Driving Robot Catalogue

May 2021

... worldwides most flexible driving robots






Made in Germany

Contacts

Germany

VEHICO GmbH
Büchnerstr. 6
38118 Braunschweig, Germany
Phone +49-531-20835-110
info@vehico.com

Kistler Instrumente GmbH
Umberto-Nobile-Str. 14
71063 Sindelfingen
Phone +49-7031-309-0
axel.ganz@kistler.com

Australia / New Zealand

Applied Measurement Australia Pty. Ltd.
5/27 Thornton Crescent
Mitcham, Victoria 3132, Australia
Phone +61-3-9874 5777
craignyssen@appliedmeasurement.com.au

China

Intelligent Connected Technology of CAERI Ltd.
Zone C, 3F, Building12, phase1, Jintai Industrial Park,
No.22 Jinyu Avenue, Liangjiang New District,
Chongqing, P.R. China
Phone +86-15086822633
puziguang@caeri.com.cn

Kistler Innovative Technology China Ltd.
Building 15, No.1588 Shenchang Road, 201107,
PRC Shanghai, China
Phone +86 21 23516 000
sales.cn@kistler.com

Czech Republic

Kistler Eastern Europe s.r.o
Zelený pruh 1560/99
140 00 Praha 4, Czech Republic
Phone +420 222 135 370
sales.cz@kistler.com

France

Kistler France
ZA de Courtaboeuf 1, 1, avenue de l'Atlantique
Bâtiment le Mont Blanc, 91976 Les Ulis Cédex, France
Phone +33 1 69 18 81 81
info.fr@kistler.com

India

ZEN MICROSYSTEMS
PRISTINE FONTANA
A Bldg, Flat No.: 607
Bavdhan, PUNE - 411 021, India
Phone +91-20-66747085
info@zenmicrosystems.co.in

Israel

MAGAL Automotive Engineering Ltd.
Nataf 58 , Israel 9080400
Phone +972-25700645
office@magaltech.com

Italy

Kistler Italia s.r.l.
Via Ludovico di Breme 78
20156 Milano, Italy
Phone +39 02 481 27 51
sales.it@kistler.com

Japan

VBox Japan Ltd.
202 Ka-sa- Toriyama Building, 237 Toriyamachou,
Kohoku-ku, Yokohama, Kanegawa, 222-0035, Japan
Phone +81-45-475-3703
Vehicojapan@vboxjapan.co.jp

Kistler Japan Co., Ltd.
2F, Benex S-3
3-20-8 Shinyokohama, Kohoku-Ku, Yokohama,
222-0033 Kanagawa, Japan
Phone +81-45-471-8620
sales.jp@kistler.com

Korea

BGF Corporation
IBC World Gate, Unseo-dong, Jung-Ku,
Incheon, 400-719 South Korea
Phone +32-743-7151
bgfco@hanmail.net

Kistler Korea Co., Ltd.
Pangyo Innovalley C-dong 702
253, Pangyo-ro,Bundang-gu
Seongnam-si, Gyeonggi-Do, Korea 13486
Phone +82 31 8045 0900
sales.kr@kistler.com

Malaysia / Singapore / Thailand

MS Instruments(SEA) Sdn Bhd
No. 52, Jalan USJ 9/5P, 47620 UEP, Subang Jaya,
Selangor Darul Ehsan, Malaysia
Phone +60-3-80241615
sales@msisb.com

Russia

Novtech Ltd.
Lunacharskogo st. 77, Office 7
620075 Jekaterinburg, Russia
Phone +7-343-328-9140
info@novtech-russia.ru

Spain

Kistler Ibérica S.L, Unipersonal
C/Pallars, 6 Planta 2
08402 Granollers, Barcelona, Spain
Phone +34 93 860 33 24
info.es@kistler.com

Sweden

Kistler Nordic AB
Kanalstraket 5
433 76 Jonsered, Sweden
Phone +46 31 871 566
info.se@kistler.com

Taiwan

ArchiAct Technology, Corp.
8F., No.275, Fuhe Rd., Yonghe Dist.,
New Taipei City 234, Taiwan (R.O.C)
Phone +886-2-7729 6766
jennifer.hsiao@archiactek.com

Turkey

Kistler Turkey Ltd.
Küçükbakkalköy Mah. Sevinçli Sok. No:3 D:3
34750 Atasehir, Istanbul,Turkey
Phone +90 216 265 10 00
sales.tr@kistler.com

United Kingdom

Kistler Instruments Ltd.
13 Murrell Green Business Park, London Road
Hook, Hampshire RG27 9GR, UK
Phone +44 1256 741 550
sales.uk@kistler.com

United States of America

Kistler Instruments Corp.
30280 Hudson Drive
Novi, MI 48377, United States
Phone +1 248 668 6900
sales.us@kistler.com

Contents

1 General Introduction

Welcome to the world of objective vehicle testing!

Are you involved with tests which require high precision steering wheel or pedal motions?

Or tests which require a reproducible driven track with precise velocity or acceleration?

Do you need to realize tests which are to risky to be driven by a test driver?

Then you are perfectly right here!

Typical applications in which VEHICO driving robots are used are EuroNCAP AEB tests, FMVSS126 / ECER13H ESC tests, embankment rollover tests, double lane change tests, tyre tests, vehicle identification tests, research projects and much more.

More and more vehicle manufacturer, supplier, test facilities, authorities and research institutions around the world are enthused users of VEHICO products. Easy operation, quick installation and a tremendous flexibility to cover all sorts of test scenarios, last but not least our outstanding support is mentioned by our customers as absolutely unique.

Illustration 1: Examples for the use of VEHICO Robots: Double Lane Change and Circle Driving

Up-to-date research results directly transferred into modern products are the base for all VEHICO systems. Our driving robots are structured into modular expansion stages to enable the highest possible adaptability to the most different vehicle tests:

The entry product level are the base versions of the robots. They are quickly installed and allow the actuation of the vehicle's pedals or steering wheel. This product level is summarized as "CO.ACT".

The higher product levels offer automated driving solutions. With "CO.TRACK" the vehicle is steered automatically. The VEHICO track control algorithm guarantees highly accurate and reproducible driving on a pre-defined or recorded course.

"CO.DRIVE" is an extension of the functions of "CO.TRACK" where the test vehicle drives completely autonomously. Besides controlling the track CO.DRIVE additionally controls freely definable speed and acceleration profiles. A human driver is no longer required because the vehicle is completely driven by "CO.DRIVE". Nevertheless the driver can operate the test car in the usual way if "CO.DRIVE" is disabled.

With "CO.SYNC" tests with synchronized driving can be realized. The driving states are optimized so that the previously defined absolute positions at certain times are followed precisely. The test vehicle can be synchronized to other test vehicles, soft targets or pedestrian dummys. In the highest expansion stage "CO.SYNC" is combined with a wireless "Inter Robot Communication" for dynamical synchronization.

Welcome to the world of VEHICO!

2 Steering Robots

Vehicle testing is simplified by the characteristic features

- operation of the vehicle's original steering wheel
- all steering wheel functions such as cruise control remain usable
- uncompromised activation of the airbag
- quick and non-destructive installation
- universal suction mounting
- steering motions in conformance with NHTSA Fishhook and FMVSS126 tests
- support of individual scalable test series
- adaptability to nearly all standard steering wheels
- manual steering in deactivated state.

2.1 Steering Robot Basics

With over 10 years of worldwide operation the VEHICO steering robots enjoy an increasing popularity. From the beginning very much appreciated by our customers was the fact that the vehicle's own steering wheel does not have to be removed. Our leading role in behind-the-wheel steering robots is even approved by competitors as they try to copy our successful design. No copy you find elsewhere reaches our quality, flexibiltiy and smooth running behaviour.

VEHICO's steering robot design guarantees that the vehicle itself remains unchanged by the robot and the vehicle electronics are not confused by the lack of the vehicle's own steering wheel. All functions integrated in the steering wheel such as airbag, vehicle computer, radio etc. remain fully functional.

Illustration 2: VEHICO Steering Robot

For VEHICO's steering robots no disturbing or even dangerous structures between the steering wheel and the driver's face are necessary. These advantages are crowned with an unbeatable short installation time.

With a VEHICO steering robot you can

- execute standardized and pre-defined steering maneuvers,
- program any desired custom steering maneuver thanks to an easy to understand scripting language,
- record and replay steering maneuvers,
- provide desired steering angles via CAN bus in steer-by-wire mode,
- read desired steering angles from a generated file,
- read and log up to 20 measurement signals by means of the CAN bus and use them as trigger signals,
- realize a reference to the proving ground with a digital reflex trigger,
- evaluate the performed maneuver graphically, quickly and clearly
- and much more…

With the VEHICO steering robot, an objectification of dynamic vehicle testing is achieved. Steering maneuvers can be executed with the highest precision and absolutely reproducible accuracy using various test vehicles.

Of course the requirements of the American NHTSA Fishhook and FMVSS 126 respectively the ECE R13-H test are fulfilled. Any steering maneuver desired may be individually specified. Standard steering maneuvers have already been pre-configured.


Illustration 3: Steering Robot installed in Passenger Car (left) and Commercial Vehicle (right)

All VEHICO steering robots are constructed in such a manner that they can be universally adapted to various vehicles and at the same time are quick to install. A driver may continue to sit in the vehicle unimpeded and operate the vehicle almost without limitation.

A separable annular gear is fastened behind the steering wheel such that no modifications need to be made to the vehicle itself for mounting. The vehicle's original steering wheel remains installed, which has many advantages, such as reduced installation time and an uncompromised activation of the airbags.


Illustration 4: Installation of the Steering Robot using Suction Mounting

An electric motor provides the necessary control behavior. The fastening in the vehicle is done by using a universal adjustable armature with suction mounting. The position of the motor can be chosen individually. The motor can be fitted to the bottom as illustrated in the picture above, but it may as well be attached to the side.

Two knuckle switches, which must be activated for the test execution, ensure that the hands of the test driver are not located on the steering wheel during the steering maneuver. Of course the steering robot has also a hold function to fix the current steering wheel position while the first switch is pressed. The motion of the steering wheel can be stopped at any time by releasing the knuckle switches.

The VEHICO steering robots are available in three different versions for passenger cars and two different versions for commercial vehicles:

Steering Robot	CS-B20	CS-B40	CS-B50	CS-B60	CS-B60T	CS-B150T
Vehicle						
Nominal torque on steering wheel	20 Nm	40 Nm	50 Nm	60 Nm	60 Nm	150 Nm
Turning speed at nominal torque	1000 °/sec	1200 °/sec	1200 °/sec	1200 °/sec	1200 °/sec	500 °/sec
Max. turning speed	1100 °/sec	3500 °/sec	1900 °/sec	1700 °/sec	1700 °/sec	800 °/sec
Steering angle resolution	0.02 °	0.02 °	0.005 °	0.01°	0.01°	0.005°
Steering wheel diameter	25 - 44 cm				38 - 55 cm	
Power supply voltage	12 VDC	12 VDC	12 VDC (with internal power pack)		24 VDC (with internal power pack)	
Weight of entire robot drive unit	3.6 kg	4.7 kg	4.2 kg	6.7 kg	10.1 kg	10.1 kg

The VEHICO steering robots are the most capable steering robots on the market. In spite of these outstanding performance characteristics they have an extremely attractive price.

2.2 Steering Robot Options

2.2.1 Steering Torque Sensor

In order to measure the torque applied by the steering robot, the system can be equipped with an optional steering torque measurement system. It consist of a high precision load cell that is integrated into the mounting of the arm to the steering robot drive. Therefore you do not need any extras or additional mounting equipment. The robot is installed all the same whether it has a torque sensor or not. The used load cell is characterized by its outstanding accuracy and by its special design angular deviations of the mounting arm have practically no influence on the torque signal.

Technical Specifications of Load Cell	CS-B20	CS-B40	CS-B50	CS-B60 / CS-B60T	CS-B150T
Full Scale Torque	+/-35 Nm	+/-86 Nm	+/-86 Nm	+/-107 Nm	+/-170 Nm
Linearity	< 0.02% full scale				
Hysteresis	< 0.02% full scale				
Sensor overload	400% full scale				
Digitisation	24 Bit ADC				

The steering torque sensor is always supplied with a manufacturer's certificate. If an ILAC-MRA certificate according to DIN EN ISO/IEC 17025 is required, this must be stated when ordering.

