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DESCRIPTION:

This Tech Net Note is an explanation of how the CAN network is set up and functioning, including network diagnostics. It also describes conditions for DTCs to be set and some tips on how to fault trace the CANbus. CANbus errors are often complicated to fault-trace simply because it is a distributed system and error codes may be or may not be set in multiple nodes.

This information is best used as background information to understand the CANbus or system diagnostics and to fault trace the CAN network, and may not help to immediately find the root cause of a specific problem. This document will supplement the normal training material and it is recommended for technicians who have completed and thoroughly understand the training on "Volvo Automotive Networks"

The structure of this document is: general information on what role the CEM plays in CANbus faults, then each of the major types of DTCs are described. Each type of DTC has a description, explanatory picture, and some typical scenarios when it can be set.

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CEM diagnostic functionality

The CEM is the only node that truly monitors the voltage levels on the CANbus. Only the CEM can post the diagnostic trouble codes for CANbus short-circuit to ground or 12V (e.g. DTC CEM-DF14), even though many nodes can post codes caused by the short circuit, e.g. E003 (this is a very subtle, but important difference).

Note: The fact that the CEM has more diagnostics for the CANbus faults does **not** mean that the CEM is the root cause of the fault! Do NOT replace the CEM for CANbus failure unless there is a confirmed hardware internal error based on the fault tracing in VADIS and this TNN.

The CEM also has the functionality of detecting the absence of other nodes.

All nodes on the CANbus need to send and receive information. More specifically, all other nodes need to receive information from the CEM, and the CEM needs to receive information from all other nodes. If a node does not receive information from the CEM, it will set the code DTC-E003, and if the CEM does not receive information from a node it will post a code CEM-1A51 to CEM-1A64 for that node.

As an example, if the CCM does not receive information from CEM it will post DTC CCM-E003, and if the CEM does not receive information from CCM it will post DTC CEM-1A55. Further, if the DDM does not receive information from CEM, it will post DDM-E003, and if the CEM does not receive information from DDM it will post the code CEM-1A52.

If there is an open circuit on the CANbus, codes are thus posted in pairs, one in the CEM and one in the corresponding node. Note that this can mean that the CEM posts a lot of codes reaching its maximum number of codes (10).

These codes will be explained in detail under sections “DTC CEM-1A51 to CEM-1A64.

Fault-codes for CANbus errors

A list of different DTCs most related to CANbus errors can be found at the end of this TNN.

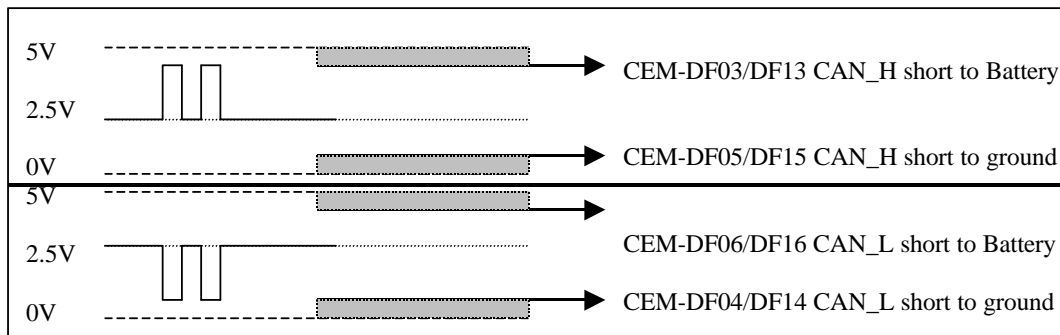
DTC CEM-DF03 to CEM-DF16.

The CEM is the only node that has diagnostic functions to detect short circuit to ground or short circuit to voltage (B+). This is done by monitoring the electrical signal levels on the CANbus by an internal voltage measurement circuit in the CEM, and the DTCs CEM-DF03 to CEM-DF16 can be set.

