Empress

Evolution Management and Process for
Real-Time Embedded Software Systems

DaimlerChrysler Demonstrator: System Specification

Instrument Cluster

Appendix B to Deliverable D.5

Written by K. Buhr, N. Heumesser, F. Houdek, H. Omasreiter,
F. Rothermel, R. Tavakoli, T. Zink

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Authors/Partners:

Partner	Author	Email
	K. Buhr, N. Heumesser, F. Houdek, H. Omasreiter, F. Rothermel, R. Tavakoli, T. Zink	

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System Specification

Instrument Cluster

MODEL EMP01

Authors: K. Buhr, N. Heumesser, F. Houdek, H. Omasreiter, F. Rothermel, R. Tavakoli, T. Zink

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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.

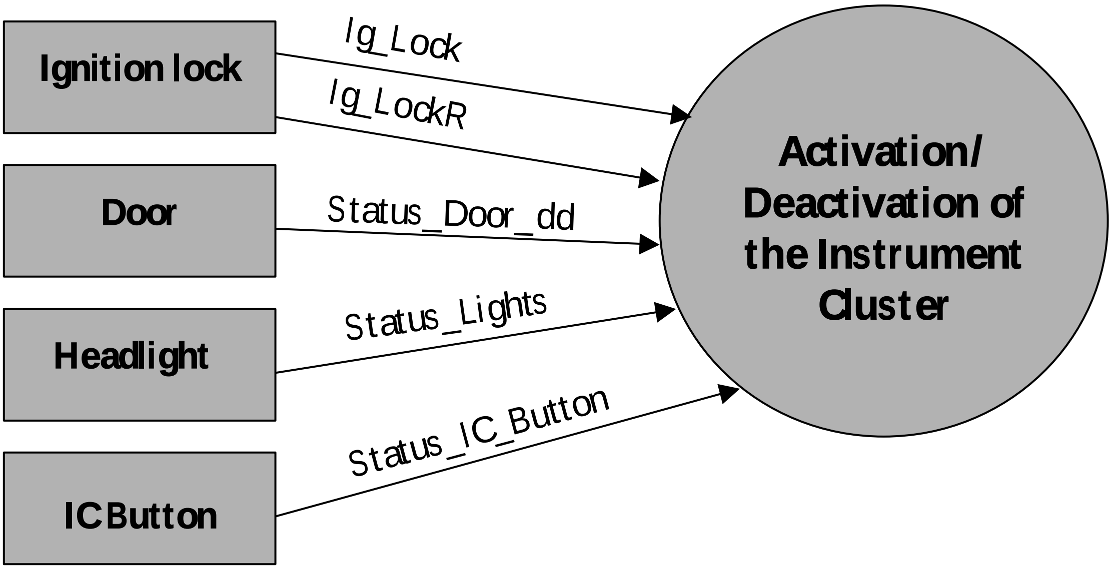
1.1.4 System Requirements

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.

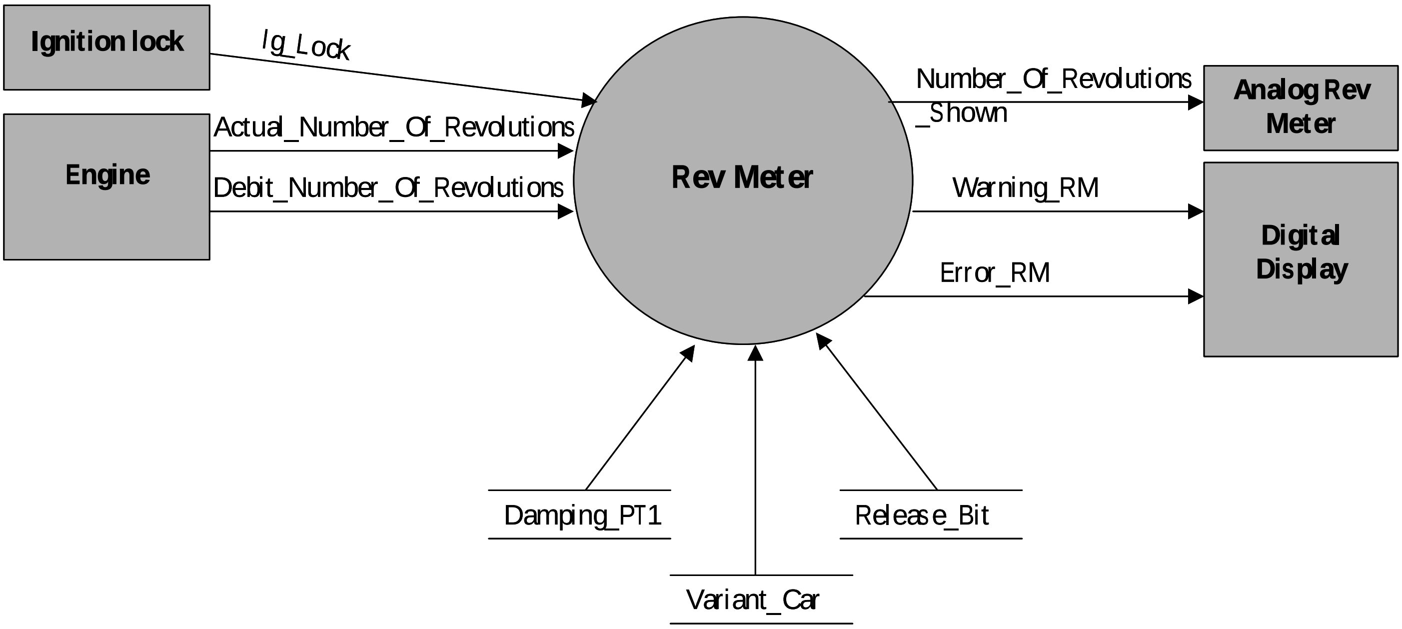
1.2.4 System Requirements

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.

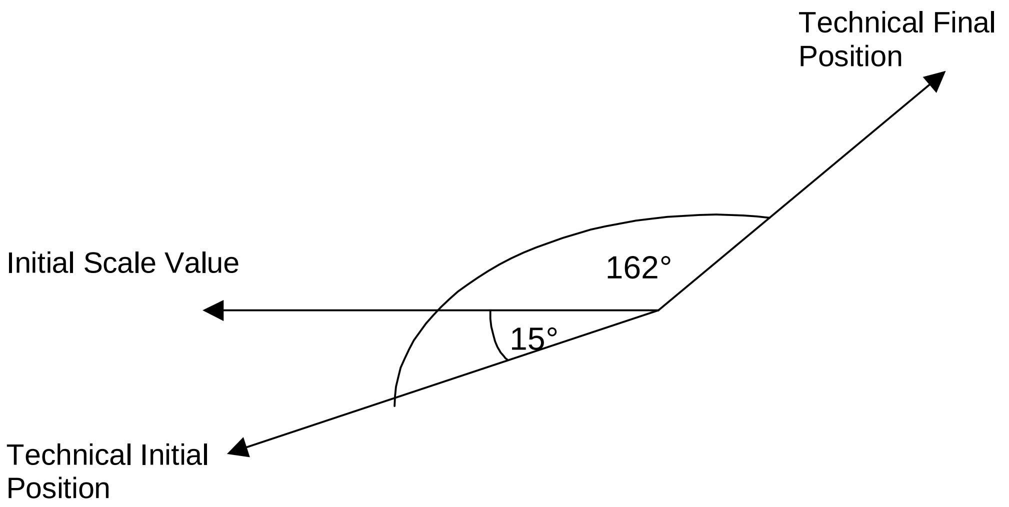
When the car is switched off, thus Ig_Lock = inactive, the readout of the engine speed is stopped. The pointer drops back to the technical initial position, damped as described below.

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.

1.3.2.2 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 Model C components

The speedometer model D has to have at least the properties, features and quality characteristics of the model C. They are to be improved by using current development know how and technology.

Rationale: The next speedometer generation has to be better than the current generation.

S-2 Turning of a wheel

The turning of a wheel (for example during a wheel change) must not be interpreted as the vehicle speed, since this would activate the automatic door lock.

1.3.3 User Requirements

This section treats the speedometer as black box and describes the relevant interactions from a user's perspective.

1.3.3.1 Features

F-1 Analog car speed display

The analog speedometer consists of a scale and a damped pointer displaying the actual car speed in an analog way.

F-2 Digital car speed display

The digital speedometer consists of LCD-display displaying the actual car speed in a digital way.

F-3 Warning message for the hand brake

A warning message is shown when the driver drives with locked hand brake.

1.3.3.2 Use Case "Displaying Car Speed"

The driver starts the car and drives while watching the speedometer. Notice: For abbreviations see subsection Cruise display.

Primary Actor: driver

Basic Flow:

1. When the driver enters the car the use case starts.

2. The driver starts the car by turning the ignition key to the marked ON - position.

3. The car is started and the pointer of the analog speedometer swings upwards in a damped way (see subsection Damping) from the NIV to the MinSV.

4. The four wheel speed sensors collect the revolution speed from each of the four wheels and regularly send them to the system.

5. The system calculates the car speed and displays it via the analog speedometer display.

6. The driver turns off the car by turning the ignition key to the marked OFF - position.

7. The car is turned off and the pointer of the analog speedometer swings downwards in a damped way (see subsection Damping) to NIV.

8. The driver gets out of the car.

Alternative Step Execution (Exception Flow):

5.a The speed determined by the system is higher than MaxSV.

6.a The pointer of the analog speedometer swings up to NFV and stays there.

7.a The system determines that the car speed is within the normal range of values.

8.a The system calculates the car speed and displays it via the analog speedometer display.

5.b The system determines that one of the four wheel speed sensors is not sending a signal.

6.b The system calculates the speed from the three remaining sensors.

7.b The analog speedometer displays the calculated speed.

8.b The system determines that all four wheel speed sensors are sending signals within the normal range.

9.b The system calculates the car speed and displays it via the analog speedometer display.

5.c The system determines that more than one of the four wheel speed sensors is not sending a signal.

6.c The system displays an error warning for defect wheel speed sensors to inform the driver.

7.c The pointer of the analog speedometer swings down to MinSV.

8.c The system determines that all four wheel speed sensors are sending signals within the normal range.

9.c The system calculates the car speed and displays it via the analog speedometer display.

10.c The systems switches off the error warning.

3.d The driver changes the function of the LCD-display from "displaying outdoor temperature" to "displaying car speed".

4.d The car is started and the digital speedometer display displays a car speed of zero.

5.d The four wheel speed sensors collect the revolution speed from each of the four wheels and regularly send them to the system.

6.d The system calculates the car speed and displays it via the digital speedometer display.

5.e The speed determined by the system is higher than MaxSV.

6.e The digital speedometer display continuously displays the maximum allowed speed value.

7.e The system determines that the car speed is within the normal range of values.

8.e The system calculates the car speed and displays it via the digital speedometer display.

5.f The system determines that one of the four wheel speed sensors is not sending a signal.

6.f The system calculates the speed from the three remaining sensors.

7.f The digital speedometer display displays the calculated speed.

8.f The system determines that all four wheel speed sensors are sending signals within the normal range.

9.f The system calculates the car speed and displays it via the digital speedometer display.

5.g The system determines that more than one of the four wheel speed sensors is not sending a signal.

6.g The system displays an error warning for defect wheel speed sensors to inform the driver.

7.g The digital speedometer display displays a speed value of zero.

8.g The system determines that all four wheel speed sensors are sending signals within the normal range.

9.g The system calculates the car speed and displays it via the digital speedometer display.

10.g The systems switches off the error warning.

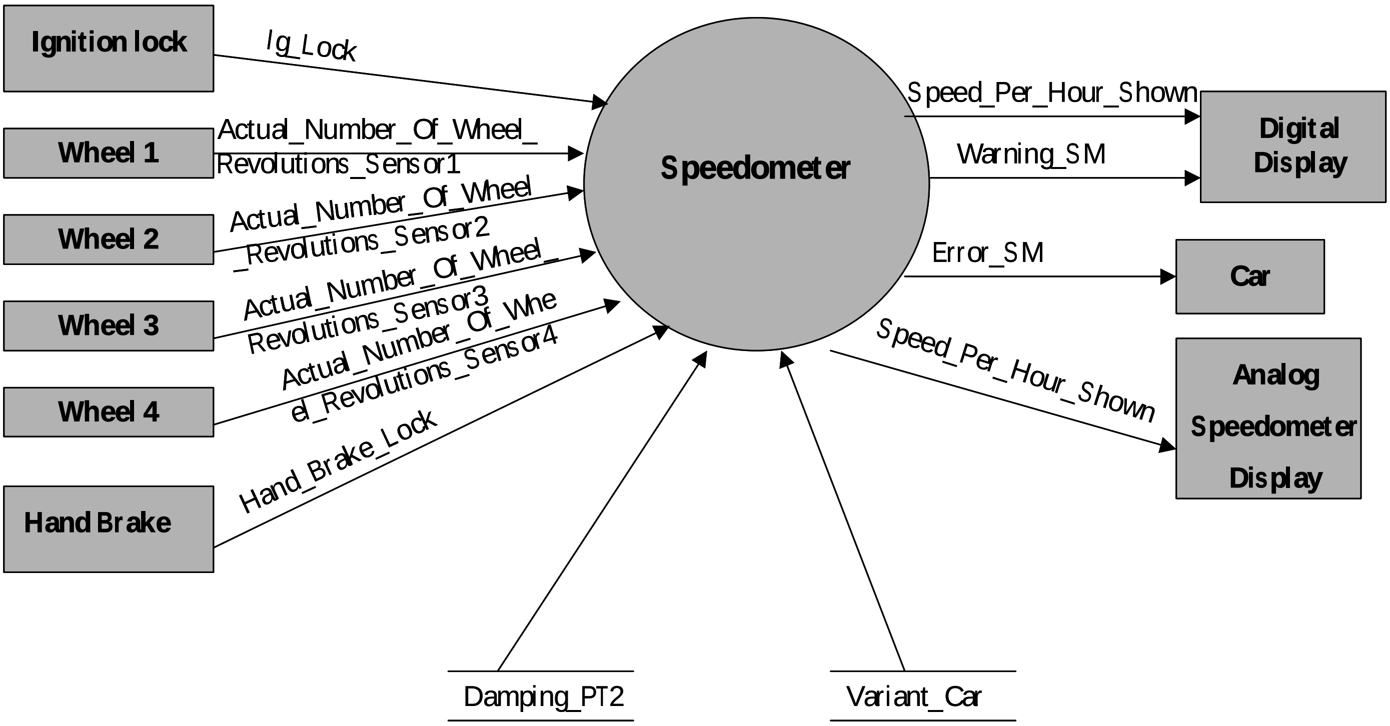
1.3.4 System Requirements

This section specifies the behavior of the speedometer on a detailed level.

1.3.4.1 Context Diagram

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

Figure: Context diagram speedometer.



1.3.4.2 Functional Requirements

The functional requirements are divided up into the following parts: (1) Cruise Display, (2) Cruise Computation Algorithm, (3) Input Signals, (4) Output Signals, (5) Parameter Values, (6) Discrimination Threshold, (7) Damping and (8) Error and Wrong Signal Handling.

1.3.4.2.1 Cruise Display

Speed can be displayed in two ways. Firstly by means of an analog indicator device. Secondly by means of a digital value presented on the display. Details on the digital presentation are described in section User Configuration and Menu Tree.

The analog and the digital speedometer both display the same speed at the same moment with an allowed deviation of +/-2km/h or 1mph.

The speedometer converts the measured speed of the car into an equivalent scale value and an equivalent digital value, respectively.

The speed scale has a minimum scale value (MinSV) of 0 km/h respective 0 mph.

The digital display has a minimum display value of 0 km/h respective 0 mph.

The speed scale has a maximum scale value (MaxSV) of 260 km/h respective 160 mph.

The digital speed display has a maximum display value of 260 km/h respective 160 mph.

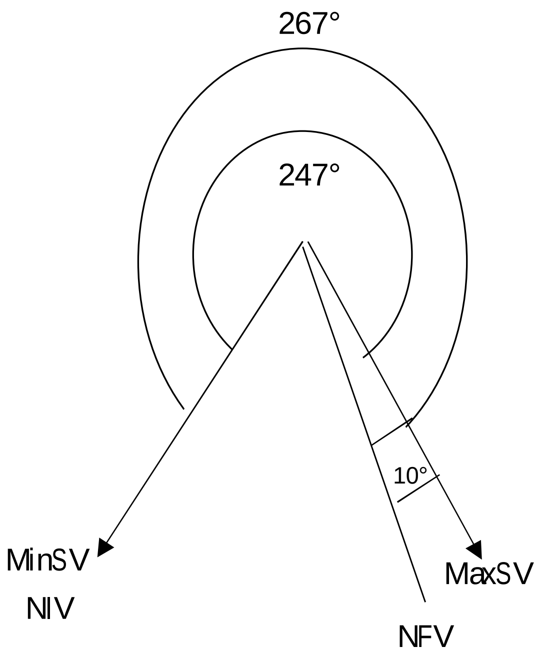
The deflection angle of the pointer of the speedometer scale is 257 degrees.

