranged units are mentioned.

Quantity	Symbol	Unit	Symbol
Voltage	U	Volt	V
Amperage	I	ampere	A
Resistance	R	Ohm	$\Omega$
Frequency	f	Hertz	Hz
Auto-induction	L	Henry	H
Capacitance	C	Farad	F
Charge	Q	Coulomb	C
Capacity	P	Watt	W

The value of these quantities is not always as practical (to much zeros before or behind the point), which might cause writing or reading faults. To prevent this the unit will be multiplied or divided. Then 0.001A turns out to 1mA, and 1000V turns out to 1kV. Next table displays a part of the conversion chart.

Name	Prefix	Power	Figure
Giga	G	10	1.000.000.000
Mega	M	10	1.000.000
Kilo	k	10	1.000
Hecto	h	10	100
Deca	da	10	10
Unit	-	-	1
Deci	d	10	0,1
Centi	c	10	0,01
Milli	m	10	0,001
Micro	$\mu$	10	0,000001
Nano	n	10	0,00000001

So it is very important to look carefully to the unit in which is measured otherwise the values can direct you in the wrong way.

Furthermore there are a couple of questions which you have to ask yourselves before you are going to measure.

1. “What” do I want to measure
2. “Where” am I going to measure
3. “Which measuring tool” am I going to use (watch the unit and the value)
4. Will the function of the system “be influenced” by the measuring tool



**You have to realise that “Don’t guess but Test” is only valid when you know what you are testing**

#### Ohm’s law in a nutshell

Voltage (U) you can compare with pressure to the water in a hose. If there is no pressure, then there is no current. If there is a lot of pressure then there is much current (depending from the resistance).

Amperage (I) you can compare with the amount of water which can go through a hose. If there is a lot of resistance (valve almost closed), then the water drips through the hose. If there is no resistance (valve completely open) then the water flows freely out of the hose.

Resistance (R) you can compare with a valve. The more you close the valve the more the resistance will be, and vice versa....

As a result from the relation between these three quantities you have Ohm’s law:  $U = I \times R$  and  $P = U \times I$

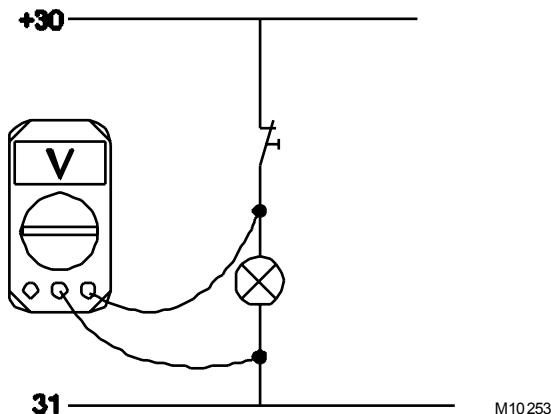
### 4.3.6 Measuring methods

For basics of the measuring method for voltage, amperage and resistance it is not interesting which measuring tool is, or isn't suitable because we don't use values for now. Later on in this manual, when we will discuss measuring tools, it will get a chance.

First we will discuss the basics of the various measuring methods.

#### Voltage measurement


The basics of a voltage measurement looks like:



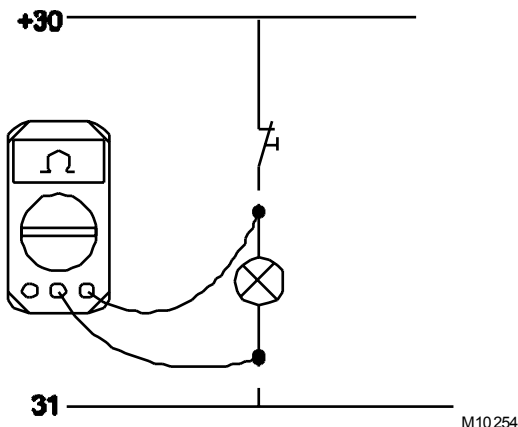
Whether it is a lamp tester, a LED tester, a multi meter or a scope, they are all connected at the same way to do a voltage measurement. By connecting the measuring tool parallel you can determine whether there is voltage on the connection (estimate the value is depending on the chosen measuring tool).