Note. There are separate codes for low speed and high speed network. DF03, DF04, DF05, DF06 refer to the low speed network and DF13, DF14, DF15, DF16 refer to the high speed network.

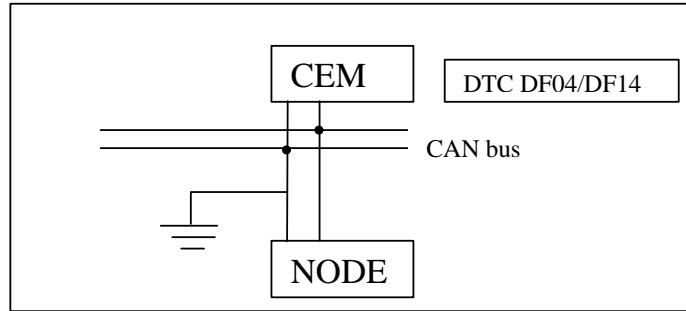
There is no strict electrical detection function for open circuit, but there will be a number of codes posted as a result of an open circuit. DTCs CEM-DF03 to CEM-DF16 are the strongest evidence for a network fault, but the code does not locate the fault. Due to the detection criteria for these codes, they can in rare cases also be posted when driving in very high electromagnetic field areas.

The detection for these codes is continuous. The detection time for a permanent fault can be up to 10 sec. CEM-DF03 to CEM-DF16 are posted when the voltage on the CAN lines are more than 4.5V or less than 0.5V respectively. See graph below.



A typical scenario when these codes are set is a pinched CAN wire to either ground or pinched together with a 12V wire, see illustration below.

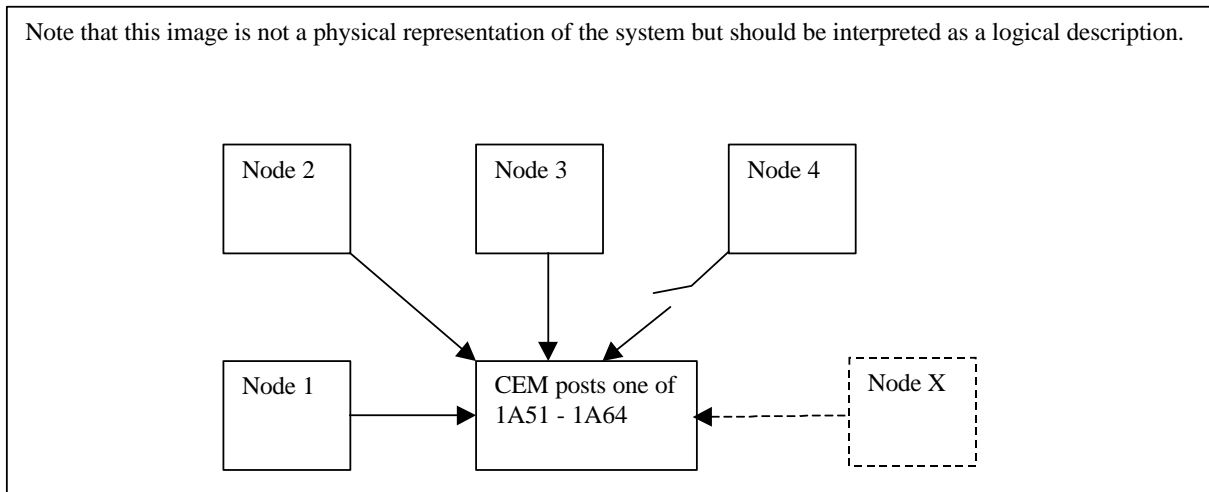
Different combinations of codes are possible, and the codes mentioned in the graph are only examples.



DTC CEM-1A51 to CEM-1A64.

The CEM expects a signal sent from every node on the network. The CEM will post a code for communication with control module, or "Node not alive", if there is no communication from the concerned node for more than 10 seconds.