The NFV is 10 degrees above the MaxSV, i.e. the indicator can pass the maximum scale value by 10 degrees.

In case of speeds, which are higher than the MaxSV, the indicator can pass the MaxSV up to NFV.

The NIV is 0 degree below the MinSV. The following figure Pointer Positions illustrates the possible pointer positions of the analog speedometer.

Figure: Pointer Positions.



When the ignition is switched off (Ig_Lock = 0), the speed display pointer is positioned at the NIV, while the digital display displays 0km/h or 0mph, respectively.

When the car is started (Ig_Lock = 1) but the speed is at 0 km/h or 0 mph the pointer position is equal to the MinSV, while the digital display displays a speed value of zero.

The reaction time of both, the pointer and the digital display, to a signal given is 500 ms +/- 10 ms, independently of its actual position.

The speedometer display pointer is powered by a stepping motor.

1.3.4.2.2 *Cruise Computation Algorithm*

The speed of the car is calculated as the arithmetic average of the valid actual number of wheel revolutions.

The input values of the cruise computation algorithm are the four current wheel speed values, supplied by the CAN, see subsection Input Signals.

The output value of the cruise computation algorithm is the computed vehicle speed, see subsection Output Signals.

The threshold value of the algorithm at speeds between 0 - 45 km/h or 0 - 28 mph is 75 %.

The threshold value of the algorithm at speeds between 45 km/h or mph and MaxSV is 20 %.

1.3.4.2.3 *Input Signals*

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

Actual_Number_Of_Wheel_Revolutions_Sensor1,

Actual_Number_Of_Wheel_Revolutions_Sensor2,

Actual_Number_Of_Wheel_Revolutions_Sensor3,

Actual_Number_Of_Wheel_Revolutions_Sensor4

> *The number of revolutions of each of the four wheels, at the moment measured (8 bits:0x0 - 0xFF, Unit: 1/6 wheel rotation per second, 0xFF = Error value). Received every 150 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.*

Hand_Brake_Lock

> *Indicates that the hand brake is locked (0 = hand brake locked, 1= hand brake is not locked)*

1.3.4.2.4 *Output Signals*

Speed_Per_Hour_Shown

> *The speed signal calculated and converted into a scale value (8 bits: 0x0 - 0xFF; Unit 1 km/h). Transmitted from the speedometer to the display.*

Error_SM

> *In case of a detected error (active/inactive). Transferred by the CAN bus. Sent every 100 ms.*

Warning_SM

> *In case of driving with locked hand brake, this warning is transmitted (0= active/1=inactive). Transferred internally.*

1.3.4.2.5 *Parameter Values*

The parameter values are stored to provide the possibility of different characteristics of the speedometer.

Damping_PT2

> *Damping of the PT2 element. Scope {0, ... 0xFF, Unit: degree/second}. Stored in the EEPROM.*

Variant_Car

Stores the variant of the instrument cluster speedometer scale. Scope: {0 = kmhl, 1 = mphl}. Stored in the EEPROM.

1.3.4.2.6 Discrimination Threshold

The discrimination threshold of the speedometer is defined with 30 rotations/minute. Numbers of wheel revolutions below 30 rotations/minute are blanked. In this case the pointer remains at MinSV.

1.3.4.2.7 Damping

The cruise computation algorithm dampens the calculated display value with a PT2 module.

1.3.4.2.8 Error and Wrong Signal Handling

If the driver drives with locked handbrake, a warning messages is diyplayed (see section Warning Messages).

If there is "0xFF" or "Timeout" for one of the signals Actual_Number_Of_Wheel_Revolutions on the CAN, the pointer of the speedometer swings up to the MinSV, damped as described below.

1.4 Indicator Lights and Engine Control Light

The section describes the indicator lights and the engine control light.

1.4.1 Function Overview

The indicator lights and the engine control light shall support the driver to keep the overview about the car. The indicator lights shall indicate audibly (via a periodic sound) that a turn signal has been set and visually, which turn signal is set. The engine control light shall indicate a problem with the engine of the car.

1.4.2 Business Requirements

1.4.2.1 Vision

This subsection presents the top goals of the indicator lights and the engine control light.

G-1 Comfortable view on important status information

The driver shall have a comfortable view on important status information of the car. The driver shall know the reliability of the engine. Furthermore the driver shall know, which information is indicated to other road users.

Rationale: The display of this information is very important for the driver, because it is a common feature in all cars.

G-2 Increase driver's safety

The safety of the driver shall be increased by providing information about the status of the engine.

Rationale: The engine control light was not placed in the digital display, because an own place in the instrument cluster increases its importance in the driver's concentration.

G-3 Reliability of the lights shall be tested

The reliability of the indicator lights and the engine control light shall be tested, whenever the instrument cluster is activated.

1.4.2.2 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 Well-known appearance and behavior

The appearance and behavior of the indicator lights and the engine control light shall be well-known to the driver, meaning that it shall be as similar as possible to actual car models.

Rationale: The driver is used to the outer appearance and behavior of these lights. A major change in the appearance of these lights would be confusing for the driver.

1.4.3 User Requirements

This subsection treats the indicator lights and the engine control light as black boxes and describes the relevant interactions from a user's perspective.

1.4.3.1 Features

F-1 Two arrows for indicator lights

The indicator lights consist of two arrows, showing to different directions.

F-2 Blinking indication, which turn signal is set

Dependent on which turn signal is set, the arrow showing in the same direction lights up blinking, as long as the turn signal is set.

F-3 Audible indication that a turn signal is set

Whenever a turn signal is set, an audible indication is provided, lasting as long as the turn signal is set.

F-4 Hazard warning signal flasher

Whenever the hazard warning signal flasher is pushed, both arrows of the indicator lights are activated at the same time and behave both as if a turn signal is set.

F-5 Engine control light display

The engine control light is displayed in an own field of the instrument cluster.

F-6 Lights check

The indicator lights and the engine control light are tested after each activation of the instrument cluster. Whenever the instrument cluster is activated, these lights are activated, too, meaning that they light up.

1.4.3.2 Use Case "User Activates Indicator Lights"

The driver activates the indicator lights by setting turn signals or the hazard-warning signal flasher.

Primary Actor: driver

Basic Flow:

1. The use cases starts when a driver enters the car.

2. The driver switches on the car.

3. The car is switched on and the instrument cluster is activated (see section Activation and Deactivation of the Instrument Cluster).

4. The indicator lights light up 2s.

5. The driver sets the car in motion.

6. The driver sets the left turn signal by means of moving the combination switch into the left turn signal set position.

7. The left arrow of the indicator lights begins to blink; a periodic sound is audible.

8. The driver moves the combination switch back into its standard position.

9. The turn signal stops.

10. The indicator lights stop their visible and audible indication.

11. The driver sets the hazard-warning signal flasher by means of a button placed outside of the instrument cluster.

12. Both arrows of the indicator lights begin to blink at the same time; a periodic sound is audible.

13. The driver stops the hazard-warning signal flasher.

14. The indicator lights stop their visible and audible indication.

15. The driver switches off the car.

16. The driver leaves the car.

Alternative Step Execution (Exception Flow):

6a. - 10a. The same steps for right turn signal and right arrow of the indicator lights.

8b. The driver sets the hazard-warning signal flasher by means of a button placed outside of the instrument cluster.

9b. Both arrows of the indicator lights begin to blink at the same time; a periodic sound is audible.

10b. The driver stops the hazard-warning signal flasher.

11b. Only the left arrow of the indicator lights blinks; the periodic sound is audible further on. (go on with step 8.)

1.4.3.3 Use Case "Engine Control Light"

The engine control light lights up, when the instrument cluster is activated. Furthermore it lights up, when a problem with the engine is determined.

Primary Actor: driver

Basic Flow:

1. The use case starts when a driver enters the car.

2. The driver switches on the car.

3. The car is switched on and the instrument cluster is activated (see section Activation and Deactivation of the Instrument Cluster).

4. The engine control light lights up 2s.

5. The driver sets the car in motion.

6. The engine control unit determines a problem with the engine.

7. The engine control light lights up at least 5s.

8. The engine control unit determines that there is no problem with the engine anymore.

9. The engine control light dims out.

10. The driver switches off the car.

11. The driver leaves the car.

Alternative Step Execution (Exception Flow):

8a. The driver switches off the car.

9a. The engine control light dims out when the instrument cluster is deactivated.

10a. The driver leaves the car.

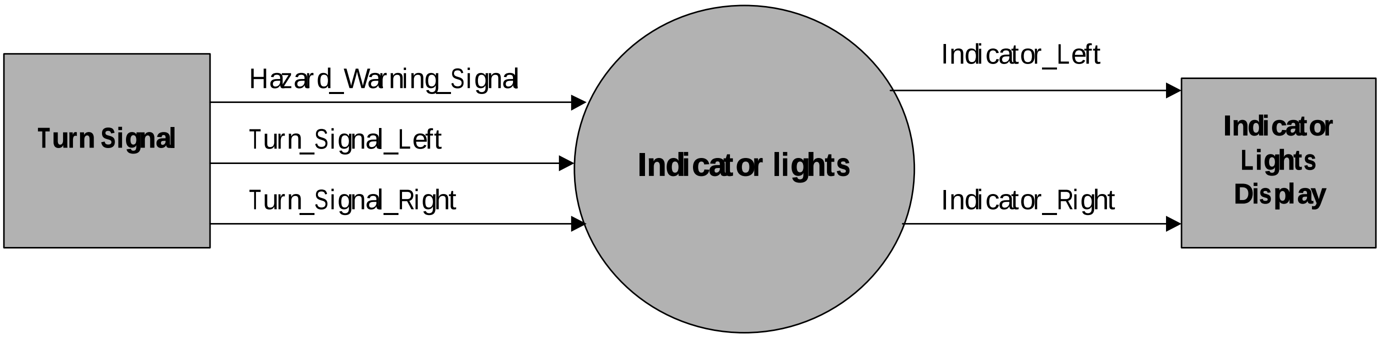
1.4.4 System Requirements

This subsection specifies the behavior of the indicator lights and the engine control light on a detailed level.

1.4.4.1 Context Diagrams

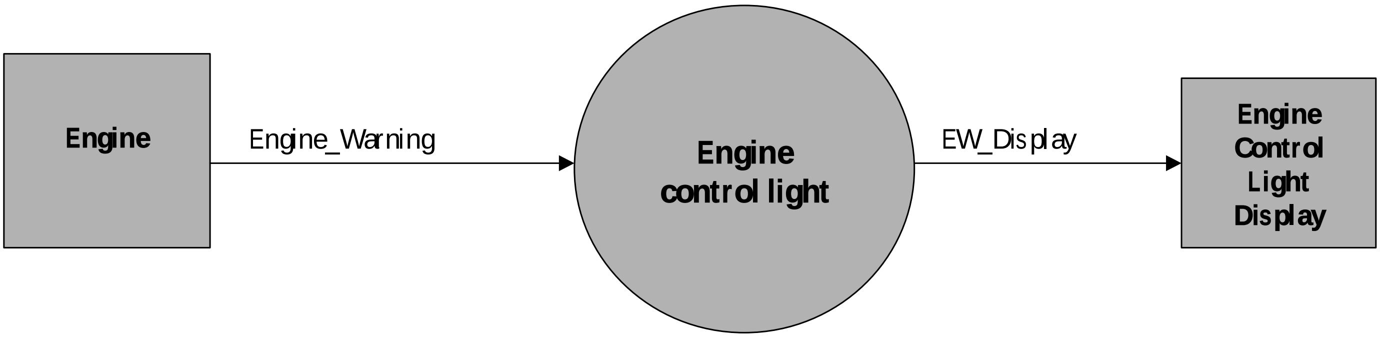
The following context diagram (see figure Context diagram indicator lights) presents the context of the indicator lights. The used notation is similar to the common notation for context diagrams SA/RT (see section References [2]).

Figure: Context diagram indicator lights.



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

Figure: Context diagram engine control light.



1.4.4.2 Functional Requirements

The functional requirements are organized as follows. After the description of the colors of the displays, the lights check is specified. Then the indicator lights and the engine control light are specified. Finally the signals are specified.

1.4.4.2.1 Color of the Indicator Lights

The color of the arrows of the indicator lights is light green, when they light up.

1.4.4.2.2 Color of the Engine Control Light

The color of the engine control light is crimson, when it lights up.

1.4.4.2.3 Lights Check

The indicator lights and the engine control light light up continuously 2s, whenever the instrument cluster is activated.

The lighting up of the indicator lights and the engine control light is addressed as specified in section Activation and Deactivation of the Instrument Cluster.

The indicator lights light up in the same color as specified above.

The engine control light lights up in the same color as specified above.

A sound during the lights check is not audible.

After 2s lighting up of the indicator lights and the engine control, the lights dim out.

The further behavior of these lights is as specified below.

1.4.4.2.4 Indicator Lights

The indicator lights consist of two arrows, placed on the right and left part of the instrument cluster (see section Hardware).

If the driver sets the turn signal left (turn signal right), the left (right) arrow of the indicator lights begins to blink (Indicator_Left = 1 respective Indicator_Right = 1).

The arrow blinks as long as the turn signal is set (only after periodic steps, the blinking is stopped, if the turn signal is not set anymore, see below for the explanation of a periodic step).

The lighting up of the arrows of the indicator lights behaves as follows:

The arrow lights up 1s and dims out 1s.

This blinking behavior recurs periodically.

One periodic step lasts 2s.

The blinking is accompanied by a sound.

The sound is audible at the beginning of each periodic step.

The sound lasts 0,5s.

The sound shall be a deep and scratching tone.

The sound shall be loud enough to be audible for the driver in most traffic situations.

1.4.4.2.5 Hazard Warning

If the hazard warning signal flasher is set, both arrows of the indicator lights begin to blink as described in the subsection Indicator Lights (Indicator_Left = Indicator_Right = 1).

The hazard warning takes priority over the turn signals.

If any turn signal is set and the hazard warning is set additionally, the hazard warning signal lights up in the same periodic steps as the turn signal blinked.

If the turn signal is not set anymore, when the hazard warning is stopped, the indicator lights stop their blinking after their last periodic step.

If the hazard warning is stopped, but a turn signal is still activated, the according arrow of the indicator lights blinks on in the same periodic mode as the hazard warning signal blinked.

The blinking of the arrow of the indicator lights is stopped as described in subsection Indicator Lights.

1.4.4.2.6 Engine Control Light

The engine control light is placed in the left part of the instrument cluster, near the middle (see section Hardware).

The engine control light lights up for at least 5s, if Engine_Warning = 1, for at least 400ms.

If Engine_Warning = 0 for at least 400ms, the engine control light dims out.

The engine control light dims out, when the instrument cluster is deactivated (see section Activation and Deactivation of the Instrument Cluster).

1.4.4.2.7 Input Signals of the Indicator Lights

The following signals are digitally transferred by the CAN bus.

Turn_Signal_Left

> *The signal describes the status of the combination switch and is sent by the combination switch control unit. Turn_Signal_Left = 1 means, the driver sets the combination switch in the turn signal left position. Turn_Signal_Left = 0 means, the driver does not set the turn signal left. Scope: {0,1}. Transmitted every 250ms.*

Turn_Signal_Right

> *The signal describes the status of the combination switch and is sent by the combination switch control unit. Turn_Signal_Right = 1 means, the driver sets the combination switch in the turn signal right position. Turn_Signal_Right = 0 means, the driver does not set the turn signal right. Scope: {0,1}. Transmitted every 250ms.*

Hazard_Warning_Signal

The signal describes the status of the hazard warning signal flasher. The signal is sent by the hazard warning signal flasher control unit. If the hazard warning signal flasher is set, then Hazard_Warning_Signal = 1, otherwise Hazard_Warning_Signal = 0. Scope: {0,1}. Transmitted every 50ms.

Rationale: The high transmission rate is important to support the security of the car occupants. The faster a hazard warning can be displayed the faster another road user can react.

1.4.4.2.8 Input Signal of the Engine Control Light

Engine_Warning

This signal describes the status of the engine. The signal is sent by the engine control unit. If the engine control unit determines a problem with the engine, Engine_Warning = 1 is sent, otherwise Engine_Warning = 0. Scope: {0,1}. Transmitted every 100ms by the CAN bus.