#### Resistance measurement

A resistance measurement is in principle the same as a voltage measurement, parallel connected over the part which has to be measured.

 **It is not allowed to have voltage on the connection otherwise the Ohmmeter will be damaged.**

The basics of a resistance measurement looks like:



At the same time you have to be sure that the circuit which you are measuring, is really the circuit which you want to measure. An Ohm measurement is also based on a voltage measurement. The Ohmmeter will send current through the connection, which will take the easiest way (even when it is not the intended circuit), and the Ohmmeter will convert this to a resistance which will appear on the display.

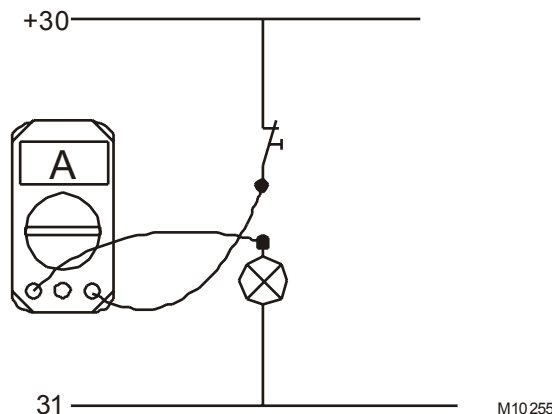
When you are not sure that you are measuring the intended circuit, you have to isolate the circuit or component like is been done in the figure.


#### Amperage measurement

An amperage measurement is more difficult than a voltage measurement or a resistance measurement and therefore seldom used.

The difficulty is in the fact that you have to do a serial measurement instead of a parallel measurement. Due to the fact that you have to do a serial measurement you always have to disconnect one side of the connection and connect the ammeter between the disconnected wire and the circuit which you want to measure.

The basics of an amperage measurement looks like:



 **Never do an amperage measurement when there is a short circuit, because the amperage will increase measureless and will destroy the ammeter.**

There is also the possibility to do a measurement with a clamp meter, but that in general is only used for high amperages.

### 4.3.7 Measuring tools

The next measuring tools will be discussed:

- Lamp tester
- LED tester
- Multimeter
- Scope

When choose a measuring tool you have to think about a few things:

- Which quantity do you want to measure
- Which kind of quantity do you want to measure (AC/DC)
- In which order of magnitude (mV, V, kV)

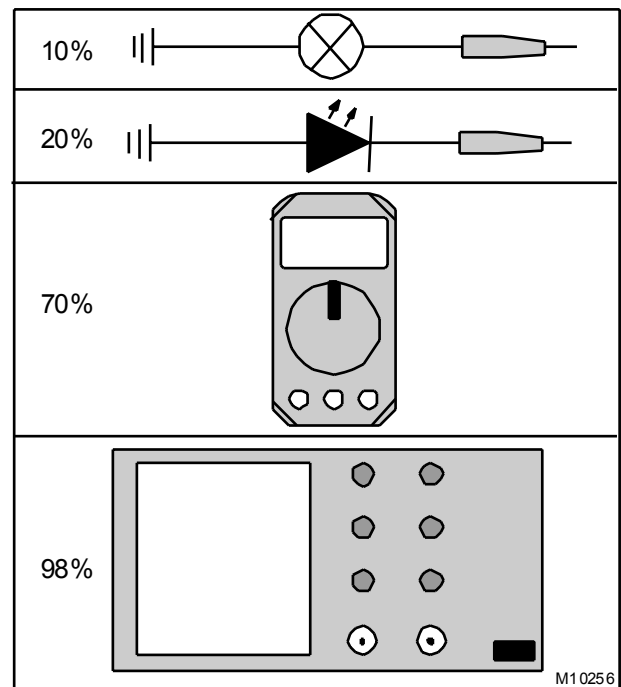
In the automotive sector we actually only talk about direct current (DC) and direct voltage, but that does not mean that there are no quantities with a frequency.

Most measurements which will take place in a vehicle are voltage measurements or resistance measurements. Amperage measurements will not often be used.

According to the facts above the four earlier mentioned measuring tools are used as follows:

- Lamp tester and LED tester:  
Voltage measurement (only an indication whether there is or there isn't voltage).
- Multimeter:  
Voltage-, resistance-, and amperage meter with value of the unit.
- Scope:  
Luxury voltage measurement; i.e., magnitude and shape of the voltage.