2.2.2 CAN Online Input

The robot can be controlled by an external signal which is provided via CAN interface. A specific CAN protocol provides the control mode and the desired values. This information is evaluated in realtime from the robot and gives the opportunity to use all available control modes and to switch between them any time. Very often this feature is used for research or development projects where a commercial car should be equipped with drive-by-wire functions.

2.2.3 Automatic Track Control CO.TRACK

The automatic track control, sometimes also known as path following, is integrated as a software option in our steering robots. It is a closed-loop control method that compensates the lateral displacement of the vehicle relative to a reference track. CO.TRACK is based on the long-standing expertise in the field of vehicle dynamics controls of VEHICO.

Reproducible, smooth and robust steering with at the same time simple applicability are essential features of CO.TRACK.

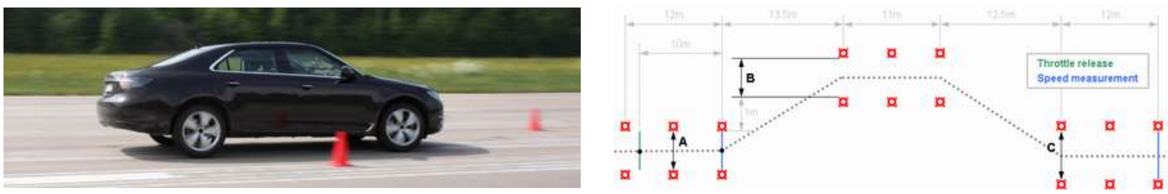


Illustration 5: Double Lane Change Maneuver with VEHICO Steering Robot

The automatic track control is available as *CO.TRACK light* for straight-line driving and driving with low dynamics or as high performance release *CO.TRACK* for highly dynamical driving tests:

	CO.TRACK light	CO.TRACK
Steering wheel turning speed	< 90 deg/sec	not limited

The position of the test vehicle is determined by any suitable GPS sensor and imported via CAN interface. The track can be defined by the VEHICO scripting language or recorded by manual driving.

Please see section 13.1 for the complete and detailed description of the automatic track control.

2.2.4 Automatic Driving CO.DRIVE

Like CO.TRACK the automatic driving CO.DRIVE is integrated as a software option in our steering robots. It extends the automatic track control with a programmable velocity profile. Accelerator and brake robot are necessary for this option.

The automatic driving is available as *CO.DRIVE light* for straight-line driving and driving with low dynamics or as high performance release *CO.DRIVE* for highly dynamical driving tests:

	CO.DRIVE light	CO.DRIVE
Steering wheel turning speed	< 90 deg/sec	not limited
Longitudinal acceleration	< 4 m/sec²	not limited

The position of the test vehicle is determined by any suitable GPS sensor and imported via CAN interface. The track and the velocity profile can be defined by the VEHICO scripting language. Recording of track and velocity by manual driving is also possible.

Please see section 13.3 for the complete and detailed description of the automatic driving.

2.2.5 Synchronized Driving CO.SYNC

CO.SYNC is also integrated as a software option in our steering robots. It extends the automatic track control with a programmable time profile. Accelerator and brake robot are necessary for this option.

The synchronized driving is available as *CO.SYNC light* for straight-line driving and driving with low dynamics or as high performance release *CO.SYNC* for highly dynamical driving tests:

	CO.SYNC light	CO.SYNC
Steering wheel turning speed	< 90 deg/sec	not limited
Longitudinal acceleration	< 4 m/sec²	not limited

The position of the test vehicle is determined by any suitable GPS sensor and imported via CAN interface. The track and the time profile can be defined by the VEHICO scripting language.

Please see section 13.4 for the complete and detailed description of the synchronized driving.

3 Accelerator Robot

Key Features of the VEHICO Accelerator Robot:

- quick and easy installation
- automatic adaption to the vehicle specific pedal travel
- driver can always override pedal
- intuitive scripting language
- control modes: pedal position, vehicle velocity and vehicle distance
- record and replay of manually driven tests
- switching between control modes within a test run
- synchronized operation with all VEHICO robots possible

3.1 Accelerator Robot Basics

The compact accelerator robot or sometimes called gas pedal robot has been specifically developed by VEHICO for the needs of vehicle testing. It allows the control of the gas pedal of handshift as well automatic vehicles.

With its three control modes pedal position, vehicle velocity and vehicle distance the gas pedal robot offers a wide range of possible applications for vehicle testing. User-defined trajectories can be assigned for each control mode and can be replayed during the test run with the highest precision and reproducibility even in most different cars. Switching between the three control modes is of course possible within a test run. As for all VEHICO robots we attached great importance to a short setup time and an intuitional operation.

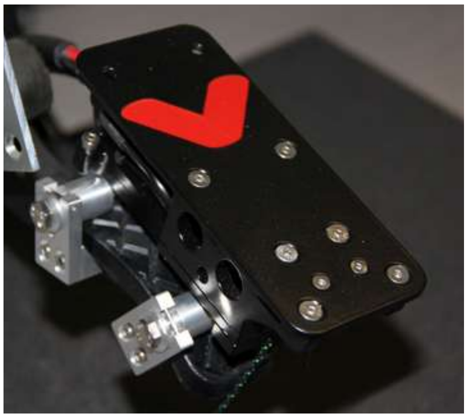


Illustration 6: Transport Case and installed Drive Unit

The pedal actuator CG300 was designed relating to an optimal power-to-weight ratio. The drive unit gets attached on top of the vehicle's accelerator pedal. This mounting approach is characterised by an especially quick and easy assembly. The pedals own restoring force is not affected by the low weight of the drive. While the unit is clamped on the pedal only a suitable counter bearing for the wire rope must be created beneath the pedal. The operation of the pedal remains still possible even with installed pedal drive unit. The driver simply steps on the drive from above and pushes the pedal down.

Typical Accelerator Robot Applications:

- EuroNCAP AEB (Automated Emergency Braking) testing
- ADAS testing and development
- autonomous driving projects
- gear box testing

The pedal actuator distinguishes a patented automatic referencing to calibrate the vehicle specific pedal travel. This makes the handling and portability between different vehicles particularly simple. An adaptation to different vehicles is executed fully automatically within a few seconds subsequent to the installation. After the referencing the pedal trajectory can very easily be provided by percentage positioning values, completely independent of the vehicle individual pedal travel of the single pedal.

Illustration 7: Drive Unit CG300 – Compact and Lightweight

As with all VEHICO robots any sensor can be connected at the freely configurable CAN interface. A dbc file import makes configuration easy. Different CAN signals may be computed with each other, e.g. to calculate a TTC (time to collision) value out of distance and speed.

	Technical Specifications of Accelerator Robot CG300
max. pedal force	300 N
max. pedal speed	110 cm/s
max. pedal travel	300 mm
resolution pedal position	0.01 mm
typ. duration for full scale gas operation:	< 0,15 s
typ. current consumption for gas operation	5 A
typ. referencing duration	5 sec
power supply voltage	12 V (vehicle power system)
dimensions incl. mounting	11,5 x 7,5 x 7 cm
weight	0,6 kg

3.2 Accelerator Robot Options

3.2.1 Vehicle Speed Control

The pedal drive CG300 can be equipped with an additional control loop for the vehicle speed. Using simple scripting commands almost any velocity trajectories can be programmed. An external sensor measures the required vehicle speed signal and delivers this information via CAN bus.

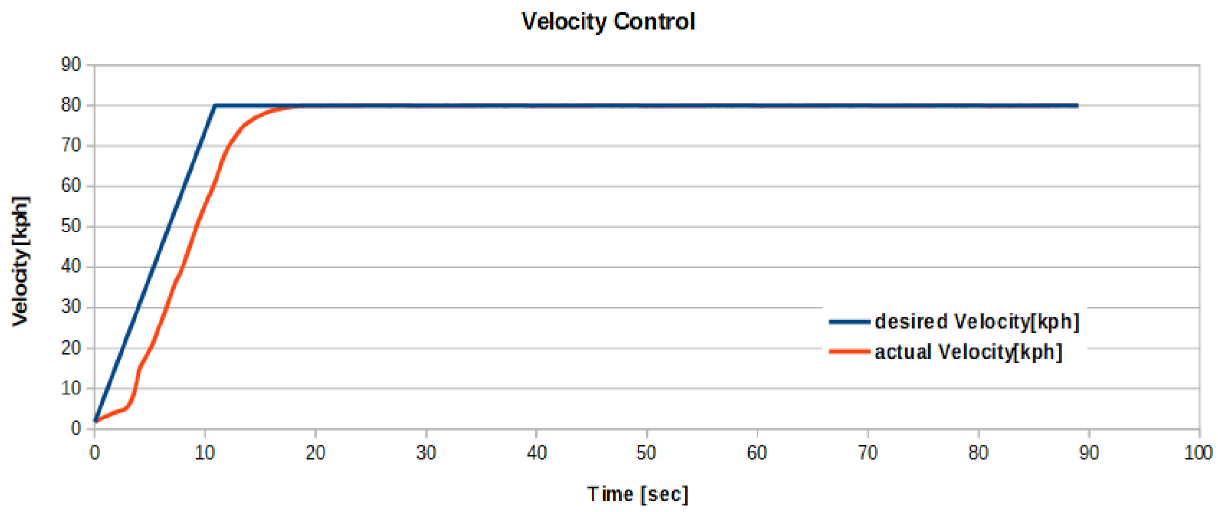


Illustration 8: Typical Velocity Control Performance

This option requires an appropriate vehicle speed sensor, which is not included. In addition, the pedal robot must have a CAN interface.

3.2.2 Distance Control

The extensive performance of the gas pedal robot becomes evident if it is operated in the distance control mode in which the relative longitudinal distance to another driving vehicle is controlled.

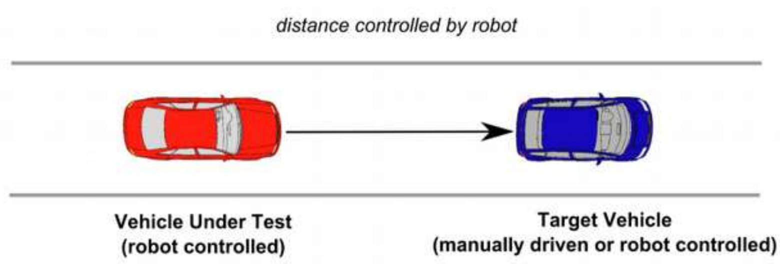


Illustration 9: Typical Distance Control Scenario

While testing with a second vehicle, the distance can be controlled with highest precision, regardless of whether the own car runs behind, in front or beside the target vehicle. Also parallel driving, crossing, overtaking or cutting in is feasible. In combination with the VEHICO steering robot and the automatic track control you have all options for testing advanced driver assistance systems (ADAS). Using simple scripting commands almost any distance trajectories can be programmed. The distance and velocity information must be provided via CAN bus.

This option requires an appropriate device for measuring the relative distance and velocity between the two vehicles, which is not included. In addition, the pedal robot must have a CAN interface. The system is compatible with all common DGPS systems and radar sensors.

