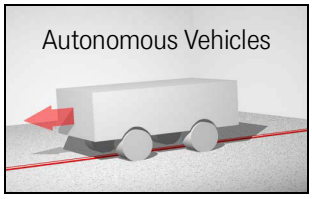
Documentation HG G-73650ZD



Navigation Controller

HG G-73650ZD

Basics, Setup and Software

English, Revision 11	Date: 05.07.2021	Dev. by: ML / LM / TE	Author(s): RAD / ML

GÖTTING

Innovation through Guidance

www.goetting-agv.com

The Götting KG in D-31275 Lehrte has a certified quality management system according to ISO 9001.

Contents

1 Introduction

The subject of this manual is the Navigation Controller HG G-73650ZD that enables AGV (Automated Guided Vehicles) to follow virtual tracks. The following terms are used synonymously throughout this document:

- Control Unit (as printed onto the hardware)
- navigation controller
- Vehicle Guidance Controller (VGC)

1.1 Presentation of Information

For you to be able to use your product simply and safely this device description uses consistent warning notices, symbols, terms and abbreviations. Those are described in the following sections.

1.1.1 Warning Notices

In this device description warning notices appear before sequences of actions that may lead to damage to persons or property. The listed actions for the danger prevention have to be observed.

Warning notices have the following structure:

⚠ SIGNAL WORD

Kind or source of the danger

Consequences

▶ Danger prevention

- The **warning symbol** (warning triangle) indicates danger to life or risk of injury.
- The **signal word** indicates the severity of the danger.
- The paragraph **kind or source of the danger** names the kind or source of the danger.
- The paragraph **consequences** describes the consequences of not observing the warning notice.
- The paragraphs for **danger prevention** explain, how to avoid the danger.

The signal words have the following meanings:

Table 1 *Hazard classification according to ANSI Z535.6-2006*

Warning Symbol, Signal Word	Meaning
DANGER	DANGER indicates a hazardous situation which, if not avoided, will result in death or serious injury.
WARNING	WARNING indicates a hazardous situation which, if not avoided, could result in death or serious injury.
CAUTION	CAUTION indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.
NOTICE	NOTICE indicates property damage: The product or the environment could be damaged.

1.1.2 Symbols

In this device description the following symbols and formatting are used:

If this information is ignored,
the product may not be operated in an optimal way.

Indicates one or more links to the Internet.

- www.goetting.de/xxx
- www.goetting.de/yyy

Indicates tips for easier
operation of the product.

✓ The check mark lists a requirement.

▶ The arrow shows an action step.
The indentation shows the result of an action or an action sequence.

- Program texts and variables are indicated through the use of `a fixed width font`.
- Menu items and parameters are shown in *cursive characters*.
- Whenever the pressing of letter keys is required for program entries, the required L etter K eys are indicated as such (for any programs of Götting KG small and capital letters are equally working).

1.2 Tasks of the Navigation Controller

The navigation controller has the following tasks:

1. Determination of the current position via transponders, GPS or external input, see section 2.3 on page 13
2. Reconstruction of the route to be driven (by means of segment files), see section 2.5 on page 23
3. Track Guidance (controlling the vehicle on a track), see section 2.6 on page 33

As the navigation controller is a very complex technical product the following pages will first cover the various aspects of the vehicle's track guidance that have to be considered before we explain the subject areas of commissioning and configuration. The following points will be explained later in this manual:

- Basic information on positioning, track creation and track guidance
- Hardware description, including displays and interfaces
- Software description, including all menus of the web configuration
- Commissioning
- Protocol description, structure of the CAN- telegrams, Feldbus (external implementation on profinet, profibus, etc.)
- Listing of data, which can be logged on an USB stick for analysis purposes
- Trouble shooting

1.3 Intended Use

DANGER

Danger through missing safety measures

The navigation controller HG G-73650ZD is not a safe device.

▶ Only use the navigation controller in applications where sufficient additional precautions for the protection of people and the detection of obstacles have been taken.

Due to its design the navigation controller is designated for a wide scope of applications. It can only be applied for the track guidance of vehicles if the manufacturer or the plant operator ensure that sensors for position detection are used that are suitable for the requirements of that specific place and thus work fully (GPS e.g. is only suitable for outdoor environments with the restriction that the GPS signals experience no interferences due to occlusions).

Furthermore it is essential that all parameters, e.g. concerning the vehicle's dimensions and functions as well as the position of the axles and wheels have to be entered with utmost accuracy. Consequently for new projects a comprehensive testing of the settings with a jacked-up vehicle within a closed down section of the plant is always recommended.

WARNING

Danger through incorrect parameters/faulty input signals

Vehicles using the navigation controller usually drive fully automated during their final / last implementation step. In case that incorrect parameters or fully input signals are used there is a danger of damages to the vehicle or its environment (including persons).

- Only use the navigation controller in applications where sufficient additional precautions for the protection of people and the detection of obstacles have been taken.
- Both the vehicle manufacturer and the plant operator must assess the risks and proceed with the utmost care.
- Inform all persons entrusted with carrying out work within or close to the area of automated operation.
- Follow the procedure described in chapter 6 „Commissioning“ on page 110 and test all parameter changes within closed down sections with a jacked-up vehicle.

1.4 Requirements / Options

- ✓ If you want to use the internal sensor fusion, at least one rotary encoder or any other velocity or distance determining sensor has to be in operation. When rotary encoders are directly connected to the steering controller please ensure that it is a push/pull type with an output voltage of 5 to 25 V, two tracks perpendicular to each other and a resolution of 0.1 to 1 mm / pulse. Using data telegrams on the bus it is also possible to work with encoders to which this limitation does not apply. For an improved accuracy or to achieve redundancy you can also use the **Gyro HG G-84300** (according to odometry).
- ✓ If a transponder positioning system is to be used, its antennas can be connected via CAN bus. Alternatively or in connection with the transponder system you can use a GPS system.
- ✓ When using the **laser scanner HG G-43600** two rotary encoders and two steering encoders have to be connected directly to the navigation controller or deliver their data via the wheel telegrams on the bus.
- ✓ Some steering servos and motor control units can be controlled / addressed directly by the navigation controller so that a vehicle control system for each individual application (e.g. PLC) is not absolutely necessary for each application. However, in terms of monitoring, redundancy and customized adaptions a vehicle control system is always recommendable for larger vehicles.
- ✓ If emergency stop functions are to be provided, a vehicle control system is mandatory as the highest possible safety can only be achieved when both steering controller and vehicle control system are installed.

2 Basic Principles of Track Guidance

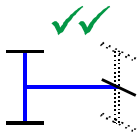
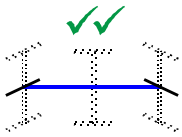
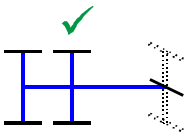
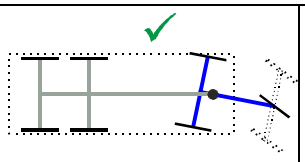
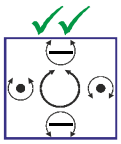
2.1 Suitable and Unsuitable Vehicle Types

The range of particularly suitable vehicle types covers all vehicles that operate predictably and reproducibly. Several non-steered axles, trailers or vehicles with a center pivot steering are not suitable.The wheel slippage has to be low and the wheels should be hard to minimize the friction.

Figure 1 *Example: Suitable vehicle types (selection)*

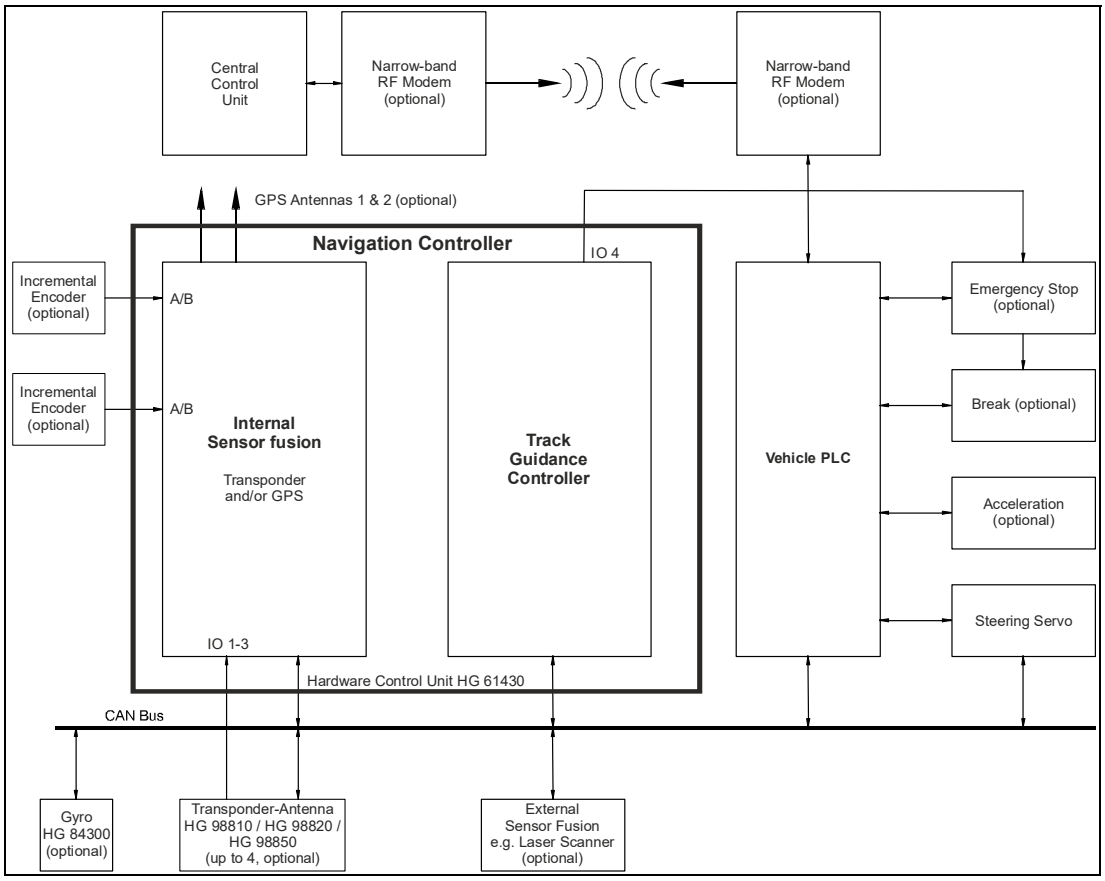
The sketch below shows simplified versions of all the vehicles as three-wheelers, because this is the base vehicle model used by the navigation controller. The navigation controller can also be used for vehicles where the steered wheel is not in the middle (e.g. some fork-lift truck types).

Figure 2 *Sketch: Suitable vehicle types*

				
One fixed axle particularly suited e.g. fork-lift truck	Symmetrical steering particularly suited e.g. some heavy duty vehicles	Two fixed axles less accuracy and partly rubbing, grinding wheels e.g. large towing tractors	Trailer less accuracy and partly rubbing, grinding wheels e.g. Trucks with semitrailer	Coordinate chassis / omnidirectional vehicles particularly suited e.g. special vehicles

2.2 System Composition

Figure 3 *Block diagram system structure*



Due to the strict separation of the track controller, sensor fusion and navigation system and the smart interaction with the vehicle control, the navigation controller offers a high degree of flexibility and is also suitable for monitoring safety-critical vehicle components.

2.3 Position Determination with Sensor Fusion

The sensor fusion calculates the current position and the vehicle's orientation. The sensor fusion provides the steering controller with the following data set (also referred to as **pose**):

- X Position
- Y Position
- Speed
- Vehicle orientation

If the internal sensor fusion is used, the position of the vehicle is calculated from the odometry, initialized and corrected by the transponder antenna and/or the GPS system. The transponder antennas will then be connected via CAN bus. Additionally their posi pulse has to be connected with IO-3 (see manual of the antenna). The optional Gyro is connected via CAN bus as well and is intended to enhance the odometry.

Since odometric calculations tend to be load-dependent the installation of a Gyro HG G-84300 is recommended.

You can find more information about the Gyro at the following address: https://goetting-agv.com/components/84300

If an external sensor fusion (determination of position and angle) shall be applied it can be connected via the CAN Bus. The relevant protocol is described in chapter 7 on page 128. This may be e.g. laser scanner **HG 43600**. As long as they are compliant with the CAN Bus protocol requirements it is possible to use other position- determination systems as well.

By the use of a short-term stable odometry in combination with an absolute position sensor the advantages of both systems are united. The absolute position sensor initializes the odometric data and thus provides both the position as well as the vehicle heading at every point. During operation the cumulative inaccuracies in the odometry will be reset at those points where an absolute position is available.

In addition to the position and the steering angle the sensor fusion provides the speed as well as an accuracy estimation. This estimation is based on the accuracy table (see Table 72 on page 153). The table is structured in such a way that the error is small right after e.g. a transponder has been passed over. With the distance traveled the error tends to grow more rapidly, as the angle is also steadily worsening. So with every meter travelled the value of the accuracy assessment is decreased by one position, i.e. it moves one line upwards in the corresponding Table 72.

When using GPS technology the GPS system determines the position's estimated accuracy in meters. If GPS and transponder antennas are used simultaneously the accuracy estimation is defined by the system in use. Switching between systems can be automated via accuracy thresholds or set manually via segment specific attributes.

2.3.1 The Odometry

The odometric system uses wheel rotations, the steering angle and/or a Gyro to determine the change in vehicle position and vehicle heading.

The odometry has the advantage to be highly accurate over short distances and to supply the vehicle position at any time. The odometry has to be initilized at start-up. However while traveling longer distances the system immanent errors accumulate. This can cause considerable deviations.

2.3.2 Freeze ONS

ONS = Odometric Navigation System – Calculation of the vehicle position via velocities nad steering angles. For some vehicles a speed is shown even though the vehicle stands still. This can e.g. happen when a Diesel engine produces vibrations. The positive and negative speeds caused by this lead to calculated positions that also jump. In the long term the calculated position moves away from the actual position due to rounding errors. This can be prevented by using the function *Freeze ONS*.

WARNING

Risk of collision

In case the vehicle does move slowly while the control unit receives the *Freeze ONS* signal the control unit uses wrong position data from the position the vehicle had when *Freeze ONS* was activated.

- This function may only ever be used when the vehicle is standing still and the brake is activated.

- If a wheel is moving faster than 0.1 m/s while the function is activated the control unit triggers a plausibility error (0x0400) since it has to assume that the vehicle in fact moves. Additionally the accuracy of the position is set to 100 m.
- For speeds below 0.1 m/s with *Freeze ONS* activated the control unit can't determine whether the vehicle moves or whether vibrations induce fake speeds. A collision of the vehicle has to be prevented by the external safety system.
- When this function is activated by setting the bit *Freeze ONS* (s. Control Box Byte 1 Bit 0, see section 7.3.1 on page 144) the position is not re-calculated. As soon as the control unit gives the vehicle a drive command (in any mode where the control unit calculates a target speed unlike zero) the *Freeze ONS* bit is ignored.

2.3.3 Compensation of Wheel Diameters

With this function the wheel diameters of the vehicle can be compensated according to the current load. If the load of the vehicle is specified the unloaded and loaded wheel diameters can be measured during commissioning. With those values the wheel diameter can be reduced (compensated) when the vehicle is loaded.

In order to be able to use this function the ID for the corresponding CAN message has to be set in the general parameter file. For this download the parameter file to a PC (see section 4.6.2 on page 90) and edit it in a text editor. The parameter with the name U32_WHEEL_REDUCTION_ID can be found in the last quarter of the parameter file. Change the accompanying value to the ID of the CAN message (decimal notation). Setting this to 0 disables the function. The edited parameter file has to be uploaded to the navigation controller (see 4.6.1 on page 89).

If the message is activated it has to be transmitted cyclically at least every 500 ms. Otherwise the navigation controller throws an error.

In the CAN message that is evaluated when this function is enabled the compensation of the individual wheel diameters is expected as an unsigned char, see section 7.3.15 on page 155. The resolution is 0.1% of the wheel diameter. If e.g. the value for wheel 2 is set to 15 the effective wheel diameter of wheel 2 is reduced by 1.5%.

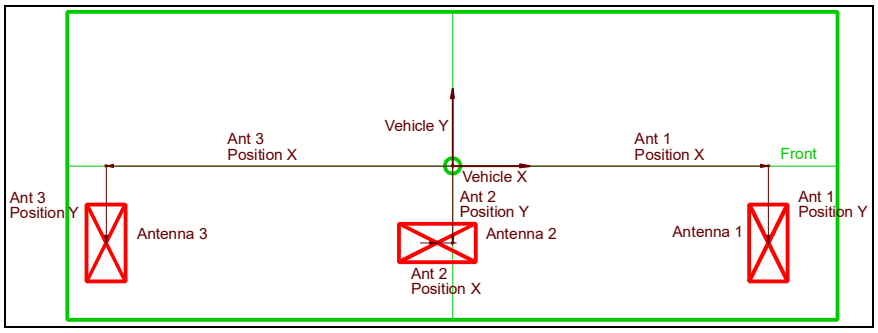
2.3.4 Sensors for Navigation

2.3.4.1 Transponder Antenna

The transponder system outputs the position and the code of the transponder currently located underneath the antenna. The position lateral to the direction of travel has an accuracy between ± 5mm and ±20mm, depending on the antenna type (mostly its size). Also depending on the antenna type the detection range is between ±125 and up to ± 500mm, the reading distance varies between 50 - 200 mm. Possible antennas are e.g. the Götting types HG G-98810, HG G-98820, HG G-98830 and HG G-98850.

The transponder position in direction of travel is only output as the posi pulse when the center of the transponder antenna is crossing the transponder. When there is no transponder underneath the antenna, the antenna delivers no position. **There may be at most one transponder underneath the antenna at any given time.** The parameters of the transponder antenna are set via a RS 232 interface which is described in the antenna manual.

Figure 4 *Determination of antenna positions underneath the vehicle*



The transponder antennas are 1.5 dimensional. That means that the relative transponder position in direction to the long side of the antenna is measured. In direction of the short antenna side only the crossing impulse (posi pulse) is available, which is generated when the transponder passes the center of the antenna. The navigation controller associates a certain task with each antenna number:

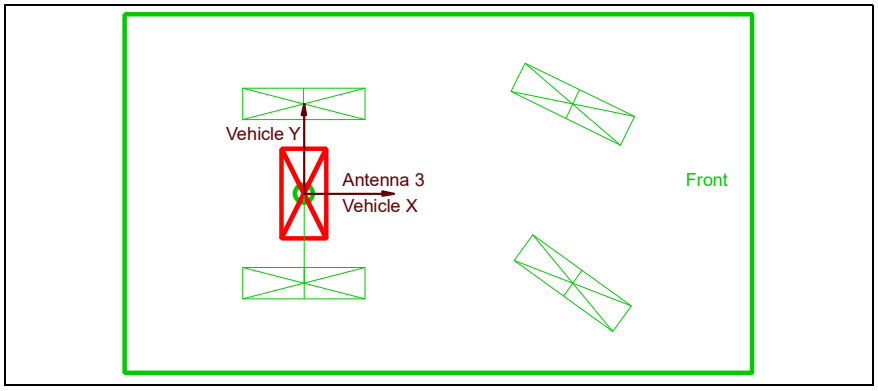
- Antenna 1: Front (if needed)
- Antenna 2: Vehicle center, rotated by 90^{0} (if needed)
- Antenna 3: Rear

2-dimensional antennas (like the Götting model HG G-98830) are an exception to the rules above. They replace antenna 1 & 2. Here the posipulse is generated by the antennas 1 & 3.

The simplest form is a set-up with a single antenna.

2.3.4.1.1 Single Antenna Evaluation – Calculation of the Position with one Antenna

Figure 5 *Single antenna: Placement*



In order to be able to calculate a position it is normally necessary to detect more than one transponder!

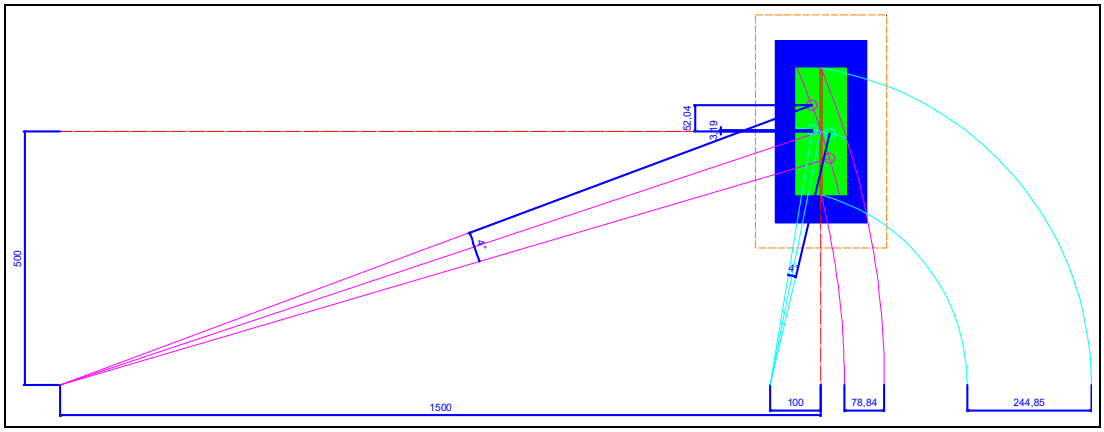
The transponder antenna is able to determine the transponder position underneath the antenna, however the direction of the antenna with regards to the transponder cannot be determined. (**exception:** The transponder – a start transponder – can only be approached in one direction, e.g. at a transfer station). Thus it is necessary to cross two transponders in order to define the position of the vehicle. The odometry additionally measures the track between these two transponders. The transponder table enables associating absolute positions with the individually measured points (transponders). With the reading of two transponders it is then also possible to determine the direction of the vehicle.

A fundamental disadvantage of the single antenna is that the calculated orientation of the vehicle depends on the distance covered between the transponders. However, the determination of this distance can only be as precise as the vehicle's odometry. Thus the accuracy of the calculation not only depends on the antenna and the transponders but also on the odometry. Subsequently this calculation is not as accurate as the measurement accuracy guaranteed if two antennas read two transponders simultaneously.

For non-omnidirectional vehicles make sure that the antenna is always mounted as close as possible to the fixed axle. If this installation proves to be difficult or isn't feasible at all, the antenna has to be located as close as possible to the fixed axle in the main direction of travel. The further away the antenna is from the fixed axle the less accurate the measurement will be. (Lever arm, high transversal speed of the transponders in curves and reduced effective detection range in curves).

Example

Figure 6 *Properties of a single antenna set-up*



Antenna properties:

- The orange area of the antenna represents the range where max. one transponder may be located. This area lies within a distance of approx. 50 mm around the antenna casing.
- The blue area is the antenna casing (here HG98820 180 mm x 360 mm)
- The green area is the reception area of the transponder antenna (here approx. ±50 mm x ±125 mm)
- If the thicker red line in the center of the antenna is crossed by a transponder, a posi pulse will be triggered.

The example shows two possible mounting positions of the antenna on the vehicle. The first position is 100 mm in front of the fixed axle (turquoise), the second one is 1500 mm in front of the fixed axle (magenta). In both cases the vehicle drives around a curve with a radius of 500 mm. The example clearly shows that the first position is much better than the second one:

- The antenna's effective reading range for the first position is still 224 mm, for the second position the range is reduced to 78 mm.
- The reading accuracy of the first position is considerably higher. In both cases the vehicle uniformly turns 4° (it turns with the same speed). The transponder readings are displayed symmetrically to the posipulse. In position 1 the transponder is read in a distance of 3,19 mm from the desired position (center of the antenna), in position two with a reading error of 52,04 mm.

- As the transponder moves much faster through the reading area in position two due to the bigger lever, the error rate, generated by the timing, will increase.
- Major corrective movements may lead to completely missing the transponder in position two.

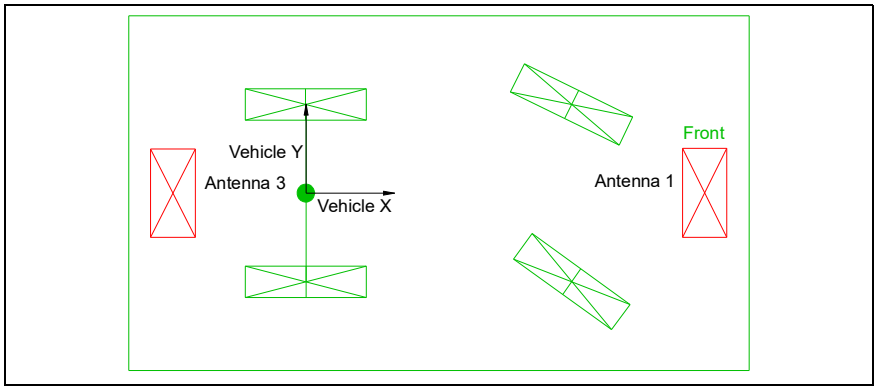
If it is not possible to install the antenna close to the fixed axle, e.g. on a fork-lift, the following should be observed:

- It should not be attempted to read transponders in tight turns. It is better to place a pair of transponders with a distance of at least 0.5 m before and after the curve.
- Where curves are to be driven that are so long that transponders have to be read, the radius has to be kept to the maximum possible and the speed should be as lowered as much as possible.
- The transponder antenna has to be mounted as close as possible to the rear axle (fixed axle or fixed roller).

For omnidirectional vehicles make sure that the antenna is mounted as close as possible to the center of the vehicle. Again the following applies: *The more tilted the vehicle moves the more restricted the measurement is.* If the vehicle only drives in diagonal direction a calculation cannot be performed at all, since the transponders are no longer crossing the antenna center and consequently no posi pulses are generated. For each transponder crossing only one calculation is performed (posi pulse of the transponder).

2.3.4.1.2 Double Antenna Evaluation

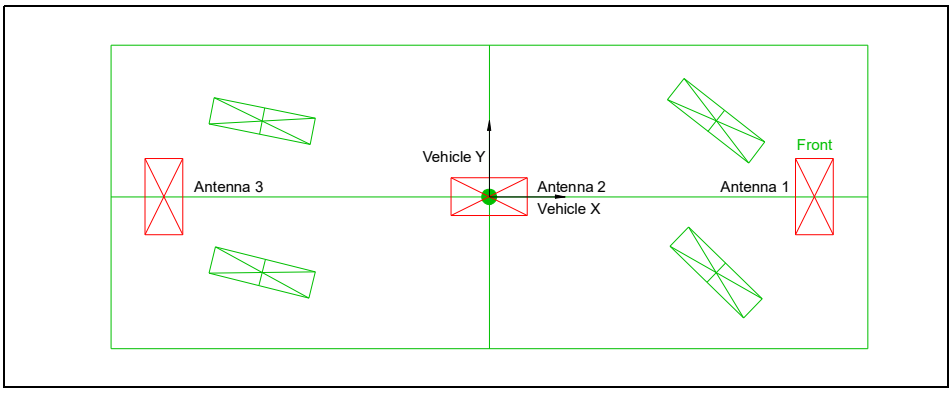
Figure 7 *Properties of a double antenna set-up*



The double antenna set-up has the advantage that the vehicle orientation can be directly measured using the second antenna. *To do so the transponders have to be laid in such a manner that both antennas are simultaneously located above a transponder each and that antenna 1 or 3 will trigger a posi pulse.* Then the calculation is independent from the odometry. Furthermore the accuracy, especially of the vehicle orientation, is much more precise in comparison with the evaluation of a single antenna. The antennas should be mounted as far apart as possible. This means that small inaccuracies during positioning will only have a slight impact on the angle error. For each transponder crossing only one calculation is performed (posipulse of antenna 1,3).

2.3.4.1.3 The Triple Antenna Evaluation

Figure 8 *Properties of a triple antenna set-up*



In contrast to the single and double antenna set-up in this application all degrees of freedom of the vehicle are measured directly. Calculations can be executed as long as all antennas are positioned above transponders at the same time. This set-up also allows the determination of the vehicle's position and orientation when driving diagonally. Antenna 1 and 3 determine the orientation and Y position, antenna 2 determines the vehicle's X position (vehicle coordinate system). If only antenna 1 and 3 are located above transponders, the position will be calculated when antenna 1 or 3 generate a posi pulse (like when using a double antenna set-up).

Alternatively one 2-dimensional antenna can either replace antennas 1 & 2 or 2 & 3, e.g. the Götting model HG G-98830. The antenna‘s second dimension replaces the tasks of antenna 2.

2.3.4.1.4 Initialising the Transponder Sensor Fusion (Placing Vehicle on the Track)

There are several options for the initialisation of the transponder sensor fusion:

1. Single antenna set-up:
   - The vehicle reads a special start transponder. The start transponder is a normal transponder which can only be read with a certain orientation due to constructional measures. This may be e.g. at a transfer station. The start transponder is marked accordingly in the transponder list and the start heading is recorded in 1/100° (s. 2.3.4.1.5 on page 20). **A start transponder is only evaluated as such directly after the system has been switched on,** afterwards it is considered a normal transponder.
   - The vehicle crosses several transponders. After the first transponder a position cannot yet be calculated. After the second transponder the position and heading can be calculated. After the third transponder the position is confirmed and the accuracy is set to a good value provided the relative position of the third Transponder corresponds with the positions of the previous ones.
2. Double antenna set-up: The start position in longitudinal direction is determined immediately with an uncertainty of ½ of the antenna width when starting over two transponders.
3. Triple antenna set-up: With this set-up the start position is exactly determined when initializing while the three antennas are placed above three transponders.

If the vehicle is also controlled by a driver (manual mode) it sometimes happens that the transponders are not crossed directly anymore. This results in an increasing deterioration of odometry accuracy. Since the system normally is not switched- off the only remaining possibility for initialization for a single antenna system then is the second alternative.

2.3.4.1.5 The Transponder List

The transponder list is a CSV file (values separated by a semi colon). It can be created and edited with Microsoft® Excel® or other spreadsheet applications. The navigation controller can import and export this list (configuration via web browser, see section 4.9.1 on page 92). Additionally the list can be displayed in the web browser, see section 4.10 on page 93.

```
0;1;-2480;-4555;9000;0;0;1
1;2;-2462;-3171;0;0;0;0
2;46;6000;0;0;0;0;0
3;4336;9500;0;0;0;0;0
4;8012;031;6891;9000;127;127;1
```

These values have the following meaning for the navigation controller:

Table 2 *Definition of transponder list*

No.	Code	X Pos.	Y Pos.	Attribute 1	Attribute 2	Attribute 3	Attribute 4
0	1	-2480	-4555	9000	0	0	1
1	2	-2462	-3171	0	0	0	0
2	46	6000	0	0	0	0	0
3	4336	9500	0	0	0	0	0
4	8012	3031	6891	9000	127	127	1

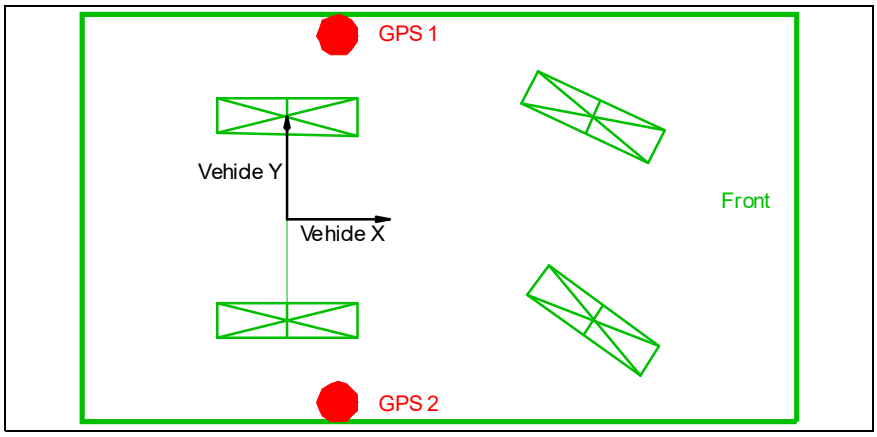
The first column displays the serial number of the transponder tags. The second column shows the corresponding transponder codes. The following two columns define the position in X resp. Y direction in mm. In the fifth column **the heading of the start transponder** is shown in 1/100°. Attribute 2 and attribute 3 are currently unused. Attribute 4 indicates a start transponder with a 1.

2.3.4.2 The GPS/GNSS System

Global Navigation Satellite Systems (GNSS) are one of several options to determine the vehicle position outdoors. Synonymously the term Global Positioning System (GPS) is used. It does not depend on land marks in the ground like e.g. Transponders. It consists of two GPS antennas, a GPS receiver and a radio modem. Antenna 1 determines the position of the vehicle. Antenna 2 determines the heading of the vehicle. In order to reach the necessary accuracy correction data has to be available. This data can either be provided via a basis or bought from a correction data service.

In order to be able to operate with the GPS system a free line of sight between the GPS antennas and the satellites is required. Generally satellites higher than 10° above the horizon are used. If the vehicle drives below a gantry, close to buildings or similar structures the line of sight is interrupted. Afterwards it can take several seconds until the satellites are used again. If less than 6 satellites are available for the position calculation or if the satellites are distributed unfavorably over the sky the system becomes less accurate or drops out.

Figure 9 *Arrangement of the GPS antennas*



It is best to mount the antennas diagonally close to the rear axle. If this is the case the error that an inclined position of the vehicle gives can be compensated: The vehicle is supposed to follow a track with its wheels but the position is determined using the GPS antennas. Due to the antenna height and the sideward inclination of the vehicle a position error develops.

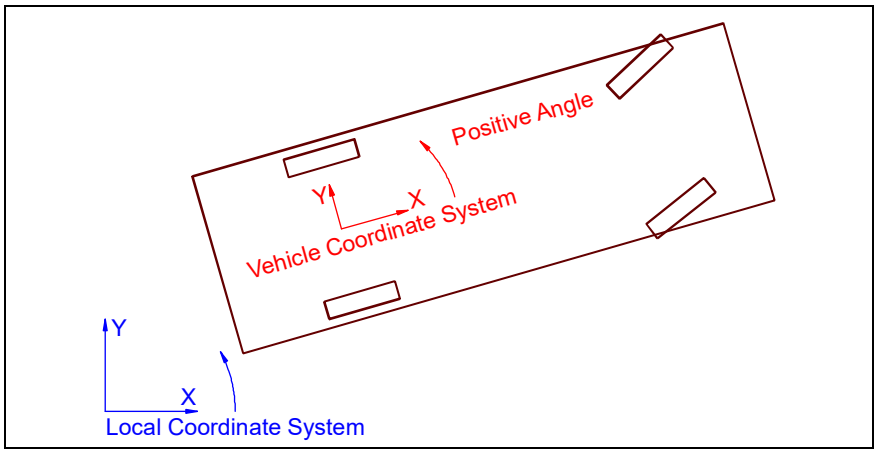
In order to increase the angular accuracy of the system the antennas should be mounted as far away from each other as possible.

2.4 Coordinate Systems

Within the Control Unit different coordinate systems are in use. Segments and transponders refer to the local coordinate system (e.g. the coordinate system of the area). All components of the vehicle refer to the vehicle coordinate system.

2.4.1 The Vehicle Coordinate System

Figure 10 *Vehicle Coordinate System*



The zero point (or origin) of the vehicle coordinate system is the point that is guided along the segments.

- For omnidirectional vehicles the zero point can be chosen freely. Not each origin makes sense, though, for the steering angles of the wheels to stay inside the possible values. When the vehicle drives curves in which the heading changes the wheels that are farthest from the origin need high steering angles.
- For non-omnidirectional vehicles the origin has to be placed on a point that is always moving in vehicle direction (e.g. the axis that is not steered).

The coordinate system is always positioned in the vehicle so that for 0° steering angle and forwards movement the vehicle drives in positive X direction. Looking in positive X direction the Y axis has its positive direction to the left. Also in positive X direction the angle is 0° and grows anti-clockwise from 0 to 360°. The same is valid for the steering angle.

2.4.2 The Local Coordinate System

For the local coordinate system the same basic definitions are valid as for the vehicle coordinate system:

- The Y direction has its positive direction to the left when looking into positive X direction. Also in positive X direction the angle is 0° and grows anti-clockwise from 0 to 360°.
- When the GPS system is used either a local base station (origin) or the country coordinate system are used. If no local base station is used the necessary GPS correction data (wireless) have to be leased from a local provider.

i

The geometer and GPS coordinate systems always have the North as 0° and the angle turns clockwise. These coordinate systems have to be transformed into a X/Y coordinate system (X = N and Y = -E).

If only Transponders are used for guidance the bearing of the coordinate system is arbitrary. Keep in mind, though, that the origin is best placed close to the center of the area for automatic driving. Otherwise the rounding errors of the calculations grow. The maximum area that can be defined is ±10 km in X and Y direction.

If the country coordinate system is used an offset should be set so that the origin of the country coordinate system is placed close to the center of the area for automatic driving.

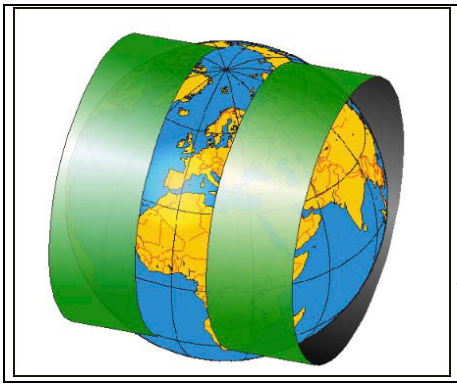
2.4.3 Characteristics of the Coordinate Systems

The basic GPS always uses an ellipsoid coordinate system since the globe of the earth is flattened by its rotation. This however results in two disadvantages:

- Lines of longitude and latitude are impossible to measure with yard sticks.
- Plate tectonic means that the land masses are drifting several centimeters each year inside the global coordinate system.

Thus country specific coordinate systems are used. Those coordinate systems drift together with the land masses and are almost flat. The GPS receiver performs the necessary transformations automatically. The following example of a cylindrical intersection explains some of the resulting quirks:

Figure 11 *Cylindrical intersection of the earth globe for a flat country coordinate system*



Artist: Anton (rp) 2005
https://commons.wikimedia.org/wiki/File:Utmzylinderrp.jpg
Creative Commons Attribution-Share Alike 3.0 Unported
https://creativecommons.org/licenses/by-sa/3.0/deed.en

For this method a 3° stripe of the surface of the earth is projected onto a cylinder. This essentially results in two errors:

- The North heading is only fully valid in the middle of the stripe.
- Distances are slightly distorted.

When using a local GPS base station a flat coordinate system is projected tangentially in north heading onto the ellipsoid. The base station then marks the origin. This still results in projection errors. Continental drift is no longer an issue since the base station drifts with the land masses.

When using a combination of Transponders and GPS the transponders have to be positioned inside the country coordinate system or the basic coordinate system in order to keep errors as small as possible!

The errors in between the transponders then are insignificant. In contrast if the Transponders are positioned in a different coordinate system the resulting error across the area is problematic.

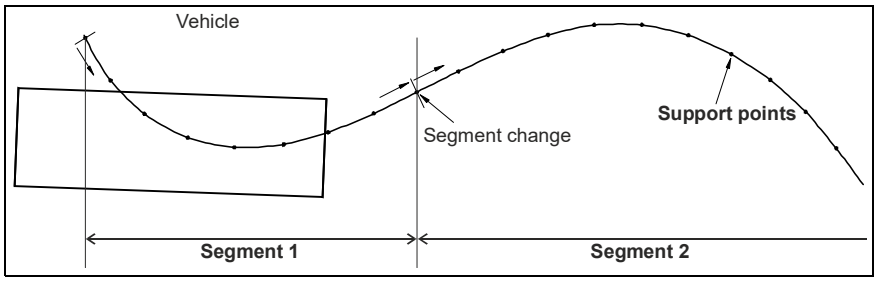
2.5 Reconstruction of the Route (Segments)

Segments are the connecting paths between branches and end points. Tracks are built by combining matching segments from start to finish. The segments are created with a special CAD program. We will refer to *Malz++Kassner® CAD 6* for which Götting provides a plug-in for the navigation controller. Each segment consists of several support points that define the segment course and contain information such as orientation, speed and attributes. Each segment consists of min. 4 and max. 1000 support points.

2.5.1 Virtual Tracks

A virtual track is a route that is not defined by actual tracks or marks (e.g. lines or guide wires). It is usually constructed in a CAD program, where the desired track is drawn directly on a ground plan. Later on the vehicle will follow this virtual track as if it were driving on a real track or „rails“. Thus the CAD program has to incorporate the special features of each vehicle to make the track guidance as accurate as possible.

Figure 12 *Example: Virtual track with support points*



The virtual track consists of several segments that define the sections between branches and terminal points. Each of the segments must consist of at least four support points which are positioned at equal distances over the whole track. These support points are not actual points on the route (for example transponders in the ground). The distance between them depends on the type of the route and the vehicle used.

The closer the support points lie to one another the more precisely the tracking will correlate with the virtual track. However, very close distances between the points are unnecessary where large vehicles are concerned because the vehicle cannot be driven that accurately. However if the distances between the points are too big, the CAD program would display them as angular curves because then no curved routes can be calculated from points which are wide apart from each other.

Rule of thumb: A 90° curve must consist of at least seven support points. The maximum drivable velocity is 0.5 support points every 10 ms. 0.5 support points every 10 ms gives 1 support point every 20 ms, i.e. at a distance of 0.1 m between the support points the maximum speed is 5 m/s.

The start point and the end point of a segment may not have the same coordinates!

2.5.2 The Segment File

All segments and the associated support points are stored in the segment file. Below the file structure is shown. Later on there‘s a description of how to create it.

2.5.2.1 Structure of the Segment File

Each line of the segment file represents one support point. It contains the segment, the support point number, the support point‘s coordinates, two velocities, one attribute 32 bit, one attribute 16 bit (not yet used), the orientation of the vehicle, a label and the version. The segment numbers must be sorted in ascending order but may contain gaps. The gaps are marked as dashes on the *Segment Table* configuration page (see Figure 84 on page 91). The labels can be used at the start or end of a segment, depending on the requirements of the lead control system. They have no significance for the control unit. The version is only shown in the first data line. The columns are separated by a semicolon. In Microsoft® Excel® this can be done, e.g, by saving the file Format *CSV (MS-DOS®)*. In a text editor the file looks as follows:

Figure 13 *Example of a segment file with support points*

```
SegNr;Point;X;Y;SpeedEnd;SpeedJob;Attributes;Attributes2;Orientation;Label;Version
1;0;-53209;-21897;1000;1000;0x00000001;0x0000;4847;Ladestation 1;5
1;1;-52546;-21148;1000;1000;0x00000000;0x0000;4847;;
1;2;-51877;-20392;1000;1000;0x00000000;0x0000;4847;;
1;3;-51214;-19644;1000;1000;0x00000000;0x0000;4847;;
1;4;-50551;-18895;1000;1000;0x00000000;0x0000;4847;;
1;5;-49881;-18139;1000;1000;0x00000000;0x0000;4847;;
1;6;-49218;-17390;1000;1000;0x00000000;0x0000;4847;;
1;7;-48548;-16634;1000;1000;0x00000000;0x0000;4847;;
1;8;-47885;-15886;1000;1000;0x00000000;0x0000;4847;;
1;9;-47216;-15130;1000;1000;0x00000000;0x0000;4847;;
1;10;-46553;-14381;1000;1000;0x00000000;0x0000;4847;;
1;11;-45883;-13625;1000;1000;0x00000000;0x0000;4847;;
1;12;-45220;-12876;1000;1000;0x00000000;0x0000;4847;;
1;13;-44550;-12120;1000;1000;0x00000000;0x0000;4847;;
```

Table 3 *Structure of a segment file with support points SP (part 1 of 2)*

Seg. No.	SP No.	X Pos.	Y Pos.	Speed End	Speed Next	Attribut 32 Bit	Attr. 2 16 Bit	Hea-ding	Label	Vers.
1	0	-53209	-21897	1000	1000	0x00000001	0x0000	4847	Lade stat ion1	5
1	1	-52546	-21148	1000	1000	0x00000000	0x0000	4847		
1	2	-51877	-20392	1000	1000	0x00000000	0x0000	4847		
1	3	-51214	-19644	1000	1000	0x00000000	0x0000	4847		
1	4	-50551	-18895	1000	1000	0x00000000	0x0000	4847		

Table 3 *Structure of a segment file with support points SP (part 2 of 2)*

Seg. No.	SP No.	X Pos.	Y Pos.	Speed End	Speed Next	Attribut 32 Bit	Attr. 2 16 Bit	Hea-ding	Label	Vers.
1	5	-49881	-18139	1000	1000	0x00000000	0x0000	4847		
1	6	-49218	-17390	1000	1000	0x00000000	0x0000	4847		
1	7	-48548	-16634	1000	1000	0x00000000	0x0000	4847		
1	8	-47885	-15886	1000	1000	0x00000000	0x0000	4847		
1	9	-47216	-15130	1000	1000	0x00000000	0x0000	4847		
1	10	-46553	-14381	1000	1000	0x00000000	0x0000	4847		
1	11	-45883	-13625	1000	1000	0x00000000	0x0000	4847		
1	12	-45220	-12876	1000	1000	0x00000000	0x0000	4847		
1	13	-44550	-12120	1000	1000	0x00000000	0x0000	4847		

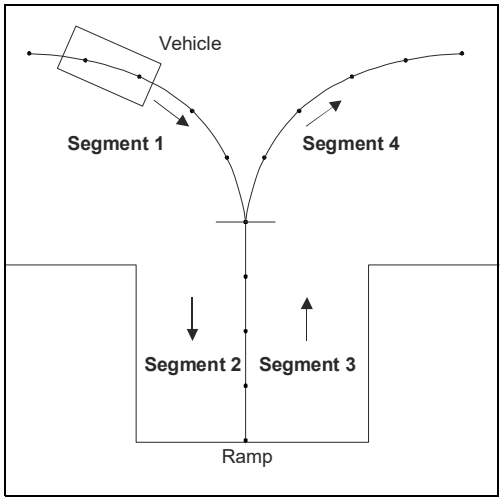
Each row of this table represents one support point. The first column specifies to which segment a specific support point belongs. In the second column the support point is addressed within its segment. Columns 3 and 4 contain the X and Y co-ordinates of the support point in mm or in 1/10mm (according to the adjustment of the CAD program and the steering controller, see Configuration Main –> Resolution Segment Points in section 4.3.1 on page 64). Columns 5 and 6 contain velocity data in mm/s. There are two velocities because on the one hand a connecting segment could exist, or the vehicle is to be stopped at the end of the segment. Therefore, for a final segment (target) or when the vehicle changes direction column 5 is automatically selected. If a connecting segment follows column 6 is selected.

The velocities are interpolated linearly depending on the position between the support points so that a continual velocity profile is created. Only in the following cases the speed will be set to 0 by the Control Unit:

- At the end of the target segment.
- When the direction of travel changes.
- If an error occurs.

Use 1 as the final speed since 0 might result in the vehicle stopping before the segment ends.

Figure 14 *Example for congruent segments*



The vehicle always moves continuously through the segment in the direction of the support points (from the start of a segment to its end). This means that when the vehicle is first to be driven in one direction on a segment and then to be reversed (e.g. when docking onto and undocking a ramp) there must be two segments for the same part of the track.

Column 7 contains the 32 bit attribute. The attribute is sub-divided into 16 higher and 16 lower bits. The lower bits refer to internal functions of the navigation controller. Table 89 on

page 184 shows the meaning of those bits. The16 higher bits – except for the two most significant bits – are freely available and are passed to the vehicle control unit, e.g. via CAN Bus, see Table 43 on page 130.

2.5.2.2 The Segment Search

When vehicle tracking is initialized, only the position of the vehicle is known. To identify the currently drivable segments and transmit them to the central control unit, a segment search can be carried out (as described in the following section this process usually runs automatically in the background). During the segment search, the navigation controller tests all the segments stored for drivability. The segment search can take several seconds depending on the number of segments. It is requested when the navigation controller is in the mode „Idle“ and bit 1 in byte 1 of the CAN Box Table 61 on page 146 is set to 1 (Segment Search Request).

While the segment search is active bit 1 in byte 1 in the CAN box Table 44 on page 130 will be set (segment search active). On completion bit 2 in byte 1 of CAN Box, table 26 on page 107 is set (segment search finished). The drivable segments are collected in the CAN box Table 44 on page 130 and transmitted to the vehicle control. When the bit "Segment Search Request" is reset, the current segments of the navigation controller will again be sent in CAN box Table 44 on page 130. This works analogously for the Feldbus telegram.

Additionally all drivable segments are permanently transmitted. The time it takes to identify all drivable segments depends on the segment size and number. It can easily take some seconds. The segment search must not be requested, as described above, but runs constantly in the background. However, the list provided is only reliable after a few seconds of standstill.

2.5.2.3 Selection of Segments

The segments are chosen by the PLC and then sent to the navigation controller via the CAN bus, Ethernet or Profinet (Anybus). For testing purposes the segments can alternatively be entered using a terminal program or the keypad. To ensure that continual driving is possible the following segment must always be known. Therefore the navigation controller has a segment memory with eight entries in the for of a FIFO (First in First Out) shifting register (see image and tables below).

Figure 15 *Segment FIFO shifting register*

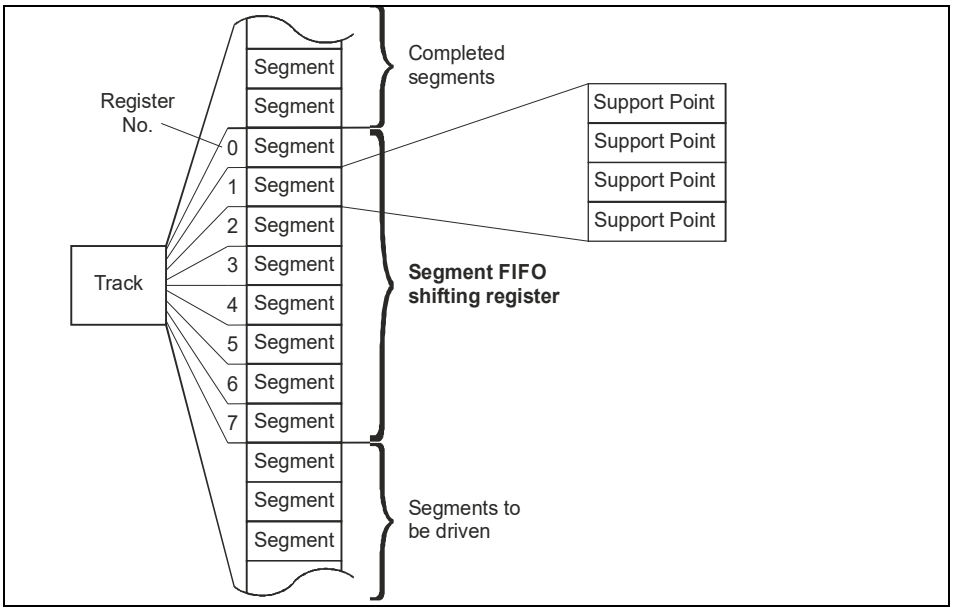


Table 4 *Example: Shifting of segments in the FIFO*

Before		Example: Segment No. 33 completed	After	
FIFO	Segment		FIFO	Segment
0	33		0	10
1	10		1	17
2	17		2	105
3	105		3	65535
4	65535		4	65535
5	65535		5	65535
6	65535		6	65535
7	65535		7	65535

This list is sent back to the vehicle control. The vehicle control may then react by placing a new segment in the FIFO.

Table 5 *Example: Adding new segments to the FIFO*

Before			After	
FIFO	Segment		FIFO	Segment
0	10		0	10
1	17		1	17
2	105		2	105
3	65535	Segment No. 55 added	3	**55**
4	65535		4	65535
5	65535		5	65535
6	65535		6	65535
7	65535		7	65535

This way more than 8 segments can be traveled in a row. In order for the segments to be concatenated the end position of a segment must be the start position of the next segment.

NOTICE

Risk of loading a segment currently being changed

A cycle consisting of *reading the list* to *list written* can easily take one second.

- In order to prevent the navigation controller from loading a segment currently being changed by the vehicle PLC, never the next, but always the next but one segment (FIFO- Register number 2) or higher segments may be changed.

2.5.2.4 Transmission of Segments

Usually the segments will be transmitted via the CAN bus, Feldbus or FTP (see below). For testing purposes the segments can be entered in the menu Parameter Test. For more detailed information see section 4.11 on page 94 and chapter 6 on page 110.