In the next diagram you get an indication of the possibilities of universal measuring tools. At every tool there is a percentage of malfunctions which you can solve comparing to the malfunctions there are.



See this diagram as if "all malfunctions" is 100%. The possibility to solve a malfunction is the highest with help of a scope (98% of the malfunctions you can solve with help of a scope). With the help of a multimeter you can solve approximately 70% etc.

Fault tracing with help of tools does not have to say that everybody can take any kind of tool to solve the problem. It all depends on the knowledge of the system and of the measuring tools, and also the interpretation of both. This can only be learned to work with it a lot.

#### Lamp tester

A lamp tester is a tool which already existed before the electronics era. With the help of this tool you can get an indication whether there is or there isn't voltage on the circuit or component, but it doesn't say a thing about the value of the unit. The lamp (mostly 5 Watt) forms a load (0,5A at a 12V system and 0,25A at a 24V system) and takes care that there is a current which goes through the lamp and makes the lamp start burning.



**Never use a lamp tester to an electronic system.**

The load formed by the lamp can cause the input or output of an electronic unit to overload. Nowadays electronics work with very little current (sometimes less than 0,025A) so this load can destroy the electronics.

This load can also affect the signal, and cause to be observed strange symptoms.

To what extent the signal may be affected you can determine yourselves with help of the next formula:

$R_v = 1/R + 1/R + 1/R$  etc. ( $R_v$  means replacement resistance)

In short it means that when the load of the lamp tester is much smaller than the load of the component it will hardly affect the signal. The smaller the load difference between the lamp and component, the higher the risk that the signal will be affected.

In some cases we require the load of the lamp tester to simulate a control light or a resistor at an input. In that case it has to be very clear that you know what you are doing. It is safer to do measurements with a LED tester.

The advantages and disadvantages of a lamp tester are:

Advantage:

- You can use the lamp tester as a load
- You have a fast indication whether there is voltage present

Disadvantage:

- It is just an indication whether there is or isn't voltage.
- You don't have an indication of the shape of the signal
- It is rather a big load for an electronic circuit
- Possibility to damage an input or output
- Possibility to affect the signal

### LED tester

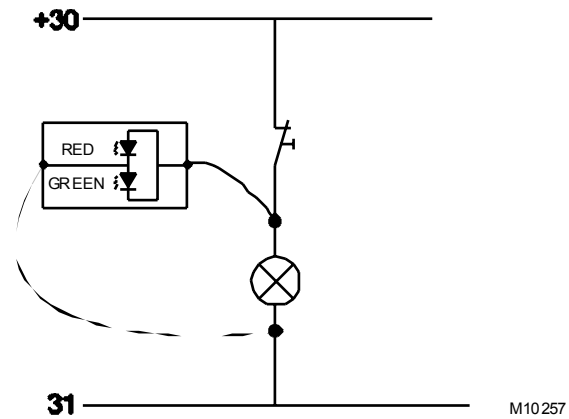
A LED tester is the successor of the lamp tester because it doesn't have the disadvantages of a lamp tester i.e. that it has a high load. The LED tester has a maximum load, for the circuit you are measuring, of 10 mA and therefore no risk for the electronics.

There are several kind of LED testers. The two most important are:

- The one with 2 LED's (1 red and 1 green or 2 red)
- The one with 2 red LED's and a voltage indicator (for 12V, 24V and 220V)

Due to the fact that the polarity of a LED is important, it is possible to see at which side the positive voltage is.

The principle diagram of a LED tester looks like:



The disadvantage of a LED tester is that you only can see whether there is or there isn't voltage on the circuit, but you can't see a value. What is more, a LED can even light up at 10% of the battery voltage although you are thinking to measure the complete battery voltage.

A better alternative is the second mentioned LED tester, the one with a voltage indicator. This LED tester gives you an indication on the polarity of the voltage (in which direction is the voltage flowing) and which level of voltage is at.

