Evolution Management and Process for
Real-Time Embedded Software Systems

DaimlerChrysler Demonstrator: System Specification

Instrument Cluster

Appendix B to Deliverable D.5

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12 December 2003

Version 1.0

Status final

Public Version

ITEA

INFORMATION TECHNOLOGY
FOR EUROPEAN ADVANCEMENT

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Document History:

Date	Version	Editor	Description
12 December 2003	1.0	S. Van Baelen, K.U.Leuven	Public version based on internal version 1.1

Filename: D5_Appendix_B.doc

System Specification

Instrument Cluster

MODEL EMP01

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Code Number: IC EMP01 1220

Version: 1.1

Date: 2003-12-12

Content

Functional Descriptions

1.1 Activation and Deactivation of the Instrument Cluster

This section describes the activation and deactivation of the instrument cluster. Activation means that the display of the instrument cluster lights up. Deactivation means that the light of the display dims out and the instrument cluster falls asleep (i.e. it only consumes the sleep time energy).

1.1.1 Function Overview

It shall be possible to provide the driver with essential information and a certain comfort whenever needed. So the activation and deactivation of the instrument cluster should be useful and intuitively manageable.

1.1.2 Business Requirements

1.1.2.1 Vision

This subsection presents the top goals of the instrument cluster's activation and deactivation .

G-1 Driver information during the trip

Driver shall be enabled to obtain information (e.g. vehicle speed, tank content, time, temperature) while driving.

Rationale: Information during the trip is essential for the driver (e.g. for keeping a speed limit etc.).

G-2 Driver information while parking

Driver shall be enabled to obtain information while parking.

Rationale: Information while parking is essential for driver (e.g. to know how much fuel is in the tank etc.) .

G-3 Maximal comfort

Driver information shall be as comfortable as possible.

Rationale: Driver shall not be distracted from driving and shall be enabled to obtain information easily.

G-4 Minimal power consumption

Provide information (= power consumption) only when needed.

Rationale: Battery power is restricted and needed for other basic car functions as well.

1.1.2.2 Scope

Besides these goals, there are also constraints on the set of possible solutions and on the development process. These business requirements belong to the solution space and are restrictions of the design.

S-1 Deployment of activation and deactivation requirements of model EMP0112

The activation and deactivation requirements of the car model EMP0112 shall be deployed.

Rationale: The activation and deactivation approach of the car model A is approved by and known to the customer. There are no further requests or wishes that have to be fulfilled.

1.1.3 User Requirements

This subsection treats the activation/deactivation as a black box and describes the relevant points from a user's perspective.

1.1.3.1 Features

F-1 Permanent activation when ignition on

After the ignition has been switched on the instrument cluster is activated.

F-2 Deactivation by switching off ignition

Half a minute after the ignition has been switched off the instrument cluster is deactivated and all (warning) lights dim out.

F-3 Permanent activation by setting ignition key in position radio

After the ignition key is set in position radio, the instrument cluster is activated.

F-4 Temporal activation by opening driver's door

After the driver's door has been opened the instrument cluster is activated for half a minute.

F-5 Temporal activation by closing driver's door

After the driver's door has been closed the instrument cluster is activated for half a minute.

F-6 Temporal activation by switching on headlights

After the headlights have been switched on the instrument cluster is activated for half a minute.

F-7 Temporal activation with the push-button

After the instrument cluster push button has been applied the instrument cluster is activated for half a minute.

1.1.3.2 Use Case "Activation of the Instrument Cluster"

The driver starts the car and the instrument cluster is turned on.

Primary Actor: Driver

Basic flow:

1. The use case begins when a driver sits in the car and the instrument cluster is deactivated. The ignition is turned off.
2. The driver switches on the car (ignition key in position ignition on).
3. The instrument cluster is turned on and stays active.
4. After the trip the driver switches off the ignition.
5. The instrument cluster stays active for 30 seconds and then turns itself off.
6. The driver leaves the car.

Alternative Step Execution (Exception Flow):

2a. The driver sets the ignition key in position radio.

3a. The instrument cluster is activated.

2b. The driver opens the door.