The navigation controller includes the segments in the Can box Path Data (Target). The structure of the box is described in Table 61 on page 146. This box only contains one element of the buffer, namely „Number of segment (LowByte)“ and „Number of Segment (HighByte)“. The segment numbers will be transferred as Unsigned int (16 bit).

To place the segment correctly into the FIFO, the register number will be transferred as well (Position of segment number in table). The navigation controller will be called up every 10 ms. Therefore the transmission of the list takes at least 8 x 10ms = 80 ms. This list always has to be transferred in ascending order. To prevent double transmissions within 10 ms (one message would get lost and the whole table would be invalid) there is the Request Count of Segments Byte. When the vehicle controller sends a box, it changes the status of byte 7 of the CAN box of Table 61 on page 146. The next box should not be transmitted before byte 7 in the CAN box Table 44 on page 130 (response of the navigation controller) has reached the same counter.

The navigation controller's CAN Box answer has a similar structure. This box indicates the current status of the segments in the navigation controller. The transmission of segments in the Feldbus telegram (Ethernet / Profinet) is less complicated, here always 8 segments are transmitted together.

For simple applications or on exhibitions the segments can also be set as segment sequences, see 12.2 on page 185.

2.5.2.5 FTP Transmission of Segments

Segment files can also be transmitted to the navigation controller via FTP. For this an FTP client program is necessary. A free solution is FileZilla that can be downloaded from the following address:

https://filezilla-project.org

In order to establish the FTP connection use the following settings:

- Server IP: 10.10.10.20 (default address of the navigation controller, might have been changed after delivery, see section 4.4 on page 87)
- Protocol: FTP
- Port: Standard (21)
- User/Password: Not necessary

This method is the best choice for the automatic transmission of segments since it triggers a feedback via the CAN bus. The segment files are transmitted into the navigation controller‘s file system and checked for consistency. If the file is OK it is copied into the designated memory for the processing of segments.

If a segment file is transmitted Byte 1 Bit 1 (New Segment File) is set in the CAN Status Box, see Table 43 on page 130. This bit is deleted when the data is transferred into the designated memory for the processing of segments. Afterwards the *Segment File* configuration page (see 4.7 on page 90) the number of loaded segments is shown.

In order to save transmission time segments are transmitted in the *.bin format. This has roughly one third of the size of *.csv files but can not be edited manually. The Götting *TrackEditor* can be used to convert segment files from the CSV into the BIN format.

http://www.goetting.de/trackeditor

2.5.3 Attributes

When the vehicle reaches a support point in automatic mode, the corresponding attributes are carried out and/or output (e.g. turn signal, horn etc.) The16 higher bits – except for the two most significant bits – are freely available (free Attributes) and are passed to the vehicle control unit. The 16 lower bits have a specific pre-defined meaning and are not output. The function of these bits is specified in the appendix in section 12.1 on page 184. The upper 16 bits are output in the CAN Status box in byte 2 and 3. For most attributes sufficient information is disclosed in the annex. The following two exceptions warrant longer explanations:

2.5.3.1 Offset Driving

Constantly driving on the same track can lead to a strong deformation of the surface structure (e.g. on asphalt). For some plants it is therefore sensible to vary the route by a few centimeters. However, the track may only be moved so far that it is still possible to read the installed transponders. Before reaching transfer points / end points the offset has to be switched off so that it is removed in time.

Offset driving is accomplished by overlaying the currently driven segments with offset segments. Those offset segments are the segments 1 – 4 in the segment list. In order to use the offset driving function at those sections there have to be segments defined that determine the transition to the offset driving (see example in Figure 16 on page 29). Offset driving may be initiated at random places on the track segments (segments with numbers > 4) if offset driving is permitted during these segments. For this the attributes Offset Left and Offset Right have to be set for those segments. The offset driving is then initiated by setting the bits Offset left resp. Offset right.

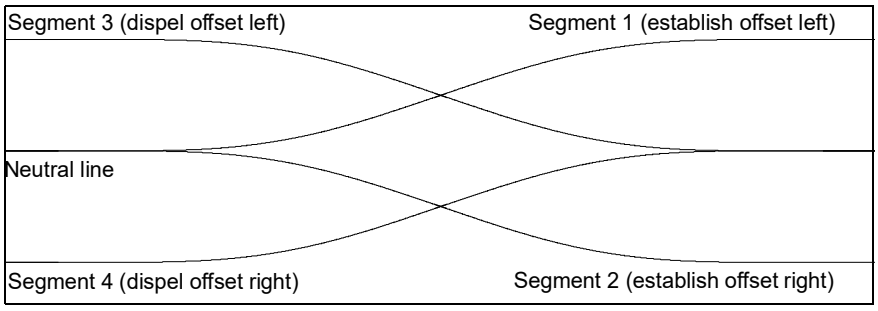
The direction (Offset left or right) always refers to the driving direction since the offset is linked to support points. This is so because omnidirectional vehicles may have a random heading. This however means that e.g. for a truck a right offset established during forward driving turns into a left offset when driving backwards!

The offset is also used during segment search. Thus when the offset increases it may happen that the segment search only finds segments that run into the same direction. In this situation segments running in opposite direction are only found when switching the offset during stand still.

Segment 0 in the navigation controller can be used as a version number of the segment file. *Segment 1* is the transition for offset left- turn driving. *Segment 2* serves as a transition for offset right- turn. Both segments have to start with the coordinates X = 0 and Y = 0. X direction is the longitudinal direction. The Y direction displays the offset to the actual track (course).

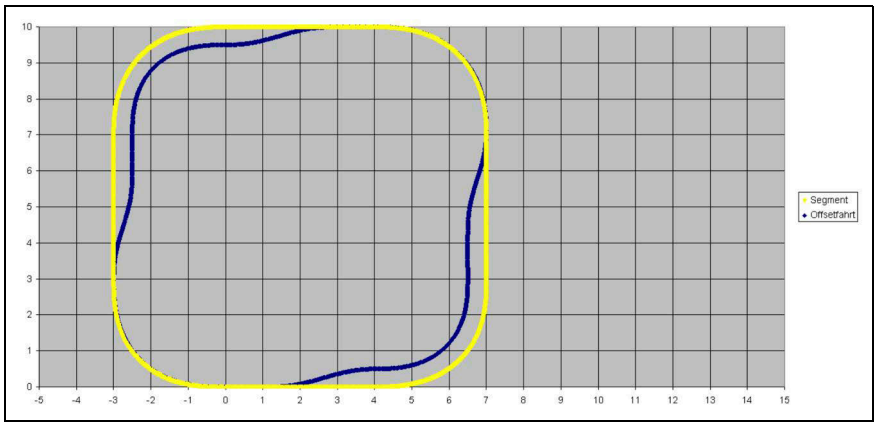
The segments should be as short as possible but as long as necessary. *Segment 3* is the return from the left offset to the actual course. *Segment 4* is the return from the right offset to the actual course.

Figure 16 *Offset segments*



The offset option is released via the attributes `offset left` (0x00000400) and `offset right` (0x00000200) in the segment. The actual offset will be initiated via the CAN box from Table 60 on page 144 through bit 2 (switching right) and bit 3 (switching left). If this attribute is switched off while the vehicle still drives with offset, the vehicle stops with an error message. Therefore the end of the offset mode should be set in motion early enough before the vehicle is supposed to switch back to the track. For this the PLC can use one of the free attributes (see section 12.1 on page 184 in the appendix). When this attribute bit goes out the PLC can delete the offset bit.

Figure 17 *Example: Offset driving*



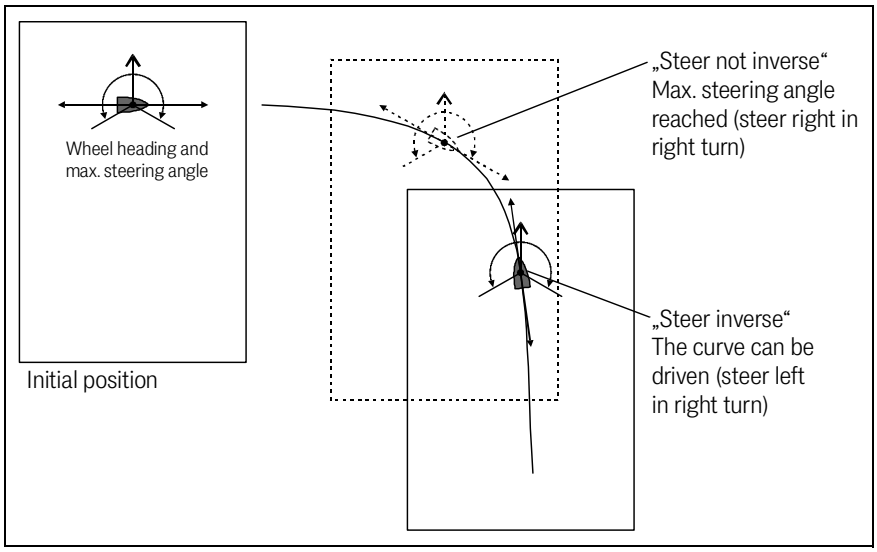
Prerequisites for offset driving operation:

- ✓ Before performing a spot turn or docking the vehicle to a station the user has to remove the offset –> set the bit to turn the offset off in time.
- ✓ At segment transitions with changes in the direction of travel the last two support points of the previous segment have to lay in line with the first two support points of the following segment.
- ✓ When driving with a small offset (up to 1/3 of the maximum deviation), the current segment is still found during segment search. If the offset is higher than the maximum deviation the segment is no longer found during segment search!
- ✓ The offset segments (segments 1 – 4) have to be shorter than 30 points.
- ✓ You should avoid turning offset off or changing them while an offset is being established. If e.g. while driving on one direction the offset is changed from left to right while the left offset is still being established the left offset is fully built and then reduced again before establishing the right offset. Otherwise the vehicle heading may jump.
- ✓ If a course ends while an offset is being established and a new course is requested the target position may jump. This leads to compensation movements of the vehicle, especially if the offset segments are different (can not be mirrored) or when the offset is too big.
- ✓ You have to ensure that the vehicle is able to drive the overlaying segments at all times! If e.g. in a right hand bend an additional right offset is added an especially sharp right turn occurs while the offset is established. This happens because the original radius is reduced by the offset. Additionally establishing the offset means that a right hand bend of its own is driven. High offsets result in the vehicle or the control unit being overburdened. Problems may arise if e.g. the offset is bigger than the curve radius. Theoretically the vehicle would have to shunt under these conditions. However problems would already occur beforehand during the track calculation. *Generally high offsets in bends have to be avoided.*

2.5.3.2 Inverted Steering

The Attributes *Steer inverse* and *Steer not inverse* are used to handle special cases for omnidirectional vehicles with limited steering angles. The following example shows an omnidirectional vehicle with a total steering angle of 120°. The vehicle starts the curve from the position on the left and is supposed to drive a rightwards curve from there. Without a pre-setting the control unit chooses the steering direction automatically when moving onto the track. In about 50 % of all tries this would lead to a false decision in the example below. If the control unit decides to steer rightwards it would drive to the position shown with dotted lines. There it would reach the maximum steering angle and could not steer any further. Before it leaves the course it is stopped.

Figure 18 *Example: Inverted steering*

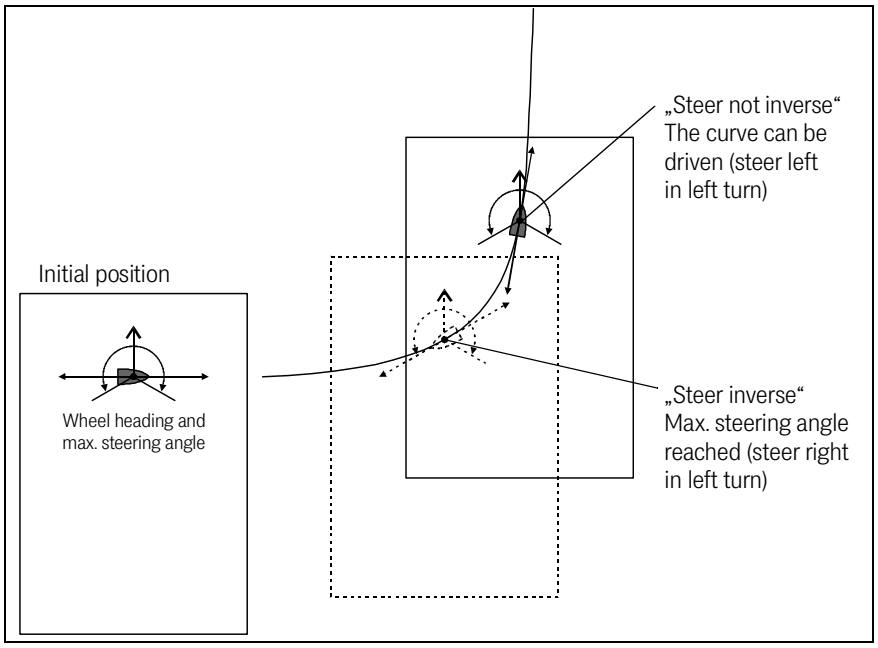


In this example it is possible to tell the control unit to not attempt to steer right but to steer the wheel left with the attribute *Steer inverse* before initiating a drive. Then enough steering angle is available to drive the curve.

Segments that have *Steer inverse* or *Steer not inverse* set need to be transferred alone and not as a part of sequence of segments. Exception: The attributes do not change for a whole segment sequence.

If from the same position the control unit is to drive a sharp left turn instead it is advisable to set *Steer not inverse* to make the control unit use the sufficient remaining steering angle when steering left.

Figure 19 *Example: Steering not inverted*



2.5.3.3 Stop Distance

If a vehicle has to stop at several targets on a straight line it is possible to define a segment for each target. This way is rather complex, though. When using segments the minimum length of segments has to be observed (a minimum of 4 support points, with a distance of 10 cm between the points = 30 cm). Also the speed has to be low enough so that the vehicle may stop inside a given segment.

Alternatively the attribute „Stop distance“ can be used. Then one segment can be defined that goes along all target stations. When „Stop distance“ is activated the PLC can send a distance larger than zero (e.g. through the CAN Box from Table 61 on page 146). The vehicle will then stop when reaching the given distance.

The control unit automatically reduces the speed to 2 cm/s 10 cm before the stop distance is reached in order to allow fine positioning. This e.g. allows the PLC to read connected light barriers so that it can stop the vehicle with „Clearance segment“.

2.5.3.4 Spot Turn

The spot turn is a special maneuver that enables to turn the vehicle on a point. It is needed to change the direction of the vehicle with minimum need for space. Spot tunr can be enabled via the corresponding attribute for the first support point of a segment. If another segment ends on the same point a spot turn is carried out if the heading difference is greater than 5^{0}. While turning on the spot all wheel axles point to the origin of the vehicle coordinate system.

- ✓ **Prerequiste 1:** The vehicle is able to steer as much as needed.
- ✓ **Prerequisite 2:** The attribute „Spot turn“ has to be set for the first support point of the segment.

i

If a greater change in the heading angle is set for a segment but the attribute *Spot turn* is not set the control unit will try to initiate the new heading with the normal calculations which usually leads to the error *Deviation*.

Spot turn means that the vehicle will stop, steers the wheels so that it can turn on the spot and then turns to the target heading. The default is that it turns in the direction in which the new heading is reached first. If the vehicle is to turn into a specific direction this can be set with the additional attributes *Right* and *Left*. *Right* means that the vehicle will turn clockwise, *Left* that it will turn anti-clockwise.

2.5.4 Creating / Editing of a Segment File

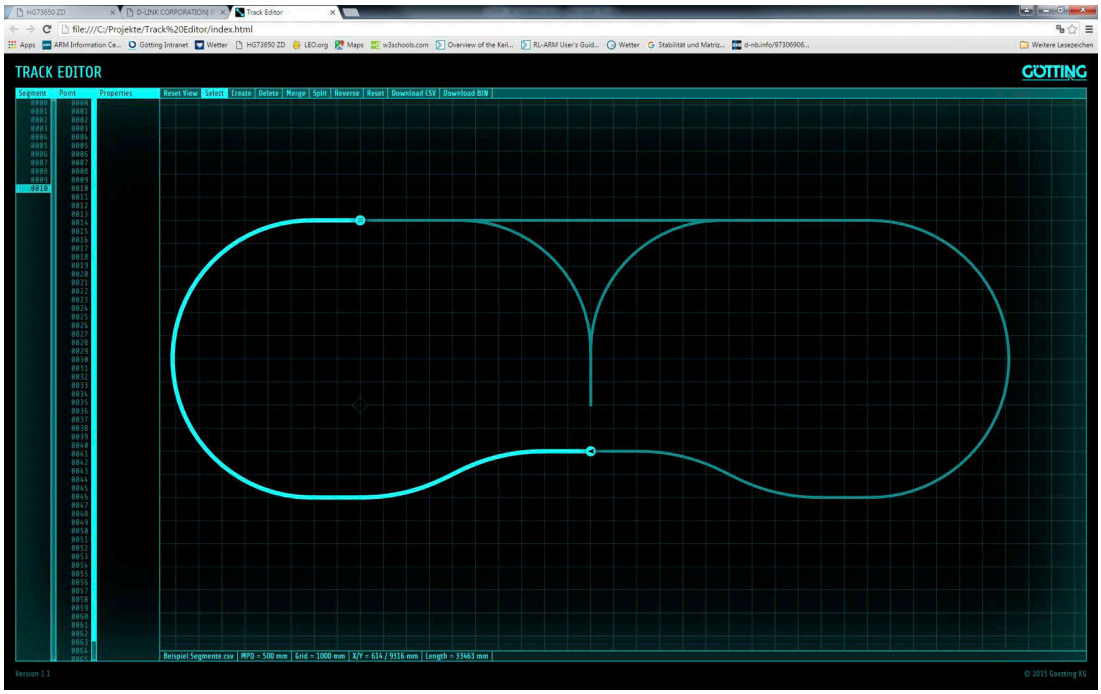
Usually the segment file is created with the CAD program *Malz ++ Kassner® CAD 6*, as this is much more convenient. If curves have to be driven this program has to be used. The CSV segment file has the advantage that some data, e.g. attributes of the support points as well as sensitive data, such as speed or position can easily be changed by the user with a spreadsheet application such as Microsoft® Excel® or with a text editor, without having to have *CAD6* available.

These modifications cannot be re-imported into the CAD program, substantial changes should only be carried out within the CAD program.

Additionally the CSV files can be directly read, processed and exported using the easy-to-use Online Track Editor of Götting. The TrackEditor is available at the following address:

http://www.goetting.de/trackeditor

Figure 20 *Online Track Editor by Götting*



2.6 Track Guidance

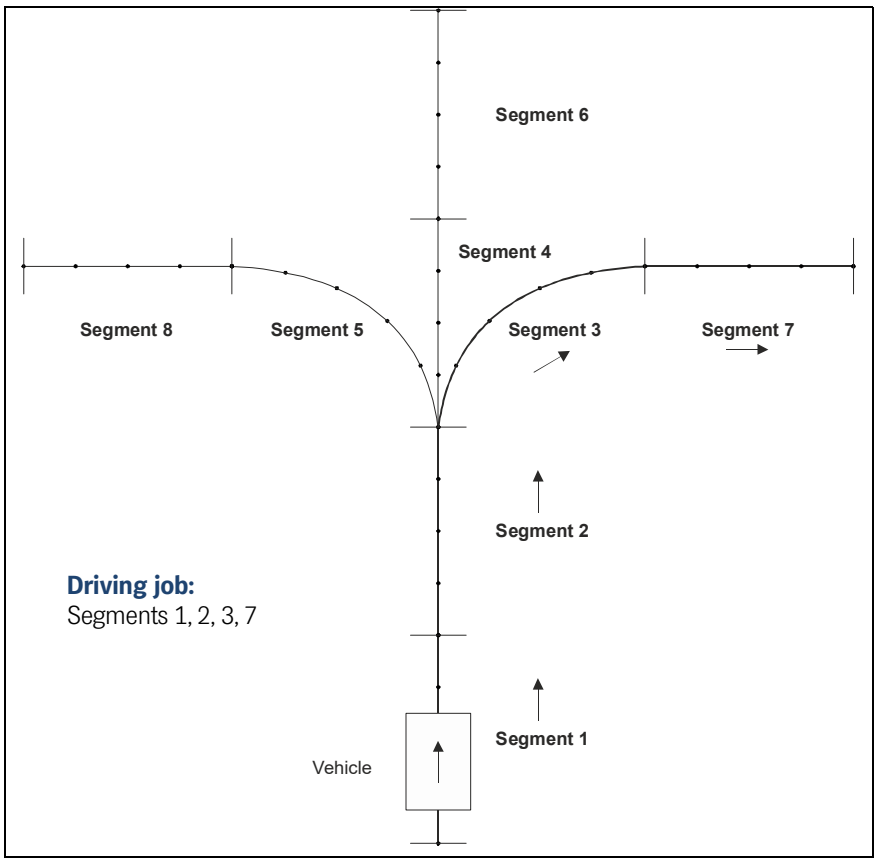
The navigation controller includes the track controller. The track controller calculates from the current position given by the sensor fusion (see section 2.3 on page 13) how to guide the vehicle to follow the intended track, which is defined by the different segments and their support points (s. section 2.5 on page 23). The navigation controller outputs:

- Target values

- Target steering angle
- Target speed
- Various additional parameters / information

- Instantaneous center of rotation, heading and speed

Figure 21 *Example course with a driving job consisting of a combination of segments*



The purpose of the navigation controller is to guide the vehicle on the intended track. This track is compiled from a segment sequence. The segments are stored in the navigation controller and can be addressed via segment numbers. The navigation controller obtains the particular segment sequence from the vehicle controller which in turn gets the information either from the guidance / control system (if several vehicles are operated) or executes its calculation independently (if a single vehicle is concerned).

The navigation controller also calculates the following parts of the track along several support points (it forms what are known as smooth regressions) and thus constructs the virtual track that the vehicle is to be driven on. The values position, accuracy, 16 free and 16 defined attributes are stored for each support point.

The vehicle can be initialized between the support points. The track controller uses the incoming position data to identify what segment it is on and which support point follows next. Using the current vehicle position and angle the relation to the segment is known. Then the steering angle and vehicle velocity can be calculated.

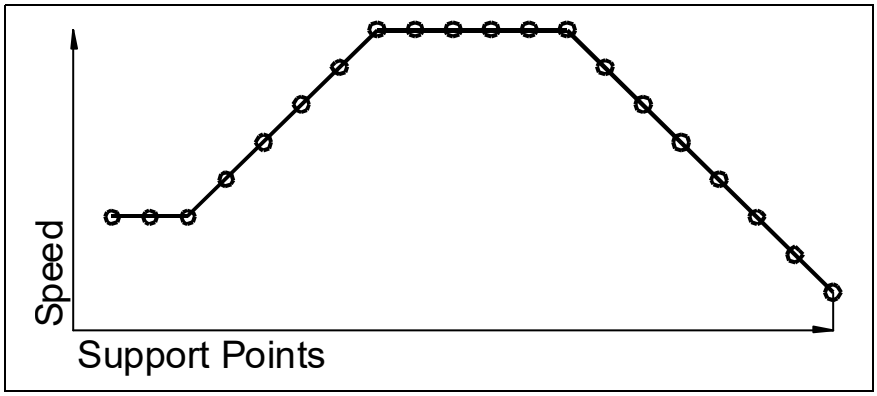
2.6.1 Speed Calculation

The speed is obtained from the information of the segment's support points. Here the velocity of the support point just passed and the upcoming support point is interpolated. Which of the two support point velocities ("speed endpoint" or "speed connection") is selected depends on whether the vehicle shall stop at the segment's end or not. If the direction of travel is reverted from forward to backward or vice versa, "speed endpoint" is selected. Also, if the following segment forms a sharp bend or terminates completely, "speed endpoint" is selected.

If an error occurs or the vehicle drives beyond the end point, the velocity is set to 0.

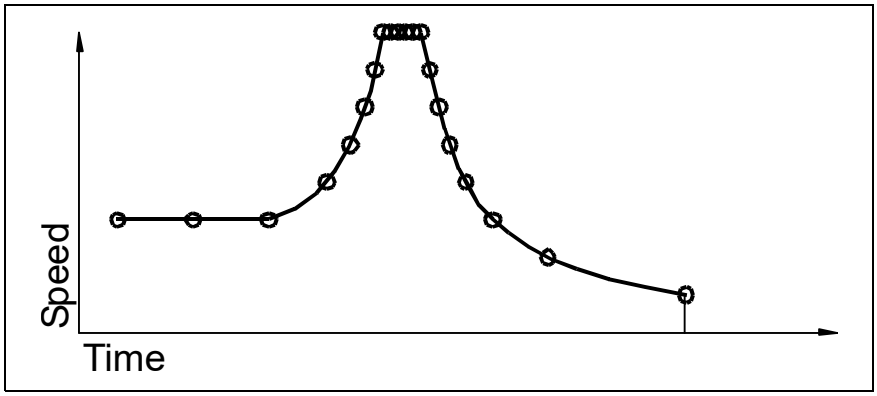
Generally the speed inside the segments is changed via linear ramps in CAD 6.

Figure 22 *Speed in Segments: Linear Ramp*



Because the support point intervals are constant this means high accelerations for high velocities and low accelerations for low velocities.

Figure 23 *Speed in Segments: Speed in relation to time*



Thus at higher speeds more support points are crossed than for lower speeds. The positive effect is that for positioning at the end of the segment the accuracy increases since the vehicle reaches the end point slowly and thus doesn‘t roll beyond it. Negative effects are the high accelerations for high velocities and the time that is needed for positioning.

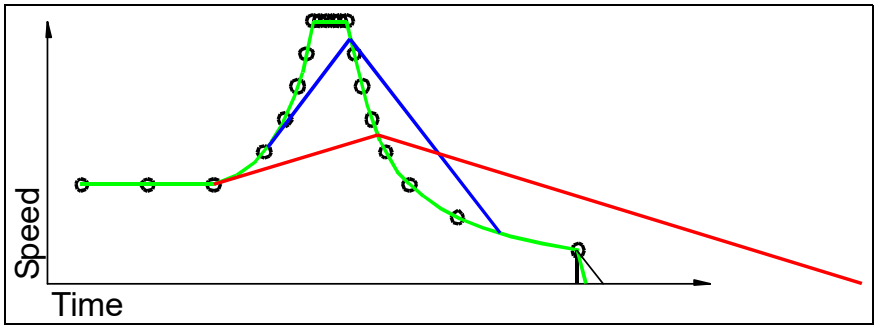
2.6.1.1 Ramps in the Navigation Controller

The ramps that can be set inside the navigation controller (see section 4.3.7 on page 76) work with constant accelerations.

2.6.1.2 Speed Ramp

If the *Speed Ramp* is high enough, the speed characteristics are the same as the segment except for the last point (green line). If the acceleration of the ramps in between the maximum acceleration of the support points and the minimal acceleration of the support points the blue line forms. If the acceleration of the ramp is too low the red line is produced.

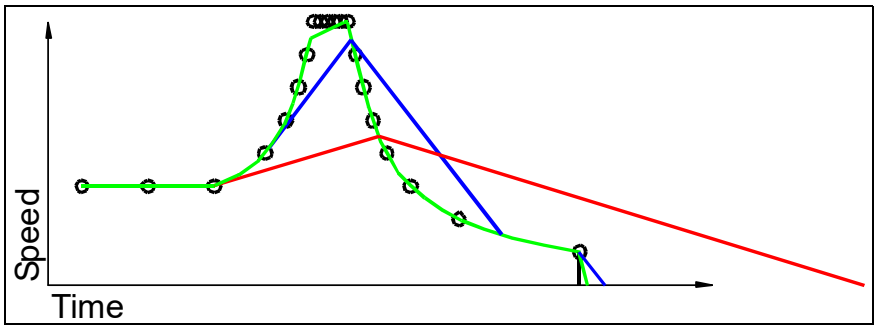
Figure 24 *Speed in segments: Impact of the ramps*



This diagram illustrates that with a too low acceleration of the ramp the vehicle drives a long distance beyond the segment end point since the speed is much too high when reaching the segment‘s end point and thus the zero line is reached later.

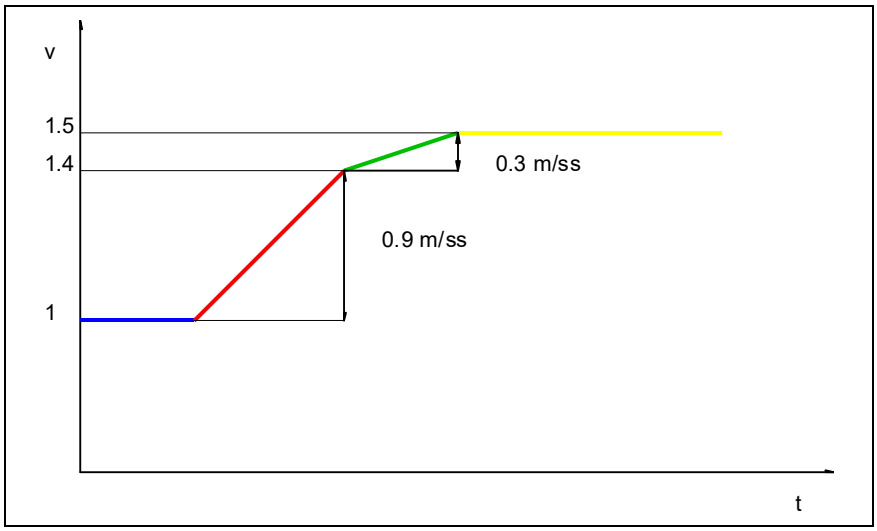
In order to limit overshooting of the speed the acceleration of the ramp is reduced by two thirds (*Speed Ramp*). This happens if less than 5 % of the maximum speed remain between the speed of the ramp and the target speed. For this the navigation controller distinguishes between forward and reverse (Vmax. Forward / Vmax. Reverse).

Figure 25 *Speed in segments: Ramps with reduced acceleration*



Example: The vehicle has a maximum speed of 2 m/s. 5 % thus are 0.1 m/s. The ramp is set to 0.9 m/ss. The vehicle is to accelerate from 1 m/s to 1.5 m/s. Up to 1.4 m/s (1.5 m/s - 0.1 m/s) it accelerates with 0.9 m/ss. From 1.4 m/s onwards it changes the acceleration to 0.3 m/ss. This behavior is intended to reduce overshooting while accelerating.

Figure 26 *Acceleration ramps*



2.6.1.3 Stop Ramp

The *Stop Ramp* is used if the target of the speed change is Zero. If e.g. an error occurs or the PLC revokes a clearance the *Stop Ramp* is used. The *Stop Ramp* is linear.

2.6.2 Adjustment of the Speed by the PLC

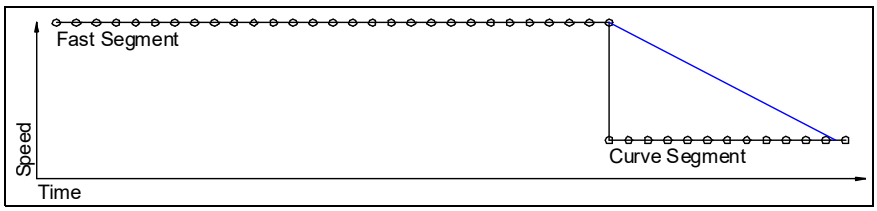
The speed can also be limited by the vehicle control. This is e.g. useful if an object is inside the warning field of the laser scanner. This limitation is transmitted as mm/s (see section 7.3.1 on page 144).

2.6.3 Automatic Adjustment of Segment Speeds

Not all speed ramps can be considered while planning segments.

Example: In the middle of a high speed track one segment with a sharp curve is to be driven. Before reaching the curve the speed has to be reduced to one fourth. One possible solution would be to make the segment with the curve so long that the deceleration can be achieved inside the segment. However sometimes the space is not sufficient. If the two segments are driven as a sequence the navigation controller combines the speeds. From this results a speed jump at the segment transition that is adjusted with the acceleration ramp (blue line).

Figure 27 *Speed ramp*

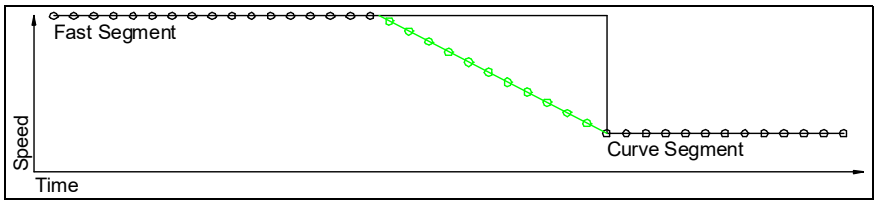


Thus the vehicle is way too fast when reaching the curve and can't steer quickly enough to follow the curve.

From firmware version 2.57 onwards the navigation controller corrects the sgement speeds. It monitors the points in the point buffer (Pos_Buffer) which consists of the next **40 points** of the subsequent segments.

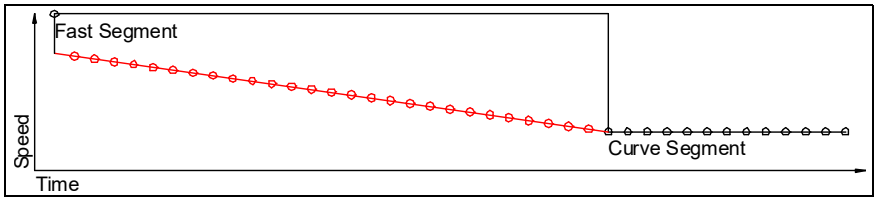
The calculation starts at the most distant point and checks whether the speed of the preceding point can be reached with the speed ramp. If that isn't the case the speed of the point preceding that point is adjusted. The speed is adjusted with an approximating, constant acceleration of the speed ramp. If the acceleration of the speed ramp is high enough, the result is the green line. In this case the curve can be driven.

Figure 28 *Speed correction before segment change*



If the acceleration of the speed ramp is not high enough the result is the red line. This again gives a speed jump that leads to problems when driving the curve.

Figure 29 *Wrong speed correction*



2.6.4 Steering Angle Calculation

The track guidance of the navigation controller is made up of two parts:

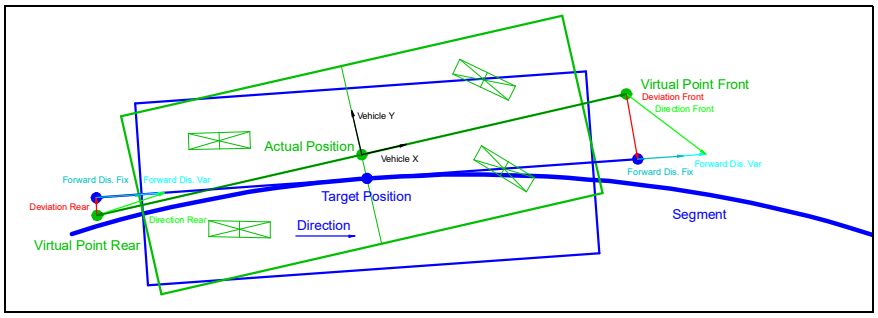
1. The feed-forward control calculates the steering angles that keep the vehicle on the segment, when there is no deviation to the driven segment. The steering angles result from the vehicle's geometry and the segment. They don't have to be parameterized and therefore will not be explained here.
2. The regulator to steer the vehicle back to the segment if a deviation occurs.

The combination of these two components provides the steering angle.

A distinction has to be made between omnidirectional vehicles and „normal“ vehicles, such as trucks and forklifts. Omnidirectional vehicles are able to steer all axles independently. These vehicles are able to drive around a curve within the possible steering angle without having to change their orientation. This behavior offers a major advantage for the control system: The vehicle doesn't have to move towards the direction of the segment to correct a deviation. It can simply drive lateral to the direction of travel.

2.6.5 Guidance of an omnidirectional Vehicle

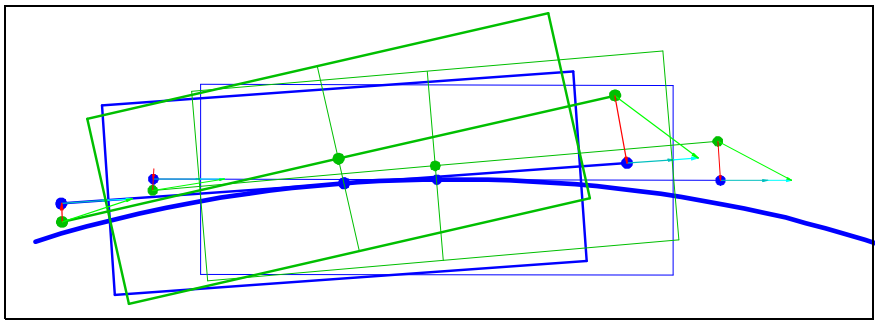
Figure 30 *Guidance of an omnidirectional vehicle*



To guide the vehicle it is necessary to determine the vehicle's target position first. At this position a tangent is applied to the segment and the two points "Virtual Point Front" and "Virtual Point Rear" are defined (in the previous control unit these points were indicated as "Länge vorne" und Länge Hinten"). These are the two points that are relevant for the vehicle control. Here the vectors "Forward Dis.Fix" and "Forward Dis Var" will be added in the segment's direction of travel. "ForwardDis Var" results from the multiplication of the corresponding parameter and the actual velocity in m/s. All steering angles of the vehicle are then calculated in such a way that the points "Virtual Point Front" and "Virtual Point Rear" will move towards the end points of these vectors ("Direction Front" and "Direction Rear").

While the vehicle continues to travel, the direction of travel of the two points "Virtual Point Front" and "Virtual Point Rear" changes in such a way that the vehicle approaches the target position.

Figure 31 *Guiding an omnidirectional vehicle: Control process*



The vehicles indicated by bolder lines display the initial position. The thinly drawn vehicles reflect the situation after having passed a short section. It is visible that the errors "Derivation Front" and "Derivation Rear" become smaller.

In principle: The shorter the vectors "Forward Dis. Fix" and "Forward Dis. Var" are, the larger the vehicle's steering angles will be. As "Forward dis.Var" is speed-dependent, "Forward Dis. Fix" determines the vehicle control at low speeds.

The positions of "Virtual Point Front" and "Virtual Point Rear" have an impact on the control system: If the distance to the zero-point of the vehicle is too short, the vehicle will quickly be guided back to the segment. However, this may have the result that points further away from the zero point might not return asymptotically to the segment. The points "Virtual Point Front" and "Virtual Point Rear" will always return asymptotically to the segment (if the vehicle doesn't swerve).

To ensure a damping of the vehicle's swaying movements the angle of "Direction Front" and "Direction Rear" can be limited. This can be done with the parameters "Approach Lim. Fix" and "Approach Lim Var". "Approach Lim Var" is speed-dependent as well. The limitation of the angles is calculated as follows:

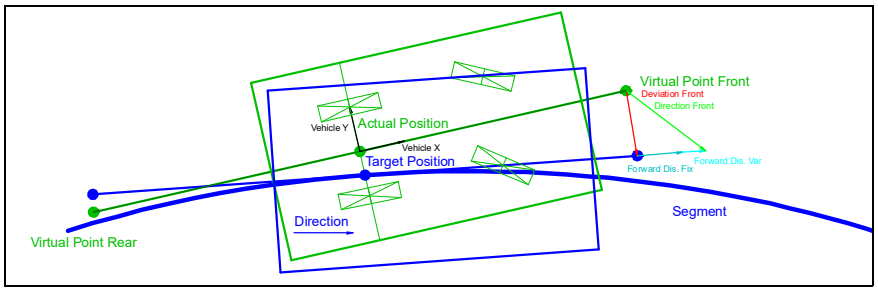
Figure 32 *Formula: Limitation of angles*

$$\text{Limit} = \left(\frac{1}{v\left[\frac{m}{s}\right] + 1}\right) \times \text{Approach Lim. Var} + \text{Approach Lim. Fix}$$

2.6.6 Guidance of a non-omnidirectional Vehicle

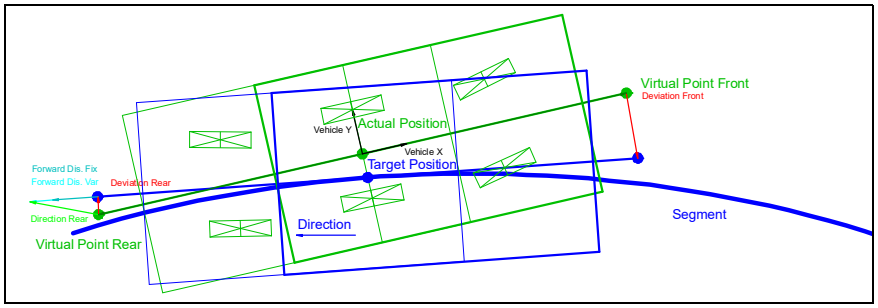
A non-omnidirectional vehicle has the fundamental disadvantage that it is unable to drive sideways to the segment. This is why the vehicle has to be steered towards the segment's direction at first to minimize deviations. Consequently additional time is required. As shown below it is even possible that the vehicle increases the deviation at its rear axle at first.

Figure 33 *Forward guidance of a non-omnidirectional vehicle*



At first the driving direction to which the steered wheels before the fixed axle are directed at (usually forward travel). Since a fixed axle cannot be steered sideways here the vehicle control only depends on the point "Virtual Point Front". The position of the rear axle follows the front in that it is dragged virtually. The vehicle control itself corresponds to the guidance of an omnidirectional vehicle. In this direction the vehicle control remains stable, as the fixed axle automatically follows the point "Virtual Point Front". When driving backwards the guidance would not be stable, as the non-steering axle would move to one side or the other. Thus the vehicle control to the opposite direction looks is as follows:

Figure 34 *Backwards guidance of a non-omnidirectional vehicle*



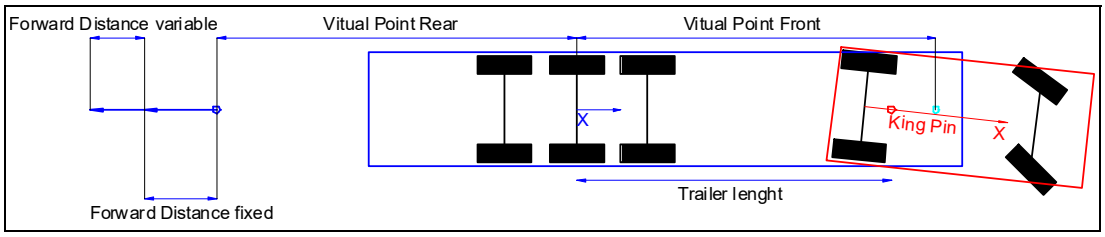
When the vehicle travels backwards, it is mirrored at the fixed axle. Figure 34 above shows the real vehicle plotted with thick lines and the mirror-image with thin lines. In this case the vehicle control is depending on the point "Virtual Point Rear". If this point is controlled the fixed axle follows and the control is stable again. The mirrored wheels always steer with opposite signs but with the same steering angles.

2.6.7 Reverse Driving with a Trailer

Currently the reverse driving with a trailer with a fixed axle is implemented in the navigation controller. A non-omnidirectional vehicle serves as the towing vehicle. In this case the trailer is steered via the angle between towing vehicle and trailer (kink angle). In order to change the kink angle the towing vehicle has to drive a bit. Thus the kink angle cannot be changed as immediately as when handling a steered wheel. Additionally the fact that the trailer tries to break away when reversing has to be taken into consideration, because that makes the trailer behave less stable. When driving forwards the trailer centers itself behind the towing vehicle.

The trailer is regarded as a vehicle of its own with its own coordinate system (the origin is the center of the fixed axle) that is connected to the towing vehicle with the king pin. The king pin itself is considered as the steered wheel. When driving forwards the control is similar to the control of the towing vehicle.

Figure 35 *Important values for the reverse driving with trailer*



When in automatic reverse driving:

- The trailer is kept on the segment if the CAN message from the trailer shows the status *Trailer present Angle OK*.
- Otherwise the towing vehicle is kept on the segment.

When reaching the end point of the drive the towing vehicle is always defining the navigation. Thus the segment should always end with a straight line which at least covers the last four support points. Preferably the straight line covers additional support points in order to be able to better compensate the error that arises at the curve‘s end.

The straight line is extended by the length of the trailer in any case.

The curve radii possible for reverse driving are much larger than the ones of the towing vehicle when driving forwards. For the most part this is due to the instable and slow situation when driving backwards. This also effects the transitions between curves and straight parts of the track. When planning reverse segments this should be taken into account by defining long clothoids and slow steering angle velocities. However those values largely depend on the specific vehicle and thus cannot be predefined in this manual. The settings for the trailer are available in the menu described in section 4.3.12 on page 85.

2.6.8 Measuring Section

In order to enhance the accuracy, especially during reverse driving (see above), it is possible to define a measuring section. When driving this section the offset between the towing vehicle and the trailer is measured (fKingPinAngleTruckRaw). This offset is necessary to achieve a zero angle between trailer and towing vehicle. During the measuring the towing vehicle drives on a straight section so that the trailer can straighten its position behind the towing vehicle.

When defining the measuring section the following points have to be observed:

- ✓ The measuring section has to be placed on a straight section.
- ✓ The start point of the measuring section is marked by setting the attribute 0x80000000.
- ✓ The end point of the measuring section is reached when the attribute 0x80000000 drops out.
- ✓ When starting the measuring the trailer has to stand straight behind the towing vehicle. Otherwise the measuring fails.
- The resolution of the incremental encoders is calculated but not yet automatically used.

It is advisable to repeat the measuring every time before performing a reverse docking.

2.6.9 Driving Modes

The normal operation of the vehicle consists of two different operation modes. The idle mode (see section 2.6.9.1) and the automatic mode (see section 2.6.9.3). The modus Parameter Test (see section 2.6.9.2) is only called up during commissioning. Remote Control, this is the modus for the remote control (see section 2.6.9.4). Vector steering, in this mode the vehicle drives to the target on a straight line (see section 2.6.9.5).

2.6.9.1 Idle Mode

This Mode allows to operate the vehicle manually or the vehicle control can initiate a segment search.

2.6.9.2 Parameter Test Mode

This mode can only be activated if the vehicle is standing still. In this mode all basic functions can be tested during commissioning. For this purpose the web browser can used to access a special menu where you can enter velocity and steering angle directly via the keyboard (see section 4.11 on page 94). Alternatively a terminal program can be used (see section 5.6 on page 105). Important characteristics including actual velocity and steering angle will be displayed.

2.6.9.3 Automatic Mode

NOTICE

Segments not transferred when starting automatic mode

If no segments have been transferred the control unit can‘t determine a target position and thus not regulate (operate properly).

- ▶ Transmit the segments before switching to automatic mode.
- ▶ The immediate start of the driving can be prevented by not setting the segment release.

In this mode the navigation controller guides the vehicle. If the vehicle shall be operated manually (by a driver) you have to exit this mode. To access or quit this mode the user sends a request to the controller via the interface of the vehicle control or via web browser. When requesting automatic mode, the following pre-conditions have to be met:

- ✓ the vehicle must be standing still
- ✓ the vehicle must be ready for automatic operation
  - – currently no vehicle errors
  - – the calculated position has to match the given segment
- ✓ it must be possible to drive the given segment

  When the segment release is then set, the vehicle starts moving.

2.6.9.4 Remote Control Mode

In this mode the vehicle can be remote-controlled via the navigation controller. The only pre-settings here are the steering angle and the speed. Then the navigation controller calculates the speeds and steering angles of the individual wheels.

The Modus Remote Control offers six different options to steer the vehicle (see the CAN Box from Table 62 on page 147 and Feldbus Bytes 42-46 from Table 84 on page 164):

1. Remote Mode = 1: Symmetric steering forward, Remote X determines the speed in mm/s in the vehicle's longitudinal direction, Remote Y the curve to be driven in 1/100°. Remote Z has no function.
2. Remote Mode = 2: Symmetric steering sideward, Remote X determines the speed in mm/s in the vehicle's lateral direction, Remote Y the curve to be driven in 1/100°. Remote Z has no function.
3. Remote Mode = 3: Dog tracking forward, Remote X determines the speed in mm/s in the vehicle's longitudinal direction, Remote Y the steering angle for all wheels in 1/100°. Remote Z has no function.
4. Remote Mode = 4: Dog tracking sideward, Remote X determines the velocity in the vehicle's lateral direction, Remote Y the steering angle for all wheels in 1/100°. Remote Z has no function.
5. Remote Mode = 5: Spot turn, Remote X determines the rotational speed of the vehicle. Remote Y has no function. Remote Z has no function.
6. Remote Mode = 6: Definition of a velocity pole (instantaneous center of rotation), Remote X determines the speed in mm/s, Remote Y the steering angle in 1/100°. Remote Z the curve radius, decoded as shown in section 12.3 on page 185 in the appendix.

2.6.9.5 Vector Steering Mode

In this mode the vehicle drives to the target position on a straight line. Additionally the heading at the target position and the driving speed are set.

Preconditions:

- ✓ Generally this mode is only available for omnidirectional vehicles.
- ✓ The target position has to be at least 2 cm away from the current position.
- ✓ In case the vehicle is supposed to turn on its way to the target make sure that the distance is sufficient for the turn, otherwise the steering angles can quickly become too big.

The vector steering mode is related to the automatic mode. For each transmitted target a segment is calculated that leads from the current position to the target position. Thus it is important to adhere to the following sequence:

- ▶ Switch to Idle mode
- ▶ Transmit the new target
- ▶ Do not set the segment release, start the vector mode
- ▶ Set the segment release

There are two distinct vector steering modes:

1. Absolute Mode
   In this mode the transmitted coordinates are interpreted as absolute coordinates respectively a heading. If the vehicle is to perform a spot turn at the target position wait until the target position is reached, then send the same target position with a different heading. Follow the same sequence as shown above.
2. Relative Mode
   In this mode the transmitted coordinates are interpreted as coordinates within the vehicle coordinate system. Internally those coordinates are converted to absolute coordinates. If the vehicle is to perform a spot turn at the current position, then the coordinates in X and Y direction have to be 0 and the desired change in heading has to be sent via the angle. Follow the same sequence as shown above.

2.7 Communication with the Vehicle Control (e.g. PLC)

The navigation controller communicates with the vehicle PLC via CAN Bus or Feldbus. The vehicle PLC adapts the navigation controller to the vehicle. This offers the advantage of a standard interface. The customer can directly affect the adaptation and is therefore able to make the necessary adjustments. vehicle PLC and navigation controller may mutually monitor their communication. This guarantees a higher level of security. The Vehicle PLC is responsible for controlling vehicle components such as motor, brake, speed and steering.

Four IO channels are available as well. Their configuration depends on the set vehicle option. For most vehicle options IO 1 - IO3 stand for the Posi Pulse inputs from the transponder antennas and IO4 for the emergency stop output.

3 Hardware

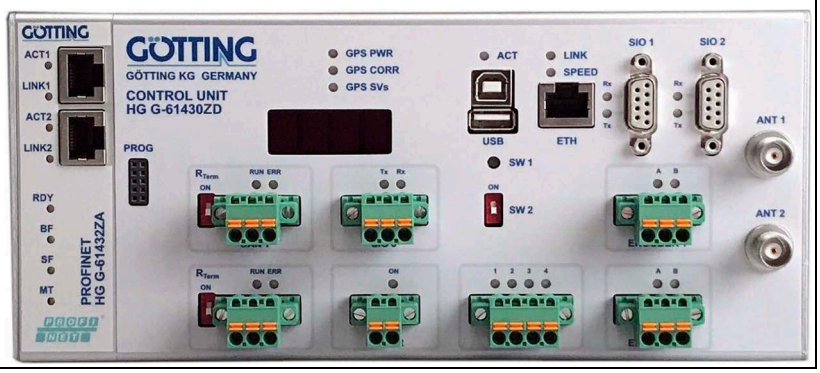
The device described on the following pages is the hardware component of the Control Unit, called HG G-61430ZD. Since the same hardware is used for the GPS system for RTG's the navigation controller as a whole has a type number based on its software, 73650. The number of the GPS system with the same hardware is HG G-57652.

The hardware is available in a basic configuration and in a version with a module that enables the connection of different bus types (s. section 3.6 on page 51).