The advantages and disadvantages of a LED tester are:

Advantage:

- Not much load for the circuit you are measuring
- Less risk of damage to an input or output of the electronics
- Less risk of affecting the signal

Disadvantage:

- It is just an indication whether there is or there isn't voltage
- A LED can even light up at 10% of the battery voltage
- You can only do a voltage measurement
- You don't have an indication of the shape of the signal

### Multimeter

A multimeter is a tool which nowadays is essential in a workshop. Of course there are different qualities of multimeters but for just little money you can get a (digital) multimeter which gives quite a good indication of the values you are measuring. The digital multimeter is the most used and therefore the only one we will discuss, so no analogue meter.

The multimeter is named that way because you can measure multiple quantities with it, namely:

- Voltage (V)
- Resistance ( $\Omega$ )
- Current (A)

A digital multimeter you can read easily, but you have to be careful which unit you are using to determine the value (kV, mV etc.).

In the previous chapter you already could see how you have to connect the multimeter (basics of measurement connections).

You have to ask yourselves a few things when you do measurements to a circuit:

- Did I connect the measurement pins correctly to the multimeter?
- Do we have AC voltage or DC voltage?
- What is the value of the quantity (kilovolt or millivolt)?
- What is the deviation of the multimeter?



**If you have no idea of the value of the quantity, you have to start with the highest value.**

We will explain a few things concerning the different quantities you are going to measure, because at every quantity you have a few specific points for attention.

### Regarding the voltmeter:

Be sure that the measurement pins are connected correctly to the multimeter (black in COM = common, and the red one in V/ $\Omega$ ) and be sure that the wires or the measuring pins have no interruption. This you can test by switching the multimeter to Ohm and hold the pins against each other. The multimeter has to indicate almost 0 Ohm.

You also have to know whether it is an AC voltage-, or DC voltage circuit. There will be no damage but the values you measure will not correspond with the real values.

You have to be sure that the multimeter is connected parallel to the connection otherwise it is the end of the multimeter (or at least the end of the fuse of the meter).

You don't have to worry about the effect of a signal or that the multimeter will damage an input or output because the multimeter is so called "high Ohmed", what means that there are no high currents generated, so there is a low load.

A disadvantage however is that a multimeter will average the measured values. Which means that if there are any interference signals (noise) together with the signal, the multimeter will take the average of the interference signals together with the signal, so you won't notice the interference signal.

Once again the advantages and disadvantages of a voltmeter:

Advantage:

- You have an indication of the polarity
- You have an indication of the value of the quantity

Disadvantage:

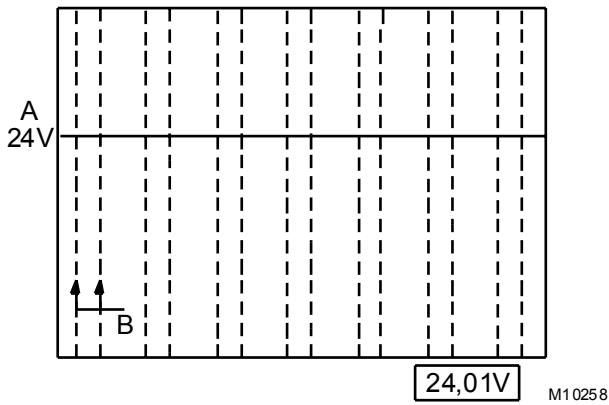
- You don't see the shape of a signal, which means that an interference signal on the signal you measured will not be recognized.
- In any case you see an average value (a multimeter will be more accurate and faster depending on the frequency of measuring (samples), which means more expensive)

This last point I will explain more.

The accuracy of a multimeter (and a scope) depends for the most of the frequency of taking samples of the offered signal.

An analogue multimeter measures, (and makes it visible by the deflection of the needle) without interruption, the offered signal.

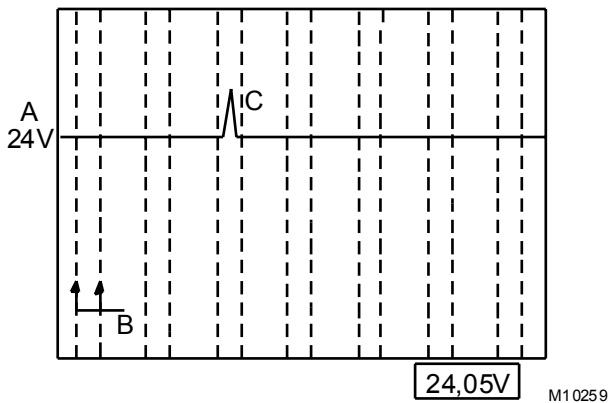
A digital multimeter can't measure that way, but functions like:



- A Input signal
- B Sample moments

In the figure above, the signal will be sampled 500 times in a certain period. The measured values will be all added up, divided into 500 and made visible on the display.

