Driving Robot Catalogue

September 2020

... worldwides most flexible driving robots






Made in Germany

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-B60	CS-B60T	CS-B150T
Vehicle					
Nominal torque on steering wheel	20 Nm	40 Nm	60 Nm	60 Nm	150 Nm
Turning speed at nominal torque	1000 °/sec	1200 °/sec	1200 °/sec	1200 °/sec	500 °/sec
Max. turning speed	2500 °/sec	3500 °/sec	1600 °/sec	1600 °/sec	800 °/sec
Steering angle resolution	0.02 °	0.02 °	0.01°	0.01°	0.005°
Steering wheel diameter	25 - 44 cm			38 - 55 cm	
Power supply voltage	12 VDC		12 VDC (with internal power pack)	24 VDC (with internal power pack)	
Weight of entire robot drive unit	3.5 kg	4.4 kg	6.1 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-B60 / CS-B60T	CS-B150T
Full Scale Torque	+/-35 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.

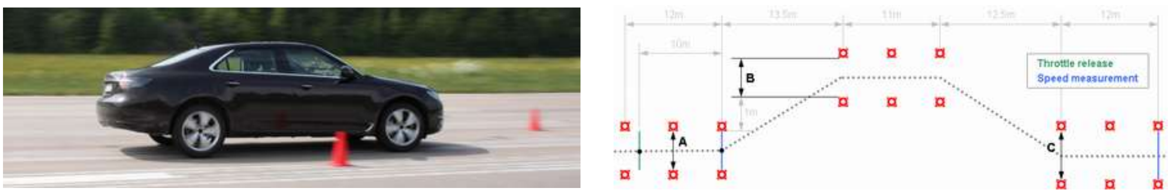

Illustration 5: Double Lane Change Maneuver with VEHICO Steering Robot

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.

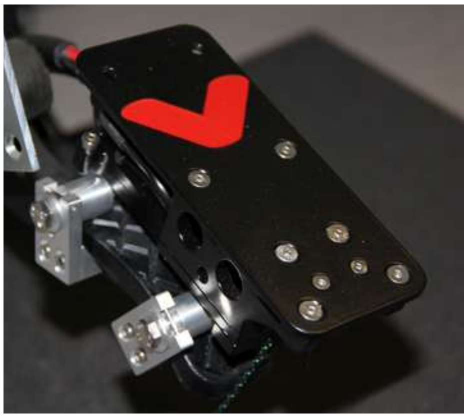

Illustration 6: Transport Case and installed Drive Unit

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.