1.4.4.2.9 Output Signals of the Indicator Lights

The following signals are transferred internally of the instrument cluster.

Indicator_Left

This signal activates the left arrow of the indicator lights. If Indicator_Left = 1, then the left arrow of the indicator lights starts to blink as described in subsection Indicator Lights. If Indicator_Left = 0, the left arrow of the indicator lights is deactivated. This signal is sent to the indicator lights display. Scope: {0,1}.

Rationale: The high transmission rate is needed because of the high transmission rate of the Hazard_Warning_Signal, to provide a prompt display of hazard warning set for the driver, because the hazard warning is activated by this signal, too.

Indicator_Right

This signal activates the right arrow of the indicator lights. If Indicator_Right = 1, then the right arrow of the indicator lights begins to blink as described in subsection Indicator Lights. If Indicator_Right = 0, the right arrow of the indicator lights is deactivated. This signal is sent to the indicator lights display. Scope: {0,1}.

Rationale: The high transmission rate is needed because of the high transmission rate of the Hazard_Warning_Signal, to provide a prompt display of hazard warning set for the driver, because the hazard warning is activated by this signal, too.

1.4.4.2.10 Output Signal of the Engine Control Light

EW_Display

This signal activates the display of the engine warning light. If EW_Display = 1, the engine warning light lights up, if EW_Display = 0, the engine warning light dims out. This signal is sent to the engine control light display. Scope: {0,1}. Transmitted internally of the instrument cluster.

1.5 Display

The display of the instrument cluster is described in the following. For a detailed description of the menu see section User Configuration and Menu Tree.

1.5.1 Digital Watch

This section describes the digital watch, which is displayed in the digital display of the instrument cluster.

1.5.1.1 Function Overview

The digital watch displays the current time in digital letters. It's placed in the instrument cluster towards the driver. The time is displayed in a 12h or 24h-mode, see section Communication and Parameter.

1.5.1.2 Business Requirements

1.5.1.2.1 Vision

In this subsection the top goals of the digital watch 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 time

The user has an optimal view on the time display in different driving situations.

G-2 Accustomed view

The time is displayed in a way that users in different countries feel accustomed to the look and feel.

G-3 Attractive appearance

The display and behavior shall be attractive, sporty and agile.

Rationale: This suits to our brand policy.

G-4 Better accuracy of the time than in model X

The accuracy in deviation of sec/week shall be at least better than in model X (in model X it was 10sec/week).

1.5.1.2.2 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 Placement

The time is displayed in the instrument cluster. Also the time is displayed in the same size and appearance according to the brand design.

S-2 Typical buttons

The watch is controlled by the typical buttons of the steering wheel (left/right, up/down). The CAN-signals from these shall be reused from model EMP012.

1.5.1.3 User Requirements

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

1.5.1.3.1 Features

F-1 Time-display h:m

The time in hours and minutes is displayed.

F-2 12/24-mode

The time is displayed in 12 or 24-hour mode according to the variants, see section Communication and Parameter.

F-3 12/24-mode parameterization

With a diagnosis tool the 12 or 24-hour mode can be selected.

F-4 Accurateness level: ‘high’

Deviation of time displayed to actual time shall be less than +/- 3sec per week.

1.5.1.3.2 Use Case "Watch Time"

The driver switches to the time display and watches the displayed time.

Primary Actor: driver

Basic Flow:

1. The use case begins, when a driver enters the car.
2. The driver switches the ignition on.
3. The car is switched on and the instrument cluster is activated.
4. The digital display of the instrument cluster displays the standard page (see section User Configuration and Menu Tree).
5. The digital display of the instrument cluster shows the current time.
6. The driver turns the ignition off.
7. The instrument cluster and the digital watch are deactivated.
8. The driver leaves the car.

Alternative Step Execution (Exception Flow):

5a. The digital display of the instrument cluster shows the current time in a parameterized mode (see subsection Use Case "Parameterize Display").

1.5.1.3.3 Use Case "Set Time"

The driver changes the time settings.

Primary Actor: driver

Basic Flow:

1. The use case begins, when a driver drives the car.
2. The digital display of the instrument cluster displays the time.
3. The driver scrolls with the steering wheel buttons to the menu level clock regulator (see section "User Configuration and Menu Tree").
4. The digital display shows the menu page "clock regulator".

5. The driver adjusts settings.

6. The driver exits the menu page "clock regulator" and enters the standard page.

7. The time is displayed according to the adjusted settings.

8. The driver switches the ignition off.

9. The instrument cluster and the digital watch are deactivated. The system keeps the adjusted settings.

10 The driver leaves the car.

1.5.1.3.4 Use Case "Parameterize Display"

A service man adjusts parameters.

Primary Actor: service man

Basic Flow:

1. The use case begins, when the car is in a garage and is switched off.

2. The service man connects the standard diagnosis system to the car.

> **Rationale: The standard diagnosis system for the car is described in a further document, not included in this specification.**

3. The service man selects either 12 h or 24 h displaying (via the diagnosis system).

4. The service man selects an adjustment speed for hours and minutes.

5. The service man selects an adjustment blinking frequency.

6. The service man disconnects the diagnosis system.

> **Rationale: The system displays the time from now on until further changes occur according to the adjusted parameters.**

Alternative Step Execution (Exception Flow):

3a., 4a., 6a. may be done in any combination; each step is optional.

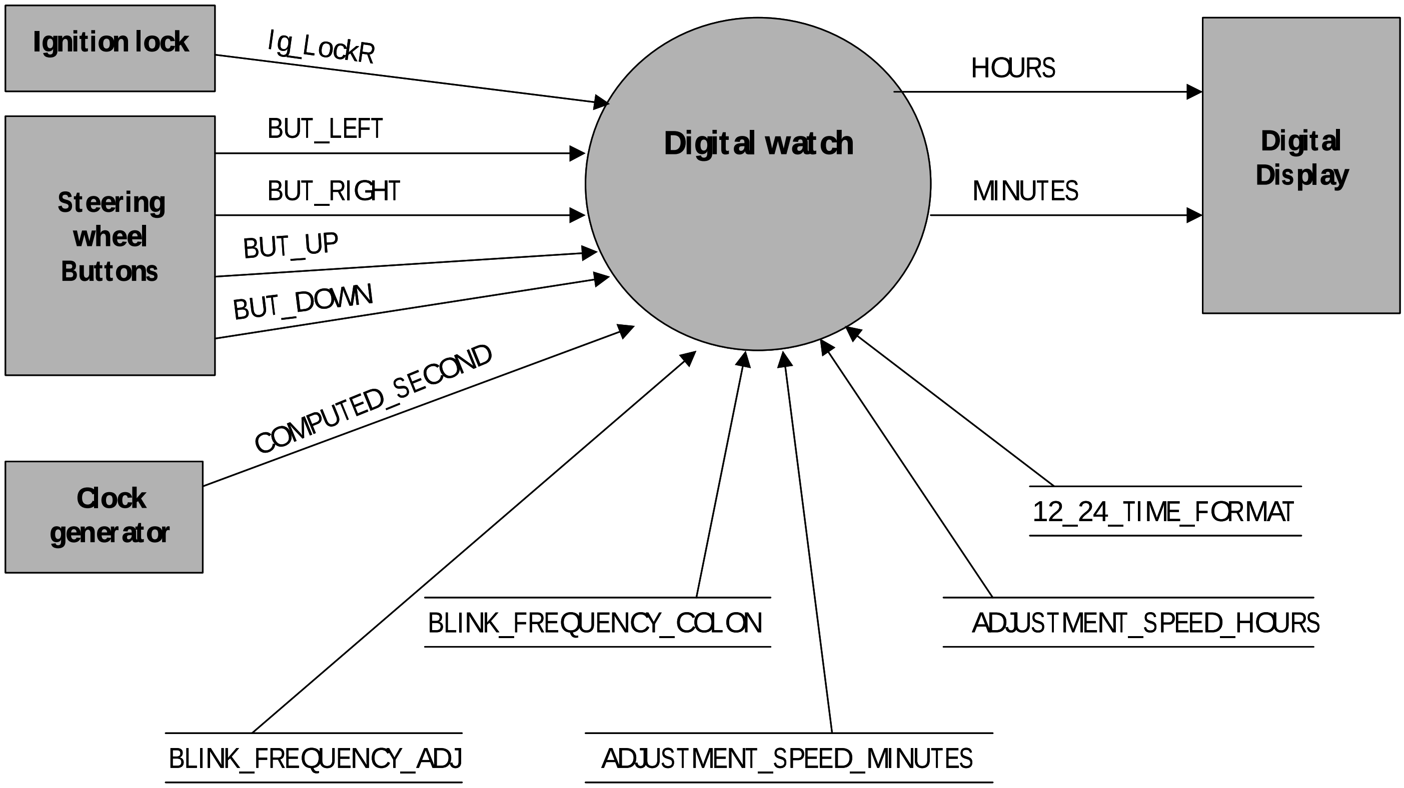
1.5.1.4 System Requirements

The requirements in this subsection specify the digital watch 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”).

1.5.1.4.1 Context Diagram

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

Figure: Context diagram digital watch.



1.5.1.4.2 Functional Requirements

The functional requirements are divided into the following parts: Displaying the Time, Setting the Time, Instrument Cluster Time on CAN Bus, Parameterization (via Diagnosis), Input Signals, Output Signals, and Parameter Values.

1.5.1.4.2.1 Displaying the Time

The digital watch displays the time in the standard page of the digital display (see section User Configuration and Menu Tree and section Activation and Deactivation of the Instrument Cluster).

The display shall use the style “hh:mm”.

If the current hour is one digit (1-9), a leading 0 shall be displayed.

The colon in the time display blinks in a frequency according to parameter BLINK_FREQUENCY_COLON.

In 12 h-mode, after 12:59 the digital watch shall display 1:00.

In 24 h-mode, after 23:59 the digital watch shall display 0:00.

1.5.1.4.2.2 Setting the Time

The driver is able to set the time.

A menu “clock regulator” shall be used, from which the driver is able to set the hours or set the minutes. (see section User Configuration and Menu Tree).

The driver shall be able to increase or decrease the hours in steps +/- 1.

While the time is set by the driver, the time shall blink in a frequency, which can be parameterized (see subsection Parameter Values).

The settings are stored if completed before Ig_LockR is inactive.

1.5.1.4.2.3 Instrument Cluster Time on CAN Bus

Time is computed by the help of the signal COMPUTED_SECOND. Whenever COMPUTED_SECOND is set from 0 to 1, an internal stored counter is incremented.

If the counter reaches 60, the signal MINUTES is incremented by one.

If the signal MINUTES is incremented to 00, the signal HOURS is incremented.

1.5.1.4.2.4 Parameterization (via Diagnosis)

12/24-mode (time format): The time format can be set to either 12 h - or 24 h - mode via diagnosis (12_24_TIME_FORMAT).

The other parameters described in the parameter table shall also be setable via diagnosis.

1.5.1.4.2.5 Input Signals

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

COMPUTED_SECOND

> *A cyclically sent signal to synchronize the time. COMPUTED_SECOND = 1 is sent 500ms, then COMPUTED_SECOND = 0 is sent 500ms. One periodic step lasts 1s. Scope: {0,1}. Transferred every 100ms.*

BUT_UP

> *If BUT_UP = 1, the steering wheel button "up" is pressed, otherwise the steering wheel button is not pressed. Sent by the steering wheel buttons control unit. Scope: {0,1}. Transferred every 100ms.*

BUT_DOWN

> *If BUT_DOWN = 1, the steering wheel button "down" is pressed, otherwise the steering wheel button is not pressed. Sent by the steering wheel buttons control unit. Scope: {0,1}. Transferred every 100ms.*

BUT_LEFT

> *If BUT_LEFT = 1, the steering wheel button "⇐" is pressed, otherwise the steering wheel button is not pressed. Sent by the steering wheel buttons control unit. Scope: {0,1}. Transferred every 100ms.*

BUT_RIGHT

> *If BUT_RIGHT = 1, the steering wheel button "⇒" is pressed, otherwise the steering wheel button is not pressed. Sent by the steering wheel buttons control unit. Scope: {0,1}. Transferred every 100ms.*

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.*

1.5.1.4.2.6 Output Signals

The following output signals are transmitted internally of the instrument cluster.

HOURS

> *This signal sends the hours to the digital display. Scope: 5 Bit; hours: {<u>00000</u> = 0h,<u>00001</u> = 1h, ... ,<u>10111</u> = 23h} , default: 0.*

MINUTES

This signal sends the minutes to the digital display.Scope: 6 Bit; minutes: {000000= 0min,000001 = 1min, ... ,111011 = 59min}, default: 0.

1.5.1.4.2.7 Parameter Values

BLINK_FREQUENCY_ADJ

When the driver is adjusting the time (hours or minutes), the time is blinking. This parameter sets the blinking frequency to X/2 blinks (on/off) per second. Scope: 3 Bit, {000=0, 001= 1, ..., 111= 7}. Stored in the EEPROM.

BLINK_FREQUENCY_COLON

This parameter sets the blinking frequency of the colon (when displaying the time) to X/2 blinks (on/off) per second. Scope: 3 Bit, {000=0, 001= 1, ..., 111= 7}. Stored in the EEPROM.

ADJUSTMENT_SPEED_HOURS

How long the left/right-button has to be pressed in order to increase/decrease the hour (when adjusting the time) in milliseconds. Scope: 3 Bit, {000=100ms, 001=200ms, ... 111=800ms}. Stored in the EEPROM.

ADJUSTMENT_SPEED_MINUTES

How long the left/right-button has to be pressed in order to increase/decrease the minutes (when adjusting the time) milliseconds. Scope: 3 Bit, {000=100ms, 001=200ms, ..., 111=800ms}. Stored in the EEPROM.

12_24_TIME_FORMAT

If hours are displayed in 12-hours-mode or 24-hours-mode. Scope: 1 Bit {0 = 24-hours-mode, 1 = 12-hours-mode}. Stored in the EEPROM.

1.5.2 Outside Temperature

This section describes the outside temperature display of the instrument cluster.

1.5.2.1 Function Overview

The indication of the outside temperature is additional information for the driver.

Because of the different variants of the instrument cluster, the temperature is displayed in degree Celsius or degree Fahrenheit (see section Communication and Parameter). Each driver is able to have the unit displayed he prefers.

A sensor measures the temperature by means of resistance. The instrument cluster processes this input by an algorithm. First, the values are mapped on values of degree Celsius or degree Fahrenheit before they are displayed. The outside temperature is presented as a numeric value on the digital display.

A warning message of an imminent danger of ice on the road in case of a quite low outside temperature enables the driver to a more secure driving.

1.5.2.2 Business Requirements

1.5.2.2.1 Vision

This subsection presents top goals of the outside temperature system. This layer describes an abstract view of the system, which gives a clear, understandable, and agreed focus.

G-1 Comfortable view of the outside temperature

The user has an optimal view on the outside temperature that provides permanently current information about the environmental conditions.

G-2 Authentic indication

The display and behavior of the outside temperature shall be authentic, which means exact and real-time.

Rationale: This suits to our brand policy.

G-3 Intuitive behavior in case of defect

The behavior of the display of the outside temperature shall be intuitive in case of defects.

G-4 Warning in case of ice

It shall occur a warning symbol if the temperature falls below a certain point (which is seen as an indicator that there might be ice on the road).

Rationale: More security for the driver.

1.5.2.2.2 Scope

Apart from 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 Costs of the outside temperature sensor

The costs of the outside temperature sensor shall not exceed the costs of the outside temperature sensor of model EMP034.

1.5.2.3 User Requirements

In this subsection the outside temperature 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.

1.5.2.3.1 Features

F-1 Display outside temperature

The display of the outside temperature consists of real-time damped values, transmitted to the display as digits.

F-2 Warning display

The warning display lights up whenever the value of the outside temperature falls below a certain point.

F-3 Error warning on the display

An error warning lights up whenever an error is realized.

1.5.2.3.2 Use Case "Show Outside Temperature"

The driver switches on the car and drives while watching the outside temperature display.

Primary Actor: driver

Basic Flow:

1. This use case starts when a driver opens the interlock of a the car and afterwards the door, or, if the driver only opens the door, when the interlock is already opened. This means, the use case starts as soon as the display is active.

2. The display switches on and establishes the outside temperature within 1 second (see section <u>Activation and Deactivation of the Instrument Cluster</u>).

3. The driver gets in the car and switches on the ignition key to the switched on position.

4. The temperature of the cooling liquid is lower than 60 degrees centigrade.

5. The measured outside temperature is mapped, damped and displayed. There is no difference between rising or falling temperature values.