An interference signal will not be noticed because of the following:



- A Input signal
- B Sample moments
- C Interference signal (will not be displayed)

Because there is only 1 peak in 500 samples, the average value will only be a little bit higher.



### Regarding the Ohm meter:

The measuring pins of the Ohm meter (usually) are connected to the same position on the multimeter as during a voltage measurement (black in COM and red in V/ $\Omega$ ). When doing an Ohm measurement it is also very important to check the deviance (resistance of pins and wire), so you can take this into account, especially during measurements of low resistances. It is easy to check by holding the pins against each other. The multimeter has to indicate almost 0 Ohm. If it is for example 2  $\Omega$ , you can subtract this 2  $\Omega$  of the result.

If the supply is AC or DC is irrelevant, but you have to be sure that there is absolutely no voltage on the circuit which you are measuring.

If there is an interruption in the circuit, the multimeter will display O.L. (Over Load).

Doing an Ohm measurement it is very important (like told before) that you are sure you are measuring the circuit that you mean. If possible isolate the meant circuit by disconnecting a connection wire or a connector. If that is not possible and you read a different value as you expected, you have to take into account that you possibly measured something else.

To do an accurate measurement it is important that you choose the right value. When you have to measure e.g. 1000 $\Omega$  you have to put the Ohm meter on the scale K $\Omega$  so you can see the figures behind the comma.

### Regarding the Ammeter:

Measuring amperes is complex and is therefore not often used. The difficulty is in the fact that you have to do the measurement by a serial connection where you always have to disconnect one side of the connection.

The measuring pins have to be connected to the multimeter in another way as the previous measurements. The black pin stays in COM, but the red pin you have to connect to one of the ampere connections. Usually there are two ampere connections (> 100mA and < 100mA) When you are not sure of the value of the current you are going to measure, you have to start with the highest scale (generally maximum 10A). You always have to take care that the value of the amperage is not higher than the maximum capacity of the multimeter. It is easy to find out with help of the formula:

$$P = U \times I$$

Where P is the capacity (in Watts), U is the voltage (in Volts) and I is the amperage (in Ampere). When you divide the capacity by the voltage you will get the ampere.

Example:

A bulb of 20 Watt and a voltage of 24 Volt.

$$20 : 24 = 0.833 \text{ mA}$$

Once again:



**Never do an amperage measurement when there is a short circuit, because the amperage will increase measureless and will destroy the ammeter.**

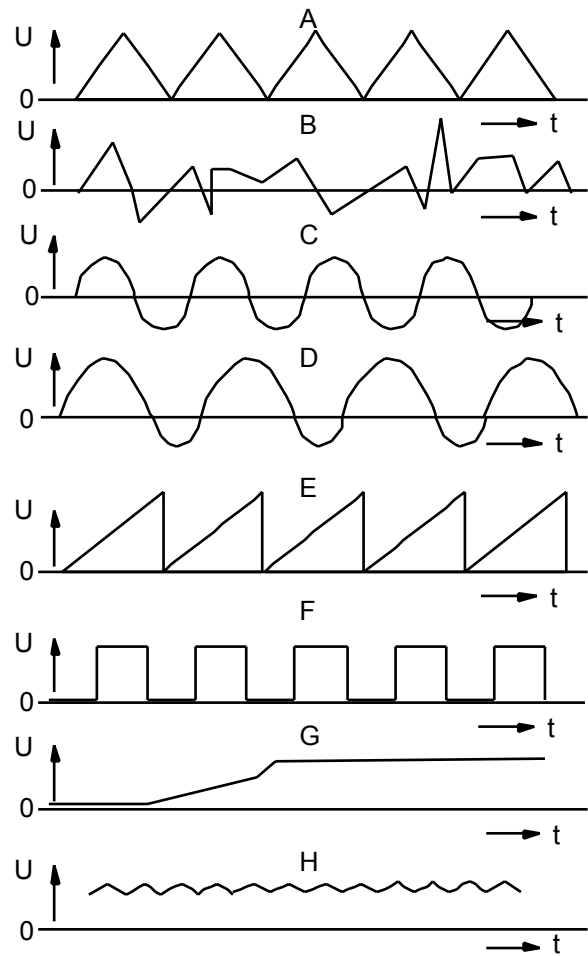
### Scope

Simply spoken the scope is not more than a tool which can visualise the voltage in function of time.