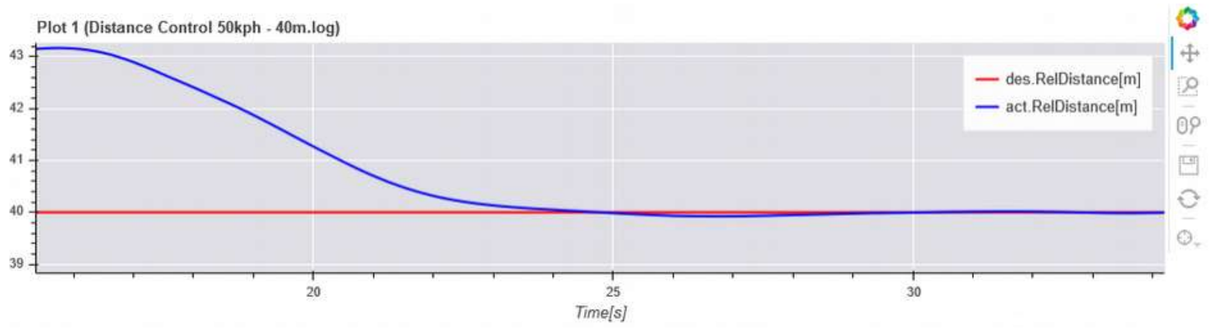


Illustration 10: Typical Distance Control Performance

3.2.3 CAN Online Input

The robot can be controlled by an external signal which is provided via CAN interface. A specific CAN protocol provides the control mode and the desired values. This information is evaluated in realtime from the robot and gives the opportunity to use all available control modes and to switch between them any time. Very often this feature is used for research or development projects where a commercial car should be equipped with drive-by-wire functions.

4 Brake Robot

Key Features of the VEHICO Brake Robot:

- quick and easy installation
- intuitive scripting language
- synchronized operation with all VEHICO robots possible
- trigger signals can be processed at any time during a test run
- multiple control modes
- switching between control modes within a test run
- record and replay of manually driven tests
- driver can always override pedal
- connect any sensors on freely configurable CAN interface with dbc file import
- different CAN signals may be computed with each other, e.g. to calculate a TTC (time to collision) value out of distance and speed

4.1 Brake Robot Basics

The powerful brake robot CB2100 is characterized by a rugged construction and the versatility of possible applications in everyday test operations.

In addition to the control variables pedal position and pedal force, the vehicle brake pressure and vehicle deceleration can also be controlled. Switching between the four control modes is of course possible even within a test run.

The brake robot is capable of applying extreme forces up to 2000 N and exceptionally high pedal speeds of up to 120 cm/sec. With its high-performance specifications the brake robot provides an optimal solution for almost any brake tests.

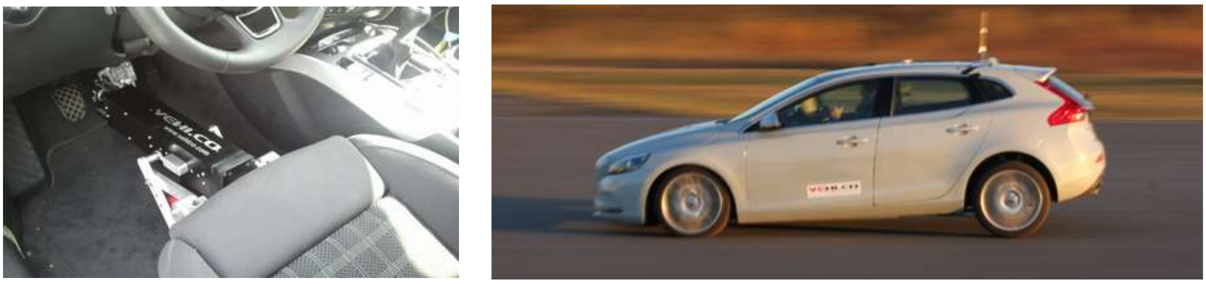


Illustration 11: Brake Robot CB2100

As for all VEHICO robots we attached great importance to a short setup time and an intuitional operation. Numerous interfaces facilitate the integration of sensors.

Typical Brake Robot Applications:

- EuroNCAP AEB (Automated Emergency Braking) testing
- HBA tests with high pressure gradients
- automated braking maneuvers
- ADAS testing and development
- autonomous driving projects
- tyre testing

The robot consists of a linear piston drive which is installed between the driver's seat and the brake pedal. By activating the drive the piston is extended, which moves the brake pedal down. The system is fixed to a seat mounting system, which in turn is fastened directly to the fixing points of the seat or by means of tension belts to the driver's seat. The brake robot transmits its force on a bracket, which is clamped on top of the brake pedal.

With installed brake robot the driver can still operate the test vehicle manually. Therefore the system has a freewheel mechanism. This ensures that a manual braking is possible at any time, even with an activated brake robot.

Thanks to its universal mounting system, the brake robot is quickly installed in different test vehicles, without the need to make changes to the vehicles.

After the installation and during the initial operation in a new test vehicle the system runs a fully automatic referencing. This measures the vehicle-specific distances and pedal forces. Subsequently, one can work either with percentage values regardless of the vehicle's physical pedal travel or with absolute values of the pedal travel. This makes the transferability between different vehicles particularly easy.

	Technical Specifications of Brake Robot CB2100
max. pedal force	2000 N
max. pedal speed	120 cm/s
max. pedal travel	180 mm
resolution pedal position	0.01 mm
typ. duration for full scale brake pedal operation:	< 0,2 s
typ. current consumption for brake pedal operation	35 A
typ. referencing duration	5 sec
power supply voltage	12 V (vehicle power system)
dimensions incl. mounting	500 x 80 x 160 cm
weight	8,0 kg

4.2 Brake Robot Options

4.2.1 Pedal Force Control

The brake robot CB2100 can be equipped with an additional force sensor to measure the pedal force. The integrated closed loop controller is used to control the applied force. Using simple scripting commands almost any force trajectories can be programmed.

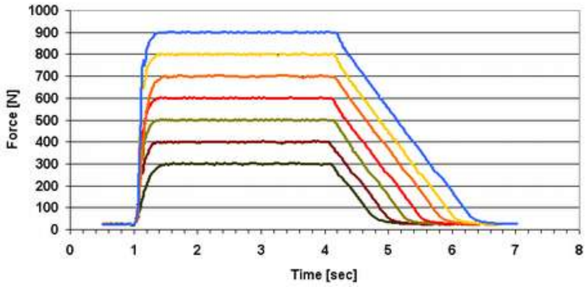


Illustration 12: Typical Output of Force Control

The force sensor and the necessary sensor electronics are included in this option and are tightly integrated into the brake robot. The technical specifications are:

	Technical Specifications of Load Cell
Full Scale Force	2000 N
Linearity	< 0.1% full scale
Hysteresis error	< 0.05% full scale
Resolution	< 0.00015 N
Sensor overload	300% full scale
Measurement delay	< 2 ms
Digitisation	24 Bit ADC

The pedal force sensor is always supplied with a manufacturer's certificate. If an ILAC-MRA certificate according to DIN EN ISO/IEC 17025 is required, this must be stated when ordering.

4.2.2 Vehicle Deceleration Control

The brake robot CB2100 can be equipped with an additional control loop for the vehicle deceleration. Like for tire or vehicle brake tests a reproducible vehicle deceleration can be guaranteed. Using simple scripting commands almost any vehicle deceleration trajectories can be programmed. An external sensor measures the required vehicle deceleration signal and delivers this information via CAN bus.

This option requires an appropriate vehicle deceleration sensor, which is not included. In addition, the brake robot must have a CAN interface.

4.2.3 Hydraulic Brake Pressure Control

The brake robot CB2100 can be equipped with an additional control loop for the hydraulic brake pressure. Using simple scripting commands almost any pressure trajectories can be programmed. An external sensor measures the required brake pressure signal and delivers this information via CAN bus.

This option requires an appropriate brake pressure sensor, which is not included. In addition, the brake robot must have a CAN interface.

4.2.4 CAN Online Input

The robot can be controlled by an external signal which is provided via CAN interface. A specific CAN protocol provides the control mode and the desired values. This information is evaluated in realtime from the robot and gives the opportunity to use all available control modes and to switch between them any time. Very often this feature is used for research or development projects where a commercial car should be equipped with drive-by-wire functions.

5 Multipurpose Pedal Robot

Features of the VEHICO Multipurpose Pedal Robot:

- quick and easy installation
- pedal actuation through lever arm mechanism
- driver can always override pedal
- intuitive scripting language
- wide range of control modes: pedal position, pedal force, hydraulic brake pressure and vehicle deceleration
- switching between control modes within a test run
- record and replay of manually driven tests
- synchronized operation with all VEHICO robots possible

5.1 Multipurpose Pedal Robot Basics

Due to its design the multipurpose pedal robot CP800 can be used likewise for brake or clutch pedal operation. The robot is installed directly in front of the driver's seat. The dimensions of the robot allows the simultaneous installation of several systems in one vehicle.

The forces and speeds of the robot are absolutely sufficient for most standard driving maneuvers. With pedal speeds of up to 100 cm/s and pedal forces of up to 800 N adequate reserves are available.

Special Feature of the VEHICO Multipurpose Pedal Robot:

- robot can be used for brake or clutch pedal operation
- all control modes of brake robot available

With the help of its universal mounting system the robot is fixed either to the driver seat or to the seat fixing points. The second mechanical connection to the car is made via a bracket, that is clamped to the vehicle pedal. Changes to the vehicle must not be made for this purpose. A lever arm with adjustable length between the robot and the vehicle pedal transmits the movements. Therefore the robot can be installed in a very short time.

As the robot has a mechanical freewheel mechanism, the driver still can operate the car in a convenient way. Even with an activated pedal robot a manual operation is possible at any time.

Illustration 13: Installation of Pedal Robot CP800 between Seat and Pedal

After the installation the system is activated by going through a referencing phase. During this period of time the pedal is pushed down ones and the robot is calibrating the system according to the vehicle specific pedal travel. After a successful referencing the robot is ready for operation. Now the pedal positions can very easily be programmed by percentage positioning values, which are completely independent of the vehicle individual pedal travel. This makes the handling and portability between different vehicles and different pedals particularly simple.

Illustration 14: Pedal Robot CP800

The CP800 can be equipped with a force sensor to measure the pedal force applied by the robot. With this sensor the pedal force can be controlled freely by programmable force trajectories.

Because if its unique design our multipurpose pedal robot CP800 can provide high pedal forces without time limit. Unlike other systems which must be switched off after a specific period of time our system can push down the clutch or brake without the need to reduce the force.

	Technical Specifications of Pedal Robot CP800
max. pedal force	800 N
max. pedal speed	100 cm/sec
max. pedal travel	200 mm*
resolution pedal position	< 0.003 mm
typ. pedal speed for brake	60 cm/sec
typ. current consumption for brake operation	15 A
typ. referencing duration	15 sec
power supply voltage	12 V (vehicle power system)
dimensions	16 x 13 x 26 cm
weight	5 kg

*depending on vehicle-specific conditions

5.2 Multipurpose Pedal Robot Options

5.2.1 Pedal Force Control

The pedal force control option of the brake robot is also available for the multipurpose pedal robot CP800. Please see section 4.2.1 for a detailed description. The technical specifications for the integrated load cell are:

	Technical Specifications of Load Cell
Full Scale Force	1000 N
Linearity	< 0.1% full scale
Hysteresis error	< 0.05% full scale
Resolution	< 0.00015 N
Sensor overload	300% full scale
Measurement delay	< 2 ms
Digitisation	24 Bit ADC

5.2.2 Vehicle Deceleration Control

The vehicle deceleration control option of the brake robot is also available for the multipurpose pedal robot CP800. Please see section 4.2.2 for a detailed description.

5.2.3 Hydraulic Brake Pressure Control

The hydraulic brake pressure control option of the brake robot is also available for the multipurpose pedal robot CP800. Please see section 4.2.3 for a detailed description.

5.2.4 Record and Replay

This option supports your daily work by the possibility to record the pedal position of a manually driven test and exactly reproduce this test in the replay control mode. For this option the robot is equipped with an additional pedal position sensor.

5.2.5 CAN Online Input

The robot can be controlled by an external signal which is provided via CAN interface. A specific CAN protocol provides the control mode and the desired values. This information is evaluated in realtime from the robot and gives the opportunity to use all available control modes and to switch between them any time. Very often this feature is used for research or development projects where a commercial car should be equipped with drive-by-wire functions.