3b. The door is opened and the instrument cluster is activated temporarily.

4b. The driver switches on the ignition within 30 seconds.

5b. The instrument cluster stays activated.

2c. The driver closes the door.

3c. The door is closed and the instrument cluster is activated temporarily.

4c. The driver switches on the ignition within 30 seconds.

5c. The instrument cluster stays activated.

2d. The driver switches on the headlights.

3d. The headlights are switched on and the instrument cluster is activated temporarily.

4d. The driver switches on the ignition within 30 seconds.

5d. The instrument cluster stays activated.

2e. The driver switches on the instrument cluster by the push-button.

3e. The instrument cluster is activated temporarily.

4e. The driver switches on the ignition within 30 seconds.

5e. The instrument cluster stays activated.

1.1.3.3 Use Case "Temporary Activation of the Instrument Cluster"

The instrument cluster is turned on temporarily by the driver.

Primary Actor: Driver

Basic flow:

1. The use case begins when a driver enters the car. The ignition is turned off.

2. The driver opens the door.

3. The instrument cluster is activated temporarily.

4. The instrument cluster turns itself off after 30 seconds.

5. The driver leaves the car.

Alternative Step Execution (Exception Flow):

2a. The driver closes the door.

2.b The driver switches on the headlights.

2.c The driver applies the push-button of the instrument cluster.

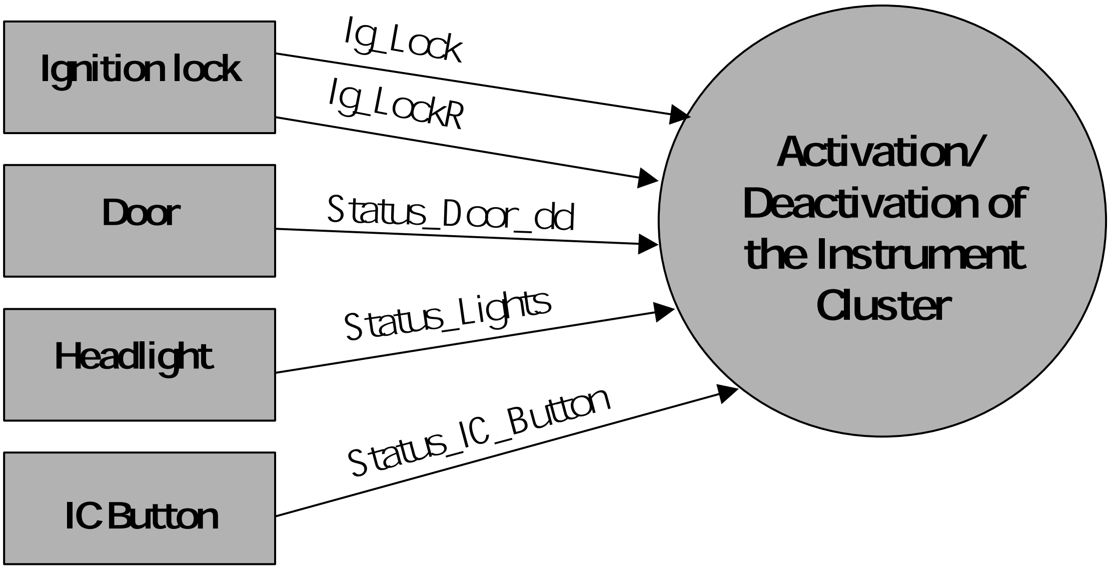
1.1.4 System Requirements

This subsection specifies the behavior of the activation/deactivation of the instrument cluster on a detailed level.

1.1.4.1 Context Diagram

The following context diagram (see figure Context diagram IC – activation/deactivation) presents the context of the activation/deactivation of the instrument cluster. The used notation is similar to the common notation for context diagrams SA/RT (see section References [2]).

Figure: Context diagram IC - activation/deactivation.



1.1.4.2 Functional Requirements

Activation/deactivation operates as long as the instrument cluster is connected to the power supply. After disconnection from the power supply the instrument cluster is completely deactivated.

The functional requirements are divided up into two parts. The first part treats the input signals. The second part treats the processing of the signals, mainly in a comprehensible and short table.