6. The driver sets the car in motion.

7. The temperature of the cooling liquid rises over 60 degrees centigrade.

8. The driver drives less than 30km/h.

9. Only those measured temperature values are displayed that are sinking. Rising ones are ignored as they are likely to happen due to the temperature of the cooling liquid.

10. The driver accelerates and drives faster than 30km/h and less than 50km/h.

11. Falling temperature values are indicated in time, rising ones are indicated with a delay of 3 minutes.

12. The driver accelerates again and drives faster than 50km/h.

13. Falling temperature values are indicated in time, rising ones are indicated with a delay of 1,5 minutes.

14. The driver stops the car.

15. The temperature of the cooling liquid is still higher than 60 degrees centigrade.

16. A delay-time of one hour is implemented. During this time only falling, no rising temperature values are edited for displaying.

17. The driver leaves and locks the car.

18. The display establishes the outside temperature the rest of the delay-time, but at least as long as the display is active.

Alternative Step Execution (Exception Flow):

5.a, 9.a, 11.a, 13.a, 16.a The system determines that the input signals are outside the determined range and displays accordingly dashes on the screen.

5.b, 9.b, 11.b, 13.b, 16.b The system determines that the input signals are lower than the predefined limit. An error warning is displayed.

16.c The engine is switched on before the delay-time is used up. The rest of the delay-time is deleted and depending on the temperature of the cooling liquid and the current speed, the outside temperature is established.

16.d If the temperature of the cooling liquid is lower than 60 degrees centigrade, the delay-time is immediately deleted and we act as described in 4. above.

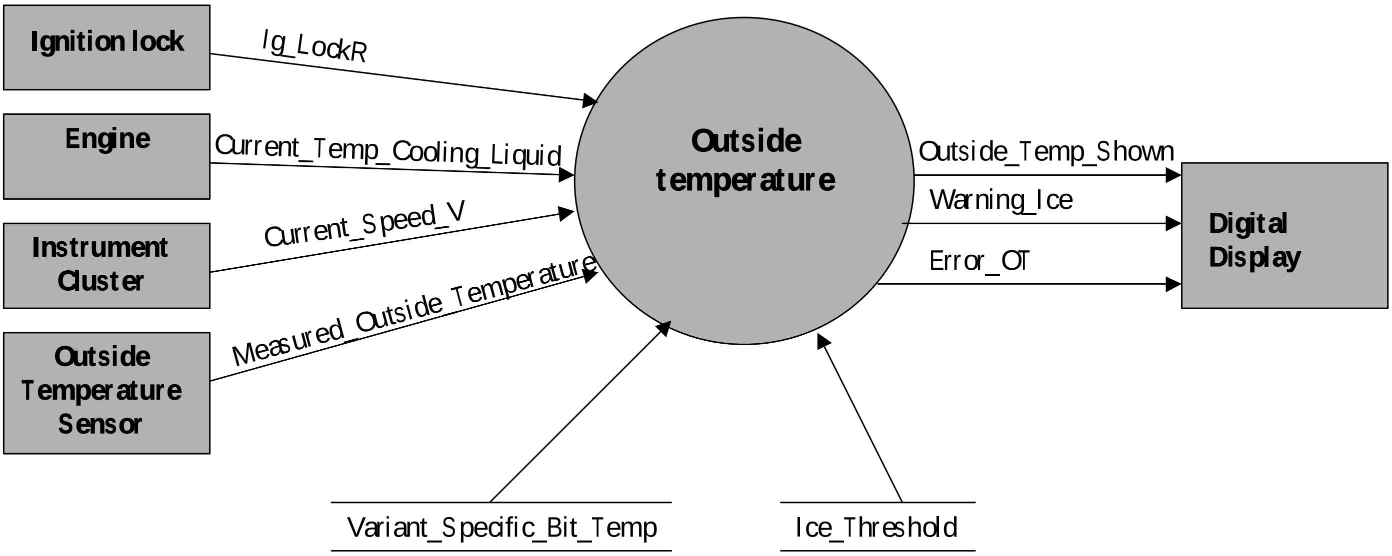
1.5.2.4 System Requirements

The requirements in this subsection specify the indication of the outside temperature on a detailed level meaning that the business and user requirements shall be realized by the system requirements. These requirements correspond to the abstraction level of current product specifications ("Lastenhefte").

1.5.2.4.1 Context Diagram

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

Figure: Context diagram - outside temperature.



1.5.2.4.2 Functional Requirements

This subsection is structured as follows. Firstly we provide a description of the indication of the outside temperature, followed by a detailed listing of the input and output signals and an algorithm describing how these signals shall be processed.

1.5.2.4.2.1 Indication

The outside temperature is shown on the standard page of the pull-down menu of the display.

For a precise description of the chosen font, its style etc. see section User Configuration and Menu Tree.

1.5.2.4.2.2 Transmitted and Indicated Value

There is a difference in the transmitted and the indicated value. The transmitter is able to measure higher and lower temperatures than the indicator is able to show.

Please see the following table Mapping of the measured values to the indicated ones for details.

Table: Mapping of the measured values to the indicated ones.

Transmitted value	Corresponding value °C	Corresponding value °F

Transmitted value	Corresponding value °C	Corresponding value °F
more than 30000	error	error
27490 - 22810	-35	-31
20640	-30	-22
18583	-25	-13
16640	-20	-4
14810	-15	5
13093	-10	14
11490	-5	23
10000	0	32
8623	5	41
7360	10	50
6210	15	59
5173	20	68
4250	25	77
3440	30	86
2743	35	95
2160	40	104
1690	45	113
1333 – 960	50	122
less than 943	error	error

1.5.2.4.2.3 Variations between US and ROW (Rest of World) Instrument Clusters

Each instrument cluster must be able to translate the outside temperature in units of degree Celsius or degree Fahrenheit. Therefore each instrument cluster is equipped with a variant specific bit for the temperature (Variant_Specific_Bit_Temp).

It is possible to modify this default assignment by using the configuration menu. In the pull-down menu of the display is one page, on which a driver can choose which unit he wants to be displayed (see section User Configuration and Menu Tree).

1.5.2.4.2.4 *Activation of Indication*

The indication (optical display) of the outside temperature has to be activated not later than 1s after the activation of the display, (see section Activation and Deactivation of the Instrument Cluster) or the switch-on of the ignition (Ig_LockR = 1).

The time until the 1s is reached, the display shows “--°C“ or “--°F”.

The starting value for the displayed outside temperature is calculated as the average value of 8 measurement points, which are provided in the first second, until the indication is displayed.

If only the display is activated and not the car, but the ignition on position radio (Ig_LockR = 1) the indication of the outside temperature is updated each minute. Else the display is activated according to the Algorithm/Characteristics (see subsection Algorithm/Characteristics).

While the outside temperature algorithm is not working or there are no meaningful temperature values available, the temperature '---°C' or '---°F' is shown.

1.5.2.4.2.5 Deactivation of Indication

The indication of the outside temperature is deactivated by the deactivation of the display (see section Activation and Deactivation of the Instrument Cluster).

1.5.2.4.2.6 Input Signals

Measured_Outside_Temperature

> *Outside Temperature measured directly by a sensor in the front of the car. Unit Ohm (65536 in case of an error), transmitted internally of the instrument cluster.*

Current_Speed_V

> *Describes the current speed of the car with access at any time; received internally from speedometer*

Current_Temp_Cooling_Liquid

> *Temperature of the cooling liquid (centigrade: -10 until +150). Scope 0x00..0xFF (Temp [°C] = Value + 50). Received every 80ms 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. Scope: {0,1}. Received every 100 ms. Transferred by the CAN bus.*

1.5.2.4.2.7 Output Signals

Outside_Temp_Shown

> *For the display edited outside temperature (Scale [°C]: -35 up to +50 and Scale [°F]: -31 up to +122). Transmitted internally.*

Error_OT

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

Warning_Ice

> *Indicates the possibility of ice on the road (1 = activated, 0= inactive) Transferred internally.*

1.5.2.4.2.8 Parameter Values

The parameter values are stored to provide the possibility to have different characteristics of the outside temperature.

Variant_Specific_Bit_Temp

> *Configuration adjustment for the representation unit of the outside temperature. Scope: {0 = °C (default value for ROW variants),1 = °F (default value for the US variants)}. Stored in the EEPROM.*

Ice_Threshold

Internal threshold, with which the produced outside temperature for the display is compared. Stored in the EEPROM. Scope: 0x00..0x1F (0x00=-20°C, 0x01=-19°C, ... 0x1F=11°C).

1.5.2.4.2.9 Missing CAN Signals and Error Handling

If the signal Current_Temp_Cooling_Liquid is not available, the indication of the outside temperature shows the same behavior as described in the algorithm below in case of Current_Temp_Cooling_Liquid >= 60 Centigrade.

If we cannot get any speed signal (i.e. Current_Speed_V = 0xFF), the indication of the outside temperature behaves as described in the algorithm in the part where the Current_Temp_Cooling_Liquid >= 60 Centigrade and the current speed Current_Speed_V is an element of the interval from 30km/h to 50km/h.

If the temperature exceeds or falls within 10 centigrade over resp. under the end of the indication scale then the indication shows the maximum respective minimum possible corresponding indication value.

If the temperature exceeds or falls more than 10 centigrade over respective under the end of the indication scale an Error_Value is transmitted and the display shows three dashes "---" and the registered temperature unit "°C" or "°F".

The same happens if an error value is transmitted for more than 3 minutes. Until then the indicator rests on the temperature shown before.

As soon as the errors are removed for more than 3,5 minutes, the temperature values are displayed as described before.

If the produced Outside_Temp_Shown falls under a certain threshold (Ice_Threshold) for more than 5 minutes an ice warning (Warning_Ice = 1) has to occur in the display. (For a detailed description of the warning see section Warning Messages).

1.5.2.4.2.10 Damping

The response time of the display shall not exceed 0,5s (T63 without electronic damping).

Rationale: We have to find a compromise between high sensitivity (long response time, small damping) and short response time (low sensitivity, big damping).

The internal signal Internal_Temp shall be damped by a PT2 element.

1.5.2.4.2.11 Precision

The accuracy of the different temperature units degree Celsius and degree Fahrenheit that has to be reached is combined in the following tables, see table Accuracy of different temperature units - centigrade and Accuracy of different temperature units - degree Fahrenheit. Errors which occur in case of the transmitter and the construction are already considered.

Table: Accuracy of different temperature units - centigrade.

Area	Precision
-35°C until -30°C	±3,5°C
-30°C until -25°C	±2°C
-25°C until +30°C	±1°C
+30°C until +35°C	±1,5°C

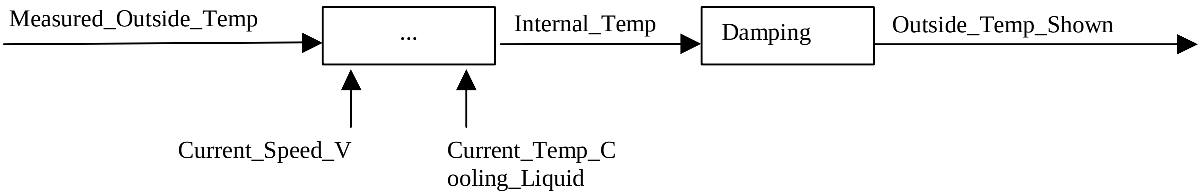
Area	Precision
+35°C until +40°C	±2°C
+40°C until +50°C	±2,5°C

Table: Accuracy of different temperature units - degree Fahrenheit.

Area	Precision
-31°F until -22°F	±6°F
-22°F until -13°F	±4°F
-13°F until +86°F	±2°F
+86°F until +95°F	±3°F
+95°F until +104°F	±4°F
+104°F until +122°F	±5°F

1.5.2.4.2.12 Algorithm / Characteristics

Figure: Schematic representation of the algorithm.



The displayed value of the outside temperature (Outside_Temp_Shown) is determined considering the current

- speed (Current_Speed_V)
- temperature of cooling liquid (Current_Temp_Cooling_Liquid) and
- Ig_LockR.

If Current_Temp_Cooling_Liquid < 60 centigrade, the Internal_Temp is damped and displayed afterwards. There is no differentiation between rising or falling Internal_Temp values.

> *First we distinguish between: Current_Temp_Cooling_Liquid < 60 degree Celsius and Current_Temp_Cooling_Liquid >= 60 degree Celsius.*

If Current_Temp_Cooling_Liquid >= 60 centigrade, the value of Current_Speed_V has to be considered additionally.

Therefore the speed values 30 km/h and 50 km/h are important threshold values:

If Current_Speed_V < 30 km/h and the Internal_Temp values are sinking, then Outside_Temp_Shown = Internal_Temp. Rising Internal_Temp values are ignored.

If 30 km/h <= Current_Speed_V <= 50 km/h rising Internal_Temp values are ignored for three minutes. After that Outside_Temp_Shown = Internal_Temp. Falling Internal_Temp values are indicated in time.

If Current_Speed_V >= 50 km/h the rising Internal_Temp values are ignored for 1,5 minutes. After that Outside_Temp_Shown = Internal_Temp. Falling Internal_Temp values are indicated in time.

If Current_Temp_Cooling_Liquid >= 60 centigrade and the engine is off (Ig_LockR = 0), we have to avoid that in case of the temperature of the engine, a wrong value of the outside temperature is displayed. Therefore we implement a so called delay-time. The delay-time is predefined to one hour.

During this delay-time only falling, no rising Internal_Temp values are allowed. So an appreciation of the displayed outside temperature over the value displayed while turning off the engine is impossible.

If the engine is turned on before the delay-time has finished, the rest of the delay-time is deleted.

If Current_Temp_Cooling_Liquid < 60 centigrade, the delay-time is immediately deleted and the announcement of falling and rising measured data is similarly allowed.

1.5.3 Radio Information

This section describes the communication between radio and instrument cluster.

1.5.3.1 Function Overview

It shall be possible to present essential information about the radio status (i.e. operation mode, current frequency, current RDS radio station) in the instrument cluster and to control basic functionalities (i.e. loudness, radio station) by means of the steering wheel buttons.

1.5.3.2 Business Requirements

1.5.3.2.1 Vision

This subsection presents the top goals of the interaction of the instrument cluster and the radio.

G-1 Increase driver's safety

It shall be possible to view the radio status and control the radio with minimal driver distraction.

Rationale: Adjusting audio devices in the car usually moves away driver's attention from the street.

G-2 Intuitive handling of radio via IC

Novice drivers should be able to control the radio control via IC without consulting the manual.

G-3 Traditional usage has to be preserved

The traditional way of using a radio shall be preserved.

G-4 Interoperability with various radios

Different kinds of radios (e.g. standard Empress radio, Blaupunkt radio, Panasonic radio) should operate with the IC without reconfiguration of the IC.

Rationale: It should be possible to exchange the radio without reconfiguration of the IC.

1.5.3.2.2 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 Communication via CAN bus

IC should communicate with radio via CAN bus.

Rationale: CAN Communication is part of the Empress radio compliance requirements.

S-2 No additional interface elements

Interaction with the driver via steering wheel buttons and IC display.

1.5.3.3 User Requirements

This subsection treats the IC – radio as a black box and describes the relevant interactions from a user's perspective.

1.5.3.3.1 Features

F-1 Radio activation

User can activate radio by means of IC menu (see Section User Configuration and Menu Tree).

F-2 Loudness adjustment

User can adjust radio loudness by pressing steering wheel buttons.

F-3 Radio frequency display

Currently used radio frequency is displayed on the radio menu page (see Section User Configuration and Menu Tree).

F-4 Radio station information display (RDS)

Currently used radio station information is displayed on the radio menu page (see Section User Configuration and Menu Tree).

F-5 Radio menu page

Radio menu page is part of the IC menu.

1.5.3.3.2 Use Case "User activates Radio"

The driver activates the radio via the IC, selects another radio station and adjusts the loudness.

Primary Actor: Driver

Basic Flow:

1. The use case begins when a driver enters the radio menu page (displayed in the IC display). The radio is turned off.

2. The display shows “Radio off, use ⇒ to turn on”.

3. The driver presses the ⇒ button on the steering wheel.

4. The radio is turned on using the last selected frequency.

5. The IC display shows the currently used radio station by means of its RDS identifier.

6. The driver presses the ⇒ button on the steering wheel.

7. The radio selects the next radio station.

8. The IC display shows the currently used radio station by means of its RDS identifier, again.

9. The driver presses the ‘+’ button on the steering wheel.

10. The loudness increases by one unit.

Alternative Step Execution (Exception Flow):

2a. The driver activates the radio by means of direct interaction with the radio. Continue with step 5.