Combined Pedal Robot

6 Combined Pedal Robot

Features of the VEHICO Combined Pedal Robot:

- operation of accelerator and brake pedal with one robot
- pedal actuation through lever arm mechanisms
- synchronized operation with other VEHICO robots possible
- perfect system for ADAS testing
- quick and easy installation
- driver can always override pedal
- intuitive scripting language
- full range of control modes available like pedal position, pedal force, vehicle velocity, vehicle distance, hydraulic brake pressure and vehicle deceleration
- switching between control modes within a test run
- record and replay of manually driven tests

6.1 Combined Pedal Robot Basics

The combined pedal robot CC800 is one system which can operate the throttle and the brake pedal in one vehicle. It is an extention of the multipurpose pedal robot CP800 with a second lever arm for the operation of 2 pedals. Because of its technical similarities the CC800 has all the characteristic advantages of its smaller brother. The robot is installed directly in front of the driver's seat. Due to the very compact dimensions of the robot a humen driver still can drive the vehicle in a convenient way.

The forces and speeds of the robot are absolutely sufficient for most standard driving maneuvers. With brake pedal speeds of up to 100 cm/s and brake pedal forces of up to 800 N adequate reserves are available.

Special Feature of the VEHICO Combined Pedal Robot:

- very light-weight and cost-efficient system
- robot has two lever arms for the operation of the accelerator and brake pedal
- all control modes of accelerator and brake robot available

With the help of its universal mounting system the robot is fixed either to the driver seat or to the seat fixing points. A bracket is clamped to each pedal to which the lever arms of the robots are mounted. The length of each arm can be adjusted, what makes the adaption to each single vehicle very easy. No changes to the vehicle must be made what makes the robot installation very straight forward.

As the robot has mechanical freewheel mechanisms for each pedal, the driver still can operate the car in a convenient way. Even with an activated pedal robot a manual operation is possible at any time.

Illustration 15: Installation of Combined Pedal Robot CC800 between Seat and Pedal

After the installation the system is activated by going through a referencing phase. During this period of time each pedal is pushed down ones and the robot is calibrating the system according to the vehicle specific pedal travels. After a successful referencing the robot is ready for operation. Now the pedal positions can very easily be programmed by percentage positioning values, which are completely independent of the vehicle individual pedal travel. This makes the handling and portability between different vehicles and different pedals particularly simple. Alternatively the pedal travel can likewise be programmed in absoltute travel distances.

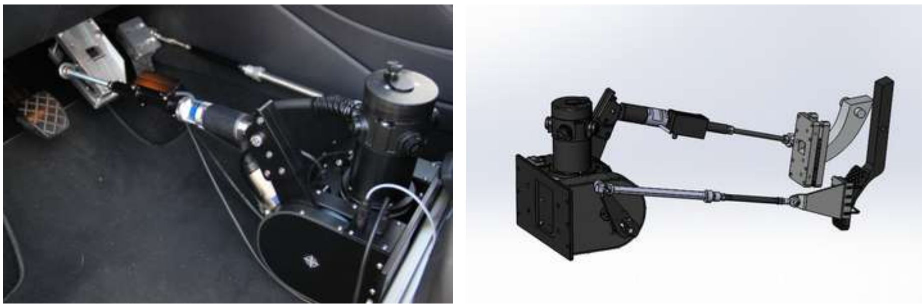


Illustration 16: Combined operation of accelerator and brake pedal

The CC800 can be equipped with a force sensor to measure the brake pedal force applied by the robot. With this sensor the brake pedal force can be controlled freely by programmable force trajectories.

	Technical Specifications of Combined Pedal Robot CC800
max. brake pedal force	800 N
max. brake pedal speed	100 cm/sec
max. brake pedal travel	200 mm*
max. accelerator pedal force	200 N
max. accelerator pedal speed	50 cm/sec
max. accelerator pedal travel	120 mm*
resolution pedal positions	< 0.003 mm
typ. current consumption for brake operation	15 A
typ. referencing duration	15 sec
power supply voltage	12 V (vehicle power system)
dimensions	16 x 22 x 26 cm
weight	6.5 kg

*depending on vehicle-specific conditions

Because if its unique design our combined pedal robot CC800 can provide high pedal forces without time limit. Unlike other systems which must be switched off after a specific period of time our system can push down the pedal without the need to reduce the force.

6.2 Combined Pedal Robot Options

6.2.1 Vehicle Speed Control

The vehicle speed control option of the accelerator robot is also available for the combined pedal robot CC800. Please see section 3.2.1 for a detailed description.

6.2.2 Distance Control

The vehicle distance control option of the accelerator robot is also available for the combined pedal robot CC800. Please see section 3.2.2 for a detailed description.

6.2.3 Pedal Force Control

The pedal force control option of the brake robot is also available for the combined pedal robot CC800. Please see section 4.2.1 for a detailed description. The technical specifications for the integrated load cell are:

	Technical Specifications of Load Cell
Full Scale Force	1000 N
Linearity	< 0.1% full scale
Hysteresis error	< 0.05% full scale
Resolution	< 0.00015 N
Sensor overload	300% full scale
Measurement delay	< 2 ms
Digitisation	24 Bit ADC

6.2.4 Vehicle Deceleration Control

The vehicle deceleration control option of the brake robot is also available for the combined pedal robot CC800. Please see section 4.2.2 for a detailed description.

6.2.5 Hydraulic Brake Pressure Control

The hydraulic brake pressure control option of the brake robot is also available for the combined pedal robot CC800. Please see section 4.2.3 for a detailed description.

6.2.6 CAN Online Input

The robot can be controlled by an external signal which is provided via CAN interface. A specific CAN protocol provides the control mode and the desired values. This information is evaluated in realtime from the robot and gives the opportunity to use all available control modes and to switch between them any time. Very often this feature is used for research or development projects where a commercial car should be equipped with drive-by-wire functions.

7 Failsafe Emergency Brake Robot

Features of the VEHICO Emergency Brake Robot:

- fail-safe operation of vehicle's own brake pedal
- compatible with other VEHICO and even foreign robots
- safe operation even during power failure
- independent from other systems in the vehicle
- wireless operation with VEHICO IRC controller

7.1 Failsafe Emergency Brake Robot Basics

During unmanned and safety-related test drives one must ensure that the vehicle can be brought to a standstill at all times even with a failure of individual system components of the driving robot. For this operation purpose the Failsafe Emergency Brake Robot is an ideal addition to conventional driving robots or custom driving dynamic controls to enhance safety during autonomous vehicle tests. It is operated completely independent from other systems in the car, uses the vehicle's brake pedal and can be triggered by numerous events.

Special Feature of the VEHICO Failsafe Emergency Brake Robot:

- operation of the vehicle's brake pedal
- independent energy storage (air pressure)
- self-monitoring ensures operational readiness
- manual braking by driver with installed robot
- usable as stand-alone system or with Pedal Robots CC800 and CP800

For safety reasons the Emergency Brake Robot has its own air pressure storage and enables fail-safe operation independent from an electric power supply. Even if all vehicle power fails the Emergency Brake Robot brings the vehicle safely to standstill. The system is activated after a self-diagnostic procedure and monitors itself during the entire test period.

The driver seat remains free even with installed emergency brake system. Therefore the test car can be driven normally, for example for transfer purposes. The manual control of the brake pedal is still possible.

It can be used addtionally to proprietary driving dynamic controls or in combination with VEHICO or foreign driving robots in order to guarantee the safety of the entire system during autonomous vehicle testing.

Illustration 17: Components of Emergency Brake Robot: Controller, Tube and Piston

The Emergency Brake Robot is universally adaptable to different vehicles and easy to install. The transmission of force to the brake pedal is provided by a pneumatic piston which is attached to the brake pedal. The brake system is attached to the driver's seat or the vehicle’s seat rails. Using a simple adaptation of the piston rod, the distance between the pedal and driver's seat can be adjusted individually. In the design of the brake system, we have placed great emphasis on ensuring that the freedom of movement of a driver remains unaffected by the installed robot and that a driver can operate the vehicle fully manually. This brings a number of advantages in daily test operation.

The Emergency Brake Robot is typically combined with the VEHICO CP800 or CC800 Pedal Robot. In this case the original pushrod of the Pedal Robot is replaced by the Emergency Brake Robot. This makes it perfectly easy to integrate the Emergency Brake Robot into the installation of our standard driving robots. Illustration 18 shows an integrated installation together with a Pedal Robot CC800.

Illustration 18: Emergency Brake Robot integrated into Combined Pedal Robot CC800

Through the pre-selection of the pneumatic pressure the desired braking force can be adjusted. With brake pedal forces of up to 600 N and a typical time to full vehicle deceleration of 200 ms a quick and likewise strong braking of the test vehicle can be realized.

As energy storage for the operation of the brake pedal an internal pressure accumulator is filled with standard compressed air. Thanks to the appropriate terminals every tire inflating system like a small car compressor with cigarette lighter connection or similar can be used. A gauge indicates the minimal necessary pressure.

	Technical Specifications of Emergency Brake Robot Drive
max. pedal force	600 N
typ. time to full vehicle deceleration	200 ms
max. pedal travel	125 mm
power supply voltage	12 V (vehicle power system)
dimensions	27 cm x Ø 3.2 cm
weight	0.7 kg

In combination with the Pedal Robot CC800 or CP800 extensive trigger events are available like signal watchdog, connection watchdog or manual triggering and if combined with VEHICOs IRC wifi system the vehicle’s brake pedal can be operated from outside of the vehicle.

8 Robot Controller

Key Features of the VEHICO Robot Controller:

- slim, leightweight and robust
- reliable embedded realtime controller
- passive cooling
- power supply from vehicle’s own power system
- undisturbed by starting the engine
- easily stackable for multi system use

Each VEHICO robot comes with a controller in a slim and lightweight aluminium case which integrates the entire power and control unit and all necessary connectors. VEHICO has succeeded to minimize the dimensions to the extent that it can be installed even in the smallest two-seat testing car.

Illustration 19: VEHICO Robot Controller

The controller can be placed near the driver on the passenger seat conveniently with the optional frame mount (see section 9.5), on the backseat or even in the trunk together with other testing equipment.

Due to our unique modular design all robots can be used either standalone or in combination with other VEHICO robots. For the multi system setup with integrated and synchronized operation the controllers can easily be placed on top of each other.

The VEHICO robot controller has been specially designed for the harsh requirements of vehicle testing. Passive cooling is used for all components, the system and all necessary data is kept on a robust solid state drive instead on an ordinary harddisk. And the heart is an embedded industrial realtime controller. Reliability and system stability are the characteristic features of this realtime system.

As a special feature the controller even contains a maintenance-free uninterruptible power supply (UPS) to cope with peak loads associated with a breakdown of the voltage level. So for example the controller remains undisturbed by starting the vehicle's engine. The UPS allows a stand-alone operating time of up to 30 seconds.

Illustration 20: The VEHICO Robot Controller installed on the Passenger Seat

Power delivery occurs exclusively from the vehicle power system. Power supply decoupling can be realized using an independent second battery as power supply for the robot. The vehicle's own power supply is only used for charging the second battery. During a test run the electrical connection is disconnected. With that no load to the vehicle's own power supply results during a test run.

The system is put into operation by means of an on-/off-switch on the front panel. All additional control steps have been centralized in a web interface for simplified manageability. A display in the front panel gives additional feedback to the user, including all important system states and the configured network address.