1.1.4.2.1 Input Signals

The following input signals for the activation/deactivation functionality are relevant.

Ig_Lock

> *Describes the position of the ignition key. If Ig_Lock = 1 then the ignition key is in position ignition on. Sent by the ignition lock control unit. Scope: {0,1}. Received every 100 ms. Transferred by the CAN bus.*

Ig_LockR

> *Describes the position of the ignition key. If Ig_LockR = 1 then the ignition key is in position radio. Sent by the ignition lock control unit. Scope: {0,1}. Received every 100 ms. Transferred by the CAN bus.*

Status_Door_dd

> *Describes the status of the driver's door. Scope: {open (= 1), closed (= 0)}. Sent by the door control unit. Received every 100 ms. Transferred by the CAN bus.*

Status_Lights

Describes the status of the headlights. Scope: {on (=1), off (=0)}. Sent by the headlight control unit. Received every 100 ms. Transferred by the CAN bus.

Status_IC_Button

Describes the status of the IC button. Scope: {pressed (=1), not pressed (=0)}. Sent by the IC button control unit. Transmitted internally by the instrument cluster.

1.1.4.2.2 Processing of the Signals

The processing of the signals is described here in a kind of pseudo code.

The processing of the signals is denoted in the table Processing of the signals. It denotes how the input signals shall be processed.

Table: Processing of the signals.

Input Signal	Input Signal	Input Signal	Effect
Ig_Lock = 0	Ig_Lock R = 0	Status_Door_dd = closed, Status_Lights = off, Status_IC_Button = not pressed	The instrument cluster is deactivated 30s after first occurrence of this state of input signals if no change of input signals occurs; changes are treated as requested in this table.
Only regarded changing signals are denoted from now on:			
Ig_Lock = 0	Ig_Lock R = 0	Status_Door_dd = open	The instrument cluster is activated for 30s if no change of input signals occurs. After 30s, the instrument cluster is deactivated again; changes of the input signals are treated as requested in this table.
Ig_Lock = 0	Ig_Lock R = 0	Status_Door_dd = closed	The instrument cluster is activated for 30s if no change of input signals occurs. After 30s, the instrument cluster is deactivated again; changes of the input signals are treated as requested in this table.
Ig_Lock = 0	Ig_Lock R = 0	Status_Lights = on	The instrument cluster is activated for 30s, if no change of input signals occurs. After 30s, the instrument cluster is deactivated again; changes of the input signals are treated as requested in this table.
Ig_Lock = 0	Ig_Lock R = 0	Status_IC_Button = pressed	The instrument cluster is activated for 30s if no change of input signals occurs. After 30s, the instrument cluster is deactivated again; changes of the input signals are

Input Signal	Input Signal	Input Signal	Effect
			treated as requested in this table.
Ig_Lock = 0	Ig_Lock R = 1		The instrument cluster is activated. Changes of the input signals are treated as requested in this table.
Ig_Lock = 1			The instrument cluster is activated. Changes of the input signals are treated as requested in this table.

1.2 Rev Meter

This section describes the rev meter.

1.2.1 Function Overview

The rev meter is an instrument, which displays the engine speed in revolutions per minute (RPM). In principle the rev meter is a voltmeter placed in the motor. The turning action is transferred to an iron core in an electrical coil and thus a measurable voltage is induced. Since the height of the voltage is directly proportional to the turning action of the iron core, the number of revolutions can be displayed with the help of a scale. The output signals of the electronic control unit activate a stepping motor, which affects a pointer over the scale.

1.2.2 Business Requirements

1.2.2.1 Vision

In this section top goals of the rev meter system are presented. This layer describes an abstract view of the system, which gives a clear, understandable and agreed focus.

G-1 Comfortable view of the revolutions of the engine

The user has an optimal view of the rev meter, which provides actual information permanently.

G-2 Maximize rev meter robustness and life span

Average life span of the rev meter has to exceed the average life span of the car as a whole: In less than one per 10000 cars a defect of the rev meter is tolerable.

G-3 Minimize power consumption

Rev meter must provide appropriate contributions to power management.