The big advantage of a scope is in the fact that you can see the shape of the voltage and that you can study possible interferences. Of course the interpretation of this study depends on the basic knowledge and of the experience of the mechanic, but also, for example, of the figures of “wrong” and “right” signals which are sometimes in the system discriptions.

In this era of electronics and mechatronics the scope will in the end replace the multimeter, because not only the speed of signals but also the shape of a signal is very important (and will be more important). Due to the fact that more and more electronics and fast signals will be used, the so called EMC (Electro Magnetic Compatibility) will be more important. Simply spoken there will be more and more interference signals, which can't be recognised by other tools than a scope.

When we talk about the shape of a signal then you have to think of:



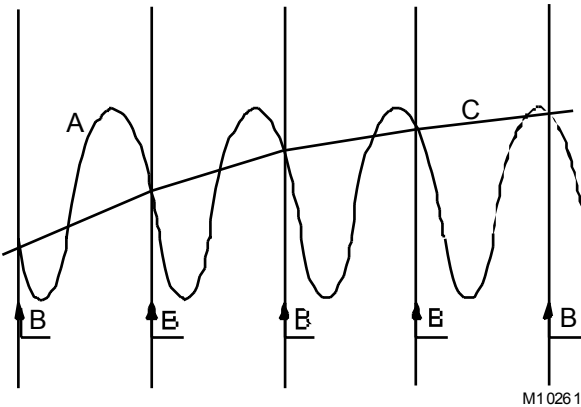
- A Repeating (triangle) signal
- B Any non repeating signal
- C Sine curved alternated voltage symmetric
- D Sine curved alternated voltage asymmetric
- E Triangular signal
- F Block signal
- G Changing DC voltage (e.g. over potentiometer)
- H Pulsating DC voltage (e.g. alternator wrinkle)

This are just a few examples to show that any voltage can be visualised with help of a scope, but:



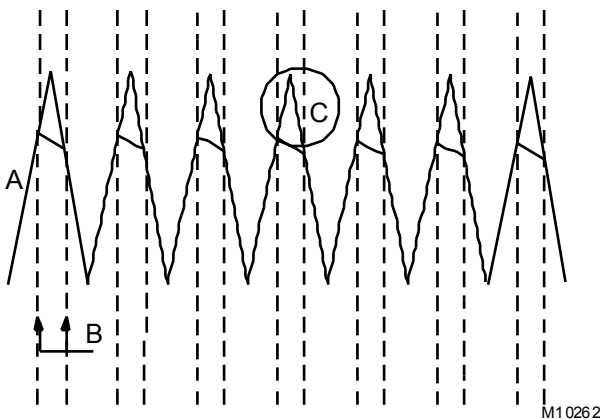
**Also when using a scope (just like using a multimeter) the frequency of taking samples is very important.**

See the next examples:



- A Signal
- B Sample moment
- C Scope signal

You can see that the scope only shows a straight line while in fact the signal is a sine.



- A Signal
- B Sample moment
- C The top of the signal is not shown by the scope

In the above figure you can see that the scope doesn't show the top of the signal.

A scope has, for example, a measurement frequency of 100 samples per second (depending on the setting "time/division"). All these samples will be shown on the display as points and connected with each other by a line, see figures above.

You can imagine that if the scope doesn't measure the interference signal (dephasing), it won't display the interference signal. In practice this will not happen often, but you always have to be aware that it can happen (certainly when you have a "slow" scope).

An advantage but also a disadvantage of a scope is that it is very sensitive, which means that every interference (also e.g. the mains voltage: 50 Hz) will be displayed. Look at the signal with this in mind, certainly when you use long measuring cables (more risk of interference because of the bigger surface).