See illustration below.



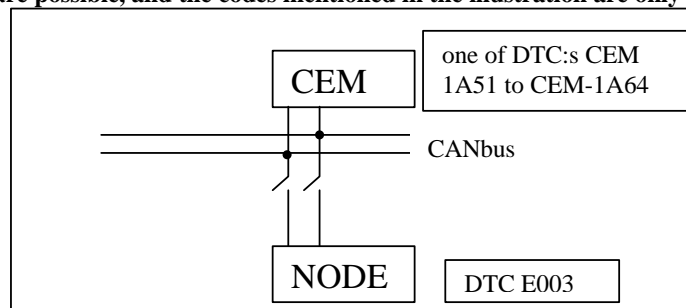
Typically these codes come together with DTC E003 in the corresponding node. Depending on where the error occurs, there may be many CEM-1A51 to CEM-1A64 codes posted at the same time and the CEM reaches maximum number of DTCs stored (10). In this case not all codes will be represented even if the criteria for posting the code was met.

The codes will generally be posted when network is open-circuit, short-circuit, node is not powered, or if a node stops communicating to the CEM for other reasons.

Combinations of CEM-1A51 to CEM-1A64 codes are very useful for locating open circuit faults, see Multiple codes and extended diagnostic (counters and Freeze Frames.)”.

If there are **intermittent** CEM-1A51 to CEM-1A64 codes but not the corresponding E003 codes, first verify that, at the time of repair, communication can be established with all nodes. Then look at the power supply for the nodes. The reason is that the node will of course not post the E003 code if it lacked power when the intermittent fault occurred. The CEM however will post the CEM-1A5x code even if the other node lacks power or has a CAN communication problem. See illustration below for an example.

Different combinations of codes are possible, and the codes mentioned in the illustration are only examples.



DTC E003 set in nodes other than CEM

The DTC E003 code is posted when the incorrect CAN Configuration ID is received during 5 sec after Power up. This means that the nodes do not receive the data frame containing the correct master configuration ID from the CEM. Normally this is due to the CANbus has an open circuit or other disturbance.

This code is intended to detect if the CEM has the wrong software, but is more common for a network/power error. Combinations of E003 codes are useful to locate the fault, see section about multiple faults. However not all nodes set this code at the same fault time due to different power-on conditions as e.g. X / 15 / 15I / 30 powered nodes.

An E003 can be the result if a node gets the wrong signal configuration downloaded to it or as a result of swapping a node from another car. That is one of the reasons that swapping of nodes is prohibited.

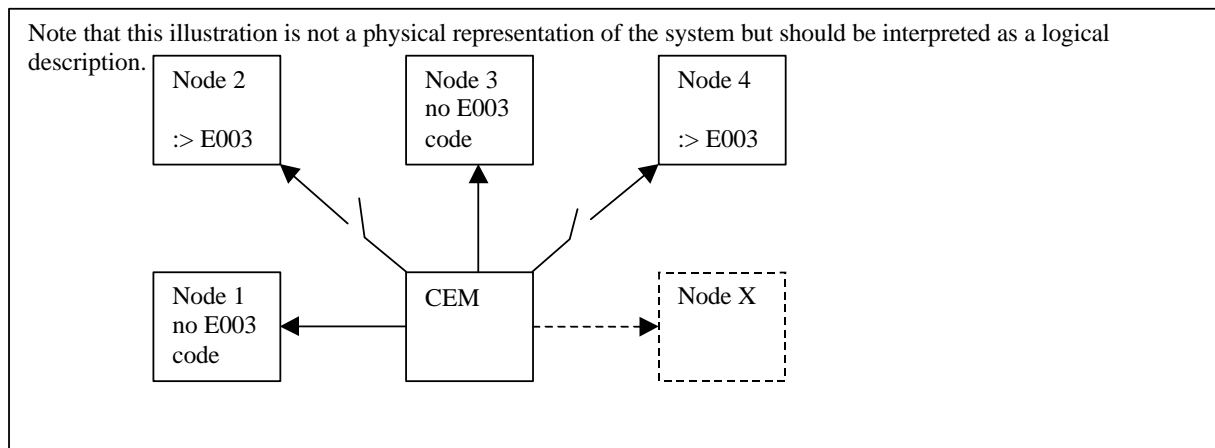
If several or all nodes have E003 it can be a result of an incorrect signal configuration being downloaded to the CEM. In practice, this is however not likely to happen, it is more commonly a physical CANbus fault.