G-4 Attractive Appearance

The display and behavior of the rev meter shall be attractive, sporty, and agile.

Rationale: This suits to our brand policy.

1.2.2.2 Scope

Besides the goals, there are also constraints on the set of possible solutions and on the development process. These business requirements belong to the solution space and are restrictions of the design.

S-1 Deployment of Model Y components

Rev meter Model X has to be developed using existing components of Model Y. For Model X we do not want to develop new hardware and mechanics, but reuse existing technology.

Rationale: Model Y got good reviews and is cheap in development (new development costs can be economized).

S-2 Error in the display

If an error is determined, this fact should be displayed.

Rationale: A new feature shall be introduced to close on the competitor.

1.2.3 User Requirements

In this section the rev meter system is viewed as a black box in such a way that the provided functions visible for the user are considered. These aspects are visualized by features and use cases.

1.2.3.1 Features

F-1 Display RPM

The display RPM consists of a scale and a damped pointer showing the actual revolutions per minute of the engine.

F-2 Warning Display

The warning display lights up whenever the value of revolutions per minute is too high.

F-3 Error Display

The error display lights up whenever an error is realized.

1.2.3.2 Use Case "Show RPM of the Engine"

The driver switches on the car and drives while watching the rev meter.

Primary Actor: driver

Basic Flow:

1. This use case starts when a driver gets in the car.

2. The driver switches on the car by turning the ignition key to the switched on position.

3. The car is switched on and the pointer of the rev meter display goes from the technical initial position to the initial position of the scale (0 min^{-1}), damped as described below.

4. The input signals from the motor are sent regularly.

5. The system determines the engine speed and displays it.

6. The driver switches off the car by turning the ignition key to the switched off position.

7. The car is switched off and the pointer of the rev meter display falls back to its technical initial position, damped as described below.

8. The driver leaves the car.

Alternative Step Execution (Exception Flow):

5.a The system determines that the input signals are too high.

6.a A speed warning is displayed. The pointer of the rev meter display remains at the right scale end (final value of the scale).

7.a The system determines that the input signals are in the normal range of values.

8.a The system determines the engine speed and displays it.

5.b The system determines that the input signals are not readable or disconnected.

6.b An error warning is displayed. The pointer of the rev meter display is directly steered back to the initial point of the scale (0 min^{-1}), damped as described below.

7.b The system determines that the input signals are stable in the normal range of values.

8.b The system determines the engine speed and displays it.