Figure 36 *Photo of the Control Unit: Basic configuration and version including the Feldbus/Profinet extension module HG G-61432ZA and with option GPS*

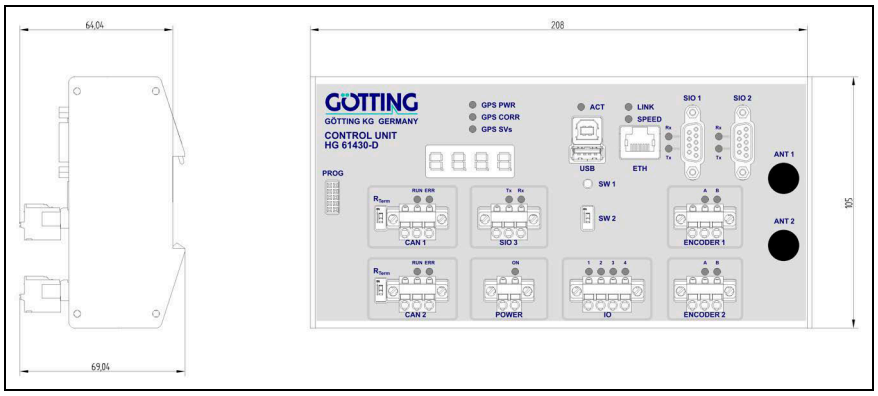
Basic configuration

With extension module HG G-61432ZA for Profinet (Feldbus) and with option GPS



3.1 Mounting

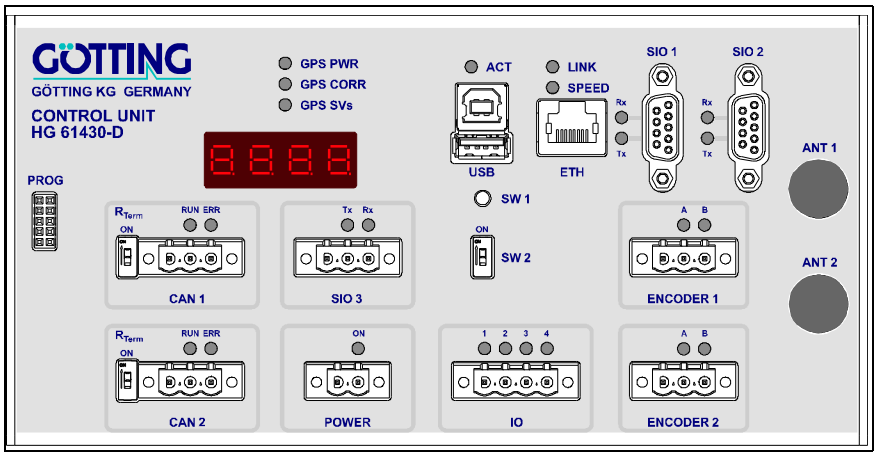
Figure 37 *Dimensions of the control unit Hardware HG G-61430ZD*



The device is designed to be mounted on a 35 mm top hat rail according to EN50022. The mounting place has to be protected against humidity. Often a control cabinet is available for other components of the vehicle control.

3.2 Front Panel

Figure 38 *LEDs and connectors*



3.3 Control Elements on Front Panel

Table 6 *Control elements of the control unit (part 1 of 2)*

Element	Position	Meaning
SW 1	Press button > 1 s	Stop data recording and eject the USB stick. As soon as the LED ACT stops blinking the stick may be safely detached.
	Press button > 10 s	Format USB stick **(Notice: erases all data on the stick without extra confirmation)**
SW 2	ON	Firmware Update via USB interface
	OFF	Normal operation of the control unit

Table 6 *Control elements of the control unit (part 2 of 2)*

Element	Position	Meaning
R_{Term} CAN 1	ON	120 Ohm terminating resistor for CAN 1 activated
	OFF	No internal terminating resistor for CAN 1
R_{Term} CAN 2	ON	120 Ohm terminating resistor for CAN 2 activated
	OFF	No internal terminating resistor for CAN 2

3.4 Display Elements on Front Panel

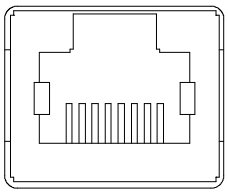
Table 7 *Display elements*

LED	Meaning when LED is lit/flashing
Display	7 segment display with 4 characters
POWER/ON	Power supply
ETH/LINK	Active data transmission via the ethernet interface
ETH/SPEED	– ON –> Ethernet transmission rate 100 Mbit/s – OFF –> Ethernet transmission rate 10 Mbit/s
USB/ACT	Data logging active
GPS PWR	Power Supply GPS receiver ok
GPS CORR	Reception of GPS correction data
GPS SVs	Reception of GNSS satellites
SIO 1/Rx	SIO 1 receiving data
SIO 1/Tx	SIO 1 transmitting data
SIO 2/Rx	SIO 2 receiving data
SIO 2/Tx	SIO 2 transmitting data
SIO 3/Tx	SIO 3 receiving data
SIO 3/Rx	SIO 3 transmitting data
CAN 1/RUN	CAN Bus 1 OK
CAN 1/ERR	CAN Bus 1 Error
CAN 2/RUN	CAN Bus 2 OK
CAN 2/ERR	CAN Bus 2 Error
ENCODER 1/A	Incremental encoder 1 / Channel A
ENCODER 1/B	Incremental encoder 1 / Channel B
ENCODER 2/A	Incremental encoder 2 / Channel A
ENCODER 2/B	Incremental encoder 2 / Channel B
IO/1	Input/Output 1 signal > programmed threshold
IO/2	Input/Output 2 signal > programmed threshold
IO/3	Input/Output 3 signal > programmed threshold
IO/4	Input/Output 4 signal > programmed threshold

3.5 Connectors

3.5.1 ETH

Figure 39 *Sketch of connector ETH*



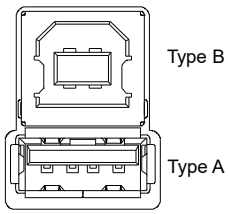
Function: Communication with higher-level control and/or PC

Interface: Ethernet

Plug type: RJ-45

3.5.2 USB

Figure 40 *Sketch USB connectors Type A and Type B*



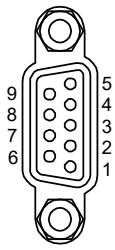
Function: Data logging on USB stick (Type A) or firmware update (Type B, see section 12.5 on page 188 in the appendix)

Interface: USB 1.1

Plug type: USB Type A and B (alternatively)

3.5.3 SIO 1 (GPS Receiver)

Figure 41 *Sketch of connector SIO 1*



Function: Communication with internal GPS receiver (optional)

Interface: RS 232 + Spannungsversorgung für externes Funkmodem

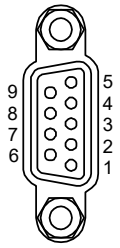
Plug type: Sub-D 9 pins (DE9) female

Table 8 *Pin assignment SIO 1*

Pin	Function	Direction
1		
2	TxD	O
3	RxD	I
4		
5	GND	O
6	+Ub (12-24 V)	O
7		
8		
9		

3.5.4 SIO 2

Figure 42 *Sketch of connector SIO 2*



Function: Configuration of Ethernet Interface, see section 12.4 on page 186 in the appendix

Interface: RS 232

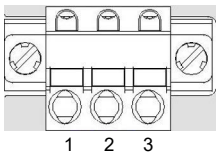
Plug type: Sub-D 9 pin (DE9) female

Table 9 *Pin assignment SIO 2*

Pin	Function	Direction
1		
2	TxD	O
3	RxD	I
4		
5	GND	
6		
7		
8		
9		

3.5.5 CAN 1

Figure 43 *Sketch of connector CAN 1*



Function: CAN Bus 1

Interface: CAN Spec. V2.0 part B

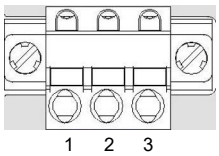
Plug type: Phoenix-Contact FKCT 2,5/3-STF-5,08

Table 10 *Pin assignment CAN 1*

Pin	Function	Direction
1	GND	
2	CAN High	I/O
3	CAN Low	I/O

3.5.6 CAN 2

Figure 44 *Sketch of connector CAN 2*



Function: CAN Bus 2

Interface: CAN Spez. V2.0 Teil B

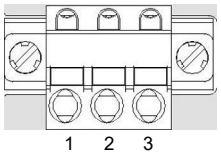
Plug type: Phoenix-Contact FKCT 2,5/3-STF-5,08

Table 11 *Pin assignment CAN 2*

Pin	Function	Direction
1	GND	
2	CAN High	I/O
3	CAN Low	I/O

3.5.7 SIO 3

Figure 45 *Sketch of connector SIO 3*



Function: Not used

Interface: RS 232

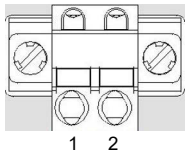
Plug type: Phoenix-Contact FKCT 2,5/3-STF-5,08

Table 12 *Pin assignment SIO 3*

Pin	Function	Direction
1	GND	
2	TxD	O
3	RxD	I

3.5.8 POWER

Figure 46 *Sketch of connector POWER*



Function: Energieversorgung 12 – 24 V

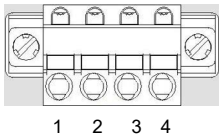
Plug type: Phoenix-Contact FKCT 2,5/2-STF-5,08

Table 13 *Pin assignment POWER*

Pin	Function	Direction
1	GND	
2	+Ub (12 – 24 V)	I

3.5.9 IO

Figure 47 *Sketch of connector IO*



Function: Connection of transponder antennas and emergency stop

Interface: Configurable, default three inputs (switching threshold 0 - 24 V) and one output 0 to +Ub

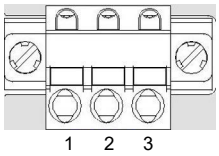
Plug type: Phoenix-Contact FKCT 2,5/4-STF-5,08

Table 14 *Pin assignment IO*

Pin	Direction	Function
1	Input	Transp.-Ant. 1
2	Input	Transp.-Ant. 2
3	Input	Transp.-Ant. 3
4	Output	Emergency Stop

3.5.10 ENCODER 1 / ENCODER 2

Figure 48 *Sketch of connectors ENCODER 1 / ENCODER 2*



Function: Connection of incremental encoders

Interface: Switching threshold 5 - 24 Volt (configurable)

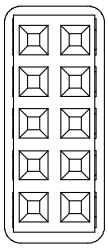
Plug type: Phoenix-Contact FKCT 2,5/3-STF-5,08

Table 15 *Pin assignment ENCODER 1 / ENCODER 2*

Pin	Function	Direction
1	GND	
2	Kanal A	I
3	Kanal B	I

3.5.11 PROG

Figure 49 *Sketch of connector PROG*



NOTICE

Damage to the device

This connector is for Götting internal use only. Other use of this connector may lead to damage of the Control Unit.

▶ Do not connect anything to this connector.

3.5.12 ANT1 / ANT2

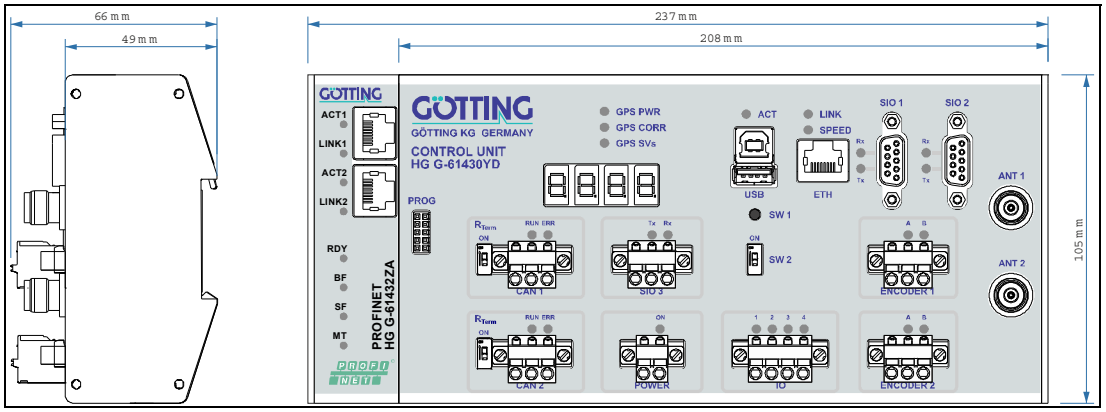
- Without option GPS: dummy plug
- With option GPS: 2 X TNC plugs for the connection of GPS antennas (s. Figure 36 on page 45)
  - ANT1: Position
  - ANT2: Heading

3.6 Extension module Feldbus

The control unit can be ordered with the following field bus options:

- HG G-61432ZA Profinet

Figure 50 *Dimensions control unit incl. expansion module HG G-61432ZA*



4 Configuration via Web Sites

An HTTP server runs in the navigation controller and it can be addressed from outside. You can use an internet browser on the PC to do so. A browser that is as up to date as possible should be used.

To configure the navigation controller, you can connect a standard PC/laptop to the device via the Ethernet interface ETH. Make sure that the devices have compatible network settings (for example PC IP: 10.10.10.1, navigation controller IP: 10.10.10.20, both network screens 255.255.255.0). Once the PC and navigation controller are connected via the network cable, start the browser on the PC and enter the IP of the navigation controller in the address line, in the example `10.10.10.20` (this is also the default address in the navigation controller). The main menu of the navigation controller opens.

The navigation controller has been tested with Google® Chrome®. On other browsers, the pages might look slightly different, but operation is the same.

Unfortunately, the characteristics of the browsers also differ. Whereas Chrome always displayed the pages, this was not the case with Internet Explorer, for example, (especially on the *Parameter Test* page when running in the test mode). If the navigation controller is restarted, the pages initially remain visible in the browser. However, the navigation controller might be in a very different mode. It should therefore always be borne in mind that the view in the browser does not unconditionally reflect the actual state in the navigation controller (a refresh can be forced by actuating one of the buttons in the left-hand bar, for example *Status* or *Configuration*).

Chrome also sometimes has the characteristic that the values shown on status pages 'freeze' for a few seconds before continuing. The navigation controller, however, runs continuously (which can be seen by the flashing dot on the LED display). Work on this issue is in progress.

WARNING

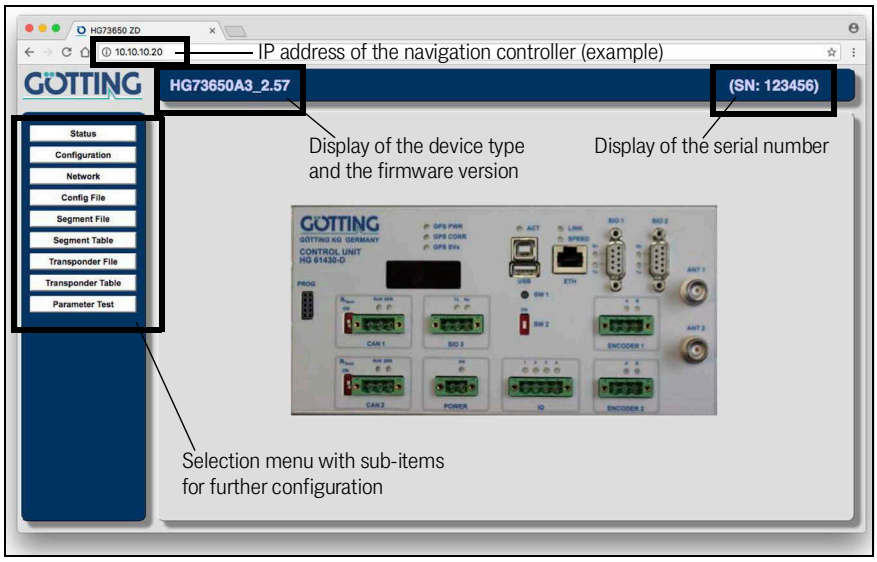
Risk of collisions with persons or objects

As described above while steering the vehicle in the *Test* mode (see 4.11 „Parameter Test Menu“ on page 94) it can happen that the connection to the browser freezes or is cut off. Then it is no longer possible to stop the vehicle using the browser. Thus use the mode *Test*

- with extreme caution,
- slowly and
- with safety devices such as emergency off within reach.

4.1 Main menu

Figure 51 *Screenshot: Main menu*



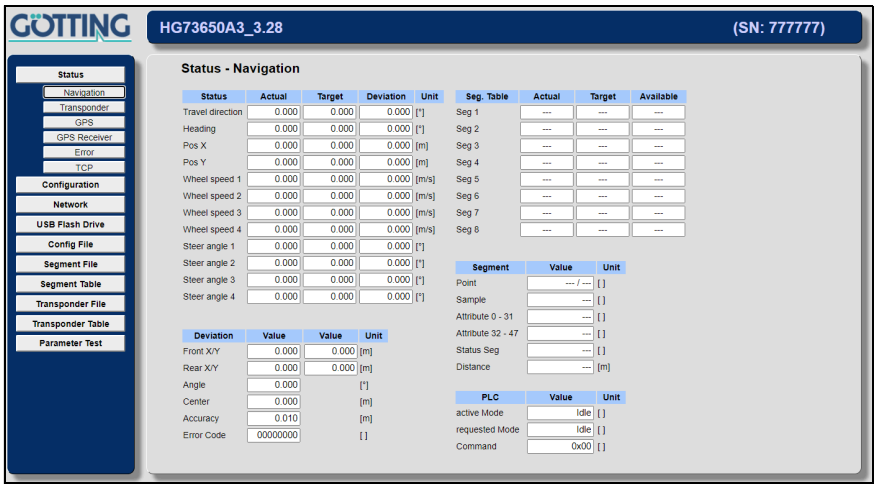
Several fundamental items of information regarding the device are displayed in the main menu. There is a selection menu on the left-hand side which you can use to call up the other configuration options:

- Status: Display of all parameters of the current vehicle status. No settings can be made in this submenu. More information in section 4.2 on page 54.
- Configuration: Submenu in which the most important parameters of the navigation controller can be changed. More information in section 4.3 on page 63.
- Network: Adaptation of the network settings of the navigation controller. More information in section 4.4 on page 87.
- Config File: Backup of the current settings in a file on the of the PC and/or restoration of settings from a file on the PC. More information in section 4.6 on page 89.
- Segment File: Saving the current segment table of the navigation controller in a segment file on the PC and/or loading a segment file from the PC, more information in section 4.7 on page 90.
- Segment Table: Display of the segment table stored in the navigation controller. More information in section 4.8 on page 91.
- Transponder File: Saving the transponder list active in the navigation controller in a transponder file on the PC and/or loading a transponder list from the PC. More information in section 4.9 on page 92.
- Transponder Table: Display of the transponders stored in the navigation controller. More information in section 4.10 on page 93.
- Parameter Test: Test mode for parameters and interfaces, for example during commissioning or troubleshooting. More information in the section entitled 'Transponder Table': Display of the transponders stored in the navigation controller. More information in section 4.11 on page 94.

4.2 Status Menu

4.2.1 Navigation Menu

Figure 52 *Screenshot: Status –> Navigation*



This menu shows the status of the navigation with the following 5 tables:

4.2.1.1 Status

This table shows the current vehicle status. The table has five columns:

1. Status: Shows which value is involved.
2. Actual: The current actual values.
3. Target: The current target values (only during automatic mode).
4. Deviation: Difference between actual and target value (only during automatic mode).
5. Unit: Unit of the displayed value

The following values are listed:

- Move: Direction of movement of the vehicle
- Heading: Alignment of the vehicle. In the case of normal vehicles, the heading is always towards 'Move' or rotated by 180^0 (if the vehicle is reversing). In the case of omnidirectional vehicles, the heading is independent of 'Move'.
- Pos X: X component of the position in the global co-ordinate system.
- Pos Y: Y component of the position in the global co-ordinate system.
- Speed 1: Speed of wheel 1
- Speed 2: Speed of wheel 2
- Speed 3: Speed of wheel 3
- Speed 4: Speed of wheel 4
- Angle 1: Steering angle of wheel 1
- Angle 2: Steering angle of wheel 2
- Angle 3: Steering angle of wheel 3
- Angle 4: Steering angle of wheel 4

4.2.1.2 Deviation

This table shows the current deviations and errors. The table has three columns:

1. Deviation: Shows which value is involved.
2. Value: Output of the value
3. Unit: Unit of the value

The following values are listed:

- Front X/Y: (Deviation Front) Error of the front regulated point (virtual Point Front) in X and Y directions of the vehicle co-ordinate system.
- Rear X/Y: (Deviation Rear) Error of the rear regulated point in X and Y directions of the vehicle co-ordinate system.
- Angle: Angle error of the vehicle
- Center: Lateral deviation in the vehicle zero point
- Accuracy: Accuracy of the vehicle position
- Error: Error code of the navigation controller

4.2.1.3 Seg. Table

This table shows the current segment lists. The table has four columns:

1. Seg. Table: Shows which segment (1 - 8) is involved.
2. Actual: Segment list currently used for driving.
3. Target: Last received valid segment list to be driven.
4. Available: List of segments that can be driven.

'Available' has a possible time delay. Example: If a segment end is driven over, the corresponding segment might still be present in the list even though it has just been completed. After a short time (1-2 seconds), it is automatically deleted from the list.

If the protocol is not complied with on transferring with the CAN bus, the new segment list does not appear and the old one remains.

4.2.1.4 Segment

This table shows information on the segment currently being driven *Actual Seg 1*. The display is only up-to-date during automatic mode.

The table has three columns:

1. Segment: Shows which value is involved.
2. Value: Output of the value
3. Unit: Unit of the value

The following values are listed:

- Point:
  Left: Point number at which the vehicle is currently located. /
  Right: Number of points in the segment.
- Sample: Position between the support points.
  - If the vehicle is located in front of the first point of the segment, the value is less than 1.
  - If the vehicle is located in the segment, the value is between 1 and 2.
  - If the vehicle is located between the last and penultimate point, the value is between 2 and 3.

  - If the vehicle is located behind the end point, the value is greater than 3.
  - Example: **2.31** –> The vehicle has covered 31 % of the path from the last to the penultimate point.

- Attribute: current attribute
- Status of the segment:
  - Up to 2nd point: Start
  - As of 2nd point: Start + 1
  - As of the 3rd point 'Middle' (becomes unnecessary in the case of segments with only 4 points)
  - As of the penultimate point: End - 1
  - As of the last point: End

- Distance: Distance driven on the segment. This is only calculated if a segment from a list of segments has been covered in automatic mode.

4.2.1.5 PLC

This table shows the data transferred from and to the vehicle control system. The table has three columns:

1. PLC: Shows which value is involved.
2. Value: Output of the value
3. Unit: Unit of the value

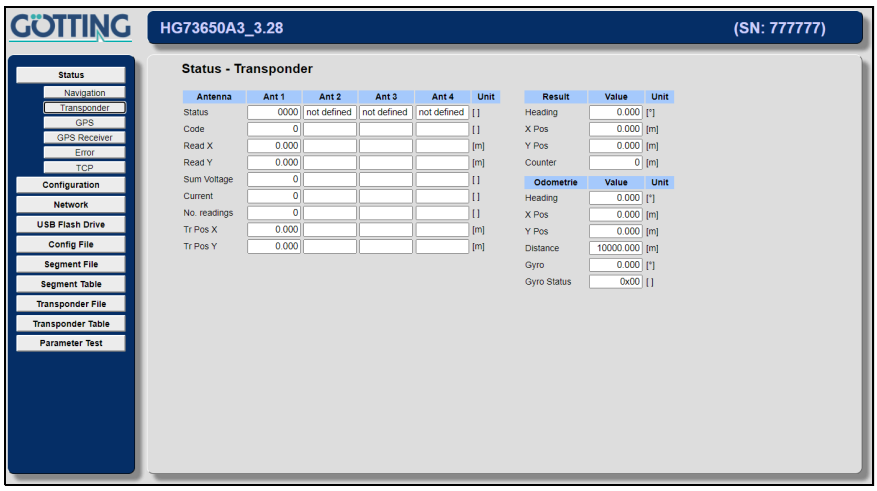
The following values are output:

- Mode: Mode in which the navigation controller is currently operating. Three modes can be displayed:
  - Idle: The vehicle is not steered by the navigation controller
  - Test: The vehicle is steered via the *Parameter Test* menu
  - Auto: The vehicle is in automatic mode
  - Vector Abs: Vector steering with absolute position
  - Vector Rel: Vector steering with relative position
  - Remote: The vehicle is operated in remote control mode

- Status: The vehicle status transferred by the vehicle to the vehicle control system, see 7.2.1 on page 130, 'Byte 1'.
- Command: The command transferred by the vehicle control system to the vehicle, see 7.3.1 on page 144, 'Byte 1'.

4.2.2 Transponder Menu

Figure 53 *Screenshot: Status –> Transponder*



Sensor fusion with transponders is only executed if it has been enabled in the parameters. Otherwise, this page is only displayed and no values are updated.

4.2.2.1 Antenna

This table shows the data of the antennas. The table has three columns:

1. Antenna: Shows which value is involved.
2. Value: Output of the value
3. Unit: Unit of the value

The following values are displayed:

- Status: Status of the antenna (hexadecimal)
  Here are only the most important bits (for more details, refer to the documentation of the transponder antennas that are deployed):
  - 0x0200: Transponder in the field
  - 0x0400: Transponder is decoded
  - 0x0800: Prefix bit (transponder is in the rear half of the antenna)
  - 0x1000: Posipuls
- Code: The code read from the transponder.
- Reading X: X position of the transponder in the vehicle co-ordinate system read by the antenna (converted by the navigation controller).
- Reading Y: Y position of the transponder in the antenna co-ordinate system read by the antenna (converted by the navigation controller).
- Sum Voltage: Total voltage of the transponder antenna. Guide values:
  - Should not exceed 20 if there is no transponder under the antenna.
  - Should not rise to more than 400 if there is a transponder under the antenna.
- Current: Current of the antenna (not so important, see antenna documentation)
- Reading: Correct reading of the antenna (is limited at 255 per transponder)

- Tr Pos X: X position from the transponder list that is linked to the transponder code. If the transponder was not found in the list, the value is zero.
- Tr Pos Y: Y position from the transponder list that is linked to the transponder code. If the transponder was not found in the list, the value is zero.

4.2.2.2 Result

This table shows the position calculated from the transponder. The table has three columns:

1. Result: Shows which value is involved.
2. Value: Output of the value
3. Unit: Unit of the value

The following values are displayed:

- Heading: Calculated alignment of the vehicle in the global co-ordinate system.
- X Pos: Calculated X position of the vehicle in the global co-ordinate system.
- Y Pos: Calculated Y position of the vehicle in the global co-ordinate system.
- Counter: Counts the position calculations.

4.2.2.3 Odometry

This table shows the odometry of the transponder fusion. The table has three columns:

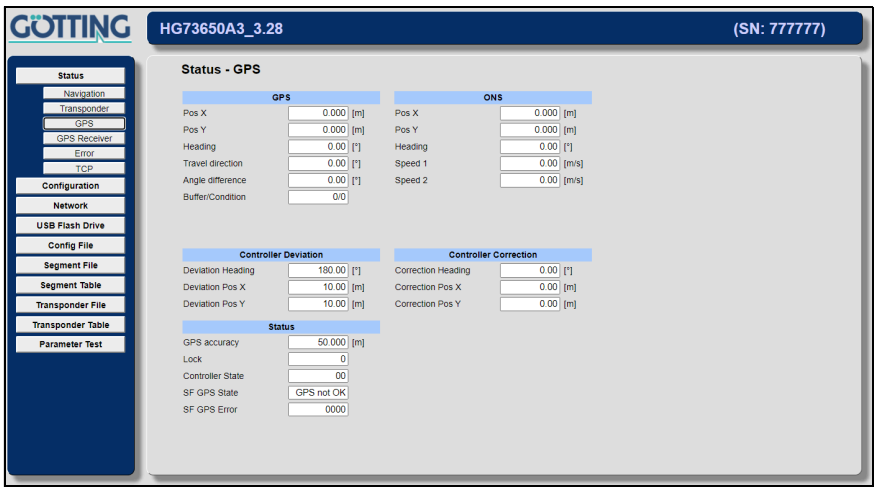
1. Odometry: Shows which value is involved.
2. Value: Output of the value
3. Unit: Unit of the value

The following values are displayed:

- Heading: Alignment of the vehicle in the global co-ordinate system.
- X Pos: X position of the vehicle in the global co-ordinate system.
- Y Pos: Y position of the vehicle in the global co-ordinate system.
- Distance: Distance driven since the last position calculation.

4.2.3 GPS Menu

Figure 54 *Screenshot: Status –> GPS*



This menu only has a function if GPS hardware is installed.

4.2.3.1 GPS

The table has three columns:

1. Shows which value is involved.
2. Output of the value
3. Unit of the value

The following values are displayed:

- Pos X
  X co-ordinate in the base co-ordinate system determined by the GPS
- Pos Y
  Y co-ordinate in the base co-ordinate system determined by the GPS
- Heading
  Angle in the base co-ordinate system measured by the GPS
- Travel direction
  Actual direction of movement
- Angle difference
  Averaged difference between "Heading" and "Travel direction"
- Buffer/Condition
  Status on calculation of the actual direction of movement
  The position buffer fills up with 4 positions before a direction of movement can be calculated. If there is a switch from forwards to reverse, the buffer is reset.

4.2.3.2 ONS

The table has three columns:

1. Shows which value is involved.
2. Output of the value
3. Unit of the value

The following values are displayed:

- Pos X
  X co-ordinate of the odometry in the base co-ordinate system
- Pos Y
  Y co-ordinate of the odometry in the base co-ordinate system
- Heading
  Angle of the odometry in the base co-ordinate system
- Speed 1
  Speed of wheel 1
- Speed 2
  Speed of wheel 2

4.2.3.3 Controller Deviation

The table has three columns:

1. Shows which value is involved.
2. Output of the value
3. Unit of the value

The following values are displayed:

- Deviation Heading
  Deviation between GPS and ONS regarding the Heading (vehicle orientation)

- Deviation Pos X
  Deviation between GPS and ONS regarding the X co-ordinate
- Deviation Pos Y
  Deviation between GPS and ONS regarding the Y co-ordinate

4.2.3.4 Controller Correction

The table has three columns:

1. Shows which value is involved.
2. Output of the value
3. Unit of the value

The following values are displayed:

- Correction Heading
  Correction value for the angle
- Correction Pos X
  Correction value for the X co-ordinate
- Correction Pos Y
  Correction value for the Y co-ordinate

4.2.3.5 Status

The table has three columns:

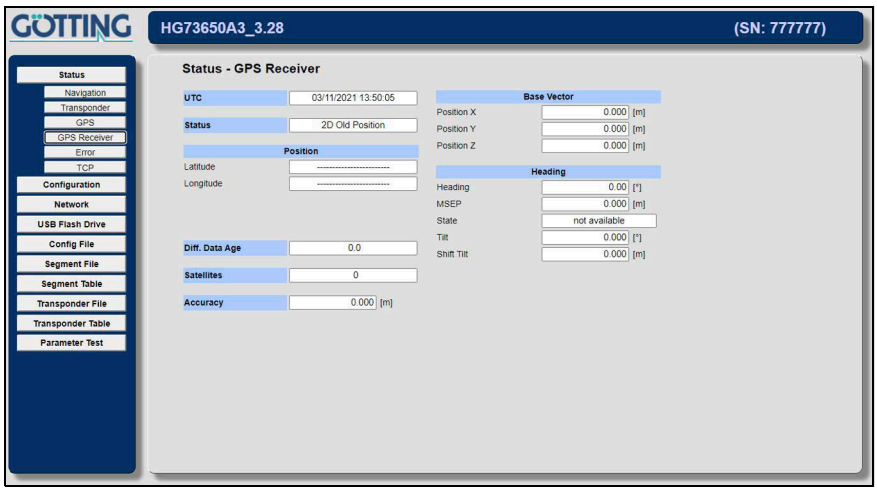
1. Shows which value is involved.
2. Output of the value
3. Unit of the value

The following values are displayed:

- GPS Accuracy
  Accuracy of the GPS receiver
- Lock
  Quality of the sensor fusion solution: 0=poor, 50(max.)=good
- Controller State
  State of the controller
  The GPS controller is started if the status is 0.
  The possible reasons that the controller is not running are binary coded:
  - 0x01 Speed of the vehicle too slow
  - 0x02 Log is high and control deviation of the angle controller too great
  - 0x04 Log is high and control deviation of the lateral controller too great
  - 0x08 Log is high and control deviation of the longitudinal controller too great
- SF GPS State
  State of the sensor fusion
- SF GPS Error
  Error in the GPS system. These are only adopted into the error list of the navigation controller of the vehicle is traveling using GPS.

4.2.4 GPS Receiver Menu

Figure 55 *Screenshot: Status –> GPS Receiver*



4.2.4.1 UTC

Date and time (co-ordinated world time)

4.2.4.2 Status

State of the navigation solution

4.2.4.3 Position

The table has two columns:

1. 1st column: Shows which value is involved.
2. 2nd column: Output of the value

The following values are displayed:

- Latitude
  Geographical width (reference system WGS 84)
- Longitude
  Geographical length (reference system WGS 84)

4.2.4.4 Diff. Data Age

Age of the correction data

4.2.4.5 Satellites

Number of satellites used

4.2.4.6 Accuracy

Accuracy of the calculated position

4.2.4.7 Base Vector

The table has three columns:

1. 1. column: Shows which value is involved.
2. 2nd column: Output of the value
3. 3. column: Unit of the value

The following values are displayed:

- Position X
  X co-ordinate in the base co-ordinate system

- Position Y
  Y co-ordinate in the base co-ordinate system
- Position Z
  Z co-ordinate in the base co-ordinate system

4.2.4.8 Heading

The table has three columns:

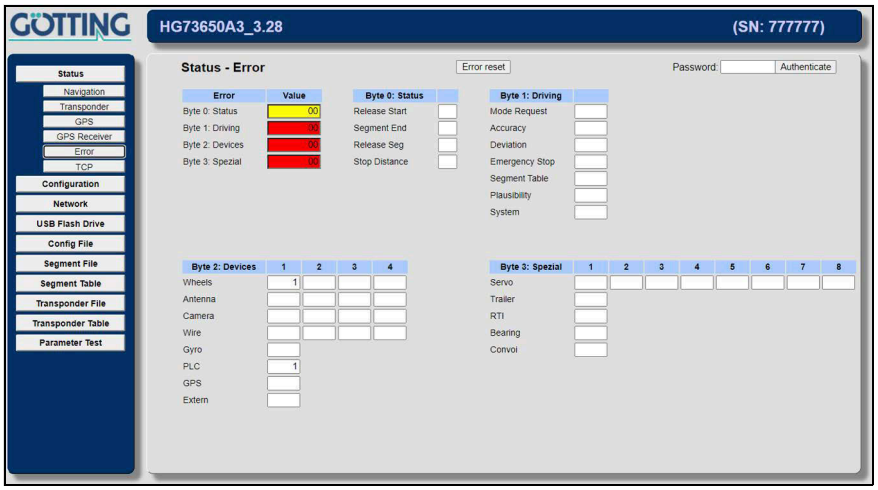
1. Shows which value is involved.
2. Output of the value
3. Unit of the value

The following values are displayed:

- Heading
  Measured angle
- MSEP
  Distance between the two GPS antennas
- State
  State of the angle calculation
- Tilt
  Inclination
- Shift Tilt
  Shift of the position due to the inclination

4.2.5 Error Menu

Figure 56 *Screenshot: Status –> Error with Tooltip shown for Byte 3 > Trailer*



Error messages are shown on this page. The *Error* table shows an overview of the current pending error messages. The other tables each show a line of the *Error* table in detail.

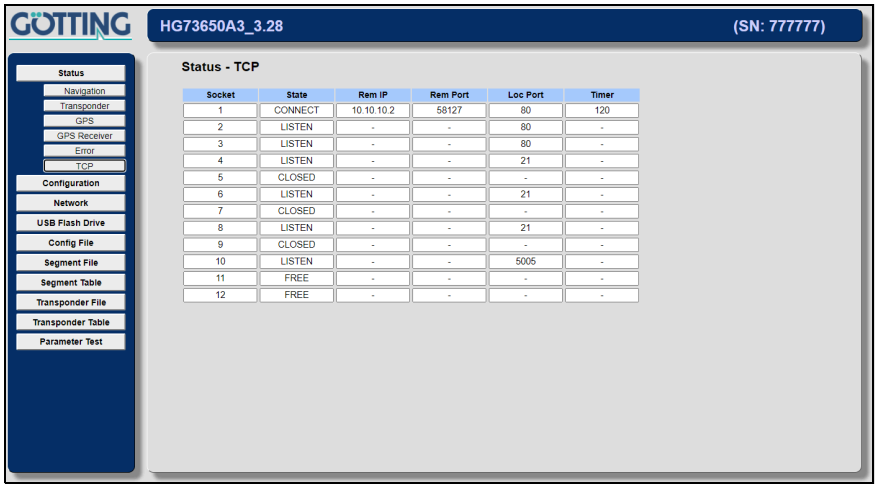
The values in the tables 'Byte 0' to 'Byte 3' remain visible until the corresponding bit is pending in the 'Error' table and the values have not been picked up by the vehicle control system (see for example 7.2.4 on page 133, similar procedure for Feldbus). For the exact meaning, refer to the error codes in Table 46 on page 135 and Table 47 on page 136. Values that appear in Table 46 and not in Table 47 consist of only one bit instead of 16 bits like the others; this means they do not have to be explained in Table 47.

Example: Wheel 2 reports an error. The third line under *Byte 2: Devices* in the 'Error' table contains a `1`. The *Byte 2: Devices* table in the line *Wheels* and column 2 contains `0x0040`, which means that wheel 2 has a steering angle error. A more detailed example can be found in section 7.2.4 on page 133.

For the error messages tooltips are available. Move the mouse cursor over one of the error fields and halt it there. Then a tooltip appears with the error definitions, see screenshot above.

4.2.6 TCP Menu

Figure 57 *Screenshot: Status –> TCP*



Socket	State	Rem IP	Rem Port	Loc Port	Timer
1	CONNECT	10.10.10.2	58127	80	120
2	LISTEN	-	-	80	-
3	LISTEN	-	-	80	-
4	LISTEN	-	-	21	-
5	CLOSED	-	-	-	-
6	LISTEN	-	-	21	-
7	CLOSED	-	-	-	-
8	LISTEN	-	-	21	-
9	CLOSED	-	-	-	-
10	LISTEN	-	-	5005	-
11	FREE	-	-	-	-
12	FREE	-	-	-	-

The table has six columns:

1. Socket: Serial number of the connection
2. State: State of the connection (FREE, CLOSED, LISTEN, CONNECT)
3. Rem IP: IP address of the remote device (PC)
4. Rem Port: Port number of the remote device (PC)
5. Loc Port: Local (HG 61430) port number
6. Timer: Duration until timeout and breaking the connection (in seconds)

4.3 Configuration Menu

WARNING

Unexpected behavior of the vehicle

Changing the parameters can mean that the navigation controller no longer functions as expected and the track guidance of the vehicle becomes defective.

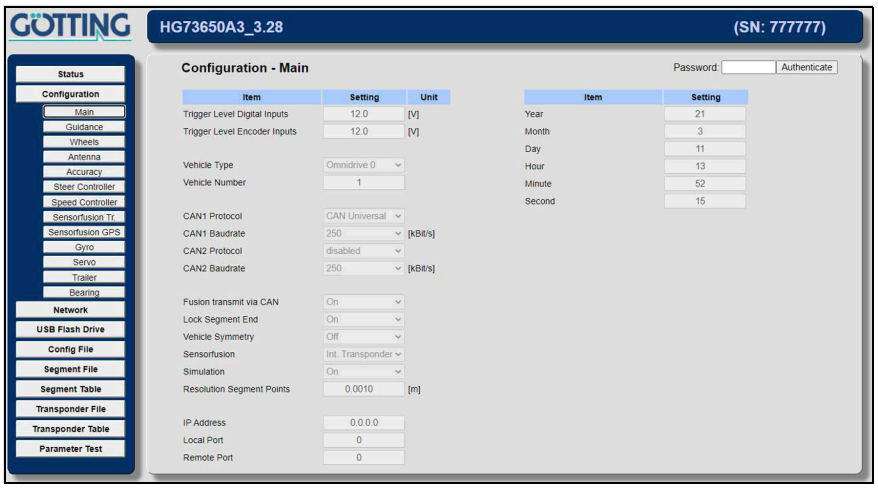
- ▶ Test new parameters exhaustively.
- ▶ Save functioning configurations in order to be able to restore them if necessary (see section 4.6 on page 89).

The navigation controller is parameterized on these pages. On all pages, the current parameters can be viewed, even without password input. To change the values, the password `314159` must be entered beforehand and confirmed with the *Authenticate* button. The navigation controller must also be in the *Idle* status.

If both requirements are met, the two buttons *OK* and *Cancel* appear. Subsequently, parameters can be changed and adopted with the *OK* button. If the changed values are not to be adopted, the *Cancel* button aborts the operation and restores the original values. To ensure that the parameters are adopted, the navigation controller should be restarted after changes.

4.3.1 Configuration –> Main

Figure 58 *Screenshot: Configuration –> Main*



Basic settings of the navigation controller. The table has three columns and is divided into two parts:

1. Item: Shows which value is involved.
2. Setting: Input of the value
3. Unit: Unit of the value

The following values can be changed:

- Trigger Level Digital Inputs: As of this voltage, analogue signals are detected at inputs 1 to 4 as logical 1.
- Trigger Level Encoder Inputs: As of this voltage, signals are detected at the encoder inputs 1 to 2 as logical 1.
- Vehicle Type: For special vehicles, special configurations can be selected if required. As default, *Omnidrive 0* should always be selected here.
- Vehicle Number: Number of the vehicle
- CAN1 Protocol: At the moment, only the *CAN Universal* protocol is active.
- CAN1 Baudrate: Baud rate of the CAN bus 1. Normally, 250 or 500 kBit/s is used.
- CAN2 Protocol: Not yet used
- CAN2 Baudrate: Baud rate of the CAN bus 2. Normally, 250 or 500 kBit/s is used.
- Fusion transmit via CAN: Specifies whether the position calculated by the internal sensor fusion is sent via CAN bus.

If an external sensor fusion is used, sending the position must be disabled!

- Log Seg End: On some vehicles, the brakes take effect relatively slowly. On segment ends on sloped levels, this can mean that the vehicle rolls back and then is no longer located at the segment end. In this case, the navigation controller nor-

mally outputs a speed once again. Consequently, the vehicle moves forward a number of times and rolls back again. If this parameter is set, after reaching the segment end once, the navigation controller always outputs that the vehicle is at the segment end and ignores the rolling back.

- Sensor fusion: selection of the sensor fusion:
  - Int. Transponder: The transponder antenna(s) are calculated to a position together with an odometry.
  - Int. Trans.+GPS: The transponder antenna(s) are calculated to a position together with a built-in GPS and an odometry.
- External Fusion: The position is sent by an external sensor fusion to the navigation controller.

- Simulation (see sections 6.6 on page 120 and 6.7 on page 121): The simulation can be used to test the communication with the vehicle control system and the segments even before commissioning of the vehicle. When enabled, the navigation controller simulates the travelling vehicle. The internal sensor fusions are disabled in this case.
- Resolution Segment Points: resolution of the segment file. **It is important here that the same setting is selected as was used in Cad 6 when creating the segments.** As a general principle, a fine resolution should be selected, as rounding errors then do not have such a strong impact.
- IP Address: address of the device to which a transmission via UDP is to be initiated
- Local Port: port number of the Control Unit
- Remote Port: port to send to

If the internal GPS module is fitted, the following specified dates and times are set automatically.

- Year: Specified year for the log file.
- Month: Specified month for the log file.
- Day: Specified day for the log file.
- Hour: Specified hour for the log file.
- Minute: Specified minute for the log file.
- Second: Specified second for the log file.

4.3.2 Configuration –> Guidance

Figure 59 *Screenshot: Configuration –> Guidance*

The CAN bus identifiers for communication with the vehicle control system are set in this menu. For the content of the messages, refer to the CAN bus description in chapter 7 on page 128. The table has three columns:

1. Item: Shows which value is involved.
2. Setting: Input of the value
3. Source: Source/target for a transmission

The following values can be changed:

- Receive Items - CAN ID Segment: Identifier for transferring the message *Segment* from the vehicle control system to the navigation controller.
- Receive Items - CAN ID Control: Identifier for transferring the control commands from the vehicle control system to the navigation controller.
- Receive Items - CAN ID Remote: Data source for the remote mode (see 2.6.9.4 on page 42)
- Receive Items - CAN ID Vector: Data source for the vector mode (see 2.6.9.5 on page 43)

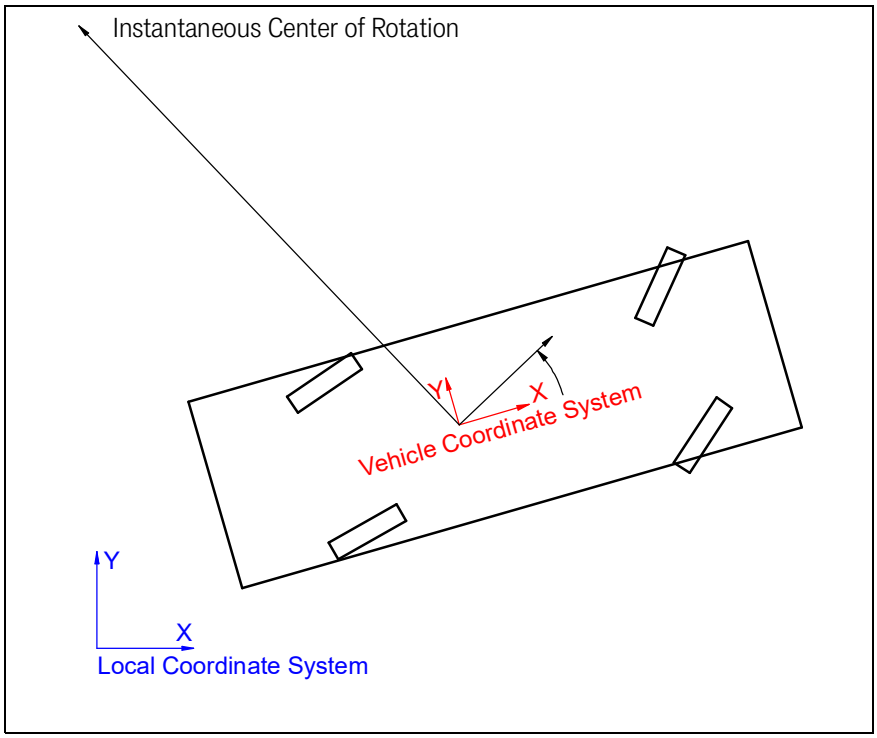
Vector: When using the CAN bus for the transmission this function is restricted compared to using Anybus or Ethernet. This is due to the fact that the CAN bus messages are limited to 8 bytes, see section 7.3.9 on page 153.

- Transmit Items - CAN ID Segment: Identifier for transferring the message *Segment* from the navigation controller to the vehicle control system.
- Transmit Items - CAN ID Segment Search: Identifier for transferring the message *Segment Search* from the navigation controller to the vehicle control system.
- Transmit Items - CAN ID Status: Identifier for transferring the navigation controller state to the vehicle control system.
- Transmit Items - CAN ID Error Message: Identifier for transferring the navigation controller errors to the vehicle control system.
- Transmit Items - CAN ID Steering: Steering of the vehicle using an instantaneous center of rotation. For this not a single wheel (speed and angle) is transmitted. Instead a point is defined around which the whole vehicle rotates and how fast it should do this.

It's possible to choose the CAN bus (CAN 1, CAN2, CAN1 + CAN2) delivering the data. The output of the velocity pole can be set to X/Y coordinates or pole coordinates (recommended). The content of the CAN box is shown in sections 7.2.13 on page 143 and 7.2.14 on page 144.

Steering: This is especially advantageous for vehicles with many wheels. In those cases the vehicle controller calculates the steering angles and velocities.

Figure 60 *Control via instantaneous center of rotation*



The target direction is calculated in relation to the local vehicle coordinate system. If the distance to the pole is positive the pole is left to the target direction. The target speed is output in target direction.

4.3.3 Wheels

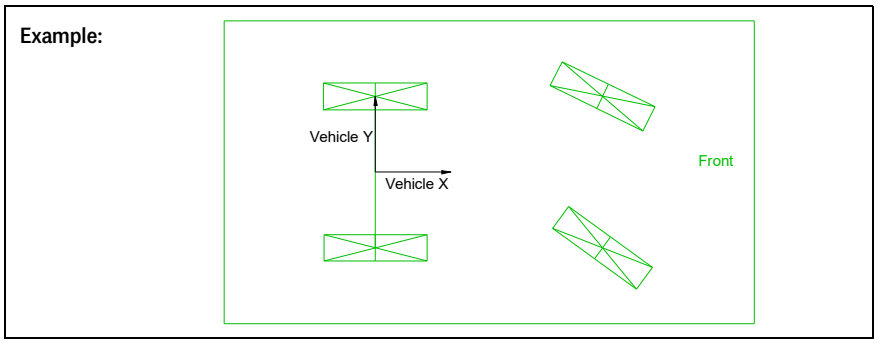
The parameters for the geometry of the vehicle are set in this menu. Before you set the first values, you have to consider the following fundamental settings:

4.3.3.1 What type of vehicle is involved?

- If the vehicle has an axle that cannot be steered independently, it is *not an omnidirectional vehicle*.
- Vehicles with two axles that can only be steered symmetrically are *not omnidirectional vehicles,* as there is a point between the two axles at which a rigid axle could be deployed.
- If the vehicle has axles that can only be steered independently, it is *an omnidirectional vehicle*.

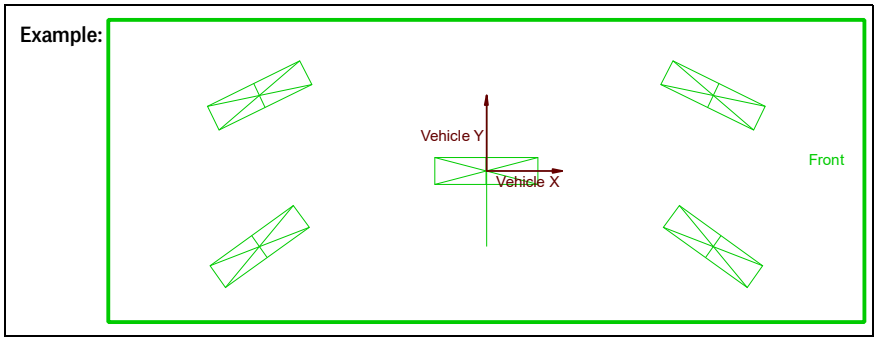
4.3.3.2 The non-omnidirectional vehicle

Figure 61 *Example: Non-omnidirectional vehicle*



In the case of these vehicles, **the vehicle zero point must be on the axle that cannot be steered**. The wheels that cannot be steered must be of the type *Fix. Angle.*

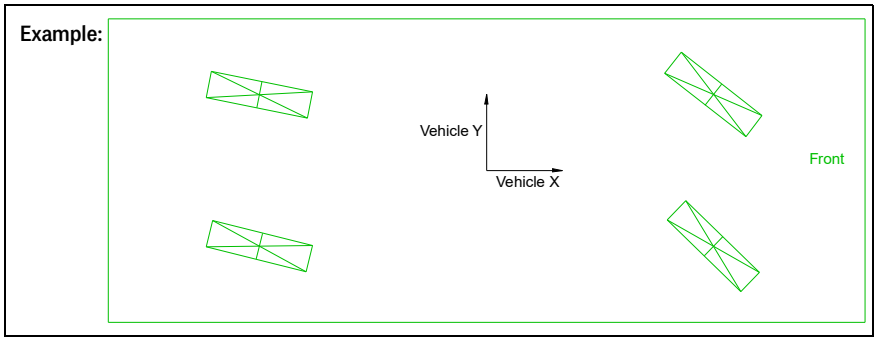
Figure 62 *Example: Symmetrically steerable axles (non-omnidirectional vehicle)*



This vehicle is not omnidirectional either, as a rigid axle could be drawn in the middle. On these vehicle, instead of the rear wheels, the middle wheel, which in reality is not present, must be set in the parameters (wheel of the type *Fix. Angle* so that the navigation controller applies the corresponding controller). **The vehicle zero point must be located on the virtual rigid axle.**

4.3.3.3 The omnidirectional vehicle

Figure 63 *Example: Omnidirectional vehicle*



On these vehicles, the vehicle zero point can be selected without restriction. If an axle only has a very small steering angle, it is advisable to set the vehicle zero point near to this axle, as otherwise only very large steering radii can be driven.