3b. The driver presses the ‘+’ (or ‘–‘ or ‘⇐’) button on the steering wheel. Nothing happens.

4c. The last selected frequency does not provide a meaningful radio signal. The radio starts to find another frequency. While doing so, the currently seeked frequency is displayed.

5d. If no RDS identifier is available, the radio frequency is displayed.

5e. The driver turns off the radio by means of direct interaction with the radio. Continue with step 2.

6f. The driver presses the ‘⇐’ button on the steering wheel.

7f. The radio selects the previous radio station.

9g. The driver keeps the ‘+’ button pressed. The loudness increases 2 units each second until the driver releases the ‘+’ button or the maximum loudness is reached.

9h. The driver presses the ‘–‘ button on the steering wheel.

10h. The loudness decreases by one unit.

1.5.3.3.3 Use Case "Browsing through Menu"

The driver browses through the IC menu.

Primary Actor: Driver

Basic flow:

1. The use case begins when a driver starts to use the IC menu by means of the steering wheel buttons. The radio operates or is turned off.

2. Whenever the currently displayed menu page is the radio menu page, the current status of the radio is displayed.

* when the radio is off, “Radio off, use ⇒ to turn on” is displayed.

* when the radio is on and an RDS identifier is available, the RDS identifier is displayed.

* When the radio is on and no RDS identifier is available, the currently used (or searched) radio frequency is displayed.

3. An error (which raises a warning message) occurs and the corresponding warning message is displayed.

4. After the warning message has been quitted, the current status of the radio is displayed again (see step 2).

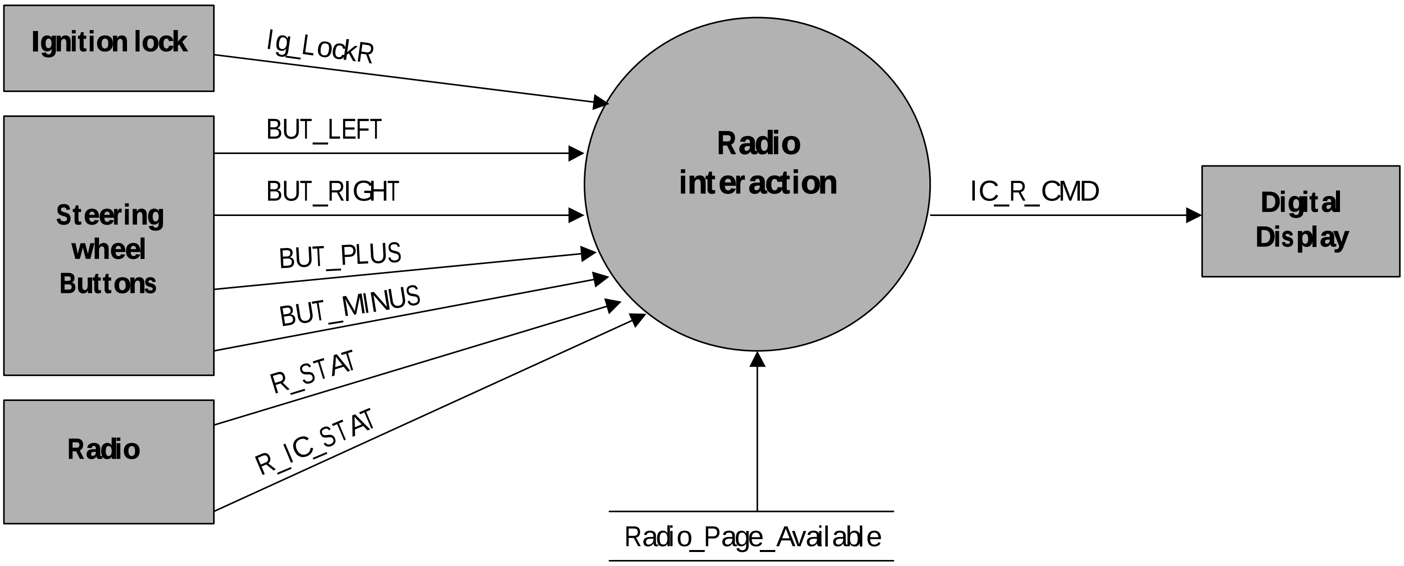
1.5.3.4 System Requirements

This subsection specifies the behavior of the IC menu page and the intercommunication protocol with the radio on a detailed level.

1.5.3.4.1 Context Diagram

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

Figure: Context diagram IC - radio interaction.



1.5.3.4.2 Functional Requirements

The functional requirements are divided up into the following parts: (1) Communication with the radio via the IRC Protocol (IC – radio communication protocol), (2) Processing of IRC Messages (3) Displaying Radio Information in the Radio Menu Page, (4) User Interaction IRC Protocol Validation, (5) Input/Output Signals, and (6) Parameter Values.

1.5.3.4.2.1 IRC Protocol, V2.0

The IRC protocol V2.0 (IC – radio communication protocol) is run via the CAN bus.

It consists of one cyclic message and two event-driven messages.

The cyclic message R_STAT is produced by the radio reporting its availability and some information about the current status.

The messages R_IC_STAT and IC_R_CMD are event-driven messages. The first contains additional information about the radio status. The second sends commands to the radio (e.g. increase loudness).

The figures Message R_STAT, Message R_IC_STAT, and Message IC_R_CMD describe the detailed content of these messages.

Figure: Message R_STAT.

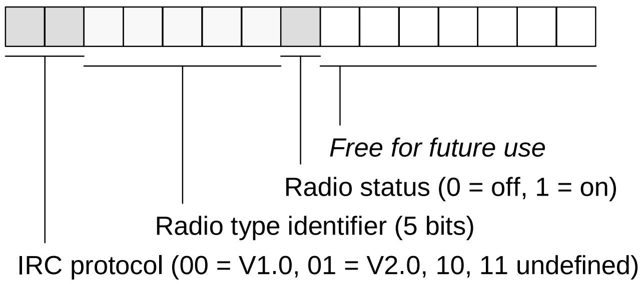
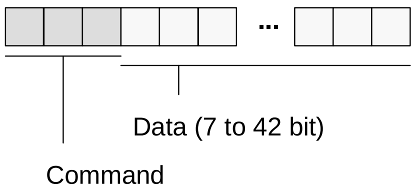


Figure: Message R_IC_STAT.

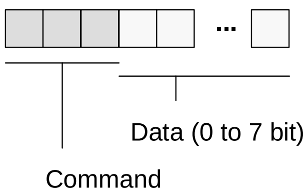


The following commands are supported:

Table: Message R_IC_STAT.

CMD	Name	Description	Datalength	Data
<u>000</u>	Unknown	Free for future use		
<u>001</u>	New fre-quency	Provides information about the currently seeked or used frequency	7 Bit	7 Bit (0..127); 0x00 = 85.0 MHz, 0x01 = 85.5 MHz, … 0x7F = 148.5 MHz
<u>002</u>	New RDS radio station part 1	Provides information about the currently used Radio (first 6 signs)	42 Bit	Each 7 Bit encode one sign; ASCII en-coded
<u>003</u>	New RDS radio station part 2	Provides information about the currently used Radio (last 5 signs)	35 Bit	Each 7 Bit encode one sign; ASCII en-coded
<u>004</u>	Loudness	Provides information about loudness	7 Bit	7 Bit (0..99)
<u>005</u> to <u>007</u>	Unknown	Free for future use		

Figure: Message IC_R_CMD.



The following commands are supported in IRC protocol V1.0.

Table: Message IC_R_CMD, V1.0.

CMD	Name	Description	Datalength	Data
000	Turn off	Turn radio off	0 Bit	None
001	Turn on	Turn radio on	0 Bit	None
002	Reset	Set radio back to its default values	0 Bit	None
003	Provide data	Forces radio to send a R_IC_STAT message	0 Bit	None
004	Adjust loud-ness	Increments or decrements loudness	2 Bit	00 = maintain loudness, 01 = increment loudness, 10 = decrement loudness, 11 = invalid
005	Next station	Skip to next station	2 Bit	00 = previous station, 01 = next station

The following commands are supported in IRC protocol V2.0.

Table: Message IC_R_CMD, V2.0.

CMD	Name	Description	Datalength	Data
000	Turn off	Turn radio off	2 Bit	00 = immediately, 01 = smoothly (if sup-ported)
001	Turn on	Turn radio on	2 Bit	00 = using previous state (e.g. loudness), 01 = using reset state
002	Reset	Set radio back to its default values	0 Bit	None
003	Provide data	Forces radio to send a R_IC_STAT message on frequency or RDS radio station	0 Bit	None
004	Adjust loud-ness	Increments or decrements loudness	5 Bit	See table Adjust loudness parameter
005	Next station	Skip to next station	2 Bit	00 = previous station, 01 = next station

Table: Adjust loudness parameter.

Data (binary)	Explanation
00 000	Set loudness to reset default
00 001	Mute on
00 010	Mute off
01 000	Maintain loudness
01 101	Increment loudness small

Data (binary)	Explanation
01 110	Increment loudness medium
01 111	Increment loudness strong
01 001	Decrement loudness small
01 010	Decrement loudness medium
01 011	Decrement loudness strong

1.5.3.4.2.2 Processing of IRC Messages

IRC messages are only processed if Radio_Page_Available is 1. Otherwise all messages are ignored and no IC_R_CMD message is generated.

If there is no R_STAT message it is assumed that no radio is available. Thus, R_IC_STAT messages are ignored and no IC_R_CMD messages are generated. The radio menu page displays “No radio available”.

If R_STAT messages are present, information about radio on/off and IRC V1.0/V2.0 is stored internally. All information broadcasted through message R_IC_STAT is stored internally, too.

Subsection User Interaction describes criteria for sending IC_R_CMD messages.

1.5.3.4.2.3 Displaying Radio Information in the Radio Menu Page

The radio menu page is only available if Radio_Page_Available is 0. Otherwise navigation in the IC menu will skip the radio menu page.

When the user enters the radio menu page, the current status of the radio is displayed. Table Displayed information summarizes all possible states.

Table: Displayed information.

Nr.	Condition	Displayed information
1	No radio available (no R_STAT messages)	“No radio available”
2	Radio off	“Radio off, use ◊ to turn on”
3	Radio on, no R_IC_STAT message received	“Radio”
4	Radio on, R_IC_STAT message received (New frequency)	Display frequency
5	Radio on, R_IC_STAT message received (New RDS radio station part 1 and 2)	Display RDS radio station
6	Detected communication error (see subsection IRC protocol validation)	“Radio interface error”

The information update frequency should not exceed 0.5 Hz (for displays number. 1, 2, 3, 5, 6) or 1 Hz (for display number. 4).

The interval starts when the information is displayed initially. This means, that after altering the radio menu page any information is displayed for at least 1 or 2 seconds before it is updated (even if there is an immediate frequency change, for example, reported by R_IC_STAT).

Frequency and RDS radio station are displayed center aligned.

Special characters in RDS radio station identifiers (i.e. characters 0x00 to 0x1F) shall be completely ignored.

Example: The identifiers ‘S’, ‘D’, ‘R’, #9, ‘3’ are displayed as ‘SDR3’.

Detailed information about layout of all display messages are presented in section Display.

1.5.3.4.2.4 User Interaction

The following activities are only performed if Radio_Page_Available is 0, Ig_LockR = 1 and no communication error is present. Otherwise no IC_R_CMD message is sent.

The IC_R_CMD messages have to take the IRC version into account.

Every time the user presses the ‘+’ button at the steering wheel (BUT_PLUS = 1), the command ‘Adjust loudness – increment loudness’ (IRC V1.0) or ‘Adjust loudness – increment loudness small’ (IRC V2.0) is sent.

If the user keeps the ‘+’ button pressed for more than 1 second, the command is sent every 0.5 seconds until the user releases the ‘+’ button.

Pressing the ‘–‘ button (BUT_MINUS = 1) is handled accordingly (using the messages ‘Adjust loudness – decrement loudness’ (IRC V1.0) or ‘Adjust loudness – decrement loudness small’ (IRC V2.0), respectively).

Loudness is possible all the time the radio is on (regardless of the displayed menu page).

If the radio menu page is the current menu page …

… the radio is off and the ‘⇒’ button is pressed (BUT_RIGHT = 1), the command with data ‘Turn on’ (IRC V1.0) or ‘Turn on – using previous state’ (IRC V2.0) is sent.

… the radio is on and the ‘⇒’ button is pressed (BUT_RIGHT = 1), the command with data ‘Next station – next station’ is sent.

… the radio is on and the ‘⇐’ button is pressed (BUT_LEFT = 1), the command with data ‘Next station – previous station’ is sent.

There is no auto-repeating for the ‘⇐’ and ‘⇒’ buttons.

1.5.3.4.2.5 IRC Protocol Validation

As the IRC protocol is mainly event message based, there are no predefined response intervals. Thus, there is the need for a more sophisticated protocol validation.

It is assumed that within 5 seconds after activating the IC the radio is ready to operate. Thus the first R_STAT message has to be there within 5 seconds after activating the IC.

Otherwise it is assumed that there is no radio. R_STAT messages that are detected later on will be ignored.

If a radio has once been detected and later on a R_STAT message is dropped (time out), we face a communication error. This error reveals after ten consecutive R_STAT messages have been received.

It is assumed that each IC_R_CMD message results in a corresponding R_IC_STAT message, see table Corresponding messages.

If there is no adequate response, the IC_R_CMD message is repeated once. If there is again no adequate response we try to recover. This means that an Reset command followed by ‘Turn on’ (IRC V1.0) or ‘Turn on – using reset state’ (IRC V2.0) is sent. If there is again no adequate response we face a communication error. This error remains until the IC is deactivated. Figure IRC protocol validation depicts the IRC protocol validation mechanism. Table Corresponding messages defines the term ‘corresponding’ message.

Figure: IRC protocol validation.

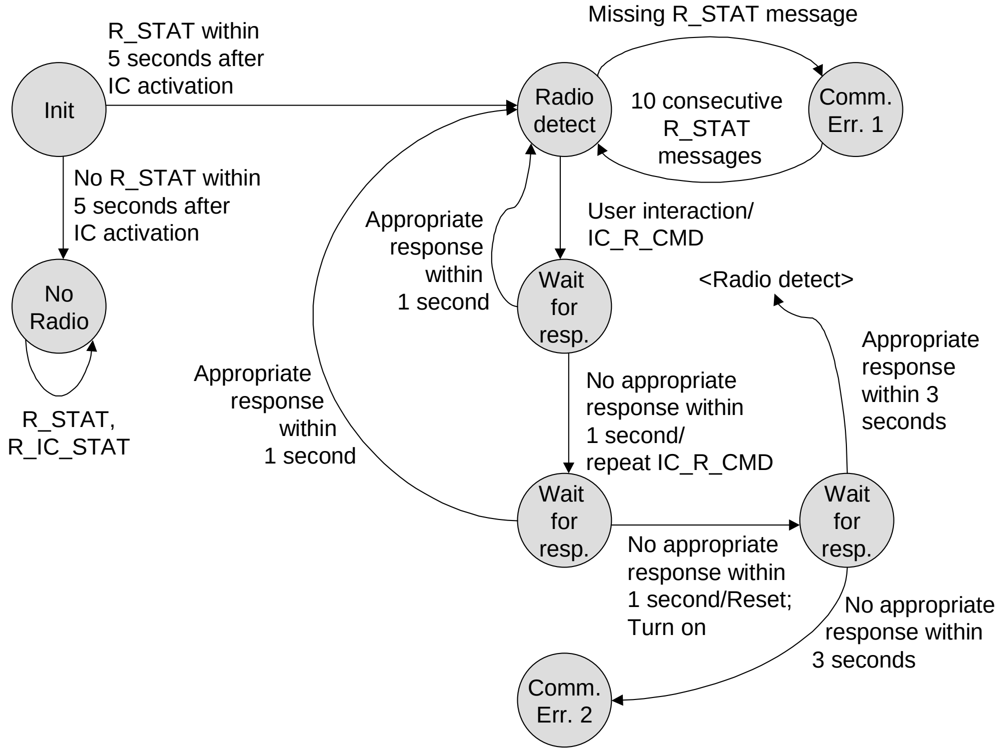


Table: Corresponding messages.

Sent message IC_R_CMD	Expected answer (corresponding R_IC_STAT message)
Turn radio off	None
Turn radio on	New frequency or New RDS radio station part 1
Reset	None
Provide data	New frequency or New RDS radio station part 1
Adjust loudness	Loudness
Next station	The following commands are supported:

1.5.3.4.2.6 Input Signals

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

R_STAT

Cyclic information concerning radio status (see figure Message R_STAT)

R_IC_STAT

Event-driven message providing information about the radio status (see figure Message R_IC_STAT)

BUT_LEFT

Steering wheel button '⇐' pressed; Scope: {0=not-pressed, 1=pressed}. Transmission rate: sent every 200ms. Sender: Steering wheel Buttons.