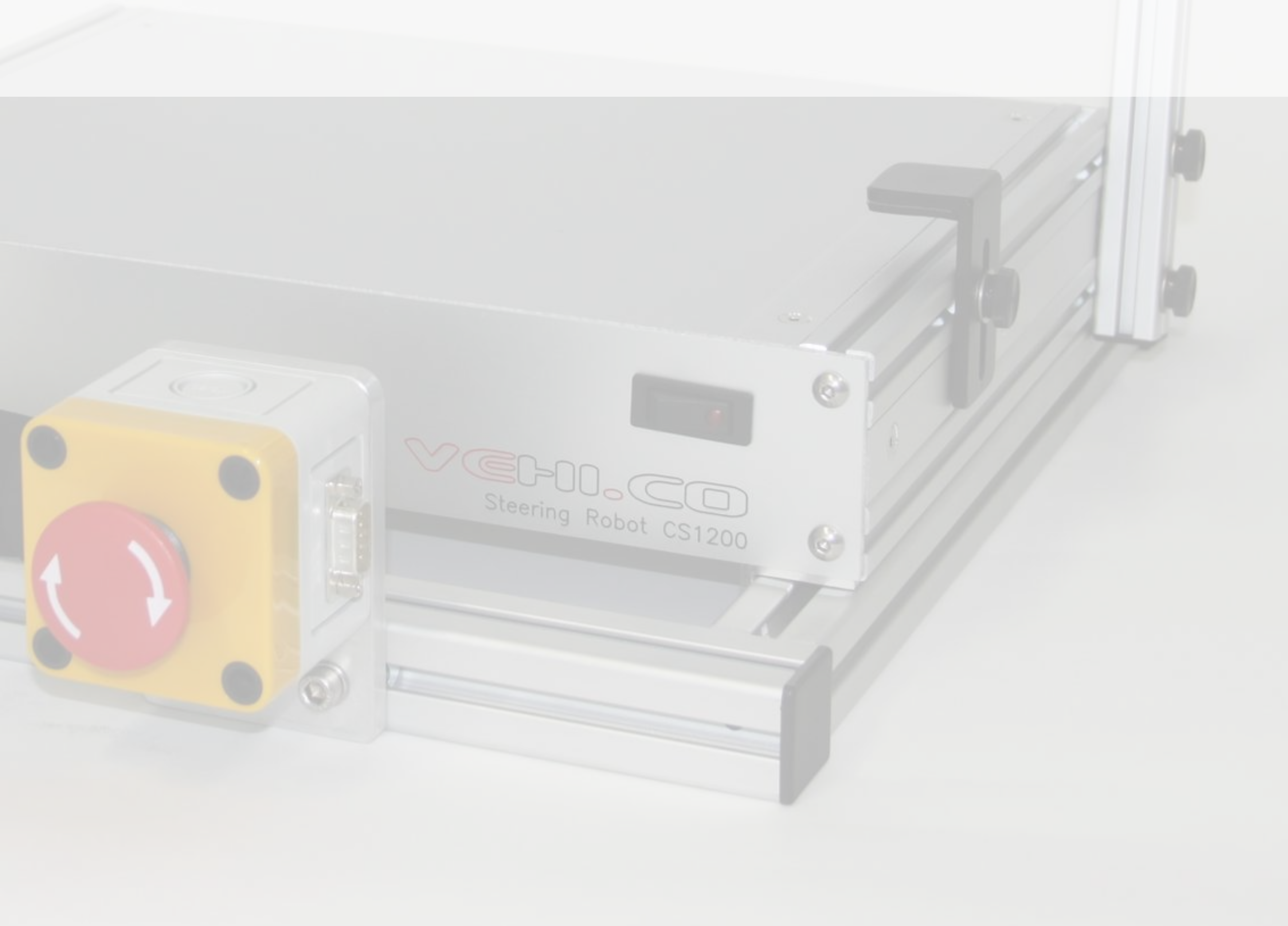
	Technical Specifications of the VEHICO Robot Controller
dimensions	36 x 28 x 6 cm
weight	5,0 kg
power supply voltage	12 V (vehicle power system)
typ. current consumption during standby	0,7 A
communication interface	ethernet
operating temperature	0°C to +70°C

General Robot Options

9 General Robot Options

Key Features of our VEHICO Robot Options:

- modular robot design
- easy upgradeable
- many additional options are available
- user can configure the robot according to its needs



9.1 CAN Interface

Illustration 21: CAN Interfaces

Each robot can be equipped with two physically independent CAN interfaces. They are realized as male 9-pin DSUB connector.

CAN 0: 10 independent input signals

CAN 1: 10 independent input signals

Both CAN interfaces can optionally be ordered as opto-decoupled version. The sampling rates for input and output signals are freely configurable up to 200Hz.

The CAN bus interface can be used to connect the controller to external sensors or to the vehicle's CAN bus system. The dbc file import makes the CAN configuration very easy. Because of the open and transparent configuration our robots are able to communicate with mainly every sensor system that provides CAN signals. The incoming CAN signals are processed in realtime and therefore can be used for triggering or as control signals. All signals are logged synchronously with the other robot data into an open format ASCII log file. This file can be used for offline processing and data analysis.

At the same time the robot CAN interface can be configured to send out its own signals in realtime. This option sometimes is useful if an external data acquisition unit already exists.

The standard CAN bus interface of the robot can further be used for the following features.

9.1.1 OBD2 CAN Interface

The CAN bus interface can be extended to connect to the OBD2 diagnosis interface of a vehicle. With this option the robot can read in the velocity and engine speed of the test vehicle. These signals can be used for triggering, as control signal and for logging. The available data rate depends on the vehicle. With the provided OBD2 cable the robot is simply connected to the vehicle's diagnosis plug connector. No other sensor is needed if you for example want to trigger the robot at a specific vehicle velocity..

9.2 Digital Interface

The optional digital interface is implemented as 15-pin female DSUB connector. Input and output is each available as 6-channel TTL interface and can be ordered as separate options.

Illustration 22: Digital Interface

All digital input and output signals are logged synchronously with all other robot data. The digital input signals can be used as trigger signals within the script program of the robot. With special trigger commands the robot can wait for a predefined signal coming in. The digital output signals can be set within the script program by specific output commands. With this feature it is easy to generate a trigger signal at a user-defined point for example to start or stop an external data acquisition unit or a warning light.

9.3 Power Supply Decoupling

Use an independent second battery as power supply for your robot. The vehicles own power supply is only used for charging the second battery. During a test run the electrical connection between the robot and the vehicle power supply is disconnected automatically. Thereby the robot does not influence the vehicle's own power supply system during a test run.

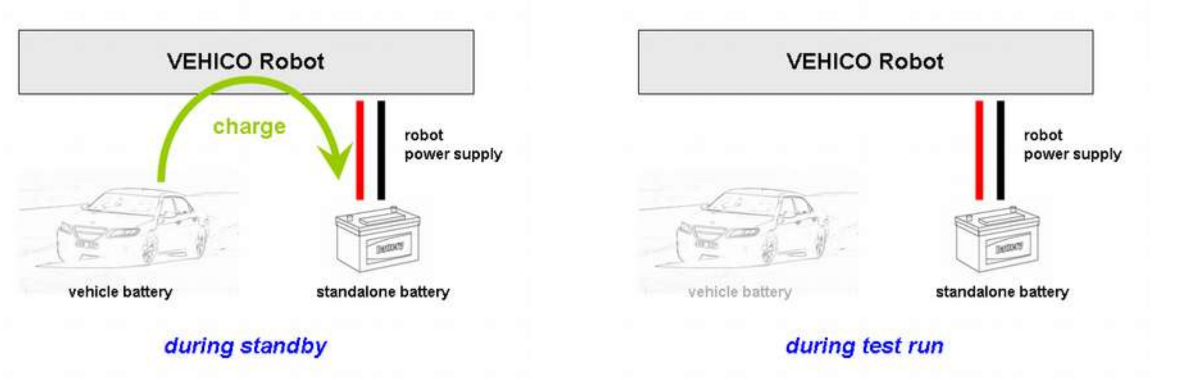


Illustration 23: Untouched Vehicle Power Supply during Test Run

9.4 Multi System Extension

Enhance your test capabilities through a combination of multiple VEHICO robots. With the multi system extension our robots can easily be operated together. During a test run time based as well as event based synchronization is possible. Each robot has full access to the entire signals of all other robots in realtime. The multi system option is necessary on each robot that should be included in the multi system environment.

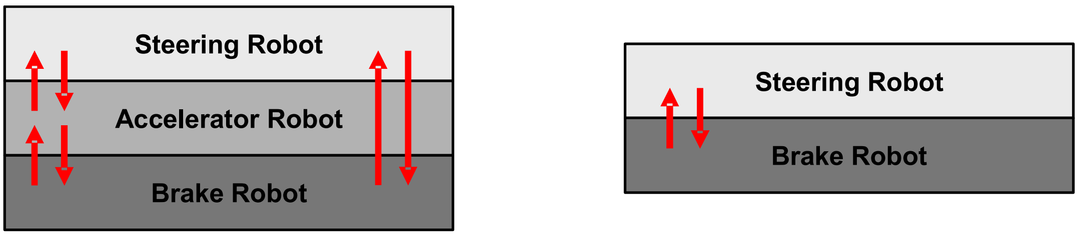


Illustration 24: Example Combinations for Multi System Environments

Key Features of the Multi System Extension:

- use same handswitches for all robots simultaneously
- synchronized start of all robots
- time based and event based online synchronization between robots
- full access to entire signals of other robots in realtime
- option is needed for each robot which should be part of the multi system environment
- unlimited number of robots combinable

- you are not limited to one encapsulated system, the robots can still be used as standalone systems even in different vehicles

Beyond all technical advantages of the modular design there is an additional major organisational profit for you: You don't need to buy the robots all at the same time but rather can purchase the robots step by step according to your personal requirements.

9.5 Frame Mount

Frame mount for an easy fixation of the controller with two belts around the passenger seat. Including brackets and arm to fix a notebook (standard width 32-36 cm). Typically the frame mount serves also as holding fixture for one knuckle switch. Suitable for left-hand as well as right-hand driven vehicles.

Illustration 25: Frame Mount with Tension Belts

The frame mount is optional available as version with Isofix holder for even faster fixing in a car.

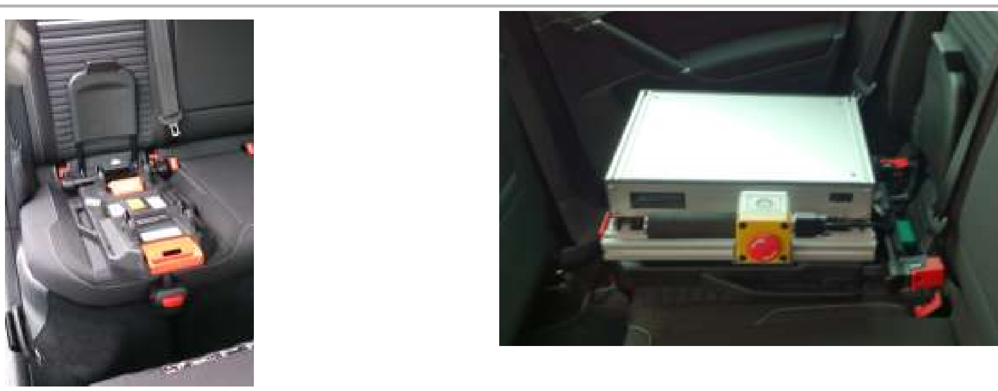


Illustration 26: Frame Mount with Isofix Holder

Illustration 27: Crash detection sensor mounted to front bumper

9.6 Trigger Sensors

9.6.1 Crash Detection Sensor

The crash detection sensor is used in cases where the exact crash event is required. The sensor is mounted at the crash area of the vehicle. Due to its flexiblity it perfectly adapts to curved surfaces like bumpers. It provides a digital signal which can be used for real time triggering of the robots or for offline postprocessing of the test data. The crash detection sensor is often used in tests with ballon car targets like the Euro NCAP AEB test procedures.

Active measurement length: 500 mm

The digital input option (9.2) is required to use the trigger sensor. The digital trigger sensor is already preconfigured and can directly be operated on the digital input plug.

9.6.2 Optical Digital Trigger Sensor

Illustration 28: Digital Trigger

Often a fixed allocation of the starting point is relevant to begin all tests at the same point of the test track. The digital trigger sensor detects marks on the ground. As trigger marks the self-adhesive reflective film is necessary (option 9.6.3). Sensor includes suction cup vehicle mounting system.

Measuring range: 0..750 mm

The digital input option (9.2) is required to use the trigger sensor. The digital trigger sensor is already preconfigured and can directly be operated on the digital input plug.

9.6.3 Reflective Tape for Trigger Marks

Illustration 29: Reflective Tape

Reflective Tape for Trigger Marks. With this self-adhesive reflective tape trigger marks can be fixed on the ground.

Reel with 22.8 meter length, **50 mm width**, polarized, self-adhesive, direction independent.