Interference of the mains you can recognize easily because of its frequency of 50 Hz (in USA 60 Hz), but it can as well be a transformer or something else in the workshop, using an other frequency, or perhaps no repeated frequency at all, which causes the interference.

You have to take this always into account!

The advantages and disadvantages of a scope are:

Advantage:

- You can see the shape, amplitude and frequency of the signal
- Interferences of the signal are also visible
- Hardly risk of affecting the signal
- Possibility to visualise more than one signal at the time
- Possibility to visualise more than one signal in relation to each other (e.g. ignition in relation to injection signal)
- Possibility for a "single shot" (especial practically when "non repeating" fault)
- Memory function and print possibility (to do an analysis by a third person)

Disadvantage:

- It is not easy (especial in the beginning) to operate a scope
- A scope is very sensitive; it visualises also interference signals of its surroundings (but that can also be an advantage when there are EMC-problems)
- The frequency of measurements of a scope you have to take into account
- A scope is expensive

### 4.3.8 Tips and tricks for fault tracing

**See to it that you have knowledge of the system that you know when, what happens.**

**See to it that you know where to do measurements (e.g. an electrical diagram)**

**See to it that you approximately know:**

- Which quantity (V, A,  $\Omega$ ) do you expect
- Which kind of voltage (AC/DC or a block signal) do you expect
- Which order of magnitude (mV, V, kV) do you expect (otherwise always start with the highest one)

**See to it that you always use measurement cables which are as short as possible in order to reduce the possibility of interference of the surroundings (the mains, transformers, etc.), or be aware of the possibility of interference.**

## 4.4 Diagnosis

### 4.4.1 General

If the system starts, all systems do a self-test of their system. When there is a malfunction of a system it will be indicated by a warning light on the dashboard.

### 4.4.2 Diagnostic equipment

There is no special diagnostic equipment for diagnosing the powertrain CAN. All systems have to be diagnosed separately with their specific tools. The procedure of diagnosing will be described in the following sections.

### 4.4.3 Diagnosing powertrain CAN

#### Checking the systems

When a warning light of one of the systems lights up on the dashboard it means that there is a failure in the concerning system, which means that there is a malfunction in the system or in the CAN connection.

To find out what the problem is you have to check:

1. Is the system of which the warning light lights up really the problem. (When several warning lights light up it could also be the CXB which has a failure).
2. The concerning system in an ordinary way.



**When the system is checked and the problem is not solved you have to check the CAN connections.**

#### Checking the CAN connections

When checking the CAN connections first check:

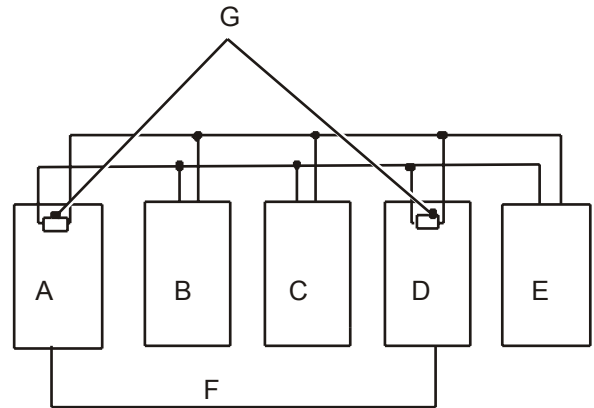
1. Supply and earth of the connected apparatus.
  2. The end resistors of the CAN connections.
  3. Is there a short circuit to earth in a CAN wire.
  4. The CAN wire connections between the apparatus.
- Supply and earth of the connected apparatus you have to check with help of a volt measurement.

Check the other steps by Ohm measurements



**Be sure that there is no voltage on the circuit when doing Ohm measurements (Switch off contact switch and main switch).**

- The end resistors of the CAN connections ( $120\Omega$  each).



M10299

- A Tacho
- B ABS/ASR
- C CXB
- D UPEC
- E EST 42
- F C3 speed signal (not a CAN signal)
- G End resistors

To check the end resistors of the CAN connections it is important to know the location of the end resistors:

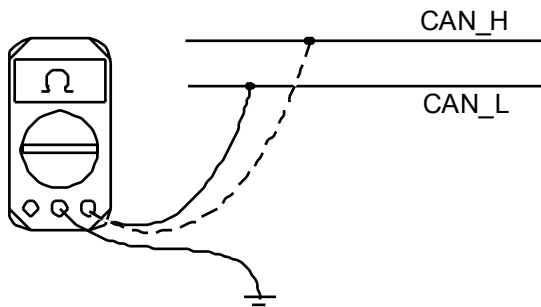
- The end resistors are located in the tacho and UPEC.