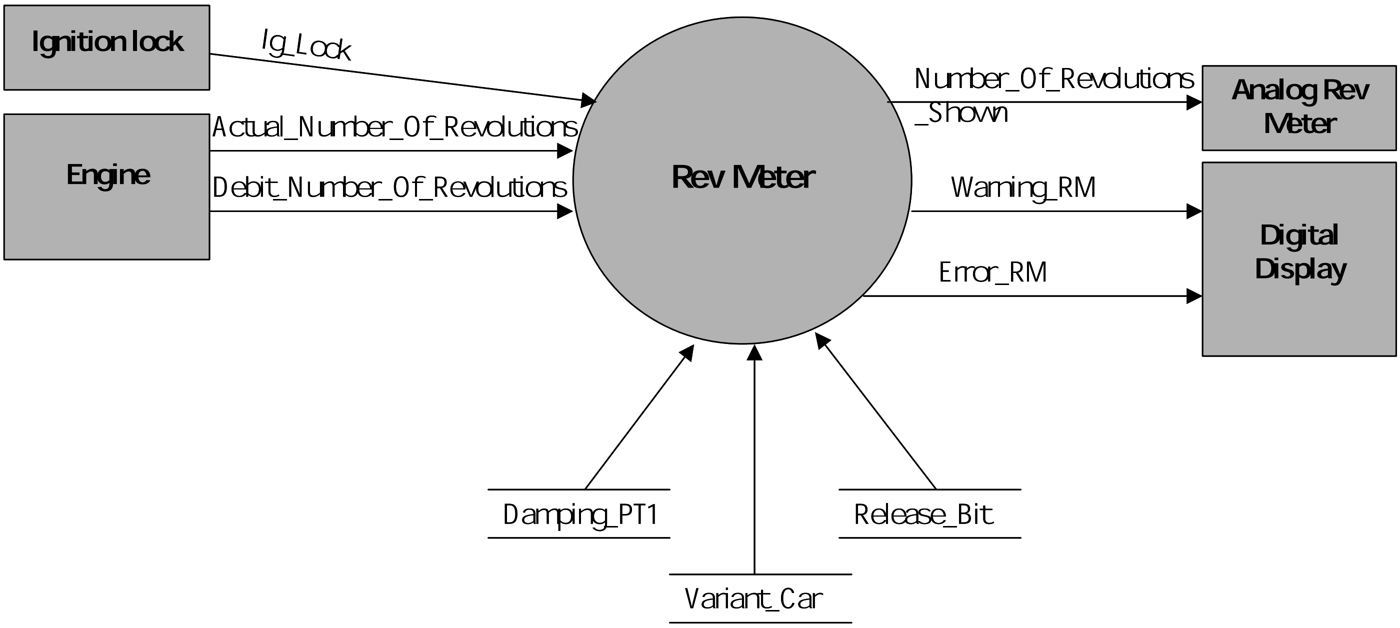
1.2.4 System Requirements

The requirements in this section specify the rev meter on a detailed level meaning that the business and user requirements have to be realized by the system requirements. These requirements correspond to the abstraction level of actual product specifications ("Lastenhefte").

1.2.4.1 *Context Diagram*

The following context diagram (see figure Context diagram – rev meter) presents the context of the rev meter. The used notation is similar to the common notation for context diagrams SA/RT (see section References [2]).

Figure: Context diagram - rev meter.



1.2.4.2 Functional Requirements

The functional requirements describe the functional behavior of the rev meter. They are structured concerning their contextual relation.

1.2.4.2.1 *Drive of the Rev Meter Pointer*

A stepping motor with at least 360 steps per rotation is the drive of the rev meter display pointer.

1.2.4.2.2 *Angle of Deflection and Display Tolerance*

The display tolerance of the system amounts to ±1,5 degree.

The angle of deflection of the pointer of the rev meter display amounts to 162 degrees.

1.2.4.2.3 *Initial Position/Final Position of the Scale*

When the car is switched on, thus Ig_Lock = active, the pointer goes from the technical initial position to the initial position of the scale (0 min^{-1}), damped as described below. Engine speed is read out.

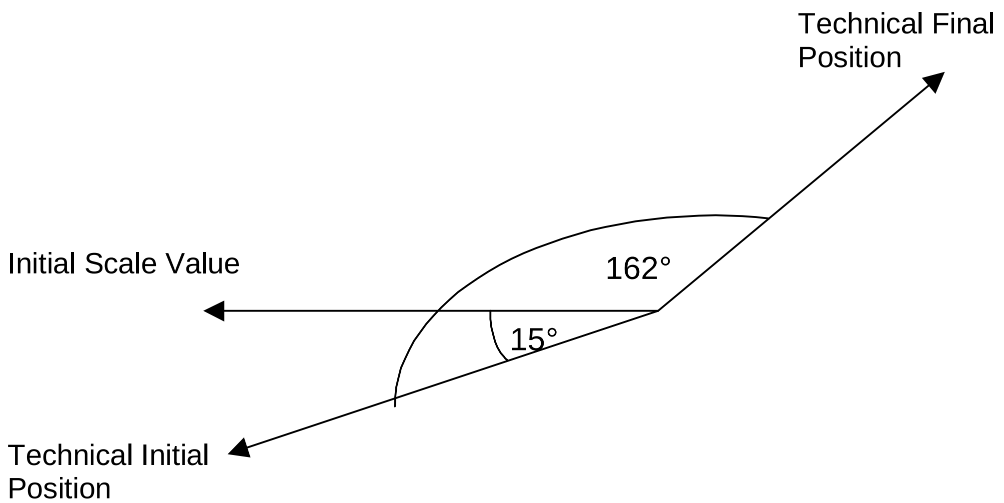
When the car is switched off, thus Ig_Lock = inactive, the readout of the engine speed is stopped. The pointer drops back to the technical initial position, damped as described below.