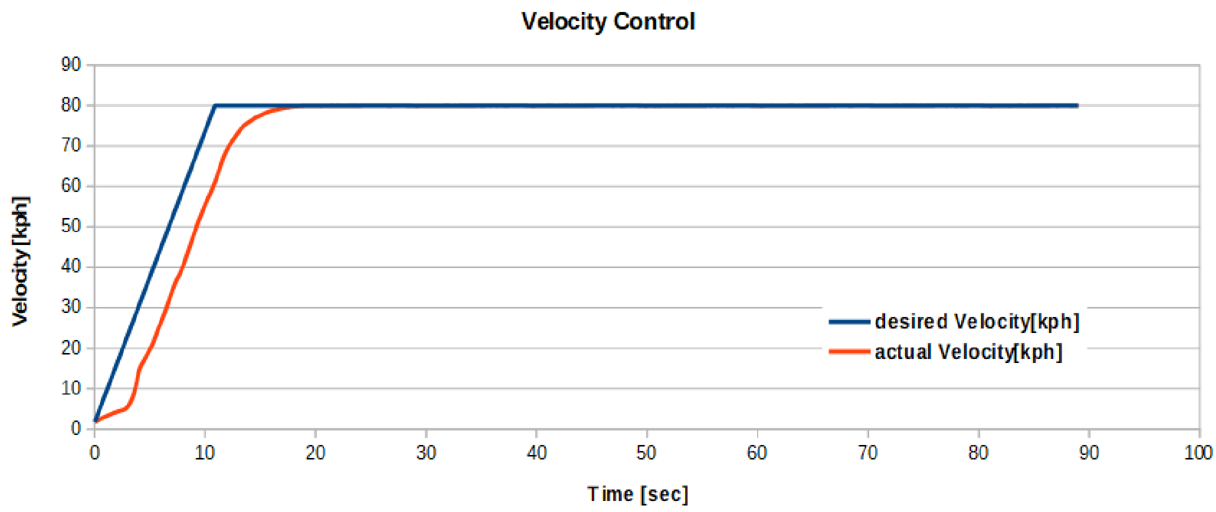

Illustration 8: Typical Velocity Control Performance

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.

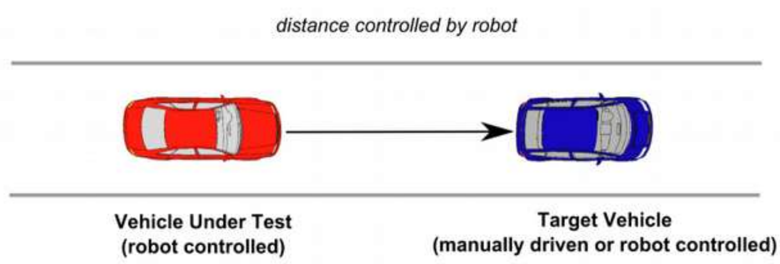

Illustration 9: Typical Distance Control Scenario

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.

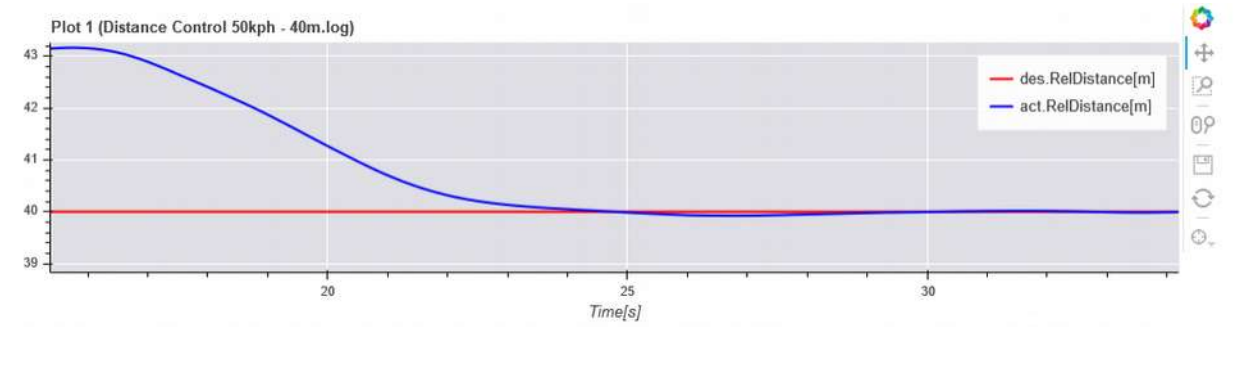

Illustration 10: Typical Distance Control Performance

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.

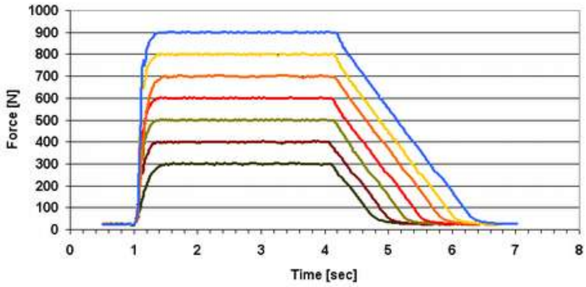

Illustration 12: Typical Output of Force Control

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.