X / 15I / 15 powered nodes detect the fault 5 second after the node is powered up (IGN ON).

The nodes compare their internal CAN configuration ID (SW version) with CAN configuration ID continuously sent out from CEM. If the CEM ID is missing or not equal to the expected value at 5 sec after powered up, the E003 code is set. A wrong ID may come from swapping node between vehicle types, but most often this code is due to signal missing completely.

A node that has battery (30) feed does not get that hardwired power up, but gets its information about ignition position via CAN bus. This means that a 30 fed node will not post the E003 at that time if the error is permanent at power up. Instead it will be posted after an approximate 10 min timeout.

NOTE: This means that for a 30 fed node the code may or may not be posted, all depending on when the error occurred.

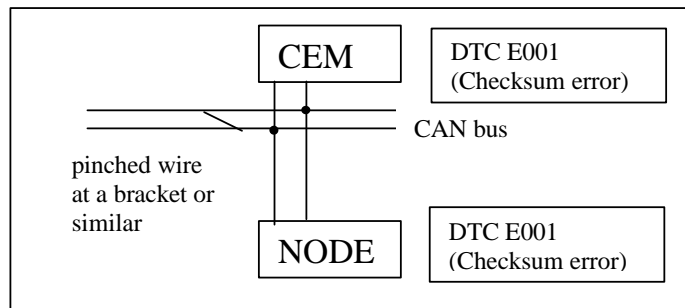


The typical scenario when this code is set is an open circuit in the CANbus, and often together with the CEM-1A51 to CEM-1A64 codes. See the illustration under “CEM-DTC CEM-1A51 to CEM-1A64.” above.

E000 and E001 DTCs set in any node (E000=HS-CAN / E001=LS-CAN).

E001 code is an error in the data communication. It can be due to any disturbance on the CANbus or if a node is not sending correct data. The detection for these codes is continuous. It is originally designed to detect contact bouncing fault and corrupted message, but are also posted when there is a short circuit between CAN H and CAN L or when there is communication on only one of the two CANbus wires. Detection time for a permanent fault is within a few seconds.

Different combinations of codes are possible, and the codes mentioned in the illustration are only examples.



Other common causes for these DTCs is if a node is disconnected without first disconnecting the battery (Does not help if IGN key is out), or if CAN-message is "weak" or disturbed. That can happen if only one of the two CAN wires is operational or if one of the two network resistors is inoperative.

Low speed network resistors are located in the UEM and REM. For the high speed network, the resistors are located in the ABS/BCM and ETM, except for Bosch EMS MY02 and later where the resistors are in BCM and ECM.

Special cases with permanent E000/E001 exist, e.g. if one node is transmitting with slightly wrong baud rate, or if the crystal in a node is faulty.

Codes posted due to signal missing, quick detection of CANbus error

Some nodes, typically ECM, ETM, ABS and TCM, are checking each other's presence and are setting codes for absent signals. These codes are driving condition dependent and often combinations of codes can be set which may confuse fault-tracing. When trying to duplicate the driving condition / fault, it is not necessarily the same combination of codes that are set.

These are often more sensitive and are set more quickly than 1A51 – 1A64 or DF03 – DF16 codes and can therefore be an indication that an intermittent quick error condition has occurred on the CAN bus.