10 Target Mover

Key Features of the VEHICO Target Mover:

- unique modular design concept
- customizable size according to application: vehicles, bicycles, pedestrians, ...
- easy transport with two persons
- screwless ramps for low RCS
- embedded radio antenna
- hot swap battery change
- integration into the VEHICO driving robot environment
- realtime synchronization with VEHICO driving robots
- operational within a few minutes

The Target Mover is a GPS-guided moving platform for testing real traffic scenarios with any kind of soft targets. It automatically follows given xy-coordinates and velocity profiles with highest precision.

Exclusive advantage of VEHICO's Target Mover is the modular design concept: Depending on the application the Target Mover can be customized to vehicle, bicycles or pedestrian size. Nearly all common soft targets can be fixed on top of the moving platform.

Illustration 30: Scalable Target Mover: For Vehicle Targets (left) and Bicycles/Pedestrians (right)

Furthermore it even can be extended with additional powertrain units or battery packs for special applications.

Illustration 31: Optional Battery or Powertrain Extensions

A pleasant second advantage of the modular design is the possibility to disassemble the whole Target Mover within a few minutes for easy transport with two persons.

Illustration 32: Moduls Allow Easy Transport with two Persons

The Target Mover is fully integrated into the VEHICO driving robot environment. It gets programmed and synchronized in the same established and convenient way you know already from our other robots. Of course it can also be used standalone.

Typical Target Mover Applications:

- EuroNCAP 2018 Lane Support Systems
- EuroNCAP 2018 Automated Emergency Braking AEB
- side assist testing
- unmanned reproducible traffic scenarios for testing new ADAS functions
- unmanned reproducible traffic scenarios for testing new autonomous vehicles

Also other design features make VEHICO's Target Mover unique in the market. The overrun height of only 8 cm makes the Target Mover to the lowest one available on the market. An adjustable suspension system leads to a smooth driving behaviour even if the proving ground surface is not perfect. When the Target Mover is being overrun by a vehicle all four wheels disappear totally within the chassis to minimize wear effects.

Illustration 33: Target Mover Withstands Dynamic Overrun

All antennas of the Target Mover are embedded so that there is no risk of being damaged or getting separated from the Target Mover.

The operability is increased by a remote control unit which can be used at any time to take over command and drive the Target Mover manually.

The Target Mover is compatible with all standard GPS sensor systems with IMU integration like Oxford, Racelogic, Genesys or iMar. VEHICO's hot swap technology allows the GPS sensor system to stay alive during battery change so that the GPS typical time consuming warm-up driving is not necessary after a battery change.

	Technical Specifications of the VEHICO Target Mover
max. speed	50 kph (Ctiy) 80 kph (Inter-Urban)
max. deceleration	0,6 g
weight	200 kg
length x width (vehicle configuration)	260 x 160 cm
length x width (single module)	160 x 50 cm
overrun height	8 cm

11 Web Interface

Benefits of the VEHICO Web Interface:

- no software installation needed
- independent of operating system
- VEHICO scripting language fully integrated into powerful Python environment
- robots can be operated also from outside the car
- multiple robots can be accessed at the same time

Web Interface

For the operation of VEHICO robots we designed a graphical user interface based on the latest web technologies. No software installation is needed anymore. You only need a standard browser like Firefox, Chrome or Internet Explorer to operate our systems. Even the type of operating system on the control computer is no issue anymore.

The outstanding highlight is our intuitive scripting language to program the robot's actions. With simple commands every robot action can be customized. During the programming you are supported by numerous assistances like a list of available commands, syntax highlighting and an interactive help with a detailed description of arguments and units. An automatic error detection completes a smooth programming.

The scripting language enables a matchless flexibility in designing customized test scenarios. Standardized tests are of course already filed as templates.

Example List of Latest Ready-to-use Templates:

- FMVSS126 / ECER13-H – sine with dwell
- ECE-R79
- J-turn
- fishhook fixed-timing / fishhook roll rate feedback
- step / pulse / ramp
- SIS slowly increasing stear
- parking effort
- sine / multiple sine / partial sine
- increasing sine / decreasing sine
- sine sweep
- steering wheel angle recording / replay
- steering wheel angle online input
- CO.TRACK vehicle identification
- CO.TRACK recording / replay
- EuroNCAP / US-NCAP AEB CCRs, CCRm, CCRb
- EuroNCAP LDW, LKA, ELK
- double lane change (ISO 3888-1/2, ADAC, AutoBild)
- and much more

The template list is regularly updated by the manufacturer. Own scripts can easily be added to the list of templates. Test series are supported by the scripting language. Before starting a real test run a simulation can give you the certainness that everything will work as desired.

And best of all, switching between the different control modes of the robot is uncomplicated and feasible at any time of the test run. Each command has a starting identifier that determines its control mode. So changing between the control modes can easily be done from command to command.

The following pictures shows a typical worksheet with grafical realtime instruments in the upper part, the robot script in the middle and a plot module at the bottom of the page.

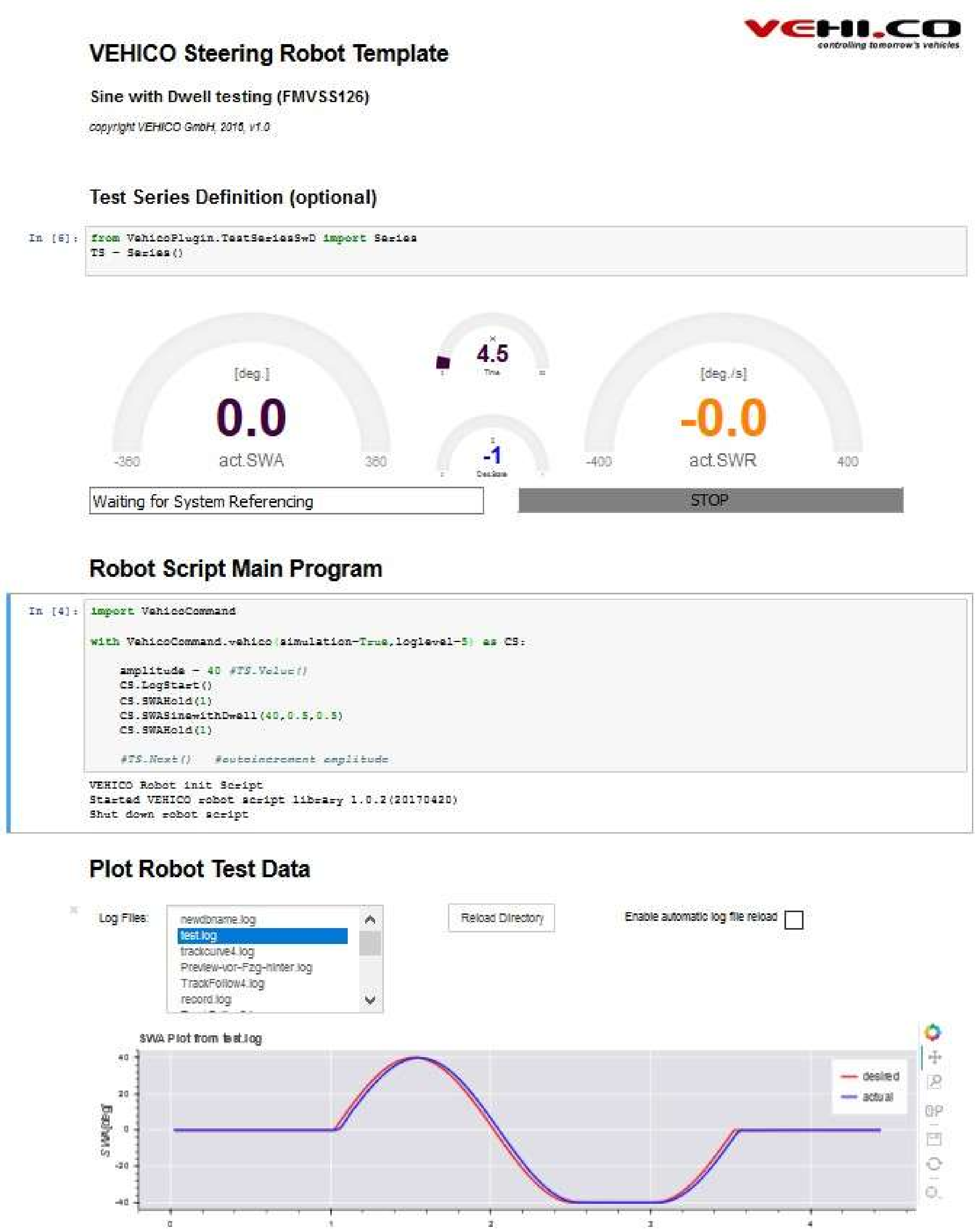


Illustration 34: VEHICO Web Interface with Programming and Online Window

If the test has been completely configured all relevant data is transferred to the robot controller through an ethernet connection. During the entire test the web interface accompanies the user likewise on the basis of a graphical interface and simultaneously serves as test monitor by visually presenting all relevant measurement data of the vehicle. An emergency stop can also be triggered from the web interface at any time.

Key Features of the VEHICO Scripting Language:

- intuitive and easy to handle
- matchless flexibility in test configuration
- switching between control modes possible from command to command
- standardized tests filed as regularly updated templates
- worldwide unique: you as customer are not limited to manufacturer given templates
- own test configurations can be saved and added to the templates
- trigger signals can be processed at any time during a test run

After the execution of a test run the logged data can be quickly and clearly visualized by the integrated graphic module. It offers all the comfort you need for convenient plot handling: easy to handle, multiple plots underneath eachother possible, y(t) as well as y(x) plots available, easy zooming.

To cut down the test drivers tasks to a minimum the log data can be saved automatically without any needed inputs of the driver with our Autosave function.

The web interface has proven itself in the field since it provides easy and user-friendly test configuration and management to the operator. Beyond this, the web interface provides the highest level of help support in the respective test situations and thus contributes to the minimization of the potential error conditions.

All robots have a similar web interface. So if you are familiar with one robot you are right away able to operate other VEHICO robots.

12 Inter Robot Communication

Key Features of the Inter Robot Communication:

- data range in open environments up to 1500 m
- capable of building a wireless mesh network
- dual frequency operation (2,4 / 5GHz) for maximum robustness
- high performance with speeds of more than 1Gbps
- dual high-gain antenna guarantees reliable communication
- low latency, optimized for vehicle control applications
- security by encrypted data transfer
- licence-free frequencies
- in accordance with the WiFi regulations for Europe, USA and many other countries

The Inter Robot Communication is a highly reliable long distance wireless data link between vehicles. It is developed and adapted for the very specific requirements of vehicle testing and therefore can likewise be used for other applications where **low latencies**, **high reliability** and **long distance communications** are key features. The typical range in open environments is up to 1500m and therefore universally usable for the very most applications in ADAS testing with two or more vehicles.

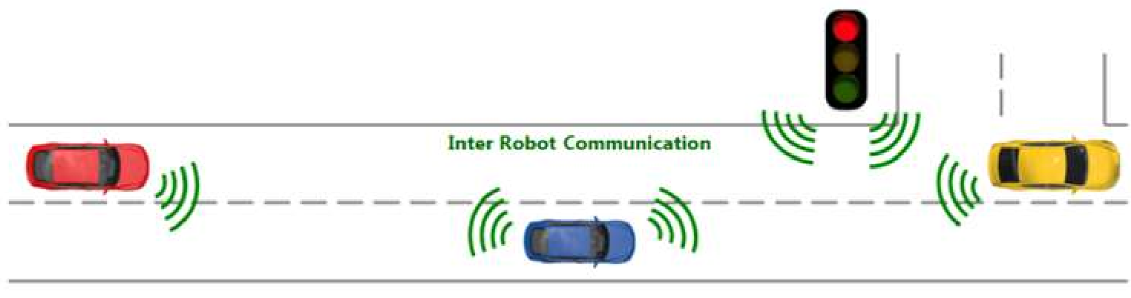


Illustration 35: Mesh Network with Unlimited Number of IRC Access Points

With the Inter Robot Communication trigger signals can be send online to another car to synchronize the robot actions. Moreover, **sensor and robot signals can even be shared online between the robots in different cars to synchronize the control modules** in the cars. The high transfer speeds makes the radio communication ideal for online communications where low latencies are of essential importance. The **covered area can easily be extended by using one or more extra IRC access points** either beside the track or within other vehicles as all IRC systems build a wireless mesh network topology where messages are forwarded up to the receiver.