BUT_RIGHT

Steering wheel button '⇒' pressed; Scope: {0=not-pressed, 1=pressed}. Transmission rate: sent every 200ms. Sender: Steering wheel Buttons.

BUT_PLUS

Steering wheel button '+' pressed; Scope: {0=not-pressed, 1=pressed}. Transmission rate: sent every 200ms. Sender: Steering wheel Buttons.

BUT_MINUS

Steering wheel button '–' pressed; Scope: {0=not-pressed, 1=pressed}. Transmission rate: sent every 200ms. Sender: Steering wheel Buttons.

Ig_LockR

Describes the position of the ignition key. If Ig_LockR = 1 then the ignition key is in position radio. Scope: {0, 1}. Received every 100 ms.

1.5.3.4.2.7 Output Signal

The following output signal is transferred by the CAN bus.

IC_R_CMD

Event-driven message requesting services from the radio (see figure Message IC_R_CMD)

1.5.3.4.2.8 Parameter Value

The parameter value is stored internally to provide the possibility of different characteristics of the radio.

Radio_Page_Available

Used to deactivate the IC – radio communication and the corresponding radio menu page. Scope: 0 = active, 1 = not-available.

1.5.4 User Configuration and Menu Tree

The following section contains a description of the various levels of the menu tree. At the end of the section, there is a survey of the coherences and connections between the levels.

The menu tree is divided into several levels:

Standard Page:

The standard page is divided into two sections, whereby in the upper half of the display the time is indicated. In the other part of the display, there is the option of denoting either the speed or the temperature.

Radio Display:

With the radio display, the programs of the radio can be chosen.

Clock Regulator:

With the clock regulator, the time can be adjusted and the illustration of time in 12 or 24 hours can be defined.

Temperature Regulator:

In this level of the menu tree, the index of degree can be chosen.

Language:

There is the possibility to set the display text either in English or in German.

Speedometer Regulator:

The speed can be indicated either in kmh or in mph.

The above-named levels of the menu tree can be changed with the steering wheel buttons „up" (indicated on the steering wheel as "⇑" - button) and „down" (⇓). With the assistance of the steering wheel buttons „left" (⇐) and „right" (⇒), it is possible to make modifications of the configurations in the different levels which affect the appearance in the display.

The steering wheel buttons "plus"(+) and "minus" (-) are only relevant to adjust the volume (see Subsection Radio Display and Section Radio Information).

1.5.4.1 Standard Page

The standard page is divided into two sections. In the upper half (100x25 pixels) of the 100x50 pixels display, the time is illustrated centered to the colon.

Hours < 10 are indicated with a preceding zero. In the lower part of the display, there is an option to indicate either the outside temperature or the speed. The choice can be conducted by the steering wheel buttons „left" and „right".

The speed can be indicated as kmh or mph. This differentiation must be chosen in the level „speedometer regulator" of the menu tree.

A positive outside temperature is displayed with a preceding „+", a negative one with a preceding „ - ". „Zero" is always written as: „+0°C" or „+0°F".

Table: Display range (temperature).

display	°C	°F	
display range	-40°C - +50°C	-40°F - +122°F	
display definition	1 °C	1 °F	

Figure: Example of a standard page (temperature).

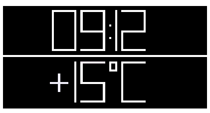


Figure: Definition of the graphic representation (temperature).

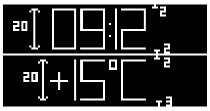


Figure: Example of a standard page (speed).

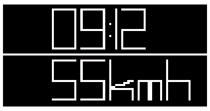
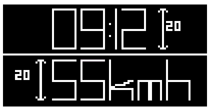


Figure: Definition of the graphic representation (speed).



The distance between the letters/ numbers amounts to two pixels. The letters/numbers are between 1 and 13 in width (proportional font) and 20 pixels vertical. The colon counts as a letter with a width of 1 pixel. The distance between the signs “+” (or “-”) and the temperature is 3 pixels.

1.5.4.2 Radio Display

With the steering wheel button “down”, the menu of the radio can be chosen. The radio programs can be changed with the steering wheel buttons “left” or “right”. The volume can be changed with the buttons "plus" and "minus".

In the upper half of the display, the RDS radio station is indicated, in the other part of the display, the frequency of the radio station is represented (in MHz, with one digit after comma). Both indications are centered to every side of the rectangular display.

If the parameter value Radio_Page_Available = 1 (non - available), the subsection "Radio Display" is skipped and the next level "Clock Regulator" is indicated.

Figure: Example of a radio display.

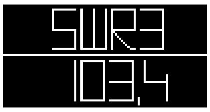
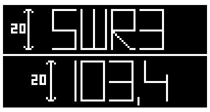
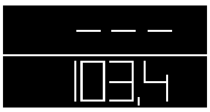


Figure: Definition of the radio display.



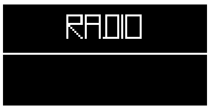
If no RDS radio station information is available, the upper line shows three centered dashes instead of RDS radio station.

Figure: Example of a radio display without available RDS radio station information.



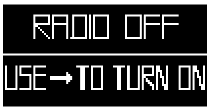
If no radio is available (see section Radio Information), the according message is displayed.

Figure: No radio message.



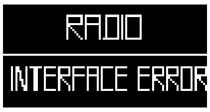
If the radio is available but turned off, the according message is displayed. Pressing the "⇒" button on the steering wheel activates the radio (see section Radio Information).

Figure: Radio off message.



If an communication error is detected (see section IRC protocol validation), the message Radio interface error is presented.

Figure: Radio interface error.



1.5.4.3 Clock Regulator

With the steering wheel button “down”, the level can be changed to the next subjacent display: from the radio display to the clock regulator.

First, one can toggle the representation of time between 12 h or 24 h with the steering wheel buttons “left” or “right”.

The small box in front of the numbers measures 12 pixels horizontally and 10 pixels vertically.

The choice of the timing is confirmed by the check mark in the small box in front of “24 h” or “12 h”.

Figure: Example 24h.

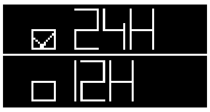
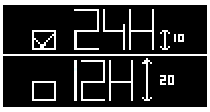


Figure: Definition of the 12_24 page.



With the steering wheel button “down”, the next subjacent level can be chosen. On this level, one is able to adjust the hours (the hours flash) with the assistance of the steering wheel buttons “left” and “right”.

Afterwards, the steering wheel button "down" has to be activated to get onto the next level in order to regulate the minutes with the steering wheel buttons “left” and “right”. On this level, the minutes flash.

By a short push on the button “left” or “right”, which lasts less than 3 sec., the minutes/ hours (depends on the level, on which you are situated) can be adjusted.

If the push lasts more than 3 sec., the indication of minutes/ hours is decreased/ increased until the time from the last change of the indication to the unhanding of the button is less than one sec. Increasing/decreasing happens with 1 unit per second. Values are handled in a ring-buffer-fashion, i.e. decreasing 00 minutes results in 59 minutes and so forth.

Figure: Example of a clock display (24h).

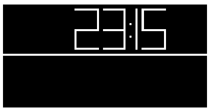


Figure: Definition of a clock display (24h).

Figure: Example of a clock display (24h) (hours flash).

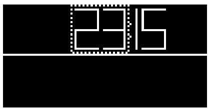
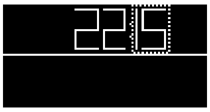


Figure: Example of a clock display (24h) (minutes flash).



If the representation of time is not 24 h but 12 h, the according representation rules have to be considered. The subsequent table presents the mapping from 24h to 12h values.

Table: Mapping from 24h to 12h values.

24h Time	12h representation
00:00	12:00pm
00:01	12:01am
00:02	12:02am
...	...
01:00	01:00am
…	…
11:59	11:59am
12:00	12:00am
12:01	12:01pm
12:02	12:02pm
…	…
23:58	11:58pm
23:59	

Figure: Example of a clock display (12h).

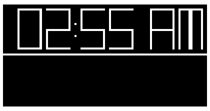
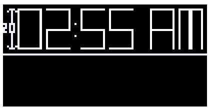


Figure: Definition of a clock display (12h).



1.5.4.4 Temperature Regulator

The temperature regulator is the next subjacent level below the clock regulator. You can get to the level of the temperature regulator with the steering wheel button “down”.

There are two possibilities of indicating the temperature: °C and °F. On the level “temperature regulator”, the representation can be changed with the steering wheel buttons “left” and “right” between °C and °F.

Figure: Example of the display (temperature regulator).

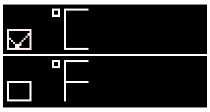


Figure: Definition of the display (temperature regulator).

1.5.4.5 Language

“Language” is the next level below the “temperature regulator”, which can be chosen with the steering wheel button “down”.

It is possible to select between two languages: English and German. With the steering wheel buttons “left” and “right”, you are able to toggle the choice.

Figure: Example of the display (language).

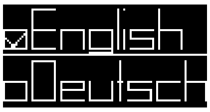
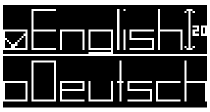


Figure: Definition of the display (language).



1.5.4.6 Speedometer Regulator

With the steering wheel buttons “left” and “right”, a choice can be made between a kmh or mph representation.

Figure: Example of the display (speedometer regulator).

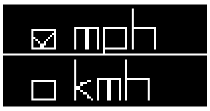
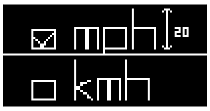


Figure: Definition of the display (speedometer regulator).

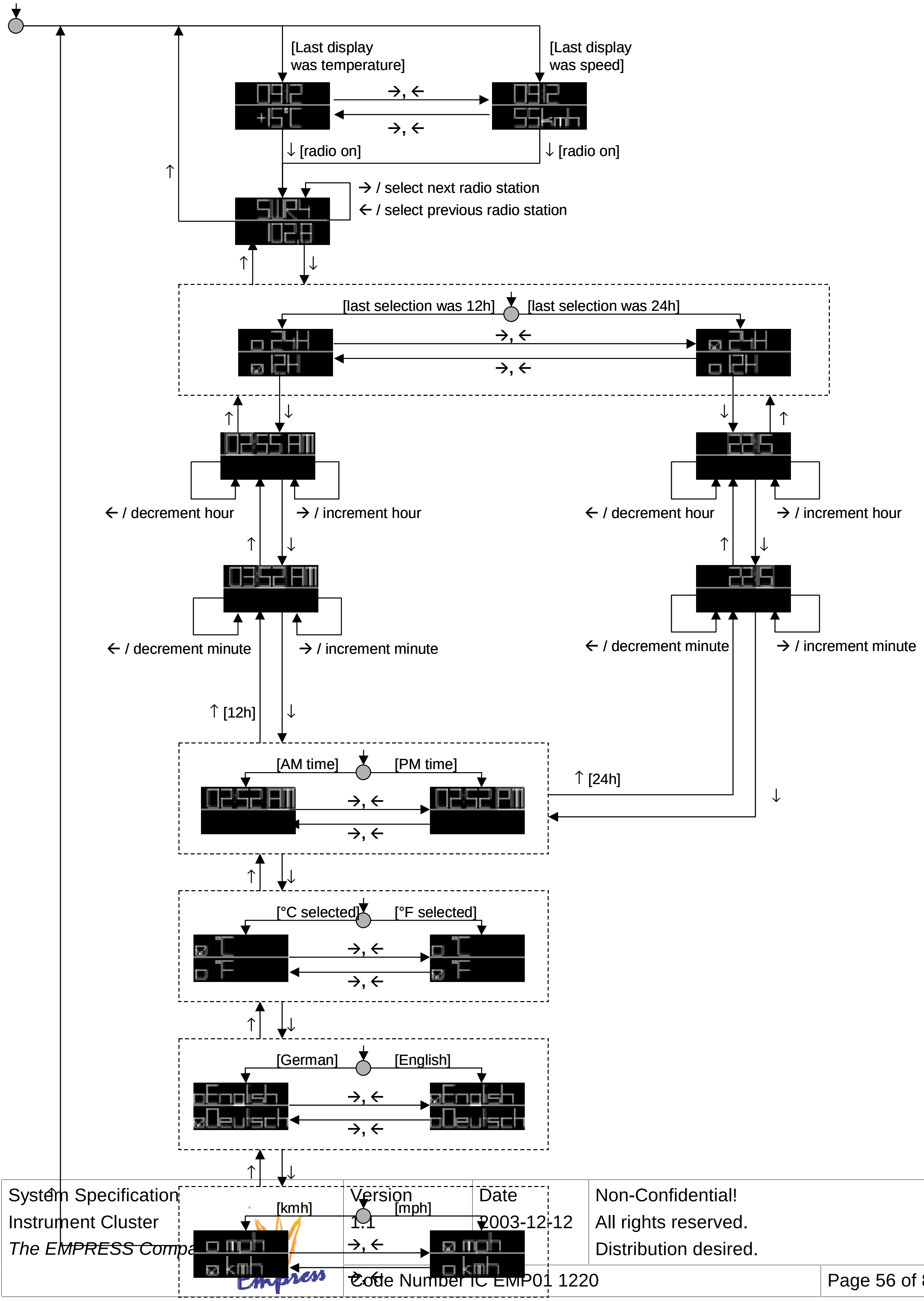


1.5.4.7 Survey

The subsequent drawing visualizes the main navigation throughout the menu tree. The notation used is similar to that of hierarchical state diagrams. The notation used at the edges is the Event [Condition] / Action syntax, i.e. when an Event is detected and the Condition is fulfilled, the Action is performed. Condition and Action are optional. Hierarchical states are used to simplify the drawing.

The menu tree does not cover all radio exceptions (see subsection <u>Radio Display</u>).

Table: Survey.


[Last display was temperature]
[Last display was speed]
0912 +15°C
0912 55kmh
→, ←
→, ←
↓ [radio on]
↓ [radio on]
→ / select next radio station
← / select previous radio station
SWR4 102.8
↑
↓
[last selection was 12h]
[last selection was 24h]
24H 12H
→, ←
→, ←
02:55 AM
22:15
← / decrement hour
→ / increment hour
← / decrement hour
→ / increment hour
03:52 AM
22:16
← / decrement minute
→ / increment minute
← / decrement minute
→ / increment minute
↑ [12h]
↑ [24h]
[AM time]
[PM time]
02:52 AM
02:52 PM
→, ←
[°C selected]
[°F selected]
°C °F
[German]
[English]
English Deutsch
[kmh]
[mph]
mph kmh

1.5.4.8 Parameters

Kmh_Mph

If speed is displayed in kmh or mph. Scope: {0 = kmh, 1 = mph}

German_English

If the language is displayed in German od English. Scope: {0 = German, 1 = English}

1.5.5 Handling of Warning Messages

In the following section, the components of the section warning messages are described.

1.5.5.1 Symbols

The following symbols are part of the warning messages and situated in the upper half of the display.

Figure: S01.

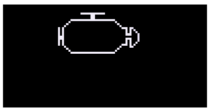


Figure: S02.

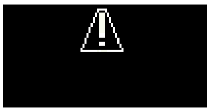


Figure: S03.

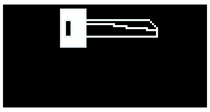


Figure: S04.

Figure: S05.

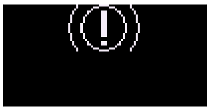
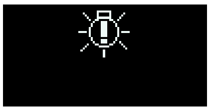


Figure: S06.



1.5.5.2 Structure

Every warning consists of two parts: the symbol and the text line(s).

Figure: Possibility 1: a symbol and one text line (numbers in pixels).

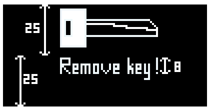


Figure: Possibility 2: a symbol and two text lines (numbers in pixels).

The display measures 100 x 50 pixels.

The symbol is illustrated in the upper half of the display (100 x 25 pixels) and is centered on every side of the rectangular display.

For each text line, there is a range of 100 x 11 pixels reserved, whereas every text line is pictured centered.

The range between two text lines and the symbol area amounts 1 pixel.

The range between two words measures 4 pixels, the range between two letters amounts 1 pixel.

1.5.6 Warning Characteristics

1.5.6.1 Appearance of a Warning

The appearance of a warning consists of two representations:

- a colored display picture and a warning tone or

- a colored display picture without a warning tone.

Attention should be paid to the warning tone, which may not occur separately without a visual picture.