Below you will find a sample of codes that may or may not be set in case of a CAN intermittent failure:

ECM 928C (Bosch), 922A (Denso), only with running engine. The codes are for cruise control signal missing and indicate that the cruise control signals were not received by ECM.

ECM 901A, 901E, 902A, 911A, 912A 913F for Bosch and 901A, 902A, 902B, 911A 912A, for Denso

SRS 00D6, Buckle signal timeout, indicate that the SRS have not received the buckle status from the CEM. (The buckle sensor is hardwired to the CEM)

SRS 00D5 bulb status signal from DIM.

Pedal sensor signal discrepancy between hardwired signal and CAN signal:

ECM Bosch.

595F AP12T APU (Analog Pedal Unit) Analog/PWM (via ETM) comparison fault

ECM DENSO

9520 ETS, APM, PWM, Electrical fault, low

ECM monitoring:

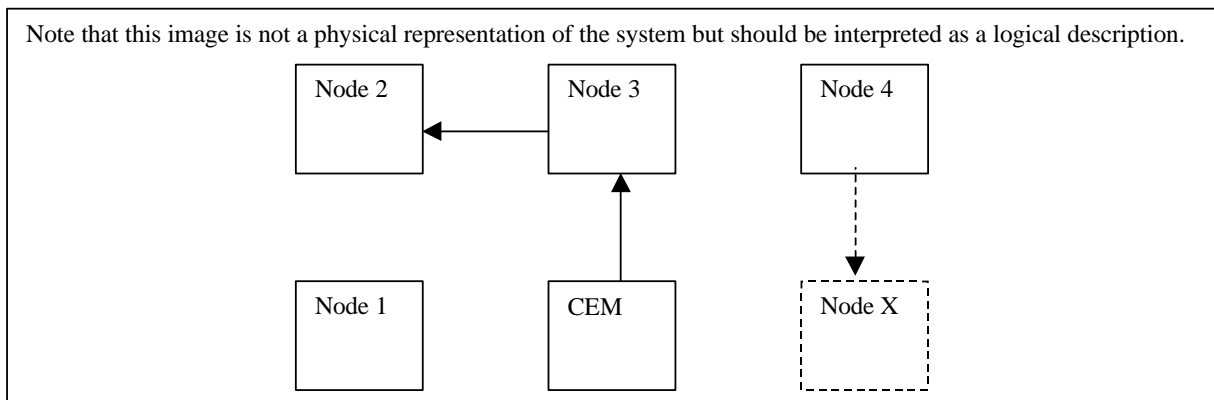
Bosch:

510F Vehicle speed signal

Denso:

510D Vehicle speed signal missing
A02B Signal missing from ABS/BCM
902A Throttle Communication signal missing

See the illustration below for a rough picture of how signals may or may not involve several nodes.



Multiple codes and extended diagnostic (counters and freeze frames)

The detection time for CANbus error DTCs differ for different codes. This means that for a specific error condition there may be a number of DTCs set in different nodes. Multiple codes in different systems can be confusing, but should be reviewed at the beginning of fault tracing to find a common link between all the codes.

Now it is possible in VADIS to read off extended diagnostics, typically counters and freeze frames. This is valuable also for CANbus diagnostics since it gives a possibility to determine which faults were posted at the same time. Remember that the counters are implemented in different ways in different control units which may make a comparison of driving cycles between different nodes difficult.

When fault-tracing a vehicle with many intermittent E003 and CEM-1A51 to CEM-1A64 codes it is useful to identify which nodes are affected. Print a copy of the "Data communication" wiring diagram in the appendix and write down all the DTCs and counters at each node. Analyze if there is a pattern that can describe where the fault can be located e.g. if the codes are grouped at one end of the CANbus. That will give a good indication where the fault is.

Limp home modes and characteristics of CAN faults

When a node does not receive any data frames from the CEM, it will enter a limp home mode. This mode may have different level of functionality depending on node.