4.3.3.4 Which wheels should be used for the odometry?

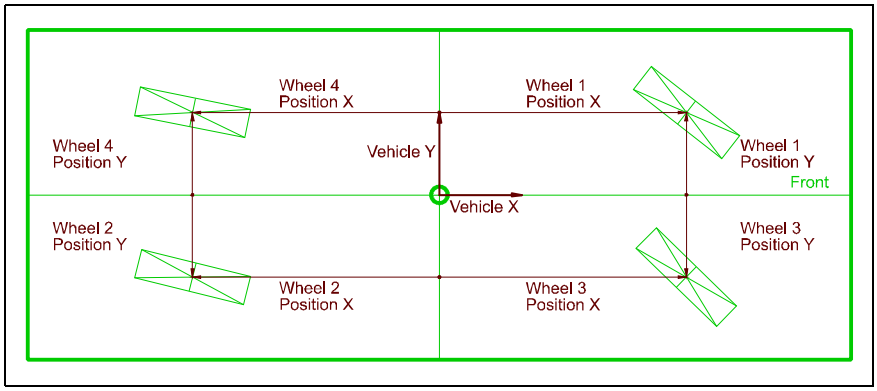
As a general principle, wheels 1 and 2 are used to calculate the odometry. The odometry is all the better the greater the distance between the wheels. A requirement is that the appropriate sensor system has been fitted at the wheels. It is also

possible to use an average steering angle if the average speed is also available. What is decisive is that the speed and steering angle values always match the point for which they are specified.

4.3.3.5 How are the positions specified on the vehicle?

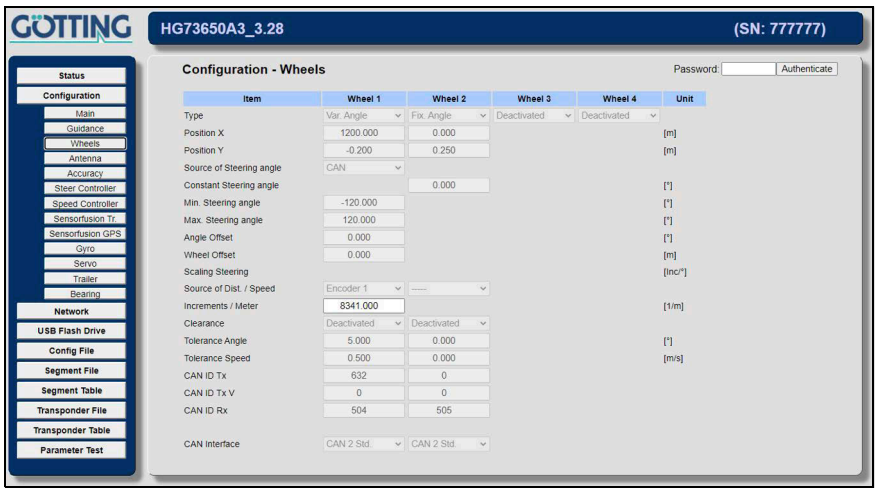
The positions on the vehicle are always specified in the vehicle co-ordinate system in metres or degrees. The angles in X direction are 0 and become more positive with rotation to the left.

Figure 64 *Specification of the position data to be determined for a vehicle*



4.3.3.6 Configuration –> Wheels

Figure 65 *Screenshot: Configuration –> Wheels*



Setting the vehicle geometry. The table has six columns:

1. Item: Shows which value is involved.
2. Wheel 1 to 4: Input of the values
3. Unit: Unit of the value

The following values can be changed:

- Type: The type of wheel can be specified here. Three possibilities are available:

1. Deactivated (wheel is not used)
2. Fix. Angle (wheel cannot be steered)
3. Var. Angle (steered wheel)

- Position X: X position of the corresponding wheel (see Figure 64 on page 69).
- Position Y: Y position of the corresponding wheel (see Figure 64 on page 69).

- Source of Angle: Interface from which the steering angle of the corresponding wheel is read. The following can be selected:

NOTICE

Faulty position calculation

If the settings for Wheel 1 and Wheel 2 are wrong, the control unit can assume wrong positions and thus transmit wrong steering information to the vehicle. If the internal sensor fusion is used and the wheel is of the type *Var. Angle*.

▶ Never choose ‚----------‘ for Wheel 1 and Wheel 2.

  - CAN (see Table 63 on page 148)
  - Feldbus (Profinet see 8.2 on page 164)
  - Ethernet (UDP see 8.2 on page 164)
  - Contelec 1, absolute angle sensor made by Contelec, address 416 (0x1A0), node number 20, always bus 2
  - Contelec 1 Inv., for the event that the sensor is on its head, i.e. is inverted
  - Contelec 2, absolute angle sensor made by Contelec, address 418 (0x1A2), node number 22, always bus 2
  - Contelec 2 Inv., for the event that the sensor is on its head, i.e. is inverted
  - Servo if the steering angle is to be read from the steering servo
  - Servo Inv., inverted value if the sensor rotates the other way around
  - Encoder (angle of the encoder transmitted via CAN bus)
  - Encoder Inv. (inverted encoder angle)
  - ME (customer-specific interface)
  - ---------- (No actual steering angle available)

- Constant Angle: If the corresponding wheel is of the type *Fix. Angle*, the angle of the wheel can be entered here. This should normally be 0.
- Min. Steering Angle: Steering angle with which the left-hand steering limit stop is reached.
- Max. Steering Angle: Steering angle with which the right-hand steering limit stop is reached.
- Angle Offset: Steering angle offset that is added to the read angle.
- Wheel Offset:
- Source of Speed: Interface from which the speed or distance of the corresponding wheel is read. The following can be selected:

NOTICE

Faulty position calculation

If the settings for Wheel 1 and Wheel 2 are wrong, the control unit can assume wrong positions and thus transmit wrong steering information to the vehicle. The odometry is calculated using wheel 1 and wheel 2. If the internal sensor fusion is used:

- For most omnidirectional vehicles both wheel 1 and wheel 2 should deliver their speed.
- Exception: Omnidirectional vehicles with insufficient steering angles, where the velocity pole is not close to or within the vehicle, wheel 1 or wheel 2 have to deliver a speed.
- For non-omnidirectional vehicles wheel 1 or wheel 2 have to deliver a speed.
- If only one speed is available, the extensions of the axles of wheel 1 and 2 must never point to the other wheel in each case.
- It is advantageous if wheel 1 and wheel 2 deliver speeds.

  - Inc 1: Incremental encoder 1 at the Encoder 1 terminal.
  - Inc 2: Incremental encoder 2 at the Encoder 2 terminal.
  - Dist. CAN: See CAN bus description *Message Wheel Rx* in Table 63 on page 148, whereby the speed is interpreted as an increment counter.
  - Dist. Profibus: (not yet available)
  - Dist. Ethernet: (not yet available)
  - Speed CAN: See CAN bus description *Message Wheel Rx* in Table 63 on page 148.
  - Speed Profibus (not yet available)
  - Speed Ethernet (not yet available)
  - ME (customer-specific interface)
  - -------- (no actual speed is available)

- Inc / Meter: Number of increments per metre. Important if increments are processed. If a speed is transferred, this parameter is not used.
- Clearance: (not yet available)
- Tolerance Angle: Tolerance of monitoring the steering angle of the corresponding wheel
- Tolerance Speed: Tolerance of monitoring the speed of the corresponding wheel
- CAN Tx: CAN identifier of the messages of the corresponding wheel sent by the navigation controller (see CAN bus description 'Message Wheel Tx' in Table 48 on page 139). These are the target values of the corresponding wheel. In the case of 0, the message is not sent.
- CAN Rx: CAN identifier of the messages of the corresponding wheel received by the navigation controller (see CAN bus description 'Message Wheel Rx' in Table 63 on page 148). These are the actual values of the corresponding wheel.
- CAN Tx Virtual: CAN identifier of the messages of the corresponding wheel sent by the navigation controller (see CAN bus description 'Message Wheel Tx Virtual' in Table 50 on page 140). These are theoretical values that could be measured at the wheel.
  Virtual wheels are practical if, for example, in the case of a 3-wheel vehicle the

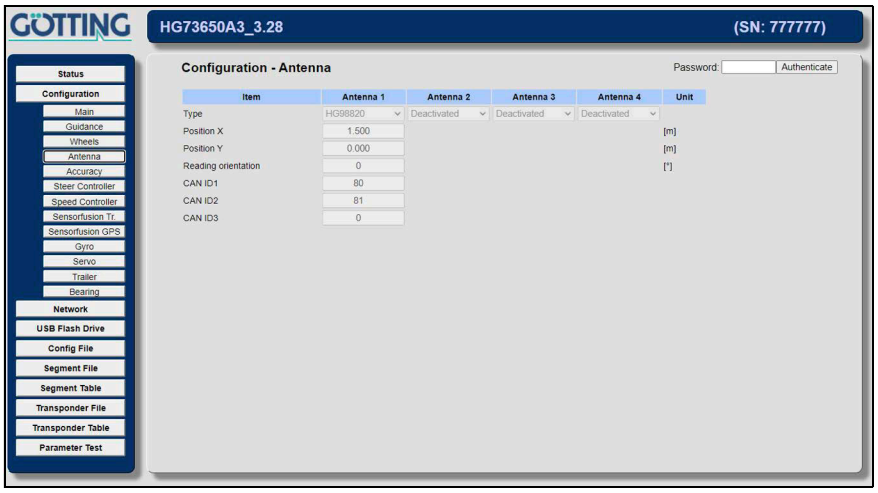
incremental encoders are attached to the wheels of the rigid axle. If the rear wheel is then driven, this message can be used as the actual speed even though no encoder is fitted on the axle. The speed is measured on the basis of the other wheels and converted to the position of this wheel. In the case of 0, the message is not sent.

- CAN Interface: Allows to switch the CAN bus (CAN1 / CAN2) for each wheel and whether the protocol is standard or extended.

4.3.4 Configuration –> Antenna

The parameters for the antennas of the vehicle are set in this menu. Fundamental considerations regarding the number and location of the antenna(s) can be found in section 2.3.4.1 on page 15.

Figure 66 *Screenshot: Configuration –> Antenna*



Setting the antennas. The table has six columns:

1. Item: Shows which value is involved.
2. Ant 1 to 4: Input of the values (the 4th antenna is a placeholder in preparation of future applications)
3. Unit: Unit of the value

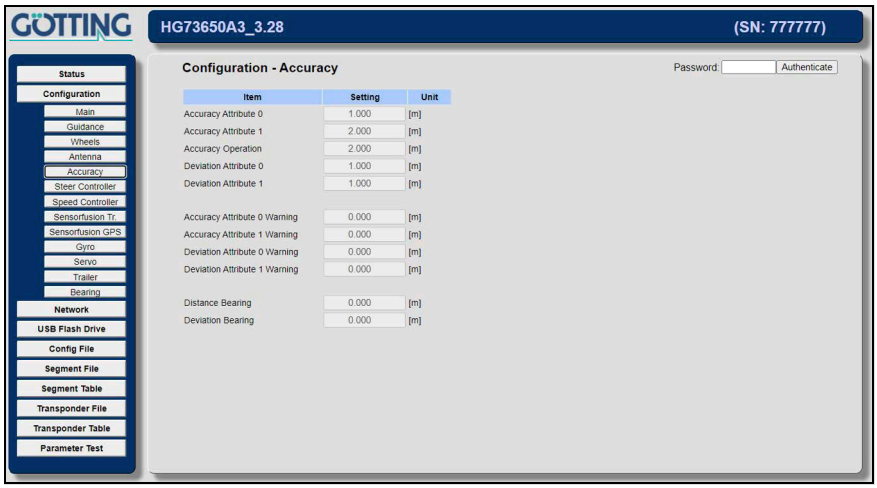
The following values can be changed:

- Type: Selection of the antenna type:
  - HG G-98810
  - HG G-98820
  - HG G-98850
  - HG G-98830, 2-dimensional, can be chosen for antenna 1 and antenna 3. If antenna 1 is set to this antenna 2 is automatically interpreted as being part of antenna 1.
- Position X: X position of the corresponding antenna (see Figure 4 on page 16)
- Position Y: Y position of the corresponding antenna (see Figure 4 on page 16)
- Reading Orientation: Installation position of the antenna. The manual for the antennas contains the corresponding co-ordinate system in X and Y directions. If the antenna is mounted turned away from the vehicle, the position must be specified accordingly. Positive values mean a left-hand rotation of the antenna. Example: If the antenna HG 98820 is mounted with the connectors to the right, 90^0 is to be entered here.

- CAN ID1: ID of the PDO 1 of the antenna
- CAN ID2: ID of the PDO 2 of the antenna

4.3.5 Configuration –> Accuracy

Figure 67 *Screenshot: Configuration –> Accuracy*



It can be set here up to which position accuracy the vehicle is to travel. This does not mean the accuracy with which the vehicle arrives at a certain position, rather the estimated accuracy of position determination. If, for example, the internal sensor fusion with transponders is used, the position becomes less precise after each metre. This is described in section 2.3 on page 13 and Table 72 on page 153. If a GPS is used, the GPS issues an accuracy estimate for every position.

The deviation between target and actual position of the vehicle at the front and rear point of the control (Virtual Point Front / Rear, see Figure 68 below) is measured in X and Y directions of the vehicle coordinate system (Deviation Front / Rear). It is also measured in the centre of the vehicle in the lateral direction.

The table has three columns:

1. Item: Shows which value is involved.
2. Setting: Input of the values
3. Unit: Unit of the value

The following values can be changed:

- Accuracy Attribute 0: Accuracy up to which the vehicle travels if the Accuracy Attribute 1 (Table 89 on page 184 `Attribute_Accuracy_Switchover`) is not set.
- Accuracy Attribute 1: Accuracy up to which the vehicle travels if the attribute 'Accuracy' is set.
- Accuracy Operation: Accuracy up to which there is a switch from Idle into Automatic mode.
- Deviation Attribute 0: Accuracy up to the vehicle travels if the attribute 'Deviation' (Table 89 on page 184 `Attribute_Deviation_Switchover`) is not set.
- Deviation Attribute 1: Accuracy up to the vehicle travels if the attribute 'Deviation' is set.

4.3.6 Configuration –> Steer Controller

The control of the vehicle takes place at the front and rear point of control (Virtual Point Front / Rear) (see 2.6.5 on page 38).

Figure 68 *Control of an omnidirectional vehicle*

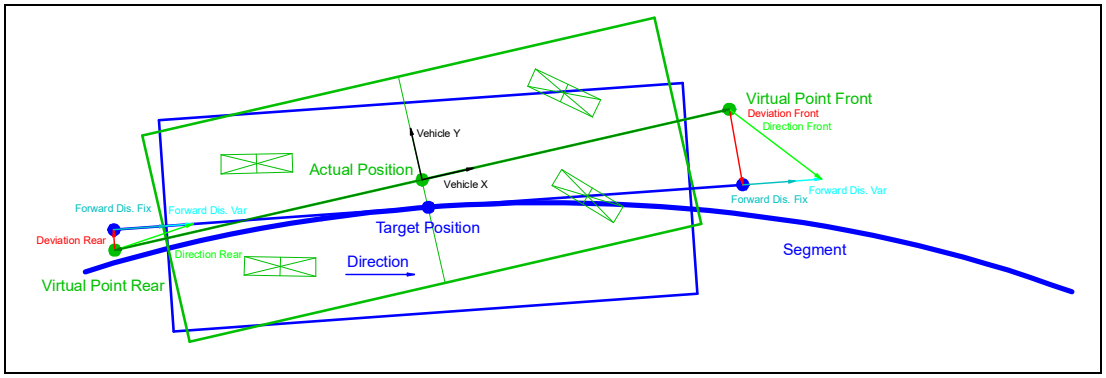


Figure 69 *Screenshot: Configuration –> Steer Controller*

Two tables, each with three columns:

1. Item: Shows which value is involved.
2. Setting: Input of the values
3. Unit: Unit of the value

The following values can be changed:

- Forward Distance fixed: This distance determines how strongly the vehicle turns the wheels at a standstill in order to return to the track.
- Forward Distance variable: This is multiplied by the speed in metres/second and added to 'Forward Dis. Fix'. This means that with rising speed the effect of the controller becomes increasingly less in order to avoid vibrations.
  Example: When parking a car, the driver aims for a point close to the front of the car. When driving on the motorway, the driver aims for a point 100 m in front of the car.
- Approach Limit fixed/Approach Limit variable: To prevent the angle between the target and actual orientation becoming too obtuse on returning to the segment, this can be limited. These two parameter together limit this angle.

Figure 70 *Formula: Limitation of angles*

$$Limit = \left(\frac{1}{v\left[\frac{m}{s}\right] + 1} \right) \times \text{Approach Lim. Var} + \text{Approach Lim. Fix}$$

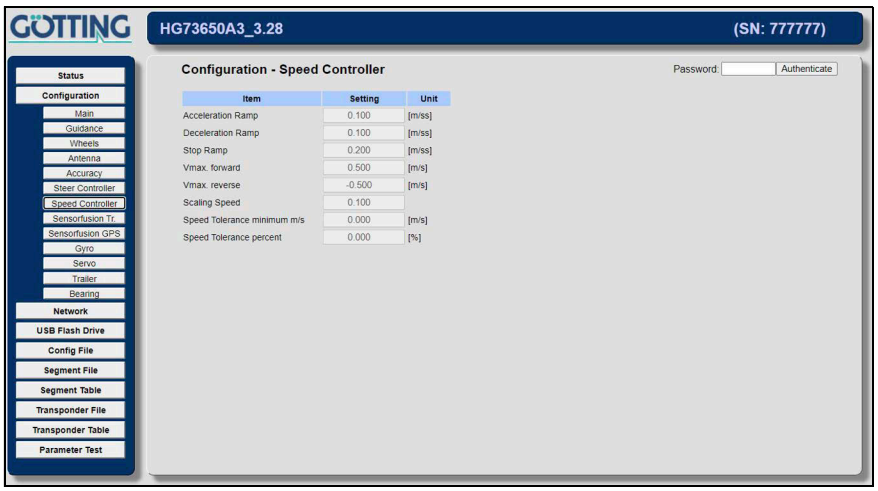
- Regulation Angle Max: This angle limits the steering angle during the remote control mode and input in the 'Parameter Test' menu.
- Regulation Angle Ramp: This ramp limits the steering angle during the remote control mode and input in the 'Parameter Test' menu.
- Speed Spot Turn: Speed of the fastest wheel during a spot turn.
- Virtual Point Front: Point at which the control for omnidirectional vehicles always take place and for non-omnidirectional vehicles take place when driving forwards (see section 2.6.5 on page 38). The deviations limited in the Accuracy menu are also determined at this point (Deviation Attribute 0 / 1 in section 4.3.5 on page 73).
  - The following applies to all non-omnidirectional vehicles: The further the point is from the symmetry axis, the slower the vehicle travels back to the line.
  - The following applies to all vehicles: The further the point is from the symmetry axis, the more exactly the angle is set in relation to the position and the more exactly the vehicle must be tracked on.

- Virtual Point Rear: Point at which the control for omnidirectional vehicles always take place and for non-omnidirectional vehicles take place when driving forwards (see section 2.6.5 on page 38). The deviations limited in the Accuracy menu are also determined at this point (Deviation Attribute 0 / 1 in section 4.3.5 on page 73).
  - The following applies to all non-omnidirectional vehicles: The further the point is from the symmetry axis, the slower the vehicle travels back to the line.
  - The following applies to all vehicles: The further the point is from the symmetry axis, the more exactly the angle is set in relation to the position and the more exactly the vehicle must be tracked on.

- Time Forward: This parameter can be used to compensate partially for the time the steering needs to set an angle. For example, steering angles due to curves are sent to the steering before the vehicle arrives at the curve, so that the steering has the right steering angle when the vehicle reaches the curve. *Deviations of the control, however, cannot be predicted.*
  For non-omnidirectional vehicles this works well (reasonable range depending on the steering: 0.2 to 1). For omnidirectional vehicles the value should be very small or zero.

4.3.7 Configuration –> Speed Controller

Figure 71 *Screenshot: Configuration –> Speed Controller*



Setting the speed controller. The table has three columns:

1. Item: Shows which value is involved.
2. Setting: Input of the values
3. Unit: Unit of the value

The following values can be changed:

WARNING

Unpredictable behavior of the vehicle

If a faulty Speed Ramp is chosen the vehicle cannot perform actions as it is expected to do. This can e.g. mean that the vehicle still has a too high speed when reaching the end of a segment. The vehicle then cannot stop at the segment end and drives beyond it.

▶ Choose a Speed Ramp resp. a support point interval so that a maximum of 40 points is sufficient to reach the target speed.

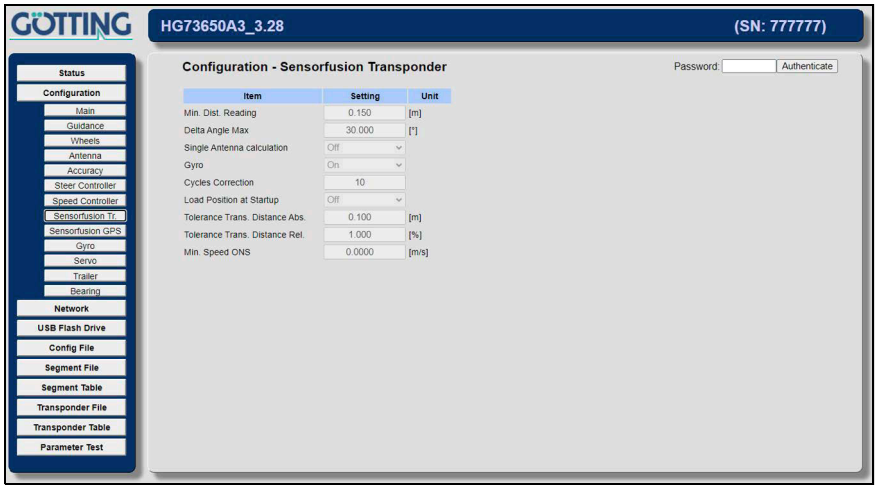
- Speed Ramp/Stop Ramp: The speed ramp is used, when the vehicle accelerates or decelerates. The stop ramp is used if the vehicle is braking down to 0 m/s, e.g. due to an error or a missing clearance.
  From firmware version 2.46 on the control unit examines the speed profile of the 40 next support points and limits the speed to the maximum speed reachable with the set speed ramp (also see section 2.6.1 on page 35).
- Vmax forward / Vmax backward: Maximum speed in forwards / backwards direction. The purpose of these parameters is not to limit the speed. Instead, they represent a safeguard. The speed of the vehicle should be limited via the segment file in conjunction with the 'Scaling Speed' parameter (see below) in such a way that it is below the limit at all times. Although the output speed is limited by these parameters, vehicles sometimes tend to travel faster than the

target speed for a brief period during acceleration. **In this case, after 5 seconds and a speed that is too high by 0.05 m/s, emergency off is triggered.**

- Scaling Speed: This parameter can be used to scale the speed of the segments. If the parameter equals 1, the speed of the segment file is interpreted in mm/s. To make the vehicle travel slower during commissioning, values below one can also be entered. In this way, the vehicle now travels with 0.1 only 1/10 as fast as with 1.

4.3.8 Configuration –> Sensor Fusion Transponder

Figure 72 *Screenshot: Configuration –> Sensor Fusion Transponder*



The table has three columns:

1. Item: Shows which value is involved.
2. Setting: Input of the values
3. Unit: Unit of the value

The following values can be changed:

- Min. Dist. Reading: Minimum distance that must be travelled before a transponder is accepted again. It should be **at least half an antenna width** to prevent repeated activation of the transponder calculation in the event of problems in the border area of the antenna (see documentation of transponder antenna).
- Delta Angle Max: Maximum angle difference between the angle changes calculated by the gyroscope and those calculated by the wheels in 10 ms. If the difference exceeds the threshold set here, the accuracy of the position deteriorates artificially and an emergency stop is triggered.
- Single Antenna calculation: Enables the calculation with only one antenna. On some vehicles with two or more antennas, a calculation with only one antenna leads to a deterioration in the accuracy. In such cases, the calculation with only one antenna can be avoided.
- Gyro: Enables the position calculations with one gyroscope. If the gyroscope is enabled, it also must be present, as otherwise an error occurs. With the gyroscope, the accuracy of the odometry can be improved in most cases. The advantage of the gyroscope is that is less dependent on load with regard to payload, air pressure and slip. The disadvantage of the gyroscope is the drift and the resulting necessity for drift compensation. **This averaging of the drift rate should be carried out at intervals of a maximum of approx. 15 minutes with the vehicle at a standstill resp. at least once after**

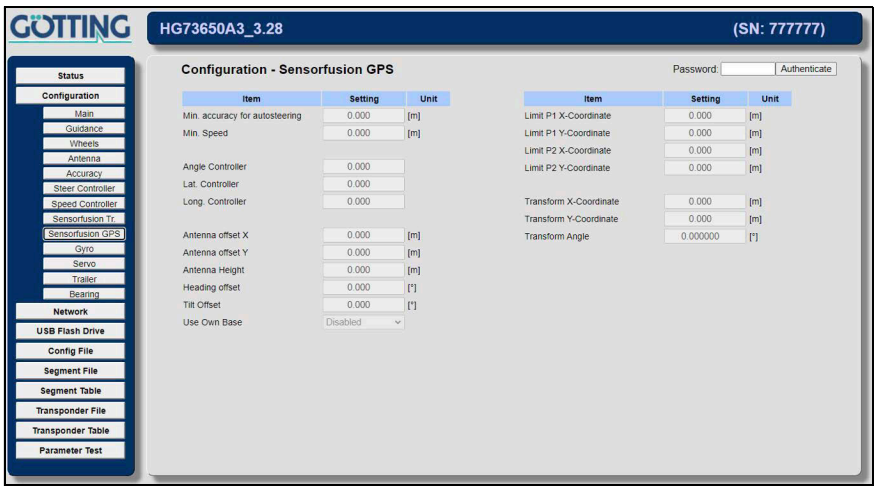
turning the control unit on before starting the first automatic drive (see section 4.3.10 on page 81). For the first averaging it is advisable to wait until the Gyro has thermally tuned itself (approx. 2 min after the Gyro is turned on).

- Cycles Correction: Specifies the number of calculation cycles in which a position calculated via the transponders is included in the position of the vehicle. If the value is 10, the calculated position is adopted in 10 steps into the position of the vehicle. As the navigation controller carries out 100 calculations per second, the correction of a value of 10 takes 0.1 seconds.
- Load Position at Startup: Enables saving the current position at a standstill. This position is then reloaded when the navigation controller is switched on. However, this is not recommended for vehicle that can be carried or moved without the navigation controller. During commissioning, loading the position when switching on is not recommended either, as it is best to start a number of measurements with the zero position.
- Tolerance Trans. Distance Abs: Tolerance of the transponder distances. A position calculation with transponders is only carried out if the distance between the transponders measured by the odometry matches the distance from the transponder table. This parameter specifies the tolerance in metres by which the distance measured by the odometry may deviate. A common value is 0.1 metres.
- Tolerance Trans. Distance Rel.: Same as 'Tolerance Trans. Distance Abs', only that the tolerance is specified relatively as a percantage value here. 1 means that at two metres between the transponders a maximum of 0.02 metres error is permitted.

4.3.9 Configuration –> Sensor Fusion GPS

In the case of sensor fusion with GPS, the position determined by the GPS is not adopted directly into the vehicle position. Instead, an odometry is corrected with the help of the GPS positions. The correction takes place by means of controllers that minimise the error between the odometry and GPS positions. This has the advantage that the vehicle positions have less noise than the GPS positions, but the dynamics are retained. The odometry makes a minor error in the relative calculation of the vehicle position in the case of short distances. It is also less sensitive to vehicle fluctuations. Over long distances, however, the GPS is better.

Figure 73 *Screenshot: Configuration –> Sensor Fusion GPS*



Two tables, each with three columns:

1. Item: Shows which value is involved.
2. Setting: Input of the values
3. Unit: Unit of the value

The following values can be changed:

- Min. accuracy for autosteering: Minimum accuracy of the GPS position so that the position calculation is carried out.
- Min. Speed: Minimum speed of the vehicle so that the controllers run to couple the GPS position into the vehicle position.
- Angle Controller: P controller that converts the alignment of the odometry to the alignment of the GPS system.
- Lat. Controller: P controller that draws the position in the lateral direction of the vehicle of the odometry to the alignment of the GPS system.
- Long. Controller: P controller that draws the position in the longitudinal direction of the vehicle of the odometry to the alignment of the GPS system.
- Antenna offset X: X position of the GPS antenna 1 with relation to the vehicle co-ordinate system.
- Antenna offset Y: Y position of the GPS antenna 1 with relation to the vehicle co-ordinate system.
- Antenna Height: Height of the GPS antenna above the ground. This parameter presupposes that the GPS antennas are mounted at the same height and laterally in relation to the direction of travel (GPS antennas 1 left, GPS antennas 2 right). Part of the rotary motion of the vehicle around the longitudinal axis (rolling) is then compensated for by allowing for the antenna height and the rolling angle. If the requirements for the antenna arrangement are not met or compensation is not wanted, this parameter should be set to zero.
- Heading offset: Angle offset between the antenna angle (between GPS antenna 1 and GPS antenna 2) and the X axis in the vehicle co-ordinate system.
- Tilt Offset: Rolling angle offset so that the tilt angle is 0 is when the vehicle is in a straight position. See parameter 'Antenna Height' above.
- Use Own Base: The GPS can work with its own GPS base station. The co-ordinate system then depends on the base station (the base station is the origin). Alternatively, the national co-ordinate system can also be loaded into the GPS receiver. The national co-ordinate system is then the reference system. It is important that any other position sensors that are present (for example the transponder system) also refer to the reference co-ordinate system.
  The parameters of the GPS receiver have to match these settings. A configuration file is available for a „own base“ and parameter sets with the appropriate country coordinate system.

The next four parameters split the area into two parts. One area is travelled preferably with the GPS, the other with the transponder system. To achieve this, two points are defined. To the left of the line of point 1 to point 2 is the GPS area and to the right is the transponder area.

- Limit P1 X Co-ordinate: X co-ordinate from point 1 in the global co-ordinate system.
- Limit P1 Y Co-ordinate: Y co-ordinate from point 1 in the global co-ordinate system.

- Limit P2 X Co-ordinate: X co-ordinate from point 2 in the global co-ordinate system.
- Limit P2 Y Co-ordinate: Y co-ordinate from point 2 in the global co-ordinate system.

The next three parameters adapt the GPS co-ordinates to area to be travelled. To keep calculation inaccuracies to a minimum, it is not expedient to calculate with co-ordinates that lie hundreds of kilometers from the co-ordinate zero point. This, however, is virtually always the case with GPS. The country-specific co-ordinate system is therefore loaded into the GPS receiver. This results in a Cartesian co-ordinate system with a zero point in the area and not in the earth's center. Subsequently, an offset to the area to be traveled is entered in the navigation controller. In this way, the co-ordinates then usually become less than 1 km.

NOTICE

Vehicle might leave the track while braking

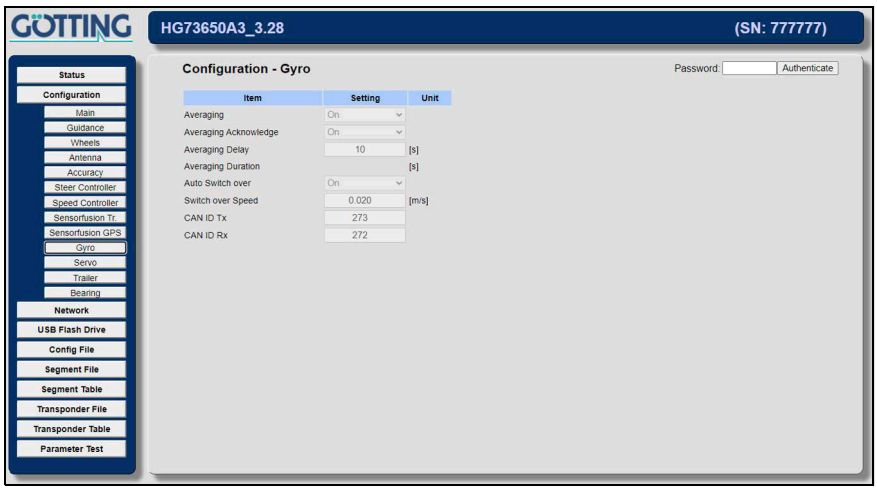
If the coordinate systems for transponders and GPS do not match switching between theses systems gives different positions. This makes the control unit tell the vehicle to stop. Additionally it outputs error messages. As the control unit still tries to compensate the different positions, the vehicle might leave the track while braking.

▶ If the transponder system and GPS are used together, the transponders must be measured in the same coordinate system that is used in the GPS.

- Transform X Co-ordinate: X offset from the zero point of the national co-ordinate system for the area to be traveled.
- Transform Y Co-ordinate: Y offset from the zero point of the national co-ordinate system for the area to be traveled.
- Transform Angle: Due to the distortions in the national co-ordinate system, an angle offset between the national co-ordinate system and the area to be traveled can be entered here.

4.3.10 Configuration –> Gyro

Figure 74 *Screenshot: Configuration –> Gyro*



Setting of the gyro. The table has three columns:

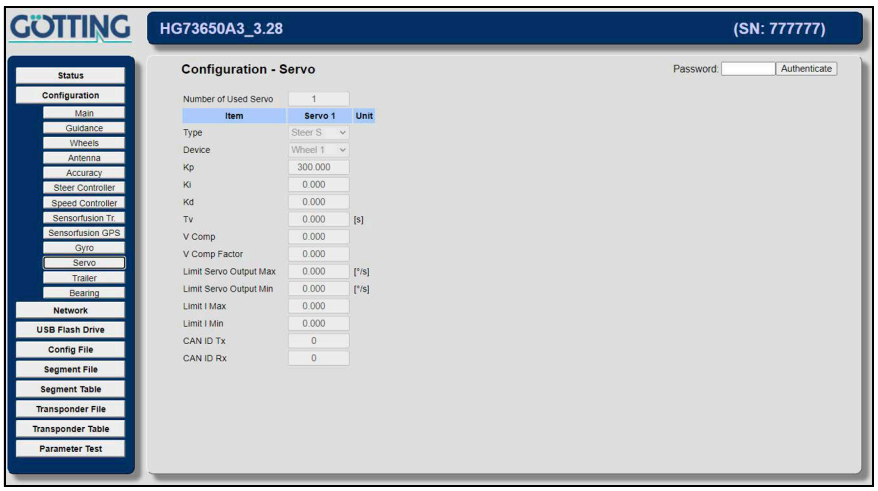
1. Item: Shows which value is involved.
2. Setting: Input of the values
3. Unit: Unit of the value

The following values can be changed:

- Averaging: The gyroscope must be averaged at regular intervals (see also section 4.3.8 on page 77) so that the drift rate does not become too great (drift compensation). If averaging the gyroscope is not carried out by another control system or automatically after the averaging delay time (see below), the averaging must be enabled here. After averaging, the drift rate of the gyroscope is significantly better that before averaging. This means that the odometry is also better than before averaging.
- Averaging Acknowledge: If enabled, averaging is carried out at least until the gyroscope reports that the drift rate is below the threshold set in the gyroscope (recommended). If a new drive command is sent to the navigation controller although the gyroscope is not yet ready, a corresponding error message from the gyroscope delays travel.
- Averaging Delay: Delay in switching on the averaging. The averaging starts automatically as soon as the time set here has elapsed after a pause in automatic mode.
- Averaging Duration: If the 'Averaging Acknowledge' parameter is not enabled, the minimum averaging time is specified. It should not be below 5 seconds (the longer the better).
- Auto Switch over: Enables use of the gyroscope as of the minimum speed 'Switch over Speed' (see below). The gyroscope is at its most accurate at high speeds. If the speed drops, the gyroscope loses accuracy, as the ratio of drift rate to driven distance becomes increasingly poorer. If the vehicle moves more slowly, the alignment is calculated once again with the odometry.
- Switch over Speed: Switchover threshold in metres / second with 'Auto Switch over' enabled.
- CAN ID Tx: Identifier with which the navigation controller transmits on the CAN bus to the gyroscope (decimal value).
- CAN ID Rx: Identifier with which the gyroscope transmits on the CAN bus to the navigation controller (decimal value).

4.3.11 Configuration –> Servo

Figure 75 *Screenshot: Configuration –> Servo*



Servo refers to a framework consisting of activation and drive unit (servomotor). In combination with the navigation controller, servos made by Schneider Elektronik of the type IcIa IFA and/or a special motor made by CPM can be used. Up to eight servos of this type can be activated.

The navigation controller usually transfers the steering angle and target speeds directly to the vehicle control system, which then activates the vehicle actuator system accordingly. It is only in exceptional cases that the navigation controller itself activates the vehicle actuator system (servos), in which case the following settings must be made. This requires knowledge of automatic control engineering. Where servos are deployed, Götting KG commissioning support subject to charges is recommended.

The table has three columns for each servo:

1. Item: Shows which value is involved.
2. Servo n: Input of the values
3. Unit: Unit of the value

The following values can be changed:

- Number of Used Servo: 0 - 8, Standard 0
- Type: The type also specifies which of the following parameters are available; in the case of some types, parameters are hidden. The following types can be selected:
  - Drive: Drive servo for which a speed is specified.
  - Steer S: Steering speed controller (the motor is activated via a specified speed until the right angle is reached)

- Steer A: Steering angle controller (the motor can be activated via a specified angle – not yet implemented; since this possibility is liable to stricter supervision inside the servo usually the speed controller is used)
- External: Here the vehicle control system can give a revolution speed via the UDP or Profinet interface that is forwarded to the Servo (High Byte = 82 , Low Byte = 83). For the UDP/Profinet telegrams see section 8.2 on page 164.

- Device: Specifies the wheel on which the servo is applied (Wheel 1 - Wheel 4). An exception is the external servo which is not applied to any wheel.

For the next parameters it is important to be aware of the effects of the controller values.

Controller

The controller calculates the difference between nominal and actual value of data output to the servo. For this a PIDT1 controller with servo control is used.

The servo control:

The servo control is only necessary for traction drives. It makes sure that a known value can be output to the servo immediately.

An example:

A vehicle with an electric engine shall accelerate from 0 to 1 m/s. If the traction drive is solely actuated via a controller at first the differential (D) and proportional (P) portion would affect the drive. The D portion will soon be gone. The P portion will be reduced while the speed increases. The integral portion (I) will rise. At last the full output value (control value) will come from the I portion (no change in speed means that the D portion is zero, no difference between nominal and current speed means, that the P portion is zero). If the factors (Kp, Ki and Kd) make the portions too big the controller starts to swing due to dead time, mass of the vehicle etc.

Advantages of a controller:

✓ Flexible

Disadvantages Controller:

- Tends to swing
- Needs time

Often dependencies are known. For example an engine might need a minimal control value due to rolling friction. Or that a certain speed needs a certain control value. If you record a characteristic curve of the control value for different constant speeds it can be used to approximate this curve with the servo control

Advantages servo control:

✓ The control value is applied immediately

✓ Does not tend to swing

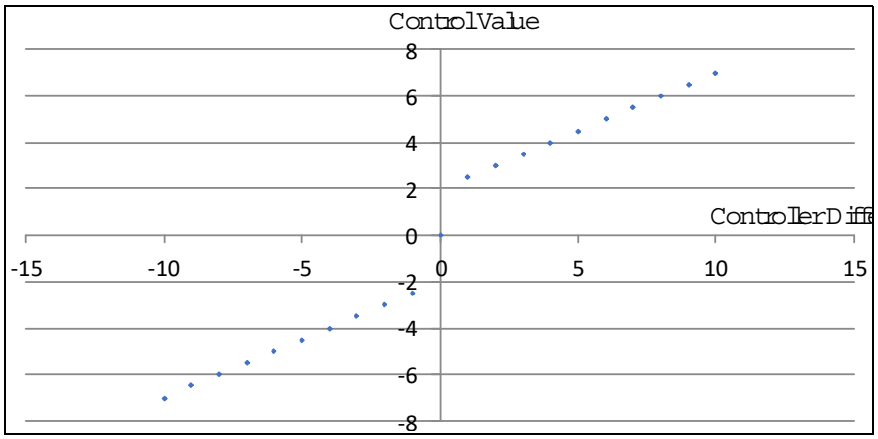
Disadvantages servo control:

- Imprecise
- Does not take load changes into account

The control value of the servo consists of the control value of the controller to which the control value of the servo control is added. For the servo control two parameters exist. *V Comp* is the offset. It is added to or substracted from the control value, depending on the sign of the controller difference (difference between nominal and current value) and represents the constant portion of the characteristic curve. *V Comp Factor* is multiplied with the controller difference and represents the linear portion of the characteristic curve.

Below you see an example with V Comp = 2 and V Comp Faktor = 0.5.

Figure 76 *Servo: Diagram control value and controller difference*



- Kp: Factor for the proportional portion of the controller
- Ki: Factor for the integral portion of the controller
- Kd: Factor for the differential portion of the controller
- Tv: Specifies the number of cycles of 10 ms in which the D component is distorted over time. The following formula applies:

Figure 77 *Formula: Distortion of the D component along Tv*

$$\text{D component} = (((\text{control difference}_{t=0} - \text{control difference}_{t=2}) \times 1000) + (\text{Tv} \times \text{D component}_{old})) / (\text{Tv} + 1)$$

- V Comp: Pre-control of the actuating variable (some motors need a minimum speed to start up; to activate this clockwise or anticlockwise running, a minimum speed can be specified here)
- V Comp Factor: Pre-control of the actuating variable (if, for example, a drive motor with a known speed requires a known motor speed, this can be entered here. The controller then only has to carry out the fine control.)
- V Comp: Constant portion of the servo control
- V Comp Factor: Linear portion of the servo control
- Limit Servo Output Max: Limits the positive value of the servo
- Limit Servo Output Min: Limits the negative value of the servo
- CAN ID Tx: Identifier with which the navigation controller transmits on the CAN bus to the corresponding servo (decimal value). Must also be adapted in the servo and be unique.
- CAN ID Rx: Identifier with which the corresponding servo transmits on the CAN bus to the navigation controller (decimal value). Must also be adapted in the servo and be unique.

4.3.12 Configuration –> Trailer

Figure 78 *Screenshot: Configuration –> Trailer*

The table has three columns:

1. Item: Shows which value is involved.
2. Setting: Input of the values
3. Unit: Unit of the value

The following values can be changed:

- Trailer Type: Fix Trailer: Trailer with at least one fixed axle
- King Pin X Truck: Position of the king pin in X direction on the towing vehicle in the coordinate system of the towing vehicle.
- King Pin Y Truck: Position of the king pin in Y direction on the towing vehicle in the coordinate system of the towing vehicle.
- Trailer length: Distance between the king pin and the fixed axle of the trailer. For trailers with two axles: Center between both axles. For trailers with three axles: Center axle.
- Trailer Angle Offset: The trailer angle used in the controller consists of three components.
  1.) The measured angle, 2.) the offset determined automatically during the measuring section and 3.) this parameter. The parameter is set so that the angle shown after switch-on is as close to zero as possible if the trailer is standing straight. Use the raw trailer angle logged in a data logging to approximate the value.
- Trailer Angle Scaling: Scaling of the angle if the angle is not provided in 1/100°. Via the leading sign the direction of rotation of the angle can be changed. The trailer angle has to be positive if the forward projection of the trailer points left of the towing vehicle.
- Forward Distance fixed: Explanation in section 4.3.6 on page 74 only this time applied to the trailer. This parameter should be considerably higher than the one for the towing vehicle.
- Forward Distance variable: Explanation in section 4.3.6 on page 74 only this time applied to the trailer. This parameter should be considerably higher than the one for the towing vehicle.
- Approach Limit fixed: Explanation in section 4.3.6 on page 74 only this time applied to the trailer. This parameter should be considerably smaller than the one for the towing vehicle.

- Approach Limit variable: Explanation in section 4.3.6 on page 74 only this time applied to the trailer.
- Virtual Point Front: Explanation in section 4.3.6 on page 74 only this time applied to the trailer. This parameter has no significance for the currently usable trailer type.
- Virtual Point Rear: Explanation in section 4.3.6 on page 74 only this time applied to the trailer. This parameter should be considerably higher than the one for the towing vehicle.
- Time Forward: In order to be able to estimate the future movement of the trailer the trailer‘s deviation is not determined at its current position. Instead the current movement and movement change is determined. For the calculated position the deviation is determined. Based on this corrections are calculated. This parameter should be chosen between 0 and 0.4 seconds. Higher values worsen the calculation and lead to swaying.
- Kp: The value calculated for the kink angle is adjusted according to the traveling and the steering angle of the towing vehicle. The difference between current kink angle and target kink angle is transmitted to the towing vehicle as a P controller for the steering angle.
- CAN ID Trailer Angle: ID of the CAN message of the trailer (decimal).

4.3.13 Configuration –> Bearing

Figure 79 *Screenshot: Configuration –> Bearing*

In situations where positioning via transponder, GPS or laser scanner is not sufficient to approach a target accurately enough, bearing can be used. Since the bearing measures directly to the target, the achievable accuracy is usually better. Bearing only affects the steering during an automatic run. The speed and the monitoring of deviations and accuracies continue to be carried out via the segment that is currently driven. If the vehicle drives out of the tolerance range of the segment due to the bearing, it stops with the error message *Deviation*.

Since different data is required for the different bearing modes, the data on the interface is interpreted depending on the mode used. The following bearing modes are distinguished.

- Normal Mode:
  In this mode, the vehicle moves towards a marker. The ratio between bearing angle and steering angle can be influenced with the *Kp Rear* parameter. The

angle *S8_Angle* (see 7.3.17 „Bearing Box“ on page 156) is used to limit the steering angle. The limitation is set in 2/10° and can reach a maximum of 25°. If the limit is set to zero, it is not active.

- Pallet Mode:
  In this mode, the orientation of the pallet to the vehicle is taken into account. The vehicle swings in with the *Virtual Point Rear* on a straight line that runs with *S8_Angle* (see 7.3.17 „Bearing Box“ on page 156) from the mark. *S8_Angle* is the angle between the marker and the vehicle. If the mark is rotated to the left in relation to the vehicle, the angle is positive. The angle may be a maximum of ±25° and has a resolution of 2/10°.

Pallet Mode is not yet available.

The menu shows a table with three columns.

1. Item: Shows which value is involved.
2. Setting: Input of the values
3. Unit: Unit of the value

The following values can be changed:

- CAN ID Rear: CAN ID of the associated message. If 0, the CAN message is deactivated.
- Scanner Offset X Rear: Position of the scanner in X direction relative to the center of the vehicle.
- Scanner Offset Y Rear: Position of the scanner in Y direction relative to the center of the vehicle.
- Kp Rear: Gain factor, determines the relationship between the angle to the target and the steering angle. The larger the factor, the greater the steering movements.

4.4 Network Menu

Local network settings for the Ethernet interface of the navigation controller hardware HG G-61430 for connection of a PC (see 3.5.1 on page 48).

Figure 80 *Screenshot: Network - Settings*

Setting the network parameters. The table has two columns:

1. Item: Shows which value is involved.
2. Setting: Input of the values

For each connection with the control unit via the Ethernet interface the values set in this mask have to be used. If you change these values prmanently you have to re-connect with the control unit and the website configuration using the new values.

The following values can be changed:

NOTICE

Connection not possible

As soon as you change the values permanently only the new values work and no longer the ones shown in this document.

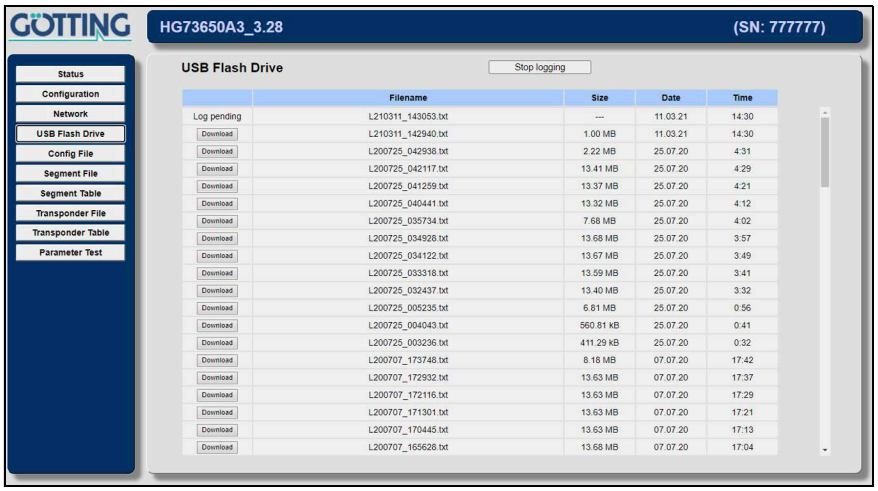
▶ Document the changed values

- LAN IP Address - IP address of the Control Unit. If you want to connect to the Control Unit via the Ethernet interface you have to use this IP address. The best way is to configure your own interface to match the default and the LAN Net Mask. Alternatively you can change this setting to match your existing network settings (see warning notice above). For examples please see section 6.3 on page 111.
- LAN Net Mask - Net Mask of the Control Unit's Ethernet interface. Usually the default setting fits.
- Default Gateway / Primary DNS Server / Secondary DNS Server - these settings arr for future applications and are not yet used.

4.5 USB Flash Drive Menu

This menu shows an overview of the log files present on an inserted USB stick.

Figure 81 *Screenshot: USB Flash Drive*



In addition to displaying the available files, the menu offers the following functions:

- With the *Stop logging* button, logging can be stopped. The button then changes to *Start logging* and the last active log shown as *Log pending* is closed and also offered for *Download*.
- Use the *Download* button in front of the log files to download the respective file.

4.6 Config File Menu

Figure 82 *Screenshot: Config File - Upload/Download*

Parameter settings from the navigation controller can be saved on this page (**Download**) or uploaded into it (**Upload**). For the upload, the navigation controller must be in the *Idle* state and the password must have been entered.

4.6.1 Upload Configuration

Load parameters from a file on the PC into the navigation controller.

The name of the parameter file must start with *parameter*, e.g. *parameter_01.txt*.

- ▶ Use the button *Select File* to select the parameter file on the hard disk.
- ▶ Click on the *Upload Configuration* button.

The message `waiting for 10.10.10.20` should appear briefly bottom left, whereby 10.10.10.20 is an example of the set network address of the navigation controller (see section 4.4 on page 87). If this message does not appear briefly, the file has not been saved in the navigation controller which, for example, can be the result of an incorrect name or missing password.

NOTICE

Overwriting/deletion of parameters

The control unit always only stores one parameter file and internally names the file parameter.txt. So if a file with the name parameter... is transmitted and that file doesn't contain actual parameters the parameters in the control unit are lost.

- ▶ Only ever transmit a file with the name parameter... if that file is a valid parameter file.

In that case, they can either be reloaded from an already saved parameter file or they have to be entered again. It is therefore recommended to back up the parameters saved on the navigation controller beforehand on the PC (see below).

As the navigation controller only loads a number of parameters once during start-up, not all the parameters of the uploaded file are active right away. If the uploaded file is to be used completely, the navigation controller must be restarted.

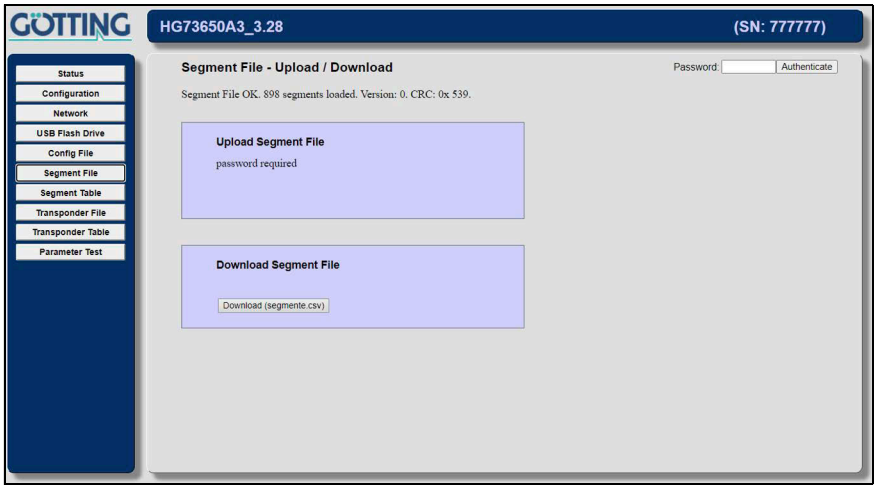
4.6.2 Download

Transfer parameters from navigation controller into a file on the PC

Download Configuration transfers the current parameter file from the navigation controller to the PC. Depending on the setting of the browser, the location on the hard disk where the file is to be saved must be specified. Alternatively, it can be that the browser transfers the file directly into its *Download* folder without a prompt. As default, the file will have the name *parameter.txt*, no matter what the name of the file was that was transferred into the navigation controller.