The period between the appearance of the mistake and the appearance of the warning may not be longer than two analysis intervals.

1.5.6.2 Behavior of Warnings

The behavior of warnings can be modified with the warning characteristics.

1.5.6.2.1 Priority

There are three different priority levels:

- Level 1: These warnings have the highest priority. The previous message will be interrupted if this message occurs. Warnings appearing at the same time with lower priorities are suppressed and turn up later.

- Level 2: These warnings are preferred in contrast to warnings of level 3: the warnings of level 3 are suppressed if warnings of level 2 appear at the same time and are interrupted, if messages of level 2 arrive. Compared with warnings of level 1, messages of level 2 are suppressed and interrupted (see “level 1”).

- Level 3: These warnings have the lowest priority. Any other warnings have preference to these warnings. Moreover, warnings of level 3 are interrupted or suppressed if other warnings appear.

If two warnings of the same priority occur at the same time, they are indicated alternately with a period of 10 sec. each, until the driver confirms one of the warnings or one of the signals is confirmed automatically.

1.5.6.2.2 Automatic Confirmation

If this attribute is activated, the warning disappears automatically, if the cause for the warning is eliminated.

To guarantee a flicker-free display, a message is displayed at least for 10 sec. (only relevant if the activation time is less than 10 sec.).

1.5.6.2.3 Manual Confirmation

If this attribute is activated, the user can terminate the warning manually by a short push on one of the buttons on the steering wheel, whereby it doesn‘ t matter, which one is pushed.

1.5.6.2.4 Color of the Warning Display

There are two different colors. The warnings can be indicated in red or in white, whereby the choice of color depends on the different priorities: warnings of priority level 1 are illustrated red and the others (level 2,3) have always the color white.

1.5.7 Condition to Switch on

The warning appears, if the condition to switch on is fulfilled.

1.5.8 Condition to Switch off

The warning disappears, if the cause of the warning has ceased to exist and thus the condition to switch on is no longer fulfilled.

Moreover, the warning can be confirmed manually or automatically.

1.5.9 Acoustics

Some warnings have a warning tone additional to the message on the display.

The warning tone is either a continuing tone (the tone is not interrupted until the warning is confirmed) or an interval tone (this tone is a short tone, which appears in intervals of 15 sec.). Which tone is dedicated to which warning can be seen in the section Warning Messages.

1.5.10 Analysis Interval

It is examined again and again, whether the error still exists or is already over. The time between every afresh check is called “analysis interval”.

1.5.11 Warning Messages

The following section contains all warnings and their specification. Only the warnings which appear on the display are considered.

1.5.11.1 Number of Revolutions too High

Figure: Number of revolutions too high.

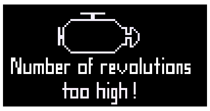


Figure: Drehzahl zu hoch.

Table: specifications of "number of revolutions too high".

Description:	The warning appears, if the number of revolutions is too high.
Condition to switch on:	Warning_RM (see section Rev Meter)
Condition to switch off:	condition to switch on is not fulfilled
Coding:	no
Analysis interval:	200 ms
Priority:	1
Automatic confirmation:	no
Manual confirmation:	yes
Interruption of the previous message occurrence this message:	yes
Comment:	-
Acoustics:	none
- type of the audio warning:	-
Language:	
- English	
symbol name	S01
text line 1	Number of revolutions
text line 2	too high!
- German	
symbol name	S01
text line 1	Drehzahl
text line 2	zu hoch!

1.5.11.2 Display Defective (Engine)

Figure: Display defective. Visit workshop.

Figure: Anzeige defekt. Werkstatt aufsuchen.

Table: specifications of "display defective (engine)".

Description:	The warning appears if the display concerning the engine is defective.
Condition to switch on:	Eng_Def = 1
Condition to switch off:	condition to switch on is not fulfilled
Coding:	no
Analysis interval:	250ms
Priority:	2
Automatic confirmation:	yes
Manual confirmation:	yes
Interruption of the previous message occurrence this message:	yes (previous message is of priority 3),no (previous message is of priority 1)
Comment:	-
Acoustics:	none
- type of the audio warning:	-
Language:	
- English	
symbol name	S01
text line 1	Display defective
text line 2	Visit workshop!
- German	
symbol name	S01
text line 1	Anzeige defekt
text line 2	Werkstatt aufsuchen!

1.5.11.3 Slipperiness

Figure: Slipperiness.

Figure: Glatteisgefahr.

Table: specifications of "slipperiness".

Description:	The warning appears if ice danger exists.
Condition to switch on:	Warning_Ice (see section Outside Temperature).
Condition to switch off:	condition to switch on is not fulfilled
Coding:	yes
Analysis interval:	100ms
Priority:	3
Automatic confirmation:	no
Manual confirmation:	yes
Interruption of the previous message occurrence this message:	no
Comment:	-
Acoustics:	none
- type of the audio warning:	-
Language:	
- English	
symbol name	S02
text line 1	Slipperiness!
text line 2	
- German	
symbol name	S02
text line 1	Glatteisgefahr!
text line 2	

1.5.11.4 Remove Key

Figure: Remove key.

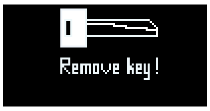


Figure: Schlüssel abziehen.

Table: specifications of "remove key".

Description:	The warning appears if the key is not re-moved.
Condition to switch on:	Ig_LockC = 1 and Ig_LockR = 0 and Status_Door_dd = 1 and Ig_Lock = 0
Condition to switch off:	condition to switch on is not fulfilled
Coding:	yes
Analysis interval:	150ms
Priority:	2
Automatic confirmation:	yes
Manual confirmation:	yes
Interruption of the previous message occurrence this mes-sage:	yes (previous message is of priority 3),no (previous message is of priority 1)
Comment:	especially for the USA
Acoustics:	yes
- type of the audio warning:	interval tone
Language:	
- English	
symbol name	S03
text line 1	Remove key!
text line 2	
- German	
symbol name	S03
text line 1	Schlüssel abziehen!

Description:	The warning appears if the key is not re-moved.
text line 2	

1.5.11.5 Engine Overheated

Figure: Engine overheated.Visit workshop.

Figure: Motor überhitzt. Werkstatt aufsuchen.

Table: specifications of "engine overheated".

Description:	The warning appears if the engine is over-heated.
Condition to switch on:	Eng_Overheated = 1
Condition to switch off:	condition to switch on is not fulfilled
Coding:	no
Analysis interval:	100ms
Priority:	1
Automatic confirmation:	no
Manual confirmation:	yes
Interruption of the previous message occurrence this mes-sage:	yes
Comment:	-
Acoustics:	yes
- type of the audio warning:	continuing tone
Language:	
- English	
symbol name	S01
text line 1	Engine overheated
text line 2	Visit workshop!
- German	
symbol name	S01

Description:	The warning appears if the engine is over-heated.
text line 1	Motor überhitzt
text line 2	Werkstatt aufsuchen!

1.5.11.6 Display Defective

Figure: Display defective. Visit workshop.

Figure: Anzeige defekt. Werkstatt aufsuchen.

Table: specifications of "display defective".

Description:	The warning appears if at least two ECU do not provide significant information or at least two speed sensors fail (see section Speed-ometer).
Condition to switch on:	timeout of at least two ECU(electronic control unit) or Error condition is described in section Speed-ometer.
Condition to switch off:	condition to switch on is not fulfilled
Coding:	no
Analysis interval:	100ms
Priority:	2
Automatic confirmation:	no
Manual confirmation:	yes
Interruption of the previous message occurrence this message:	yes (previous message is of priority 3),no (previous message is of priority 1)
Comment:	-
Acoustics:	none
- type of the audio warning:	-
Language:	
- English	

Description:	The warning appears if at least two ECU do not provide significant information or at least two speed sensors fail (see section Speed-ometer).
symbol name	S04
text line 1	Display defective
text line 2	Visit workshop!
- German	
symbol name	S04
text line 1	Anzeige defekt
text line 2	Werkstatt aufsuchen!

1.5.11.7 Release Hand Brake

Figure: Release hand brake.

Figure: Feststellbremse lösen.

Table: specifications of "release hand brake".

Description:	This warning is transmitted (active/inactive) in case of driving with locked hand brake
Condition to switch on:	Warning_SM (see section Speedometer)
Condition to switch off:	condition to switch on is not fulfilled
Coding:	no
Analysis interval:	100ms
Priority:	2
Automatic confirmation:	no
Manual confirmation:	yes
Interruption of the previous message occurrence this message:	yes (previous message is of priority 3),no (previous message is of priority 1)
Comment:	-
Acoustics:	yes

Description:	This warning is transmitted (active/inactive) in case of driving with locked hand brake
- type of the audio warning:	interval tone
Language:	
- English	
symbol name	S05
text line 1	Release
text line 2	hand brake!
- German	
symbol name	S05
text line 1	Feststellbremse
text line 2	Werkstatt aufsuchen!

1.5.11.8 Turn Signal Front Left Defective

Figure: Turn signal front left defective.

Figure: Blinker vorne links defekt.

Table: specifications of "turn signal front left defective".

Description:	The warning appears if the turn signal front left is defective.
Condition to switch on:	TS_FL_DEF = 1
Condition to switch off:	condition to switch on is not fulfilled
Coding:	no
Analysis interval:	200ms
Priority:	3
Automatic confirmation:	no
Manual confirmation:	yes
Interruption of the previous message occurrence this message:	no
Comment:	-

Description:	The warning appears if the turn signal front left is defective.
Acoustics:	none
- type of the audio warning:	-
Language:	
- English	
symbol name	S06
text line 1	Turn signal front left
text line 2	defective!
- German	
symbol name	S06
text line 1	Blinker vorne links
text line 2	defekt!

1.5.11.9 *Turn Signal Front Right Defective*

Figure: Turn signal front right defective.

Figure: Blinker vorne rechts defekt.

Table: specifications of "turn signal front right defective".

Description:	The warning appears if the turn signal front right is defective.
Condition to switch on:	TS_FR_DEF = 1
Condition to switch off:	condition to switch on is not fulfilled
Coding:	no
Analysis interval:	200ms
Priority:	3
Automatic confirmation:	no
Manual confirmation:	yes

Description:	The warning appears if the turn signal front right is defective.
Interruption of the previous message occurrence this message:	no
Comment:	-
Acoustics:	none
- type of the audio warning:	-
Language:	
- English	
symbol name	S06
text line 1	Turn signal front right
text line 2	defective!
- German	
symbol name	S06
text line 1	Blinker vorne rechts
text line 2	defekt!

1.5.11.10 Turn Signal Rear Left Defective

Figure: Turn signal rear left defective.

Figure: Blinker hinten links defekt.

Table: specifications of "turn signal rear left defective".

Description:	The warning appears if the turn signal rear left is defective.
Condition to switch on:	TS_RL_DEF = 1
Condition to switch off:	condition to switch on is not fulfilled
Coding:	no
Analysis interval:	200ms
Priority:	3

Description:	The warning appears if the turn signal rear left is defective.
Automatic confirmation:	no
Manual confirmation:	yes
Interruption of the previous message occurrence this message:	no
Comment:	-
Acoustics:	none
- type of the audio warning:	-
Language:	
- English	
symbol name	S06
text line 1	Turn signal rear left
text line 2	defective!
- German	
symbol name	S06
text line 1	Blinker hinten links
text line 2	defekt!

1.5.11.11 Turn Signal Rear Right Defective

Figure: Turn signal rear right defective.

Figure: Blinker hinten rechts defekt.

Table: specifications of "turn signal rear right defective".

Description:	The warning appears if the turn signal rear right is defective.
Condition to switch on:	TS_RR_DEF = 1
Condition to switch off:	condition to switch on is not fulfilled
Coding:	no
Analysis interval:	200ms

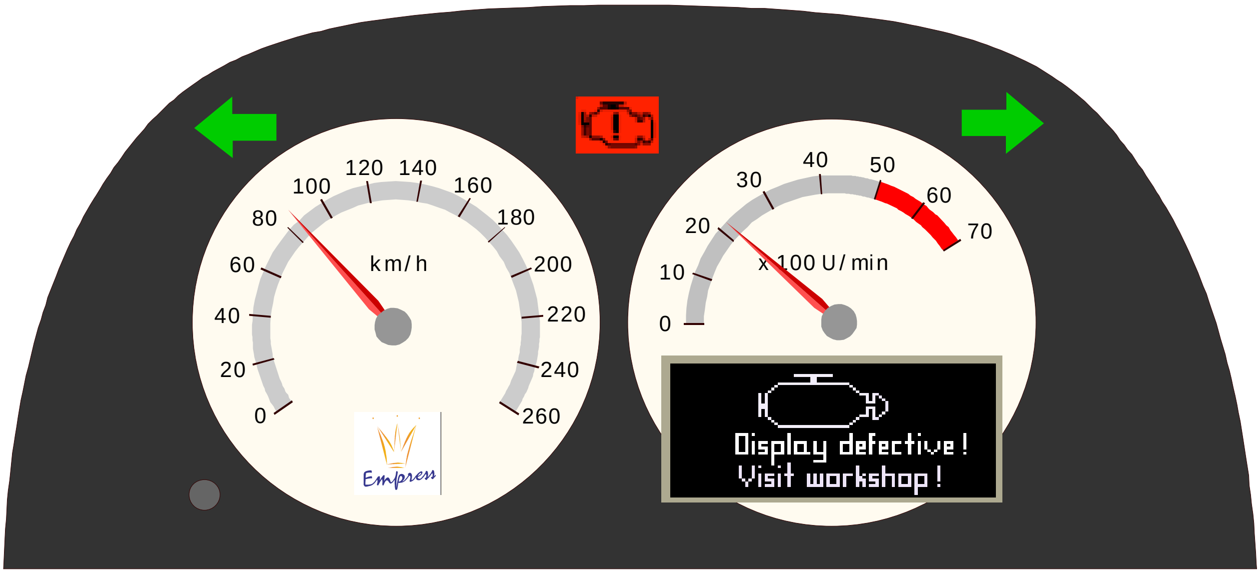
Description:	The warning appears if the turn signal rear right is defective.
Priority:	3
Automatic confirmation:	no
Manual confirmation:	yes
Interruption of the previous message occurrence this message:	no
Comment:	-
Acoustics:	none
- type of the audio warning:	-
Language:	
- English	
symbol name	S06
text line 1	Turn signal rear right
text line 2	defective!
- German	
symbol name	S06
text line 1	Blinker hinten rechts
text line 2	defekt!