If the error has occurred after the startup of the nodes, the nodes will normally keep the last recorded values as limp home values. Exceptions do exist though, e.g. fuel gauge for DIM.

For the Low speed network there are some distinct characteristics:

DIM: Since the DIM is a display of signals on the CANbus, it will quickly be visible if signals are missing. Depending on the filtering of signals internally in DIM, the displayed information will disappear at slightly different times. Normally the gauges freeze for 10 seconds and then they go to 0 and the DIM goes dark.

If only one node has disappeared, the DIM may give the first indication of that. An example is if the REM stops communicating, the first indication would be that the fuel gauge goes to zero.

CCM: This module has to keep a certain functionality in the absence of CAN communication. It is also a very good indicator that the CAN communication is lost, since it will light the diodes exactly ten seconds after ignition position 1 or 2 is chosen.

Other symptoms: if the AC-compressor is not cycling, except for the initial 1 sec activation controlled by ECM on power up, it can indicate a communication problem in the chain CCM>CEM>ECM. An obvious symptom is also that fan is running for one to ten minutes when IGN key turned off. This is due to that CCM is powered by Extended-X from CEM and it normally turns fan and other functionality off based on a CAN command from CEM notifying ignition key out. If there is no CAN communication, the CCM will run until the power is lost.

DDM: The DDM will operate the functions in the driver's door but not in other areas of the car such as window lifts for rear windows and door locks for rear and passenger doors. Also the memory mirror will not work but it will be possible to maneuver the driver side mirror with the knob.

PSM: The seat memory functionality will not work. Stored seat and mirror locations will not function for the remote and seat memory.

UEM: Buckle up is displayed even when the seat belts are buckled if no communication from CEM to UEM. Also no remote function since there is no communication UEM to CEM.

AUM: Audio has most functionality left, except e.g. steering wheel switches control.

PDM: Windows and locks will not operate from driver side switches.

REM: The fuel gauge does not function and the rear doors will not lock with the central lock button. Also Defroster and foldable headrests will be inoperative.

SAS: No DSTC functionality

SWM: The steering wheel switches and turn signals do not work, but the horn works due to a redundant hardwired signal to CEM.

And for high speed network:

Engine: no start can be caused by no communication CEM>ECM+TCM.

ETM: has three levels of limp home:

Level 1. Cruise inoperative

Level 2. Throttle dull, no quick response.

Level 3. Default limp home. The RPM is controlled by means of the injectors.

TCM: GSM functions inoperative, only certain gears active. Note that once the TCM goes into its limp home mode for no CAN communication, it will not come back in that driving cycle even if the error disappears.

ABS/BCM: Generally limp home modes depend on fault. AYC sensor fault gives loss of DSTC and lamp lit. Wheel sensor fault gives lamp lit, loss of anti-lock but power assist still functions. May lose diagnostic possibility if in limp home mode.

CEM: Major loss of functionality. Note that the CEM has separate buses for CAN H and CAN L, which means that it is possible to communicate to e.g. the CEM via high speed bus even if the low speed network has an interruption.

Tips for fault-tracing

If the CEM has DTC CEM-DF14 , CAN low short to ground, it does NOT mean that the CEM is shorting the CANbus. The short is from any point on CAN low to ANY grounding point, either in the wiring harness, which is most common, or in any control unit. Note that an E001 can be set in certain nodes but not others, and the short-circuit can still be far from the control unit.

Statistically there is a high likelihood it is a cable harness problem (check behind radio, by the SRS control unit, TCM/ECM CANbus female terminals).

Note that a male terminal p/n 9441394 can successfully be used to probe the tension at the female CANbus terminals. If the female terminal does not provide the proper tension it should be replaced by p/n 9442486.

If E001 occurs permanently and the cable harness is OK, a good tip is to remove all nodes having E001 in them (except the CEM) , clear the codes in the remaining nodes and read them again to see if the code disappears. Then reinstall them one by one until the code reappears. If it is possible to communicate with the vehicle in ignition position 0 and 1 but not in 2, look for a 15 fed node corrupting the CANbus.