Illustration 36: Car-to-Car Communication

To use the Inter Robot Communication you simply connect an IRC access point to the robots in the car and fix the unit onto the roof or to the window. The IRC access point comes with a 5-port LAN switch for the ethernet based onboard communication and the PoE power supply.

Illustration 37: Roof-/Window-Mounted IRC Access Point with High-Gain Antenna

The Inter Robot Communication is suitable for many kinds of ADAS testing where data has to be transferred between two or more moving vehicles or between moving vehicles and a stationary base station.

Automated Driving Solutions

13 Automated Driving Solutions

Key Features of the VEHICO Driving Solutions:

- highly dynamic driving maneuvers with lateral acceleration up to 1g
- smooth, yet very quick steering response
- compatible with all common GPS sensor systems
- simple track definition by recording or by using the VEHICO scripting language
- quick and easy adaptation to different vehicles

VEHICO offers various levels of driving solutions to cover all the specific needs of vehicle ADAS testing.

The most basic level is the CO.REMOTE system where a robot vehicle can be controlled remotely from outside via a radio link.

As enhancement we offer three progressive systems for automatic test driving: It starts with the automatic track control CO.TRACK for the lateral control of the test vehicle, continues with the automatic driving solution CO.DRIVE with the combined operation of all robots and leads at the top end to the high sophisticated driving solution CO.SYNC which enables synchronized driving.

	CO.TRACK	CO.DRIVE	CO.SYNC
Automatic Lateral Control	✓	✓	✓
Automatic Longitudinal Control		✓	✓
Synchronized Driving			✓

13.1 CO.REMOTE – Remote Controlled Driving

CO.REMOTE combines our driving robots with a remote control. Unmanned vehicle testing can be realized in a very simple manner, by remotely controlling the driving robots from outside the vehicle.

Required Components for Remote Controlled Driving CO.REMOTE:

- Steering Robot CS-B20, CS-B40 or CS-B60
- Accelerator Robot CG300
- Brake Robot CP800 or CB2100
- Inter Robot Communication
- external remote computer with user interface

The test vehicle is equipped with the necessary driving robots to operate the steering and pedals of the vehicle. Additionally our Inter Robot Communication System realizes a radio link in order to transmit the control commands from a remote control computer to the driving robots. By means of this interconnection the steering wheel and pedal positions in the test vehicle can be operated by a human used without the need to sit inside the vehicle. Simple tests in the near range can be performed without expensive sensor systems. An optional video camera can provide online data from inside of the vehicle. With a visual feedback from the remote-controlled vehicle a nearly realistic driving behavior can be achieved.

Key Features of Remote Controlled Driving CO.REMOTE:

- the driver seat remains free and can be used for a dummy
- expandable with video transmission from inside of the test vehicle
- simple test configuration without expensive sensor
- equipped vehicle can still be driven manually
- universally applicable for different vehicles

The classical area of application of CO.REMOTE are vehicle tests, where no driver is allowed inside of the vehicle and where a human driver's accuracy is sufficient. As no extra sensor systems are needed the setup and handling is very straight forward. Additionally the expenses are much lower compared to automatic driving solutions like CO.DRIVE or CO.SYNC. Nevertheless it is possible to combine remote control functions with driving dynamics control. For example, the steering robot can be operated over the remote control while the accelerator robot automatically controls the vehicle velocity. Because of the flexibility of programming our robots various combinations are possible.

Range of Applications of Remote Controlled Driving CO.REMOTE:

- unmanned misuse testing
- special tests in the area of crash testing, such as roll-over tests
- general tests, in which the driver would be exposed too large physical stress

13.2 CO.TRACK – Automatic Track Control

With CO.TRACK the vehicle is steered automatically and drives arbitrarily predefined tracks reproducible and with highest precision. The automatic track control, sometimes also known as path following, is integrated as a software option in our steering robots. It is a closed-loop control method that compensates the lateral displacement of the vehicle relative to a reference track. CO.TRACK is based on the long-standing expertise in the field of vehicle dynamics controls of VEHICO.

Reproducible, smooth and robust steering with at the same time simple applicability are essential features of CO.TRACK.

Illustration 38: Handling Course and Double Lane Change driven with CO.TRACK

The automatic track control is available as *CO.TRACK light* for straight-line driving or driving with low dynamics and as high performance release *CO.TRACK* for highly dynamical driving tests:

	CO.TRACK light	CO.TRACK
Steering wheel turning speed	< 90 deg/sec	not limited

Our steering robots are compatible with all standard GPS sensors which can be integrated via CAN interface. These provide all necessary data for the automatic vehicle driving. Suitable sensor systems with IMU integration are for example Genesys ADMA, Oxford RT or Racelogic VBox.

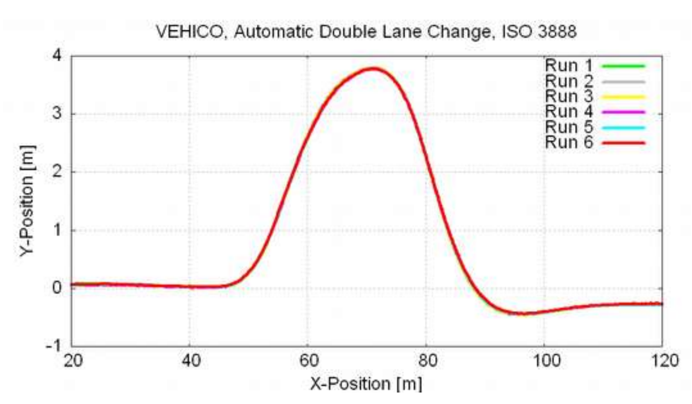
Required Components for the Automatic Track Control CO.TRACK:

- Steering Robot CS-B20, CS-B40 or CS-B60
- Option CO.TRACK or CO.TRACK light
- GPS Sensor System with IMU integration

An outstanding feature is that you don't have to do a time-consuming search for control parameters. How does it work? Largely responsible for the automatic track control of the vehicle are complex control algorithms that are based on latest scientific results. Only an easy to handle vehicle identification procedure has to be carried out once before you start testing – that's all you have to worry about!

Different control algorithms are computed in parallel and under real-time conditions on the steering robot controller. Even the slightest deviation from the nominal track results in opposite steering to drive the vehicle with high precision along the desired track.

The controller achieves highest track accuracies completely independent of the vehicle speed. Even with maneuvers at the physical limit or on slippery surfaces the vehicle remains stable. The performance of our system can be demonstrated in an impressive way for example by an ISO 3888 lane change test. At a constant speed, the same maneuver was repeated and plotted several times. Even under these extreme dynamic conditions a reproducibility of a few cm is achieved.



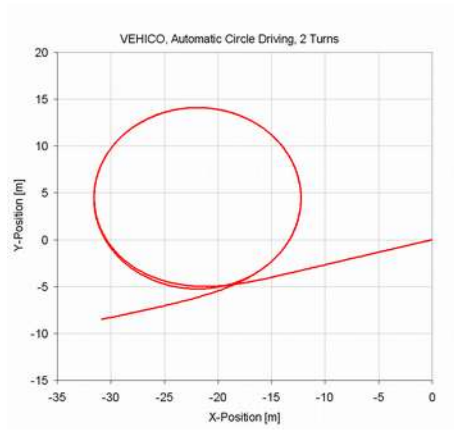


Illustration 39: Double Lane Change and Circle with Two Turns driven with CO.TRACK

Key Features of the Automatic Track Control CO.TRACK:

- highly dynamic driving maneuvers with lateral acceleration up to 1g
- smooth, yet very quick steering response
- unattached of the vehicle velocity
- also usable for low-mu testing on snow, ice or gravel
- compatible with all common GPS sensor systems
- simple track definition by recording or by using the VEHICO scripting language
- any combination of open-loop and closed-loop maneuvers possible
- quick and easy adaptation to different vehicles

The track definition is carried out in the same easy way as all tests with VEHICO robots are specified: with the intuitive scripting language. You design your desired track with simple segments like lines and curves, use either relative or absolute GPS coordinates. You are supported in the familiar way with templates for standard tests. For more sophisticated tests like for example the double lane change you are supported by an additional scripting assistant.

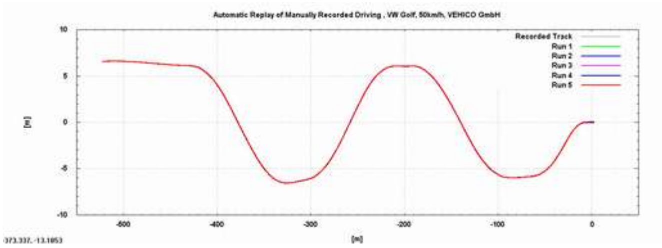


Illustration 40: Recording of Manual Driving and High-Precision Replay

Of course a recording and replay functionality is also available. You can drive the desired test manually while the GPS coordinates are recorded. This recorded track then can be replayed very accurate and with high reproducibility. The recorded maneuvre can even be transferred easily to other locations!

Highlights of CO.TRACK Record and Replay:

- one-click operation
- highest accuracy and reproducibility
- recorded track can easily be transferred to other locations

The areas of CO.TRACK are tests in which the accuracy of the vehicle's track is of particular importance. CO.TRACK can be operated in the entire dynamic range of a vehicle. Thus, the system can be used in a variety of applications, whether you want to drive up a straight line exactly or reproduce a dynamic handling course.

Range of Applications of the Automatic Track Control CO.TRACK:

- ADAS development and testing
- EuroNCAP AEB city, inter urban and pedestrian testing
- ISO 3888 double lane change
- tests of lane keeping systems
- brake tests with maximum track accuracy
- cornering stability and aquaplaning tests
- steady-state circular driving
- and much more

13.3 CO.DRIVE – Automatic Driving

With CO.DRIVE the vehicle is driven reproducible and with highest precision on predefined tracks. It is based on the automatic track control CO.TRACK and is supplemented by the capability to define velocity trajectories related to the GPS track. The smooth and robust steering of CO.TRACK is combined with a speed and braking control for the pedal robots.

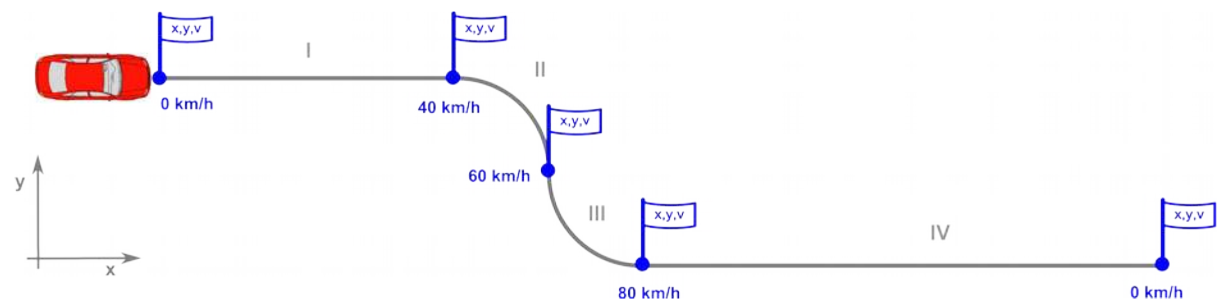


Illustration 41: Desired GPS-Track with Velocity Profile

CO.DRIVE is integrated as a software option in our steering robots. It is based on VEHICO's long-standing expertise in the field of lateral and longitudinal vehicle control.