1.2.4.2.4 *Technical Initial Position, Technical Final Position of the Pointer*

The technical initial position of the pointer is 15 degrees below the horizontals, the technical final position of the pointer is at the angle of deflection of the pointer over the technical initial position (see figure Illustration of the possible pointer positions).

> **Rationale: The technical position of the pointer relative to its environment. The technical initial position is differentiated from the initial position of the scale.**

Figure: Illustration of the possible pointer positions.



1.2.4.2.5 Initial Scale Value, Final Scale Value, Partitioning of the Scale, and Danger Zone

The scale starts 15 degrees over the technical initial position of the pointer.

The initial scale value amounts to 0 min^{-1}.

The end of scale is on the technical final position of the pointer.

The final scale value for the diesel version amounts to 6000 min^{-1}. The danger zone (red field) begins at 4000 min^{-1}.

For the fuel version the final scale value amounts to 7000 min^{-1}. The danger zone (red field) begins at 5000 min^{-1}.

The scale is partitioned linearly.

1.2.4.2.6 Input Signals

The following input signals are digitally transferred by the CAN bus.

Actual_Number_Of_Revolutions

> *The number of revolutions of the engine, at the moment measured (8 bits: 0x0 – 0xFF; Unit 32 rotations/minute). Received every 100 ms.*

Debit_Number_Of_Revolutions

> *This signal is sent by the engine (8 bits: 0x0 – 0xFF; Unit 32 rotations/minute). Received every 100 ms.*

Ig_Lock

> *Describes the position of the ignition key. If Ig_Lock = 1 then the ignition key is in position ignition on. Scope: {0,1}. Received every 100 ms.*

1.2.4.2.7 Output Signals

Error_RM

> *In case of a realized error (active/inactive). Scope: {0=active, 1=inactive}. Transferred by the CAN bus to the digital display of the instrument cluster. Sent every 100 ms.*

Warning_RM

> *In case of exceeding number of revolutions, this warning signal is transmitted (active/inactive). Transmitted internally of the instrument cluster to the digital display of the instrument cluster. Sent every 100 ms.*

Number_Of_Revolutions_Shown

> *For the display edited engine speed signal (8 bits: 0x0 – 0xFF). Transmitted internally of the instrument cluster to the analog display of the rev meter. Sent every 100 ms.*

1.2.4.2.8 Parameter Values

The parameter value is stored internally to provide the possibility to have different characteristics of the rev meter.

Release_Bit

> *Configuration adjustment for the representation of the number of revolutions. Stored in the EEPROM. Scope: {0, 1}.*

Damping_PT1 (in the ROM)

Damping of the PT1 element. Stored in the ROM. Scope: {0, …, max}.

Variant_Car

Stores the variant of the car. The variant has an impact on the scale of the rev meter display. Scope: {0 = diesel, 1 = fuel}. Stored in the EEPROM.

1.2.4.2.9 Discrimination Threshold

The discrimination limit of the rev meter lies above 320 min^{-1}.

Numbers of revolutions below 320 min^{-1} are suppressed, such that the pointer remains at 0 min^{-1} (scale value).

1.2.4.2.10 No or too high CAN Bus Signals and Error Handling

Non-defined transfer values (whether “Actual_Number_Of_Revolutions” or “Debit_Number_Of_Revolutions”) between the final scale value of the display and the maximal transfer value of the CAN are limited by the final scale value.

Furthermore a speed warning is sent and displayed.

The speed warning is sent, if the non-defined transfer value is sent 400 ms.

The warning symbol lights up for 5 s.

Time is started new, whenever the non-defined transfer value is sent for at least 400 ms.

The warning symbol dims out when the car is switched off.

When the input signals are in the normal range of values, the engine speed is displayed as usual, otherwise the pointer stays at the final scale value. An adaptation to the engine cylinder number is not necessary.

If on the CAN bus there is "0xFF" or "Timeout" (whether Actual_Number_Of_Revolutions or Debit_Number_Of_Revolutions), then the pointer of the engine speed indicator is steered directly to the left end of the scale (0 min^{-1}), damped as described below.