The above method is also useful in another error scenario. At rare occasions a node can start sending irrelevant information on the CAN bus. This may block the correct messages from coming through. The result may be one or more E003 or 1A51 to 1A64 codes. It is very difficult to know which node is disturbing so the above method can be the only way to find the root cause.

If there is no response from any of the low speed nodes, but the high speed nodes respond...

The CEM protects the CANbus from short-circuits occurring by the Data Link Connector. This is achieved by four relays internally in the CEM, one for each wire on CAN high speed bus and CAN low speed bus. The relays are closed when CEM receives a command on the K-line from VADIS.

So if you encounter this, check the following:

1. VCT2000 cable, this has caused problems before. Try another cable and VCT200.
2. Continuity and signal level of K-line wire.
3. Continuity on CAN wires between Data Link Connector and CEM.

If 1-3 check OK, there is most likely a permanent CANbus failure in the wires or a node. Continue fault-tracing according to

CANbus hardware and measurement “ below.

Appendix. List of DTC codes for CAN bus errors¹:

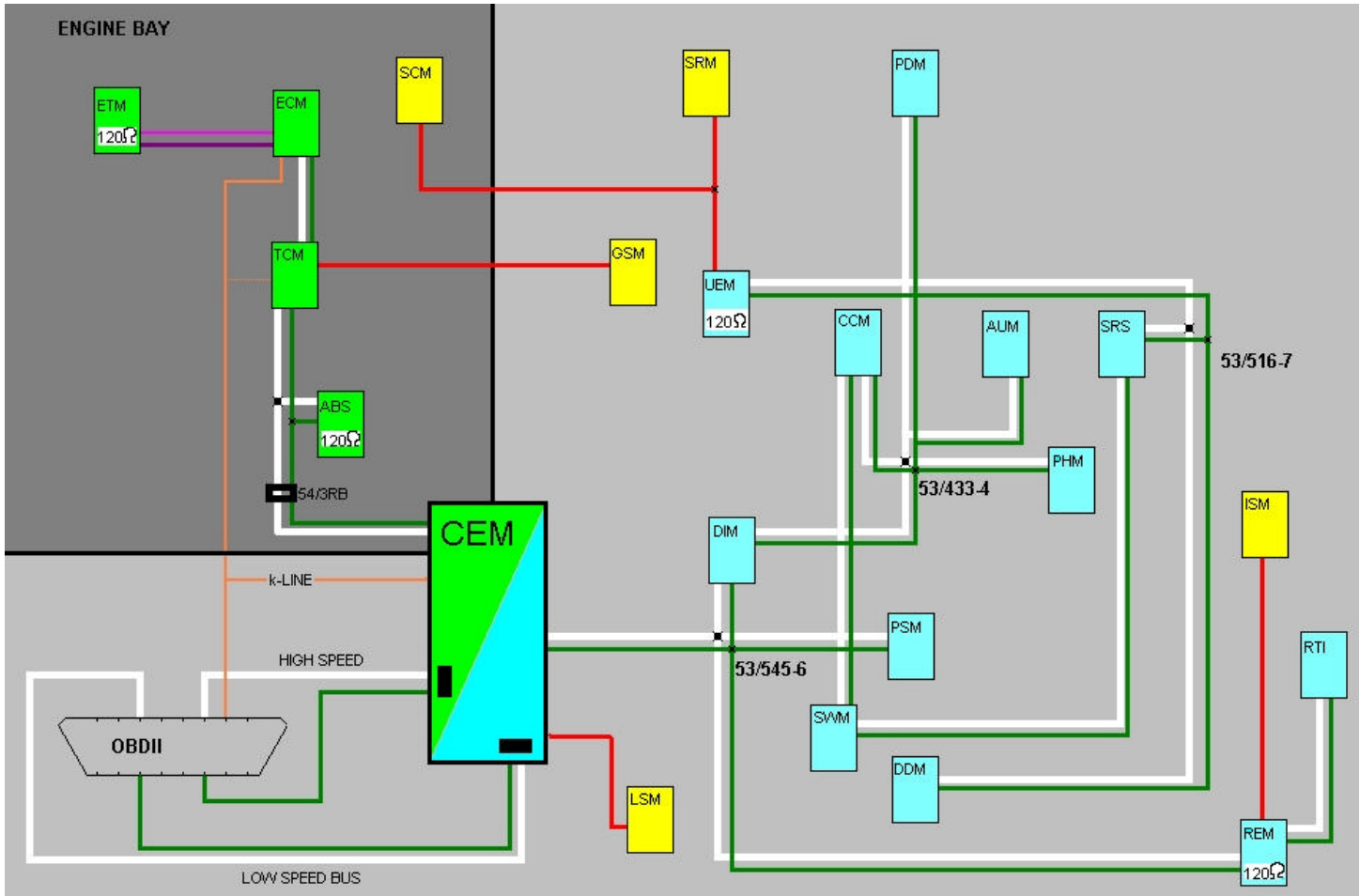
<u>NODE</u>	<u>Code</u>	<u>Comment</u>
CEM	1A51	Communication with SRS control unit
CEM	1A52	Communication with DDM
CEM	1A53	Communication with PDM
CEM	1A54	Communication with Power Seat Module
CEM	1A55	Communication with CCM
CEM	1A56	Communication with DIM
CEM	1A57	Communication with RTI
CEM	1A58	Communication with PHM
CEM	1A59	Communication with AUM
CEM	1A5A	Communication with Rear Electronic Module
CEM	1A5B	Communication with Steering Wheel Module
CEM	1A5C	Communication with UEM
CEM	1A5D	Communication with Electronic Throttle Module
CEM	1A5E	Communication with SAS
CEM	1A5F	Communication with ABS