4.7 Segment File Menu

Figure 83 *Screenshot: Segment File - Upload/Download*



On this page, segment files can be downloaded from the navigation controller (**Download**) or transferred to it (**Upload**). For the upload, the navigation controller must be in the *Idle* state and the password must have been entered.

4.7.1 Upload Segment File

Transfer a segment file from the PC into the navigation controller.

The name of the segment file must start with *segmente*, e.g. *segmente_01.csv*.

- ▶ Use the button *Select File* to select the segment file on the hard disk.
- ▶ Click on the *Upload Segment File* button.

The messages `Uploaded (XX%)` and subsequently `waiting for 10.10.10.20` should appear briefly in the bottom left, whereby 10.10.10.20 is an example of the set network address of the navigation controller (see section 4.4 on page 87). In the case of short files such as with the test segments, the first message can become unnecessary.

If very large CSV files are transferred (27000 support points e.g. result in a file size of approx. 14 MB) the transmission can take several minutes. After the file is transmitted (Uploaded 100%) the point in th e7 segment display stops blinking for some time. This is no dysfunction. During this period the transmitted file is compressed into the BIN format inside the control unit and subsequently transferred to the storage area for segments.

If the message `waiting for 10.10.10.20` does not appear for even a brief moment, the file has not been saved in the navigation controller which, for example, can be the result of an incorrect name or missing password.

NOTICE

Overwriting/deletion of segment files

The navigation controller always saves only one segment file and always stores it internally under the name segmente.csv. If a file with the name 'segmente...' is transferred and this file contains no segments, the segments stored in the navigation controller are lost.

▶ Only ever transmit a file with the name segmente... if that file is a valid parameter file.

It is therefore recommended to back up the segments saved on the navigation controller beforehand on the PC (see below). The new segments are active immediately, i.e. the navigation controller does not need to be restarted.

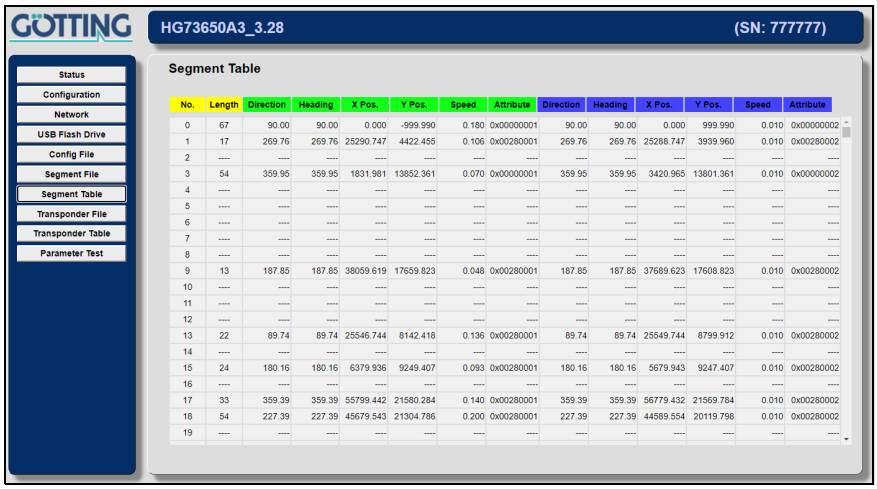
4.7.2 Download Segment File

Transfer segment file from the navigation controller into a file on the PC

Download Segment File transfers the current segment file from the navigation controller to the PC. Depending on the setting of the browser, the location on the hard disk where the file is to be saved must be specified. Alternatively, it can be that the browser transfers the file directly into its 'Download' folder without a prompt. As default, the file will have the name *segment.csv*, no matter what the name of the file was that was transferred into the navigation controller.

4.8 Segment Table Menu

Figure 84 *Screenshot: Segment Table*



No.	Length	Direction	Heading	X Pos.	Y Pos.	Speed	Attribute	Direction	Heading	X Pos.	Y Pos.	Speed	Attribute
0	67	90.00	90.00	0.000	-999.990	0.180	0x00000001	90.00	90.00	0.000	999.990	0.010	0x00000002
1	17	269.76	269.76	25290.747	4422.455	0.106	0x00280001	269.76	269.76	25288.747	3939.960	0.010	0x00280002
2	----	----	----	----	----	----	----	----	----	----	----	----	----
3	54	359.95	359.95	1831.981	13852.361	0.070	0x00000001	359.95	359.95	3420.965	13801.361	0.010	0x00000002
4	----	----	----	----	----	----	----	----	----	----	----	----	----
5	----	----	----	----	----	----	----	----	----	----	----	----	----
6	----	----	----	----	----	----	----	----	----	----	----	----	----
7	----	----	----	----	----	----	----	----	----	----	----	----	----
8	----	----	----	----	----	----	----	----	----	----	----	----	----
9	13	187.85	187.85	38059.619	17659.823	0.048	0x00280001	187.85	187.85	37689.623	17608.823	0.010	0x00280002
10	----	----	----	----	----	----	----	----	----	----	----	----	----
11	----	----	----	----	----	----	----	----	----	----	----	----	----
12	----	----	----	----	----	----	----	----	----	----	----	----	----
13	22	89.74	89.74	25546.744	8142.418	0.136	0x00280001	89.74	89.74	25549.744	8799.912	0.010	0x00280002
14	----	----	----	----	----	----	----	----	----	----	----	----	----
15	24	180.16	180.16	6379.936	9249.407	0.093	0x00280001	180.16	180.16	5679.943	9247.407	0.010	0x00280002
16	----	----	----	----	----	----	----	----	----	----	----	----	----
17	33	359.39	359.39	55799.442	21580.284	0.140	0x00280001	359.39	359.39	56779.432	21569.784	0.010	0x00280002
18	54	227.39	227.39	45679.543	21304.786	0.200	0x00280001	227.39	227.39	44589.554	20119.798	0.010	0x00280002
19	----	----	----	----	----	----	----	----	----	----	----	----	----

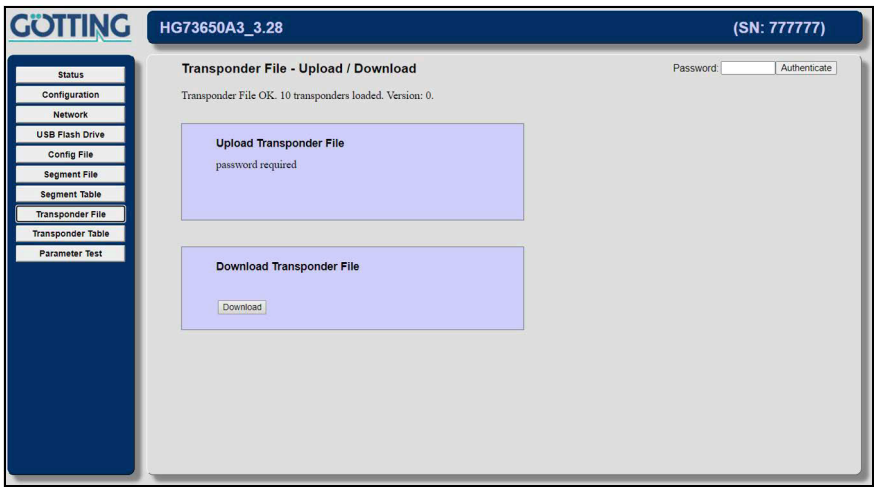
The segments stored in the navigation controller are shown on this page. The data concerning the segments are shown in yellow; the data concerning the segment start are shown in green; and the data concerning the segment end are shown in blue.

- No.: Segment number
- Length: Number of support points in the segment.

- Move: Direction of movement of the segment at the start (green) / end point (blue) [°].
- Heading: Alignment of the vehicle at the start (green) / end point (blue) [°].
- X Pos.: X position of the segment at the start (green) / end point (blue) [m].
- Y Pos.: Y position of the segment at the start (green) / end point (blue) [m].
- Speed: Speed of the segment at the start (green) / end point (blue) [m/s].
- Attribute: Attributes of the segment at the start (green) / end point (blue).

4.9 Transponder File Menu

Figure 85 *Screenshot: Transponder File - Upload/Download*



On this page, transponder files can be downloaded from the navigation controller (**Download**) or transferred to it (**Upload**). For the upload, the navigation controller must be in the 'Idle' state and the password must have been entered.

4.9.1 Upload Transponder File

Transfer a transponder file from the PC into the navigation controller

The name of the transponder file must start with *transponder*, e.g. *transponder_01.csv*.

- ▶ Use the button *Select File* to select the transponder file on the hard disk.
- ▶ Click on the *Upload Transponder File* button.

The messages `Uploaded (XX%)` and subsequently `waiting for 10.10.10.20` should appear briefly in the bottom left, whereby 10.10.10.20 is an example of the set network address of the navigation controller (see section 4.4 on page 87). In the case of short files such as with the test segments, the first message can become unnecessary.

If the message `waiting for 10.10.10.20` does not appear briefly, the file has not been saved in the navigation controller which, for example, can be the result of an incorrect name or missing password.

NOTICE

Overwriting/deletion of transponder files

The navigation controller always saves only one transponder file and always stores it internally under the name *transponder.csv*. If a file with the name 'transponder...' is transferred and this file contains no transponders, the transponders stored in the navigation controller are lost.

▶ Only ever transmit a file with the name transponder... if that file is a valid transponder file.

It is therefore recommended to back up the transponders saved on the navigation controller beforehand on the PC (see below). The new transponders only become active after a restart.

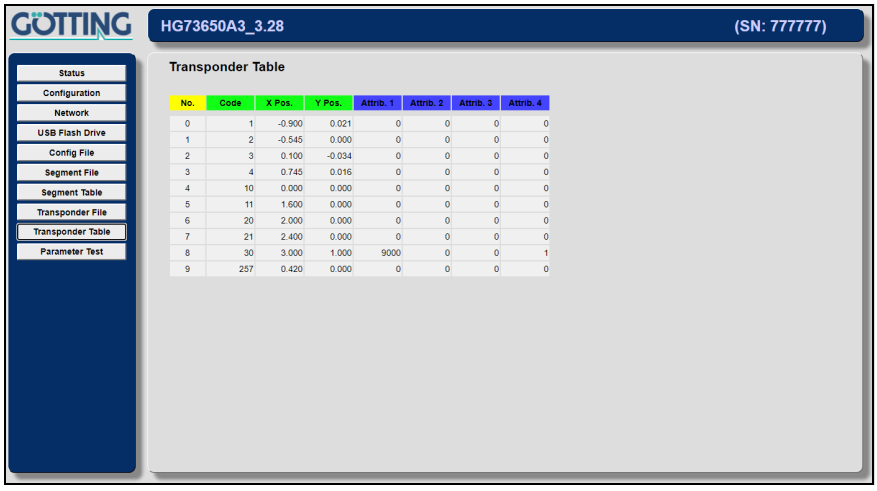
4.9.2 Download Transponder File

Transfer transponder file from the navigation controller into a file on the PC

Download Transponder File transfers the current transponder file from the navigation controller to the PC. Depending on the setting of the browser, the location on the hard disk where the file is to be saved must be specified. Alternatively, it can be that the browser transfers the file directly into its 'Download' folder without a prompt. As default, the file will have the name *transponder.csv*, no matter what the name of the file was that was transferred into the navigation controller.

4.10 Transponder Table Menu

Figure 86 *Screenshot: Transponder Table*



No.	Code	X Pos.	Y Pos.	Attrib. 1	Attrib. 2	Attrib. 3	Attrib. 4
0	1	-0.900	0.021	0	0	0	0
1	2	-0.545	0.000	0	0	0	0
2	3	0.100	-0.034	0	0	0	0
3	4	0.745	0.016	0	0	0	0
4	10	0.000	0.000	0	0	0	0
5	11	1.600	0.000	0	0	0	0
6	20	2.000	0.000	0	0	0	0
7	21	2.400	0.000	0	0	0	0
8	30	3.000	1.000	9000	0	0	1
9	257	0.420	0.000	0	0	0	0

The transponder list stored in the navigation controller is shown on this page.

- No.: Serial number of the list
- Code: Code of the transponder (**the list should be sorted in ascending order, as otherwise the start of the navigation controller is delayed by the sorting**)
- X Pos.: X position of the transponder in the local co-ordinate system [m].
- Y Pos.: Y position of the transponder in the local co-ordinate system [m].
- Attrib. 1: Attribute 1 of the transponder, e.g. starting angle of a start transponder (see Transponder 39, see Figure 86)

- Attrib. 2: Attribute 2 of the transponder.
- Attrib. 3: Attribute 3 of the transponder.
- Attrib. 4: Attribute 4 of the transponder, e.g. start transponder (see Transponder 39, see Figure 86)

4.11 Parameter Test Menu

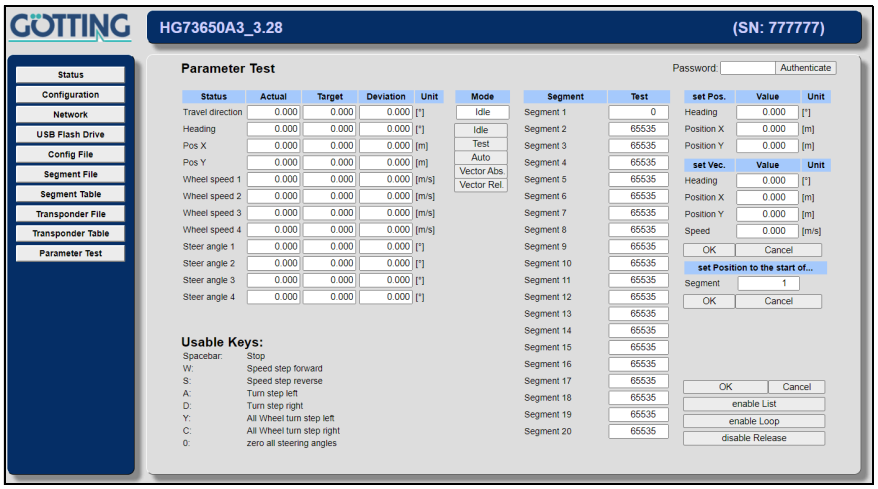
WARNING

Risk of collisions with persons or objects

When controlling the vehicle in the *Test* mode it can happen that the connection between the browser and the control unit freezes or stalls. the vehicle can then no longer be stopped using the browser. Thus use the *Test* mode only

- ▶ with extreme caution
- ▶ slowly and
- ▶ with safety devices such as emergency off within reach.

Figure 87 *Screenshot: Parameter Test*



This page is used for commissioning (see chapter 6 on page 110) and troubleshooting. Here...

- the simulation of a run can be carried out
- the vehicle can be moved by hand in the 'Test' mode and
- positions can be specified.

If the operating modes are changed via the parameter test page the clearance for other interfaces like CAN is revoked. This means that changes that are requested via other interfaces are ignored.

To do so, the password must be entered on this page or on one of the parameter pages. If the navigation controller is in the *Idle* mode and the password has been entered, all buttons are displayed. In other modes, some buttons are removed.

The table in the top left (Status) shows the current actual and target values and deviations and was already described in section 4.2.1 „Navigation Menu“ on page 54.

In the center of page is the output of the current mode (*Mode*) of the navigation controller. Below this are buttons to switch the navigation controller into the modes

- Idle: The navigation controller does not control the vehicle
- Test: The navigation controller controls the vehicle with the buttons shown in the bottom left
- Auto: The navigation controller controls the vehicle via segments
- Vector Abs.: The navigation controller switches to the absolute vector mode with the vector given in the table *set Vec.*
- Vector Rel.: The navigation controller switches to the relative vector mode with the vector given in the table *set Vec.*

The other modes can be selected from *Idle*.

4.11.1 Requirements for switching into the different modes

- It is always possible to switch to 'Idle'
- It is possible to switch to 'Test' when
  - the vehicle is at a standstill
  - the mode is 'Idle'
- It is possible to switch to 'Auto' when
  - the vehicle is at a standstill
  - the mode is 'Idle'
  - when the simulation is switched on
  - when the matching segments have been transferred.
- It is possible to switch to one of the 'Vector' modes when
  - the vehicle is at a standstill
  - the mode is 'Idle'
  - a vector has been given in *set Vec.*

4.11.2 Possibilities in the 'Idle' mode

In the 'Idle' mode, the following are possible:

- Specifying segments for the navigation controller
- Setting the vehicle position
- Switching into the 'Test' mode
- Switching into the 'Auto' mode
- Switching into one of the 'Vector' modes

4.11.3 Possibilities in the 'Test' mode

In the Test mode, the following are possible:

- Control of the vehicle via the buttons shown in the bottom left:
  - Spacebar: Stop
  - w / W: Increment speed (larger steps are possible with the shift key)
  - s / S: Decrement speed (larger steps are possible with the shift key)
  - a / A: Steer to the left (larger steps are possible with the shift key)
  - d / D: Steer to the right (larger steps are possible with the shift key)

  - y / Y: Crab steering to the left (larger steps are possible with the shift key)
  - c / C: Crab steering to the right (larger steps are possible with the shift key)

- Switching into the 'Idle' mode

4.11.4 Possibilities in the 'Auto' mode

In the 'Auto' mode, the following are possible:

- Having the vehicle / simulation travel automatically according to segments
- Switching into the 'Idle' mode
- Switching into one of the 'Vector' modes

4.11.5 Specification of segments

The *Segment* table can be used to specify 21 segments for the navigation controller. This list (Test: 21 segments) is then loaded into the list of target segments as if they came from the vehicle control system. The above screenshot shows that the first 17 segments have been entered. Unused segments must be filled with the value 65535.

Once this list has been entered, it is important to click on the 'OK' button under the segments, as otherwise these are only on the website and not yet known to the navigation controller.

If the *enable List* button is then actuated, the label changes into *disable List* and the first 8 segments of the *Test* list are copied into the target segments of the navigation controller. This can be checked on the 'Status - Navigation' page. From this point on, no more segments are adopted into the vehicle control system. If the OK button is actuated on one of the parameter pages, these segments are also saved. If the list is to be changed, the *disable List* button must be switched back to *enable List* by clicking.

The *enable Loop* button provides the possibility to specify the test segments in an endless loop. This is of interest, for example, at trade fairs.

The *enable Release* button can be used to set or reset the segment release during automatic mode. This is the simplest possibility to stop the vehicle / simulation.

4.11.6 Setting a starting position

If the navigation controller is in the *Idle* mode, the current position can be set to another position. The corresponding values must be entered in the table *set Pos*. Clicking the 'OK' button adopts then these into the current actual position.

5 Configuration via Terminal Program

Alternatively to the web sites shown in chapter 4 on page 52 a part of the functionality can be controlled via a terminal. The usage of a terminal program compared to the web sites has the advantage that the connection is considerably faster. However the interface is less comfortable. Especially the control of the vehicle is more convenient and has less latency.

Also the data logging (s. 5.5 on page 104) is substantially faster than the USB logging (see chapter 9 on page 168). Where the USB stick writes a new record every 60 ms the terminal program – depending on the workload of the control unit – outputs a data set every 10 – 20 ms.

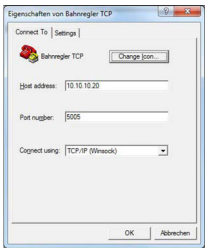
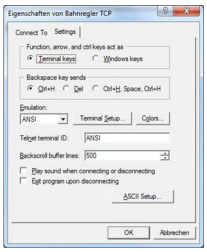
Every compatible terminal program can be used, examples are HyperTerminal® or Tera Term®. HyperTerminal® was included in former versions of Microsoft® Windows®. Furthermore it can be downloaded for all Windows® versions at the following address:

https://www.hilgraeve.com/hyperterminal/

5.1 Connection Establishment

The data is exchanged via the Ethernet interface. The PC/Notebook has to be connected to the control unit via the Ethernet interface. For the connection establishment the following parameters have to be set (examples shown for HyperTerminal®):

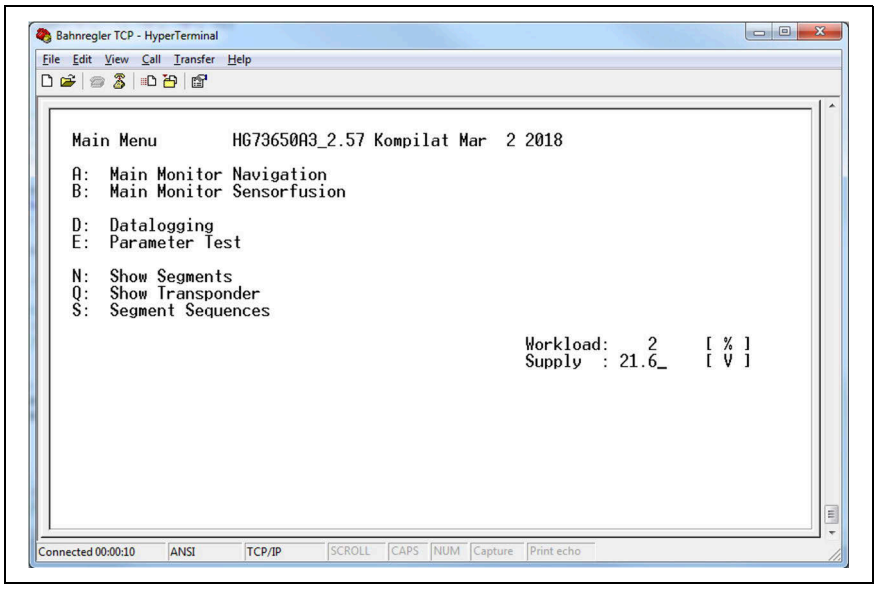
Table 16 *Terminal program: Parameter for the connection establishment*

Setting (HyperTerminal®)	Parameter
	– Host address: The IP address of the control unit – Port number: 5005 – Connect using: TCP/IP
	– Terminal Emulation: ANSI – Terminal Setup: - Row: 24 - Columns: 80 – ASCII Setup: - Line delay: 0 - Character delay: 0

5.2 Main Menu

In some cases this menu only shows the workload and the supply voltage. In those cases press ESC on your keyboard. Then the menu is re-loaded completely.

Figure 88 *Terminal program: Main menu*



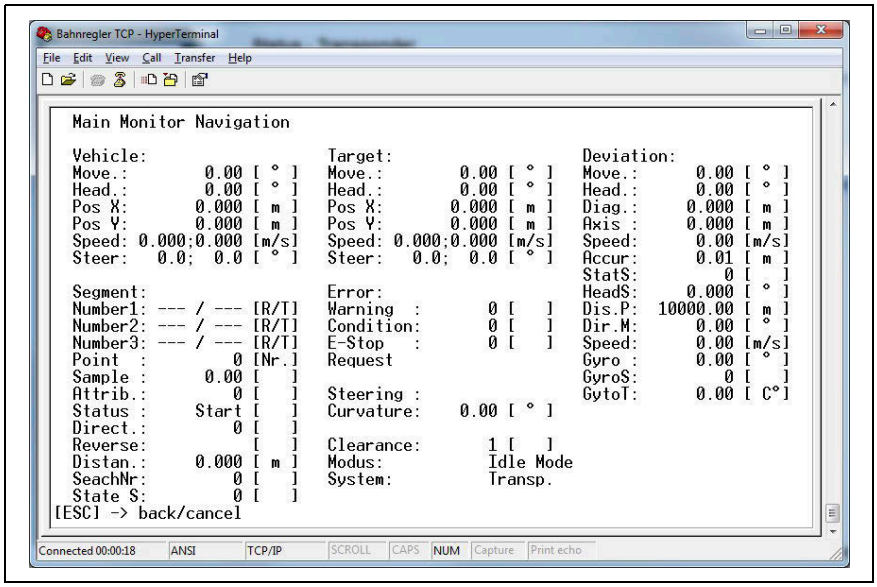
The sub menus are opened via the key for the character shown at the start of each line, e.g. A for *Main Monitor Navigation*. The sub menus are described below. All sub menus can be left by hitting the ESC key, which leads back to the main menu.

The *Parameter Test* menu can only be opened after entering the password *314159*. To do so type the password while the main menu is shown. An extra prompt/input field is not shown. This also unlocks the web sites.

5.3 A: Main Monitor Navigation

On this screen the most important parameters for the navigation are shown.

Figure 89 *Terminal program: Menu Main Monitor Navigation*



5.3.1 Display Output

Under *Vehicle* the current values of the vehicle are shown.

Table 17 *Main Monitor Navigation: Section Vehicle*

Vehicle	Description	Unit
Move	Current direction of movement	[Degrees]
Head.	Current vehicle heading	[Degrees]
Pos X	X component of the position	[Meter]
Pos Y	Y component of the position	[Meter]
Speed	Actual speed of the vehicle	[Meter/Second]
Steer	Current steering angle	[Degrees]

Under *Target* the target values of the current segment are shown.

Table 18 *Main Monitor Navigation: Section Target*

Target	Description	Unti
Move	Target direction of movement	[Degrees]
Head.	Target vehicle heading	[Degrees]
Pos X	X component of the position	[Meter]
Pos Y	Y component of the position	[Meter]
Speed	Target speed of the vehicle	[Meter/Second]
Steer	Target steering angle	[Degrees]

Under *Deviation* the deviations between the actual and the target values are shown.

Table 19 *Main Monitor Navigation: Section Deviation*

Deviation	Beschreibung	Einheit
Move	Deviation direction of movement	[Degrees]
Head.	Deviation vehicle heading	[Degrees]
Diag.	Lateral deviation of the vehicle	[Meter]
Axis	Longitudinal deviation of the vehicle	[Meter]
Speed	Speed error	[Meter/Second]
Accur.	Estimated position accuracy	[Meter]
StatT	Status spot turn	
DifS	Angle deviation spot turn	[Degree]
Dis.P	Distance from velocity pole	[Degree]
DirM	Deviation direction of movement	[Grad]
Speed	Target speed ramp	[Meter/Secund]
Gyro	Angle from Gyro	[Degree]
GyroS	Status of the Gyro, s. Table 68 on page 150	
GyroT	Temperature of the Gyro	[° Celsius]

Under *Segment* the segment data is shown.

Table 20 *Main Monitor Navigation: Section Segment (part 1 of 2)*

Segnment	Description
Number1	Segment received from / transmitted to vehicle controller. This is the most current segment at any one time.
Number2	Segment received from / transmitted to vehicle controller. This is the next segment at any one time.
Number3	Segment received from / transmitted to vehicle controller. This is the next but one segment at any one time.
Point	Number of the last crossed support point on the current segment.
Sample	Position in between support points. At the beginning of a segment Sample is set to 1. It rises up to 3. When the third support point is reached Sample is reset to 2 (the following support points are used to reconstruct the track). After the end of the segment Sample rises above 3 since here no new support points are available.
Attrib.	Current attribute in hexadecimal presentation. The lower 16 bits are pre-configured internal bits, the upper 16 bits can be freely programmed, s. section 2.5.3 on page 29.
Status	What is shown here depends on the position of the vehicle within the segment: – If the vehicle is before the second support point: *Start* – Between the second and third support point: *Start+1* – Between the last but one and last support point: *End-1* – After the last support point: *End* – At all other positions: *Middle*
Direction	Direction of travel
Reverse	Currently not used

Table 20 *Main Monitor Navigation: Section Segment (part 2 of 2)*

Segnment	Description
Distan.	Distance traveled within the segment
SearchNr	No. of manually performed segment searches
State S	Status of the manual segment search

Under *Error* different errors are shown.

Table 21 *Main Monitor Navigation: Section Error*

Error	Description
Warning	See Table 47 on page 136
Condition	Error automatic mode (Table 47 on page 136)
E-Stop	Emergency stop
Request	Error requesting automatic mode (Table 47 on page 136)

Under *Steering* the components of the steering angle are shown.

Table 22 *Main Monitor Navigation: Section Steering*

Steering	Beschreibung
Curvature	Component of the steering angle that is generated by the curvature of the target track

If *Clearance* is set to1 the vehicle controller can operate the control unit.

As soon as manual inputs are transmitted via the terminal program the clearance is revoked. The control unit then only reacts in inputs from the terminal program.

Modus outputs the state of the navigation. The current driving mode is shown, see section 2.6.9 on page 42.

System shows, whether driving is performed using GPS or Transponders.

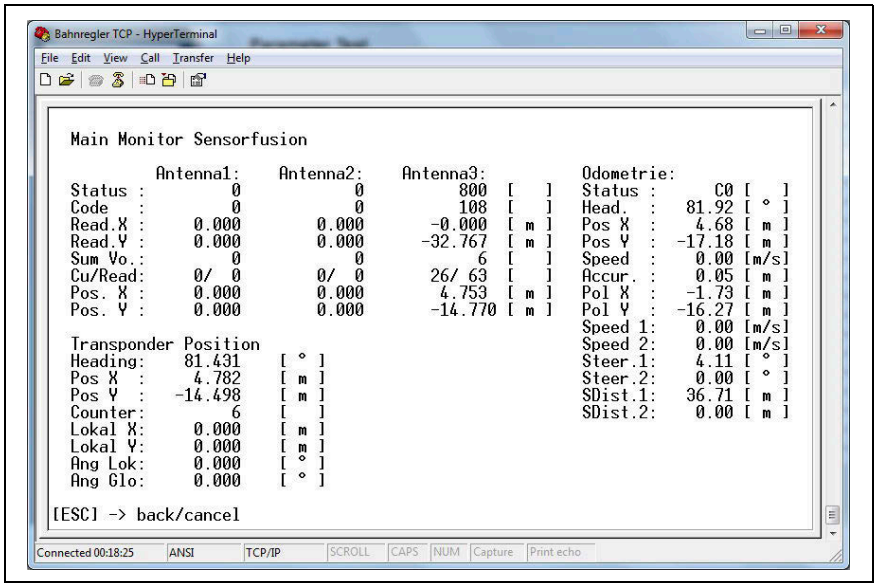
5.3.2 Input Possibilities

With ESC you can return to the main menu.

5.4 B: Main Monitor Sensorfusion

On this screen the most important parameters of the sensor fusion are shown.

Figure 90 *Terminal program: Menu Main Monitor Sensorfusion*



5.4.1 Display Output

Under *Antenna 1 / Antenna 2 / Antenna 3* the state of up to 3 antennas is shown:

Table 23 *Main Monitor Sensorfusion: Section Antenna 1 / 2 / 3*

Antenna 1 / 2 / 3	Description	Unit
Status	Bit coded state of the antenna	
Code	Read transponder code	
Read.X	X position of the transponder converted into the vahicle coordinate system	[Meter]
Read.Y	Y position of the transponder converted into the vahicle coordinate system	[Meter]
Sum Vo.	Sum voltafe of the transponder (represents the quality of the reception level, has to be higher than 400)	
Cu/Read	Current consumption of the transmitter	
Pos. X	X position of the transponder, taken from transponder table	[Meter]
Pos. Y	Y position of the transponder, taken from transponder table	[Meter]

Under *Odometrie* the state of the odometry is shown:

Table 24 *Main Monitor Sensorfusion: Section Odometrie*

Odometrie	Description	Unti
Status	Status byte of the odometry in the CAN bus telegram s. Table 70 on page 152	
Angle	Vehicle angle (mathematically positive)	[^{o}]
Pos X	X position of the vehicle	[Meter]
Pos Y	Y position of the vehicle	[Meter]
Speed	Vehicle speed	[Meter/Second]
Accur.	Number of readings of the transponder	[Meter]
Pol X	Velocity pole of the odometry in X direction of the global coordinate system	[Meter]
Pol Y	Velocity pole of the odometry in Y direction of the global coordinate system	[Meter]
Speed 1	Speed wheel 1	[Meter/Second]
Speed 2	Speed wheel 2	[Meter/Second]
Steer.1	Steering angle wheel 1	[Degrees]
Steer.2	Steering angle wheel 2	[Degrees]
SDist.1	Sum of the distance traveled by wheel 1	[Millimeter]
SDist.2	Sum of the distance traveled by wheel 2	[Millimeter]

Under *Transponder Position* the most important parameters of the Gyro are shown:

Table 25 *Main Monitor Sensorfusion: Section Transponder Position*

Transponder Position	Description	Unit
Heading	Heading calculated using the transponder system	[^{o}]
Pos X	X position calculated using the transponder system	[Meter]
Pos Y	Y position calculated using the transponder system	[Meter]
Counter	Number of calculations performed so far	
Lokal X	Distance measured between the last two transponders in X direction	[Meter]
Lokal Y	Distance measured between the last two transponders in Y direction	[Meter]
Ang Lok	Angle measured between the last two transponders	[Grad]
Ang Glo	Angle measured between the last two transponders converted to global coordinate system	[Grad]

5.4.2 Input Possibilities

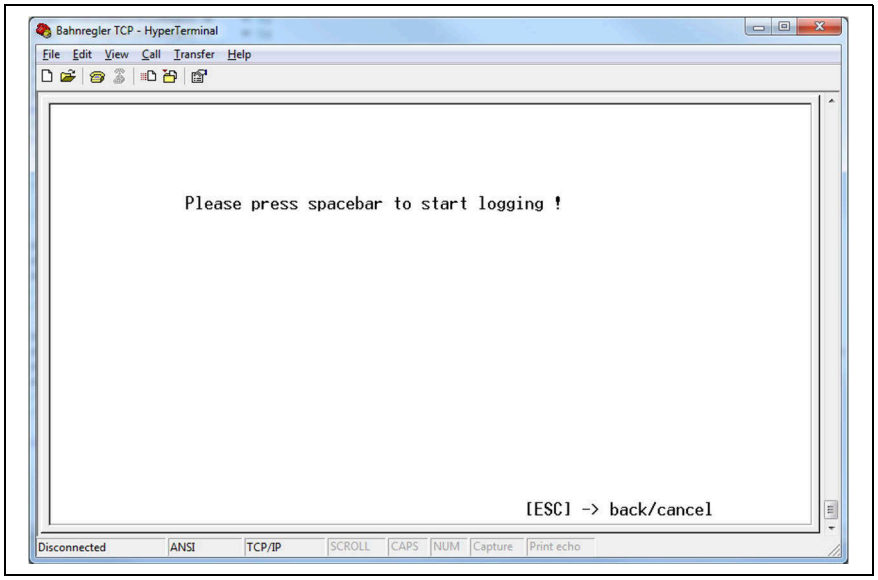
With ESC you can return to the main menu.

5.5 D: Data Logging

On this screen the control unit outputs data that can be logged using the PC. The scope of the data is the same that is output via the USB interface (s. chapter 9 on page 168). However the data output in the terminal program has lower latencies as the USB data output, thus it is faster.

With the terminal program the data can be saved as text or CSV files that can be opened in a text editor or evaluated in a spreadsheet application like e.g. Microsoft® Excel®.

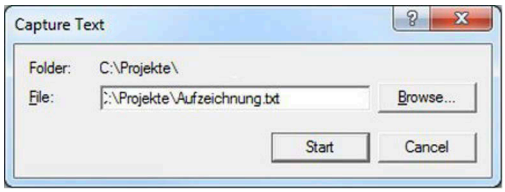
Figure 91 *Terminal program: Menu Datalogging*



In order to log data observe the following sequence:

- Switch from the main menu to this screen
- Start the logging in the terminal program. For e.g. HyperTerminal® use the menu *Transfer*, subitem *Capture Text*.

Figure 92 *Terminal program: Capture Text (data logging)*



- Give the file either the extension *.txt* or *.csv*, then press *Start*.
- Press the spacebar. The control unit starts outputting the data.

In order to stop data logging observe the following sequence:

- Stop the logging in the terminal program. For e.g. HyperTerminal® use the menu *Transfer*, subitem *Stop Capture Text*.
- Then press the ESC key to make the control unit stop the data output.

5.6 E: Parameter Test

This screen, like the web site with the same name (s. section 4.11 „Parameter Test Menu“ on page 94) allows to test parameters and drive the vehicle manually.

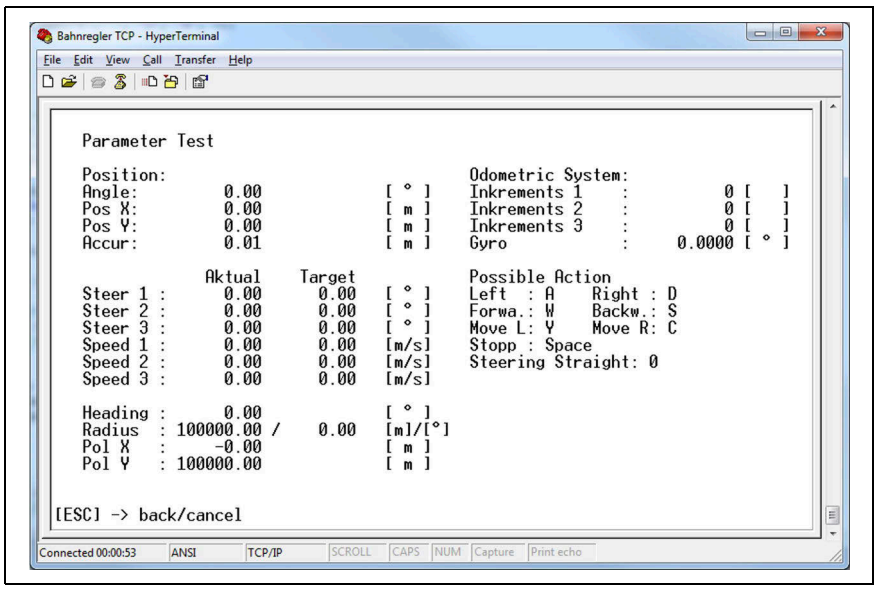
WARNING

Risk of collisions with persons or objects

When controlling the vehicle in the *Test* mode it can happen that the connection between the browser and the control unit freezes or stalls. the vehicle can then no longer be stopped using the browser. Thus use the *Test* mode only

- with extreme caution
- slowly and
- with safety devices such as emergency off within reach.

Figure 93 *Terminal program: Menu Parameter Test*



5.6.1 Display Output

Under *Position* the position of the vehicle is shown.

Table 26 *Parameter Test: Section Position*

Position	Description	Unit
Angle	Vehicle angle (mathematically positive)	[Degrees]
Pos X	X position of the vehicle	[Meter]
Pos Y	Y position of the vehicle	[Meter]
Accur	Accuracy of the position	[Meter]

Under *Odometric System* the sensor data of the odometry are shown.

Table 27 *Parameter Test: Abschnitt Odometric System*

Odometric System	Description	Unit
Inkrements 1	Increments of wheel 1	[ ]
Inkrements 2	Increments of wheel 2	[ ]
Inkrements 3	Increments of wheel 3	[ ]
Gyro	Gyro angle without offsets	[Degrees]

Additionally target and current steering angle as well as target and current speed are shown.

Table 28 *Parameter Test: Section target and current steering angle*

Name	Beschreibung	Einheit
Steer1/2/3 Aktual	Current steering angle	[Degrees]
Steer1/2/3 Target	Target steering angle	[Degrees]
Speed1/2/3 Aktual	Current speed	[m/s]
Speed1/2/3 Target	Target speed	[Meter/Second]
Heading	Target heading	[Degrees]
Radius	Target radius	[Meter/Degrees]
Pol X	X position of the velocity pole in the vehicle coordinate system	[Meter]
Pol Y	Y position of the velocity pole in the vehicle coordinate system	[Meter]

5.6.2 Input Possibilities

The input always refers to a vehicle with an axle distance of 1 meter. When driving a curve only the front wheel is steered. When driving sideways all axles are steered.

Table 29 *Parameter Test: Input possibilties (part 1 of 2)*

Taste	Beschreibung	Einheit
ESC	Returns to the main menu	
a	Target steering angle - 5	[Degrees]
A	Target steering angle - 10	[Degrees]
b	Target steering angle + 5	[Degrees]
B	Target steering angle + 10	[Degrees]
c	Steer sideways - 0,5	[Degrees]
C	Steer sideways - 5	[Degrees]
y	Steer sideways + 0,5	[Degrees]
Y	Steer sideways + 5	[Degrees]
w	Target speed + 0.02	[Meter/Second]
W	Target speed + 0.5	[Meter/Second]
s	Target speed - 0,02	[Meter/Second]
S	Target speed - 0.5	[Meter/Second]

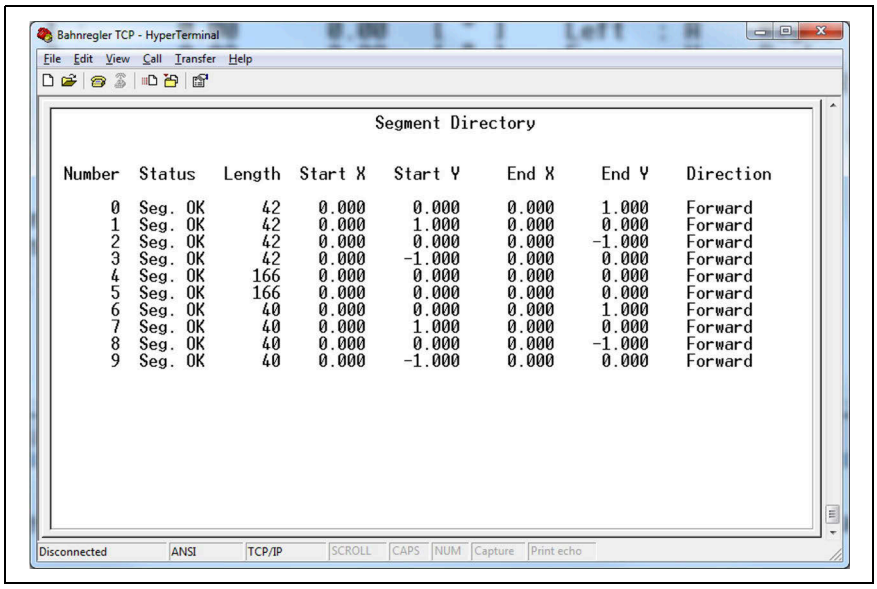
Table 29 *Parameter Test: Input possibilties (part 2 of 2)*

Taste	Beschreibung	Einheit
Spacebar	Target speed = 0	[Meter/Second]
+	Break harder (if available in the vehicle model)	[ ]
-	Break less (if available in the vehicle model)	[ ]

5.7 N: Show Segments

This screen shows the segments stored in the control unit, 10 at a time. Press any key to show the following 10 segments. This works until the last segment is shown. Use ESC to return to the main menu.

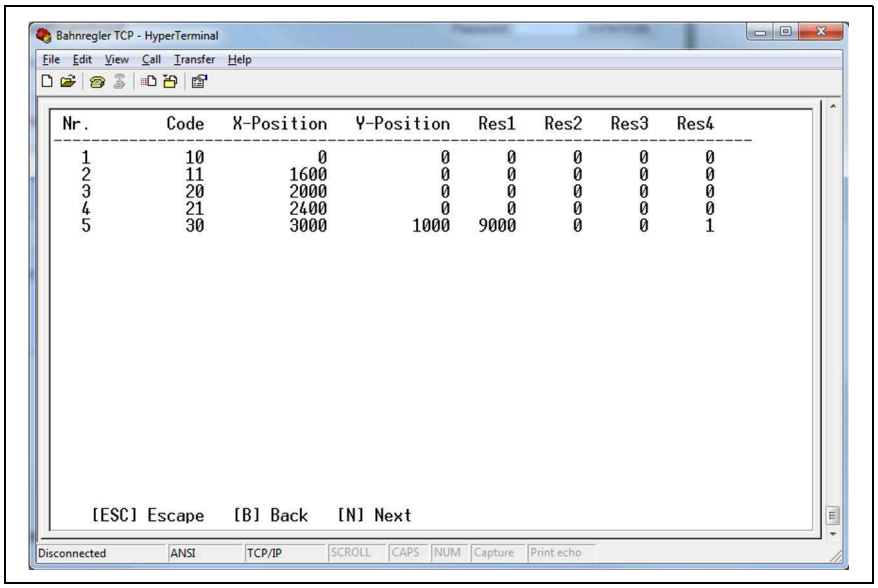
Figure 94 *Terminal program: Menu Segment Directory*



5.8 Q: Show Transponder

This screen shows the transponders stored in the control unit, 20 at a time. With B the following 20 are shown, with N the previous 20. Use ESC to return to the main menu.

Figure 95 *Terminal program: Menu Show Transponder*



5.9 S: Segment Sequences

This screen allows to control segment sequences. You can find an explanation of segment sequences in section 12.2 on page 185. Alternatively segment sequences can be started via the CAN bus, s. section 7.3.18 on page 157.

WARNING

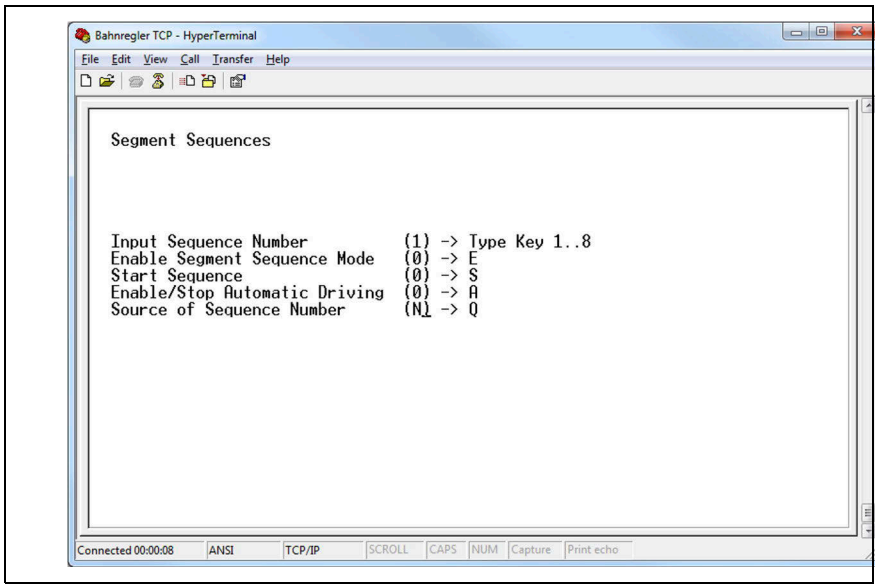
Unpredictable behavior of the vehicle

The terminal program also uses the values transmitted via the CAN bus. Thus it is important to exclusively use the CAN bus OR the terminal program. If both terminal program and CAN bus are used to transmit segment sequences there is a risk of segments being mixed up. Thus the vehcile might choose other segments than the user expects.

- Exclusively use the CAN bus OR the terminal program

In order to minimize this risk the terminal program internally has a higher priority. If segment sequences are started via the terminal program, the CAN bus is ignored.

Figure 96 *Terminal program: Segment Sequences*



The keys shown allow to operate the control unit:

1 ... 8 *Input Sequence Number* Input of the number of the segment sequence to be driven.

E *Enable Segment Sequence Mode* Turns the segment sequence mode on.

S *Start Sequence* Toggling this from 1 to 0 transfers the segments of the sequence into the control unit and starts the automatic driving mode.

A *Enable Automatic Driving* Sets the driving clearance (1) and the vehicle starts moving.

Q *Source of Sequence Number* Sets the source from where to receive the number of the segment sequence:

- 1 = Transponder list = T oder
- 0 = CAN bus / terminal program = N

If the segment sequence is taken from the transponder list, antenna 3 has to be used. The transponders read by this antenna is used to determine the sequences.

6 Commissioning

For installation of the hardware, please refer to section 3.1 on page 46.

6.1 Interfaces usually connected

1. In the case of transponder navigation
   - Antennas and gyroscope via CAN 1
   - Vehicle control system (segments, status...) via CAN 1 or Feldbus.
   - Wheels (CAN 1, CAN 2 or Feldbus)
   - IO4 emergency off output
   - IO 1-3 Posipuls input of antennas 1-3
2. Laser scanner
   - Laser via CAN 1 Otherwise same as transponder
3. GPS
   - GPS antennas
   - Correction date via SIO1
   - Otherwise same as transponder

6.2 Test / Real Operation

If a vehicle is to be put into operation, there are a number of possibilities to do so:

- Simulation and parameter test:
  Particularly if the user is not yet familiar with handling the navigation controller, it is recommended to start with a simulation. The scope of this simulation can vary:
  - If there no vehicle or vehicle control system is present yet, segments can still be 'covered'. It can also be recorded on a USB stick, see chapter 9 on page 168. This enables a check of segments and segment sequences. Moreover, the user practices using the navigation controller.
- If a vehicle control system is present, the communication and segments can be tested using the simulation.
- Real operation: The vehicle is subsequently put into operation.

⚠ DANGER

Danger through missing safety measures

The navigation controller HG G-73650ZD is not a safe device.

- ▶ Only use the navigation controller in applications where sufficient additional precautions for the protection of people and the detection of obstacles have been taken.
- ▶ Make sure that all safety equipment is fully functional before commissioning the vehicle for the first time.

WARNING

Unexpected behavior of the vehicle

When commissioning the vehicle the parameters have not yet been verified by real tests. Thus there is a risk that the vehicle does not behave as expected.

- At the start of commissioning, the vehicle must be jacked up.
- Begin testing in a closed down area.

If the vehicle also has a vehicle control system (recommended), some of the commissioning can be carried out without a vehicle. This concerns the communication between the navigation controller and components as well as the vehicle control system.

6.3 Commissioning the communication

To configure the navigation controller, you can connect a standard PC/laptop to the device via the Ethernet interface ETH. Make sure that the devices have compatible network settings (for example PC IP: 10.10.10.2, navigation controller IP: 10.10.10.20, both network screens 255.255.255.0). To set the IP address on your PC, please consult the documentation for the network setting of the operating system you are using. The default setting in the navigation controller is 10.10.10.20.

Once the PC and navigation controller are connected via the network cable, start a browser that is as up to date as possible on the PC (for example Google® Chrome®) and enter the IP of the navigation controller in the address line, in the example `10.10.10.20`. The main menu of the navigation controller opens. All the menus of the navigation controller are described in chapter 4 on page 52.

6.4 Setting the parameters

You reach the parameters of the navigation controller in the web configuration via the *Configuration* menu. For this example of commissioning, a small forklift truck is to be parameterised.

First of all, you have to enter the password `314159` in the 'Configuration' menu and log in with the *Authenticate* button to be able to change any values.

Every time a parameter is changed on a configuration page, the OK button in the interface should be clicked so that the new parameters are saved permanently in the navigation controller.

Then, enter the following values in the corresponding configuration menus.

You can download the file `parameter_default.txt` from our web site (see below) and upload it into the navigation controller (see section 4.6 on page 89). In that case, all of the parameters listed below for the example are set appropriately.

http://goetting-agv.com/components/73650

If after an update the error message *SErr 0100* blinks on the 7 segment display this doesn't necessarily mean that the file was defect. It could also be that there is a newer Software Version in the control unit already.

In this case switch to one of the parameter sites, enter the password, authenticate and press OK. The control unit then adds the new parameters from the file and saves it. After a re-start of the control unit the message should then be gone.

If this error message appeared check all parameters in case the parameter file was defect after all. In that case upload a correct parameter file.