On the CAN circuit you have to do an Ohm measurement parallel on the circuit. It doesn't matter where on the circuit you do the measurement.

- When you measure  $60\Omega$  it means that both end resistors are O.K.
- When you measure  $120\Omega$  it means that one end resistor is not O.K. or wiring to ECU is not O.K.
- When you measure  $0\Omega$  it means that both end resistors are damaged or wiring to both ECU's is not O.K..

When power supply, earth and end resistors are O.K. you have to check:

- Is there a short circuit to earth in the CAN wires.

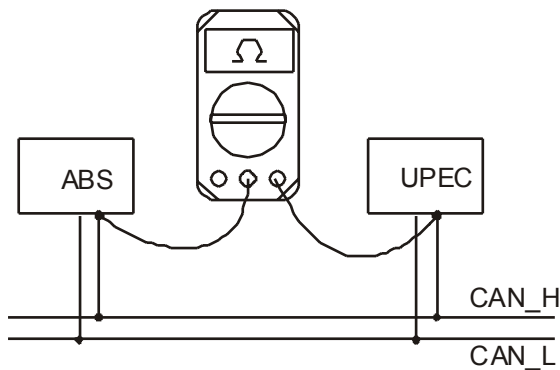


M10281

You have to measure the resistance between CAN\_H and earth and between CAN\_L and earth. The resistance should be  $\geq 250 \text{ K}\Omega$ .

When power supply, earth and end resistors are O.K. and there is no short circuit you have to check:

- The wire connections between the apparatuses.

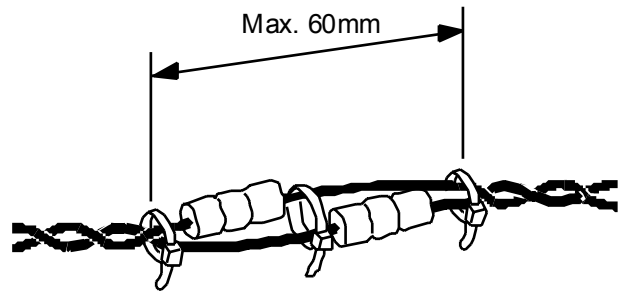


M10300

As an example we let you see the measurement between ABS and UPEC. The resistance should be  $0 \Omega$ .

When there is a resistance then there is a problem with the twisted wire or contacts on the wire.

If the twisted wire is damaged or broken you have to think of a few things when repairing or replacing the wire(s).



M10283

- When replacing the CAN wire, the length and the diameter of the twisted wire has to be identical to the original wire.
- The maximum untwisted length is 60 mm.
- The density of twisting must be 40 - 50 rotations/meter.

### Electronic Control Units

With help of the diagrams of the concerned systems you can determine whether power supply, earth and the CAN connections of the ECU's are O.K.

If power supply and earth are O.K. and the CAN connection is O.K. you can check the various in-, and outputs of the ECU.



**Of course there is also the possibility that the ECU itself is broken....**



# 5. Repair and maintenance

## 5.1 General



**Always switch off the main switch and disconnect the battery clamps when working on parts of the electrical system.**

After the repair has been made and the battery clamps are reconnected don't forget to:

- Adjust the time of the central digital clock
- Adjust the time of the pre-heater timer
- Synchronize the tachograph disc recorder, see the driver's manual
- Re-enter the anti-theft code of the radio if applicable.

## 5.2 Maintenance

Maintenance of the electrical system contains of:

- Checking connections for fixation and corrosion
- Checking fixation of the components
- Prevent components and connectors of getting moisten.

## 5.3 Special tools

Repair on the electrical system can be done with ordinary workshop equipment.

## 5.4 Repair

Repair on the electrical system can result in exchanging:

- Electronic Control Units
- Sensors
- Actuators
- Repair of wiring or connectors.

One of the above mentioned actions can be done with ordinary mechanic skills and need therefore no special attention.