The automatic driving is available as *CO.DRIVE light* for straight-line driving or driving with low dynamics and as high performance release *CO.DRIVE* for highly dynamical driving tests:

	CO.DRIVE light	CO.DRIVE
Steering wheel turning speed	< 90 deg/sec	not limited
Longitudinal acceleration	< 4 m/sec²	not limited

Required Components for the Automatic Driving CO.DRIVE:

- Steering Robot CS-B20, CS-B40 or CS-B60
- Option CO.DRIVE or CO.DRIVE light
- Accelerator Robot CG300 with velocity control option
- Brake Robot CP800 or CB2100 with deceleration control option
- GPS Sensor System with IMU integration

The vehicle dynamics control CO.DRIVE represents a modular extension of CO.TRACK by including the vehicle longitudinal dynamics into the control circuit. It does not matter whether it is a vehicle with a diesel or gasoline engine or whether the vehicle has an automatic or manual transmission. CO.DRIVE is able to accelerate the vehicle according to the previously defined driving maneuvers, decelerate or to maintain a constant speed. Even complex maneuvers can be easily configured.

The driving maneuver definition is carried out nearly in the same easy way as with CO.TRACK: with the intuitive scripting language. You design your desired track with simple segments like lines and curves, use either relative or absolute GPS coordinates. In addition to the GPS coordinates the related vehicle velocity profile is defined. Out of this profile the desired values for accelerator and brake control are generated in realtime.

Key Features of the Automatic Driving CO.DRIVE:

- highly dynamic driving maneuvers with lateral acceleration up to 1g
- smooth, yet very quick steering response
- track based velocity and deceleration control
- high reproducibility and accuracy in lateral and longitudinal direction
- simple driving maneuver definition by recording or by using the VEHICO scripting language
- regardless of engine concepts (diesel, petrol) or transmissions (manual, automatic)
- quick and easy adaptation to different vehicles
- compatible with all common GPS sensor systems
- any combination of open-loop and closed-loop maneuvers possible

Illustration 42: Automatically Driven Test with CO.DRIVE

Typical fields of application of CO.DRIVE are tests in which exactly reproducible driving without the influence of a human driver is necessary. For example, the high-publicity effective elk test may be carried out repeatedly under exactly the same conditions. As our driving robots leave the driver seat completely free a driver can still sit in the car and at any time can take control of the vehicle itself.

For the system it is irrelevant whether a driver still sits inside the vehicle or not. So even maneuvers like accident reconstruction which would be to dangerous for a human driver can be carried out completely unmanned.

CO.DRIVE combines maximum accuracy, extreme reliability and robustness for use in the daily test environment. It opens up a broad range of applications.

Range of Applications of the Automatic Driving CO.DRIVE:

- ADAS development and testing
- fully automated ISO 3888 double lane change
- misuse testing
- brake tests with maximum track accuracy
- endurance testing, rough road testing
- accident reconstruction
- stunt scenes with moving cars
- and much more

13.4 CO.SYNC – Synchronized Driving

CO.SYNC represents the high-end functionality for tests with more than one car. The track and velocity profile are defined in the well-known way as for CO.DRIVE. Separately for each vehicle the test duration is exactly calculated. With VEHICO's Inter Robot Communication all vehicles get a synchronized start of their time-based trajectory control

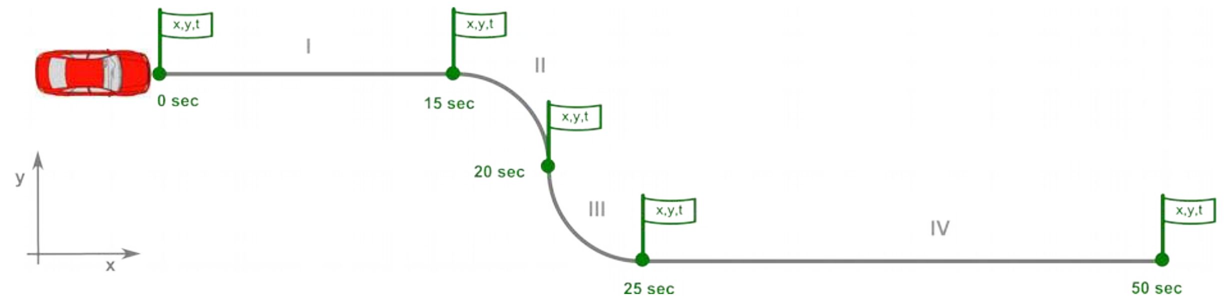


Illustration 43: Desired GPS-Track with Time Profile

The Inter Robot Communication (see page 44) extends the capability of CO.SYNC: Trigger signals can be send online to synchronize robots in other cars and sensor and robot signals can be shared online between the robots in the different cars to synchronize the control modules in the cars.

CO.SYNC is integrated as a software option in our steering robots. The synchronized driving is available as *CO.SYNC light* for driving with low dynamics and as high performance release *CO.SYNC* for highly dynamical driving tests. CO.SYNC includes the performance of the automatic track control CO.TRACK and the automated driving CO.DRIVE.

	CO.SYNC light	CO.SYNC
Steering wheel turning speed	< 90 deg/sec	not limited
Longitudinal acceleration	< 4 m/sec²	not limited

Required Components per Vehicle for the Synchronized Driving CO.SYNC:

- Steering Robot CS-B20, CS-B40 or CS-B60
- Option CO.SYNC or CO.SYNC light
- Combined Pedal Robot CC800 with velocity, distance and deceleration control option
- Inter Robot Communication
- GPS Sensor System with IMU integration

Typical test scenarios for CO.SYNC are all kind of intersection maneuvers where time-based synchronization to an intersection point is absolutely necessary like intersections with another car, with soft targets or pedestrian dummys. The very high accuracy of VEHICO's dynamic vehicle control is the prerequisite for such test scenarios.

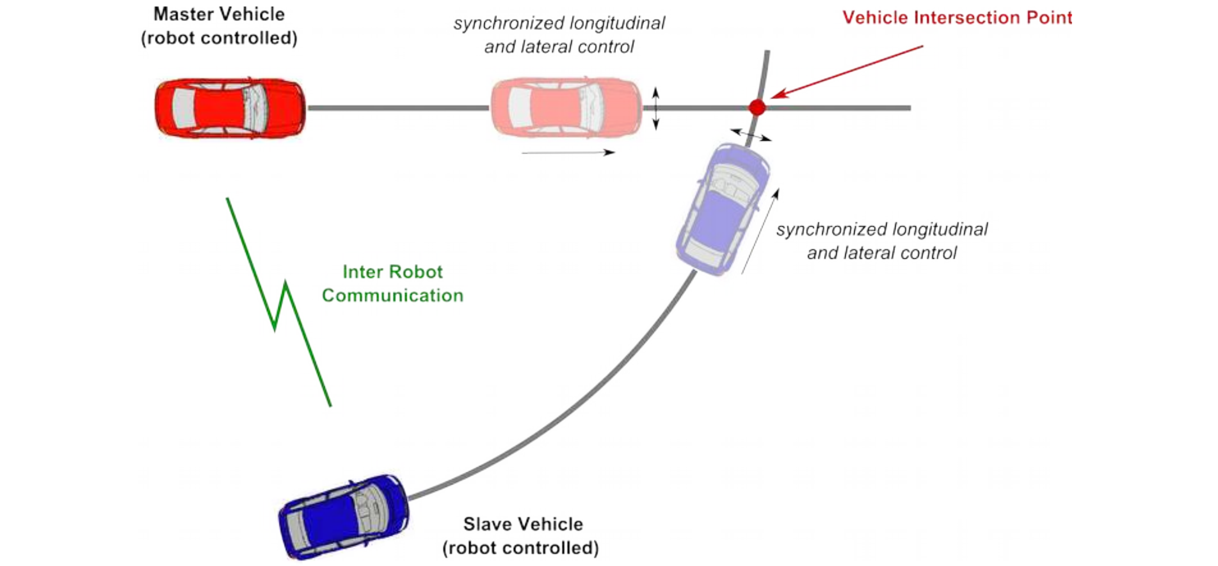


Illustration 44: Typical Test Scenario: Intersection

Cut-in scenarios are also typically realized with CO.SYNC. The vehicle under test is running with velocity and track control while the overtaking target vehicle cuts into the same track when a predefined distance between the two vehicles is reached. Both vehicles are exactly controlled and dynamically synchronized.

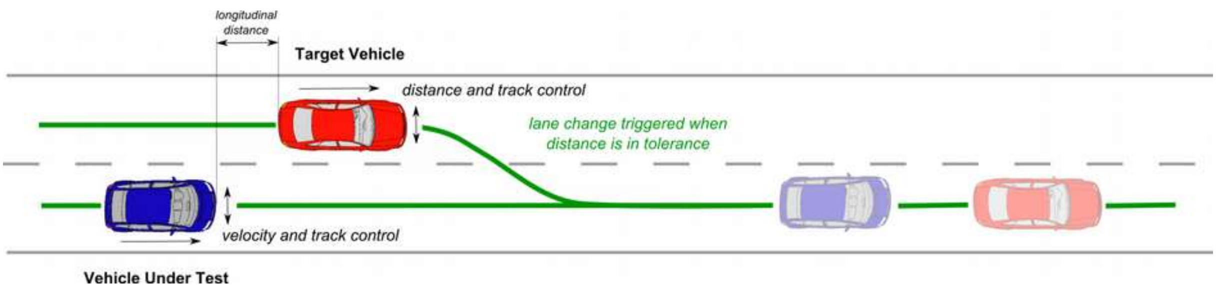


Illustration 45: Typical Test Scenario: Cut-In

Key Features of the Synchronized Driving CO.SYNC:

- precise track based time trajectory control
- unlimited number of vehicles
- trigger signals can be send online to robots in other cars
- sensor and robot signals can be shared online between the vehicle robots
- GPS time is not necessary for synchronization
- compatible with all common GPS sensor systems

Range of Applications of the Synchronized Driving CO.SYNC:

- ADAS development and testing
- pedestrian tests
- intersection scenarios
- cut-in / pull-out scenarios
- accident reconstruction with two involved vehicles
- and much more

13.5 Safety Corridor

Working with automated driving solutions safety becomes a very significant aspect. VEHICO developed a high-sophisticated safety concept with multiple safety levels. The most obvious is of course the emergency button which can be placed inside or outside the car. Not visible but highly effective is the permanent monitoring of various important signals. As user you can additionally set limitations for the maximum allowable steering wheel angle and steering wheel angle deviation. To meet the specific requirements of all kinds of different test scenarios the VEHICO safety concept allows user-defined programmable emergency actions.

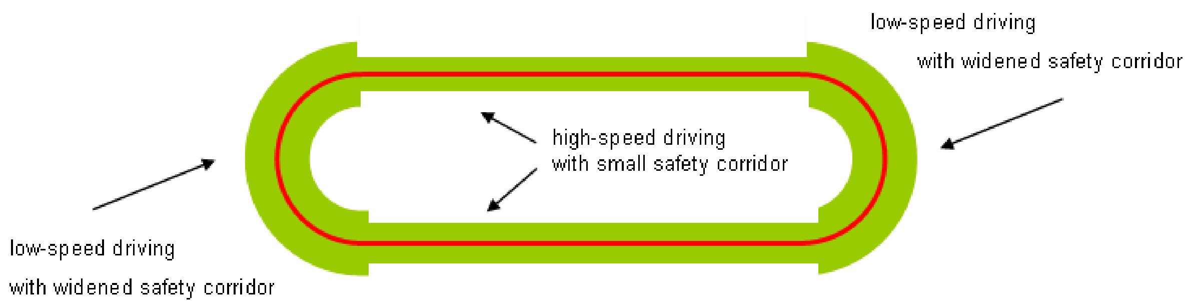


Illustration 46: Track Safety Corridor with Adaptable Width

The top level safety feature is a safety corridor along your track. The width of the safety corridor can be fitted corresponding to the varying safety requirements on different segments of the track. A typical configuration is a wide safety corridor for low-speed driving and a smaller corridor width for high-speed driving. With this powerful option you are for example able to automatically initiate an emergency stop and bring the vehicle into a safe condition.

All mentioned safety features are by default included in VEHICO's automated driving solutions.

Important Note

We have exercised the greatest care in the compilation of the technical information, text, illustrations and drawings. Despite this, errors cannot be completely excluded, unfortunately. The publisher points out that they cannot assume either a judicial responsibility or any form of liability for erroneous information and their consequences. However, the publisher is always thankful for any comments on possible errors or suggestions for improvements.