CEM	1A61	Communication with TCM
CEM	1A62	Communication with ECM
CEM	1A64	Communication with DEM
CEM	DF03	CAN_H (or CAN_L) short to battery low speed network
CEM	DF04	CAN_L short to ground, low speed network
CEM	DF05	CAN_H short to ground, low speed network
CEM	DF06	CAN_L or CAN_H short to battery , low speed network
CEM	DF13	CAN_H or CAN_L short to battery, high speed network
CEM	DF14	CAN_L short to ground, high speed network
CEM	DF15	CAN_H short to ground, high speed network
CEM	DF16	CAN_L or CAN_H short to battery, high speed network
CEM	E000	Communication with the control module, (CAN High speed checksum error)
CEM	E001	Communication with the control module, (CAN Low speed checksum error)
PSM	E001, E003	Communication problems with control module
AUM, DDM, PDM, AEM, DIM, CCM, REM, RTI, SRS, SWM, UEM	E001	Control module communication (LS CAN transmit / receive error)
AUM, DDM, PDM, AEM, DIM, CCM, REM, RTI, SRS, SWM, UEM	E003	Configuration fault ("Control module communication" for RTI)
ABS	0090	Control module communication
ABS	0091	Control module communication
ABS	0092	Control module communication
ABS	0093	Control module communication
ABS	0094	Control module communication
ABS	0095	Control module communication
SAS	E000	Communication fault with control unit
SAS	E003	Communication fault with control unit
TCM	E000	Control module communication
TCM	E003	Configuration fault
ECM	E000	Control module internal fault (CAN High speed checksum error)
ECM	E003	Control module internal fault (CAN configuration fault)

Note that the description in "Comment" is not always consistent. They are mostly taken from the Vadis description.

¹ Not including the codes that are posted as a consequence of lack of communication, e.g. 928C.

Appendix Data communication wiring diagram

Denso EMS and Bosch EMS up until MY01



Bosch EMS from MY02