2 Hardware

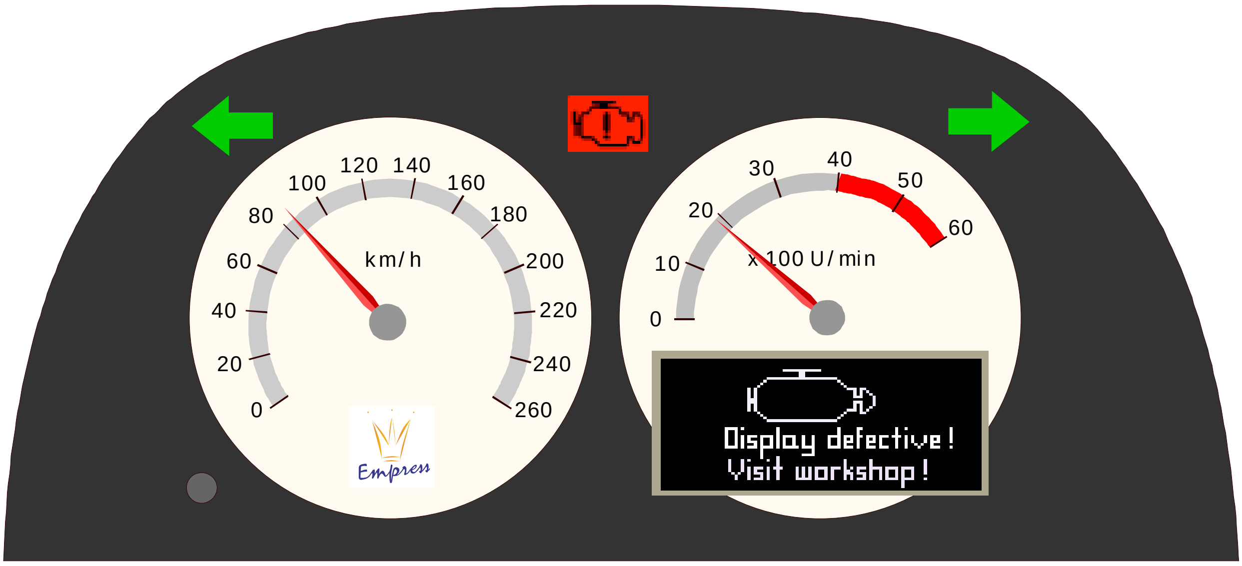
2.1 Optical Design

The following drawings specify the optical design of the instrument cluster in the various variants (see also section General Remarks)

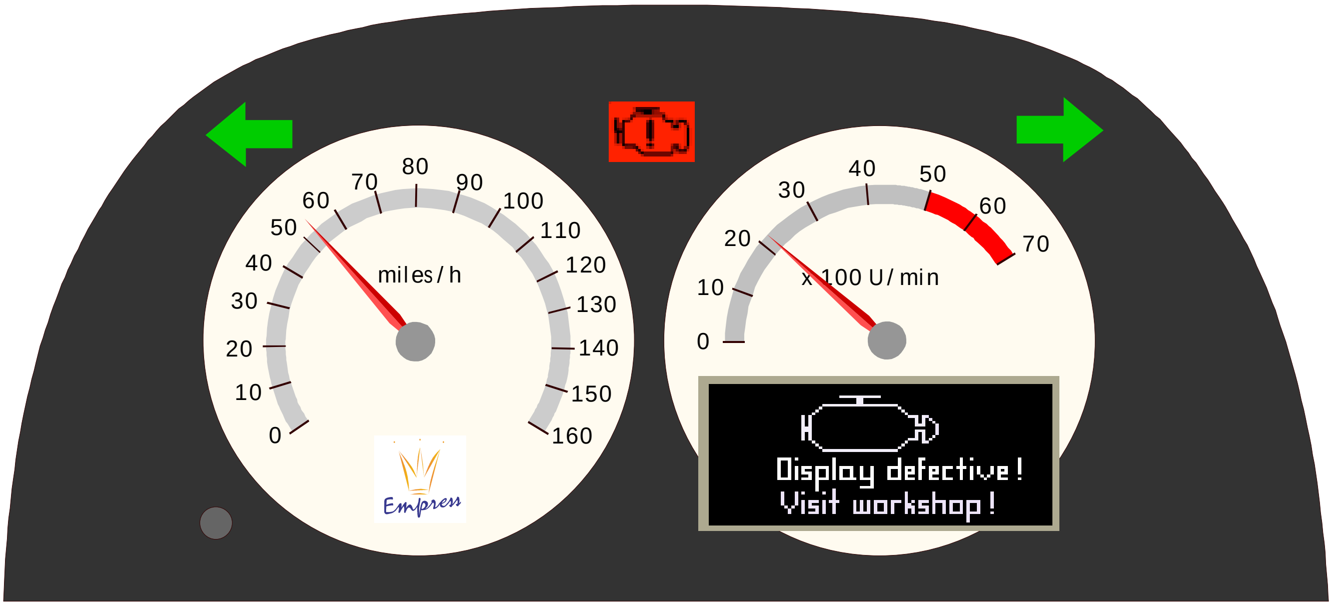
IC EMP01 1221



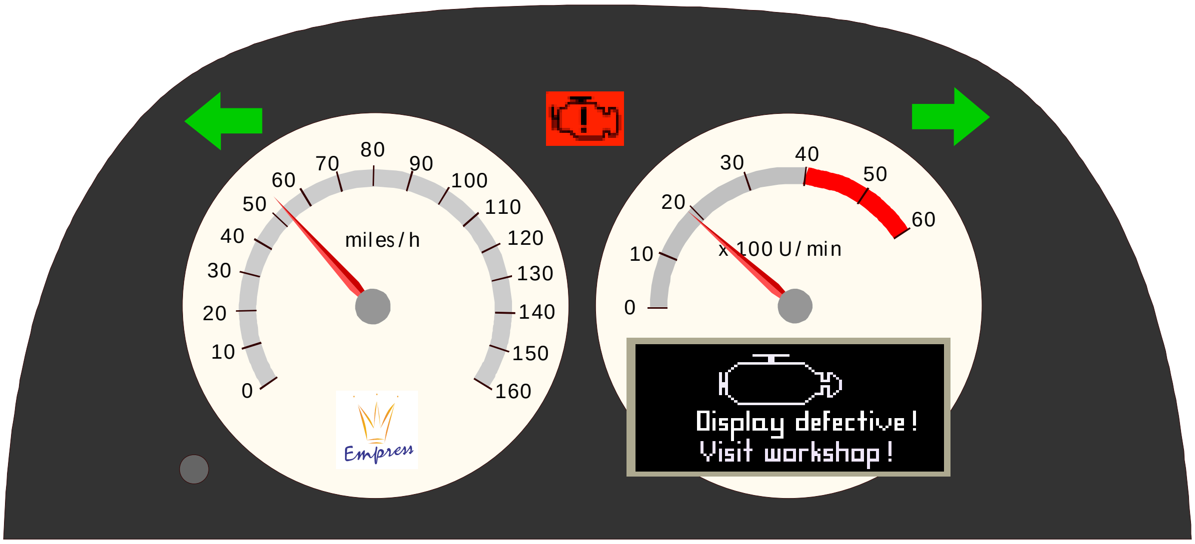
IC EMP01 1222



IC EMP01 1223



IC EMP01 1224



3 Communication and Parameter

This section describes the input and output signals that are important for the instrument cluster. Furthermore, it describes all parameters needed. Please note that all signals and parameters are described in the according section; here, only a subsumption of all of them is provided.

3.1 Input - Output

Table: Input and Output Signals.

function / module	Signal name	In -/ Output (only external signals trans-ferred by CAN bus)	Description
Activation and Deac-tivation of the In-strument Cluster	Ig_Lock	Input	Describes the position of the ignition key. If Ig_Lock = 1 then the ignition key is in posi-tion ignition on. Sent by the ignition lock control unit. Scope: {0,1}. Received every 100 ms. Transferred by the CAN bus.
	Ig_LockR	Input	Describes the position of the ignition key. If Ig_LockR = 1 then the ignition key is in posi-tion radio. Sent by the ignition lock control unit. Scope: {0,1}. Received every 100 ms. Transferred by the CAN bus.
	Status_Door_dd	Input	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	Input	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.
Digital Watch	BUT_UP	Input	If BUT_UP = 1, the steering wheel button „up" is pressed, otherwise the steering wheel button is not pressed. Sent by the steering wheel buttons control unit. Scope:{0,1}. Transferred every 100ms.
	BUT_DOWN	Input	If BUT_DOWN = 1, the steer-ing wheel button „down" is pressed, otherwise the steer-ing wheel button is not pressed. Sent by the steering wheel buttons control unit. Scope:{0,1}. Transferred

function / module	Signal name	In -/ Output (only external signals trans-ferred by CAN bus)	Description
			every 100ms.
	BUT_LEFT	Input	If BUT_LEFT = 1, the steering wheel button „?“ is pressed, otherwise the steering wheel button is not pressed. Sent by the steering wheel buttons control unit. Scope:{0,1}. Transferred every 100ms.
	BUT_RIGHT	Input	If BUT_RIGHT = 1, the steer-ing wheel button „?“ is pressed, otherwise the steer-ing wheel button is not pressed. Sent by the steering wheel buttons control unit. Scope:{0,1}. Transferred every 100ms.
	Ig_LockR	Input	Describes the position of the ignition key. If Ig_LockR = 1 then the ignition key is in posi-tion radio. Sent by the ignition lock control unit. Scope: {0,1}. Received every 100 ms.
	COMPUTED_SECOND	Input	A cyclically sent signal to syn-chronize the time. COM-PUTED_SECOND = 1 is sent 500ms, then COM-PUTED_SECOND = 0 is sent 500ms. One periodic step lasts 1s. Scope: {0,1}. Trans-ferred every 100ms.
Indicator Lights	Turn_Signal_Left	Input	The signal describes the status of the combination switch and is sent by the combination switch control unit. Turn_Signal_Left = 1 means, the driver sets the combination switch in the turn signal left position. Turn_Signal_Left = 0 means, the driver does not set the turn signal left. Scope: {0,1}.

function / module	Signal name	In -/ Output (only external signals transferred by CAN bus)	Description
			Transmitted every 250ms.
	Turn_Signal_Right	Input	The signal describes the status of the combination switch and is sent by the combination switch control unit. Turn_Signal_Right = 1 means, the driver sets the combination switch in the turn signal right position. Turn_Signal_Right = 0 means, the driver does not set the turn signal right. Scope: {0,1}. Transmitted every 250ms.
	Hazard_Warning_Signal	Input	The signal describes the status of the hazard warning signal flasher. The signal is sent by the hazard warning signal flasher control unit. If the hazard warning signal flasher is set, then Hazard_Warning_Signal = 1, otherwise Hazard_Warning_Signal = 0. Scope: {0,1}. Transmitted every 50ms.
Engine Control Light	Engine_Warning	Input	This signal describes the status of the engine. The signal is sent by the engine control unit. If the engine control unit determines a problem with the engine, Engine_Warning = 1 is sent, otherwise Engine_Warning = 0. Scope: {0,1}. Transmitted every 100ms by the CAN bus.
Outside Temperature	Current_Temp_Cooling_Liquid	Input	Temperature of the cooling liquid (centigrade: -10 until +150). Scope 0x00..0xFF (Temp [°C] = Value + 50). Received every 80ms by the CAN bus.

function / module	Signal name	In -/ Output (only external signals transferred by CAN bus)	Description
	Ig_LockR	Input	Describes the position of the ignition key. If Ig_LockR = 1 then the ignition key is in position radio. Scope: {0,1}. Received every 100 ms. Transferred by the CAN bus.
	Error_OT	Output	In case of a realized error (active/inactive). Scope {0=active, 1=inactive}. Transferred every 100ms by the CAN bus.
Radio Information	R_STAT	Input	Cyclic information concerning radio status (see section Radio Information: figure Message R_STAT)
	R_IC_STAT	Input	Event-driven message providing information about the radio status (see section Radio Information: figure Message R_IC_STAT)
	BUT_LEFT	Input	Steering wheel button '?' pressed; Scope {0=not-pressed, 1=pressed}. Transmission rate: sent every 200ms. Sender: Steering wheel Buttons.
	BUT_RIGHT	Input	Steering wheel button '?' pressed; Scope {0=not-pressed, 1=pressed}. Transmission rate: sent every 200ms. Sender: Steering wheel Buttons.
	BUT_PLUS	Input	Steering wheel button '+' pressed; Scope {0=not-pressed, 1=pressed}. Trans-

function / module	Signal name	In -/ Output (only external signals trans-ferred by CAN bus)	Description
			mission rate: sent every 200ms. Sender: Steering wheel Buttons.
	BUT_MINUS	Input	Steering wheel button '–' pressed; Scope {0=not-pressed, 1=pressed}. Trans-mission rate: sent every 200ms. Sender: Steering wheel Buttons.
	Ig_LockR	Input	Describes the position of the ignition key. If Ig_LockR = 1 then the ignition key is in posi-tion radio. Scope: {0, 1}. Re-ceived every 100 ms.
	IC_R_CMD	Output	Event-driven message re-questing services from the radio (see section Radio In-formation: figure Message IC_R_CMD)
Rev Meter	Actual_Number_Of_Revolutions	Input	The number of revolutions of the engine, at the moment measured (8 bits: 0x0 – 0xFF; Unit 32 rotations/minute). Re-ceived every 100 ms.
	Debit_Number_Of_Revolutions	Input	This signal is sent by the en-gine (8 bits: 0x0 – 0xFF; Unit 32 rotations/minute). Re-ceived every 100 ms.
	Ig_Lock	Input	Describes the position of the ignition key. If Ig_Lock = 1 then the ignition key is in posi-tion ignition on. Scope: {0,1}. Received every 100 ms.
	Error_RM	Output	In case of a realized error (active/inactive). Scope: {0=active, 1=inactive}. Trans-ferred by the CAN bus. Sent every 100 ms
Speedometer	Ac-tual_Number_Of_Wheel_Revolutions	Input	The number of revolutions of each of the four wheels, at the

function / module	Signal name	In -/ Output (only external signals transferred by CAN bus)	Description
	_Sensor1 Actual_Number_Of_Wheel_Revolutions_Sensor2 Actual_Number_Of_Wheel_Revolutions_Sensor3 Actual_Number_Of_Wheel_Revolutions_Sensor4		moment measured (8 bits:0x0 - 0xFF, Unit: 1/6 wheel rotation per second, 0xFF = Error value). Received every 150 ms.
	Ig_Lock	Input	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.
	Hand_Brake_Lock	Input	Indicates that the hand brake is locked (0 = hand brake locked, 1= hand brake is not locked)
	Speed_Per_Hour_Shown	Output	The speed signal calculated and converted into a scale value (8 bits: 0x0 - 0xFF; Unit 1 km/h). Transmitted from the speedometer to the speedometer display. Transferred by the CAN bus. Sent every 150 ms.
	Error_SM	Output	In case of a detected error (active/inactive). Transferred by the CAN bus. Sent every 100 ms.
Warning Messages			
- Turn Signal xx defective	TS_xx_DEF	Input	The warning appears if the turn signal front left is defective. Scope: {1 = defective, 0 = not defective}
- Engine overheated	Eng_Overheated	Input	The warning appears if the engine is overheated. Scope:{1 = overheated, 0 =

function / module	Signal name	In -/ Output (only external signals trans-ferred by CAN bus)	Description
			not overheated}
- Remove key	Ig_LockC	Input	The warning appears, when the key has to be removed from the ignition lock.
- Display defective	Eng_Def	Input	The warning appears if the display concerning the engine is defective. Scope: {1 = de-fective, 0 = not defective}

3.2 Parameter

Table: Parameters.

Function/Module	Parameter Name	Value Range
Digital Watch	BLINK_FREQUENCY_ADJ	Range: 1..7, blinking frequency (while adjusting the time): X/2 blinks (on/off) per second
	BLINK_FREQUENCY_COLON	Range: 1..7, blinking frequency (of the colon): X/2 blinks (on/off) per second
	ADJUSTMENT_SPEED_HOURS	How long the „left“ or „right“ button has to be pressed to de-/increase the hours; scope: 3 Bit {000=100ms,..111=800ms}
	ADJUSTMENT_SPEED_MINUTES	How long the „left“ or „right“ button has to be pressed to de-/increase the min-utes; scope: 3 Bit {000=100ms,..111=800ms}
	12_24_TIME_FORMAT	0 = 24h, 1 = 12h
Outside Temperature	Variant_Specific_Bit_Temp	0 = °C, 1 = °F
	Ice_Threshold	Internal threshold with which the pro-duced outside temperature for the dis-play is compared. Scope: {0x00 .. 0x1F} (0x00 = -20°C, 0x01 = -19°C..0x1F=11°C)
Radio Information	Radio_Page_Available	0 = active, 1 = not available
Rev Meter	Release_Bit	0 = no consideration of

Function/Module	Parameter Name	Value Range
		Debit_Number_Of_Revolution, 1 = consider Debit_Number_Of_Revolution
	Damping_PT1	Damping of the PT1 element. Stored in the ROM. Scope: {0 .. 0xFF, Unit: degree/second.
Rev Meter and Speedometer	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.
Speedometer	Damping_PT2	Damping of the PT2 element. Stored in the ROM. Scope: {0 .. 0xFF, Unit: degree/second}.
User Configuration and Menu Tree	Kmh_Mph	0 = km/h, 1 = mph
	German_English	0 = German, 1 = English

3.3 Configuration

BLINK_FREQUENCY_ADJ

BLINK_FREQUENCY_COLON

ADJUSTMENT_SPEED_HOURS

ADJUSTMENT_SPEED_MINUTES

Ice_Threshold

Release_Bit

Damping_PT1

Damping_PT2

Radio_Page_Available

Table: Configuration.

Variant	12h or 24h	°C or °F	German or English	km/h or mph
HW IC EMP01 1221				
- market: EU:GB	1	0	1	0
EU:D,A,CH	0	0	0	0
EU (except GB,D,A,CH)	0	0	1	0
HW IC EMP01 1222				

Variant	12h or 24h	°C or °F	German or English	km/h or mph
- market: EU:GB	1	0	1	0
EU:D,A,CH	0	0	0	0
EU (except GB,D,A,CH)	0	0	1	0
HW IC EMP01 1223				
- market: US	1	1	1	1
HW IC EMP01 1224				
- market: US	1	1	1	1

4 References

[1] Empress, Evolution Management and Process for Real-Time Embedded Software Systems, *Framework for Requirements*, Deliverable 3.1.1, Edited by Thomas Zink, December 2002.

[2] D. J. Hatley and I. A. Pirbhai. *Strategies for Real-time System Specification*. Dorset House Publishing, 1987.