6.4.1 Configuration -> Main

Table 30 *Example commissioning parameters in Config. Main (part 1 of 2)*

Parameter	Value	Explanation
Trigger Level Digital Inputs	12V	Decision threshold low / high to 12V
Trigger Level Encoder Inputs	12V	Decision threshold low / high to 12V
Vehicle Type	Omnidrive 0	A universal omnidirectional vehicle with properties that are specified via the parameterisation of the wheels is used as the basis for almost all vehicles.
Vehicle Number	1	Vehicle number (for assignment in the case of several vehicles)
CAN1 Protocol	CAN Universal	To date, this is the only available protocol
CAN1 Baudrate	250	Baud rate for the CAN 1 interface
CAN2 Protocol	disabled	Not yet available. CAN messages of the wheels can still be placed on CAN 2
CAN2 Baudrate	250	Baud rate for the CAN 2 interface
Fusion transmit via CAN	On	The sending of the position, alignment and speed on the CAN bus can be controlled here
Log Seg End	On	Once a segment end is reached, it is recorded, even if the vehicle rolls back
Sensor Fusion	Int. Transponder	The vehicle is to move with the help of a transponder antenna: No GPS and no external position sensor.
Simulation	On	This is enabled for the moment in order to be able to carry out the simulation in this description. **Has to be disabled later on to be able to control a vehicle.**
Resolution Segment Points	0.001	The resolution of the test segments is 1 mm (more manageable). To minimise rounding errors in the case of segments that are not located in the direction of a co-ordinate axis or curves, **a resolution of 0.1 mm (0.0001) should be selected for the real segments later here and in the CAD program**.
IP Address	0.0.0.0	When using the UDP interface: IP address of the device with which data is to be exchanged.
Local Port	0	When using the UDP interface: Own port number
Remote Port	0	When using the UDP interface: port number of the other device
Year	15	Current year (without 2000). The date is important for recording data on a USB stick
Month	12	Current month
Day	18	Current day

Table 30 *Example commissioning parameters in Config. Main (part 2 of 2)*

Parameter	Value	Explanation
Hour	14	Current hour
Minute	20	Current minutes
Second	29	Current second

6.4.2 Configuration –> Guidance

If a CAN identifier is set to 0 the corresponding message is not transmitted.

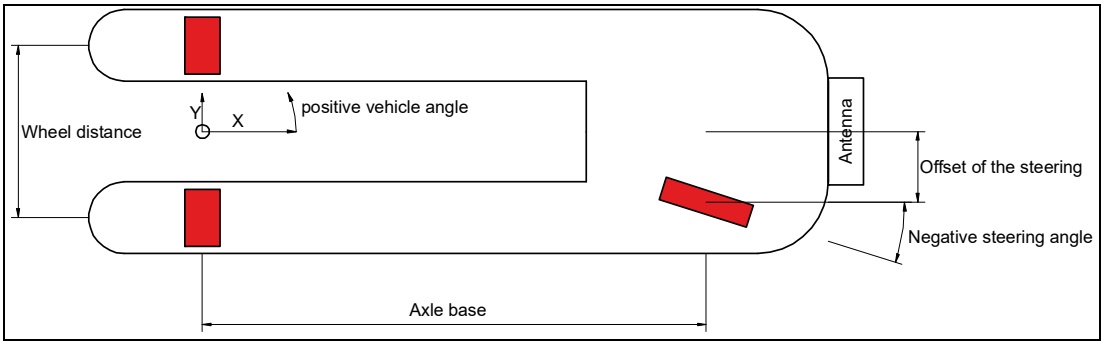
Table 31 *Example commissioning parameters in Config. Guidance*

Parameter	Value	Explanation
CAN ID Rx Segment	772d = 304h	CAN identifier under which the target segment list is received (freely definable, is entered in decimal form)
CAN ID Rx Control	775d = 307h	CAN identifier under which the vehicle control system sends the specifications to the navigation controller (freely definable, is entered in decimal form)
CAN ID Rx Remote	0	CAN Identifier under which the parameters for the remote control are sent (freely definable, is entered in decimal form)
CAN ID Rx Vector	0	CAN Identifier under which the vehicle control sends the parameters for driving with vectors to the control unit (freely definable, is entered in decimal form)
CAN ID Tx Segment	773d = 305h	CAN identifier under which the actual segment list is sent (freely definable, is entered in decimal form)
CAN ID Tx Segment Search	774d = 306h	CAN identifier under which the results of the segment search are sent
CAN ID Tx Status	769d = 301h	CAN identifier under which the navigation controller sends the actual status to the vehicle control system (freely definable, is entered in decimal form)
CAN ID Tx Error message	768d = 300h	CAN identifier under which the navigation controller sends the error messages to the vehicle control system (freely definable, is entered in decimal form)
CAN ID Tx Steering	0	CAN identifier under which the control unit sends the velocity pole to the vehicle control

6.4.3 Configuration –> Wheels

The configuration of the wheels specifies the characteristics of the vehicle. In the case of this vehicle example, the navigation controller must know that there is an unsteered fixed castor and where it is located. With this information, the navigation controller selects the controller for non-omnidirectional vehicles and specifies the symmetry axis (the straight line on which the instantaneous centre of rotation moves during steering).

Figure 97 *Schematic diagram of a forklift truck*



The other fixed castor of the vehicle contains no other information and can therefore be ignored. If this were a driven wheel, it would also have to be parameterized, as the navigation controller would otherwise not calculate any target values for the speed.

The co-ordinate system must always be selected in such a way that the vehicle x-axis points forwards. The steering angle of the wheels and the vehicle orientation are 0 in this direction. If a steering angle or the vehicle turns to the left, the angle becomes more positive. The vehicle alignment moves between 0° and 360°. The steering angles move between -180° and +180°. If the vehicle moves in a forward direction, a wheel with the steering angle 0° must indicate a positive speed.

Table 32 *Example commissioning parameters in Config. Wheels: Wheel 1 (part 1 of 2)*

Parameter Wheel 1	Value	Explanation
Type	Var. Angle	This is a steered wheel
Position X	1,200	X position of the wheel
Position Y	-0.200	Y position of the wheel
Source of Steering Angle	CAN	The steering angle is transferred via the CAN bus
Constant Steering Angle	0.000	Is only important if the type is 'Fix. Angle'
Min. Steering angle	-120,000	Right-hand limit stop of the steering
Max. Steering angle	120,000	Left-hand limit stop of the steering
Angle Offset	0.000	Since the wheel turns on the spot this offset stays at 0
Wheel Offset	0	As the steering angle is transmitted via CAN these can remain at 0
Scaling Steering	0	
Source of Dist. / Speed	Encoder 1	The terminal Encoder 1 is used to determine the path covered by the wheel.
Increments / metre	1000.000	1000 increments per metre
Clearance	----------	Not yet used
Tolerance Angle	5,000	Tolerance of the steering angle

Table 32 *Example commissioning parameters in Config. Wheels: Wheel 1 (part 2 of 2)*

Parameter Wheel 1	Value	Explanation
Tolerance Speed	0.5	Tolerance Speed
CAN ID Tx	632d = 278h	CAN identifier under which the navigation controller sends the target values to the wheel. (freely definable, is entered in decimal form)
CAN ID Tx V	0	Virtual actual steering angle and speed, not sent at 0.
CAN ID Rx	504d = 1F8h	CAN identifier under which the navigation controller receives the actual values for the wheel. (freely definable, is entered in decimal form)
CAN Interface	CAN 2 Std.	See Table 34 on page 115

Since wheel 2 is not steered several of the following parameters are empty/not used.

Table 33 *Example commissioning parameters in Config. Wheels: Wheel 2*

Parameter Wheel 2	Value	Explanation
Type	Fix. Angle	This is a non-steered wheel Specifying this wheel is important so that the navigation controller knows how the vehicle responds.
Position X	0.000	X position of the wheel (vehicle co-ordinate system) Specifies the position of the symmetry axis. **For normal vehicles the symmetry axis must go through the zero point.**
Position Y	0.250	Y position of the wheel (vehicle co-ordinate system)
Source of Steering angle	----------	No steering angle is transferred
Constant Steering angle	0.000	Specifies the direction of the wheel
Min. Steeering angle	0.000	Right-hand limit stop of the steering
Max. Steering angle	0.000	Left-hand limit stop of the steering
Angle Offset	0.000	Not used for wheel 2
Wheel Offset	0	Not used fro wheel 2
Scaling Steering	0	Not used fro wheel 2
Source of Dist. / Speed	----------	As the wheel in the example has no incremental encoder, no source for the speed / increments is entered here either
Inc. / metre	0.000	Is not used
Clearance	----------	Is not used
Tolerance Angle	0.000	Tolerance of the steering angle
Tolerance Speed	0.000	Tolerance Speed
CAN ID Tx	0	Is not used
CAN ID Tx V	0	Virtual actual steering angle and speed, not sent at 0.
CAN ID Rx	0	Is not used
CAN Interface	CAN 2 Std.	See Table 34 below

Table 34 *Example commissioning parameters in Config. Wheels: CAN Interface*

Parameter	Value	Explanation
CAN Interface	CAN 2 Std.	– Specifies that the communication with the wheels is performed via the CAN 2 socket – Std. means that 11 bit identifiers are used

The navigation controller does not have to know the position of the third wheel. Wheel 3 and Wheel 4 are therefore disabled.

Table 35 *Example commissioning parameters in Config. Wheels: Wheel 3*

Parameter Wheel 3	Value
Type	Deactivated

Table 36 *Example commissioning parameters in Config. Wheels: Wheel 4*

Parameter Wheel 4	Value
Type	Deactivated

6.4.4 Configuration –> Antenna

Only one of the antennas is parameterized, as in the example only is mounted. Antennas two, three and four are parameterized as *Deactivated*.

Table 37 *Example commissioning parameters in Config. Antenna*

Parameter Antenna 1	Value	Explanation
Type	HG98820	Smallest of the antennas (± 125 mm scanning width)
Position X	1,500	Position of the transponder antenna in X direction (vehicle coordinate system)
Position Y	0.000	Position of the transponder antenna in Y direction (vehicle coordinate system)
Reading orientation	0.000	As the antenna is mounted in 0° direction this angle stays at 0
CAN ID1	80 (= 50h)	Freely definable; **must match parameterization in the transponder antenna**
CAN ID2	81 (=51h)	Freely definable; **must match parameterization in the transponder antenna**

Other settings directly in the transponder antenna:

- Threshold value for decoding: at least 300
- Threshold value for positioning: Threshold value for decoding + at least 30
- Send at the latest every 10 ms
- Freeze 10 telegrams
- Set the CAN bus with the corresponding baud rate and matching identifiers

The position of the antennas of this vehicle is a negative example, because the antenna is very far from the fixed castors and thus from the symmetry axis (see section 2.3.4.1.1 on page 16).

6.4.5 Configuration –> Accuracy

Table 38 *Example commissioning parameters in Config. Accuracy*

Parameter	Value	Explanation
Accuracy Attribute 0	1,000	To enable relatively free movement, the accuracy limits are set relatively high
Accuracy Attribute 1	2,000	see above
Accuracy Operation	2,000	see above
Deviation Attribute 0	1,000	see above
Deviation Attribute 1	1,000	see above

6.4.6 Configuration –> Steer Controller

Table 39 *Example commissioning parameters in Config. Steer Controller*

Parameter	Value	Explanation
Forward Distance fixed	0.300	For a vehicle of this size and steering with approx. 40^{0}/s, 0.3 metres at a standstill should be an acceptable starting value
Forward Distance variable	0.200	Increases the distance to the destination point at 1 m/s to 0.5 metres (calculation after 0.3 m (Forward Dis. Fix) + 1 m/s * 0.2 (Forward Dis. Var))
Approach Limit fixed	8,000	Vehicle moves with a maximum of 8^{0} back to the track. Initial starting value that can be optimised later
Approach Limit variable	0,000	Can initially remain 0
Regulation Angle Max	30,000	Limits the angles of the steering. To date, only in the remote control mode and with presetting in the 'Parameter Test' menu
Regulation Angle Ramp	0,100	Limits the angle speed of the steering. Currently used in the remote control mode, for Trailer backwards and with presetting in the 'Parameter Test' menu
Speed Spot Turn	0,200	Speed during the spot turn (fastest wheel)
Virtual Point Front	1,600	The point at the front to be regulated is placed near the vehicle front
Virtual Point Rear	-0,800	The point at the rear to be regulated is not as far away from the rigid axle as the front point, but is significantly further way than the forks protrude (a compromise). The vehicle regulates backwards faster onto the track and therefore significantly more "nervous".
Time Forward	0,000	still has to be determined. At low speed, this parameter does not have a very strong effect.

6.4.7 Configuration –> Speed Controller

Table 40 *Example commissioning parameters in Config. Speed Controller*

Parameter	Value	Explanation
Speed Ramp	0.100	Vehicle accelerates each second with 0.1 m/s
Stop Ramp	0.500	When an error occurs the vehicle stops and decelerates with 0.5 m/ss
Vmax. forward	0.500	At the start, driving should be slow. As in this example the start is in the simulation, 0.5 m/s is OK. **For the first trips with a real vehicle, this parameter should be set to 0.1 m/s.**
Vmax. reverse	-0.500	At the start, driving should be slow. As in this example the start is in the simulation, 0.5 m/s is OK. **For the first trips with a real vehicle, this parameter should be set to 0.1 m/s.**
Scaling Speed	0.1	Initially, 10 % of the final speed from the segment should be enough. This can be increased as commissioning progresses.

6.4.8 Configuration –> Sensorfusion Transponder

Table 41 *Example commissioning parameters in Config. Sensor Fusion*

Parameter	Value	Explanation
Min. Dist. Reading	0.200	Should be set in such a way that at least the antenna width is travelled before a new transponder is accepted
Delta Angle Max	400	It is better to disable the monitoring for the moment
Single Antenna calculation	On	There is only one antenna in the example
Gyro	On	Although it is more expensive, in most cases, however, it is also better.
Cycles Correction	20	The position calculated by a transponder is not adopted in a cycle of 10 ms, rather distributed to 20 x 10 ms (ensures smoother steering)
Load Position at Startup	Off	More of a hindrance during commissioning, as some measurements are to start from position 0
Tolerance Trans. Distance Abs.	0.100	The distance of the transponder measured with the odometry should correspond to the distance from the transponder list with a maximum deviation of 0.1 metres so that a valid position can be calculated.
Tolerance Trans. Distance Rel.	1,000	The distance of the transponder measured with the odometry should correspond to the distance from the transponder list with a maximum 1 % deviation so that a valid position can be calculated.

6.4.9 Configuration –> Sensorfusion GPS

In this example, the GPS is not configured, as no GPS is installed in the commissioning example. All parameters can therefore be set at zero.

6.4.10 Configuration –> Gyro

Table 42 *Example commissioning parameters in Config. Gyro*

Parameter	Value	Explanation
Averaging	On	Should always be enabled if the vehicle control system does not take over the averaging.
Averaging Acknowledge	On	At least average until the gyroscope reports that it is within the tolerances
Averaging Delay	10	Averaging the position is started 10 seconds after a standstill in the automatic mode
Averaging Duration	5	Averages for at least 5 seconds if Averaging Acknowledge is not enabled. In the example Averaging Acknowledge is enabled, thus this parameter is not visible.
Auto Switch over	On	The gyroscope uses the equation only if the vehicle speed exceeds the speed set in 'Switch over Speed'
Switch over Speed	0.020	Speed in m/s as of which the gyroscope is used, see 'Auto Switch over'. With the example value the Gyro is only used when the speed is above 0.02 m/s.
CAN ID Tx	273d (=111h)	Identifier of the CAN bus on which the navigation controller transmits to the gyroscope. Freely definable; should correspond to the setting in the gyroscope.
CAN ID Rx	272d (=110h)	Identifier of the CAN bus on which the gyroscope transmits to the navigation controller. Freely definable; should correspond to the setting in the gyroscope.

Other settings directly in the gyroscope:

- The gyroscope should transmit every 10 ms
- The threshold value as of which the gyroscope reports that averaging is OK should be set in such a way that it is also reached under adverse conditions (wind, motor running, cold, etc.). The best setting can be determined by trial and error. Default is 0.005.
- Averaging on switching on should be disabled.

6.4.11 Configuration –> Servo

In this example, no Servos are used. The *Number of Used Servo* can thus remain at 0 and no parameters have to be set.

6.4.12 Configuration –> Trailer

In this example, the Trailer is not used. The Trailer Type should thus be -----.

6.5 Creating the segments

Without segments, the navigation controller can only be used to a very limited degree. Without segments, the navigation controller in the remote control mode can convert the specifications of the vehicle control system into the different driving modes (1: Symmetric steering forward, 2: Symmetric steering sideward, 3: Dog tracking forward 4: Dog tracking sideward, 5: Spot turn, 6: specification of a velocity pole). Or the vehicle is controlled via the website 'Parameter Test'.

Normally, however, the vehicle is controlled by the navigation controller in the automatic mode. To do so, it needs segments. Test segments are available so as not to commission a new vehicle at the customer right away. These should be simply structured, bur contain at least one longer straight section, a curve and a backwards segment. A sample segment file, to which this description also refers, is available in the download area:

`segmente_default.csv` on the site
http://goetting-agv.com/components/73650

This segment file contains segments for a small vehicle. However, these can be enlarged for example using the parameter 'Configuration –> Main > Resolution Segments or in Excel (multiply X and Y co-ordinates by a factor). This segment file contains segments for normal vehicles (numbers 0 - 13, 16 and 17), segments for vehicles that are capable of performing a spot turn (numbers 14, 15, 18, 19) and segments for omnidirectional vehicles (numbers 22-27). The best way to get an overview of the segment file is to use the Track Editor, which can be reached through the following link in the internet:

http://www.goetting.de/trackeditor

To do so, simply drag and drop the segment file into the track editor. Creating your own files is explained in the description of the CAD program. The simplest segment files (straight sections with spot turn or sidewards travel) can also be created using Microsoft® Excel® or the track editor.

Transferring the segment file

To load the segment file in the navigation controller, the name must start with 'segmente', for example *segmente_02b.csv*. On transfer, the name is tested by the navigation controller; different names are ignored. Before the segment file can be transferred, the password `314159` must be entered. For the transfer, click on the 'Segment File' button and select the file on the hard disk with *Select File*. Then click on the 'Upload Segment File' (PC –> HG61430) button. "Waiting for 10.10.10.20" should then appear in the bottom left of the window for a few seconds. The 'Segment Table' button can be used to check whether the right segments have been transferred. The operation is described in detail in section 4.7.1 on page 90.

6.6 Simulation without vehicle and vehicle controller

Now that the parameters and segments have been set relatively roughly, a first simulation can be carried out. The purpose of this is to ensure a better understanding of the navigation controller or troubleshooting. Operators who have already performed this commissioning a number of time can skip this step.

If the navigation controller has not yet been rebooted after input of the parameters and segments, this reboot should be carried out now.

Subsequently, it makes sense to check whether the enter parameters and the segment file have been loaded. To do so, take a look at the corresponding parameter pages and the *Segment Table* page.

Now, on one of the parameter pages enter the password, log in and switch to the *Parameter Test* page:

- In the 'Segment' table, enter 0 at segment 1 and 1 at segment 2. Segments 3 to 21 must be set to 65535 (placeholders for *no segment*).

- Bottom right next to the segments, click on *OK* to send the changes from the website to the navigation controller.
- Use the *enable List* button to adopt the test list into the target segment list (see Status - Navigation).
- Use the *Auto* button to switch to the automatic mode.
- To run the simulation, use the *enable Release* button to set the segment release.

  Once this has been done, it can be observed in the 'Status' table how the simulation travels the oval specified by the segments.

The simulation can be stopped at any time with the *disable Release* button.

Once the trip has been completed, a new travel request can be entered:

- Click on the *Idle* button.
- Click on *disable List*.
- For example, enter the segment sequence 4, 5, 10 and 16.
- Click on *enable List*. The new segments are adopted into the target segments.
- Optionally, the *enable Loop* button can be used to switch the list into an endless loop of the segments.
- *Auto* switches the navigation controller back into the automatic mode.
- Start the simulation with *enable Release*.

  If a USB stick is plugged into the navigation controller, the data of the trip are also recorded in the simulation.

6.7 Simulation without vehicle and with vehicle controller

If the communication between the navigation controller and vehicle controller is to be tested, this can also be done with the simulation. In this case, the segment lists, the driving mode and the segment releases are sent by the vehicle control system via the corresponding interface. **The 'Segment' table in the parameter test, including all buttons below it, may not be used in this case.**

6.8 Commissioning a vehicle

DANGER

Danger through missing safety measures

The navigation controller HG G-73650ZD is not a safe device.

- Carry out the commissioning of a (new) vehicle carefully and with caution.
- Only use the navigation controller in applications where sufficient additional precautions for the protection of people and the detection of obstacles have been taken.
- Make sure that all safety equipment of the vehicle is fully functional.
- Make sure that you can always stop the vehicle safely even if the control unit has a failure.

For commissioning of the vehicle, as described above, all parameters should be set initially. Parameters that are not known exactly should be estimated as well as possible. Most of these parameters (for example 'Increments / Meters') are optimized in the course of commissioning.

6.8.1 Testing and Optimizing the Parameters

WARNING

Unexpected behavior of the vehicle

When commissioning a vehicle the parameters have not yet been verified by real tests. Thus there‘s a risk that the vehicle doesn‘t operate as expected.

- Never go into automatic mode immediately with a freshly parameterized vehicle.

This can mean that the vehicle suddenly behaves unexpectedly due to incorrect parameters. This is why the test and optimization of the parameters are initially carried out with the manual control system of the vehicle. If this possibility does not exist, the vehicle must be pushed or set in motion in some other manner.

- ✓ **The parameter 'Configuration –> Main –> Simulation' must be disabled.**
- ✓ The parameter 'Configuration –> Speed Controller –> Scaling Speed' should be set to a tenth of the theoretically calculated value.
- ✓ The parameter 'Configuration –> Speed Controller –> Vmax. forward' should be less than 0.5.
- ✓ The parameter 'Configuration –> Speed Controller –> Vmax. reverse' should be greater than -0.5.

- The starting point is always the plausibility of the steering angle.
  Most important here is the setting of the zero angle. Where possible, this angle should be set at the sensor or mechanically. If this does not work, the parameter 'Wheels –> Angle Offset' can also be used. It is important to make sure here that no mechanical limit stops of the steering angle sensor are damaged, as they are not installed symmetrically.
- Test the direction and scaling of the steering angle.
  To do so, turn the wheel to the right to an angle that permits easy measurement (for example -90^{0} or limit stop). A negative steering angle with the value actually turned should now be displayed at the corresponding wheel. Otherwise make a correction.
- Check of the path detection
  To do so, move the steering angle into the 0^{0} position. Subsequently, move the vehicle forwards and make sure that all wheels indicate a positive speed. Otherwise correct the path detection (for example by swapping the A and B tracks of the incremental encoder). Repeat the test backwards (the speeds of the wheels should now be negative). Then switch the vehicle off and on again. Make sure that both the alignment (Heading) and the position (Pos X and Pos Y) in the 'Status –> Navigation' menu are at zero. If this is not the case, it is likely that an old position was loaded on starting –> disable the parameter. Alternatively, the alignment and position can also be set to zero in the 'Parameter Test' menu (do not forget the password). Measure a track of approx. 5 m straight ahead in front of the vehicle and then drive the vehicle manually along this track. ***It is not important to drive exactly 5 metres, but the distance actually covered should be measured exactly.*** The distance should be positive. If the displayed distance is longer than the distance actually driven, the parameter 'Increment / Meters' is set too low. The formula for optimization is:

Figure 98 *Formula: Correction of 'Increment / Meters'*

$$\text{Increment / Metres (new)} = \text{Increment / Metres (old)} \times \frac{\text{Distance (displayed)}}{\text{Distance (actual)}}$$

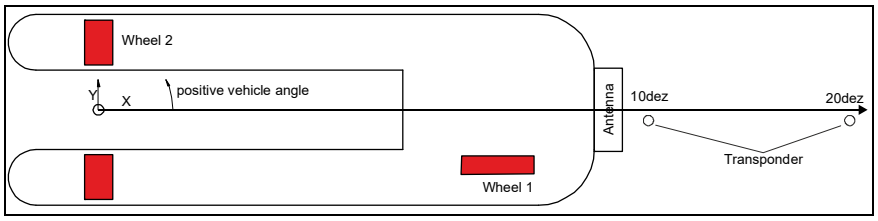
The test should be repeated until the error lies below 1 %. Proceed in the same way for the other sensors.

- Test of the odometry
  Switch the vehicle off and on again and mark the position of the vehicle zero point (in this example, the point between the fixed castors on the ground). Then drive a 90° curve to the left. The alignment of the vehicle should now be 90° and the displayed position should match the actual position (X and Y components should be positive). If they are not, the parameters should be checked once again, particularly the positions of the wheels (also pay attention to the + or - sign).
- Test of the transponder antenna
  Place a transponder 5 cm to the left of the centre of the transponder antennas under the antenna. The transponder should be displayed with the right code in the 'Status –> Transponder' menu. *Read Y* should say 0.05, otherwise check the parameters! The output takes the set orientation of the antenna into account. If it says -0.05 the parameter Reading Orientation has to be set to 180°. When the Reading Orientation is set correctly the output corresponds to the vehicle coordinate system.
- Test of the transponder table
  If the transponder table contains the transponder code from the previous test, the position of the transponder set in the transponder list should appear in the 'Status Transponder' menu at 'Tr Pos X' and 'Tr Pos Y'. Otherwise, check / re-transfer the transponder list in the 'Transponder Table' menu
- Test of the transponder fusion
  To test the sensor fusion with transponders, two transponders with the transponder numbers 10dez and 20dez have to be programmed and placed at a distance of 2 meters. These codes have been chosen deliberately to reveal problems with the conversion between hexadecimal and decimal and vice versa. Create a transponder file with these two transponders or download one from the download area:

`transponder_default.csv` on the site
http://goetting-agv.com/components/73650

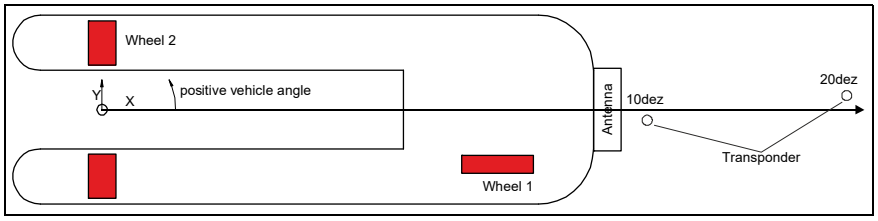
- In this file, transponder 10dez has the co-ordinates X = 0; Y = 0 and transponder 20dez the co-ordinates X = 2000; Y = 0. The results of the following tests will deviate from the displayed values by a few centimetres, but the +/- signs should match. Otherwise, check the parameters – particularly those affecting the geometry of the antennas and wheels. If the vehicle now moves manually in a straight line from transponder 10dez to transponder 20dez and in doing so remains 5 cm to the left of the transponders and comes to a standstill when the zero point of the vehicle passes transponder 20dez, the following should be visible in the 'Status Transponder' menu (the transponder antenna must have read both transponders for this test):
  - *Table Result:* Heading approx. 0°; X Pos approx. +2.0 m; Y Pos approx. +0.05 m; Counter 1
  - *Table Odometry:* Heading approx. 0°; X Pos approx. +2.0 m; Y Pos approx. +0.05 m; Distance approx. Antenna X Position

Figure 99 *Test run 1 at two transponders*



- The same test once again, only that the transponder antenna passes transponder 10dez 5 cm to the left and transponder 20dez 5 cm to the right. The following should now appear in the 'Status Transponder' menu:
  - *Table Result:* Heading: approx. 357°; X Pos: approx. +2.0 m; Y Pos: approx. -0.05 m; Counter: 2
  - *Table Odometry:* Heading: approx. 0°; X Pos: approx. +2.0 m; Y Pos: approx. -0.05 m; Distance: approx. Antenna X Position

Figure 100 *Test run 2 at two transponders*



With these tests, the vehicle should now have a matching parameterisation, so that the first use of the automatic mode can be attempted. **This does not take place by means of segments, rather where possible with a jacked-up vehicle with the 'Parameter Test' menu of the web site. The vehicle control system must be set to the automatic mode for this test.** Proceed as follows for the test:

- Turn the control unit on.
- In one of the 'Configuration' menus, enter the password.
- On the 'Parameter Test' page, click the *Test* button.
- The navigation controller should now display `Test` on the seven-segment display.
- It should now be possible to use the A and D buttons to change the steering.
- It should be possible to use the W and S buttons to drive the vehicle. If the vehicle cannot be driven, it is likely that there are pending errors. This can be checked in the 'Status –> Error' menu.
- Click on the *Idle* button to exit the test mode.

Once this test has been successfully completed, automatic driving by segments can begin. In order to reference the vehicle a number of times, at least two transponders must be positioned and driven over a number of times. The odometry only makes relative measurements. If two transponders are driven over, the absolute position can be calculated and the odometry set (referenced) to this position.

As almost all segments start from X = 0 and Y = 0 and first of all move one meter straight ahead, with a position of the transponder antenna of X = 1.5 meters (vehicle co-ordinates) it is a good idea to place a transponder (11dez) at X = 1.6 meters Y = 0 metres and the other transponder (21dez) at X = 2.4 meters Y = 0 meters. **Transponders 10dez and 20dez should be removed, as the resulting distance between the transponders would otherwise be too short.**

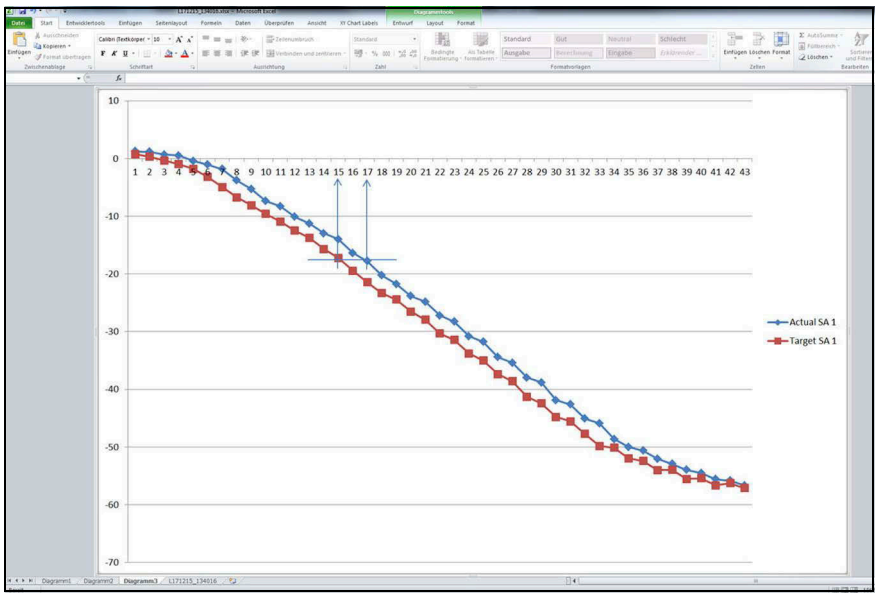
Once the transponders have been programmed and the transponder list is updated, the vehicle can be tracked onto the test track by driving over at least two transponders in succession. If the navigation controller displays a value less than 0.1 metres in the 'Status –> Navigation' menu in the 'Deviation' table at 'Accuracy', tracking has succeeded.

Segments can now be specified with the vehicle control system. These must appear in the table 'Seg. Table'. Subsequently, the vehicle control system can place the navigation controller in automatic mode in that a 1 is sent in the control box (CAN bus) in operation mode. In response, the navigation controller should display `Auto` on the seven-segment display and the 'PLC' table. If the segment release is then set in the CAN Box Path data (target) in the byte *Commands for vehicle guidance*, the vehicle travels the segment provided no errors are pending.

6.8.2 Other Optimisations

If recording on a USB stick is available (see chapter 9 on page 168), the *Time Forward* parameter can be optimised on the 'Configuration –> Steer Controller' page. This specifies the timing of the curve pre-control.

Figure 101 *The actual and target steering angle over time are shown in 10 ms steps*



In this example, it can be seen that the actual steering angle (Actual SA 1) is lagging behind the target steering angle (Target SA 1). To specify the time that the actual steering angle requires to catch up with the target steering angle, two points with approximately the same value are selected. In this example, the actual steering angle at point in time 17 has the same value as the target steering angle at point in time 15. The actual steering angle therefore needs 2 x 10 ms = 20 ms to reach the target value. If 0.02 seconds is now entered in *Time Forward* (section 4.3.6 on page 74), the navigation controller delivers the steering angle for the curve pre-control 0.02 seconds before the value is to apply. This reduces the error in the curve. The steering of the test vehicle that is used is very fast. Usually, the time difference will be even higher.

Once the track has been covered a few times, it can be read in the log files (USB stick) at what positions of the track which deviations and accuracy can be expected.

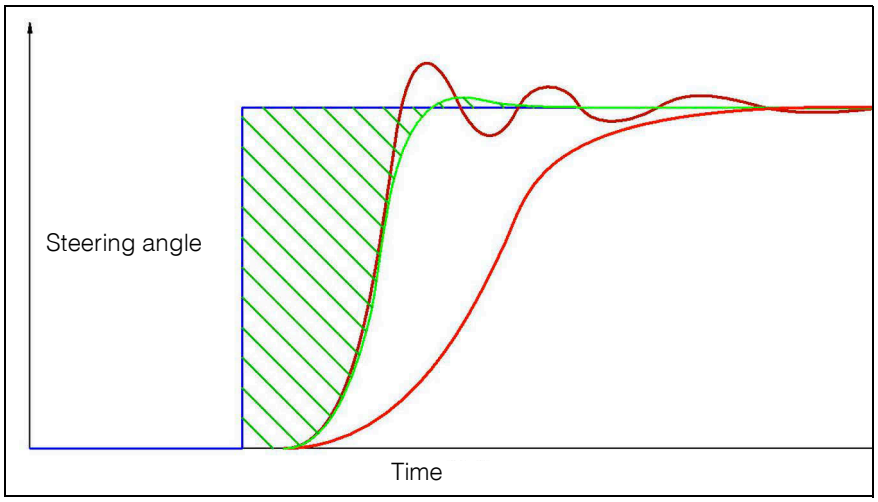
To optimize safety, the parameters 'Accuracy Attribute 0/1' and 'Deviation Attribute 0/1' should be adapted accordingly on the 'Configuration –> Accuracy' page (see section 4.3.5 on page 73).

In doing so, a reserve for the values determined is to be kept. If, for example, a deviation of 10 cm is determined at some positions, but at most positions only a maximum of 3 cm, it is a good idea to set the 'Deviation Attribute' in the segment file only at the few positions that have the 10 cm error: Set the parameter *Deviation Attribute 1* to 15 cm and the parameter *Deviation Attribute 0* to 6 cm. With the accuracy, proceed in the same way.

6.8.3 Optimizing the Steering Controller

The aim of the steering servo is to set the steering angle as quickly and exactly as possible.

Figure 102 *Characteristics of differently adj. steering controllers over time*



- The graphic shows a steering angle jump (blue curve).
- The dark red curve represents a steering controller that tends to oscillate.
- The bright red curve represents a very slow steering controller.
- The green curve represents a well adjusted steering controller.

The optimum is reached, when the shaded area between the target and actual angle is as small as possible. This area corresponds to the approximate proportional lateral error the vehicle will have on driving the curve.

As can be seen in the diagram, a considerable portion of the area arises due to the dead time from the jump of the target elbow to the first reaction of the steering. This time arises due to the necessary communication of the individual components, activation times of valves etc. This is why it is necessary to optimize here. **Fast communication across as few control systems as possible is the best.** Valves that are as fast as possible and/or strong and fast steering servos should also be fitted.

⚠ WARNING

Unexpected behavior of the vehicle

The maximum speed of the vehicle, particularly in curves, depends on the speed and response time of the steering. Driving too fast means that the vehicle leaves the track or can't stop when it's supposed to halt.

- ▶ Drive slowly
- ▶ Use the commissioning to test, which maximum speeds are possible in different situations (curves, straight-ahead driving). Start with really slow speeds, then gradually drive faster.

The target steering angles should also be set as precisely as possible. For example, if a dead band of one degree is permitted, the vehicle will oscillate around the target line. That happens because the vehicle moves so far from the target track until the target steering angle exceeds the dead band. Only then does a correction take place. The vehicle runs over the target line and, on the other hand, the vehicle only reacts if the deviation of the vehicle has become so large that the target steering angle breaks through the dead band.

6.8.4 Optimizing the Speed Ramps

A number of ramps are active in the speed control. The ramp of the navigation controller can be adjusted with the parameter *Speed Ramp* on the Configuration –> Speed Controller page (see section 6.4.7 on page 118).

This ramp refers to a time: If the parameter is set to 0.5, the vehicle reaches 0.5 m/s after one second and 1 m/s after two seconds. **It is important here that the vehicle must be technically capable of building up these accelerations.** What makes this even more difficult is that the speed profile that arises on creating the segments with CAD6 contains fixed-location speeds. This means that the acceleration resulting from the speed profile in the segment file is higher at high speeds than at speeds.

WARNING

Unexpected behavior of the vehicle

If speed changes are wrongly chosen the vehicle can not perform actions as intended. This can e.g. mean that the vehicle still has a too high speed at segment ends and consequently overshoots the intended stopping point.

- ▶ Drive slowly
- ▶ Use the commissioning to test, which maximum speeds are possible in different situations (curves, straight-ahead driving). Start with really slow speeds, then gradually drive faster.
- ▶ Adjust the speed ramps to match the speeds

Example:

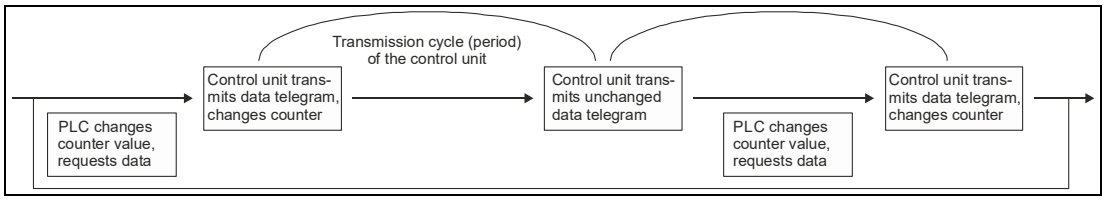
- Support point clearance = 0.5 m
- In the case of a speed change from 1.1 m/s to 0.9 m/s, the vehicle travels an average of approx. (1.1 m/s + 0.9 m/s) / 2 = 1 m/s. From the first to the second support point, it requires approx. 0.5 m / 1 m/s = 0.5 s. This results in a necessary acceleration of approx. 0.2 m/s / 0.5 s = **0.4 m/ss**.
- In the case of a speed change from 0.3 m/s to 0.1 m/s, the vehicle travels an average of approx. (0.3 m/s + 0.1 m/s) / 2 = 0.2 m/s. From the first to the second support point, it requires approx. 0.5 m / 0.2 m/s = 2.5 s. This results in a necessary acceleration of approx. 0.2 m/s / 2.5 s = **0.08 m/ss**.

7 CAN Bus Protocol

On the following pages you'll find tables showing the structure of the telegrams used on the CAN Bus. The internal CAN module is based on the CAN specification V2.0 part B. Typically standard frames are transmitted, for some messages extended frames may be set (see section 4.3.3.6 on page 69).

In some cases one telegram is not enough to transmit all data in one go. In these cases the data is split over several consecutive telegrams. Because of the fact that control unit and PLC have different transmission cycles in those cases counters (switch bits) are used to synchronize the telegram exchange:

Figure 103 *CAN synchronization via counters*



The control unit can only transmit in fixed cycles. Nonetheless it is able to receive and buffer telegrams from the PLC at all times. Thus it can answer with new data in each telegram it sends if the PLC signals that it successfully has received the last telegram by changing the counter in between.

An example of how this synchronization works is shown for the transmission of several error messages in section 7.2.4 on page 133.

7.1 How to send Segments to the Control Unit via the CAN Bus

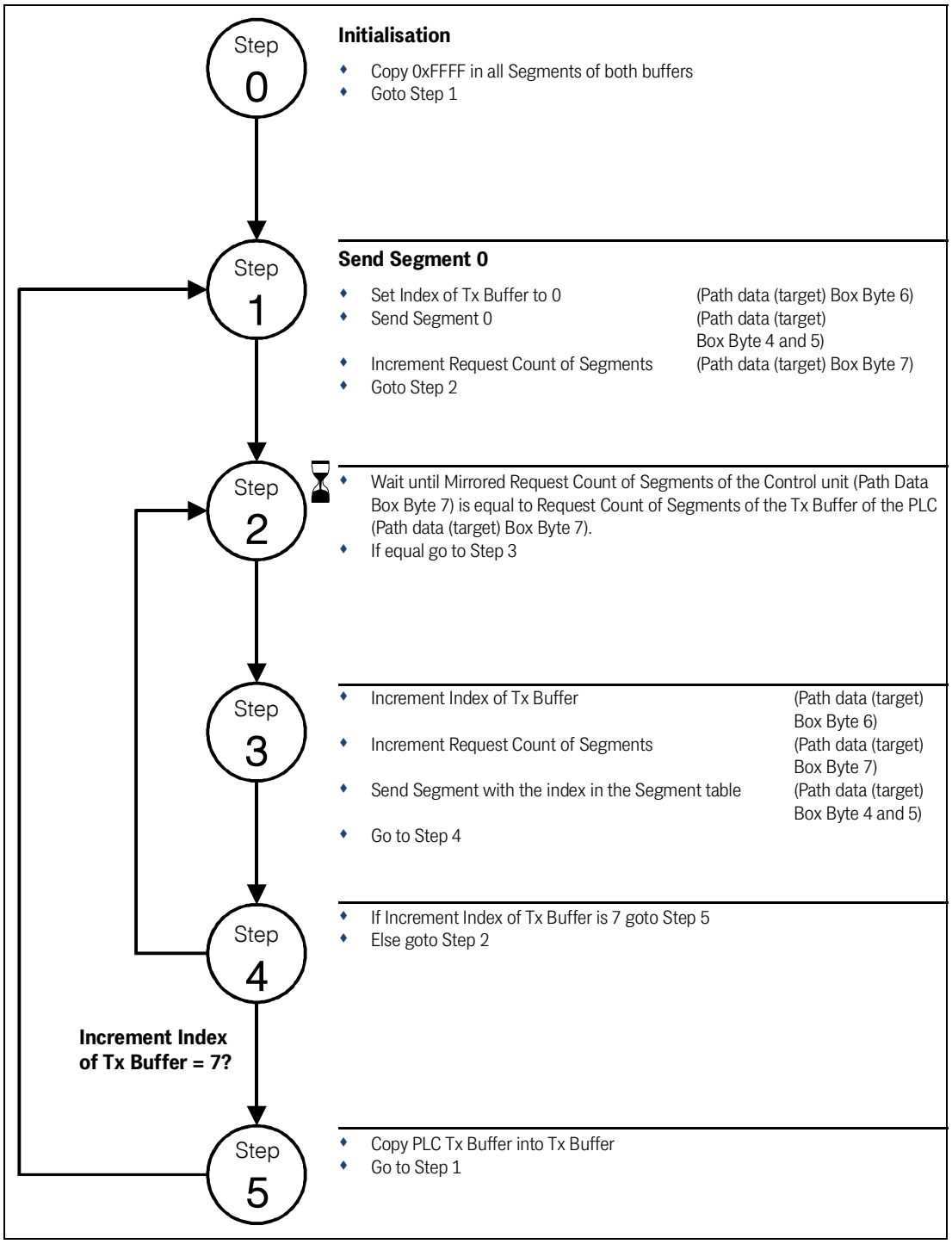
Make sure never to mix the current Segment List with an old one. Otherwise the control unit reports errors.

Define two buffers:

1. Tx buffer with 8 segments (index 0 to 7)
2. PLC Tx buffer with 8 segments (index 0 to 7)

The Segment List to be transmitted has to be complete (8 Segments). If less than 8 Segments are to be driven, the remaining Segments have to be filled with 0xFFFF (65535). Several Segments that are navigable may not be separated by 0xFFFF. The main program of the PLC only has access to the PLC Tx buffer. The transmission routine sends via the Tx Buffer according to the state machine shown below. After index 7 of the Tx Buffer is sent, it copies the PLC Tx buffer into the Tx buffer.

Figure 104 *State machine segment transmission via CAN buffers*



7.2 Transmission Telegrams from Control Unit to PLC, the Wheels and the Gyro

7.2.1 Status Box

Table 43 *CAN Rx Telegram: Status Box*

Message	Status Box	
Transmitter	Vehicle Guidance Controller (VGC)	
Receiver	PLC / Vehicle	
Period	10 ms	
ID	Parameter (301h / 769d)	
Data	byte 0	Operation Mode 0 = manual driving 1 = automatic driving 2 = Remote control 3 = Parameter Test 4 = Vector steering
	byte 1	bit-0 New Segment File bit-1 – bit-2 – bit-3 – bit-4 – bit-5 – bit-6 – bit-7 –
	byte 2	Attribute Low Byte
	byte 3	Attribute High Byte
	byte 4	–
	byte 5	–
	byte 6	–
	byte 7	Message-Counter The Message-Counter will be increased with each transmission as sign of operation.

7.2.2 Path Data Box

Table 44 *CAN Tx Telegram: Path data (actual) (part 1 of 2)*

Message	Path data (actual)
Transmitter	Vehicle Guidance Controller (VGC)
Receiver	PLC / Vehicle
Period	20 ms
ID	Parameter (305h / 773d)

Table 44 *CAN Tx Telegram: Path data (actual) (part 2 of 2)*

Message	Path data (actual)	
Data	byte 0	Status of vehicle guidance (LowByte) bit-0 – bit-1 – bit-2 – bit-3 – bit-4 – bit-5 – bit-6 – bit-7 –
	byte 1	Status of vehicle guidance (HighByte) bit-0 – bit-1 Segmentsearch active bit-2 Segmentsearch finished bit-3 – bit-4 – bit-5 – bit-6 – bit-7 –
	byte 2	– Automatic mode / even: Lowbyte of Actual Point Number (Byte 7) – Automatic mode / odd: Lowbyte of Max Point Number (Byte 7) – Vector modes / even: Lowbyte of Distance travelled so far in mm *) – Vector modes / odd: Lowbyte of Full distance of the vector in mm *)
	byte 3	– Automatic mode / even: Highbyte of Actual Point Number (Byte 7) – Automatic mode / odd: Highbyte of Max Point Number (Byte 7) – Vector modes / even: Highbyte of Distance travelled so far in mm *) – Vector modes / odd: Highbyte of Full distance of the vector in mm *)
	byte 4	Lowbyte of segment (table)
	byte 5	Highbyte of segment (table)
	byte 6	– Index number of table (0-7) for the actual segments (not during segmentsearch) – Index number of table (0-max 39) during segmentsearch
	byte 7	Mirrored Request Count of Segments
*) = Output limited to 0 – 32000 mm		

7.2.3 Segment Search Box

Table 45 *CAN Tx Telegram: Segment search*

Message	Segment Search	
Transmitter	Vehicle Guidance Controller (VGC)	
Receiver	PLC / Vehicle	
Period	20 ms	
ID	Parameter (306h / 774d)	
Data	byte 0	Lowbyte of first segment (table)
	byte 1	Highbyte of first segment (table)
	byte 2	Lowbyte of second segment (table)
	byte 3	Highbyte of second segment (table)
	byte 4	Lowbyte of third segment (table)
	byte 5	Highbyte of third segment (table)
	byte 6	Index of the First Segment in the List
	byte 7	Message-Counter The Message-Counter will be increased with each transmission as sign of operation.

7.2.4 Error Box

The following section describes the behavior in case of errors. For this the Tx telegram Error (see below) and the Rx telegram Control Box (s. Table 60 on page 144) are used.

In the example the following errors occur:

1. Segment Release
2. Deviation error: Rear
3. Wheel 2: - Error Speed
   - Error Steering Release
   - Error Driving release
4. Wheel 3: Receive CAN Increments

Each error message consists of the following elements:

- **Error Number, Object Number, Error Code**
  - Error Number: One bit of the Error Bytes 0-3, see Table 46 (e.g. Deviation error = bit 10 in Table 46),
  - Object Number: (e.g. 0 for a mode request object; in case of Wheel 0, 1, 2 or 3 for the corresponding wheels 1, 2, 3 and 4, see Table 47),
  - Error Code: An additional error code for certain error numbers (e.g. Wheels –> Error Speed, defined in Table 47)

The CAN Error telegram is transmitted cyclically every 10 ms. It always contains all actual errors in the error bytes 0-3. Thus the PLC can react immediately as soon as an error occurs. In addition to the errors (Error Numbers) each telegram can only transmit one error code and the corresponding Object Number.

Since not all Error Codes from the example can be transmitted in a single telegram they are split over several telegrams. In order to synchronize with the PLC, which works with a different timing, a two bit counter (switch bits) is used: The PLC transmits e.g. Bit 1 in Byte 5 of the Control Box shown in Table 60. The control unit answers with e.g. Bit 7 in Byte 6 of the error telegram (Table 46).