Additionally an error warning is sent and displayed.

The error warning is sent, if the error value is sent 400 ms.

The error symbol lights up for 5 s.

Time is started anew, whenever the error value is sent for at least 400 ms.

The error symbol dims out when the car is switched off.

When the system determines input signals in the normal range of values, it waits 400 ms. If the input signals are stable and sent regularly, the engine speed is displayed as usual, otherwise the pointer of the rev meter display stays at the initial point of the scale.

1.2.4.2.11 Damping

The input signals are damped by a PT^1 element.

Rationale: A system with a flattening transient step response is also defined as a system with adjustment. This term is used for all systems, which react to a branch excitation with a transition to a finite final value. Such transfer elements are called PT^1 elements. One typical

characteristic of the PT[1] element is that the step response possesses a finite starting upward gradient.

1.2.4.2.12 Pointer Behavior

The following step responses result (see table Step responses):

Rationale: The step response is the characterization of the reaction of the system to a special test function.

Table: Step responses.

Step from 0 degree to	Reaching 95% of the debit value after
80 degrees	500 ms
150 degrees	1200 ms

1.2.4.2.13 Algorithm/Characteristics

In order to avoid a varying of the RPM indication under certain operating conditions, the Actual_Number_Of_Revolutions is not considered all the time, but the Debit_Number_Of_Revolutions, dependent on the speed limits and the Release_Bit. The conditions for it are as follows.

If "Release_Bit" = "1" and “Actual_Number_Of_Revolutions” is greater than “Debit_Number_Of_Revolutions” and “Actual_Number_Of_Revolutions” is less than 110% “Debit_Number_Of_Revolutions”, then “Debit_Number_Of_Revolutions” is displayed meaning that “Number_Of_Revolutions_Shown” = “Debit_Number_Of_Revolutions”.

Otherwise “Actual_Number_Of_Revolutions” is displayed always meaning that “Number_Of_Revolutions_Shown” = “Actual_Number_Of_Revolutions”.

If "Release_Bit" = "0", then “Actual_Number_Of_Revolutions” is displayed always.

The selected value is transferred over a characteristic with 2 bases on the actual output value. Only after exceeding the discrimination limit the output of the number of revolutions begins.

Characteristic for fuel version (see table Characteristic fuel version) (interpolate linearly):

Table: Characteristic fuel version.

Number_Of_Revolutions_Shown (hexadecimal)	Angle of deflection of the pointer
-	0 degree (technical initial position of the pointer)
0x0	15 degrees
0x8	15 degrees
0x19	36 degrees
0x7D	120 degrees
0xAF	162 degrees (technical final position of the pointer)
greater than 0xAF	162 degrees (technical final position of the pointer)

Characteristic for diesel version (see table Characteristic diesel version) (interpolate linearly):

Table: Characteristic diesel version.

Number_Of_Revolutions_Shown (hexadecimal)	Angle of deflection of the pointer
-	0 degree (technical initial position of the pointer)
0x0	15 degrees
0x8	15 degrees
0x19	39.5 degrees
0x64	113 degrees
0x96	162 degrees (technical final position of the pointer)
greater than 0x96	162 degrees (technical final position of the pointer)

1.3 Speedometer

This section describes the speedometer, which displays the speed of the car.

1.3.1 Function Overview

The speedometer displays the speed of the car in mph or km/h. The speed is computed with the help of the speed of each wheel and is displayed by a pointer over a scale.

1.3.2 Business Requirements

1.3.2.1 Vision

This section presents the top goals of the speedometer.

G-1 Display speed of the car in two variants

The speedometer displays the car speed in km/h or mph.

G-2 Display speed of the car in two ways.

The speedometer displays the car speed in an analog and a digital way.

G-3 Display actual speed value

The speedometer constantly provides the actual speed value.

G-4 Reliability

The display and behavior of the speedometer shall be agile and dynamic.

G-5 Maximize speedometer life span and robustness

The average live span of the speedometer has to exceed the average life span of the car as a whole: a speedometer defect is tolerable in less than one per 10000 cars.