The control unit receives the PLC Control Box telegrams independently from its 10 ms transmission timing and buffers the last one. Ideally it can then send an error telegram with a new Error Code each time. This depends on the PLC changing the counter Request Count of Error in the meantime. In the next telegram the Control Unit then sets the counter Mirrored Request Count of Error to the same value in order to signal the PLC that new data is coming in. The following applies:

- If all values except for Mirrored Request Count of Error are 0 there is no error.
- If the Error Number is not changed between two telegrams even though the Mirrored Request Count of Error changes there is only 1 error.
- When there are several Errors they are sent in ascending order. As soon as the Error Number decreases in between two telegrams a new sequence begins,

The following image shows the corresponding sequence for the example above:

Figure 105 *CAN Error telegram transmission/synchronization sequence*

Example: 4 Error messages in 4 Telegrams
1. Segment Release
2. Deviation error –> Rear
3. Wheel 2 –> Error Speed & Error Steering release & Error Driving release
4. Wheel 3 –> Receive CAN Increments

Further information:
- Error Numbers: Table 46 on page 135
- Object Numbers: Table 47 on page 136
- Error Codes: Table 47 on page 136
- SPS Control Box: Table 60 on page 144

Cyclical sequence spanning all 4 error messages:

CAN Telegram Error

t = 0

Telegram 1		Meaning	Explanation
Byte	**Value**		
0	0x04	Error	bit-2 Segment Release
1	0x04		bit-10 Deviation error
2	0x01		bit-16 Wheels
3	0x00		–
4	0x01	Error Code	Low Byte: Error Segment Release
5	0x00		High Byte: –
6	0x00	Req. Count & Obj.	Request Count 0 (00) & Object Number (0)
7	0x02	Error Number	2 Segment Release

If PLC has answered with Request Count

t = 10 ms

Telegram 2		Meaning	Explanation
Byte	**Value**		
0	0x04	Error	bit-2 Segment Release
1	0x04		bit-10 Deviation error
2	0x01		bit-16 Wheels
3	0x00		–
4	0x04	Error Code	Low Byte: Rear
5	0x00		High Byte: –
6	0x80	Req. Count & Obj.	Request Count 1 (01) & Object Number (0)
7	0x0A	Error Number	10 Deviation error

If PLC has answered with Request Count

t = 20 ms

Telegram 3		Meaning	Explanation
Byte	**Value**		
0	0x04	Error	bit-2 Segment Release
1	0x04		bit-10 Deviation error
2	0x01		bit-16 Wheels
3	0x00		–
4	0x80	Error Code	Low Byte: Error Speed
5	0x03		High Byte: Error Steering + Driving rel.
6	0x02	Req. Count & Obj.	Request Count 2 (10) & Object No. (Rad 2)
7	0x10	Error Number	16 Wheels

If PLC has answered with Request Count

t = 30 ms

Telegram 4		Meaning	Explanation
Byte	**Value**		
0	0x04	Error	bit-2 Segment Release
1	0x04		bit-10 Deviation error
2	0x01		bit-16 Wheels
3	0x00		–
4	0x02	Error Code	Low Byte: Receive CAN Increments
5	0x00		High Byte: –
6	0x83	Req. Count & Obj.	Request Count 3 (11) & Object No. (Rad 3)
7	0x10	Error Number	16 Wheels

If PLC has answered with Request Count

If new errors occur during the current sequence the corresponding Error Bit is set immediately. If the new error has a higher error number than the currently transmitted error no. its telegram is added to the current sequence. Otherwise the telegram is added to the next sequence

Error Number decreases = new sequence starts

Table 46 *CAN Telegram: Error*

Message	Error Box			
Transmitter	Vehicle Guidance Controller (VGC)			
Receiver	PLC / Vehicle			
Period	10 ms			
ID	Parameter (300h / 768d)			**Error Number** (s. Table 47)
Data	**Error**	byte 0	bit-0 release segment Start bit-1 Segment end reached bit-2 Segment Release bit-3 Stop Distance bit-4 – bit-5 – bit-6 – bit-7 –	0 1 2 3 4 5 6 7
		byte 1	bit-8 Mode request bit-9 Sensor accuracy bit-10 deviation Error bit-11 Emergency Stop bit-12 Error Segment Table bit-13 Error plausibility bit-14 Error System bit-15 –	8 9 10 11 12 13 14 15
		byte 2	bit-16 Wheels bit-17 Antenna bit-18 Camera bit-19 Wire bit-20 Gyro bit-21 PLC bit-22 GPS bit-23 Extern	16 17 18 19 20 21 22 23
		byte 3	bit-24 Servo bit-25 Trailer bit-26 RTI bit-27 Bearing bit-28 – bit-29 – bit-30 – bit-31 –	24 25 26 27 28 29 30 31
	Error Code	byte 4	Low Byte (from Table 47)	(Bit coded = up to 16 errors)
		byte 5	High Byte (from Table 47)	
		byte 6	– bit-0 to bit-5 **Object Number** (from Table 47) – bit 6 & bit-7 **Mirrored Request Count of Error**	
		byte 7	– **Error Number** (0-31) from the bytes 0-3 above / vehicle stops – **Warning Numbers** (> 31, s. Table 47) / vehicle continues operation	

Table 47 *CAN Error Codes (part 1 of 3)*

Error Number	Object Number	Error Code
8 Mode request	–	Errors when requesting automatic drive 0x0001 Speed too high to switch modes 0x0002 Accuracy too low 0x0004 Error segment number 0x0008 Error in point buffer 0x0010 Error Mode
10 Deviation Error	–	0x0001 Front 0x0002 Middle 0x0004 Rear 0x0008 – 0x0010 Trailer Front 0x0020 Trailer Middle 0x0040 Trailer Rear
11 Emergency Stop	–	0x0001 Vehicle is not stopping 0x0002 Vehicle speed too high 0x0004 Driver intervention 0x0008 PLC 0x0200 ONS Angle difference 0x0400 ONS X Pos difference 0x0800 ONS Y Pos difference 0x1000 Gyro 0x2000 Test 0x4000 Anybus 0x8000 UDP
12 Error Segment Table	Segment Index	Index of the table cell containing the wrong segment number 0x0100 Speed too high
13 Error plausibility	–	0x0001 Speed is high but position doesn't change 0x0002 Vehicle in front of segment 0x0004 Vehicle behind segment 0x0008 Vehicle is moving in wrong direction 0x0010 Pos Buffer 0x0020 Segment invalid 0x0040 NAN in Calculation 0x0080 Segmentlist differ from Pos Buffer 0x0100 Wheel 0x0200 Gyro 0x0400 Freeze ONS 0x0800 Offset
14 System Errors	–	0x0001 Error deleting flash drive 0x0002 Error programming of flash drive 0x0004 Error reading from flash drive 0x0010 Error initialising flash drive 0x0020 Error testing flash drive 0x0040 Error defragmenting flash drive 0x0080 USB error 0x0100 No parameter file 0x0200 No segment file 0x0400 No transponder file

Table 47 *CAN Error Codes (part 2 of 3)*

Error Number	Object Number	Error Code
16 Wheels	Wheel Number	0x0001 Error CAN receive 0x0002 Error receive CAN Increments 0x0004 Error receive CAN Steering 0x0008 Error receive Profibus 0x0010 Error receive Ethernet 0x0020 Error receive Reduction 0x0040 Error Steeringangle 0x0080 Error Speed 0x0100 Error Steering release 0x0200 Error Driving release 0x0400 Error Min Steeringangle 0x0800 Error Max Steeringangle 0x1000 Plausibility Angle 0x2000 Plausibility Speed
17 Antenna	Antenna Number	0x0001 PDO 1 Offline 0x0002 PDO 2 Offline
20 Gyro	–	0x0001 Gyro Offline 0x0002 Gyro is compensating the drift
21 PLC	–	0x0001 Error PLC receive 0x0002 Error PLC receive (according to old communication)
22 GPS	–	0x0001 No data from GPS 0x0002 No base vector from GPS 0x0004 Lock has dropped to 0 0x0010 No GPS correction data 0x0040 GPS not sufficient for autosteering 0x0100 Deviation Longitudinal 0x0200 Deviation lateral
23 Extern	–	0x0001 No extern position received 0x0002 No remote data received 0x0004 No vector data received
24 Servo	Servo Number	0x0001 Error Receive – Servo is not received 0x0002 Error Init – is set during initialisation to disable the servo 0x0004 Error Mode A – Servo not in correct operation mode 0x0008 Error Toggle, currently not used 0x0010 Error Timing, currently not used 0x0020 Error Servo 0x0040 Error Mode B – error regarding the Servo mode 0x0080 Error Reset – Control Unit resets the Servo after an error 0x0100 Error Reference – error regarding the Servo angle transmitter

Table 47 *CAN Error Codes (part 3 of 3)*

Error Number	Object Number	Error Code
25 Trailer	–	0x0001 Error Receive – kink angle not received 0x0002 Error Valid – kink angle invalid 0x0004 Error Trailer 0x0008 Error Count – counter in CAN box doesn't change
26 RTI	–	0x0001 Error RX_CPC3 0x0002 Error RX_CPC3_1 0x0004 Error RX_EBS 0x0008 Error RX_APS 0x0010 Error RX_EIS 0x0020 Error RX_COM 0x0040 Error RTI_ERROR 0x0080 Error RTI_E_STOP 0x0100 Error THROTTLE 0x0200 Error SPEED 0x0400 Error GEAR 0x0800 Error BRAKE 0x1000 Error STEERING 0x2000 Error RTI 0x4000 Error HAND_BRAKE 0x8000 Error EBS
27 Bearing	–	0x0001 Error Receive – CAN message not received 0x0002 Error Count – counter in CAN box doesn't change 0x0004 Error Bearing – bearing is not ok 0x0008 Error Angle – angle in wrong direction 0x0010 Error Angle – angle too big
Warnings (unlike errors, the vehicle doesn't stop on warnings, s. Table 46 on page 135)		
32 Transponder not in List	Antenna Number	Transponder Code which is not in Transponder list, currently not used
33 Transponder absent	Antenna Number	Transponder Code which is expected but missing, currently not used
41 Sensor Accuracy	–	–
42 Deviation Warning	–	–
48 Wheel Warning	Wheel Number	–

7.2.5 Sensorfusion Boxes

If the control unit calculates the sensor fusion internally (see web site Configuration Main in section 4.3.1 on page 64), the sensor fusion boxes can alternatively be transmitted from the control unit to the PLC via *Fusion Transmit via CAN*. The structure of the boxes is shown in section 7.3.8 on page 151.

7.2.6 Wheel Boxes

Table 48 *CAN Tx Telegram: Wheel Tx*

Message	Wheel Tx	
Transmitter	Vehicle Guidance Controller (VGC)	
Receiver	PLC / Vehicle	
Period	10 ms	
ID	Parameter CAN ID Tx for the respective wheel, see section 4.3.3.6 on page 69	
Data	byte 0	Lowbyte Target Steering Angle Format: 16-bit complement to two Resolution: 0.01° Value range: -180.00° ...+180.00° Offset: 0
	byte 1	Highbyte Target Steering Angle
	byte 2	Lowbyte Target Speed Format: 16-bit complement to two Resolution: 1 mm/s Value range: -32768mm/s ...+32767mm/s Offset: 0
	byte 3	Highbyte Target Speed
	byte 4	Lowbyte Target Radius Format: 16-bit complement to two Resolution: 1 mm Value range: -32767mm ...+32767mm (see section 12.3 „Radius Calculation with 16 Bit Resolution“ on page 185) Offset: 0 -32768mm means that Radius is infinite
	byte 5	Highbyte Target Radius
	byte 6	Lowbyte Command (s. Table 49 unten)
	byte 7	Highbyte Command (s. Table 49 unten)

Table 49 *Wheel Tx Command Bits*

Command	
Bit 0..12	not used
Bit 13	Steering enable
Bit 14	Driving enable
Bit 15	Toggle

Table 50 *CAN Tx Telegram: Wheel Tx Virtual*

Message	Wheel Tx Virtual	
Transmitter	Vehicle Guidance Controller (VGC)	
Receiver	PLC / Vehicle	
Period	10 ms	
ID	Parameter CAN ID Tx Virtual for the respective wheel, see section 4.3.3.6 on page 69	
Data	byte 0	Lowbyte Target Steering Angle Format: 16-bit complement to two Resolution: 0.01° Value range: -180.00° ...+180.00° Offset: 0
	byte 1	Highbyte Target Steering Angle
	byte 2	Lowbyte Target Speed Format: 16-bit complement to two Resolution: 1 mm/s Value range: -32768mm/s ...+32767mm/s Offset: 0
	byte 3	Highbyte Target Speed
	byte 4	Lowbyte Target Radius Format: 16-bit complement to two Resolution: 1 mm Value range: -32767mm ...+32767mm Offset: 0 -32768mm means that Radius is infinite
	byte 5	Highbyte Target Radius
	byte 6	Lowbyte Command (s. Table 51 below)
	byte 7	Highbyte Command (s. Table 51 below)

Table 51 *Wheel Tx Virtual Command Bits*

Command	
Bit 0	0: not inverted 1: inverted

7.2.7 CAN Open Start / Stop Box

Table 52 *CAN Tx Telegram: CAN Open Start / Stop*

Message	CAN Open Start / Stop	
Transmitter	Vehicle Guidance Controller (VGC)	
Receiver	Vehicle	
Period	As needed	
ID	0x000	
Data	byte 0	command
	byte 1	Node Address

7.2.8 Servo Box

Table 53 *CAN Tx Telegram: Servo*

Message	Servo	
Transmitter	Vehicle Guidance Controller (VGC)	
Receiver	Servo	
Period	10ms	
ID	Parameter: Configuration Servo CAN ID Tx	
Data	byte 0	Drive Control
	byte 1	Mode Control
	byte 2	Target Speed Low Byte
	byte 3	Target Speed High Byte
	byte 4	Target Pos Low Byte signed long
	byte 5	Target Pos
	byte 6	Target Pos
	byte 7	Target Pos High Byte

7.2.9 Gyro Box

Table 54 *CAN Tx Telegram: Gyro*

Message	Gyro	
Transmitter	Vehicle Guidance Controller, (VGC)	
Receiver	Gyro	
Period	10 ms when needed	
ID	Parameter CAN Tx, see section 4.3.10 on page 81	
Data	byte 0	Command Bit 0: Driftcompensation Bit 1: Angle reset
	byte 1	–
	byte 2	–
	byte 3	–
	byte 4	–
	byte 5	–
	byte 6	–
	byte 7	–

7.2.10 Angle and Speed Box

Table 55 *CAN Tx Telegram: Angle and Speed*

Message	Angle and Speed (when U32_CAN2_PROTOCOL = 2) Is only enabled in exceptional cases by editing the parameter file.	
Transmitter	Vehicle Guidance Controller (VGC)	
Receiver	PLC / Vehicle	
Period	10 ms	
ID	0x294	
Data	byte 0	Steering Angle High Byte (16 Bit signed short) copy of Wheel 1 CAN Box
	byte 1	Steering Angle Low Byte copy of Wheel 1 CAN Box
	byte 2	Steering Angle High Byte (16 Bit signed short) copy of Wheel 2 CAN Box
	byte 3	Steering Angle Low Byte copy of Wheel 2 CAN Box
	byte 4	Speed / Increments High Byte (16 Bit signed short) Wheel 1
	byte 5	Speed / Increments Low Byte Wheel 1
	byte 6	Speed / Increments High Byte (16 Bit signed short) Wheel 2
	byte 7	Speed / Increments Low Byte Wheel 2

7.2.11 ME1 Box

Table 56 *CAN Tx Telegram: ME1*

Message	ME1	
Transmitter	Vehicle Guidance Controller (VGC)	
Receiver	ME	
Period	Sync	
ID	0x1D0	
Data	byte 0	Direction Low Byte
	byte 1	Direction High Byte
	byte 2	Radius Low Byte
	byte 3	Radius
	byte 4	Radius
	byte 5	Radius High Byte
	byte 6	Info
	byte 7	Counter

7.2.12 ME2 Box

Table 57 *CAN Tx Telegram: ME2*

Message	ME2	
Transmitter	Vehicle Guidance Controller (VGC)	
Receiver	ME	
Period	Sync	
ID	0x2D0	
Data	byte 0	0
	byte 1	0
	byte 2	0
	byte 3	0
	byte 4	Low Byte Target Speed
	byte 5	High Byte Target Speed
	byte 6	Bits 1
	byte 7	Bits 2

7.2.13 Pol X/Y CAN2 Box

Table 58 *CAN Tx Telegram: Pol X/Y CAN2*

Message	Pol X/Y CAN2	
Transmitter	Vehicle Guidance Controller (VGC)	
Receiver	PLC / Vehicle	
Period	10ms	
ID	Parameter: Configuration - Guidance - Steering, see 4.3.2 on page 66	
Data	byte 0	Pol X Low Byte signed long [mm]
	byte 1	Pol X
	byte 2	Pol X
	byte 3	Pol X High Byte
	byte 4	Pol Y Low Byte signed long [mm]
	byte 5	Pol Y
	byte 6	Pol Y
	byte 7	Pol Y High Byte

7.2.14 Polar CAN 1 / CAN 2 / CAN 1+2 Box

Table 59 *CAN Tx Telegram: Polar CAN 1 / CAN 2 / CAN 1+2*

Message	Polar CAN 1 / CAN 2 / CAN 1+2	
Transmitter	Vehicle Guidance Controller (VGC)	
Receiver	PLC / Vehicle	
Period	10ms	
ID	Parameter: Configuration - Guidance - Steering, see 4.3.2 on page 66	
Data	byte 0	Travel Direction Low Byte unsigned short 1/100°
	byte 1	Travel Direction High Byte
	byte 2	Target Speed Low Byte signed short 1mm/s
	byte 3	Target Speed High Byte
	byte 4	Distance Pol Low Byte signed long 1mm
	byte 5	Distance Pol
	byte 6	Distance Pol
	byte 7	Distance Pol High Byte (Bit 0-3) Tx Counter (Bit 4-7)

7.3 Reception Telegrams from PLC, Wheels, Antennas, Gyro and Sensor Fusion to the Control Unit

7.3.1 PLC Control Box

Table 60 *CAN Rx Telegram: Control Box (part 1 of 2)*

Message	Control Box	
Transmitter	PLC / Vehicle	
Receiver	Vehicle Guidance Controller (VGC)	
Period	10 ms	
ID	Parameter (307h / 775d)	
Data	byte 0	Operation Mode 0 = manual driving 1 = automatic driving 2 = Remote control 3 = Parameter Test 4 = Vector steering absolute 5 = Vector steering relative
	byte 1	bit-0 Freeze ONS *) bit-1 – bit-2 Offset right bit-3 Offset left bit-4 – bit-5 Error Acknowledge **) bit-6 Emergency Stop active ***) bit-7 Emergency Stop Acknowledge **)

Table 60 *CAN Rx Telegram: Control Box (part 2 of 2)*

Message	Control Box	
	byte 2	Lowbyte Speed Limitation Format: 16-bit Resolution: 1 mm/s Value range: 1..65535mm/s Value 0: Speed Limit not used Offset: 0
	byte 3	Highbyte Speed Limitation
	byte 4	–
	byte 5	Request Count of Error (Bits 0 and 1)
	byte 6	Request Count of Segment search
	byte 7	Message-Counter The Message-Counter will be increased with each transmission as sign of operation.

*) PLC may set this bit while the vehicle stands still and the brakes are active to prevent influences on the vehicle position calculation by vibrating wheels. **Use carefully**, see section 2.3.2 on page 14.
**) By setting „Error Acknowledge/Emergency Stop Acknowledge“ to 1 all errors in the Vehicle Guidance Controller are cleared. This helps to reset errors where the reason for the error has been removed. All errors that are still valid will reappear again. Make sure to only set these Bits to 1 when needed and to set them back to 0 afterwards.
Most of the errors that can appear are self-resetting once the reason disappears. Emergency stops have to be cleared by sending „Emergency Stop Acknowledge“ once.
***) When the PLC sets the bit „Emergency Stop active“ the accuracy is decreased artificially. This ensures that the next position is referenced by measuring transponders or GPS. It is strongly recommended to re-position the vehicle onto the track after emergency stops. Each emergency stop means that the wheels might have blocked which leads to a less accurate position calculation!

7.3.2 Path data (target) Box

Table 61 *CAN Rx Telegram: Path data (target)*

Message	Path data (target)	
Transmitter	PLC / Vehicle	
Receiver	Vehicle Guidance Controller (VGC)	
Period	10 ms	
ID	Parameter (304h / 772d)	
Data	byte 0	Commands for vehicle guidance (LowByte) bit-0 release segment 0 bit-1 – bit-2 – bit-3 – bit-4 – bit-5 – bit-6 – bit-7 –
	byte 1	Commands for vehicle guidance (HighByte) bit-0 – bit-1 Segmentsearch request bit-2 – bit-3 – bit-4 – bit-5 – bit-6 – bit-7 –
	byte 2	Lowbyte of Stop Distance of the last segment Format: 16-bit Resolution: 1 mm Value range: 1..65535mm Value 0: Stop Distance - not used Offset: 0
	byte 3	Highbyte of Stop Distance of the last segment
	byte 4	Lowbyte of segment (table)
	byte 5	Highbyte of segment (table)
	byte 6	Index number of table (0-7) in normal mode
	byte 7	Request Count of Segments

7.3.3 Remote Control Box

Table 62 *CAN Rx Telegram: Remote Control*

Message	Remote Control	
Transmitter	PLC / Vehicle	
Receiver	Vehicle Guidance Controller (VGC)	
Period	10 ms	
ID	Parameter (100h / 256d)	
Data	byte 0	Lowbyte Remote X Format: 16-bit complement to two Resolution: dependant on mode 1 mm / 1 mm/s Value range: -30000 mm/s ... +30000 mm/s Offset: 0
	byte 1	Highbyte Remote X
	byte 2	Lowbyte Remote Y Format: 16-bit complement to two Resolution: dependant on mode 1 mm / 1 mm/s Value range: -30000 mm/s ... +30000 mm/s Offset: 0 See 2.6.9.4 on page 42
	byte 3	Highbyte Remote Y
	byte 4	Remote Mode (s. section 2.6.9.4 on page 42) 0: No remote (normal automatic steering) 1: Symmetric steering forward 2: Symmetric steering sideward 3: Dog tracking forward 4: Dog tracking Sideward 5: Spot turn 6: Pole
	byte 5	Lowbyte Remote Z Format: 16-bit complement to two Resolution: dependant on mode 1 mm / 1 mm/s Value range: -30000 mm/s ... +30000 mm/s Offset: 0 See 2.6.9.4 on page 42
	byte 6	Highbyte Remote Z
	byte 7	Message-Counter The Message-Counter will be increased with each transmission as sign of operation.

7.3.4 Wheel Box

Table 63 *CAN Rx Telegram: Wheel Rx*

Message	Wheel Rx	
Transmitter	PLC / Vehicle	
Receiver	Vehicle Guidance Controller (VGC)	
Period	10 ms	
ID	Parameter CAN ID Rx for the respective wheel, see section 4.3.3.6 on page 69	
Data	byte 0	Lowbyte Actual Steering Angle Format: 16-bit complement to two Resolution: 0.01° Value range: -180.00° ...+180.00° Offset: 0
	byte 1	Highbyte Actual Steering Angle
	byte 2	Lowbyte Actual Speed Format: 16-bit complement to two Resolution: 1 mm/s Value range: -32768mm/s ...+32767mm/s Offset: 0
	byte 3	Highbyte Actual Speed
	byte 4	not used
	byte 5	not used
	byte 6	Lowbyte Status (s. Table 64 below)
	byte 7	Highbyte Status (s. Table 64 below)

Table 64 *Wheel Rx Status Bits*

Command	
Bit 0..12:	not used
Bit 13:	Steering enable
Bit 14:	Driving enable
Bit 15:	Toggle

7.3.5 Servo Box

Table 65 *CAN Rx Telegram: Servo*

Message	Servo	
Transmitter	Servo	
Receiver	Vehicle Guidance Controller (VGC)	
Period	10ms	
ID	Parameter: Configuration Servo CAN ID Rx	
Data	byte 0	Status Low Byte
	byte 1	Status High Byte
	byte 2	Mode
	byte 3	IO
	byte 4	Pos Low Byte signed long
	byte 5	Pos
	byte 6	Pos
	byte 7	Pos High Byte

7.3.6 Antenna Boxes

Table 66 *CAN Rx Telegram: Antenna Status, Code and Deviation*

Message	Antenna Status, Code and Deviation	
Transmitter	Transponder Antenna	
Receiver	Vehicle Guidance Controller, (VGC)	
Period	8 ms	
ID	Parameter CAN ID 1 for the respective antenna, see section 4.3.4 on page 72	
Data	byte 0	Antenna Status Low
	byte 1	Antenna Status High
	byte 2	Antenna Code Low unsigned long
	byte 3	Antenna Code
	byte 4	Antenna Code
	byte 5	Antenna Code High
	byte 6	Antenna Deviation Low
	byte 7	Antenna Deviation High

Table 67 *CAN Rx Telegram: Antenna Info (part 1 of 2)*

Message	Antenna Info
Transmitter	Transponder Antenna
Receiver	Vehicle Guidance Controller, (VGC)
Period	8 ms
ID	Parameter CAN ID 2 for the respective antenna, see section 4.3.4 on page 72

Table 67 *CAN Rx Telegram: Antenna Info (part 2 of 2)*

Message	Antenna Info	
Data	byte 0	Sum Voltage Low
	byte 1	Sum Voltage High
	byte 2	Div Voltage Low
	byte 3	Div Voltage High
	byte 4	Number of readings
	byte 5	Supply Voltage
	byte 6	Antenna Current
	byte 7	Antenna Temp.

7.3.7 Gyro Box

Table 68 *CAN Rx Telegram: Gyro*

Message	Gyro	
Transmitter	Gyro	
Receiver	Vehicle Guidance Controller, (VGC)	
Period	10 ms	
ID	Parameter CAN Rx, see section 4.3.10 on page 81	
Data	byte 0	Angle Gyro Low Float
	byte 1	Angle Gyro
	byte 2	Angle Gyro
	byte 3	Angle Gyro High
	byte 4	Gyro Temp. Low
	byte 5	Gyro Temp. High
	byte 6	Gyro Status Bit 0: Driftcompensation Bit 1: Acknowledge Angle Reset
	byte 7	Message-Counter The Message-Counter will be increased by 1 with each transmission as sign of operation.

7.3.8 Sensor Fusion Boxes

Table 69 *CAN Rx Telegram: Sensorfusion Position X, heading, aerea nr.*

Message	Sensorfusion Position X, heading, aerea nr.	
Transmitter	Sensorfusion	
Receivers	Vehicle Guidance Controller (VGC)	
Period	10 ms	
ID	0x192	
Data	byte 0	X Pos Lowbyte Format: 32-bit complement to two Resolution: 1 mm Value range: -10km ... +10km Offset: 0
	byte 1	X Pos
	byte 2	X Pos
	byte 3	X Pos Highbyte
	byte 4	Vehicle Angle (heading) Lowbyte Format: 16-bit Resolution: 0.01° Value range: 0°... 360° Offset: 0
	byte 5	Vehicle Angle (heading) Highbyte
	byte 6	Status bit-0 Transponder bit-1 GPS bit-2 Laser bit-3 – bit-4 – bit-5 – bit-6 – bit-7 –
	byte 7	Message-Counter The Message-Counter will be increased with each transmission as sign of operation.

Table 70 *CAN Rx Telegram: Sensorfusion Position Y, heading, status of navigation*

Message	Sensorfusion Position Y, heading, status of navig.	
Transmitter	Sensorfusion	
Receiver	Vehicle Guidance Controller (VGC)	
Period	10 ms	
ID	0x193	
Data	byte 0	Y Pos Lowbyte Format: 32-bit complement to two Resolution: 1 mm Value range: -10km ... +10km Offset: 0
	byte 1	Y Pos
	byte 2	Y Pos
	byte 3	Y Pos Highbyte
	byte 4	Vehicle speed (actual) Lowbyte Format: 16-bit complement to two Resolution: 1 mm/sec (Note: Until software version 231 this was cm/sec) Value range: -30 m/sec ... +30 m/sec (-30000 ..... +30000) Offset: 0
	byte 5	Vehicle speed (actual) Highbyte
	byte 6	Status Byte (siehe Table 71 unten)
	byte 7	Message-Counter The Message-Counter will be increased by 1 with each transmission as sign of operation.

Table 71 *CAN Sensorfusion Status Byte*

Bit	Meaning	Unit
0	–	[ ]
1	–	[ ]
2	–	[ ]
3	–	[ ]
4 - 7	Accuracy table, see Table 72 below	[ ]

Table 72 *CAN Sensorfusion Boxes Coding of the accuracy*

Code	Value	Traveled distance since last transponder	Unit
0	10	16	[Meter]
1	7	15	[Meter]
2	5	14	[Meter]
3	3	13	[Meter]
4	2	12	[Meter]
5	1	11	[Meter]
6	0.5	10	[Meter]
7	0.3	9	[Meter]
8	0.2	8	[Meter]
9	0.15	7	[Meter]
10	0.1	6	[Meter]
11	0.07	5	[Meter]
12	0.05	4	[Meter]
13	0.03	3	[Meter]
14	0.02	2	[Meter]
15	0.01	1	[Meter]

7.3.9 Vector Box

Table 73 *CAN Rx Telegram: Vector*

Message	Vector	
Transmitter	PLC	
Receiver	Vehicle Guidance Controller (VGC)	
Period	10ms	
ID	Parameter: Configuration Guidance –> Vector	
Data	byte 0	Pos X Low Byte signed 1mm
	byte 1	Pos X
	byte 2	Pos X High Byte
	byte 3	Pos Y Low Byte signed 1mm
	byte 4	Pos Y
	byte 5	Pos Y High Byte
	byte 6	Heading unsigned char 2°
	byte 7	Speed unsigned char 1cm/s

7.3.10 Steering Encoder Box

Table 74 *CAN Rx Telegram: Steering Encoder*

Message	Steering Encoder	
Transmitter	Encoder	
Receiver	Vehicle Guidance Controller (VGC)	
Period	10ms	
ID	Parameter: Configuration Wheels –> CAN ID Rx Steering Encoder Only visible if Source of steering angle is set to Encoder/ Encoder Inv.	
Data	byte 0	Pos Low Byte
	byte 1	Pos
	byte 2	Pos
	byte 3	Pos High Byte

7.3.11 Contelec Steering Encoder Box

Table 75 *CAN Rx Telegram: Contelec Steering Encoder*

Message	Contelec Steering Encoder	
Transmitter	Encoder	
Receiver	Vehicle Guidance Controller (VGC)	
Period	10ms	
ID	0x1A0 / 0x2A0	
Data	byte 0	Pos Low Byte
	byte 1	Pos High Byte

7.3.12 ME PDO 1 Box

Table 76 *CAN Rx Telegram: ME PDO 1*

Message	ME PDO 1	
Transmitter	ME	
Receiver	Vehicle Guidance Controller (VGC)	
Period	10ms	
ID	0x250	
Data	byte 0	Steering Angle Wheel 1 Low Byte
	byte 1	Steering Angle Wheel 1 High Byte
	byte 2	Steering Angle Wheel 2 Low Byte
	byte 3	Steering Angle Wheel 2 High Byte
	byte 4	Distance Wheel 1 Low Byte
	byte 5	Distance Wheel 1 High Byte
	byte 6	Distance Wheel 2 Low Byte
	Byte 7	Distance Wheel 2 High Byte

7.3.13 ME PDO 2 Box

Table 77 *CAN Rx Telegramm: ME PDO 2*

Message	ME PDO 2	
Transmitter	ME	
Receiver	Vehicle Guidance Controller (VGC)	
Period	10ms	
ID	0x350	
Data	byte 0	Status Bits
	byte 1	Status Bits
	byte 2	Deviation Low Byte
	byte 3	Deviation High Byte
	byte 4	Speed Master Control Low Byte
	byte 5	Speed Master Control High Byte
	byte 6	Load
	Byte 7	Info

7.3.14 ME PDO 3 Box

Table 78 *CAN Rx Telegramm: ME PDO 3*

Message	ME PDO 3	
Transmitter	ME	
Receiver	Vehicle Guidance Controller (VGC)	
Period	10ms	
ID	0x450	
Data	byte 0	Ref Axis X Low Byte
	byte 1	Ref Axis X
	byte 2	Ref Axis X
	byte 3	Ref Axis X High Byte
	byte 4	Ref Axis Y Low Byte
	byte 5	Ref Axis Y
	byte 6	Ref Axis Y
	Byte 7	Ref Axis Y High Byte

7.3.15 Wheel Reduction Box

Table 79 *CAN Rx Telegram: Wheel Reduction (part 1 of 2)*

Message	Wheel reduction
Transmitter	PLC
Receiver	Vehicle Guidance Controller (VGC)
Period	10ms
ID	Parameter: U32_WHEEL_REDUCTION_ID, see section 2.3.3 on page 15

Table 79 *CAN Rx Telegram: Wheel Reduction (part 2 of 2)*

Message	Wheel reduction	
Data	byte 0	Reduction Wheel 1 unsigned char 0-255 in 0.1%
	byte 1	Reduction Wheel 2 unsigned char 0-255 in 0.1%
	byte 2	Reduction Wheel 3 unsigned char 0-255 in 0.1%
	byte 3	Reduction Wheel 4 unsigned char 0-255 in 0.1%

7.3.16 Trailer Box

Table 80 *CAN Rx Telegram: Trailer*

Message	Trailer	
Transmitter	PLC	
Receiver	Vehicle Guidance Controller (VGC)	
Period	10ms	
ID	Parameter: Configuration Trailer –> CAN ID Trailer Angle	
Data	byte 0	King Pin Angle Low Byte unsigned short 1/100°
	byte 1	King Pin Angle High Byte
	byte 2	Status unsigned char Bits 0-2: – 0: Trailer detection timeout – 1: Trailer Absent – 2: King Pin Error – 3: Angle Error – 4: reserved – 5: Trailer present Angle OK Bit 3: Bearing OK Bit 4: Use Bearing
	byte 3	Low byte bearing angle
	byte 4	High byte bearing angle
	byte 5	Low byte bearing distance
	byte 6	High byte bearing distance
	Byte 7	Counter

7.3.17 Bearing Box

Table 81 *CAN Rx Telegram: Bearing (part 1 of 2)*

Message	Bearing
Transmitter	PLC
Receiver	Vehicle Guidance Controller (VGC)
Period	40ms
ID	Parameter: U32_BEARING_ID_REAR, see section 4.3.13 on page 86

Table 81 *CAN Rx Telegram: Bearing (part 2 of 2)*

Message	Bearing	
Data	byte 0	S16_Angle Low Byte Angle on target in 1/100°. Zero degrees is in the direction of the scanner which faces backwards so here 180° relative to the direction of the vehicle. Left turning positive.
	byte 1	S16_Angle High Byte
	byte 2	U16_Distance Low Byte Distance between scanner and target in mm.
	byte 3	U16_Distance High Byte
	byte 4	U16_Status Low Byte Bit 0: Bearing requested Bit 1: Bearing OK Bit 3-7: Mode: 0x00 Normal Mode 0x40 Pallet Mode
	byte 5	U16_Status High Byte
	byte 6	S8_Angle Used depending on the mode, see above and 4.3.13 on page 86
	byte 7	U8_Counter: telegram counter

7.3.18 Segment Sequence Box

With this CAN Box segment sequences are controlled. You can find an explanation of segment sequences in section 12.2 on page 185. Alternatively segment sequences can be started via the terminal program, see section 5.9 on page 108.

WARNING

Unpredictable behavior of the vehicle

The terminal program also uses the values transmitted via the CAN bus. Thus it is important to exclusively use the CAN bus OR the terminal program. If both terminal program and CAN bus are used to transmit segment sequences there is a risk of segments being mixed up. Thus the vehcile might choose other segments than the user expects.

- Exclusively use the CAN bus OR the terminal program

In order to minimize this risk the terminal program internally has a higher priority. If segment sequences are started via the terminal program, the CAN bus is ignored.

Table 82 *CAN Rx Telegram: Segment sequences*

Message	Segment Sequence	
Transmitter	PLC / Vehicle	
Receiver	Vehicle Guidance Controller (VGC)	
Period	10ms	
ID	Parameter U32_CAN_ID_SEG_BLOCK in Parameter file	
Data	byte 0	bit-0 Enable segment sequences inside the control unit bit-1 Toggling from 0 to 1 transmits segment sequence into the control unit bit-2: 0: Stop 1: Clearance for driving bit-3: 0: Number of the segment sequence is provided via CAN message or terminal program 1: Number of segment sequence is read from the transponder list
	byte 1	Number of the segment sequence
	byte 2 - 7	No function

8 Feldbus/Ethernet (UDP) Output

The optional Feldbus module (s. section 3.6 on page 51) enables telegram output via e.g. Profinet. The same telegrams may also be output via UDP protocol using the Ethernet interface.The following tables show the telegram structure.

The supervision of the data transmitted via Profinet/Ethernet is only active if in the last byte a counter is sent. Increment the counter with each new telegram or PLC cycle. Otherwise the control unit might output error messages.

8.1 Tx Transmission Telegram Control Unit –> PLC

Table 83 *Feldbus Protocol Tx Telegram Control Unit –> PLC (part 1 of 5)*

Byte No.	Order	Type	Name	Explanation
0	–	Byte	Operation Mode	– 0 = manual driving – 1 = automatic driving – 2 = Remote control – 3 = Parameter Test (only via Website, s. 4.11 on page 94) – 4 = Vector steering absolute – 5 = Vector steering relative
1	–	Byte	Status	bit-0 = New Segment File
2	H	Word	Attribute	Bit 17-32 of the Segment Attribute at the actual Segment at the actual Point
3	L			
4	–	–	–	spare
5	–	–	–	spare
6	–	–	–	spare
7	–	–	–	spare
8	H	Word	Segment Status	bit-8: – bit-9: Segmentsearch active bit-10: Segmentsearch finished
9	L			
10	H	Word	Number of Points	Automatic mode: Number of Points in the actual Segment Vector modes: Full distance of the vector in mm *)
11	L			
12	H	Word	Actual Point Number	Automatic mode: Actual Point Number of the actual segment Vector modes: Distance travelled so far in mm *)
13	L			
*) = Output limited to 0 – 32000 mm				

Table 83 *Feldbus Protocol Tx Telegram Control Unit –> PLC (part 2 of 5)*

Byte No.	Order	Type	Name	Explanation
14	H	Word	Segment Table 0	Actual Segment Table or during Segment search Search Result depending on Segment Page
15	L			
16	H	Word	Segment Table 1	
17	L			
18	H	Word	Segment Table 2	
19	L			
20	H	Word	Segment Table 3	
21	L			
22	H	Word	Segment Table 4	
23	L			
24	H	Word	Segment Table 5	
25	L			
26	H	Word	Segment Table 6	
27	L			
28	H	Word	Segment Table 7	
29	L			
30	–	Byte	Segment Page	During Segment Search 0-4 else 0
31	–	Byte	Segment Search Page	0-4
32	H	Word	Search Table 0	Search Result depending on Segment Search Page
33	L			
34	H	Word	Search Table 1	
35	L			
36	H	Word	Search Table 2	
37	L			
38	H	Word	Search Table 3	
39	L			
40	H	Word	Search Table 4	
41	L			
42	H	Word	Search Table 5	
43	L			
44	H	Word	Search Table 6	
45	L			
46	H	Word	Search Table 7	
47	L			

Table 83 *Feldbus Protocol Tx Telegram Control Unit –> PLC (part 3 of 5)*

Byte No.	Order	Type	Name	Explanation
48	H	double Word	**Error**	**Bit** — **Error Number** – bit-0 release segment Start 0 – bit-1 Segment end reached 1 – bit-2 Segment Release 2 – bit-3 Stop Distance 3 – bit-8 Mode request 8 – bit-9 Sensor accuracy 9 – bit-10 deviation Error 10 – bit-11 Emergency Stop 11 – bit-12 Error Segment Table 12 – bit-13 Error plausibility 13 – bit-14 Error System 14 – bit-16 Wheels 16 – bit-17 Antenna 17 – bit-18 Camera 18 – bit-19 Wire 19 – bit-20 Gyro 20 – bit-21 PLC 21 – bit-22 GPS 22 – bit-23 Extern 23 – bit-24 Steering Servo 24 – bit-25 Driving Servo 25 – bit-26 Trailer 26
49	L			
50	H			
51	L			
52	H	Word	**Error Code**	s. Table 47 on page 136
53	L			
54	–	Byte	**Object Number**	s. Table 47 on page 136
55	–	Byte	**Error Number**	s. above and Table 47 on page 136
56	H	signed long	X Position	Format: 32-bit complement to two Resolution: 1 mm Value range: -10km ... +10km Offset: 0
57				
58				
59	L			
60	H	signed long	Y Position	Format: 32-bit complement to two Resolution: 1 mm Value range: -10km ... +10km Offset: 0
61				
62				
63	L			
64	H	unsigned short	Angle	Format: 16-bit Resolution: 0.01° Value range: 0°... 360° Offset: 0°
65	L			
66	H	signed short	Speed	Format: 16-bit complement to two Resolution: 1 mm/sec (Note: Until software version 231 this was cm/sec) Value range: -30 m/sec ... +30 m/sec (-30000 ..... +30000) Offset: 0
67	L			

Table 83 *Feldbus Protocol Tx Telegram Control Unit –> PLC (part 4 of 5)*

Byte No.	Order	Type	Name	Explanation
68	–	Byte	Nav System	– bit-0 Transponder – bit-1 GPS – bit-2 Laser
69	–	Byte	Nav Status	see Table 71 on page 152
70	H	signed short	Wheel 1 Angle	Format: 16-bit complement to two Resolution: 0.01° Value range: -180.00° ...+180.00° Offset: 0
71	L			
72	H	signed short	Wheel 1 Speed	Format: 16-bit complement to two Resolution: 1 mm/s Value range: -32768mm/s ...+32767mm/s Offset: 0
73	L			
74	H	signed short	Wheel 1 Radius	Format: 16-bit complement to two see section 12.3 on page 185 in the appendix
75	L			
76	H	word	Wheel 1 Command	– bit-0 ..12 not used – bit-13 Steering enable – bit-14 Driving enable – bit-15 Toggle
77	L			
78	H	signed short	Wheel 2 Angle	Format: 16-bit complement to two Resolution: 0.01° Value range: -180.00° ...+180.00° Offset: 0
79	L			
80	H	signed short	Wheel 2 Speed	Format: 16-bit complement to two Resolution: 1 mm/s Value range: -32768mm/s ...+32767mm/s Offset: 0
81	L			
82	H	signed short	Wheel 2 Radius	Format: 16-bit complement to two see section 12.3 on page 185 in the appendix
83	L			
84	H	word	Wheel 2 Command	bit-0 ..12 not used bit-13 Steering enable bit-14 Driving enable bit-15 Toggle
85	L			
86	H	signed short	Wheel 3 Angle	Format: 16-bit complement to two Resolution: 0.01° Value range: -180.00° ...+180.00° Offset: 0
87	L			
88	H	signed short	Wheel 3 Speed	Format: 16-bit complement to two Resolution: 1 mm/s Value range: -32768mm/s ...+32767mm/s Offset: 0
89	L			
90	H	signed short	Wheel 3 Radius	Format: 16-bit complement to two see section 12.3 on page 185 in the appendix
91	L			
92	H	word	Wheel 3 Command	bit-0 ..12 not used bit-13 Steering enable bit-14 Driving enable bit-15 Toggle
93	L			

Table 83 *Feldbus Protocol Tx Telegram Control Unit –> PLC (part 5 of 5)*

Byte No.	Order	Type	Name	Explanation
94	H	signed short	Wheel 4 Angle	Format: 16-bit complement to two Resolution: 0.01° Value range: -180.00° ...+180.00° Offset: 0
95	L			
96	H	signed short	Wheel 4 Speed	Format: 16-bit complement to two Resolution: 1 mm/s Value range: -32768mm/s ...+32767mm/s Offset: 0
97	L			
98	H	signed short	Wheel 4 Radius	Format: 16-bit complement to two see section 12.3 on page 185 in the appendix
99	L			
100	H	word	Wheel 4 Command	bit-0 ..12 not used bit-13 Steering enable bit-14 Driving enable bit-15 Toggle
101	L			
102	H	word	Servo Position	Format: 16 Bit
103	L			
104	–	–	–	Spare
105	–	–	–	Spare
106	–	–	–	Spare
107	–	–	–	Spare
108	–	–	–	Spare
109	–	–	–	Spare
110	–	–	–	Spare
111	–	–	–	Spare
112	–	–	–	Spare
113	–	–	–	Spare
114	–	–	–	Spare
115	–	–	–	Spare
116	–	–	–	Spare
117	–	–	–	Spare
118	–	–	–	Spare
119	–	–	–	life counter

8.2 Rx Reception Telegram PLC –> Control Unit

Table 84 *Feldbus Protocol Rx Telegram PLC –> Control Unit (part 1 of 4)*

Byte No.	Order	Type	Name	Explanation
0	–	Byte	Requested Mode	– 0 = manual driving – 1 = automatic driving – 2 = Remote control – 3 = Parameter Test only via Website – 4 = Vector steering
1	–	Byte	Command	– bit-0 Freeze ONS *) – bit-1 – – bit-2 Offset right – bit-3 Offset left – bit-4 – – bit-5 Error Acknowledge **) – bit-6 Emergency Stop active ***) – bit-7 Emergency Stop Acknowledge **)

*) PLC may set this bit while the vehicle stands still and the brakes are active to prevent influences on the vehicle position calculation by vibrating wheels. **Use carefully**, see section 2.3.2 on page 14.
**) By setting „Error Acknowledge/Emergency Stop Acknowledge“ to 1 all errors in the Vehicle Guidance Controller are cleared. This helps to reset errors where the reason for the error has been removed. All errors that are still valid will reappear again. Make sure to only set these Bits to 1 when needed and to set them back to 0 afterwards.
Most of the errors that can appear are self-resetting once the reason disappears. Emergency stops have to be cleared by sending „Emergency Stop Acknowledge“ once.
***) When the PLC sets the bit „Emergency Stop active“ the accuracy is decreased artificially. This ensures that the next position is referenced by measuring transponders or GPS. It is strongly recommended to re-position the vehicle onto the track after emergency stops. Each emergency stop means that the wheels might have blocked which leads to a less accurate position calculation!

2	H	word	Speed Limitation	Format: 16-bit Resolution: 1 mm/s Value range: 1..65535mm/s Value 0: Speed Limit not used Offset: 0
3	L			
4	–	–	–	spare
5	–	Byte	Request Count of Error	Counter modulo 2 bit (Bit 0 and 1)
6	–	Byte	Request Count of Segment Search	Counter modulo 8 bit
7	–	–	–	spare
8	H	Word	Segment Command	– bit-0 release segment 0 – bit-9 Segment search request
9	L			
10	H	Word	Stop Distance	Format: 16-bit Resolution: 1 mm Value range: 1..65535mm Value 0: Stop Distance not used Offset: 0
11	L			
12	–	–	–	spare
13	–	–	–	spare

Table 84 *Feldbus Protocol Rx Telegram PLC –> Control Unit (part 2 of 4)*

Byte No.	Order	Type	Name	Explanation
14	H	Word	Target Segment Table 0	Target Segment Table
15	L			
16	H	Word	Target Segment Table 1	
17	L			
18	H	Word	Target Segment Table 2	
19	L			
20	H	Word	Target Segment Table 3	
21	L			
22	H	Word	Target Segment Table 4	
23	L			
24	H	Word	Target Segment Table 5	
25	L			
26	H	Word	Target Segment Table 6	
27	L			
28	H	Word	Target Segment Table 7	
29	L			
30	H	signed long	Target X for vector mode	Format: 32-bit complement to two Resolution: 1 mm Value range: -10000000mm ...+10000000mm Offset: 0
31				
32				
33	L			
34	H	signed long	Target Y for vector mode	Format: 32-bit complement to two Resolution: 1 mm Value range: -10000000mm ...+10000000mm Offset: 0
35				
36				
37	L			
38	H	unsiged short	Target Angle for vector mode	Format: 16-bit Resolution: 0.01° Value range: 0°... 360° Offset: 0°
39	L			
40	H	signed short	Target Speed for vector mode	Format: 16-bit complement to two Resolution: 0.001 m/sec Value range: 0 m/sec ... +30 m/sec (0 ..... +30000) Offset: 0
41	L			
42	H	signed short	Remote X	Format: 16-bit complement to two Resolution: dependant on mode 1 mm / 1 mm/s Value range: -30000 mm/s ... +30000 mm/s Offset: 0 See 2.6.9.4 on page 42
43	L			
44	H	signed short	Remote Y	Format: 16-bit complement to two Resolution: dependant on mode 1 mm / 1 mm/s Value range: -30000 mm/s ... +30000 mm/s Offset: 0
45	L			

Table 84 *Feldbus Protocol Rx Telegram PLC –> Control Unit (part 3 of 4)*

Byte No.	Order	Type	Name	Explanation
46	–	Byte	Remote Mode s. section 2.6.9.4 on page 42	– 0: No remote (normal automatic steering) – 1: Symmetric steering forward – 2: Symmetric steering sideward – 3: Dog tracking forward – 4: Dog tracking Sideward – 5: Spot turn – 6: Pole
47	–	–	–	spare
48	H	signed short	Remote Z	Format: 16-bit complement to two Resolution: dependant on mode 1 mm / 1 mm/s Value range: -30000 mm/s ... +30000 mm/s Offset: 0 See 2.6.9.4 on page 42
49	L			
50	H	signed short	Wheel 1 Angle	Format: 16-bit complement to two Resolution: 0.01° Value range: -180.00° ...+180.00° Offset: 0
51	L			
52	H	signed short	Wheel 1 Speed	Format: 16-bit complement to two Resolution: 1 mm/s Value range: -32768mm/s ...+32767mm/s Offset: 0
53	L			
54	H	–	–	spare
55	L			
56	H	word	Wheel 1 Command	– bit-0..12 not used – bit-13 Steering enable – bit-14 Driving enable – bit-15 Toggle
57	L			
58	H	signed short	Wheel 2 Angle	Format: 16-bit complement to two Resolution: 0.01° Value range: -180.00° ...+180.00° Offset: 0
59	L			
60	H	signed short	Wheel 2 Speed	Format: 16-bit complement to two Resolution: 1 mm/s Value range: -32768mm/s ...+32767mm/s Offset: 0
61	L			
62	H	–	–	spare
63	L			
64	H	word	Wheel 2 Command	– bit-0..12 not used – bit-13 Steering enable – bit-14 Driving enable – bit-15 Toggle
65	L			
66	H	signed short	Wheel 3 Angle	Format: 16-bit complement to two Resolution: 0.01° Value range: -180.00° ...+180.00° Offset: 0
67	L			

Table 84 *Feldbus Protocol Rx Telegram PLC –> Control Unit (part 4 of 4)*

Byte No.	Order	Type	Name	Explanation
68	H	signed short	Wheel 3 Speed	Format: 16-bit complement to two Resolution: 1 mm/s Value range: -32768mm/s ...+32767mm/s Offset: 0
69	L			
70	H	–	–	spare
71	L			
72	H	word	Wheel 3 Command	– bit-0..12 not used – bit-13 Steering enable – bit-14 Driving enable – bit-15 Toggle
73	L			
74	H	signed short	Wheel 4 Angle	Format: 16-bit complement to two Resolution: 0.01° Value range: -180.00° ...+180.00° Offset: 0
75	L			
76	H	signed short	Wheel 4 Speed	Format: 16-bit complement to two Resolution: 1 mm/s Value range: -32768mm/s ...+32767mm/s Offset: 0
77	L			
78	H	–	–	spare
79	L			
80	H	word	Wheel 4 Command	– bit-0..12 not used – bit-13 Steering enable – bit-14 Driving enable – bit-15 Toggle
81	L			
82	H	signed short	Extern Servo	Revolutions / Min -10000 bis 10000
83	L			
84	–	–	–	spare
85	–	–	–	spare
86	–	–	–	spare
87	–	–	–	spare
88	–	–	–	spare
89	–	–	–	spare
90	–	–	–	spare
91	–	–	–	spare
93	–	–	–	spare
94	–	–	–	spare
95	–	–	–	spare
96	–	–	–	spare
97	–	–	–	spare
98	–	–	–	spare
99	–	–	–	Life counter

9 USB Data Logging: Scope of the Data

When a USB memory stick is inserted into the Control Unit (s. section 3.5.2 on page 48), the Control Unit automatically starty to log driving data on it. Data logging being active is indicated by the flashing LED ACT. The data is logged in the CSV (MS-DOS®) format. This writes data line by line into a file and the different values in each line are separated by semicolon.

The Control Unit limits those files to have a maximum length of 6,000 lines. Afterwards the Control Unit closes the actual file and automatically starts a new one. The file names comprise the current time, the file extension is *.txt*. At a timing of 60-70 ms each file contains approx. 5 minutes of a drive.

Another possibility to log data is the terminal program (section 5.5 on page 104). With the terminal program the timing of the logging is faster and no USB stick is needed.

i As soon as there are more than 20 files on the stick the control unit automatically deletes the oldest files in order to prevent the stick from becoming filled!

i As the stick receives data in short intervals it is important that it is fast enough. We e.g. successfully used an USB 3.0 memory stick by SanDisc Ultrafit 16GB.

NOTICE

Risk of data loss

If the stick has to be removed while the Control Unit is powered on press and hold the button SW1 (below the stick) until the LED ACT turns off (approx. 5 Sek.)! (s. section 3.3 on page 46) Do not press SW1 longer than 10 seconds because then the stick will be formatted and all data erased.

- ▶ Press the button SW1 until the LED ACT stops blinking.
- ▶ Don‘t press button SW1 **longer than 10 seconds** since after this period the stick is formatted and all data erased.

When the LED ACT stops flashing the current file is closed safely and the stick ejected. When switching the Control Unit off it also closes the file and the stick may be removed.

9.1 Opening logged Data in Excel®

The files on the stick may be viewed and analyzed in a spreadsheet calculation like e.g. Microsoft® Excel®. Firstly ensure that in your Windows® install the decimal separator is the point:

1. Control panel –> Regions and Languages –> More –> Control of decimal separator. If necessary switch the decimal separator and the symbol for the grouping of digits.
2. Start the spreadsheet application (e.g. Excel®).
3. Use File –> Open and navigate to the stick. Set the file types to be shown to *Text files (*.prn; *.txt; *.csv)*. All log files should appear. Double click on one to open it.

4. The text conversion assistant opens. In step 1/3 choose *Separated* and click on *Next*.
5. In step 2/3 set check mark for *Semicolon*, click ***Next***.
6. In step 3/3 click on *Finish assistant*.
7. In order to make all column headings fully visible mark all cells (e.g. with the symbol left of the A in column A), then go to *Format –> Adjust column width automatically*.

9.2 List of Logged Parameters

The following table lists all the parameters that the Control Unit logs to a USB memory stick.

Table 85 *List of the parameters logged on a USB memory stick (part 1 of 11)*

Name	Description
Time	Time stamp of the internal clock of the Control Unit. The unit millisecond has been removed so that it‘s easier to use the values in Excel® (see next entry).
ms	The unit belonging to the time stamp (see entry above)
Actual Direction	Actual moving direction of the vehicle zero point in [°]
Actual Heading	Actual heading of the vehicle in [°]
Actual Pos X	Actual X position of the vehicle zero point in [m]
Actual Pos Y	Actual Y position of the vehicle zero point in [m]
Actual Speed	Actual speed of the vehicle zero point in [m/s]
Actual Speed Avg.	Actual speed averaged from the last 5 measuring periods in [m/s]. Algebraic sign is removed. Used to estimate the position with the parameter "Time Forward“.
Actual System	Currently used sensorfusion
Actual Dist	Traveled distance since the last referencing via the currently used sensorfusion (only applicable when the internal sensorfusion is in use)
Actual Accur.	Estimated current accuracy of the currently used sensorfusion
Target Direction	Target direction of the vehicle zero point in [°]
Target Heading	Target heading of the vehicle in [°]
Target Pos X	Target X position of the vehicle zero point in [m]
Target Pos Y	Target Y position of the vehicle zero point in [m]
Target Speed	Target speed for the segment in [m/s] (valid for the fastest wheel)
Target Speed Ramp	Target speed for the segment with the set speed ramp in [m/s] (valid for the fastest wheel)
Error Heading	Error vehicle orientation in [°]
Error Center	Error of the vehicle zero point vertical to the direction of movement in the segment in [m]
Error Front X	Error at the front point of regulation (Virtual Point Front) in the X direction of the vehicle coordinate system in [m]
Error Front Y	Error at the front point of regulation (Virtual Point Front) in the Y direction of the vehicle coordinate system in [m]
Error Rear X	Error at the rear point of regulation (Virtual Point Rear) in the X direction of the vehicle coordinate system in [m]

Table 85 *List of the parameters logged on a USB memory stick (part 2 of 11)*

Name	Description
Error Rear Y	Error at the rear point of regulation (Virtual Point Rear) in the Y direction of the vehicle coordinate system in [m]
Attribute	Current attribute of the segment (see section 12.1 on page 184 in the appendix)
Mode	Mode of the Control Unit (0: Idle; 1: Auto; 2: Remote; 3: Parameter_test; 4 Vektor_abs; 5: Vektor_rel)
Cond Spot turn	Current mode spot turn (0: spot turn not active; 1: brake; 2: turn in; 3: circular driving; 4: brake circular driving; 5: turn out; 6: finish)
PLC	State of the vehicle control (communication included for compatibility reasons)
Clearence	Clearing for the PLC to specify values
A Dir.	Target direction of movement of the vehicle zero point at the current position in [°]
A Head	Target heading of the vehicle at the current position in [°]
A Pos X	Target X position of the vehicle zero point at the current position in [m]
A Pos Y	Target Y position of the vehicle zero point at the current position in [m]
A Curv	Steering angle at the current position resulting from the curvature of the segment in [°]
A Point No.	Segment point number at the current position
A Sample	Sample point of the regression at the current position
A State	State of the segment at the current position
A Bit	Last loaded regression at the current position
F Dir.	Target direction of movement of the vehicle zero point at the position estimated with the parameter Time Forward in [°]
F Head	Target heading of the vehicle at the position estimated with the parameter Time Forward in [°]
F Pos X	Target X position of the vehicle zero point at the position estimated with the parameter Time Forward in [m]
F Pos Y	Target Y position of the vehicle zero point at the position estimated with the parameter Time Forward in [m]
F Curv	Steering angle at the position estimated with the parameter Time Forward resulting from the segment‘s curvature at that point in [°]
F Point No.	Segment point number at the position estimated with the parameter Time Forward
F Sample	Sample point of the regression at the position estimated with the parameter Time Forward
F State	State of the segment at the position estimated with the parameter Time Forward
F Bit	Last loaded regression at the at the position estimated with the parameter Time Forward
Rx Seg. 1	Segment 1 received from PLC
Rx Seg. 2	Segment 2 received from PLC
Rx Seg. 3	Segment 3 received from PLC
Rx Seg. 4	Segment 4 received from PLC
Rx Seg. 5	Segment 5 received from PLC
Rx Seg. 6	Segment 6 received from PLC
Rx Seg. 7	Segment 7 received from PLC

Table 85 *List of the parameters logged on a USB memory stick (part 3 of 11)*

Name	Description
Rx Seg. 8	Segment 8 received from PLC
Tx Seg. 1	Segment 1 sent to PLC
Tx Seg. 2	Segment 2 sent to PLC
Tx Seg. 3	Segment 3 sent to PLC
Tx Seg. 4	Segment 4 sent to PLC
Tx Seg. 5	Segment 5 sent to PLC
Tx Seg. 6	Segment 6 sent to PLC
Tx Seg. 7	Segment 7 sent to PLC
Tx Seg. 8	Segment 8 sent to PLC
Connection	This variable shows the speed profile used for driving through each segment. Each digit is a hexdecimal number consisting of the following bits: – No bit selected: Drive without stop – 1: Segment invalid – 2: Change in direction – 4: End of drive – 8: Stop speed profile chosen The leftmost digit stands for the first segment in the segment list sent to the PLC. The rightmost digit stands for the eighth segment sent to the PLC. **Example:** The test segments 0 and 1 form an oval. In the segment list test segment 0 is segment 1 (first of the segments sent to the PLC) and test segment 1 is segment 2. The segments 3 to 8 are set to 65535 (place holder for *no segment*). Connection then is set to 0C111111. The 0 stands for drive through test segment 1 without stop. The C is a combination of 4 (end of drive) and 8 (stop speed profile chosen). It means that the vehicle will stop in test segment 1. The following six 1 indicate the non-existent invalid segments.
I_Start	Start index of the point buffer
I_Act.	Index of the current position in the point buffer
I_Pre.	Index at the position estimated with the parameter Time Forward
I_End	Last index of the point buffer
PB Seg. No.	Segment number of the support point in the point buffer at the index of the current position
PB Point No.	Point number of the support point in the point buffer at the index of the current position
PB Head.	Vehicle heading of the support point in the point buffer at the index of the current position
PB X Pos.	X position of the support point in the point buffer at the index of the current position
PB Y Pos.	Y position of the support point in the point buffer at the index of the current position
PB Speed	Speed of the support point in the point buffer at the index of the current position
PB Attribute	Attribute of the support point in the point buffer at the index of the current position
Emergency Stop	s. Table 47 on page 136
Error	s. Table 46 on page 135

Table 85 *List of the parameters logged on a USB memory stick (part 4 of 11)*

Name	Description
E_START	State clearance to start not set (normally only during test operation)
E_END	Segment end / Ende of drive reached
E_SEG_REL	Segment clearance not set
E_MODE_REQ	Error when requesting automatic drive – 0x0001 Speed too high for switching – 0x0002 Accuracy too low – 0x0004 Error segment number – 0x0008 Error point buffer
E_ACCURACY	Error accuracy
E_DEVIATION	Deviation Error, s. Table 47 on page 136
E_E_STOP	Emergency Stop, s. Table 47 on page 136
E_SEG_TAB	Error Segment Table, s. Table 47 on page 136
E_PLAUSI.	Error plausibility, s. Table 47 on page 136
E_WHEEL 1	Wheels, s. Table 47 on page 136
E_WHEEL 2	Wheels, s. Table 47 on page 136
E_WHEEL 3	Wheels, s. Table 47 on page 136
E_WHEEL 4	Wheels, s. Table 47 on page 136
E_ANT 1	Antenna, s. Table 47 on page 136
E_ANT 2	Antenna, s. Table 47 on page 136
E_ANT 3	Antenna, s. Table 47 on page 136
E_ANT 4	Antenna, s. Table 47 on page 136
E_KAM 1	Error camera 1 (not yet available)
E_KAM 2	Error camera 2 (not yet available)
E_KAM 3	Error camera 3 (not yet available)
E_KAM 4	Error camera 4 (not yet available)
E_WIRE 1	Error guide wire 1 (not yet available)
E_WIRE 2	Error guide wire 2 (not yet available)
E_WIRE 3	Error guide wire 3 (not yet available)
E_WIRE 4	Error guide wire 4 (not yet available)
E_GYRO	Gyro, s. Table 47 on page 136
E_PLC	PLC, s. Table 47 on page 136
E_GPS	Error GPS, s. Table 47 on page 136
E_SERVO 1	Error servo 1, s. Table 47 on page 136
E_SERVO 2	Error servo 2
E_SERVO 3	Error servo 3
E_SERVO 4	Error servo 4
E_SERVO 5	Error servo 5
E_SERVO 6	Error servo 6
E_SERVO 7	Error servo 7
E_SERVO 8	Error servo 8
E_TRAILER	Error trailer

Table 85 *List of the parameters logged on a USB memory stick (part 5 of 11)*

Name	Description
Actual S.A. 1	Current steering angle wheel 1
Actual S.A. 2	Current steering angle wheel 2
Actual S.A. 3	Current steering angle wheel 3
Actual S.A. 4	Current steering angle wheel 4
Target S.A. 1	Target steering angle wheel 1
Target S.A. 2	Target steering angle wheel 2
Target S.A. 3	Target steering angle wheel 3
Target S.A. 4	Target steering angle wheel 4
Actual Speed 1	Current speed wheel 1
Actual Speed 2	Current speed wheel 2
Actual Speed 3	Current speed wheel 3
Actual Speed 4	Current speed wheel 4
Target Speed 1	Target speed wheel 1
Target Speed 2	Target speed wheel 2
Target Speed 3	Target speed wheel 3
Target Speed 4	Target speed wheel 4
Virtual S. A. 1	Actual steering angle wheel 1 calculated from odometry
Virtual S. A. 2	Actual steering angle wheel 2 calculated from odometry
Virtual S. A. 3	Actual steering angle wheel 3 calculated from odometry
Virtual S. A. 4	Actual steering angle wheel 4 calculated from odometry
Virtual Speed 1	Actual speed wheel 1 calculated from odometry
Virtual Speed 2	Actual speed wheel 2 calculated from odometry
Virtual Speed 3	Actual speed wheel 3 calculated from odometry
Virtual Speed 4	Actual speed wheel 4 calculated from odometry
Distance Pol 1	Distance between wheel 1 and the point around which the vehicle turns.
Distance Pol 2	Distance between wheel 2 and the point around which the vehicle turns.
Distance Pol 3	Distance between wheel 3 and the point around which the vehicle turns.
Distance Pol 4	Distance between wheel 4 and the point around which the vehicle turns.
Pole Wheel 1 X	Length between the point around which the vehicle turns and wheel 1 in X direction
Pole Wheel 1 Y	Length between the point around which the vehicle turns and wheel 1 in Y direction
Pole Wheel 2 X	Length between the point around which the vehicle turns and wheel 2 in X direction
Pole Wheel 2 Y	Length between the point around which the vehicle turns and wheel 2 in Y direction
Pole Wheel 3 X	Length between the point around which the vehicle turns and wheel 3 in X direction
Pole Wheel 3 Y	Length between the point around which the vehicle turns and wheel 3 in Y direction

Table 85 *List of the parameters logged on a USB memory stick (part 6 of 11)*

Name	Description
Pole Wheel 4 X	Length between the point around which the vehicle turns and wheel 4 in X direction
Pole Wheel 4 Y	Length between the point around which the vehicle turns and wheel 4 in Y direction
Speed direction	Direction of the speed
Dist. Forward	Distance for which the control system looks ahead
Target X	Target X position in the vehicle coordinate system
Target Y	Target Y position in the vehicle coordinate system
Target Pos Front X	Target X position of the front point of regulation (Virtual Point Front) in the vehicle coordinate system
Target Pos Front Y	Target Y position of the front point of regulation (Virtual Point Front) in the vehicle coordinate system
Target Pos Rear X	Target X position of the rear point of regulation (Virtual Point Rear) in the vehicle coordinate system
Target Pos Rear Y	Target Y position of the rear point of regulation (Virtual Point Rear) in the vehicle coordinate system
Actual Pos Front X	Actual X position of the front point of regulation (Virtual Point Front) in the vehicle coordinate system (by definition Y is always 0)
Actual Pos Rear X	Actual X position of the rear point of regulation (Virtual Point Rear) in the vehicle coordinate system (by definition Y is always 0)
Target dir. X	X component of the vector of the target direction of travel at the zero point of the vehicle in the vehicle coordinate system
Target dir. Y	Y component of the vector of the target direction of travel at the zero point of the vehicle in the vehicle coordinate system
Target dir. front X	X component of the vector of the target direction of travel at the front point of regulation of the vehicle in the vehicle coordinate system
Target dir. front Y	Y component of the vector of the target direction of travel at the front point of regulation of the vehicle in the vehicle coordinate system
Target dir. rear X	X component of the vector of the target direction of travel at the rear point of regulation of the vehicle in the vehicle coordinate system
Target dir. rear Y	Y component of the vector of the target direction of travel at the rear point of regulation of the vehicle in the vehicle coordinate system
Dir. Front X	X component of the vector target direction at the front point of regulation
Dir. Front Y	Y component of the vector target direction at the front point of regulation
Dir Rear X	X component of the vector target direction at the rear point of regulation
Dir Rear Y	X component of the vector target direction at the rear point of regulation
Sign. rot. Pol reg.	Sign of the rotation direction of the pole of the regulation (used in the modes Parameter Test and Remote Control)
Pol Reg. X	X component of the point around which the vehicle is supposed to turn in the vehicle coordinate system
Pol Reg. Y	Y component of the point around which the vehicle is supposed to turn in the vehicle coordinate system
Lim. Approach A	Restriction of the angle of the segment approach

Table 85 *List of the parameters logged on a USB memory stick (part 7 of 11)*

Name	Description
Dir. Rotation Pol.	Sign of the rotation direction of the pole of the regulation (used for automatic driving)
workload	Workload of the Control Unit in 0/00
Dist. 1	Distance traveled by wheel 1 in a cycle
Dist. 2	Distance traveled by wheel 2 in a cycle
Sum Dist. 1	Distance traveled by wheel 1
Sum Dist. 2	Distance traveled by wheel 2
Ant1 H	Vehicle heading of the odometry of antenna 1 between the second to last and the last transponder
Ant1 X	X position of the odometry of antenna 1 between the second to last and the last transponder
Ant1 Y	Y position of the odometry of antenna 1 between the second to last and the last transponder
Ant1 Odo H	Vehicle heading of the odometry of antenna 1 since the last transponder
Ant1 Odo X	X Position of the odometry of antenna 1 since the last transponder
Ant1 Odo Y	Y Position of the odometry of antenna 1 since the last transponder
Ant1 Dist.	Distance of the odometry of antenna 1 since the last transponder
Ant1 Pulse	Time slot between posi pulse of antenna 1 and the corresponding telegram of antenna 1 (max. 3 cycles)
Ant1 Int. Cnt.	Posi pulse counter antenna 1
Ant3 H	Vehicle heading of the odometry of antenna 3 between the second to last and the last transponder
Ant3 X	X position of the odometry of antenna 3 between the second to last and the last transponder
Ant3 Y	Y position of the odometry of antenna 3 between the second to last and the last transponder
Ant3 Odo H	Vehicle heading of the odometry of antenna 3 since the last transponder
Ant3 Odo X	X Position of the odometry of antenna 3 since the last transponder
Ant3 Odo Y	Y Position of the odometry of antenna 3 since the last transponder
Ant3 Dist.	Distance of the odometry of antenna 3 since the last transponder
Ant3 Pulse	Time slot between posi pulse of antenna 3 and the corresponding telegram of antenna 3 (max. 3 cycles)
Ant3 Int. Cnt.	Posi pulse counter antenna 3
OdoTr Head	Vehicle heading of the odometry of the sensor fusion with transponders
OdoTr X Pos	X position of the odometry of the sensor fusion with transponders
OdoTr Y Pos	Y position of the odometry of the sensor fusion with transponders
OdoTr Dist	Distance since last referencing of the odometry of the sensor fusion with transponders
Dist. Wheel 1	Distance change wheel 1
Dist. Wheel 2	Distance change wheel 2
delta Head. Wheel 1	Vehicle heading change calculated via wheel 1
delta Head. Wheel 2	Vehicle heading change calculated via wheel 2

Table 85 *List of the parameters logged on a USB memory stick (part 8 of 11)*

Name	Description
delta Head. Dir. 1	Direction of the vehicle heading change calculated via wheel 1
delta Head. Dir. 2	Direction of the vehicle heading change calculated via wheel 2
Odo delta Head Wheel	Vehicle heading change of the primary odoemtry calculated via wheels 1 and 2
Odo delta Head	Used vehicle heading change of the primary odometry (may come from the gyro)
Odo local Pol X	X component of the vehicle pivot point in the vehicle coordinate system
Odo local Pol Y	Y component of the vehicle pivot point in the vehicle coordinate system
Odo global Pol X	X component of the vehicle pivot point in the global coordinate system
Odo global Pol Y	Y component of the vehicle pivot point in the global coordinate system
Odo delta Pos. X	Position change in X direction of the primary odometry
Odo delta Pos. Y	Position change in Y direction of the primary odometry
Odo Direction	Angle of the direction of travel of the primary odometry
Odo Head.	Vehicle heading of the primary odometry
Odo Pos. X	X position of Odo Pos. X of the primary odometry
Odo Pos. Y	Y position of Odo Pos. X of the primary odometry
Dist Odo D	Distance between the two transponders during a double reading (Antenna 1 and 3 with two different transponders)
Dist Tab D	Distance between the two transponders during a double reading according to the transponder list
Code Own D	Code of the transponder underneath the antenna that has triggered a posi pulse (double reading)
Code Other D	Code of the transponder underneath the other antenna (double reading)
State 1	Transponder antenna 1: Status
Code 1	Transponder antenna 1: Transponder code
Deviation 1	Transponder antenna 1: Position of the transponder in direction of measurement **Note:** This position value is in the antenna coordinate system and not the vehicle coordinate system.
Voltage 1	Transponder antenna 1: Sum voltage
Trans. X 1	Transponder antenna 1: X position from the transponder table
Trans. Y 1	Transponder antenna 1: Y position from the transponder table
State 2	Transponder antenna 2: Status
Code 2	Transponder antenna 2: Transponder code
Deviation 2	Transponder antenna 2: Position of the transponder in direction of measurement **Note:** This position value is in the antenna coordinate system and not the vehicle coordinate system.
Voltage 2	Transponder antenna 2: Sum voltage
Trans. X 2	Transponder antenna 2: X position from the transponder table
Trans. Y 2	Transponder antenna 2: Y position from the transponder table
State 3	Transponder antenna 3: Status
Code 3	Transponder antenna 3: Transponder code

Table 85 *List of the parameters logged on a USB memory stick (part 9 of 11)*

Name	Description
Deviation 3	Transponder antenna 3: Position of the transponder in direction of measurement **Note:** This position value is in the antenna coordinate system and not the vehicle coordinate system.
Voltage 3	Transponder antenna 3: Sum voltage
Trans. X 3	Transponder antenna 3: X position from the transponder table
Trans. Y 3	Transponder antenna 3: Y position from the transponder table
Ant1 Dist. Odo	Transponder antenna 1: Distance between second to last and last transponder calculated by the odometry
Ant1 Dist. Tab	Transponder antenna 1: Distance between second to last and last transponder calculated from the transponder table
Ant1 Stat. Calc.	Transponder antenna 1: Status of the transponder calculation, see Table 86 on page 179
Ant2 Dist. Odo	Transponder antenna 2: Distance between second to last and last transponder calculated by the odometry
Ant2 Dist. Tab	Transponder antenna 2: Distance between second to last and last transponder calculated from the transponder table
Ant2 Stat. Calc.	Transponder antenna 2: Status of the transponder calculation, see Table 86 on page 179
Ant3 Dist. Odo	Transponder antenna 3: Distance between second to last and last transponder calculated by the odometry
Ant3 Dist. Tab	Transponder antenna 3: Distance between second to last and last transponder calculated from the transponder table
Ant3 Stat. Calc.	Transponder antenna 3: Status of the transponder calculation, see Table 86 on page 179
Angle Local	Angle between second to last and last transponder calculated by the odometry
Angle Global	Angle between second to last and last transponder calculated from the transpon-der table
lgtd. corr.	3 antenna system: Longitudinal correction by the middle antenna
lgtd. corr glob. X	X component of the longitudinal correction in the global coordinate system
lgtd. corr glob. Y	Y component of the longitudinal correction in the global coordinate system
Calc. Counter	Counter of the number of position calculations with transponders
Tr Vehicle Head.	Vehicle heading of the position calculated with transponders
Tr Vehicle Pos X	X position of the position calculated with transponders
Tr Vehicle Pos Y	Y position of the position calculated with transponders
No. Cycles	Number of cycles for which the referencing of the transponders flows into the odometry
No. used Cycles	Number of cycles that have already flown in
total. Head. corr	Total correction of vehicle heading
total. X. corr.	Total correction of X Position
total. Y. corr.	Total correction of Y Position
Cycle inc. Head	Single correction cycle of vehicle heading
Cycle inc. X	Single correction cycle of X position
Cycle inc. Y	Single correction cycle of Y position

Table 85 *List of the parameters logged on a USB memory stick (part 10 of 11)*

Name	Description
Sum cycle Head	Sum of correction of vehicle heading
Sum cycle X	Sum of correction of X position
Sum cycle Y	Sum of correction of Y position
TR Error H	Error vehicle heading between transponder odometry and referencing
TR Error X	Error vehicle position X between transponder odometry and referencing
TR Error Y	Error vehicle position Y between transponder odometry and referencing
TR Error Lat.	Error vehicle position in lengthwise direction between transponder odometry and referencing
TR Error Lgtd.	Error vehicle position in diagonal direction between transponder odometry and referencing
Tr Accuracy Code	Estimated accuracy of the sensor fusion transponder as a code
Tr Accuracy	Estimated accuracy of the sensor fusion transponder in [m]
Tr Dist	Distance traveled since last referencing
Gyro Heading	Vehicle heading gyro
Gyro Offset	Offset gyro
Gyro Moving	Set to 1 when vehicle is moving
Gyro Use	Shows if gyro is used
GPS Heading	Vehicle heading of the sensor fusion GPS
GPS X Pos.	X position of sensor fusion GPS
GPS Y Pos.	Y position of sensor fusion GPS
GPS Dist.	Distance traveled since last referencing
GPS H	Vehicle heading from GPS (transformed to vehicle coordinate system)
GPS X	X position from GPS (transformed to vehicle coordinate system)
GPS Y	Y position from GPS (transformed to vehicle coordinate system)
GPS H Raw	Vehicle heading from GPS (raw value)
GPS X Raw	X position from GPS (raw value)
GPS Y Raw	Y position from GPS (raw value)
GPS ONS Ring H	Vehicle heading from ring buffer GPS odometry in [°]
GPS ONS Ring X	X position from ring buffer GPS odometry in [m]
GPS ONS Ring Y	Y position from ring buffer GPS odometry in [m]
GPS E Head	Deviation of the P regulator for the vehicle heading in [°]
GPS E Lat.	Deviation of the P regulator for the position correction in lengthwise direction in [m]
GPS E Lgtd.	Deviation of the P regulator for the position correction in diagonal direction in [m]
GPS Y Head	Output of the P regulator for the vehicle heading in [°]
GPS Y Lat.	Output of the P regulator for the position correction in lengthwise direction in [m]
GPS Y Lgtd.	Output of the P regulator for the position correction in diagonal direction in [m]
GPS Y global X	Correction of the X position in [m]
GPS Y global Y	Correction of the Y position in [m]
Log	Latch state of the GPS: good at 50 / bad at 0

Table 85 *List of the parameters logged on a USB memory stick (part 11 of 11)*

Name	Description
Accur.	Accuracy of the GPS position in [m] (without sensor fusion)
Accur. Code	Coded accuracy of the sensor fusion GPS (15 is good / 0 bad)
Accur. SF	Accuracy of the sensor fusion GPS in [m]
Age	Correction data age of the GPS system
Error	Error of the sensor fusion GPS
State	State of the position of the sensor fusion GPS (0: not ready / 1: ready)
H State	State of the direction of the sensor fusion GPS (0: not ready / 1: ready)
Flag 1	Flags 1 GPS
Flag 2	Flags 2 GPS
Travel dir. ok	Indicates that the moving angle is valid
Travel dir	Moving angle GPS system. Calculated from the traveled distance (**should only be used on straight sections**)
GPS Aktiv	Shows the bits that lead to the selection of the GPS system – 0x0001 A limit has been entered – 0x0002 Vehicle beyond limit –> GPS released – 0x0004 Segment has released GPS – 0x0008 Latch onto GPS when ready
Head. Cnt.	Telegram counter for the direction of the antenna of the GPS system
Head. mem.	Last telegram counter for the direction of the antenna of the GPS system
Dist. Border	Distance from border between transponder and GPS area. Values above 0 mean that the vehicle is inside the GPS area
GPS Tilt	When the antennas are mounted crosswise to the direction of travel this parameter shows the sideward inclination of the vehicle
GPS Tilt dist.	The sideward position error caused by the inclination (depending on the antenna height)
rec. State	Shows which telegrams have been received by the GPS receiver
rec. cnt.	Counts how often all GPS telegrams have been received
State SF	Shows whether transponder or GPS are active
Actual State	State of the sensor fusion (sent in the CAN bus telegram)

Table 86 *Explanation status of the Transponder calculation (part 1 of 2)*

Code	Name	Description
0x00000001	ANT_BACK_UP_ON	Backup is active
0x00000002	ANT_WARTE_POSI	Posipulse is triggered, the telegram isn't triggered yet
0x00000004	ANT_STATUS_OK	Status = Posipulse, Transponder in Field, Code OK
0x00000008	ANT_DATEN_NEU_OK	Current data is OK
0x00000010	ANT_SINGLE_CALC	Single calculation has been carried out
0x00000020	ANT_DOUBLE_CALC	Double calculation has been carried out
0x00000100	ANT_SINGLE_TRY	Single calculation has been invoked
0x00000200	ANT_DOUBLE_TRY	Double calculation has been invoked
0x00000400	ANT_FREEZE	Calculation not carried out due to Freeze
0x00001000	ANT_DATEN_ALT_OK	Current data stored

Table 86 *Explanation status of the Transponder calculation (part 2 of 2)*

Code	Name	Description
0x00002000	ANT_START_TR	Start transponder
0x00004000	ANT_WAIT_POSI	Partner transponder waits for Posipulse
0x00008000	ANT_RELOAD_ONS	Reconstruction of the odometry has to be carried out
0x00010000	ANT_SINGLE_E_LAST_CODE	Single calculation: Last code not OK
0x00020000	ANT_SINGLE_E_EQU_CODES	Single calculation: Last transponder had the same code
0x00040000	ANT_SINGLE_E_DIST_TR	Single calculation: The transponders have the same position
0x00080000	ANT_SINGLE_E_DIST_MES	Single calculation: Distance of measurement does not match transponder
0x00400000	ANT_SINGLE_E_DIST_ODO	Single calculation: Distance of odometry since last transponder is too high
0x01000000	ANT_DOUBLE_E_OWN_CODE	Double calculation: Code of own antenna not OK
0x02000000	ANT_DOUBLE_E_OTHER_CODE	Double calculation: Code of other antenna not OK
0x04000000	ANT_DOUBLE_E_EQU_CODES	Double calculation: Last transponder had the same code
0x08000000	ANT_DOUBLE_E_DIST_TR	Double calculation: The transponders have the same position
0x10000000	ANT_DOUBLE_E_DIST_MES	Double calculation: Distance of measurement does not match transponder
0x20000000	ANT_DOUBLE_E_BASELINE	Double calculation: Antenna distance is higher than transponder distance
0x40000000	ANT_DOUBLE_E_DIST_ODO	Double calculation: Distance of odometry since last transponder is too high

10 Trouble Shooting

Following you will find a tabular listing of any possible malfunctions. This trouble-shooting chart lists occurring symptoms and the malfunctions that may be causing the symptoms.

In the third column you'll find instructions how to detect errors and how errors can ideally be resolved. If it is not possible to resolve the error, before contacting us please isolate the failures as precisely as possible using the table below (type of malfunction, time of occurrence etc.).

Table 87 *Trouble Shooting (part 1 of 2)*

Error	Possible cause(s) of failure	Possible diagnosis / trouble shooting
Speed incorrectly displayed or set	1. Rotary encoder defective or connected incorrectly. 2. Parameter "increments per meter" or „wheel diameter“ are wrong	1. Check the rotary encoder via the Parameter Test menu (section 4.11 on page 94 check and replace if necessary 2. Re-adjust odometry (see section 6.8.1 on page 122)
Automatic mode is not accepted / is not executed	1. Vehicle is not close to the selected segment. 2. No start release for the vehicle control unit (the vehicle might be in test mode, visible by the word „Test“ shown in the 7 segment display on the device) 3. Errors "Request" or "Vehicle" are displayed in menu Status Error 4.2.5 on page 62	1. Drive the vehicle to the segment start then use the Seg. Table from the menu Status Navigation 4.2.1 on page 54 at Seg. Table to check whether the coordinates of the segment are shown in the column „Available“. If not, check whether the parameters for Configuration Accuracy are set too tight. 2. Use the Parameter Test menu (section 4.11 on page 94) to activate the clearance by switching to the mode Idle 3. Check the indicated error message in Table 47 on page 136
Vehicle does not steer	1. Steering angle not properly parameterized 2. Steering angle not transmitted 3. Steering clearance from PLC not available	1. Check the following parameters. Make sure, none of the parameters is 0! – D: Steering Scaling – Comp. Left 1 – Comp. Right 1 – E: Speed Comp. Fix – Min/max steering angle of the corresponding wheel. Possibly set to Fix Angle or Deactivated instead of Var Angle 2. & 3. Use P CAN View or a Profinet tool to check, whether the steering angle of the wheel and the steering clearance are transmitted at all.

Table 87 *Trouble Shooting (part 2 of 2)*

Error	Possible cause(s) of failure	Possible diagnosis / trouble shooting
Transponder is not evaluated	1. Signal strength of the transponder is too low 2. Position pulse missing 3. Not enough distance to other transponders	1. Check ground reinforcement; minimize reading distance; check adjustment of antenna; possible defect of the antenna or transponder. 2. Reduce threshold for antenna position pulse; re-connect antenna properly 3. Relocate the transponder. Adjust parameters
Driving in automatic mode not possible	1. Error is displayed in menu Status Error 4.2.5 on page 62 2. Speed is not transmitted	1. Check the indicated error message in Table 47 on page 136 2. Use P CAN View or a Profinet tool to check, whether the speed of the wheel is transmitted at all.
Segment list is not accepted	1. No release for vehicle control unit 2. Incomplete sequence of segments	1. Use the Parameter Test menu (section 4.11 on page 94) to activate the clearance by switching to the mode Idle 2. - Call the segments in the correct order - Check whether the end positions of the segments are the start positions of the following segments. - Check whether the orientation of the segments fits (Exception: When the Attribute Spot Turn is set for a segment)

11 Technical Data

Table 88 *Technical Data Hardware HG G-61430ZD*

Hardware HG G-61430ZD	
Casing	Aluminium
Dimensions	Basic configuration s. Figure 37 on page 46 With expansion module HG 61431 s. Figure 50 on page 51
Weight	Basic configuration: approx. 800 g With expansion module HG 61431: approx. 950 g
Operating temperature	-25 to 70° C
Storage temperature	-40 to 85° C
Protection class	IP20
Shock / vibration	DIN rail mount: 3.5 mm from 5-9 Hz, 1G from 9-150 Hz 10 sweeps each axis, 1 octave per minute
Relative humidity 25° C	95 % (not condensing)
Interfaces	See section 3.5 on page 48
Power supply	Nominal: 12 – 24 Volt (Maximum range 10 – 30 Volt)
Current consumption	Basic configuration: 200 mA @ 24 Volt With expansion module HG 61431: approx. 300 mA @ 24 V

12 Appendix

12.1 Attributes

List of the attributes that may be set in the segment file (s. section 2.5.2.1 on page 24).

Table 89 *Attributes*

Code (bitcoded)	Description	Function
0x00000001	Segment start	Has to be set when reaching the first support point for the control unit to correctly recognize the segment start
0x00000002	Segment end	Has to be set when reaching the last support point for the control unit to correctly recognize the segment end
0x00000004	Right	for „Spot turn“, see below
0x00000008	Left	for „Spot turn“, see below
0x00000010	Deviation 2	This bit can be used to switch between two parameters for the maximum acceptable deviation between the target position and the actual position. – **0** Deviation 0 is used – **1** Deviation 1 is used
0x00000020	Use GPS	Navigation with GPS System
0x00000040	Accuracy	This bit can be used to switch between two parameters for the maximum acceptable position accuracy. – **0** Accuracy Track 0 is used – **1** Accuracy Track 1 is used
0x00000080	Use Transponder	Navigation with Transponders
0x00000100	Wire drive	not yet used
0x00000200	Offset right	s. section 2.5.3.1 on page 29
0x00000400	Offset left	
0x00000800	Steer not inverse	s. section 2.5.3.2 on page 31
0x00001000	Steer inverse	
0x00002000	Stop distance	s. section 2.5.3.3 on page 32
0x00004000	Spot turn	s. section 2.5.3.4 on page 32 When this bit is set and a suitable vehicle type is in use the vehicle turns on the symmetry axis until the desired vehicle orientation is reached (forklift). – If „Right“ and „Left“ are not set the vehicle turns into the direction that means the shortest possible distance to reach the desired orientation. – If one of those bits is set it determines the direction in which the vehicle turns regardless of the distance.
0x00008000	Steering straight	not yet used / by setting this bit the steering is set straight ahead (0° steering angle)
0x3FFF0000	Free	The higher 16 bits (except the two highest ones) are available for free attributes.

12.2 Steering via Segment Sequences

For fairs or similar occasions it is possible to define 8 fixed segment sequences inside the control unit.

12.2.1 Definition of Segment Sequences

The control unit's parameter file can be downloaded using the web site (see section 4.6.2 on page 90). In the last ranges of the file you can find the following parameters:

`U32_CAN_ID_SEG_BLOCK:` Decimal address of the CAN message

`U32_SEG1_BLOCK1:` first segment of the first segment sequence

`U32_SEG2_BLOCK1:` second segment of the first segment sequence

...

`U32_SEG8_BLOCK1:` eighth segment of the first segment sequence

`U32_SEG1_BLOCK2:` first segment of the second segment sequence

...

`U32_SEG8_BLOCK8:` eighth segment of the eighth segment sequence

These parameters can be changed directly within the parameter file using a text editor. Afterwards the file can be re-uploaded into the control unit (see section 4.6.1 on page 89).

12.2.2 Starting Segment Sequences

The segment sequences can be started via a CAN message (see 7.3.18 on page 157) or via a terminal program (see 5.9 on page 108).

WARNING

Unpredictable behavior of the vehicle

The terminal program also uses the values transmitted via the CAN bus. Thus it is important to exclusively use the CAN bus **OR** the terminal program. If both terminal program and CAN bus are used to transmit segment sequences there is a risk of segments being mixed up. Thus the vehicle might choose other segments than the user expects.

▶ Exclusively use either the CAN bus **OR** the terminal program

In order to minimize this risk the terminal program internally has a higher priority. If segment sequences are started via the terminal program, the CAN bus is ignored.

If the number of the segment sequence is to be determined via the transponder list the number has to be put into attribute 2 of the respective transponder (see Table 2 on page 20.

The segment sequence receives clearance automatically as soon as the automatic mode is started. If the clearance is revoked the control unit switches to the mode *Idle*.

12.3 Radius Calculation with 16 Bit Resolution

For the transmission of the radius only 16 bit are available. This means that the available number range for a millimeter resolution covers an area of about ±32,7 metres. In order to be able to set higher radii a number transformation is applied. This means

that for higher radii the increments are also higher. The transformation uses the tangent / arcus tangent function. The following equation shows the transformation used to calculate the number that has to be transmitted for a given radius:

Figure 106 *Formula: Equation for the calculation of 16 bit radii*

$$\texttt{s16 = (signed short)}\frac{65534}{\pi} \times \texttt{arctan}\frac{1000}{R} \quad | R \neq 0$$

s16 is the number that is to be transmitted over the bus. *R* is the radius that is to be driven in millimetre. When s16 is set to 0, straight-ahead driving is the result ($R = \infty$).

Figure 107 *Increased radius range through transformation*

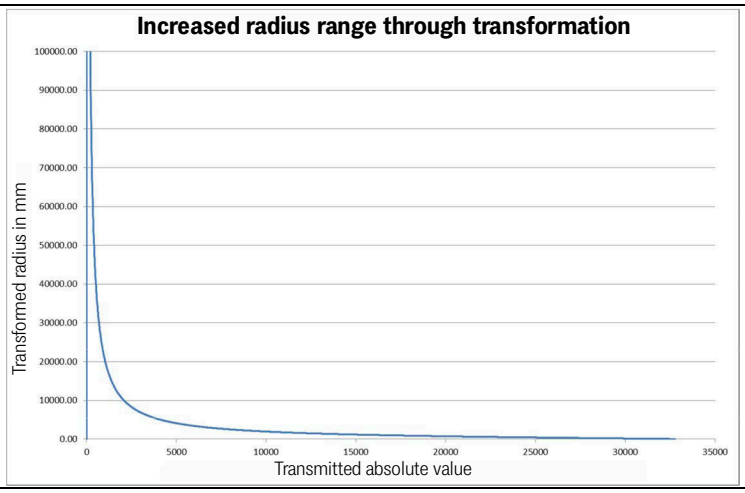
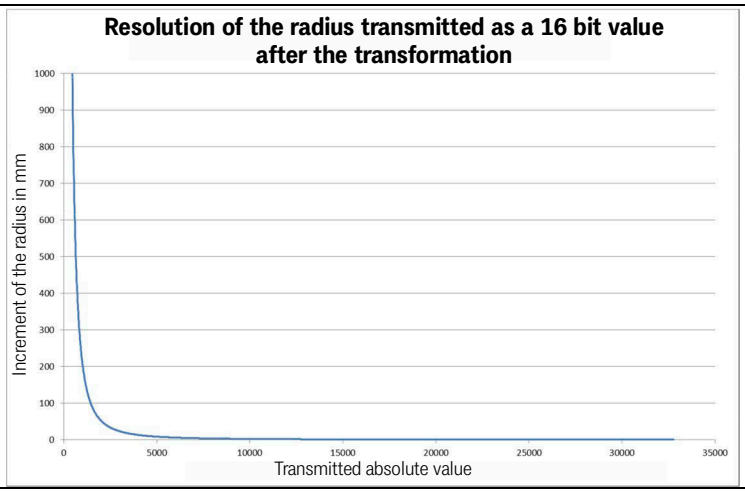


Figure 108 *Resolution of the radius after transformation*



12.4 Configuration of the Ethernet Interface Parameters via SIO 2

Normal communication with the navigation controller is performed via the Ethernet interface. In case the settings of the Ethernet interface are not known, Götting provides a program to read and change the Ethernet parameters via a serial interface SIO 2.

▶ Download the program `HG61430-D Vxxx setup.zip` from:

http://goetting-agv.com/components/73650

- Use a cable matching your computer‘s hardware to connect a serial port of the computer to the RS 232 interface SIO 2.
- Unpack the downloaded ZIP archive and start the EXE. The following screen comes up:

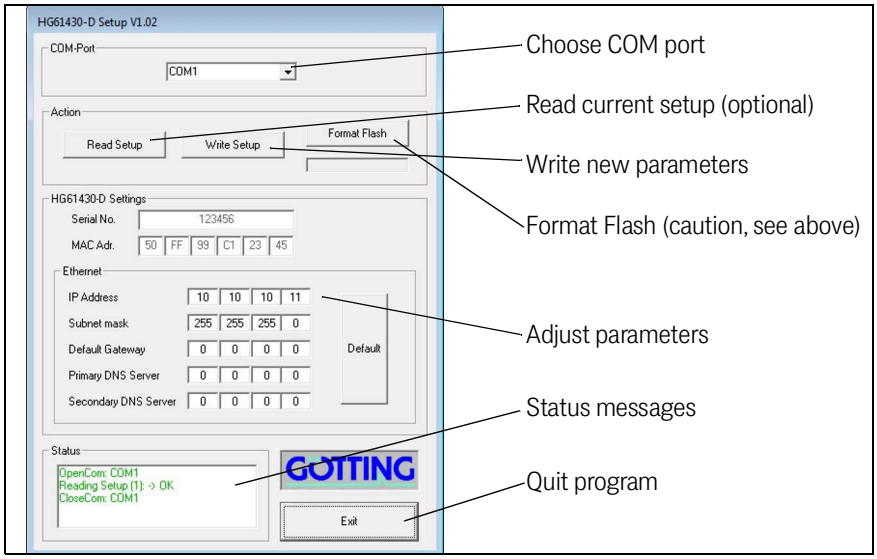
NOTICE

Risk of data loss

The button *Format Flash* erases the internal memory of the navigation controller.The Ethernet settings of the navigation controller remain but all configurations including the config file, segments.csv and transponder.csv are deleted and have to be re-uploaded (see chapter 4 on page 52).

- The function *Format Flash* should only be carried out in exceptional cases to resolve errors.

Figure 109 *Screenshot: Software for setting t. parameters of t. Ethernet interface via SIO 2*



- Choose the correct COM port. The program only shows available ports. However in case there are more than one it cannot detect to which the navigation controller is connected.
- Optionally use *Read Setup* to fetch the current settings from the navigation controller.
- Use the section *Ethernet* to adjust the parameters or give new ones. *Default* sets the standard parameters.
- Use *Write Setup* to transmit your Ethernet parameters to the navigation controller.
- Exit the program and remove the cable that connects the serial interface to SIO 2.

  If you connect your computer with the Ethernet interface of the navigation controller afterwards you have all the configuration options shown in chapter 4 on page 52.

12.5 Firmware Update via the USB Interface

You can download the Firmware Update Software from:

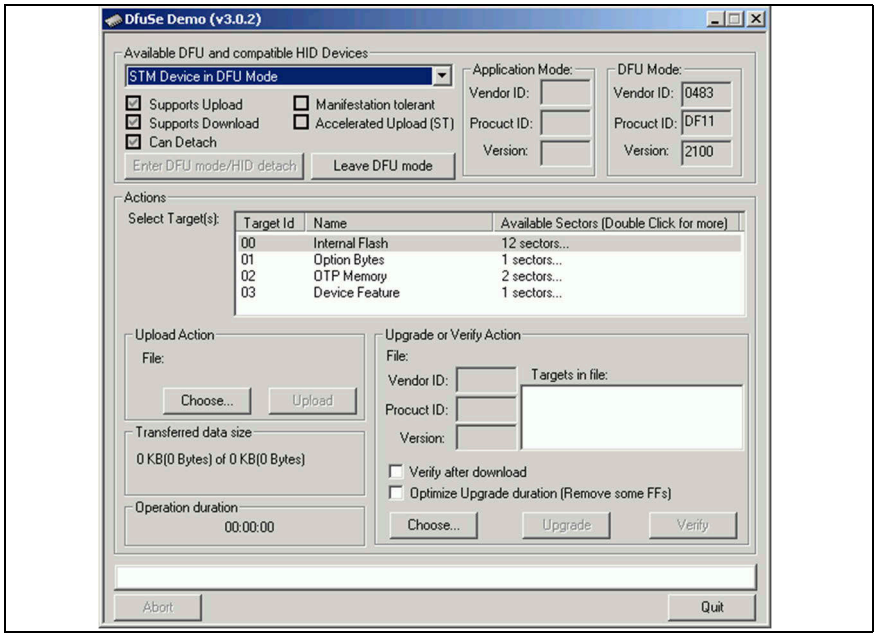
http://goetting-agv.com/components/73650

Only change SW2 when the control unit is switched off. After changing SW2 wait 30 seconds before turning the control unit on again. Otherwise a computer will not detect the device.

During the firmware update no USB stick may be present in or inserted into the control unit. The sockets for USB type A and type B are connected to the same data lines internally. Only one of them may ever be connected since otherwise no devices are detected.

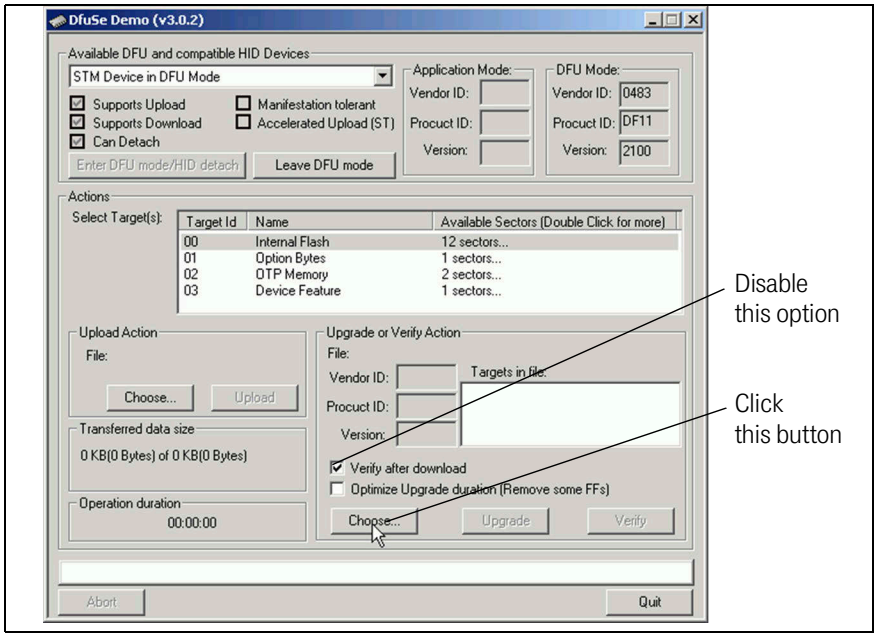
- Preparation: Install the PC software by executing `DfuSe_Demo_Vx.x.x_Setup.exe`.
- Power the control unit off.
- Switch SW2 to *ON*.
- Wait for at least 30 seconds.
- Establish a connection between the computer and the USB type B socket of the control unit.
- Turn the Control Unit on.
  The device should be detected automatically and the corresponding drivers should be installed.
- Start *DfUse Demo* on your computer. It starts in demo GUI mode, which is sufficient for the firmware update. The following screen should be shown when the Control Unit is connected:

Figure 110 *Firmware Update Software: Start screen*



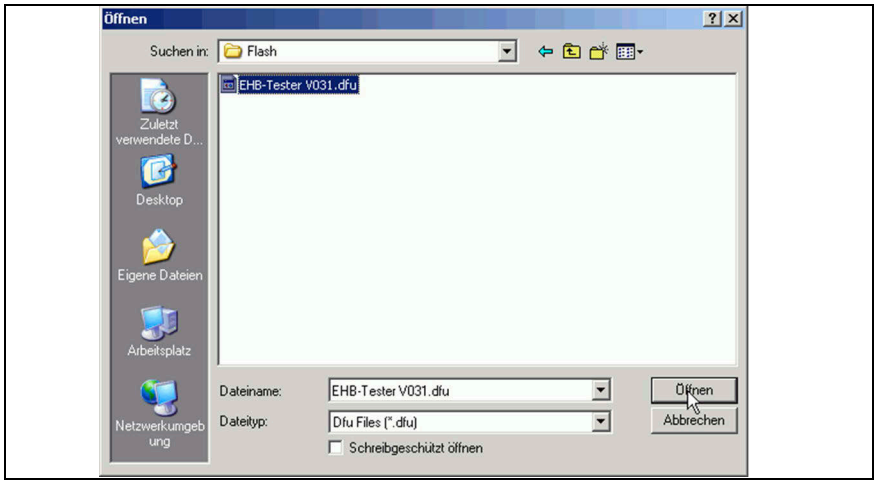
▶ Disable the option *Verify after download* in the section *Upgrade or Verify Action*. Click *Choose* in the section *Upgrade or Verify Action*.

Figure 111 *Firmware Update Software: Adjust options*



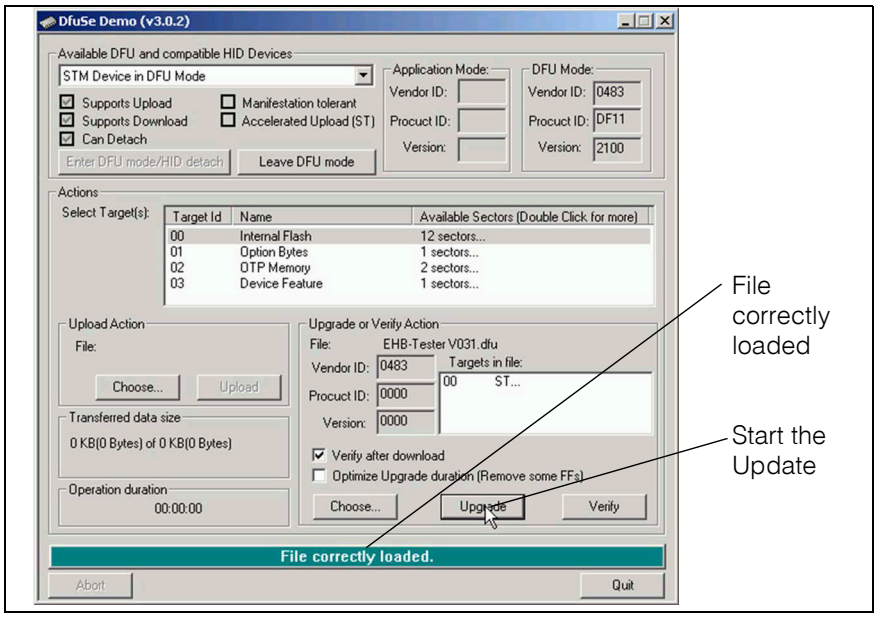
▶ Choose a firmware file with the type `*.dfu`

Figure 112 *Firmware Update Software: Choose firmware file*



▶ Status message: *File correctly loaded.* Now click on *Upgrade*.

Figure 113 *Firmware Update Software: Start the update*

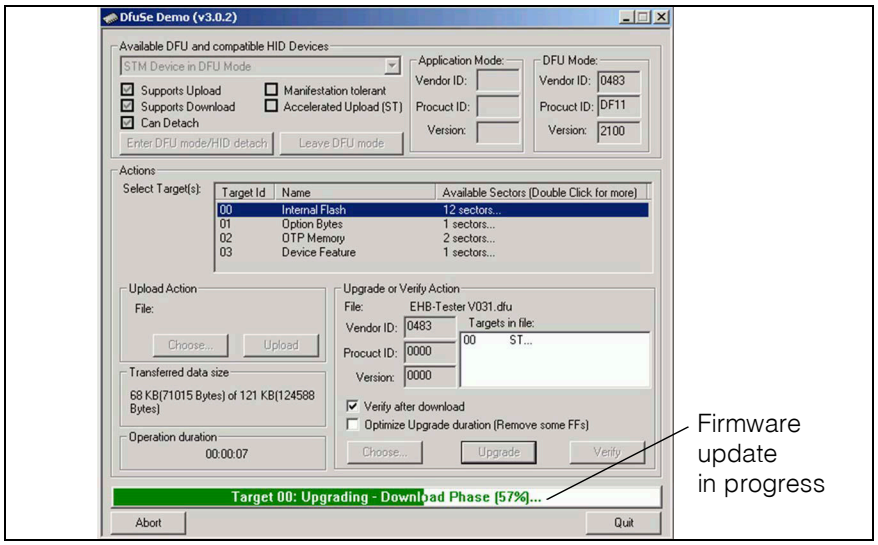


▶ The following dialog appears. Confirm by clicking *Yes*.

Figure 114 *Firmware Update Software: Confirmation dialog*

▶ Afterwards the deletion and programming process starts.

Figure 115 *Firmware Update Software: Update in progress*



▶ When it is finished power the control unit off.

▶ Wait at least 10 seconds until the USB connection to the PC is disconnected (the operating system usually indicates with a sound or a symbol in the tray that a connected USB device has logged off).

▶ Remove the USB cable and switch SW2 to *OFF*.

▶ Turn the control unit on again.

If after an update the error message *SErr 0100* blinks on the 7 segment display this doesn't necessarily mean that the parameter file was defect. It could also be that there is a newer Software Version in the control unit that includes new parameters that are not yet included in the control unit's parameter file.

If the error message appeared:

- Switch to one of the parameter web sites, enter the password, authenticate and press OK.

The control unit then adds the new parameters in the file and saves it.

- Re-start the control unit.

  The message should be gone.

- To be on the safe side, check the parameters.

If the reason was a defect parameter file after all:

- Upload a correct parameter file, see section 4.6.1 „Upload Configuration“ on page 89.

13 List of Figures

14 List of Tables

15 Index

S

T

U

V

W

16 Copyright and Terms of Liability

16.1 Copyright

16.2 Exclusion of Liability

Any information given is to be understood as system description only, but is not to be taken as guaranteed features. Any values are reference values. The product characteristics are only valid if the systems are used according to the description.

This instruction manual has been drawn up to the best of our knowledge. Installation, setup and operation of the device will be on the customer's own risk. Liability for consequential defects is excluded. We reserve the right for changes encouraging technical improvements. We also reserve the right to change the contents of this manual without having to give notice to any third party.

16.3 Trade Marks and Company Names

Unless stated otherwise, the herein mentioned logos and product names are legally protected trade marks of Götting KG. All third party product or company names may be trade marks or registered trade marks of the corresponding companies.

Innovation through Guidance

Götting KG
Celler Str. 5 | D-31275 Lehrte
Tel. +49 (0) 5136 / 8096 -0
Fax +49(0) 5136 / 8096 -80
info@goetting-agv.com | www.goetting-agv.com